INDUSTRIAL MINERALS AND SELECTED RARE METALS IN MONGOLIA

An Investors' Guide

Prepared by the
Government of Mongolia

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FOREWORD

In your hands you have the first edition of the publication "Industrial Minerals and Selected Rare Metals in Mongolia. An Investors' Guide", which supplements the many publications already available on the geology and the mineral wealth in Mongolia. This brochure is published at a time when prices for many minerals are rising again and exploration is picking up speed again.

Although mining investments in Mongolia have so far concentrated on coal, copper, and gold, the industrial mineral wealth of the country is also substantial. Available industrial minerals and rocks include celestite, fluorite, graphite, gypsum, lepidolite, nepheline syenite, perlite, phosphate, various salts, rock quartz, sillimanite, zeolite and many others.

In addition to industrial minerals, selected rare metals in Mongolia, i.e. beryllium, tin, tungsten, tantalum, niobium, and rare earths, are attracting increasing attention. Tin and tungsten are already being mined, and there is still good remaining potential.

In general, investment in industrial minerals and selected rare metals is still at a low level despite the opportunities: which is why this potential is now being promoted, so that such minerals can be economically exploited. The time has now come to focus on the industrial minerals which our rapidly developing country needs in larger quantities. Industrial minerals and rocks are used for the construction of buildings, the production of fertilizers, and the manufacture of many basic goods like glass, paper, and paint. Most of these commodities can be found in Mongolia, but only a few are being mined, and even fewer are being exported.

Rare metals are not in urgent need in Mongolia, but they can easily be exported because their prices are very high compared to their tonnage. Our country will benefit from their extraction.

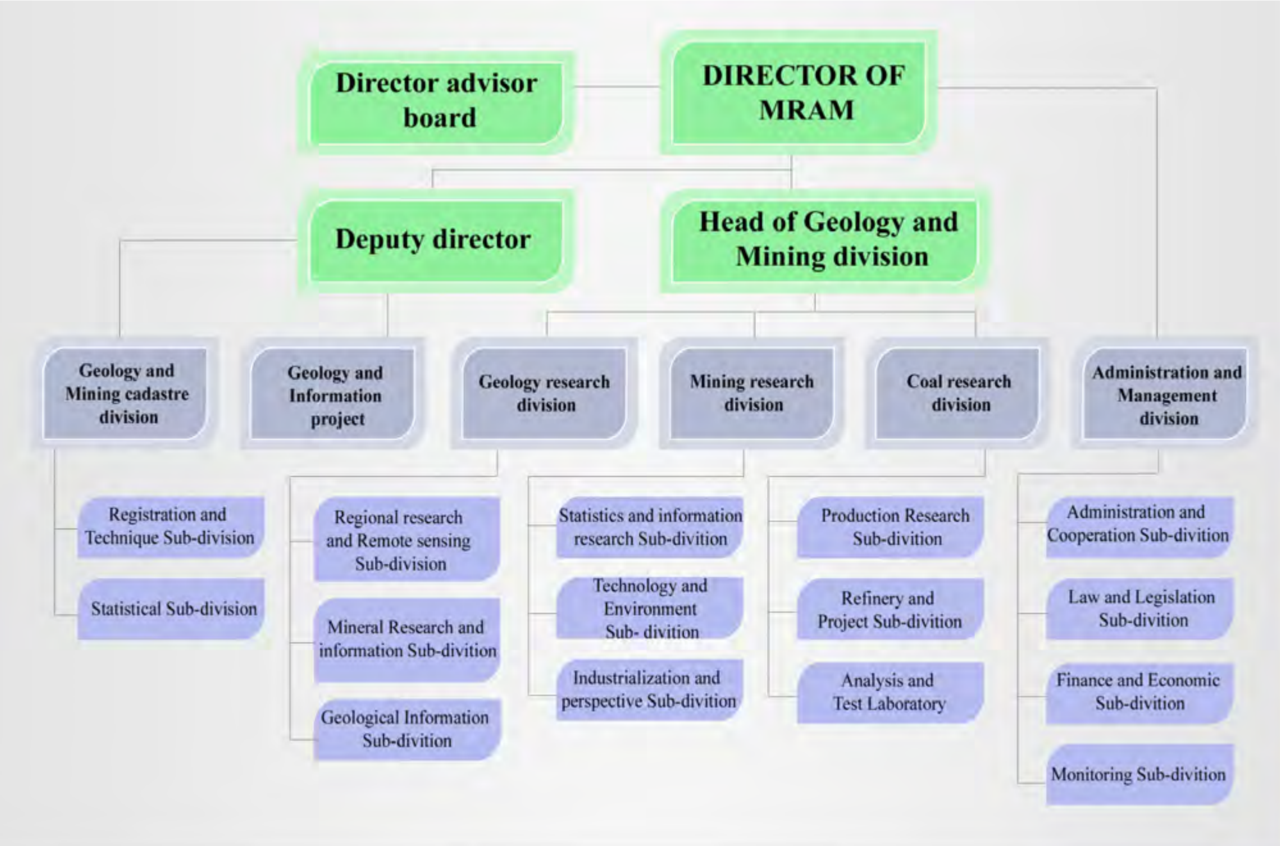
This brochure is devoted to providing important information on the deposits of industrial minerals and selected rare metals in Mongolia, and points out the many opportunities for investment. We hope you will find this investment guide not only attractive but also a clear indicator of where to invest best. We look forward to a growing revival in the exploration and exploitation of this additional important mineral wealth in our country for mutual benefit. With respect to the investment climate for mining in Mongolia, the Government is committed to ensuring that the country remains a prime investment destination in Asia.

Let me conclude by inviting you to visit our beautiful country, and form your own opinion regarding the manifold investment opportunities for the exploration and mining of industrial minerals and selected rare metals.

You are welcome.
Tavtai moril

D. Batkhuyag
Chairman
Mineral Resources Authority of Mongolia

ORGANISATION STRUCTURE OF THE MINERAL AUTHORITY OF MONGOLIA



MONGOLIA HAS MUCH TO OFFER INVESTORS

1. Over 1500,000 km^2 of varied geological terrain with potential mineral resources. Mongolia's mineral resources are largely unexplored and unexploited. Some 80 different minerals have been discovered in Mongolia so far, of which the most valuable are coal, fluorspar, and ores of copper, gold, iron, lead, molybdenum, silver, tungsten, uranium, and zinc.

   a. Mongolia is endowed with large proven coal reserves, which could sustain a considerable prospective increase in coal production. The economic coal potential of Mongolia is determined by four coal-forming epochs: the Carboniferous, Permian, Jurassic and Cretaceous. The Carboniferous coal-bearing formations are developed in the Mongolian Altai and Lake Zone and are represented by grey terrigenous sediments filling the basins. Carboniferous coals constitute high calorific power-generating fuels. Late Permian sediments, with potentially economic coal are developed mainly in South Mongolia where they fill near East-West-trending intermontane troughs. The Tavan Ttolgoi deposit is unique in terms of the size of the reserves and quality of the coal. The overall coal reserves of the Tavan Tolgoi deposit proper are estimated to be 5 billion tonnes. The economic potential of coal in Jurassic basins is developed in the western and central parts of the country, and Cretaceous deposits of coal and oil shales were formed in the central, south and eastern parts of Mongolia.

b. Mongolia has considerable copper reserves allowing the country to set up a new subsector of the mining industry. The main Mongolian copper reserves are in the porphyry type copper-molybdenum and copper-gold deposits. One Oyu Tolgoi copper-gold deposit has reserves of 45 million tonnes of copper and 819 tonnes of gold. Besides porphyry type mineralisation, other economic types of ore occurrences are also known: copper-skarn, copper-massive sulphide, copper-nickel, native copper, copper sandstone and shale in the Devonian and Silurian sequences.

c. Mongolia‘s production of fluorspar ranks third in the world behind China and Mexico. There are more than 600 deposits and occurrences of fluorite in Mongolia. Most of the fluorite deposits are of hydrothermal or epithermal origin, and can be divided into two groups by their genetic relationship to magmatic rocks. One group is related to volcanic rocks, and the other one to plutonic rocks.

d. Mongolia has considerable reserves and resources of gold in both placer and primary deposits. Gold mineralisation took place with varying intensity in the Neo Proterozoic, Early Cambrian, Early Palaeozoic, Middle Palaeozoic and Late Palaeozoic, Early Mesozoic, Late Mesozoic and Cenozoic mineragenic epochs. The intensity of mineralisation increases from older to younger epochs. At present, several potential gold metallogenic belts and gold-bearing belts have been identified. The known gold deposits of Mongolia are represented by three economic types: veins, mineralized zones and placers. Economic deposits and potentially economic occurrences belong mainly to the gold-sulphide-quartz and gold-quartz ore formations.

2. The Mongolian Government has adopted a package of long-term programmes to explore and develop large promising mineral deposits such as gold, silver, oil, coal, copper and other metals and minerals. Mongolia is now becoming one of the largest producers of several of these metals and minerals.

3. Mining operations are mostly state owned, but foreign investment in a wide range of industries is openly invited, especially in the exploration, extraction and processing of Mongolia‘s mineral resources. The World Bank has funded a mining and minerals sector study. It is also reviewing present and potential mineral operations.

4. The potential for Mongolia to benefit from its resources has been improved through the country‘s new minerals law and tax system, which has also brought about more certainty for foreign investment and involvement. It has strengthened environmental protection and rehabilitation issues, has given more rights to local administrative bodies, and increased the duties of licence holders.

CONTENTS

GENERAL INFORMATION

Figure 1: Map of Mongolia

Location:	between China and Russia in East Asia
Territory:	1.56 million sq. km
Capital city:	Ulaanbaatar
Population:	2.7 million
Average altitude:	1,580 m above sea-level
Land:	Mongolia ranks highest with an average of 64 ha per capita

Present day Mongolia is a booming country in terms of construction and infrastructure development, it therefore needs an economic evaluation of its non-metallic or industrial mineral resources. Previous research work only included an evaluation of the general geological situation and distribution of non-metallic raw materials, but did not contain an economic evaluation of those deposits and related aspects.

Thus the main aim for the preparation of this investors' guide was to complete an economic evaluation of non-metal deposits in regard to the demand of the booming economy of Mongolia. Additionally, selected rare metal deposits were also evaluated because rare metals, fetching high prices when exported, are of major interest to international investors.

INVESTMENT ENVIRONMENT

All sectors of the Mongolian economy are open to foreign investment. As a developing economy in transition, Mongolia is interested in the transfer of technology and know-how, modern management and learning skills, through foreign investment. The National Investment Code and the government encourages forms of foreign investment via joint ventures, 100 % foreign invested companies, co-production arrangements and concessions of land and natural resources, as well as the establishment of customs bonded houses.

Mongolia has much to offer investors. It has vast, untouched natural resources, a stable political situation, a developing economy, recent legal developments favourable to foreign investment, and a pool of skilled, low-cost labour. It sits between the huge Russian and Chinese markets.

To attract investment, Mongolia has enacted new laws and embraced new concepts. Recent legislation of interest to foreign investors covers partnerships and companies, bankruptcy, antimonopoly, banking, foreign exchange, land use, securities, consumer rights, customs, tax and property. Other related laws have been modified.
For the foreign investor, the most important is the Foreign Investment Law of 1993.

Foreign investment treatment applies to all enterprises in which the share of foreign investors is 20 % or more of the registered capital. All such foreign investments are subject to an approval procedure that involves obtaining a certificate from the Board of Foreign Investment.
The Foreign Investment Law of 1993 provides for a package of investment incentives. It pursues specific development objectives and also provides significant inducements for foreign businesses.

The incentives are principally fiscal. Foreign investors are provided with assurances and guarantees in the following areas:

- transfer of investment income;
- repatriation of capital;
- non-expropriation of property;
- dispute settlement through international arbitration.

The law also grants incentives in the region of custom duties, sales tax and corporate income-tax relief.
The import of equipment and machinery that forms part of the registered capital of foreign invested enterprises is exempt from customs duties and sales tax.
In addition, raw material, components, spare parts and material needed for the operation of such enterprises (except those in trading and catering businesses) are exempt from customs duties for the first five years.

A five-year tax exemption with a 50 % tax relief in the subsequent five-year period is granted to foreign-invested enterprises in the following industries:

- mining and processing of oil, coal and mineral resources (except precious metals),
- metallurgy and metal processing,
- chemical production and machinery,
- electronics.

For enterprises that export more than 50 % of their output and are not listed above, a full tax holiday is provided for the first three years, with 50 % tax relief accorded in the subsequent three-year period.

INVESTMENT AGREEMENT

Investment agreements can be concluded if an investment of more than 50.0 million USD is made within the first 5 years, or as follows for larger amounts:

- 50.0 - 100.0 million USD 10 years
- 100.0 - 300.0 million USD 15 years
- 300.0 million or more USD 30 years

The agreement with an investor will be made jointly by cabinet members responsible for financial, geological, mining and environmental issues.

INVESTMENT IN THE MINING SECTOR

Since 2003, investment in mineral exploration has rapidly increased in Mongolia.

TAXES AND CHARGES FOR ENTREPRENEURS IN THE MINING SECTOR

1. Economic entity and organisation income tax;
2. Individual income tax;
3. Value added tax;
4. Excise duty;
5. Automotive petroleum and diesel fuel;
6. Customs duty;
7. Royalties;
8. Land use fees;
9. Water and mineral water use fees;
10. Taxation of price increases of some goods;
11. Special licence fees;
12. Compensation fees for geological studies and surveys conducted at the expense of state budget funds;
13. Tax on automobiles and means of transportation;
14. Mineral resources use fees;
15. Immovable property tax;

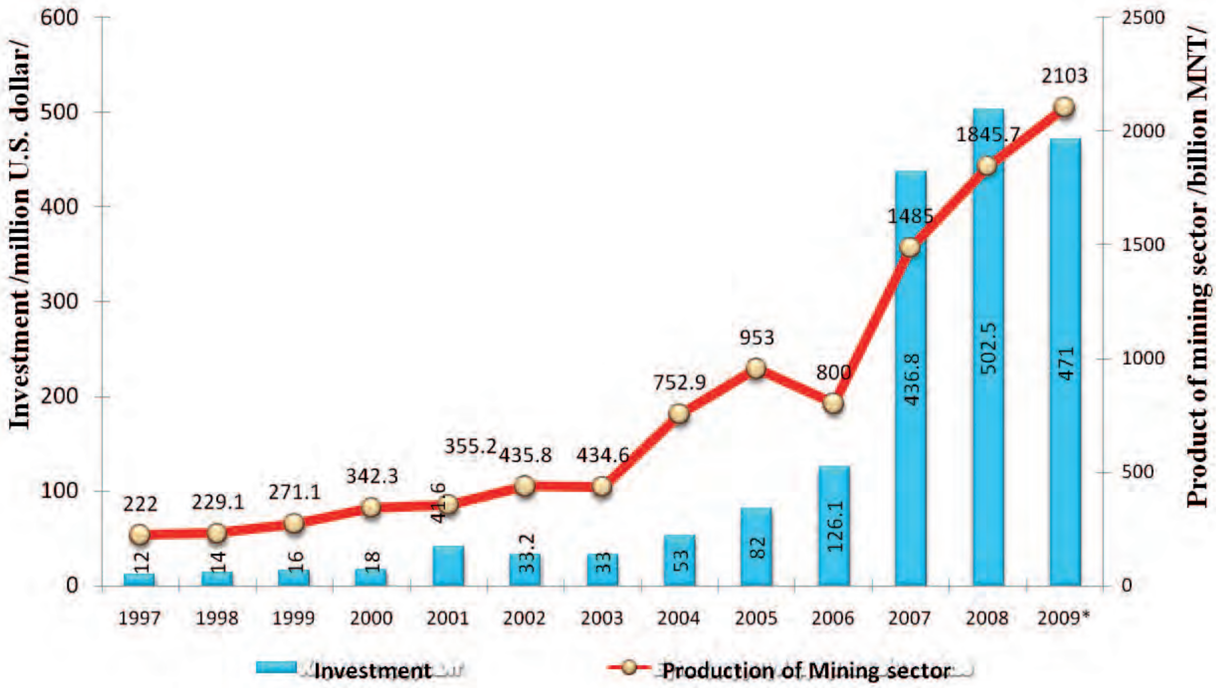


Figure 2: Diagram showing growing investment in and production of the Mongolian mining sector

THE MINERAL POLICY

Relevant laws, guidelines, and procedures for the prospecting, exploration and mining of minerals in Mongolia

- Minerals law of Mongolia;
- Mongolian underground resource law;
- Land law of Mongolia;
- Law on land fees;
- Law on nuclear energy;
- General taxation law;
- Law on water
- Law on taxation of price increases of some goods;
- Law on protection of mineral resources mining and exploration in the forests and buffer zones of protected areas with river-head and water resources;
- Law on environmental protection;
- Law on environmental impact assessment;
- Law on water and mineral water use fees;
- Law on economic entity and organisation income tax;
- Law on special licence of economic entity;
- Foreign investment law of Mongolia;
- Law on customs tariff and customs duty;
- Law on exemption of customs duty;
- Law on exemption of customs duty and value added tax;

- Guideline for confirming the minimum limit of expenses of the prospecting works plan and report;
- Guideline for classification of hard mineral resource reserves;
- International accounting standard – 6
- Guideline for sending samples across borders;

o Procedure for concluding pre-mining operation agreements;
o Procedure for accepting technical and commercial feasibility;
o Procedure for accepting mining work plan and report;
o Procedure for accepting the mine;
o Procedure for calculating the compensation amount of the expenses financed by state budget funding and paying off the compensation (Government Resolution No: 81, 2007)
o Procedure for using the widespread mineral resources by land owners and land possessors for non-profit purposes (Order No: 214 by the Minister of Trade and Industry, 2006)
o Procedure for paying, distributing and spending royalties;

MINERALS LAW OF MONGOLIA

(Revised [and updated] edition)

This English language version of the Minerals Law of Mongolia is not an official translation sanctioned by the Government of Mongolia. The Mongolian language version shall at all times be considered the sole authoritative source of the law.

CHAPTER ONE
GENERAL PROVISIONS

Article 1 Purpose of the law

1.1 The purpose of this law is to regulate relations within the territory of Mongolia with respect to reconnaissance, exploration and mining of minerals.

Article 2 Legislation on minerals

2.1 Mineral related legislation consists of the Constitution of Mongolia, the Subsurface Law, Land Law, Environmental Protection Law, National Security Law, this law and other relevant legislation which is consistent with those laws.

2.2 If an international treaty to which Mongolia is a party provides otherwise, the provisions of the international treaty shall be complied with.

Article 3 Scope of this law

3.1 This law shall regulate relations with respect to exploration and mining of all types of mineral resources except water, petroleum and natural gas.

3.2 Relations with respect to the artisanal mining and exploitation of minerals from micro mines shall be regulated by a dedicated law.

Article 4 Definition of terms

4.1 In this law the following terms shall have the following meaning:

4.1.1 „mineral“ means any usable naturally occurring mineral concentration that has been formed on the surface or in the subsoil as the result of geological evolutionary processes;

4.1.2 „reconnaissance“ means investigations to identify mineral concentrations without disturbing the subsoil through rock sampling, airborne surveys, and reviewing related geological and mineral information;

4.1.3 „geological survey to be conducted at expense of State budget“ means geological mapping, thematic surveys, geological prospecting and exploration which are being funded by the State budget;

4.1.4 „mineral prospecting“ means geological surveys conducted for the purpose of identifying the existence of mineral concentrations in areas prospective for mineral resources.

4.1.5 „mineral exploration“ means geological and exploration surveys conducted on and under the earth‘s surface for the purpose of identifying the location and quantity of mineral concentrations in detail and determining the technical and commercial feasibility of mining such mineral concentrations;

4.1.6 „mineral mining“ means the entire range of activities that include separating and extracting minerals from the land surface and subsurface, ore stockpiles, waste or tailings, increasing the concentration of their usable contents, producing products, marketing those products and other activities related therewith;

4.1.7 „minimum cost of exploration" means an obligatory minimum amount of expenditure on exploration work;

4.1.8 „mineral deposit" means a mineral concentration that has been formed on the surface or in the subsurface as the result of geological evolutionary processes, whose quality and reserves are proven and economically feasible to mine by production methods;

4.1.9 „hard rock mineral deposit" means any mineral concentration that has been formed as the result of geological evolutionary processes and exists in the same space with its host rock;

4.1.10 „placer mineral deposit" means a mineral concentration that has been separated from its first subsurface location as a result of erosion and mechanical processes and that is located on a separate surface after re-concentration.

4.1.11 „mineral deposit of strategic importance" means a mineral concentration where it is possible to maintain production that has a potential impact on national security, the economic and social development of the country at national and regional levels, or deposits which are producing or have the potential of producing above 5 per cent of total Gross Domestic Product[1] of the year.

4.1.12 „special purpose territory" means land taken by authorized government entities pursuant to Articles 17, 18 and 20 of the Land Law for special public needs at national and local levels where exploration and mining are restricted or precluded;

4.1.13 „reserved area" means an area previously granted under exploration or mining licence which is now taken under State control by order of the competent authority and exempted from any reconnaissance, exploration or mining activities;

4.1.14 „exploration licence" means a document granting the right to conduct reconnaissance and exploration in accordance with this law;

4.1.15 „mining licence" means a document granting the right to conduct mining in accordance with this law;

4.1.16 „exploration area" means the area granted under an exploration licence;

4.1.17 „mining area" means the area granted under a mining licence;

4.1.18 „mining claim" means part of a geological formation overlapping with a mining area and where mining is to be conducted;

4.1.19 „licence fee" means the payment that a licence holder makes as provided in this law in order to maintain the validity of the licence;

4.1.20 „licence holder“ means a legal person to whom an exploration or mining licence has been granted or transferred in accordance with this law;

4.1.21 „legal person“ means a company or cooperative stipulated in Article 33.1 of the Civil Code of Mongolia.

[1)] GDP (official exchange rate): $1.4 billion (2005 est.).

Article 5 Ownership of minerals

5.1 The mineral resources naturally occurring on and under the earth‘s surface in Mongolia are the property of the State.

5.2 The State, as the owner, has the right to grant exploration and mining rights in accordance with the terms and conditions of this law.

5.3 The percentage[2] of the State share in a minerals deposit, whose proven reserves have been determined through State funded exploration, shall be established by an agreement on development of the deposit.

5.4 In the case of a mineral deposit of strategic importance with proven reserves determined through State funded exploration and being exploited in partnership with a private business entity, the percentage of the State participation may be up to 50 %. The percentage of the State share shall be determined by an agreement on the use (exploitation of the) deposit considering the amount of investment made by the State.

5.5 The State may own shares up to 34 % of the investment made in a deposit of strategic importance by a business entity that holds a deposit with proven reserves which have been proven through exploration funded by sources other than the State budget; the percentage of the State share shall be determined by an agreement on the use (exploitation of the) deposit considering the amount of investment made by the State.

5.6 Not less than 10 % of the shares of a legal person holding a mining licence for a mineral deposit of strategic importance shall be sold through the Mongolian Stock Exchange.

[2)] Participation = percentage, LLXM

Article 6 Classification of mineral deposits

6.1 Mineral deposits are classified as follows;

6.1.1 Deposits of strategic importance;

6.1.2 Deposits of common minerals;

6.1.3 Deposits of conventional minerals;

6.2 Mineral deposits specified in Article 6.1.1 of this law shall refer to a deposit which meets the requirements of Article 4.1.11 of this law.

6.3 Abundant sediments and rock concentrations that might be used as construction material are classified as common mineral deposits.

6.4 All mineral concentrations except as specified in Articles 6.2 and 6.3 of this law shall be classified as conventional mineral deposits.

Article 7 General requirements of a licence holder and to conduct minerals exploration and mining operations

7.1 A mineral exploration and mining licence shall be granted to a legal person duly formed and operating under the laws of Mongolia and [holding the status of a] Mongolian taxpayer.

7.2 A licence holder shall meet the requirements specified in Article 7.1 of this law for the entire validity of the licence.

7.3 It is prohibited to conduct exploration or mining without a valid licence.

7.4 One licence may be granted to one legal person only.

7.5 Landowners or land-possessors may use common minerals from their land for private and non-commercial purposes. A list of such minerals that can be mined without a licence shall be approved by the Government.

CHAPTER TWO
STATE REGULATION IN THE MINERALS SECTOR

Article 8 The full powers of the State Great Hural (Parliament of Mongolia)

8.1 The full powers of the State Great Hural with respect to mineral issues are as follows:

8.1.1 Establish State policy with respect to development of geology and mining sector;

8.1.2 Oversee the Government for implementation of legislation on minerals exploration and mining;

8.1.3 Resolve matters concerning reconnaissance, exploration and mining of minerals on areas with special State protection.

8.1.4 Approve a mineral deposit as of strategic importance, upon proposal by the Government or by its own initiative

8.1.5 Restrict or prohibit exploration and mining activities or grants of exploration and mining licences for certain territories, either proposed by the Government or at its own initiative.

8.1.6 Establish special regulatory regime for mining, storage and transport of radioactive minerals;

8.1.7 Determine the percentage of the State share in deposits of strategic importance, either proposed by the Government or at its own initiative considering the mineral reserves registered in the State integrated registry and the percentage specified in 5.5 and 5.6 of this law.

Article 9 The full powers of the Government

9.1 The full powers of the Government with respect to mineral issues are as follows:

9.1.1 Enforce implementation of legislation on reconnaissance and exploration of minerals and mining;

9.1.2 Implement State policy with respect to the development of geology and mining sector;

9.1.3 Resolve matters concerning reconnaissance and exploration of minerals and mining on State special needs territory, exclusive of areas with State special protection;

9.1.4 Submit proposal to the State Great Hural on approving a deposit as having strategic importance;

9.1.5 Submit proposal to the State Great Hural on determination of the State share percentage in a deposit of strategic importance;

9.1.6 Resolve matters concerning the investment of Mongolia in a joint venture to develop a deposit of strategic importance;

9.1.7 Resolve issues or submit a proposal to the State Great

Hural with regard to taking specific areas for reserve or special purpose;

9.1.8 Participate in certain operations of mineral exploration and mining through a legal entity with a share of State ownership.

Article 10 Full powers of the State Central Administrative body

10.1 The State Central Administrative body in charge of geology and mining shall exercise the following full powers:

10.1.1 Develop and implement State policy with respect to the development of the geology and mining sectors;

10.1.2 With the authorisation of the Government, approve the selection procedures stated in Article 19.12, 20.1, 24.2 and 26.9 of this law;

10.1.3 Ensure enforcement of the legislation on minerals and resolutions of the Government with regard to implementation of such legislation;

10.1.4 Determine service fee rates for submitting an application to obtain a licence, transferring a licence, extending the term of a licence, pledging a licence, transferring a licence pursuant to a pledge, or surrendering all or part of a licence area, resolving boundary disputes and reviewing exploration work plans, information and reports;

10.1.5 Approve the annual integrated plan of geological studies to be funded by the State budget;

10.1.6 Approve procedures for funding, implementing and assessing results of geological studies to be funded by the State budget;

10.1.7 Approve procedures with regard to exploration and mining activities, and develop and approve product standards;

10.1.8 Oversee operations with respect to development of strategic deposits;

10.1.9 Approve charter of and establish a Minerals Professional Council in charge of reaching conclusions and issuing recommendations on reports of geological studies conducted within the territory of Mongolia.

Article 11 The obligations of the State administrative body

11.1 The State administrative body in charge of geology and mining issues shall implement the following duties:

11.1.1 To conduct regional geological, geochemical, hydrogeological cartographic and geophysical surveys within the territory of Mongolia;

11.1.2 To conduct research on the patterns of distribution and types of occurrence of mineral resources within the territory of Mongolia and the evaluation of such resources;

11.1.3 To provide geo-ecological research and recommendations with respect to natural and human factors that may have an impact on the social and economic development of Mongolia;

11.1.4 Providing interested persons with all available geological and mining related information, including information provided by licence holders in accordance with this law, except for information classified as confidential;

11.1.5 Maintaining and up-dating the information base with respect to national geological and related resources;

11.1.6 To monitor the plan, reports and the minimum work expenses of an exploration licence holder provided in this law;

11.1.7 To receive and resolve requests regarding mineral reconnaissance;

11.1.8 To provide evaluations and recommendations with respect to technology and equipment used in the mining industry, and implementation of mining technology policy;

11.1.9 To create a favourable investment environment for the mining sector and evaluations and recommendations with respect to the existing investment environment;

11.1.10 To do research, evaluations and issue recommendations with respect to the impact of the mining industry on the social and economic development of Mongolia;

11.1.11 To do research on the supply, demand and prices of mining products, and forecasting long-term trends;

11.1.12 Proposals with respect to State policies regarding particular mining projects and implementation of such policies;

11.1.13 To organize a bid to issue licences for mineralized zones investigated by state budget funding;

11.1.14 Integrated control of the operations related to an exploration and exploitation licence;

11.1.15 Give opportunities to carry out the operation to issue and reissue licences, revocation, transfer, pledge, surrender the entire or a part of the licence area under public and governmental control;

11.1.16 To receive, register and make decisions with respect to applications for licences; to maintain the register of licences;

11.1.17 To maintain the cartographic register of licences;

11.1.18 To issue exploration and mining licences;

11.1.19 To collect application processing and licence fees;

11.1.20 To review and resolve boundary disputes between and among licence holders;

11.1.21 To provide interested persons with access to the register of licences and the cartographic register of licences and to notify relevant government agencies of changes in these registers, and to publish official notices informing the public of such changes.

11.2 The State administrative unit in charge of geology shall be responsible for issues specified in Articles 11.1.1-11.1.7; the unit in charge of mining shall be responsible for issues specified in Articles 11.1.8-11.1.12; and the unit in charge of cadastre shall be responsible for issues specified in Articles 11.1.13-11.1.21.

11.3 The professional monitoring office shall implement State monitoring of mineral exploration, mining activities and implementation of mineral laws and legislation.

Article 12 Full power of local administrative[3] and self-governing bodies[4]

12.1 Local administrative and self-governing bodies shall implement the following with regard to mineral issues:

12.1.1 Ensure implementation of this law and the regulations of higher administrative bodies in their respective territories;

12.1.2 Permit the use of the area for the purposes specified in the licences; stop any violations

12.1.3 Monitor the compliance by licence holders of their obligations with respect to environmental restoration, health and safety regulations for workers and local residents, and payment of their obligations to the treasuries of local administrative bodies;

12.1.4 Adopt a resolution on establishing local special purpose territory in accordance with the grounds and regulations provided by Land Law.

[3]Local governors [4]Local Citizen's hurals

Article 13 Reserved areas

13.1 The establishment of reserved areas in exploration and mining licence areas shall be resolved by decision of the Government for the following purposes:

13.1.1 To put in order the register of licences;

13.1.2 To resolve boundary disputes among licence holders;

13.1.3 To conduct geological mapping, reconnaissance and exploration of minerals with State budget funding,

13.2 Where a reserved area is established in accordance with Article 13.1 of this law, the decision to establish a reserved area shall be made by official public notice and contain the following information:

13.2.1 The name of the Aimag or capital city and Soum or district where the reserved area is located;

13.2.2 The coordinates of the reserved area;

13.2.3 The purpose of reserving the area;

13.2.4 The time period for which the area shall be reserved.

13.3 The State administrative body shall record the area reserved in accordance with Article 13.1 of this law [both] in the licensing and cartographic register.

13.4 Reserved areas shall be released for the following reasons:

13.4.1 A decision by the Government to release the reserved area prior to expiration of the original term;

13.4.2 Expiration of the term for which the reserved area has been reserved;

13.4.3 circumstances specified in Articles 13.1.1-13.1.3 of this law are settled.

13.5 If a licence area is located within the boundary of a reserved area established in accordance with Article 13.1,3 of this law, the rights and liabilities of the licence holder shall remain effective for the period of reservation.

Article 14 Special purpose territory with restrictions and prohibitions on exploration and mining activities.

14.1 In the event that a competent body issues a resolution to establish a special purpose territory, a written notice containing the following information shall be delivered to the State administrative body within ten (10) business days:

14.1.1 The name of the Aimag, Soum and bagh where the territory is located;

14.1.2 The coordinates of the land where the special purpose territory is established;

14.1.3 The purpose for which the land has been taken for special purpose; the time period for which the land shall be used for special purpose.

14.2 The time period that the land shall be used for special purpose is not less than 5 years. The State administrative body shall record the coordinates of special purpose territory in the exploration licence register, mining licence register and cartographic register.

14.3 If a special purpose territory overlaps entirely or in part with a territory covered by a valid licence, precluding further exploration or mining in the overlapping area, the authority that decided to establish the special purpose territory shall be obliged to compensate the licence holder,

14.4 The amount of the compensation and time of payment shall be negotiated and agreed by the authority that decided to establish the special purpose territory and the affected licence holder. If the parties fail to reach an agreement, then the amount of compensation and time for payment shall be determined by the State administrative body based on the conclusions of the respective independent party [expert].

14.5 The licence holder shall have the right to resume its activities if the compensation is not paid in time as specified in Article 14.4.

14.6 Disputes related to compensation shall be decided by a court.

14.7 Within 1 month after the State administrative body gives public notice of the expiration of the period for special purpose territory, the legal person that previously held the specific area under the licence shall have an exclusive right to re-obtain the exploration or mining licence after submitting a request.

CHAPTER THREE
MINERAL EXPLORATION

Article 15 Reconnaissance

15.1 Any legal person shall have the right to conduct reconnaissance for minerals without a licence in areas already under exploration or mining licence and within the territory of Mongolia, except for reserved areas and special purpose territories. However, any person proposing to conduct reconnaissance must notify the State and local administrative body registering its name and address and a description and location of the area in which it proposes to conduct reconnaissance.

15.2 Disturbing the subsurface while conducting reconnaissance is prohibited and any person proposing to conduct reconnaissance shall obtain permission from the landowners or land-possessors or land-users to enter their land.

Article 16 Geological survey and research work to be conducted with State budget funding

16.1 Geological surveys and research work to be conducted with State budget funding shall be conducted without a licence.

16.2 With the purpose of identifying the geological setting, mineral distribution and areas with prospective mineral concentrations, the geological survey shall be done in accordance with scientific methods and methodologies at different stages.

16.3 The reconnaissance of minerals with State budget funding shall be conducted comprehensively.

16.4 Data from State funded geological exploration shall be placed in a State database and be open to the public.

16.5 Research work and geological surveying may be conducted in special use territory. No fee shall be paid in this case.

16.6 The State administrative central body in charge of geology and mining shall approve regulations on financing, implementing and monitoring, and receiving the results of State funded geological surveying in accordance with this law.

Article 17 Requirements for obtaining an exploration licence

17.1 The applicant must be eligible to hold an exploration licence in accordance with Article 7.1 of this law. Location and coordinates of all corners of a requested exploration area shall be marked in degrees, minutes and seconds on a standard map prepared by the State administrative body and the map shall be attached to the application.

17.2 The requested exploration area shall meet the following requirements:

17.2.1 It shall be tetragonal in shape and its borders shall be straight lines overlapping with directions along longitude and latitude;

17.2.2 No part of the requested exploration area may overlap with a reserved area or a special purpose territory;

17.2.3 No part of the requested exploration area may overlap with an existing licence area or an area covered by a previously filed pending licence application.

17.3 In order to avoid overlapping as set forth in Article 17.2.2 and 17.2.3 of this law, the borders of an exploration area may deviate from straight lines if the area borders with the following;

17.3.1 National borders;

17.3.2 A reserved area;

17.3.3 A special purpose territory;

17.3.4 An exploration or mining licence area granted before this law became effective having a shape and position other than as provided under this law;

17.3.5 Lakes, ponds and other natural formations that are considered impossible to be included in the exploration area.

17.4 The size of an exploration area shall be not less than twenty-five (25) hectares and may not exceed four hundred thousand (400 000) hectares.

17.5 A legal person may hold any number of exploration licences.

Article 18 Procedure for submitting an application for an exploration licence

18.1 An exploration licence shall be granted to the first applicant who registers and files an application for an exploration area and which meets the requirements of Articles 7.1 and 17.2.

18.2 A person specified in Article 18.1 of this law shall submit an application to the State administrative body in accordance with the approved form. The following documents shall be attached to the application:

18.2.1 The applicant‘s name, mailing address, phone and fax numbers;

18.2.2 Certified copy of the applicant‘s State registration certificate;

18.2.3 Area map prepared in accordance with the requirements of Article 17.1 of this law and the name of the Aimag, Soum or district in which the exploration area is located on the map;

18.2.4 A document showing that the applicant has paid the service fee specified in Article 10.1.4 of this law;

18.2.5 Information about qualified staff to conduct exploration activities;

18.2.6 Document proving that the applicant meets the requirements of Article 7.1;

18.2.7 Preliminary plan that includes type, scope and cost of exploration work to be conducted by the applicant requesting a licence specified in Article 20 of this law.

Article 19 Registering and processing of applications

19.1 Upon receiving the application specified in Article 18.2 of this law, the State administrative body shall carry out the following:

19.1.1 Register the application in the application register and record the number, date, hour and minute of registration on each page attached to the application and issue the applicant a receipt acknowledging the filing of the application;

19.1.2 Record the first and last registered application of that day;

19.1.3 Immediately following the registration it shall be determined by preliminary screening whether the application and the attached documents meet the requirements specified under Articles 17.1,17.2 and 18.2 of this law;

19.1.4 Following the preliminary screening specified in Article 19.1.3 of this law, it shall be determined whether the requested exploration area overlaps with an area with restrictions or prohibitions on mineral exploration or mining, reserved area, special purpose territory, or any area subject to an existing valid licence or previously filed pending application for a licence.

19.2 Upon completing the actions specified in Article 19.1, the State administrative body shall make one of the following decisions within twenty (20) business days of registration of the application:

19.2.1 Refuse the request and give written notice to the applicant containing the grounds of such a decision if the application and attached documents fail to meet the requirements of Articles 17.1,17.2 and 18.2 of this law, and record it in the application registration book.

19.2.2 Notify the applicant that the requested area is available for issue under exploration licence, if the requested area does not overlap with any part of the areas specified in Article 19.1.4.

19.2.3 Notify the applicant in writing that the application is rejected, if the requested area overlaps completely or partially with an area with restrictions or prohibitions on mineral exploration or mining, special purpose territory, reserved area, or an area subject to an existing valid licence, and record the decision in the application registration book.

19.2.4 Notify the applicant in writing that the application is rejected, if the requested area overlaps completely with an area requested by a pending application for a licence filed prior to the application, and record the decision in the application registration book;

19.2.5 Notify the applicant that the exploration licence may be granted for the part of the requested area which does not overlap, if the requested area partially overlaps an area requested in a pending application for a licence submitted prior to the application. Another application shall be submitted if the applicant wishes to obtain an exploration licence for the area.

19.3 The State administrative body shall give written notice to the Governor of the Aimag or capital city if it is deemed possible to grant a licence in accordance with Articles 19.2.2 and 19.2.5 of this law. An area map prepared in accordance with Article 17.1 of this law shall be attached to the written notice.

19.4 Within thirty (30) days of receiving the notice specified in Article 19.3, the Governor of the Aimag or capital city shall respond to the State administrative body after obtaining the opinions of Citizens Representatives Hural of the Soum or district and the Presidium of Citizens Representatives Hural of an Aimag or district. Failure to respond in the specified time shall be deemed as approval.

19.5 The Governor of the Aimag or district may only refuse the granting of an exploration licence based on grounds provided in the laws [of Mongolia],

19.6 If the Governor of the Aimag or capital city gives a response supporting the decisions specified in Articles 19.2.2 and 19.2.5 of this law, the State administrative body shall make a decision to grant the area under an exploration licence and notify the applicant that the licence fee for the first year is to be paid within the period specified in Article 34.1 of this law,

19.7 If the applicant fails to obtain the licence within one (1) month of the decision specified in Article 19.6 of this law or fails to pay the first year‘s licence fee within the period specified in Article 34.1 of this law, the State administrative body shall remove the application from the register and notify the applicant of this action, and record it in the application registration book.

19.8 Within three (3) business days of receiving the payment in the specified period for the first year‘s licence fee, the State administrative body shall issue an exploration licence for a period of three (3) years and record the exploration licence and the area in the licence register and licence cartographic register.

19.9 An exploration licence shall contain the date of issuance, the licence holder‘s name, the coordinates of the area covered by the licence and an attachment in which all subsequent changes with respect to the licence shall be recorded.

19.10 Immediately following the granting of an exploration licence, the State administrative body shall notify the State central administrative body in charge of environmental issues, governors of the Aimag, Soum or district where the licence area is located, and the professional inspection agency, and publish an official notice in a daily newspaper.

19.11 The State administrative body shall return the application and attached documents to the applicant if the decisions specified in Articles 19.2.1, 19.2.3, 19.2.4, and 19.7 of this law are made.

19.12 The exploration licence for an area with a mineral concentration which was determined through State budget funded geological survey work shall be granted by tender.

Article 20 Granting of an exploration licence for an expired licence area

20.1 If a licence is revoked on the grounds specified in Article 56 of this law, the State administrative body shall reissue the licence through tender bidding in accordance with the procedure stated below.

20.1.1 To select areas specified in Article 20.1 of this law, and make a public announcement in a daily newspaper 30 days in advance of the application date for tender bids.

20.1.2 Applicants shall be evaluated in accordance with the procedures specified in Article 10.1.2 of this law considering the skills of the applicant‘s professional staff. The applicant with the highest rating shall be granted the licence.

20.1.3 If the evaluation of 2 or more applicants results in the same rating, the licence shall be granted to the first applicant. The first applicant shall be determined in accordance with Article 19.1.2 of this law.

20.2 If an application and attached documents fail to meet the requirements of Article 18.2 of this law, the application shall be refused and written notice containing the grounds of such refusal shall be issued to the applicant. This shall be recorded in the application registration book; the application and documents attached to it shall be returned.

20.3 If no bid is submitted for the tender called in accordance with Article 20.1 of this law, the exploration licence for this area shall be granted in compliance with Article 18 and 19 of this law.

Article 21 Rights of exploration licence holder

21.1 An exploration licence holder shall have the following rights:

21.1.1 To conduct exploration for minerals within the boundaries of an exploration area in accordance with this law;

21.1.2 To obtain a mining licence for any part of an exploration area upon fulfilling the terms and conditions of this law;

21.1.3 To transfer the exploration licence under the terms and conditions of this law or surrender all or part of the exploration licence area with permission and under supervision of the respective authority;

21.1.4 To obtain two extensions of the term of an exploration licence for three (3) years each, upon fulfilling the terms and conditions of this law;

21.1.5 To have access to the exploration area and construct temporary structures for the purpose of conducting exploration work;

21.1.6 To pass through the land surrounding the exploration area for the purpose of entering the exploration area;

21.1.7 To enter and pass through the land owned or possessed by other persons as approved by the owner or possessor of the land in order to exercise the rights provided by this law.

Article 22 Extension of the term of an exploration licence

22.1 One (1) month prior to the expiration of an exploration licence, the licence holder may apply for an extension of the term of the licence by submitting an application to the State administrative body. The following documents shall be attached to the application:

22.1.1 Certified copy of the exploration licence certificate;

22.1.2 Receipts for payments of annual licence fees and service fees and a document proving that the cost of exploration work conducted is no less than the minimum cost of exploration;

22.1.3 Document proving the renewed approval of an environmental protection plan in accordance with Article 40 of this law;

22.1.4 A report on completion of the exploration work for a given stage and documents on its acceptance.

22.2 Within ten (10) business days following the receipt of an application for an extension specified in Article 22.1 of this law, the State administrative body shall review whether the licence holder has complied with the conditions and requirements of Articles 7.2 and 31. If there are no violations, the licence term shall be extended for the period specified in Article 21.1.4 of this law, and the extension will be recorded in the licence register book.

22.3 Immediately following the extension of an exploration licence, the State administrative body shall notify the professional inspection agency and publicise the extension in a daily newspaper.

Article 23 Pre-mining operation

23.1 Pre-mining operation is a period after exploration is completed and reserves of a mineral deposit have been State registered , and during which the design package, feasibility study, mine development and commencement of production are implemented,

23.2 The commencement period for the mining of the mineral deposit or mine development period shall be no more than 3 years upon expiration of the exploration licence.

23.3 Pre-mining operations shall be regulated by a pre-mining agreement concluded between the exploration licence holder and the State administrative body.

23.4 The licence holder shall pay exploration licence fees for the seventh to ninth years of the term as specified in Article 32.2 of this law and within the period specified in Article 23.2 of the law.

CHAPTER FOUR
MINERAL MINING

Article 24 Requirements for obtaining a mining licence

24.1 In the case of areas covered by a valid exploration licence, only the exploration licence holder may apply for a mining licence.

24.2 If the exploration licence has expired in accordance with Article 53.1.1 of this law and the exploration licence holder fails to submit an application for a mining licence, the mining licence for the area shall be granted through tender.

24.3 The application specified in Articles 24.1 and 24.2 shall contain coordinates of all corners of the requested mining area in degrees, minutes and seconds on a standard map approved by the State administrative body, and the map shall be attached to the application.

24.4 A requested mining area shall meet the following requirements:

24.4.1 A requested mining area shall have the shape of a polygon with borders that are straight lines, not less than 500 metres in length, oriented north-south and east-west;

24.4.2 A requested mining area may not overlap with a reserved area, special purpose territory or an area under existing valid licence;

24.4.3 For salt and common minerals, each side of the area shall be not less than 100 metres.

24.5 The borders of a mining licence area may deviate from straight lines in order to avoid overlapping as specified in Articles 24.4.2, when the following areas are involved:

24.5.1 National border;

24.5.2 Reserved area;

24.5.3 Special purpose territory;

24.5.4 Mining licence area granted under the prior minerals law having a shape and location that does not conform with the requirements of this law

24.5.5 Natural formations, such as lakes and ponds that may be excluded from the mining area.

Article 25 Procedure for submitting an application requesting a mining licence

25.1 An applicant for a mining licence shall submit an application in the approved form specified in Articles 24.1 and 24.2 of this law to the State administrative body. The following documents shall be attached to the application:

25.1.1 The applicant‘s name, mailing address for official post, phone and fax numbers and a certificate containing the name of its officer authorized to make decisions;

25.1.2 A document certifying that the applicant meets the requirements of Article 7.1 of this law;

25.1.3 A map of the area prepared in accordance with the requirements of Article 24.3 of this law. The map shall contain the name of the Aimag or capital city and Soum or district in which the area is located.

25.1.4 A document showing that the applicant has paid the service fee specified in Article 10.1.4;

25.1.5 Minerals Council‘s note on the discussion of exploration work results, and the decision of the State administrative body;

25.1.6 A verification of performance of the duties with regard to the environmental protection plan during exploration work;

25.1.7 An evaluation of the effect on the environment;

25.1.8 The decision of an organisation and an official who organised tender bidding specified in Article 24.2 of this law for the licence areas explored with State budget funding.

Article 26 Registering and processing the application

26.1 Upon receiving the application specified in Article 25.1 of this law, the State administrative body shall carry out the following:

26.1.1 Register the application in the application register and record the number, date, hour and minute of registration on each page attached and issue a receipt to the applicant acknowledging the registration of the application.

26.1.2 Immediately following the registration, preliminary screening will be carried out to determine whether the application and the attached documents meet the requirements specified in Articles 24.3, 24.4 and 25.1 of this law.

26.2 Following the preliminary screening specified in Article 26.1.2 of this law, the following shall be clarified:

26.2.1 Whether the requested mining area is located entirely within the boundaries of the area covered by the exploration licence in the case of an exploration licence holder applying for a mining licence for the exploration licence area;

26.2.2 Whether the requested mining area overlaps with any reserved area, special purpose land or an area already subject to an existing valid licence;

26.2.3 Whether the size and evaluation of the mineral reserves estimated by exploration would be enough for restoring any ecological damage that might be caused by mining activities.

26.3 Within twenty (20) business days following the registration of an application for a mining licence, the State administrative body shall take one of the following decisions based on the clarifications specified in Articles 26.1 and 26.2, and notify the applicant accordingly:

26.3.1 Refuse the request and give written notice to the applicant containing the grounds of such a decision if the application and attached documents fail to meet the requirements of Articles 24.3, 24.4 and 25.1 of this law, and record it in the application registration book.

26.3.2 When the exploration licence holder submits an application for a mining licence for the exploration area, the mining licence shall be granted according to the application registration book.

26.3.3 Exclusive rights of the applicant, and the applicant shall be required to pay the first year‘s licence fee specified in Article 34.1 of this law;

26.3.4 The requested mining area shall be granted if it does not overlap with any part of an area with restrictions or prohibitions on exploration or mining, reserved area, special purpose land or any area subject to a valid licence, and the applicant shall be required to pay the first year‘s licence fee specified in Article 34.1 of this law;

26.3.5 If the requested area overlaps in any way with an area specified in Article 26.3.3 of this law, the application for a mining licence shall be refused and written notice containing grounds of such a refusal shall be issued to the applicant. This shall be recorded in the application registration book

26.4 If the applicant who has received a mining licence approval notice in accordance with Articles 26.3.2 and 26.3.3 of this law fails to pay the first year's licence fee within the period specified in Article 34.1 of the law, the State administrative body shall remove the application from the application register and notify the applicant in writing and record it in the application registration book.

26.5 Within three (3) business days following the payment by the applicant of the licence fee for the first year in accordance with Articles 26.3.2 and 26.3.3 of this law, the State administrative body shall issue a mining licence to the applicant for a term of thirty (30) years and shall register the licence and mining area in the licence register and licence cartographic register.

26.6 A mining licence shall contain the date of issuance, the licence holder's name, address and the coordinates of the corners of the mine area covered by the licence, and an attachment in which all subsequent changes with respect to the licence shall be recorded.

26.7 Within seven (7) business days following the issuance of a mining licence, the State administrative body shall notify the State central administrative body in charge of environmental issues, the State administrative body in charge of taxation and fiscal issues, the Aimag, Soum and district governors where the licence area is located, and the professional inspection agency, and publish an official notice informing the public about the granting of the licence.

26.8 The State administrative body shall return the application and attached documents to the applicant if the decisions specified in Articles 26.3.1, 26.3.4, 19.2.4, and 26.4 of this law are made.

26.9 A mining licence for an area explored and reserves determined with State budget funding shall be granted by tender.

Article 27 Rights and obligations of mining licence holders

27.1 A mining licence holder shall have the following rights and obligations:

27.1.1 The right to engage in the mining of minerals within the mining claim in accordance with the provisions of this law;

27.1.2 To fulfil obligations specified in Chapter 6 of this law;

27.1.3 The right to sell mineral products from the mining claim at market prices on foreign markets;

27.1.4 The right to conduct exploration for minerals within the mining claim;

27.1.5 The right to transfer and pledge all or part of the mining licence in accordance with the provisions of this law;

27.1.6 The right to extend the term of the mining licence twice for a period of twenty (20) years each depending on the reserves of the mineral;

27.1.7 The right to enter and pass through the mining area, construct necessary structures and use the mining area in order to carry out mining activities;

27.1.8 The right to pass through the land adjacent to the mining area;

27.1.9 To enter and pass through the land owned or possessed by other persons as approved by the owner or possessor of the land in order to exercise the rights provided by this law.

27.1.10 The right to use land and water in compliance with applicable laws;

Article 28 Extension of the term of a mining licence

28.1 Not less than two (2) years prior to the expiration of a mining licence, the licence holder may submit an application in the form approved by the State administrative body for an extension of the mining licence. The following documents shall be attached to the application:

28.1.1 Certified copy of the mining licence;

28.1.2 Receipts for payments of the licence fee and service fee;

28.1.3 Certificate verifying the inspection of the implementation of the environmental plan carried out in accordance with Article 39 of this law.

28.2 Within fifteen (15) business days following the receipt of an application specified in Article 28.1 of this law, the State administrative body shall verify whether the licence holder has complied with the conditions for maintaining its eligibility to hold the licence. If there are no violations, the licence term shall be extended for the period specified in Article 27.1.6 of this law. The extension shall be recorded in the licence register book and the applicant notified.

28.3 Within seven (7) business days following the decision to extend the mining licence, the State administrative body shall notify the authorities specified in Article 26.7 of this law and publicise the extension in a daily newspaper.

Article 29 Investment agreement

29.1 At the request of the licence holder, an investment agreement may be concluded with a mining licence holder, which undertakes to invest no less than fifty (50) million US Dollars in Mongolia for the first five (5) years of its mining project, in order to provide a stable environment for the operations of the mining licence holder. The agreement shall contain the following:

29.1.1 Maintaining a stable tax environment;

29.1.2 The right of the licence holder to sell its products at international market prices;

29.1.3 Guarantee the rights of the licence holder to receive and dispose of income derived from its sales;

29.1.4 The amount and term of the licence holder‘s investment;

29.1.5 Mining of the minerals with minimum damage to the environment and public health;

29.1.6 Protection and restoration of the environment;

29.1.7 Not to negatively effect other industries and operations;

29.1.8 Developing the region and creating employment;

29.1.9 Compensation for damage caused.

29.2 The agreement specified in Article 29.1 of this law shall be concluded with the investor by the cabinet members in charge of finance, geology, mining and environmental issues upon authorisation of the Government of Mongolia;

29.3 If the amount of the investment for the first 5 years is no less than fifty (50) million US Dollars, the term of the agreement shall be ten (10) years; if the investment is more than one hundred (100) million US Dollars, the term of the agreement shall be fifteen (15) years; or if more than three hundred (300) million US Dollars, the term shall be 30 years.

Article 30 Procedure for concluding an agreement with an investor

30.1 The licence holder interested in concluding the agreement specified in Article 29.1 of this law shall submit its request and draft agreement to the State central administrative bodies specified in Article 29.2 of this law. The following shall be attached to the request:

30.1.1 Feasibility study and information describing the period and amount of investment in the first 5 years of the mining activities, mining production capacity, types of mining products, mining methods and technology;

30.1.2 A note from the Minerals Council that the reserves of the deposit are registered in the national register of reserves,

30.2 The State central administrative bodies specified in Article 30.1 of this law shall review whether the draft agreement, request for an investment agreement, and the attached documents meet the requirements of Article 29.3 and 30.1 of this law, and shall notify the licence holder of its status within ten (10) business days.

30.3 The State central administrative body in charge of finance, geology, mining and environmental issues shall review the request, draft agreement and attached documents for three (3) months after their receipt, and if additional clarification is deemed necessary, up to 3 months more. On the basis of the comments and conclusions from the relevant organisations and specialists, the agreement shall be concluded with the investor in accordance with Article 29.1 of this law.

30.4 Upon signing the investment agreement in accordance with Article 30.3 of this law, notice of the terms and conditions of the agreement shall be delivered to Mongolbank (Central Bank of Mongolia) and other relevant authorities.

CHAPTER FIVE
CONDITIONS FOR MAINTAINING ELIGIBILITY TO HOLD A LICENCE

Article 31 Maintaining the eligibility to hold a licence

31.1 A licence holder is obliged to comply with the conditions and requirements set forth in Article 32 and 33 of this law. Failure to comply shall result in revocation of the licence pursuant to Article 56 of this law.

Article 32 Licence fees

32.1 Licence holder shall pay licence fees annually in accordance with this law.

32.2 Exploration licence fees shall be payable with respect to each hectare included within the exploration area at the following rates:

32.2.1 US$ 0.1 for the first year, US$ 0.2 for the second and US$ 0.3 for the third year of the term of the exploration licence;

32.2.2 US$ 1.00 for each of the fourth to sixth years of the term of the exploration licence;

32.2.3 US$ 1.50 for each of the seventh to ninth years of the term of the exploration licence.

32.3 Mining licence fees of US$ 15.00 shall be payable with respect to each hectare included within the mining area. However, in the case of coal and other common mineral resources, the fee shall be US$ 5.00 for each hectare.

Article 33 The minimum amount of exploration expenses and its verification

33.1 Each year an exploration licence holder shall undertake reconnaissance and exploration work with expenses not less than the amounts specified below on each hectare of the licence area:

33.1.1 US$ 0.5 for each of the second and third years of the term of the exploration licence;

33.1.2 US$ 1.00 for each of the fourth to sixth years of the term of the exploration licence;

33.1.3 US$ 1.50 for each of the seventh to ninth years of the term of the exploration licence;

33.2 The costs of exploration work shall be verified by the State administrative body based on the annual exploration work report and financial report of the legal person involved.

33.3 The State administrative body may carry out inspection work on the amount of expenses at the actual work site if necessary.

Article 34 Payment of licence fees

34.1 Licence fees for the first year shall be paid within ten (10) business days after the licence holder receives the notice specified in Articles 19.6, 26.3.2 and 2.3.3 of this law.

34.2 Licence fees for subsequent years shall be payable annually in advance, on or before the anniversary date of the issuance of the licence.

34.3 The amount of the licence fee shall be calculated on the basis of the measurements of the licence area as registered in the register of licences and the amount of the fee shall not change for the particular year.

34.4 The licence fee shall be deemed paid upon receipt by the State administrative body of documents certifying the payment of the fees; the date of payment shall be the day the bank transaction is made.

CHAPTER SIX
OBLIGATIONS OF A LICENCE HOLDER

Article 35 General obligations of a licence holder,

35.1 While carrying out their activities, a licence holder shall comply with the general obligations set forth in this article. Failure to comply with the general obligations will subject the licence holder to the penalties set forth in Article 66.1.4 of this law.

35.2 An exploration licence holder shall keep the following documents at the actual site of the exploration work:

35.2.1 Certified copy of the exploration licence;

35.2.2 Environmental protection plan and report;

35.2.3 Exploration work plan reviewed by the State administrative body and professional inspection agency;

35.3 A mining licence holder shall keep the following documents at the mine:

35.3.1 Certified copy of the mining licence;

35.3.2 Feasibility study on mineral mining and a mining plan reviewed by the relevant organisation;

35.3.3 Environmental impact assessment;

35.3.4 Environmental protection plan;

35.3.5 Property lease and sales agreements;

35.3.6 A certificate for establishing and marking the boundary of the mining area;

35.3.7 Agreements on land and water use.

35.4 A mining licence holder shall commence the activities of the mine after it has been accepted by a commission appointed by the State central administrative body in charge of geology and mining.

35.5 The mining licence holder shall extract the mineral reserves appropriately. It is prohibited to mine by selecting the high grade areas only.

Article 36 Establishing the boundaries and marking the area held under a mining licence

36.1 Within three (3) months following the registration of the mining licence in the register of licences, the mining licence holder shall establish the boundaries and mark the approved mining area by permanent markers in accordance with technical requirements specified by the professional inspection agency. The establishment of the boundaries of the mining area shall be performed by a person authorized by the State administrative body, who shall file a report with the State administrative body upon completion of the establishment of the boundaries.

36.2 A mining licence holder shall preserve the markers and adjust and replace the markers upon reorganisation within the area in accordance with the decisions of the State administrative body.

Article 37 Environmental protection

37.1 Exploration and mining licence holders shall comply with the laws and legislation on environmental protection and Articles 38 and 39 of this law.

37.2 A licence holder may not commence exploration operations without first obtaining written approval from the relevant environmental agency, or commence mining operations without a commission act set forth in Article 35.4 of this law. In the event of any dispute arising out of these matters, the complaint may be lodged with the professional inspection agency.

Article 38 Environmental protection obligations of an exploration licence holder

38.1 An exploration licence holder shall have the following obligations regarding environmental protection;

38.1.1 Within thirty (30) days following the receipt of an exploration licence, the exploration licence holder shall prepare an environmental protection plan by consulting with the environmental inspection agency and the Governor of the Soum or district in which the exploration area is located;

38.1.2 The environmental protection plan shall include measures to ensure the level of the environmental pollution does not exceed the accepted limits, and reclamation of the area by means of backfilling, plugging, and cultivation to allow future utilisation for public purposes.

38.1.3 The environmental protection plan shall be delivered to and approved by the Governor of the relevant Soum or district where the exploration area is located.

38.1.4 Upon approval of the environmental protection plan in accordance with Article 38.1.3 of this law, a copy of the plan shall be submitted to the local environmental inspection agency.

38.1.5 The licence holder shall record all instances of adverse environmental impact resulting from the exploration activity in the annual report of the environmental protection plan and deliver the report to the Governor of the relevant Soum or district and environmental inspection agency.

38.1.6 The report specified in Article 38.1.5 shall contain information on measures taken to protect the environment and proposed amendments to the environmental protection plan directed at preventing the possible impact on the environment of new exploration machinery and technology. All amendments to the environmental protection plan shall be approved by the Governor of the relevant Soum or district.

38.1.7 To provide the State and local administrative body official in charge of monitoring implementation of the laws on environmental protection with an opportunity to enter the exploration area to conduct monitoring activities on the site.

38.1.8 To ensure the discharge of its responsibilities with respect to environmental protection, an exploration licence holder shall deposit an amount equal to 50 % of its environmental protection budget for the year in a special bank account established by the Governor of the relevant Soum or district.

38.2 Within ten (10) days of receiving the environmental protection plan and proposed amendments to it, the Governor of the relevant Soum or district shall review and approve the plan and deliver it to the licence holder.

38.3 If a licence holder fails to fully implement the measures provided in the environmental protection plan, the Governor of the relevant Soum or district shall use the deposit stated in Article 38.1.8 of this law to implement these measures, and the licence holder shall provide any additional funds required without dispute.

38.4 The deposit specified in Article 38.1.8 of this law shall be returned to the licence holder if all the obligations of the environmental protection plan are complied with.

Article 39 Environmental protection obligations of mining licence holders

39.1 A mining licence holder shall have the following obligations with regard to environmental protection:

39.1.1 An environmental impact assessment and an environmental protection plan shall be prepared by a person specified in Article 24.1 of this law before obtaining a mining licence and by a person who obtained a mining licence through tender.

39.1.2 The environmental impact assessment shall identify the possible adverse environmental impacts of the proposed mining operations on public health and the environment, and shall include preventive measures to avoid and minimise such adverse impacts.

39.1.3 The environmental protection plan shall contain measures to ensure that mining operations are conducted in the least damaging way to the environment. The plan shall also identify preventive measures to protect air and water, humans, animals and plants from the adverse effects of mining operations

39.1.4 In addition to Article 39.1.3 of this law, an environmental protection plan must include the following:

39.1.4.1 Storage and control of toxic and potentially toxic substances and materials;

39.1.4.2 Protection, utilisation and conservation of the surface water and underground water;

39.1.4.3 Construction of tailings dams and ensuring the mine area safety;

39.1.4.4 Reclamation measures stated in Article 38.1.2 of this law;

39.1.4.5 Other measures as may be appropriate for the particular type of mining operation;

39.1.5 The environmental impact assessment and environmental protection plan shall be submitted to the State central administrative body in charge of environmental issues.

39.1.6 Immediately following the approval of the environmental impact assessment and environmental protection plan, the licence holder shall deliver the copy of the documents to the Governor of the Aimag, Soum or district and local environmental inspection agency of the area in which the mineral deposit is located.

39.1.7 Mining licence holders shall record all instances of adverse environmental impacts resulting from mining activity, prepare and send a copy of annual reports on the implementation of the environmental protection plan to the State central administrative body in charge of the environment, the Governor of the relevant Aimag, Soum or district, and the professional inspection agency. The report shall contain the following:

39.1.7.1 Information on measures taken to protect the environment

39.1.7.2 New machinery and technology utilised

39.1.7.3 Proposed amendments to the environmental impact assessment and environmental protection plan with regard to possible adverse impacts on the environment due to an expansion of mining operations.

39.1.8 A mining licence holder shall provide officials of local and State administrative bodies in charge of monitoring the implementation of legislation on environmental protection with an opportunity to enter the mining claim area and to conduct monitoring activities on the site.

39.1.9 To ensure the discharge of its responsibilities with respect to environmental protection, a mining licence holder shall deposit an amount equal to 50 % of its environmental protection budget for the particular year in a special bank account established by the Governor of the relevant Soum or district.

39.2 The State central administrative body in charge of environmental issues shall review the documents specified in Articles 39.1.5 and 39.1.7.3 and notify the licence holder of its decision within thirty (30) days after receiving such documents.

39.3 If a mining licence holder fails to fully implement the environmental protection measures, the State central administrative body in charge of environmental issues shall use the deposit specified in Article 39.1.9 of this law to implement protection work and the licence holder shall provide any additional funds required without dispute.

39.4 The deposit specified in Article 39.1.9 of this law shall be refunded to the licence holder upon fulfilment of the obligations of the environmental protection plan and environmental impact assessment. The funds specified in Article 39.3 of this law shall be transferred within one (1) month following the commencement of mining activities of the year; the State central administrative body in charge of environmental issues shall notify the Governor of the relevant Soum or district of the transfer. If the licence holder fails to transfer the funds specified in Article 39.1.9 of this law within the period required by this Article, the Soum or district Governor shall have the right to end the mining activities for the year.

39.5 In the event of failure to complete protection activities for the year, the Governor of the relevant Soum or district and the professional inspection agency jointly hold the right to prevent the commencement of the mining activities for the next year.

39.6 The procedures for monitoring the transactions of special accounts specified in Articles 38.1.8 and 39.1.9 shall be approved by the member of government in charge of environmental issues.

39.7 The State central administrative body in charge of environmental issues shall require the licence holder to provide amendments to the environmental protection plan and environmental impact assessment if new circumstances arise which have adverse impacts on the environment due to introduction of new equipment and technology during the valid licence term.

Article 40 Review of environmental protection plan in connection with extensions of licences

40.1 Exploration licence holders applying for a licence extension shall submit their revised environmental protection plan to the Governor of the relevant Soum or district for approval prior to the expiration of the exploration licence.

40.2 Mining licence holders applying for a licence extension shall submit their revised environmental impact assessment and environmental protection plan to the State central administrative body in charge of environmental issues for approval.

40.3 The assessment and plan specified in Articles 40.1 and 40.2 of this law shall be approved in accordance with the Articles 38.2 and 39.2 of the law.

Article 41 Compensation for damages to property

41.1 Licence holders shall fully compensate owners and users of private and public residential dwellings, wells, winter huts, other structures, and historic and cultural landmarks for the damage caused by exploration or mining operations, including, if necessary, relocation costs.

Article 42 Relations with local administrative bodies

42.1 A licence holder shall conclude agreements and work in cooperation with local administrative bodies on issues of environmental protection, infrastructure development in relation to mine development and mine use and employment.

42.2 A licence holder in cooperation with the local administrative body may organise a public forum in relation to issues specified in Article 42.1.

42.3 A representative with obligations to implement public monitoring on the licence holder's activities may be selected from the public and employed.

Article 43 Employment requirements

43.1 The licence holder is obliged to provide employment for citizens of Mongolia and up to 10 per cent of the employees may be foreign citizens.

43.2 In case the number of hired foreign personnel exceeds the percentage specified in Article 43.1, the licence holder shall pay every month an amount equal to 10 times the minimum monthly salary of each person exceeding the quota.

43.3 The payment specified in Article 43.2 of this law shall be concentrated in the budget of the relevant Soum or district and shall be disbursed to the educational and health sectors; relevant procedures shall be approved by the Citizens Representatives Hural of the Soum or district.

Article 44 Ensuring health and safety standards

44.1 The licence holder shall carry out the relevant activities to safeguard the citizens of the relevant Soum or district, and for the occupational safety and health of employees in accordance with the applicable laws and regulations.

Article 45 Requirements for closure of a mine

45.1 The mining licence holder shall take preparatory measures pursuant to the regulations of the professional inspection agency prior to the closure of a mine. Licence holders shall inform the professional inspection agency with an official letter that the mine shall be closed in whole or in part, at least one year prior to such closure, and the following measures must be implemented:

- 45.1.1 To take all necessary measures to ensure safe use of the mine area for public purposes and protection of the environment;
- 45.1.2 To take preventive measures if the mine claim is dangerous for public use;
- 45.1.3 To remove all machinery, equipment and other property from the mining area except as permitted by local administrative bodies or the professional inspection agency.

45.2 Mining licence holders shall prepare a detailed map at an appropriate scale showing dangerous or potentially dangerous areas created by mining operations, by placing necessary warnings and markings in the vicinity of the mining claim, and shall submit the map to the specialised inspection agency and the local Governor.

Article 46 Registration and sale of precious stones and metals

46.1 All precious stones and metals extracted by mining licence holders shall be assayed and registered by the State Assaying Agency.

46.2 Regulations on the assaying and registration of precious stones and metals, and a list of minerals and precious stones subject to assaying and registration shall be approved by the Government.

46.3 Mongolbank shall pay international market prices when purchasing precious stones and metals.

46.4 A mining licence holder may export the extracted precious stones and metals through Mongolbank.

46.5 If a nugget weighing more than 400 grams or which has a peculiar shape though weighing less, or a precious stone with a rare colour and shape is extracted, the licence holder is obliged to sell it to the treasury fund of Mongolbank at an extra rate.

Article 47 Royalties

47.1 A mining licence holder shall pay royalties to the treasuries of the central and local administrative bodies on the sales value of all products extracted from the mining claim that are sold, shipped for sale, or used.

47.2 The sales value shall be determined as follows:

47.2.1 For exported products, the sales value shall be the average monthly prices of the products, or similar products, based on regularly published international market prices or on the recognized principles of international trade;

47.2.2 For products sold or used on the domestic market, the sales value shall be based on the domestic market price for the particular or a similar product;

47.2.3 For products sold on international or domestic markets, where it is impossible to determine market prices, the sales value shall be based on the revenue derived from the sale of the product as declared by the licence holder.

47.3 The rate of royalties shall be as follows:

47.3.1 Royalties for domestically sold coal for energy and common mineral resourses shall be equal to 2.5 per cent of the sales value of all products extracted from the mining claim that are sold, shipped for sale, or used.

47.3.2 Royalties for extracted products other than those specified in Article 47.3.1 shall be equal to 5.0 per cent of the sales value of all products extracted from the mining claim that are sold, shipped for sale, or used.

47.4 An exploration licence holder shall pay royalties at the same rate as a mining licence holder with respect to minerals extracted during the exploration phase for surveying purposes which may be sold upon registering the type and quantity of the mineral with the professional inspection agency.

47.5 A mining licence holder shall pay royalties with respect to all extracted products that are sold, shipped for sale or used during a calendar quarter before the end of the next quarter.

47.6 A mining licence holder shall submit to the professional inspection agency a quarterly report in the form approved by the professional inspection agency and verified by the licence holder‘s signature, indicating the quantity of products extracted and sold, shipped for sale, or used during the relevant quarter, the total value of the sales, and the basis of evaluation.

47.7 The Government shall prepare, and periodically publish, a list of commodity exchange prices and related information, which shall be used for the purpose of calculating the sales value of exported products.

Article 48 Submission of information and reports

48.1 A licence holder shall prepare the following information and reports on a timely and accurate basis, and submit copies of the information and reports to the professional inspection agency and State administrative body:

48.1.1 A plan of exploration activities shall be submitted within thirty (30) days after the grant of the exploration licence;

48.1.2 Annual reports on exploration activities detailing the prospecting and exploring stages for the previous year shall be submitted in the form approved by the State administrative body within thirty (30) days after the expiration of the relevant period;

48.1.3 Annual report on safety specified in Article 44 of this law shall be released by the 20th of January,

48.2 The report specified in Article 48.1.2 shall contain information on the amount of work completed and expenses incurred in reconnaissance, geophysical and geochemical work, drilling and other activities, information on the labour force, and the results of the exploration work. A map indicating the places where the work was done shall be attached to the report. This map shall be prepared according to the State geodesy system.

48.3 A copy of the final report on the results of the exploration work developed in accordance with the approved form and requirements and original materials shall be submitted to the State administrative body before the expiration of the licence.

48.4 The State administrative body shall accept the estimates of the ore reserves submitted in the report specified in Article 48.3 after receiving an opinion from a qualified expert and shall include the ore reserves in the national register of reserves.

48.5 The State administrative body shall also have the right to demand information and reports from the licence holder if such information or reports are incomplete.

48.6 A mining licence holder shall submit the following information and reports to the State administrative body:

48.6.1 A feasibility study on the development of the deposit within sixty (60) days of obtaining the mining licence;

48.6.2 Estimated data with respect to the next year‘s production on an approved form not later than September of every year;

48.6.3 Basic indicators of the mining work approved by surveyors of mines, mining and geometry drawings, and a report on the activities of the year shall be submitted on an approved form by February 15 of the following year.

48.7 The report specified in Article 48.6.3 of this law must contain the following:

48.7.1 Number of working days, number of employees, and all contracts affecting the licence holder‘s right of ownership;

48.7.2 Information on implementation of the mining plan, an estimate of changes in reserves, time periods of operation of the mine, a general overview of production facilities, and any expansion or renovation of such facilities;

48.7.3 Information on the quantity of ore mined, the quantity of products produced, shipped and sold, the price of the products sold, information with respect to the purchasers, information on investments made during the year, operating expenses, royalty payments and information with respect to the equipment and technology used in mining operations, and information on other related properties.

48.7.4 A safety report as specified in Article 44 of this law.

48.8 A licence holder shall prepare a report on the implementation of the environmental protection plan as specified in Articles 38 and 39 of this law, and submit it to the relevant authorities.

48.9 A licence holder shall prepare a report on royalties as specified in Article 48.7.3 of this law in the form approved by the tax office in an accrued sum each quarter, and shall submit it by the 20th of the following month and submit an annual final report by January 20 of the following year to the tax office.

48.10 A licence holder shall report to the public the amount of their product sales for that year and the amount of taxes and payments paid to the State and local budget within the 1st quarter of the following year.

48.11 The forms specified in Articles 48.6.2 and 48.6.3 of this law shall be approved by the head of the State administrative body.

CHAPTER SEVEN
TRANSFER AND MORTGAGE OF LICENCES

Article 49 Transfer of licences

49.1 A licence holder may transfer the licence in the event of a merger pursuant to civil law, company law and cooperative laws and legislation, or a subsidiary and an affiliated company may transfer the licence to its parent company.

49.2 An exploration licence holder may transfer a licence to another party eligible to hold such licences if it can be demonstrably proven that materials and reports on prospecting and exploration work have been sold in accordance with the applicable laws and regulations and that the taxes have been paid accordingly.

49.3 A mining licence holder may transfer the licence if it can be demonstrably proven that the mine, together with its machinery, equipment and documents, has been sold in accordance with the applicable laws and regulations and that the taxes have been paid accordingly.

49.4 The transferor of a licence shall submit an application in the approved form in accordance with Articles 49.1-49.3 of this law. The following documents shall be attached to the application:

49.4.1 The transferring licence.

49.4.2 A document verifying that the transferee of a licence meets all the requirements specified in Article 7.1 of this law.

49.4.3 Acknowledgement that the licence transferee shall accept all the rights and duties that arise from the licence transfer.

49.4.4 Reference from the environmental office on the protection of the area affected by mining, if transferring a mining licence.

49.4.5 The evidence that the required protection expense deposit has been deposited in the account specified in Articles 38.1.8 and 38.1.9 of this law.

49.4.6 Notification about the submission of the exploration work plan and the report to the State administrative body.

49.4.7 A document showing that the applicant has paid the service fees.

49.5 Immediately following the receipt of an application specified in Article 49.4 of this law, the State administrative body shall record the application and verify the following:

49.5.1 Whether the application complies with the requirements of this article;

49.5.2 Whether the licence to be transferred is valid;

49.5.3 Whether the licence transferee is eligible to hold the licence.

49.5.4 Whether the licence fees have been paid in a timely manner

49.5.5 Whether the exploration costs exceeded the minimum costs of exploration work specified in Article 33 of this law.

49.6 Within five (5) business days following the receipt of an application for recording the transfer of a licence, the State administrative body shall take one of the following decisions:

49.6.1 Record the transfer of the licence and make appropriate notes on the licence certificate; or

49.6.2 If the application does not comply with Article 49 of this law, inform the applicant to submit the necessary additional information; or

49.6.3 If the transferee is not eligible to hold a licence, or the licence to be transferred is invalid, the application shall be returned unapproved and the applicant shall be notified accordingly.

49.7 In the event the licence holder is subdivided or segregated according to civil law, company law or cooperative law, the licence shall be returned to the State administrative body. The returned licence shall be reissued in accordance with the tender procedure mentioned in Article 10.4.2 of this law.

49.8 If the subdivided or segregated legal person has maintained the status to hold the licence stipulated in Article 7.1 of this law, the legal person shall have an exclusive right to re-obtain the licence.

49.9 A person obtaining a licence through transfer shall pay the fees and costs stipulated in Article 32.2, 32.3 and 33.1 of this law beginning from the subsequent year.

49.10 In the event that a licence dispute is under review by the court, it is prohibited to transfer the licence prior to a resolution by the court.

49.11 The State administrative body shall notify the professional inspection agency and the State administrative body in charge of taxation of the recording of the licence transfer and publicize it in a daily newspaper.

Article 50 Transfer of parts of licence areas

50.1 Licence holders may transfer parts of a licence area to persons eligible to hold a particular type of licence in accordance with Article 49 of this law. In this case, the shape, size and orientation of the transferred and retained parts shall comply with the requirements of this law.

50.2 The transfer of a part of a licence area shall be recorded by the State administrative body in accordance with Article 49.6.1 of this law,

50.3 The application for recording the transfer of a part of a licence area shall contain a description of the land and the description shall contain the information required by Articles 17 and 24 of this law, and the payment receipt of the application processing fee should be attached to the application.

50.4 The State administrative body shall verify and confirm that the transferred area lies entirely within the boundaries of the licence area covered by the transferor‘s licence.

50.5 The State administrative body shall implement the registration specified in Article 50.2 of this law by the following procedure:

50.5.1 Record the location and coordinates of the transferred and retained parts of the licence area in the register of licences and in the cartographic licence register

50.5.2 Make appropriate notes in the licence certificate of the transferor

50.5.3 Issue the transferee a separate exploration and mining licence for the area acquired through transfer.

50.6 The State administrative body shall notify the registration of the transfer of a part of a licence area to the professional inspection agency and the State administrative body in charge of taxation in accordance with Article 50.5 of this law.

Article 51 Pledges of licences

51.1 To provide security for the financing of their investments and operations of a particular project, a licence holder can pledge their licences to a bank or financial organisation with the related documents such as the exploration work results, geological information, feasibility study report and properties which are permitted to be pledged by law. A licence alone shall not be a pledge item.

51.2 The licence holder shall submit to the State administrative body a copy of the pledge agreement, together with the licence certificate and application.

51.3 Upon verification that the application for recording the pledge of the licence complies with the terms and conditions specified in this law, the State administrative body shall record the pledge of the licence and let the pledgee keep the licence certificate. The record entry includes the registration number of the licence, and the names and addresses of the holder and pledgee of the licence.

51.4 Upon termination of the pledge agreement, the licence holder shall submit an

51.4.1 Application to the State administrative body together with the following documents:

51.4.2 A statement signed by the pledgee to the effect that the licence holder has fulfilled its obligations under the pledge agreement;

51.4.3 The pledged licence certificate.

51.5 Upon receipt of the documents specified in Article 51.4 of this law, the State administrative body shall record the termination of the pledge.

51.6 The pledgee shall not assume the obligations under the licence.

51.7 If the licence holder fails to fulfil its obligations under the pledge agreement, and the grounds for termination of the licence are satisfied in accordance with Articles 22 and 28 of this law, the State administrative body shall notify the pledgee, and the pledgee has the right to first propose a transfer of the licence to a person eligible to hold such a licence.

51.8 The State administrative body shall notify the pledgee of the licence expiry (14) fourteen days prior to such date. Within ten (10) days of receiving the notice, the pledgee shall deliver its proposal to transfer the licence in accordance with Article 51.7 of this law.

Article 52 Transfer of a licence pursuant to a pledge agreement

52.1 In the event the licence holder fails to fulfil its obligations under the pledge agreement and the pledgee wishes to transfer the licence to a person eligible to hold such a licence, the pledgee, in accordance with Article 49 of this law, shall submit an application to the State administrative body. The following documents shall be attached to the application:

52.1.1 Proposal of the pledgee submitted according to Article 51.7 of this law;

52.1.2 Confirmation by the transferee of the licence, that it has agreed to obtain the materials and properties to be pledged with the licence specified in Article 51.1 of this law;

52.1.3 Certificate of the pledged licence;

52.1.4 Document proving the eligibility of the transferee to hold a licence in accordance with Article 7.1 of this law;

52.1.5 Confirmation by the transferee of its acceptance of the rights and obligations that arise upon transfer of the licence.

52.2 The State administrative body shall review the document mentioned in Article 52.1 of this law, and reach a decision to record the transfer of the licence.

CHAPTER EIGHT
TERMINATION OF EXPLORATION AND MINING LICENCES

Article 53 Grounds for termination of a licence

53.1 A licence shall be terminated in the following cases:

53.1.1 Expiration of the licence term;

53.1.2 Surrender by the licence holder of the entire licence area in accordance with the provisions of Article 54; or

53.1.3 Revocation of the licence by the State administrative body.

53.2 A licence shall be terminated as to each and every part of a licence area being surrendered by the licence holder.

53.3 Upon termination of the licence, the rights and obligations of the licence holder under the licence shall be deemed to be annulled, except the licence holder's obligations with respect to environmental protection, reclamation and mine closure as stipulated in Articles 38, 39 and 45 of this law, and other obligations pursuant to laws and legislation on environmental protection.

53.4 Upon termination of the licence, the licence holder shall return the licence certificate to the State administrative body, and a new licence may be issued for the area in accordance with the provisions of this law.

53.5 The ownership of buildings and structures, equipment and other property allowed to be left on the exploration or mining area in accordance with Article 45.1.3 of this law shall be determined in accordance with the provisions of the civil law.

Article 54 Surrender of the entire licence area

54.1 A licence holder may submit an application approved by the State administrative body to surrender the entire licence area at its own request.

54.2 Verification that the licence holder has met the obligations under the law such as environmental protection and reporting, and the requirements for mine closure, shall be attached to the application for surrendering the entire licence area.

54.3 Upon receipt of an application to surrender the entire licence area, the State administrative body shall make appropriate changes to the licence registration and cartographic registration, upon verifying that the licence holder has met the requirements stipulated in Article 54.2 of this law.

54.4 Upon surrender of the entire licence area, the licence certificate shall be retained by the State administrative body.

54.5 The State administrative body shall notify the relevant authorities of the surrender of the entire licence area, and publicise it in a daily newspaper.

54.6 A licence holder that surrenders a particular licence area shall not have the right to submit a new application for the same area for a period of two years following the surrender.

Article 55 Surrender of part of the licence area

55.1 A licence holder may surrender part of the licence area in accordance with this article of the law.

55.2 A licence holder shall submit an application for surrender of part of the licence area together with the description of the surrendered part in the form approved by the State administrative body. In the case of surrender of part of an exploration area, the description of the surrendered area shall meet the requirements of Article 17.2 of this law, and in the case of the surrender of part of a mining area, the description of the surrendered area shall meet the requirements of Article 24.4 of this law.

55.3 The following documents shall be attached to an application for surrender of part of a licence area.

- 55.3.1 The licence certificate;
- 55.3.2 Certificate from the Governor and the environmental inspection agency of the relevant Soum or district stating that the licence holder has fulfilled the obligations in the environmental protection plan for the surrendered area;
- 55.3.3 A report as described in Article 48.1.2 and 48.6.3 of this law.

55.4 The area retained by the licence holder after surrender of part of the licence area shall meet the requirements of Article 17.2 and 24.4 of this law.

55.5 If the application for surrender of part of a licence area meets the requirements of Articles 55.2-55.4 of this law, the State administrative body shall register the application and enter appropriate notes on the licence certificate, upon which it shall be deemed surrendered.

55.6 The State administrative body shall notify the surrender of a part of a licence area to the relevant bodies and publicise it in a daily newspaper.

55.7 The surrender of a part of a licence area shall not entitle the licence holder to a refund or discount of the licence fees previously paid.

55.8 The licence holder shall not have the right to resubmit an application on the same area for 2 years after surrendering the licence area.

Article 56 Revocation of licences

56.1 The State administrative body shall revoke a licence on the following grounds:

- 56.1.1 The licence holder has failed to meet the requirements of Articles 7.2 and 31 of this law;
- 56.1.2 The licence holder has failed to pay the licence fees within the specified period;
- 56.1.3 An exploration or mining area has been designated as special purpose land and the licence holder has been fully compensated;

56.1.4 The exploration cost of the particular year is lower than the minimum cost of exploration specified in Article 33 of this law;

56.1.5 If the State central administrative body in charge of environmental issues has reached the conclusion according to the report of the local administrative bodies that the licence holder had failed to fulfil its environmental protection duties.

56.2 Within five (5) working days following the determination of the existence of grounds for revocation of a licence, the State administrative body shall notify the licence holder. The notice shall specifically indicate the grounds for revocation of the licence.

56.3 If the licence holder disagrees with the grounds stated in the notice specified in Article 56.2 of this law, the licence holder shall submit documentary evidence to the State administrative body.

56.4 The State administrative body shall review the documents specified in Article 56.3 of this law and if it determines that the documentary evidence submitted by the licence holder does not establish invalidity of the grounds for revocation of the licence, the licence shall be revoked and the licence holder notified accordingly.

56.5 The licence holder shall have a right to file a complaint with the court if he/she does not accept the decision of revocation in accordance with Article 56.4 of this law. The court shall not suspend the revocation decision according to Article 46.1.3 of the law on administrative case procedure.

56.6 If the licence holder has filed a complaint with the court, no licence shall be issued with respect to the licence area until a valid court ruling has been made.

56.7 The State administrative body shall notify the professional inspection agency if an exploration licence is revoked, and the State administrative body in charge of taxation if a mining licence is revoked, and publicise it in a daily newspaper.

CHAPTER NINE
INFORMATION, ROYALTY REVENUE DISTRIBUTION, REIMBURSEMENT AND SPECIFICS OF FINANCE AND ACCOUNTING

Article 57 Access to minerals-related information and reports

57.1 Any interested person shall have a right of access to the register of licences, and the cartographic register of licences during office hours in specially designated rooms.

57.2 The State administrative body, upon the licence holder‘s request, shall treat reports of exploration work, information with respect to mine operations and feasibility studies prepared by a licence holder as the licence holder‘s confidential information during the valid period of the licence. The licence holder may conclude a confidentiality agreement with the State administrative body when they hand over information and reports.

57.3 Information classified as confidential pursuant to Article 57.2 of this law shall not be disclosed, published or disseminated except pursuant to provisions and procedures established in the Law on State Secrets, the Law on Organisation Secrets, and the Law on Private Secrets.

57.4 The State central administrative bodies in charge of environmental, geological and mining issues shall publicise and disseminate electronic copies of information on environmental impact assessments, environmental protection plans, and report information about hazardous chemicals and other substances that may negatively effect human health and the environment.

Article 58 Distribution of royalty revenues

58.1 All royalty payments shall be deposited in the central and local budget.
58.2 The royalty payment shall be distributed as follows: 10 % in the budget of the Soum or district, 20 % in the budget of the Aimag or capital, and 70 % in the State budget. The size of the royalty payment to local areas shall not exceed the annual budget of the Soum, district, Aimag or capital.
58.3 Up to 30 % of the royalty payment paid to the State budget shall be distributed to the geological and mining sector.
58.4 The Government shall approve the procedure to pay, distribute and dispose of the royalty payment.

Article 59 Distribution of licence fees

59.1 The exploration and mining licence fee payments shall be deposited in the budget of the Aimag, capital city, Soum and district where the exploration area or the mineral deposit is located, as well as the State budget.
59.2 The licence fee payment shall be distributed as follows: 25 % to the Soum or district budget, 25 % to the Aimag budget of the Aimag or capital city, and 50 % to the State budget
59.3 The Government shall approve the procedures to pay, distribute and dispose of the licence fees.

Article 60 Reimbursement of mineral deposit exploration financed by the State budget

60.1 A licence holder who is extracting minerals from any deposit where the exploration work and reserves determination was undertaken with funds from the State budget, and was registered in the State integrated register, shall reimburse the exploration expenses to the State budget by entering into an agreement at the commencement of mining activities.
60.2 Exploration expenses funded from the State budget shall include expenses of detailed exploration work of any mineral resources, exploration and assessment work done in the licence area, and the costs incurred at each stage of exploration work funded from the State budget.
60.3 For an economic entity privatized under the Law on State and Local Properties, the exploration expenses to be imposed on the remainder of the reserves shall be calculated by proportionally subtracting the exploration costs funded from the State budget for the extracted reserves.
60.4 An exploration licence shall not be granted for a deposit for which the exploration work and reserves determination were undertaken with funding from the State budget and which is registered in the State integrated register.
60.5 The reimbursement agreement shall include the amount of total reimbursement and its duration, and annual instalments.
60.6 The annual amount of reimbursement shall be determined on the basis of the annual production rate.
60.7 If the annual reimbursement is not paid punctually in accordance with the time schedule in the reimbursement agreement, a penalty equal to 0.1 % of the total amount due shall be imposed for each overdue day.
60.8 The government shall approve the procedure for reimbursement and the amount of reimbursement.
60.9 If the reimbursement and the penalty mentioned in Articles 60.1 and 60.7 of this law are not paid within thirty (30) days after the receipt of a notice from the State administrative body regarding the breach of the reimbursement agree-

ment, the licence shall be revoked and a tender shall be announced.

Article 61 Specifics of mining industry finance and accounting

61.1 All costs incurred for exploration, and all expenses incurred in preparing a mine site for production, shall be amortized on a straight line basis over a period of five (5) years commencing with the tax year in which production from the mine commences.

61.2 The licence acquisition costs, either directly or by transfer, shall be amortized on a straight line basis over the term of the licence.

61.3 Fixed assets used in mining operations shall be depreciated on a straight line basis.

61.4 A loss incurred in any tax year may be deducted from taxable income during the two (2) tax years following the year in which the loss was incurred.

61.5 All costs incurred in developing industrial and social infrastructure shall be depreciated on a straight line basis over the useful lives of the constructed facilities. All costs of maintaining and operating such infrastructure facilities shall be reported in the accounts in that particular year.

61.6 Costs for essential maintenance incurred in connection with mining operations shall be included in the operations cost.

61.7 The State central administrative body in charge of finance shall adopt regulations implementing Articles 61.1 through 61.6.

CHAPTER TEN
RESOLUTION OF DISPUTES ARISING IN CONNECTION WITH LICENCES

Article 62 Resolution of boundary disputes

62.1 Boundary disputes between or among licence holders shall be resolved by the State administrative body.

62.2 The State administrative body shall give all parties involved in the dispute an opportunity to present their position and arguments in writing.

62.3 The State administrative body shall verify if there is an overlap between disputed areas in the register of licences and the cartographic register of licences. If there is an overlap, it shall determine, based on the original applications and reports of field surveys, whether the coordinates and boundaries of the area were correctly recorded.

62.4 If, as a result of a field survey, an overlap is confirmed, the State administrative body shall modify the area covered by the more recently granted licence and eliminate the overlap.

62.5 The State administrative body shall have disputed boundaries of a licence area surveyed and established by an accredited professional geodesic surveyor, and any costs and loss relating thereto shall be paid for by the party shown to be in the wrong.

62.6 The State administrative body shall verify the disputed boundaries, make decisions on relevant modifications, and notify the parties to the dispute accordingly.

62.7 If the parties to the dispute disagree with the decision of the State administrative body, they may file a complaint with the court.

Article 63 Resolution of disputes between licence holders and land owners, possessors or users

63.1 Land access, rights of passage, and land use disputes between or among licence holders and land owners or land users, shall be resolved in accordance with the provisions of the Land Law, the Civil Law and other relevant laws.

Article 64 Filing of complaints to State bodies

64.1 Where any actions or failures to act by civil servants or State administrative bodies have prevented the exercise by licence holders of rights conferred upon them hereunder, such citizens or legal persons may file a complaint with respect thereto with relevant senior officials, State bodies or courts.

Article 65 Resolution of disputes arising out of an investment agreement

65.1 Any disputes arising out of an investment agreement according to Articles 29 and 30 of this law shall be resolved in accordance with the laws and international treaties of Mongolia.

CHAPTER ELEVEN
LIABILITIES

Article 66 Liabilities or breach of legislation

66.1 If a breach of the minerals legislation does not constitute a criminal offence, an authorised state inspector shall impose the following penalty on the guilty person whilst taking into account the circumstances of the infringement:

66.1.1 If any person has conducted exploration or mining activities or sold minerals without holding a mineral licence, all income or products derived from such activities shall be confiscated by the State and a fine of from 500000 to 1000000 tugrugs shall be imposed on the guilty officer.

66.1.2 In the case of the late submission of statements set forth in Article 48 of this law or the submission of false statements, a fine of 100,000 to 500,000 tugrugs shall be imposed on the guilty officer, and a fine of from 500000 to 1000000 tugrugs shall be imposed on the guilty legal person.

66.1.3 Preventing a licence holder from exercising rights conferred by this law shall give rise to the imposition of fines as follows:
a) with respect to citizens, from 100000 to 300000 tugrugs
b) with respect to officers, from 500000 to 1000000 tugrugs
c) with respect to legal entities from 1000000 to 2000000 tugrugs.

66.1.4 Failure to comply with the general obligations with respect to the conduct of activities under a licence as set forth in Article 35 of this law shall be fined as follows and, in addition, such licence holder must pay for any damage resulting from such failure:
a) with respect to officers, from 100000 to 500000 tugrugs
b) with respect to legal persons, from 500000 to 1000000 tugrugs

66.1.5 Failure of a licence holder to comply with legitimate requirements imposed by an authorised State inspector with respect to the elimination of deficiencies discovered in the course of exploration or mining shall be fined as follows:
a) with respect to officers, from 200000 to 500000 tugrugs

b) with respect to business entities, from 500000 to 1000000 tugrugs

66.1.6 If an officer fails to comply with the regulations with respect to the assaying and registration of precious metals and gemstones as provided by this law, the officer shall be fined from 100000 to 250000 tugrugs, and in the case of legal persons, such penalty shall be from 1000000 to 2000000 tugrugs.

66.1.7 Where a mining licence holder has intentionally underreported the volume or amount of minerals extracted, or has intentionally underreported the sales revenue by intentionally underreporting the sales price by entering into a fictitious contract, or by selling the product at an unfair price, such licence holder shall be fined from 100000 to 250000 tugrugs and the amount by which the revenue has been underreported shall be paid by such licence holder to the State treasury.

66.1.8 The officer who deliberately destroys the primary material, specimens and samples, shall be fined from 200000 to 500000 tugrugs, and the legal person shall be fined from 500000 to 1000000 tugrugs,

66.2 A court may impose a fine of 200000 to 300000 tugrugs on any person who intentionally prevents an authorized official from performing his or her duties in the course of an inspection.

66.3 Where a licence holder continues to violate laws with respect to environmental protection, mine operation safety regulations, or the provisions of its environmental protection plan, the exploration and mining activities of such a holder shall be suspended by an authorized state inspector for up to 2 months, and if such deficiencies are not eliminated within this period, the exploration activities of the licence holder shall be terminated or, in the case of an operating mine, the mine shall be closed.

66.4 If a mining licence holder causes serious damage to the environment, fauna and human health because of its failure to implement safety rules and the technological regime while using toxic chemicals and substances for its operations, the licence shall be revoked in accordance with Article 56 of this law and no licence shall be issued to the guilty party for the next 20 years.

COUNTRY PROFILE

Geography: Mongolia is a landlocked country in East and Central Asia. It is bordered by Russia to the north and the People's Republic of China to the south.

Landscape: Vast semi-desert and desert plains, grassy steppe, mountains in west and southwest; Gobi Desert in south-central area; almost 90% of land area is pasture or desert, of varying usefulness; 1% arable; 9% forested. Vast relatively flat steppes to the east.

Area: 1 566 500 sq. km. (604 103 sq. mi.);

People: Mongolia's population of about 2.75 million in 2009 represents a diversity of ethnic groups. About 85 % Mongol (predominantly Khalkha), 7 % Turkic (largest group, Kazakh) 4.6 % Tungusic, and 3.4 % others, including Chinese and Russian.

Languages: Mongolian, Kazakh, Russian, and English.

Religions: Tibetan Buddhist Lamaism 94 %, Muslim 6 % (primarily in the southwest), and Shamanism.

Major towns: Mongolia is divided into 21 Aimags (provinces), which are in turn divided into 329 Soums (districts). The capital Ulaanbaatar is administrated separately as a Khot (municipality) with provincial status

History: The Mongol Empire was founded by Genghis Khan in 1206. After the collapse of the Yuan Dynasty, the Mongols returned to their earlier pattern of constant internal conflict and occasional raids on the Chinese borderlands. In the 16th and 17th centuries, Mongolia came under the influence of Tibetan Buddhism. At the end of the 17th century, most of Mongolia had been incorporated into the area ruled by the Qing Dynasty. During the collapse of the Qing Dynasty in 1911, Mongolia declared independence, but had to struggle until 1921 to firmly establish de facto independence from the Republic of China, and until 1945, to gain international recognition.
As a consequence, it came under strong Russian and Soviet influence. In 1924, the Mongolian People's Republic was declared, and Mongolian politics began to follow the same patterns as the Soviet politics of the time.
After the breakdown of communist regimes in Eastern Europe in late 1989, Mongolia saw its own democratic revolution in early 1990, which led to the establishment of a multi-party system, a new constitution in 1992, and the transition to a market economy.

Climate: Harsh continental, marked by four seasons. Average summer temperature +17 °C, average winter temperature -26 °C.

Agricultural products: Wheat, barley, vegetables, forage crops, sheep, goats, cattle, camels, horses.

Industries: Construction and construction materials; mining (e.g. coal, copper, molybdenum, fluorspar, and gold); oil; food and beverages; processing of animal products, cashmere and natural fibre manufacturing.

Environment: The name "Gobi" is a Mongol term for a desert steppe, which usually refers to a category of arid rangeland with insufficient vegetation to support marmots but with enough to support camels. Mongols distinguish Gobi from desert proper, although the distinction is not always apparent to outsiders unfamiliar with the Mongolian landscape. Gobi rangelands are fragile and are easily destroyed by overgrazing, which results in expansion of the true desert, a stony waste where not even Bactrian camels can survive.

Vegetation: The country contains very little arable land, as much of its area is covered by steppes, with mountains to the north and west and the Gobi Desert to the south.

LOGISTICS INFRASTRUCTURE

Rail transport - The Trans-Mongolian Railway is the most important route that facilitates north-south transit and domestic trade. Linking Sukhbaatar in the north and Zamyn-Uud in the south, and passing through the capital of Ulaanbaatar, this 1,100 kilometre (km) railway transports major imports and exports of crude oil, timber and wood products, fertilizers, and machinery. Efforts must therefore be exerted to promote the competitiveness of this route.

Figure 3: Rail network in Mongolia and adjoining countries

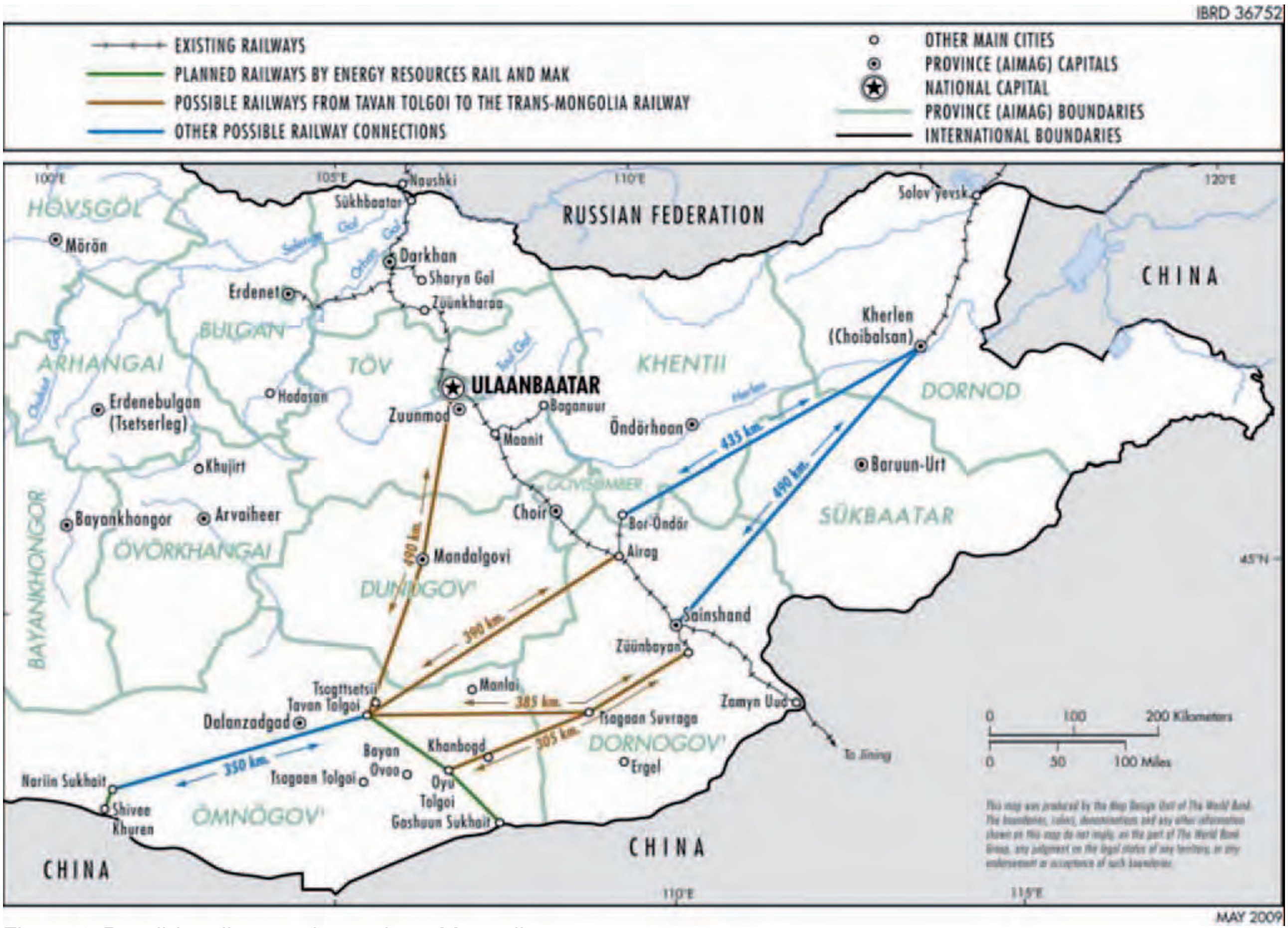


Figure 4: Possible rail routes in southern Mongolia

Road Transport – Road networks are another significant transport infrastructure for Mongolia. Because of the country's large landmass, the "last mile" link these networks provide will offer benefits to rural areas, as well as serve to complement the main railway lines to allow intermodal transport. With many roads more than 20 years old, there is an urgent need to upgrade current roads and extend these to less-developed regions, such as the western part of the country. Various initiatives are being implemented toward this, such as the construction of the Millennium Road, Asian Highway. While these provide the core network systems, similar road projects that yield economic benefits will be needed for the Ulaanbaatar-Darhan-Erdenet area, around the South Gobi, and the Oyu Tolgoi region.

The lack of basic infrastructure is clearly a major factor constraining economic growth and poverty alleviation in Mongolia. This persistent under-investment in infrastructure is having a negative impact on economic growth, living standards, and the "transaction costs" of businesses.

Judging from these rankings and everyday experiences, Mongolian fiscal resources have not been sufficient to provide the requisite investment to supply adequate infrastructure in logistics, railroads, and energy, to name a few priority sectors. Neither will these resources be enough in the near future as investments in the mining sector put increased pressure on an already inadequate infrastructure. Clearly, a new model to provide the investment needed to modernise Mongolia's infrastructure will be required, especially in the logistics, transport, and energy sectors. Properly structured Public Private Partnerships (PPPs), and an internationally competitive legal and regulatory framework for concessions, are key instru-

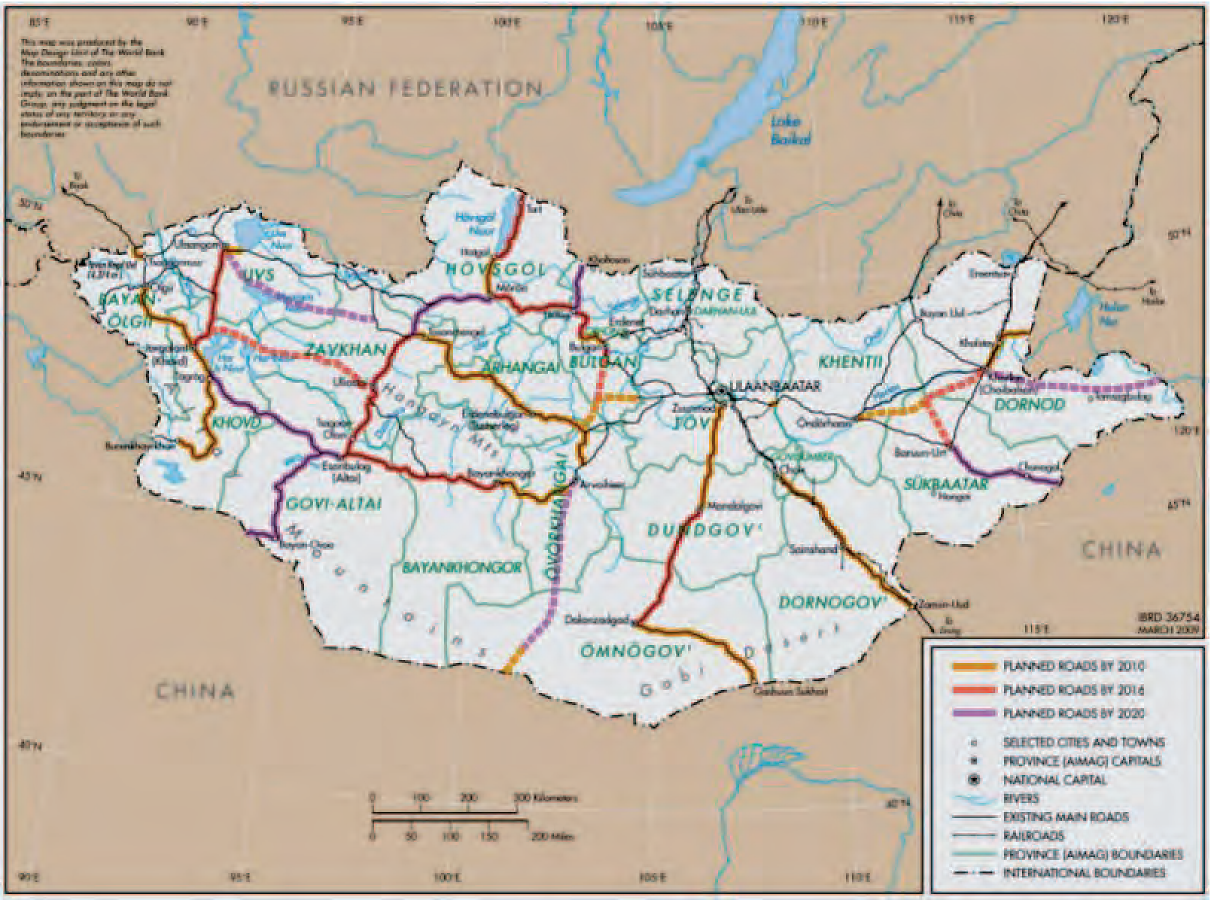


Figure 5: Road Master Plan projects, 2008-2020

ments to attract much needed private investment as a partner in developing the needed infrastructure.

GEOLOGY

Within the territory of Mongolia, formations and sediments belonging to all different ages from Archean to Quaternary have been identified. The area is structurally divided into Precambrian microcontinent massifs, Paleozoic (Hercynian and Caledonian) fold belts which developed in the oceanic stage, and structural basins which are formed in the continental stage.

Precambrian microcontinents
The following Precambrian microcontinents have been distinguished in the territory of Mongolia: Tuva-Mongolian massif, Precambrian uplifts: Hanhohii, Dariv, Gobi-Altay, Tseel, Songino, Tarvagatay, Khungui, Baidrag, Dundgobi, Khutag-Uul, Bayanterem, Ereendavaa, Ulaan-Uul, and Tsagaan-Uul massif.

Archean (3600- 2500 Ma)
The Archean metamorphic rocks are exposed in the Hanhohii, Gobi-Altay, Baidrag, and Tseel uplifts, and consist of "grey gneiss", migmatite, gneiss, and quartzite which belong to the granulite to amphibolite facies. However, the primary structure and lithologies of the metamorphic rocks are unknown. In the Hanhohii and Baidrag uplifts, identified metamorphic rocks are dated as 3370- 2990 Ma.

Paleoproterozoic-Mesoproterozoic (2500-1000 Ma)
The Paleoproterozoic-Mesoproterozoic rocks are distributed in almost all microcontinents in the territory of Mongolia. They mostly consist of gneiss, migmatite, graphitic marble, quartzite and amphibolite. They are strongly folded and faulted.

Neoproterozoic (1000-542 Ma)
The Neoproterozoic rocks are distributed more widely. Most of the rocks are greenschist, marbleised limestone, and dolomite. Those rocks are metamorphosed until amphibolite facies due to contact and regional metamorphism.

Some Neoproterozoic rocks are not metamorphosed, and consist of sandstone, siltstone, conglomerate, and limestone. In the calcareous rocks, cyanobionts such as stromatolites, and oncolites have been found. They are also the main raw material for cement in Mongolia. The Upper Neoproterozoic: Edicarian-Lower Cambrian formation includes fairly rich phosphorite deposits in the territory of Khubsugul and Zavkhan Aimag.

Intrusive complex
The Precambrian intrusive complexes are exposed in the large Tuva-Mongolian massif, Songino Dome, Tarvagatay Mountain, Buteel Mountain, Gobi-Altay, Ereendavaa, and Bayanterem uplifts. The absolute age has been dated in each intrusive complex.

Paleozoic fold belts

Northern Mongolian Caledonides
During Neoproterozoic-Lower Paleozoic time, the Northern Mongolian Caledonides formed when the oceanic stage transformed into the continental stage. It is divided into the Early and Late Caledonides.

Northern and Central Mongolian Early Caledonides
During Edicarian-Lower Cambrian time, the Northern and Central Mongolian Early Caledonides formed. Most of the area is covered by young structural basins. Some exposures are identified in the Nuur, Bayanhongor, Zed, and Kherlen zones.

The *Nuur zone* includes the Great Lake Valley, and Khantaishir, Khasagt Khairkhan Mountain Range. In this zone, distributed Khantaishir ophiolite complex and siliceous sediment occurs as seafloor remnants of the Neoproterozoic-Lower Cambrian oceanic stage. Also present are volcanic rocks dominated by andesite, their tuffitic terrigenous sediments and Lower Cambrian limestone with fossil Archycyats.

The *Bayankhongor zone* covers an area approximately 400 km in length and 10-20 km wide, along the margins of the Khangay Mountain Range. This zone also contains Neoproterozoic-Lower Cambrian ophiolite complexes, greenschist, and shelf calcareous rock.

The *Zed zone* is relatively poorly studied, but volcanic-calcareous rocks which originated from seamounts, and an accretionary complex, have been identified.

The *Kherlen zone* includes greenschist of island arc volcanic origin.

Intrusive complex

The territory of Mongolia has widely concentrated granite related to Caledonian folding. The Nuur zone includes the Togtohynshil calc-alkaline granite complex. The age of the granite complex is defined as Lower-Middle Cambrian, but the ages fluctuate. Central Mongolia contains the Cambrian-Ordovician Modonkhudag complex, Eastern Mongolia the widely distributed Lower Paleozoic Kherlen complex. Central and Northern Mongolia contain the Boroo complex, and the Devonian alkaline Tes complex occurs in Zavkhan, Khuvsgul Aimag.

Late Caledonides of Mongolian Altay

This fold system forms the Mongolia Altay Mountain Range. On the east side, the Nuur zone of the Northern and Central Mongolian Caledonides are bounded by the Tsagaan shiveet fault, and on the south side, the Baruun Khuurai zone of the Southern Mongolian Hercynides is bounded by the Turgengol fault. The Mongolian Altay Caledonian system formed when the Ordovician-Silurian oceanic stage transformed into the continental stage in the Devonian period. It is divided into the Altay, Khovd, and Tsagaanshiveet zones and the Deluun depression which formed in the Devonian.

Intrusive complex

This fold system contains the widely distributed Hovd (Ordovician), Kharkhiraa (Silurian), and Altay (Devonian) granite complex.

Southern Mongolian Hercynides

The Southern Mongolian Hercynides formed during the Lower Paleozoic period. It is bordered by the Northern Mongolian Caledonides and the Mid Mongolian tectonic line. The south border continues into China. It is divided into the Southern Mongolian Early Hercynides and the Inner Mongolian Late Hercynides.

Southern Mongolian Early Hercynides

This fold system has a complex structure and occupies most of the Southern Mongolian fold belt. It is divided into the Goby Altay-Sukhbaatar, Gobi-Khyangan, Baruun khuurai, Gobyn Tenger Uul, and Nuheddavaa zones. However, mapping is patchy and the boundaries of the zones are uncertain. The most studied zone is the Gobi Altay-Sukhbaatar zone.

Gobi Altay-Sukhbaatar zone begins in the Gichgene and Jinst Mountain Range on the west side and extends to the east into the Sukhbaatar Soum, and Sukhbaatar Aimag of Mongolia. Width is about 50-100 km. This zone contains three key cross sections which reveal the structure. These key sections are in Shine Jinst Soum which is located in the Bayankhongor Aimag, and Mushgai Khudag which is located in Mandalovoo Soum, Umnugobi Aimag,

Shargynuul-Shovdolovoo which is located in Asgat Soum, Sukhbaatar Aimag. The section starts in a Middle-Upper Ordovician shelf terrigenous calcareous sequence rich in fossils, and continues to Silurian calcareous, terrigenous partially turbiditic sequence. This Silurian sequence contains fossils from all stages of the Silurian period. The Devonian marks an increase in the occurrence of calcareous rocks such as reef limestone. Volcanic rock is exposed in all sections of the Middle-Upper

Devonian. During the Lower Carboniferous period, dominated by relatively minor tectonic activity, limestones, calc-siltstones, and sandstone sequences rich in fossils accumulated in Shinejinst and Mushgai Khudag. This zone reflects oceanic passive margin deposition from Ordovician to Lower Carboniferous.

Gobi-Hyangan zone in the Gurvansaikhan, Bayan Bor, Zuulun, and Nomgon Mountain Range. This zone extends from the west to the east of Mongolia. Although still speculative, most scientists consider that this zone runs parallel to the Gobi Altay-Sukhbaatar zone. The Bayan Bor, Zuulun Mountain Range contains siliceous seafloor sediments and back arc basin sandstones in the Gurvan Saikhan Mountain Range.

The *Baruun Khuurai zone* is relatively poorly studied. However, Devonian-Carboniferous calcareous-terrigenous sediments with fossils have been indentified. This sediment is assigned to the oceanic stage.

The *Gobyn Tenger Uul zone* is poorly studied and has poor exposure. Therefore its structure and geological history are poorly understood.

The *Nuhetdavaa zone* is also poorly studied and with poor exposures. Only a few sequences possibly belonging to the Paleozoic oceanic stage, and intruded by Carboniferous granites, are considered to belong to the Hercynides.

Intrusive complex
In this zone, mostly Devonian, Carboniferous, and Permian intrusive complexes are very widely distributed.

Inner Mongolian Late Hercynides
The Inner Mongolian Late Hercynides are present in Erdene, Ulaanbadrakh, Huvsgul, and Hatanbulag Soums, Dundgobi Aimag, in south east Mongolia, and Nomgon Soum, Umnugobi Aimag bordered by the Ulaanbadrakh fault on the north side. This fold system is divided into Lugiingol-Dalan-uul, Hutag-Uul, and Sulinkheer on the north side.

The *Lugiingol-Dalan-Uul zone* is composed of thick Lower Permian calcareous schist and turbidites assigned to the oceanic stage. It overlines a Devonian-Carboniferous marine formation and ophiolite body of the Lower Paleozoic oceanic stage. All the formations are intruded by Middle-Upper Devonian, Upper Carboniferous, and Middle Permian granites.

The *Hutag-Uul zone* is composed of a Proterozoic metamorphic complex.

The *Sulinkheer zone* has a complex structure, composed mainly of Middle Permian calcareous terrigenous sequences with fossils. In this zone there is a hyperbasic (perhaps ophiolitic) body which is not fully defined in terms of age and structure. The Inner Mongolian Late Hercynides include Upper Carboniferous-Lower Permian calcareous rock with foraminifera and fossils of warm marine facies.

Intrusive complex
This zone contains the Carboniferous Hangay complex, Upper Paleozoic Shar-Usgol complex, and Early Mesozoic Egiindavaa complex.

Khangai-Khentey Late Hercynides
This fold system includes the Khangay Mountain Range, Khar Khorin, and Khentey Mountain Range. The north boundary is marked by the Bayangol and Tamir faults, and the south boundary is marked by the Bayankhongor, Hoitgobi, Onon, and Ulz faults. This fold system is divided into the Khangai, Khar Khorin, Khentey, and Duchgol depressions. Khangay, Khar Khorin, and Khentey contain Devonian-Carboniferous sandstones and siltstones of great thickness but poor in fossils. Recent studies revealed thick Devonian sandstones and siltstones with radiolaria fossils. Therefore many scientists consider it to be part of an accretionary complex. The Duchgol depression

contains Permian and Triassic terrigenous formations, except the Devonian-Carboniferous formation.

Intrusive complex
This zone contains the Carboniferous Khangai complex, Upper Paleozoic Shar-Usgol complex, and Early Mesozoic Egiindavaa complex.

Superimposed structure
The superimposed structure is made up of accumulated sediment, and the formation of volcanic and intrusive bodies after transformation to the continental stage. In the territory of Mongolia, structural basins formed since the Ordovician period. It is divided into five stages depending on the different geodynamic evolution: Paleozoic orogenic depressions, Upper Paleozoic-Lower Mesozoic volcanic provinces, Mesozoic tectonic-magmatic activity, Upper Cretaceous-Miocene continental sediments, and Late Cenozoic new tectonic-magmatic activity.

Paleozoic intermontane basins
This structure formed in the Northern and Central Mongolian Early Caledonides from the Ordovician to Silurian period, and in the Mongolian Altay Late Caledonides until the Carboniferous period.

The *Ordovician basin* developed in the Nuur and Bayanhongor zones is an orogenic and volcanic depression. It is composed of andesite, basalt-andesite, dacite-andesite, and their tuffs, distributed in the Namirgol Basin, Chargatuul Mountain, and south mountains of the Sharga desert in the Nuur zone. The Ordovician molasse formation which includes conglomerate, sandstone, and siltstone, is distributed on the back side of Dariv Mountain, south mountains of the Sharga desert in the Nuur zone, and in the Bayankhongor zone. Ordovician basalt formed in this zone.

The *Silurian basin* developed in Altay, Nuur, Bayankhongor, Ereendavaa and south part of Central Mongolia. This depression was filled with arkosic sandstone, fine grained conglomerate, and conglomerate including calcareous layers with shallow marine fossils. Rare volcanic rocks are also present. This Silurian molasse formation includes the specific fossil Tuvaella which is included in the brachiopod group.

The *Devonian basin* developed in the Northern and Central Mongolian Early Caledonides. It is composed of calcareous rock with fossils, terrigenous sequences, and continental formations. Also volcanic rocks are present along the ancient depression of the mountains and the deep faulted zone. Thick greenish, greyish, and blackish schists also accumulated in the Deluun and Kherlen rift and depression.

The *Carboniferous basin* is present in the Altay, Khovd, and Tsagaanshuvuut zones in the Mongolian Altay Mountain Range, and in the Nuur, Bayankhongor, and Northern Kherlen zones of the Early Caledonides. The terrigenous sediments of the Carboniferous structural basin in the Mongolian Altay area include a number of coal deposits such as Nuurst khotgor and Khar Tarvagatay, etc. Shallow marine and continental terrigenous sequences accumulated in other areas.

Upper Paleozoic-Lower Mesozoic volcanic provinces
Tectonic activity along the Paleozoic continental margin took place in southern Mongolia since the Carboniferous period and in Northern Mongolia since the Permian period. Geodynamically, the oceanic plate collided with the Paleozoic continent, forming an “Andes” type active continental margin. It continued until the Triassic period. This collision produced a great volume of volcanic rocks, tuffs and terrigenous sediment in the territory of Mongolia. These volcanic provinces are divided into the Southern Mongolian, Central Mongolian and Orkhon-Selenge volcanic province.

The *Southern Mongolian volcanic province* developed in the Southern Mongolian Early Hercynides, beginning in the Devonian, was most intense in the Carboniferous period, and continued until the Lower Triassic. Geographically, the Southern Mongolian volcanic province is found in Sukhbaatar Aimag, southern part of the Dundgobi, and in Umnugobi. Geodynamically, the Devonian period was dominated by island arc conditions (which formed the Oyou Tolgoy Cu-Au deposit). The Lower Carboniferous period was dominated by shallow marine conditions, and strongly concentrated volcanism. During this period large volumes of calc-alkaline andesite, basalt-andesite, dacite-andesite, rarely rhyolite, rhyodacite, and their tuff-terrigenous sequences were deposited. Volcanism-related mineralisation of copper and associated minerals took place. For example, the Oyou Tolgoy Cu-Au, Tsagaan Suvarga Cu-Mo, Shuteen and Kharmagtay porphyry deposits. Volcanism-related Devonian-Carboniferous intrusive bodies formed. An alkaline intrusive body formed during the Permian period. During the Middle-Upper Permian period, the tectonic activity relatively decreased, and a low-lying landscape formed with many rivers, and lakes affected by warm weather. For instance, many basins and depressions formed with many coal deposits of good quality. Other sediments accumulated: sandstone, siltstone, mudstone, and rarely conglomerate sequences with fossils. Since the Triassic period, tectonics increased leading to the accumulation of coarse grained molasse in the Permian depressions. For example, the Noyon syncline in Umnugobi Aimag.

The *Central Mongolian volcanic province* consists of a series of depressions: Ulz, Choibalsan, Tsenkhergol, Dundgobi, Delgerkhangay, Khar Argalant, Buutsagaan, and Khantaishir. They extend 2000 km from northeast to southwest. The stages of those depressions and the accumulated formations are generally the same. Volcanic activity occurred since the Lower Permian, depositing intermediate-acidic lavas, and their pyroclastic materials in the depressions. The volcanic rocks were conformably overlain by Middle-Upper Permian sandstone, siltstone, rarely conglomerate sequences. These sequences contain benthic fossils such as brachiopods, crinoids, fresh water shells, ostracods, molluscs, etc. In the Dundgobi, Bayankhongor area, these Middle-Upper Permian formations yielded fauna but no marine fossils. The Middle-Upper Permian terrigenous sequences include economic coal deposits.

The *Orkhon-Selenge volcanic province* distributed along the Selenge River extends 20-30 km, with a width of about 100 km. During the Permian period, the area was affected by volcanism. The Khanui River basin contains the key section. The key section is composed of 3 large sequences. The lowest sequence consists of conglomeratic bed rock, the middle sequence consists of andesite porphyry and tuffitic basalt consisting of tuffitic sandstone, tuffitic breccia, and tuffitic conglomerate, and the upper part consists of acidic volcanic rock which is mainly composed of basalt, trachybasalt, tuffitic sandstone, tuff dacite and andesite basalt. The Permian sequences underlie the Triassic formation which is divided into conglomerate and volcanic sequences.

Mesozoic tectonic-magmatic superimposed structures

Since the Upper Triassic period, the Pacific oceanic plate collided with the Asian craton. This collision gave rise to tectonic-magmatic activity from 102nd longitude to the whole eastern part of Asia including eastern Mongolia, Inner Baikal, and the eastern part of the Chinese craton. Hereupon, the geodynamic condition developed differently in the Eastern and Western Mongolian territory. This is displayed in the stratigraphic classification. In eastern Mongolia, there are the Lower-Middle Jurassic Khamarkhuuvur, Upper Jurassic Sharil, and Lower Cretaceous Tsagaantsav, Shinekhudag, and Khuhteeg formations. In western Mongolia there are the Lower-Middle Jurassic Jargalant, Upper Jurassic Dariv, Ikhesnuur, and Lower Cretaceous Gurvan-Ereen, Zereg formations according to Khosbayar (1972).

Khamarkhuuvur horizon (Lower-Middle Jurassic). During this time, continental clastic sediments were deposited in alluvial, diluvial, and lake environments. It is divided into two sequences. The lower sequence consists of coarse grained formations such as conglomerate, fine grained conglomerate, and sandstone. The upper sequences are dominated by fine grained shale formations of lacustrine origin. In western Mongolia, the Jargalant Formation is composed of greyish sandstone with fossils, conglomerate and coal layers and coaly slates.

Sharil horizon (Upper Jurassic). During this time, clastic rocks were laid down in alluvial and diluvial conditions. Alkaline effusive rocks formed in Ulgii-Hiid, Mushgay-Khudag, and Undur-Bogd. This alkaline effusive rock is associated with a rare earth element deposit around the Mushgay khudag area. In western Mongolia, the Dariv Formation is composed of red calcareous muddy sediment, and sandstone with ostracod fossils, and the Ikhesnuur Formation has bright reddish conglomerate, fine grain conglomerate, sandstone, and rarely mud sediment.

The Lower Cretaceous formation is divided into the Tsagaantsav, Shine-Khudag, and Khukhteeg horizons.

The Tsagaantsav horizon (Berriasian-Valanginian) present in eastern and central Mongolia is composed of rift volcanic rock and terrigenous sediment. The volcanic rock is composed of basalt, rhyolite, an acidic subvolcanic body, and tuffitic rock. The terrigenous sediment is composed of conglomerate, calcareous lacustrine rock, muddy sediment and greyish, greenish grey porous sandstone with ostracods, molluscs, and fish. The porous sandstone contains oil. In Western Mongolia at this time the Gurvan-Ereen Formation was deposited composed of grey, blackish grey paper shale, grey, bluish grey, yellowish siltstone, mudstone, marble, and sandstone. The fossils include freshwater molluscs, phyllopods, ostracods, insects, and small dinosaur fossils.

Shine-Khudag horizon (Goterivian-Barremian). This horizon is widely distributed in Mongolia and easy to recognize. It is composed of grey, greenish grey, blackish grey slatey schist, combustible shale, shale, light grey siltstone, sandstone, and grey marble. The slate formation is very rich in fossils such as insects, fish, phyllopods, etc. Generally, this formation is very rich in shells, molluscs, ostracods, and dinosaur fossils. This stratigraphic horizon was previously named the lower member of the Zuunbayan Formation. The upper part of the Gurvan-Ereen Formation is at the same level as the Shine-Khudag horizon.

Khukhteeg horizon (Apt-Alb). This horizon is widely distributed in central, and south-eastern Mongolia. It is composed of greyish, yellowish sandstone, conglomerate, fine grained conglomerate, and mudstone layers. The horizon has a number of lignite deposits such as Uvdugkhudag, Baganuur, Chandmani, Aduunchuluu, Tevshiingobi, Shivee-Ovoo, and Nalaikh, etc. The fossils include freshwater molluscs, ostracods, and plants. Not to mention many dinosaur fossils. In western Mongolia, this stratigraphic level contains the Zereg Formation. It is composed of reddish, brownish, greyish, yellowish sandstone, fine grained conglomerate, siltstone, and shale layers. The bedding is characterised by rhythmic bedding. The fossils include fresh water molluscs, ostracods, phyllopods, etc.

Intrusive rock

During the Upper Triassic-Lower Permian period, intrusive complexes were widely distributed, mostly in Eastern Mongolia. The younger intrusive bodies are relatively limited in their distribution.

Upper Cretaceous-Miocene platform cover
During this time in the territory of Mongolia, tectonic-magmatic activity was relatively calm. The mountains had been eroded, and the valleys were filled with sediments. Furthermore, all of the Mongolian landscape had changed to steppe with low altitude mountains. The accumulated sediment was not very thick, and covered a wide area. The main lithologies were sandstone, and shale deposited in lakes, swamps, rivers, and alluvial fans. The colour of the sediments varied depending on the weather
during that period. The following horizons are distinguished:

Upper Cretaceous Baruunbayan, Bayanshiree, Bayanzag, Baruungoyot, and Nemegt horizons. All these horizons have a large number of dinosaur, reptile, invertebrate, and ancient mammal fossils. The Cenozoic sediments also include large numbers of mammal fossils. They are in biostratigraphically classified Cenozoic sediments.

Palaeogene horizons: Khashaat (Upper Paleocene), Bumban, Kholbolj, Ergelynzoo (Eocene), and Shandgol (Oligocene) horizons.

Neogene horizons: Luu, Builstey, Uush (Miocene), Altanteel, Khyargasnuur, and Shaamar (Pliocene) horizons. During Neogene time, hotspot volcanism occurred.

Late Cenozoic new tectonic structures
New geodynamic activity began in Central Asia in the Miocene. This is attributed to either Indian-Asian collision, and/or a mantle plume, and/or the Baikal rift system. This tectonism revived ancient deep faults which built new mountain ranges, and led to the accumulation of coarse grained clastic sediments of diluvial and alluvial origin deposited in new depressions. Lakes formed in the depressions, and accumulated fine grained sediments. This tectonism created today's Mongolian landscape. The following structures have been identified:

- *Northern Mongolian Baikal rift type landscape*. This landscape displayed by Khuvsugul lake and the Darkhad rift depressions
- *Khangai-Khentey dome*
- *Mongolian Altay and Gobi Altay linear horst uplift*
- *Local uplift blocks*
- *Eastern Mongolian wide depressions*

GEOLOGICAL DATABASE

GEOLOGICAL MAPPING

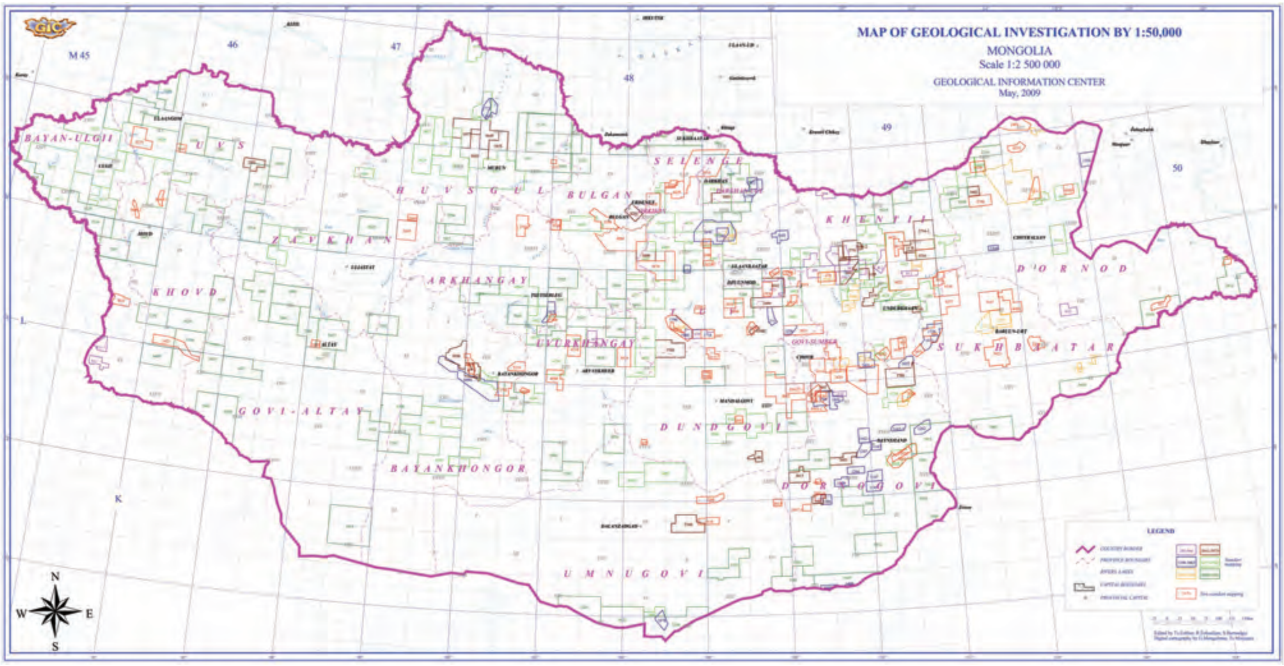


Figure 6: Geological maps of Mongolia, scale 1:50 000

- 100 % of the Mongolian territory is covered by geological mapping on a scale of 1:200 000,
- 27.1 % of the Mongolian territory is covered by general exploration work and geological mapping on a scale of 1:50 000,
- 100 % of the Mongolian territory is covered by gravimetric surveys on a scale of 1:100 000,
- 22 % of the Mongolian territory is covered by gravimetric surveys on a scale of 1:200 000,
- 60 % of Mongolian territory is covered by aerial magnetic surveys on a scale of 1:200 000,
- 32 % of the Mongolian territory is covered by aerial multispectral surveys on a scale of 1:50 000 and 1:25 000.

RESULTS OF GEOLOGICAL MAPPING AND MINERAL EXPLORATION IN MONGOLIA

Until January 1st, 2010, 1,130 "mineral deposits" and 7,668 "mineral occurrences" with 80 different commodities were discovered and recorded in Mongolia (cf. Map).

In Mongolia, "mineral deposit" means a mineral concentration that has been formed on the surface or in the subsurface as a result of geological evolutionary processes, whose quality and reserves are proven, and are economically feasible to mine by production methods

In Mongolia "mineral occurrence" means a sorted mineral concentration whose quantitative and potential mineral resources have been preliminarily evaluated in a pre-feasibility study for final exploration and evaluation in the next stage.

Potential investors should note that in this guide a different classification system has been applied:

- A "deposit" is an economically mineable mineral concentration applying international standards,
- An "occurrence" is a non-economically mineable mineral concentration applying international standards, because either the grade or tonnage is too low or the quality is too poor.

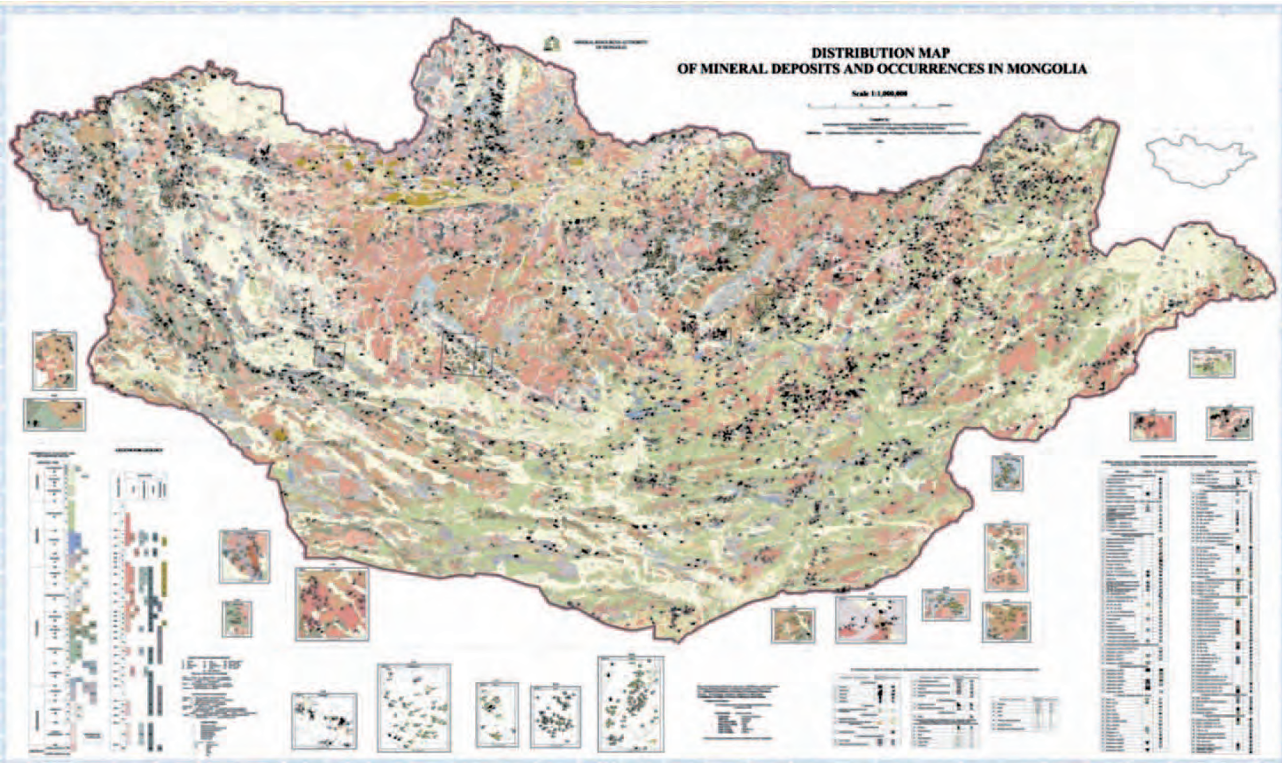


Figure 7: Mineral deposits and occurrences in Mongolia

ORIGIN AND QUALITY OF DATA

The geological information centre was established in 1957 when it was called the “State Geological Fund”. In 1997 it was renamed the Geological Information Centre of the Geological Survey, MRAM
All results of geological investigations in Mongolia including primary materials are registered and handed over to the archive where the results are processed on the basis of GIC to produce geo-information data. The project will consist of two databases. Private persons and organisations can gain access to the information from primary material, associated information in certain areas and the prepared material. This shows that it is necessary to improve and speed up the service. For this purpose it is necessary to have a computer-supported geographical information system (GIS) database to speed up the processing of the information.

The database on 1 January 2010 has the following registered content.
The database contains information on 1130 deposits, 7668 occurrences, and 194 deposits of water (cf. Distribution map).

1. English database information – 1070 deposits and occurrences;
2. Separate databases for non-metal deposits – 712 sample analysis results are included in the database ;
3. Database of probable resource minerals – 1299 deposits;
4. Database of sub marginal reserves – 2097 deposits and occurrences;
5. Additional database of new information – in province (Aimag) 640, in 9 series – 1250
6. Database of water points – L-46-50, M-46-50, K-47-49 on all sheets – 49565 entries;
7. Geochemical database - Coordinates of samples on 262 sheets at a scale 1:200 000 are marked and have formed a

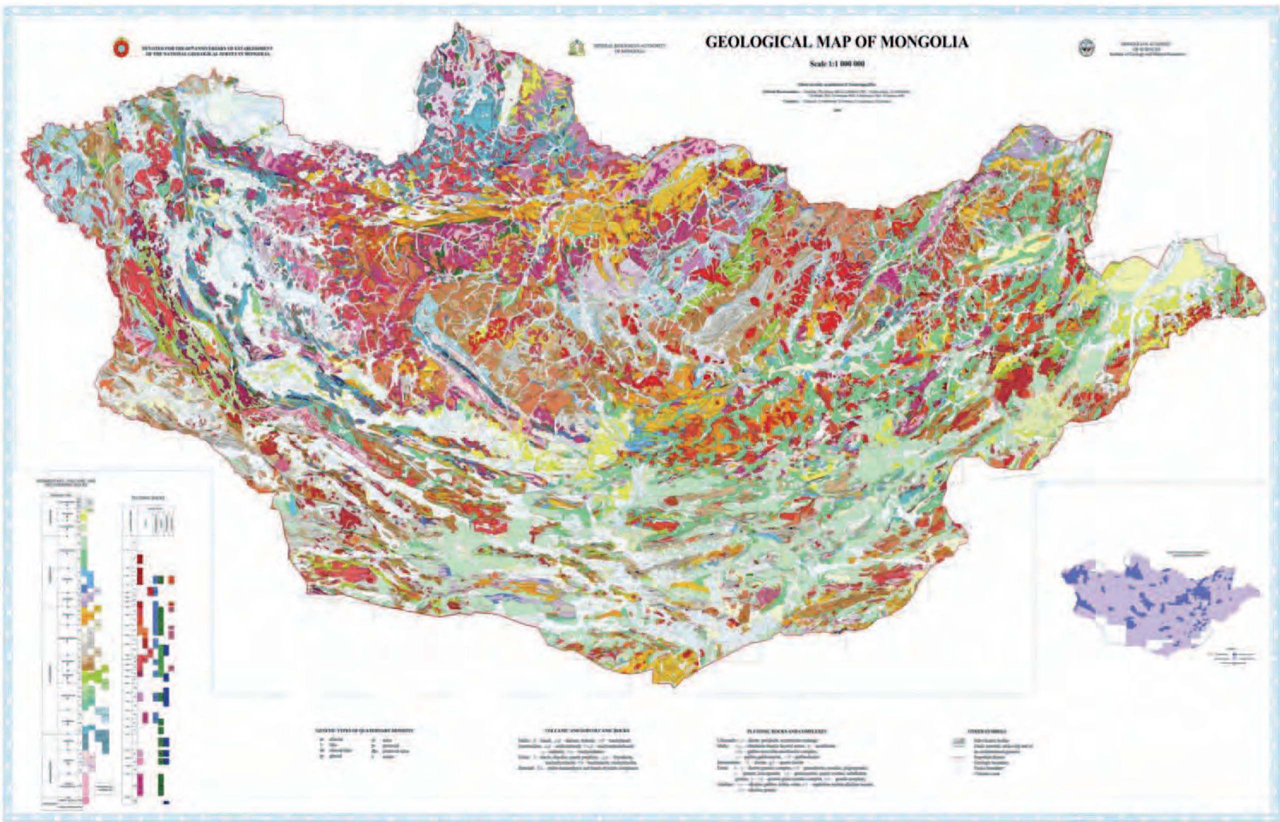
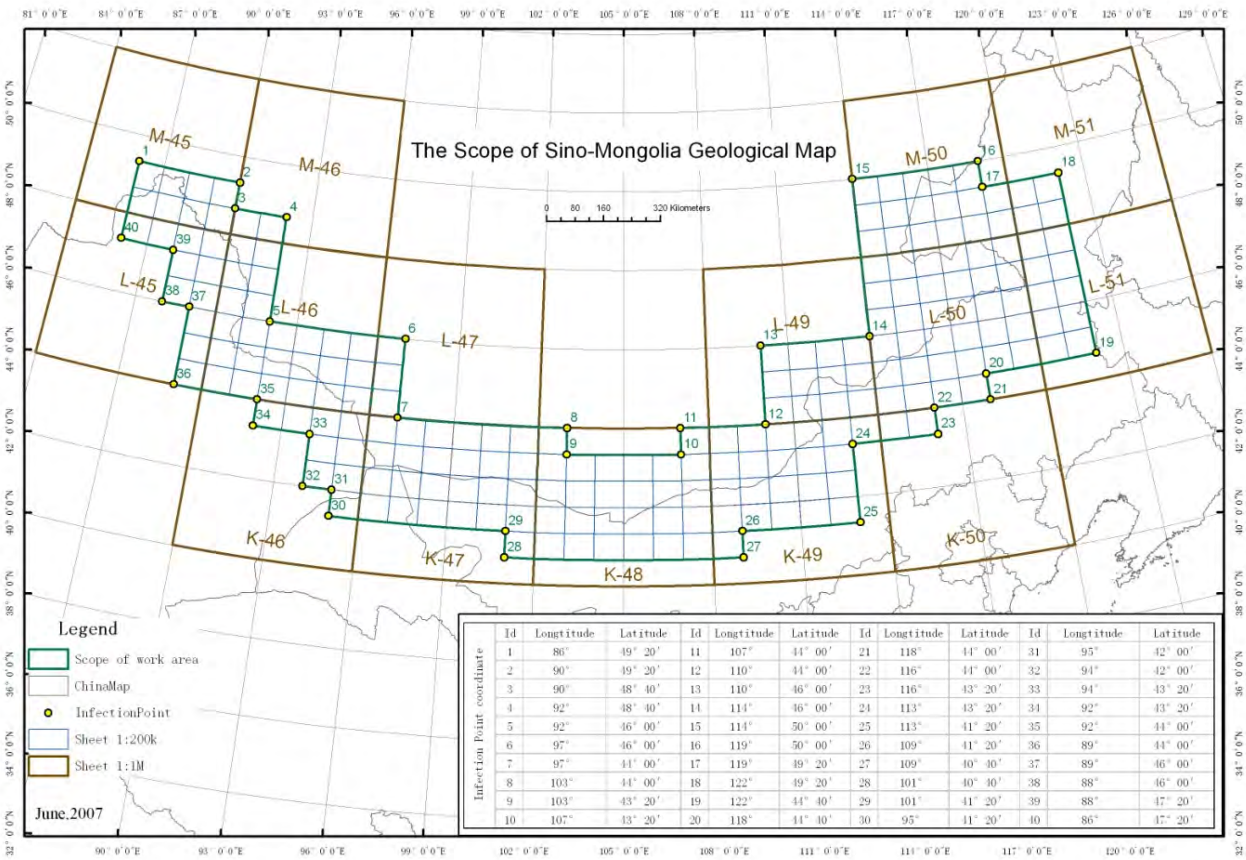


Figure 8: Geological map of Mongolia at scale 1:1 000 000, based on 80 years of geoscience

database, including the results of analyses from 305860 sampling points in a primary database;

8. Database of registration of the geo-chemical anomalies – 5894 entries;
9. Database of registration of the heavy mineral anomalies – 3699 entries;
10. Database of registration: on all sheets M-45-50, L-46-50, K-47-49
    - Geology – 2142 entries;
    - Geophysical – 1144 entries;
    - Engineering geology – 526 entries;
    - Hydrogeology – 1022 entries;
11. Database of intrusive rocks – 3843 bodies;
12. Database of registration of the stratigraphic
    geology – 1040 units;
13. Database of the palaeontology on all sheets M-45-50, L-46-50, K-47-49 – 3980 entries;
14. Database of the reports – 6098 entries;
15. Database of the editions – 1043 entries;
16. Database of the boreholes – 9785 boreholes;
17. 350 miscellaneous information reports
18. Digital topographic maps at a scale 1:200 000 – 313 sheets;
19. Database of geophysical maps:
    - Airborne geophysical magnetic database, digital data at a scale 1:200000 – 216 sheets;
    - Database of digital data at a scale 1:200, U-103 sheets, K, Th-109 -sheets;
21. Geological maps, digital, deposits 82 p.
22. The geological complexes, digital, at a scale 1:200 000 – 80 sheets;
23. The geological maps, digital, at a scale 1:50 000 – 260 sheets.

Currently, a geosurvey cooperation project is compiling 1:1,000,000 geological complex



Id	Longtitude	Latitude	Id	Longtitude	Latitude	Id	Longtitude	Latitude	Id	Longtitude	Latitude
1	86°	49° 20′	11	107°	44° 00′	21	118°	44° 00′	31	95°	42° 00′
2	90°	49° 20′	12	110°	44° 00′	22	116°	44° 00′	32	94°	42° 00′
3	90°	48° 40′	13	110°	46° 00′	23	116°	43° 20′	33	94°	43° 20′
4	92°	48° 40′	14	114°	46° 00′	24	113°	43° 20′	34	92°	43° 20′
5	92°	46° 00′	15	114°	50° 00′	25	113°	41° 20′	35	92°	44° 00′
6	97°	46° 00′	16	119°	50° 00′	26	109°	41° 20′	36	89°	44° 00′
7	97°	44° 00′	17	119°	49° 20′	27	109°	40° 40′	37	89°	46° 00′
8	103°	44° 00′	18	122°	49° 20′	28	101°	40° 40′	38	88°	46° 00′
9	103°	43° 20′	19	122°	44° 40′	29	101°	41° 20′	39	88°	47° 20′
10	107°	43° 20′	20	118°	44° 40′	30	95°	41° 20′	40	86°	47° 20′

Figure 9: Area of the compilation of maps along the Chinese-Mongolian border

maps and related geological studies in the Chinese-Mongolian border areas. The working area for compilation of maps in this project is limited to 100 km on either side of the Chinese-Mongolian boundary and a total width of 200 km. The boundary of the working area is set in its own international 1:1 000 000 topographic sheet upon mutual agreement (cf. Figure 9).

The project work shall include the compilation of the following series of maps for the working area:

- Geological map at a scale 1:1,000,000
- Tectonic map at a scale 1:1,000,000
- Mineral resources map at a scale 1:1,000,000

MINERAL RESERVES AND RESOURCES CLASSIFICATION SYSTEM OF MONGOLIA

1 General

1.1 This classification is a basic document covering all mineral reserves and resources within the territory of Mongolia and based on their degree of geological identification, economic and technological feasibility of recovery, to calculate and evaluate mineral reserves and resources, with subsequent registration in the state mineral resources statistics (fund).

1.2 Those reserves and resources which have been investigated in all aspects of geology including hydrogeology, engineering, geoecology, mining, methods, and mineral processing technology, should be registered in the state mineral resources fund. Basic documents are exploration reports including reserves and resources estimations and calculations which should be verified by reliable independent professionals and discussed by the state professional mineral resources commission when declared.

1.3 The State unified mineral statistics fund should register reserves and resources in the following groups:

- Reserves and resources of active mines
- Reserves and resources of planned mines
- Reserves and resources stored in the state mineral fund

1.4 Mineral reserves shall be calculated on the basis of the exploration results and data.

1.5 Mineral resources shall be evaluated on the basis of exploration along the margins of and deeper parts of previously explored deposits, and the results of semi-detailed surveys within ore belts, ore fields and ore zones based on the results of geological, geophysical, geochemical surveys and other comparative methods.

1.6 Multi-mineral deposit complexes should be evaluated on the basis of the calculated reserves of the main and/or other minerals which are economically valuable.

1.7 Satellite (associated) mineral reserves of commodities recovered during ore processing should be calculated as a product of the plant, as well as the underground ore.

1.8 Mineral ore quality and processing technology testing of the ore shall be conducted in accordance with State standards, and reserves and resources shall be evaluated with the aim of exploiting the deposit as fully as possible to extract all possible commodities.

1.9 Evaluation of resources and reserves calculation shall be expressed in units of mass and volume.

1.10 For some types of deposits, special standards and methods apply as stipulated by a higher institution.

2 Types of commodity mineral deposits and mineral resources

2.1 Mineral resources: mineral concentrations which have been identified by geological mapping, remote sensing, prospecting and exploration and their quantity shall be evaluated.

2.2 Reserves of mineral deposits: those deposits identified by exploration, and parts of resources where the quaiity and quantity of ore, economic importance and mining conditions have been determined.

2.3 Reserves divided into two types: reserves calculated by exploration for still underground reserves; and “in situ” minable reserves include those parts of an ore body where factors such as ore contamination, loss during operation, and protecting columns, pillars etc., are deducted from geological reserves.

2.4 On the basis of economic importance, ore reserves are divided into three main groups:

- Economically feasible or profitable reserves. The deposit is economically feasible at the moment according to feasibility study on mining, milling and processing.
- Economically feasible under certain conditions. Due to unprofitability of the mining and processing the deposit is not economic. May become economic in the light of scientific and technological developments, rising commodity prices, lower government taxation etc.
- Reserves with limited economic value. Although deposit is economic from the feasibility study, the economic conditions, government policy, social factors, legal conditions etc., do not allow operation of the deposit.

3 Classification of deposit based on complexity of the geological setting

3.1 Hard mineral deposits are divided into three main groups of complexity.

3.2 First group deposits show a simple geological setting and inner structure, not so affected by faults and folding, economic components are distributed evenly, parameters of body are uniform within deposit, ore quality is high grade, deposit size is large, sometimes large to medium etc., such deposits have ore reserves which can be classified as proven (A), probable (B) and potential (C).

3.3 Second group deposits include those deposits which have complicated geological settings, affected by faulting and folding, economic components distributed unevenly, quality of ore not uniform, parameters of the body are not regular, size is large to medium.
This also includes deposits with simple geology but difficult mining conditions and very irregular distribution. The geological exploration reserves of the deposit should be classified as probable (B) and potential (C).

3.4 Third group deposits cover ore bodies with a very complicated geological setting, ore bodies affected by strong folding and faulting, recoverable components very irregularly distributed, ore quality and thickness very irregular, deposit size medium to small.
Ore reserves of this group should be classified as potential (C).

4 Classification of mineral deposits in terms of their study level

4.1 All mineral deposits can be classified into two types in terms of their degree of geological study:

- Explored deposit
- Evaluated deposit

4.2 Explored deposits have been studied with the following techniques: such as reserve calculation, assessment of ore quality, study of mineral processing technology, hydrogeological conditions, etc. These exploration stages should have involved trenching and underground excavation such as shaft sinking tunnelling etc. Finally, sufficient information should be available to complete an exploration feasibility study of the deposit. The following requirements are stipulated for the exploration of deposits:

- Exploration activity should be sufficient to classify deposit as 3.2, 3.3, or 3.4, and the relevant category of reserves
- Mineralogical and chemical composition of the ore should be studied as well as technological characteristics, technological types of ore to select the most efficient way of processing with maximum extraction of all possible major and minor commodities. It should also study the possibility of processing plant tailings and compliance with waste disposal directives.
- Estimating the reserves of associated minerals; determine stripping ratio and study of possibility of using underground water.
- It is recommended that the following studies should be completed within the framework of exploration: hydrogeology, engineering geology, geoecology and other survey data necessary to complete a feasibility study.
- Selection of a small sized block which fully represents all the characteristics of the deposit which has been explored in maximum detail.
- Basic parameters (conditions) for ore reserves calculations should be suggested (recommended) on the basis of feasibility studies. Also basic parameters could be chosen in comparison with neighbouring deposits which lie within the same geological structure, with the same or similar geology and mineralisation.
- Possible environmental impacts should be properly studied, and proposals for their prevention should be suggested.

4.3 Evaluated mineral deposits: these mineral deposits have been looked at to determine their geology, quality of the ore and minerals, their processing technological characteristics, hydrogeology, engineering geology, mining environment, etc. to such a level that they satisfy the requirements for planning further detailed exploration. Evaluation should cover the following aspects:

- Part of the deposit should be explored at the level required for reserves category C.
- Mineralogical and chemical composition and mineral processing technology studies should be completed. These studies must be executed at a level to establish a basic choice of relevant mineral processing technology for maximum and complex mineral recovery.
- Hydrogeology, engineering geology, geoecology, mining and other relevant conditions should be studied at the level required for further determination of the exploration details.
- The size and shape of the ore body, and the geological setting should be studied in detail within the framework of one selected block
- Basic parameters (conditions) for the ore reserves calculation should be suggested (recommended) on the basis of feasibility studies. Also basic parameters could be chosen in comparison with neighbouring deposits which

lie within the same geological structure, with the same or similar geology and mineralisation.

- Possible environmental impacts should be properly studied, and proposals for their prevention should be suggested.
- Reserves composed of different categories distinguished on the basis of mineral types, geological setting, mining and processing conditions, and special aspects of investment, should be assessed by professional authors and verified by a consultant.

5 Reserves of mineral deposits, reserve categories and related requirements

5.1 Reserves of hard mineral deposits are divided into proven, probable and potential categories and given related indexes as “A”, “B” and “C” respectively.

5.2 Proven (A) reserves should meet the following requirements:

- Determination of the shape, size, depositional environment, irregularities of inner structure. Barren or unproductive parts or barriers and boundaries, special fold and fault structures, and size should be well explored and mapped in detail.
- Important parameters to show anomalies and compliancy should be mapped in greater detail in 3-D.
- Natural types of ore and technological types and grades of ore should be differentiated and outlined (contoured), and the quality and composition of the ore should be determined
- Processing technological characteristics should be studied at plant and semi-plant level.
- Positive and negative constituents and impurities and their distribution in the ore, concentrate and final product should be studied
- The contour of the proven reserves must be outlined through surface excavation and boreholes, and it should be based on selected conditions (cut-off grade, minimum economic thickness, etc.)

5.3 Probable (B) reserves should meet the following requirements:

- Determination of the shape, size, depositional environment, irregularities of inner structure. Barren or unproductive parts or barriers and boundaries, special fold and fault structures, and size should be well explored and mapped in detail.
- Important parameters to show anomalies and compliancy should be mapped in greater detail in 3-D.
- Natural types of ore and technological types and grades of ore should be differentiated and outlined (contoured), and the quality and composition of the ore should be determined at a probable level.
- Processing technological characteristics should be studied at semi-plant level of testing
- Recoverable and non-recoverable constituents and impurities and their distribution in the ore, concentrate and final product should be studied
- The contour of probable reserves must be based on the results of chemical analysis, selected parameters (cut-off grade, minimum economic thickness, etc.) and outlined through surface excavation and or borehole data, and if proven by the geological, geo-

physical and geochemical data, should be outlined by an extrapolation line.

5.4 Possible (C) reserves should meet the following requirements:

- Determination of the shape, size, depositional environment to explain anomalies in the inner structure. Special folding and big fault structures should be observed.
- Important parameters to show anomalies and compliancy should be at a probable level in 3-D.
- Natural and technological types of ore must be determined, and their depositional environment and ore quality should be investigated.
- Processing technological characteristics should be studied at laboratory level of testing, and parameters should be determined by comparison.
- Recoverable and non-recoverable constituents and impurities, and their distribution in the ore, concentrate and final product should be studied
- The contour of possible reserves must be based on selected parameters (cut-off grade, minimum economic thickness, etc.) and outlined through surface sampling and excavation and or borehole data, and if proven by the geological, geophysical and geochemical data, should be outlined by an extrapolation line.

5.5 Inferred resources (P1) shall cover deeper and marginal parts of explored deposits and occurrences. Inferred resources should be contoured (outlined) with the extrapolation method based on the outer line of the mineralized geological structure of the explored ore body. Geophysical, geochemical, structural, lithological, and stratigraphic survey data should also be applied. In addition to the above, ore body outcrops, and data from a few excavations and boreholes, with data from a few samples, should also be used for qualitative and quantitative evaluation of the mineralisation.

5.6 Hypothetical (P2) resources are usually evaluated during geological mapping and reorganisation surveys at a scale 1:50 000. At the same time, regional geological structural survey data, geophysical and geochemical anomalies with a few exploratory boreholes should be completed. For qualitative and quantitative evaluation: data from a few samples, and data from other analogous (similar) areas, and structural data.

5.7 Speculative (P3) resources estimations are usually based on 1: 50 000 and 1:200 000 scale geological mapping and airborne surveys, remote sensing and regional geological mapping, regional metallogenic and structural geological studies, regional geophysical and geochemical surveys, and some geoscientific investigations. Also speculative estimation could be made within ore fields, metallogenic provinces, and basins by way of comparison.

5.8 Evaluation of resources is usually made on the basis of observation of modern trends in ore processing technology, comparative analysis of active mines and explored deposits.

MINING INDUSTRY

The mineral sector and mining history in Mongolia dates back to the early 1900's, gold mining was initiated in 1901, and the first coal mine was developed in 1912. Before the 1930's, there was only sporadic geological exploration. Systematic and scientific geological prospecting and exploration of Mongolia's territory was started in 1939.

The beginning of the development of the modern mining industry dates to the 1940's and 1950's. In the period 1943-1948, the Yugzur, Tumentsogt and Burentsogt tungsten mines were built, and the mining of fluorspar began. The "Mongol-oil" enterprise developed the Zuunbayan oil field starting in 1950. Later the level of oil production decreased because of limited reserves, and by the mid 1960's, the field was exhausted.

The important stage of mining development was in the 1970's and 1980's, when financial aid and technical assistance was available from the Council of Mutual Economic Assistance (CMEA). In the 1970's and 1980's, the Modot placer gold mine; the Khajuu-Ulaan, Khar-airag, Urgen, Chuluut tsagaan del, Borundur, Berkh fluorspar mines, the Erdenet copper-molybdenum mine, and the Baganuur lignite mines began operation. The copper and fluorspar mines are developed on the basis of joint venture agreements with the former Soviet Union.

Since 1989, a series of changes in Mongolia has led to the development of a market economy and major restructuring of all institutions. The loss of major financial aid and technical assistance from the CMEA reinforces Mongolia's urgent need to obtain new foreign investment to develop its economically vital mining sector. New ties are being established with market economy countries.

In the early 1990's, geological exploration for oil was started again in joint ventures with companies from developed countries and Russia. There is growing interest from international mining companies to invest in mineral prospecting, exploration and mining of the

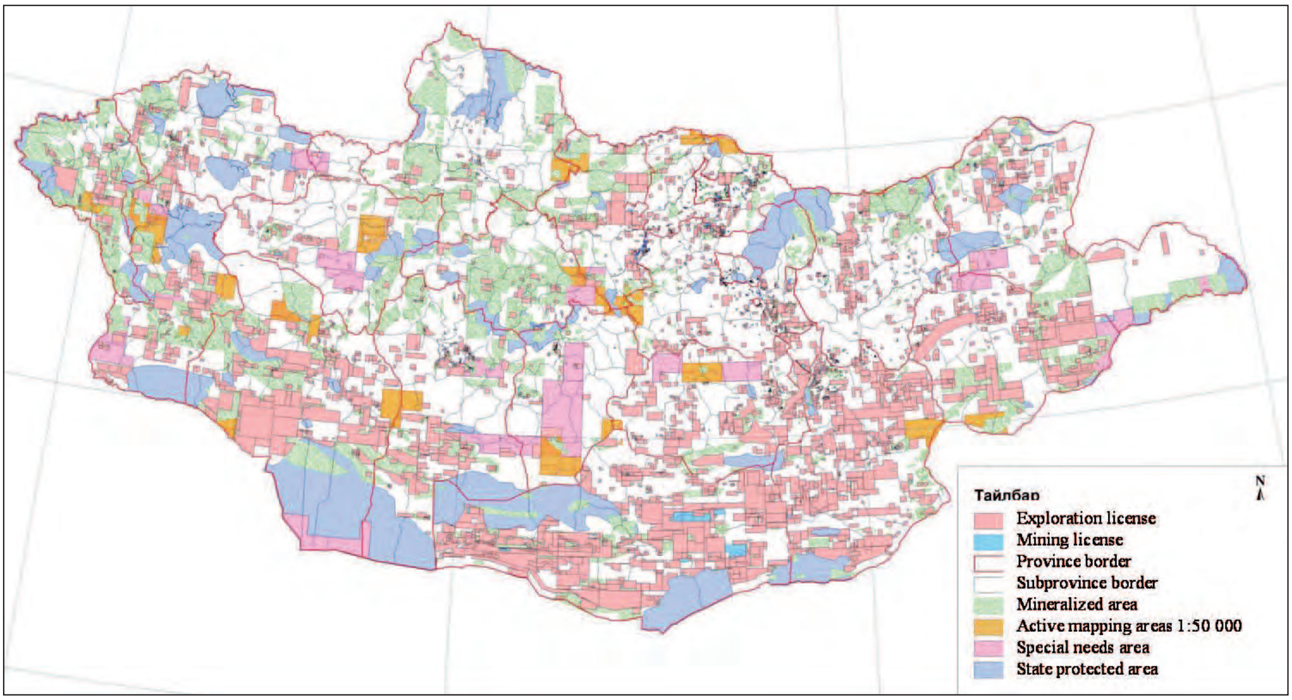


Figure 10: Map of current mapping, exploration, and mining activities in Mongolia

primary gold, oil, copper, polymetal, uranium, iron, tin, silver, etc. Over 40 Mongolian private companies started to work on the placer gold mining project.

Today there are a total of 200 deposits of coal, copper, molybdenum, placer gold, placer tin, tungsten, and fluorspar, plus various non-metallic and building materials, being mined by 158 mining enterprises.

ENVIRONMENTAL PROTECTION

Mongolia cares about environmental protection in mining. The relevant articles of the Mining Law (cf. earlier parts of this report) are:

Article 37	Environmental protection
Article 38	Environmental protection obligations of an exploration licence holder
Article 39	Environmental protection obligations of mining licence holders
Article 40	Review of environmental protection plans in connection with extensions of licences

INDUSTRIAL MINERALS IN MONGOLIA

DEFINITION

An industrial mineral according to the Glossary of Geology: "is any rock, mineral, or other naturally occurring substance of economic value, exclusive of metallic ores, mineral fuels, and gemstones; one of the non-metallics."
An even shorter definition is: Industrial minerals are non-metallic and non-fossil fuel rocks, minerals, and sediments that have an industrial use.
Probably most geologists and engineers would accept these simple and straightforward definitions, at least as a general statement.

On analysis, however, at least one anomaly crops up, i.e., what is metallic and what is non-metallic? Nepheline syenite, containing alumina, and lepidolite, a lithium mica, certainly qualify as metallic ores, but both are also raw materials of important non-metallic substances; hence they are included in this brochure. The same is true of rare earths. All the individual rare earth elements are metals but most of them, at least by weight, for along time were used in the glass industry. In this publication we will describe rare earths among the selected rare metals in Mongolia.

USES

Industrial minerals are the workhorses of our world. Without them, life as we know it today would simply stop.
Let us just take a soft drink bottle as an example. For the production of the glass you need silica sand, soda, lime, dolomite and feldspar as basic components. The melting furnace needs to be cladded with refractory bricks, which can be made out of sinter magnesia – made from magnesite – or alumina-zirconia-silica – made from bauxite-zircon-quartz. The melting furnace will be made out of steel.
For the production of steel, however, you not only need iron ore and coal but also fluxes, the most important being fluorite. We do not know all the ingredients of the soft drink but at least the water has to be purified e.g. by using diatomite. The bubbling gas is carbon dioxide, which is a natural gas. The boxes in which the bottles are transported are made out of plastic. This is a petroleum product.
To drill for oil and gas, however, you need a heavy fluid with a high viscosity. This is produced by using barite and bentonite. Now you have the soft drink in the bottle in the transport box. Because you do not want to go to the factory yourself to get your soft drink, it has to be brought to your favourite shop or bar. The most convenient way to do so is by truck. Well, now you might think that the truck is made out of steel plates and rubber for the tyres only. But how about the windows and the headlights, which are made out of special glass? And your truck should have brakes with brake linings made out of graphite. For welding steel plates you need welding rods, which are made out of rutile, which is a heavy mineral. Okay, but now you finally have

the soft drink in your favourite bar. Its walls will be made out of bricks. Did they use clay bricks, lime sand bricks or lightweight concrete blocks made out of cement and pumice? Most probably you will not be able to find out because the walls are painted. The paint is made out of water, ground calcium carbonate, fillers, like scrap mica or talc, clay minerals, and titanium dioxide, produced from ilmenite, to guarantee the best white colour. Enjoy your drink – in a developing world which needs industrial minerals and rocks everywhere.
By the way: this brochure itself could not have been produced without the extensive use of various industrial minerals.

Because the uses of industrial minerals and rocks are numerous and are growing every day, only the most important applications are mentioned at the beginning of each commodity chapter. Most potential investors in the industrial minerals of Mongolia will know what they can use each commodity for. Potential investors, who do not know and are just looking for a suitable investment, should get very familiar with their mineral of choice, or they might miss a very important niche in the market.

ECONOMIC IMPORTANCE OF INDUSTRIAL MINERALS IN MONGOLIA

The deposits and occurrences of industrial minerals and rocks in Mongolia are numerous and abundant. The minerals for construction purposes, for soil improvement and for use as fertilizer are the ones of most importance for the development of Mongolia in the near future. However, there are other industrial minerals which are more suitable for export because there is currently no market for them in Mongolia, or processing is highly complicated and therefore extremely expensive. Also because of quality or quantity restrictions, not all of the deposits of industrial minerals mentioned in the text can compete with deposits of the same minerals in neighbouring and more distant countries. For this reason, and to give both the interested reader and the potential investor a general overview of the industrial mineral potential of Mongolia, the following list has been prepared.

Important deposits of industrial minerals in Mongolia mainly for export

- Various fluorite deposits (partly in production)

Possible important deposits and occurrences of industrial minerals in Mongolia which need more investigation but might be suitable, mainly for export

- Jargalant graphite deposit (no production)
- Khutul Ulaan graphite deposit (no production)
- Ovor Maraat graphite occurrence (no production)
- Tuvshin Uul-1 graphite occurrence (no production)
- Doltai rock quartz occurrence (no production)
- Orkhon/Bayanondor rock quartz occurrence (no production)
- Kharmagtei rock quartz occurrence (no production)
- Bayan Uul/Zalaan Tsagaan rock quartz occurrence (no production)
- Sangiin Dalay Nuur sodium sulphate deposit (no production)
- Baruun Shavar sodium sulphate deposit (no production)
- Shorvog Nuur sodium sulphate deposit (no production)
- Shar Burdiin Nuur sodium sulphate deposit (no production)
- Buir magnesium sulphate deposit (no production)
- Sukhbaatar sillimanite deposit (no production)
- Tomor Malgai sillimanite deposit (no production)

Deposits and occurrences of industrial minerals in Mongolia of relevance not only for Mongolian industries but also suitable for export to neighbouring countries

- Bayan Khoshuu celestite deposit (no production)
- Baruun Tserd gypsum deposit (no production)
- Munkhtiin Tsagaan Dorvoljin lepidolite occurrence (no production)
- Ovor Maraat Gol nepheline syenite deposit (no production)
- Burenkhaan phosphate deposit (no production)
- Maikhan Uul phosphate deposit (no production)
- Shuden Uul (Davst Uul) sodium chloride deposit (temporary production)

Deposits and occurrences of industrial minerals in Mongolia of relevance for Mongolian industries

- Shiree Uul gypsum deposit (no production)

- Taragt gypsum deposit
  (former production)
- Tsogt Ovoo kaolin deposit
  (no production)
- Mandal Ovoo kaolinitic clay deposit
  (no production)
- Ulaan Nuur kaolinitic clay deposit
  (no production)
- Bideriin Gol magnesite deposit
  (no production)
- Bodonch muscovite deposit
  (former production)
- Zamiin Ulaan perlite deposit
  (no production)
- Avdarant dimension stone deposit
  (temporary production)
- Tsagaan Gol talc deposit
  (no production)
- Tsagaan Tsav zeolite deposit
  (in production)
- Khaalgan Uul zeolite deposit
  (no production)

Deposits of industrial minerals in Mongolia of relevance for local people only

- Gurvan Tes sodium chloride deposit
  (temporary production)
- Sangiin Dalay Nuur sodium chloride deposit
  (temporary production)
- Davsan Nuur sodium chloride deposit
  (temporary production)
- Erdene and Ikh Shankhai agalmatolite
  deposits for production of ornaments
  (temporary production)

ASBESTOS

GENERAL INFORMATION AND USES

Asbestos is a collective term for fibrous minerals, some belonging to the serpentine group (serpentine, chrysotile), others to the amphi-bole group of minerals (crocydolite, anthophyllite, amosite, tremolite, actinolite). Asbestos is non-flammable, flexible, acid-resistant, and possesses high tensile strength in one direction. For these reasons, asbestos was used extensively in earlier decades in all kinds of building materials, and in brake linings. It was then realised that asbestos fibres are all highly toxic, causing pulmonary damage and cancer even after short exposure and at low dose rates. Chrysotile asbestos is still commercially exploited in the western world, but to a very limited extent and for very special applications like chrysotile cement only. Also very long asbestos fibres which can be woven are still in demand for the production of heat resistant textiles.
It must be mentioned that some countries, e.g. Russia, Canada, Kazakhstan, and Brazil continue mining and using all kinds of asbestos because they have not imposed restrictions for the use of asbestos in industrial applications.

RELEVANT DEPOSITS IN MONGOLIA

According to Dejidmaa et al. (2001) there are four deposits and 30 occurrences of asbestos in Mongolia. Jargalsaihan et al. (1996) also mention four deposits, but only three occurrences, while Geological Information Center (2003) lists three deposits and eight occurrences of this commodity. All of these deposits contain chrysotile asbestos. However, none of them was explored in great detail.

- The **Taishir** asbestos deposit in Taishir Soum of Govi-Altai Aimag was first explored by trenching and drilling in 1959. The ultrabasic ore zone has a length of 200-1,000 m, on average 500 m, a width of 50 m, a thickness of 3 m, and dips steeply. The ore consists of antigorite-serpentinite, apoperidotite pyroxenite, chrysotile, Fe-hydroxides, chromite, talc, and magnetite. The asbestos occurs in the form of thin radiant, short (0.5-4 mm) fibres of partly lamellar, partly slatey fabric. The asbestos is of yellow-green, copper-golden, or snow-white colour. It is fire resistant up to 1,550 °C, with a heat-transfer retention time of 5 °C/min. The average grade of asbestos in the ore is given as 4.34 %, the category C1 resources are around 150,000 tonnes of asbestos.

- The **Alag Uul** asbestos deposit lies in Sharga Soum of Govi-Altai Aimag. Prospecting this deposit discovered antigorite, chrysotile, apodunite, apoperidotite serpentinite, fibreous bastite, carbonates, Fe-hydroxides, magnetite, olivine, picotite, and serpopyhte.
  The chrysotile asbestos mineralisation occurs in the form of fibres, flakes, plates, and irregular lumps (up to 4 cm in diameter) in complicated veinlets, veins, and nests along tectonic faults and brittle cracks. The average length of asbestos fibres is only 0.5 mm; their humidity varies from 4 to 11 %. The grade of asbestos in four different ore bodies varies from 0.5 to 2 %, resulting in category C2 resources of some 100,000 tonnes of asbestos.

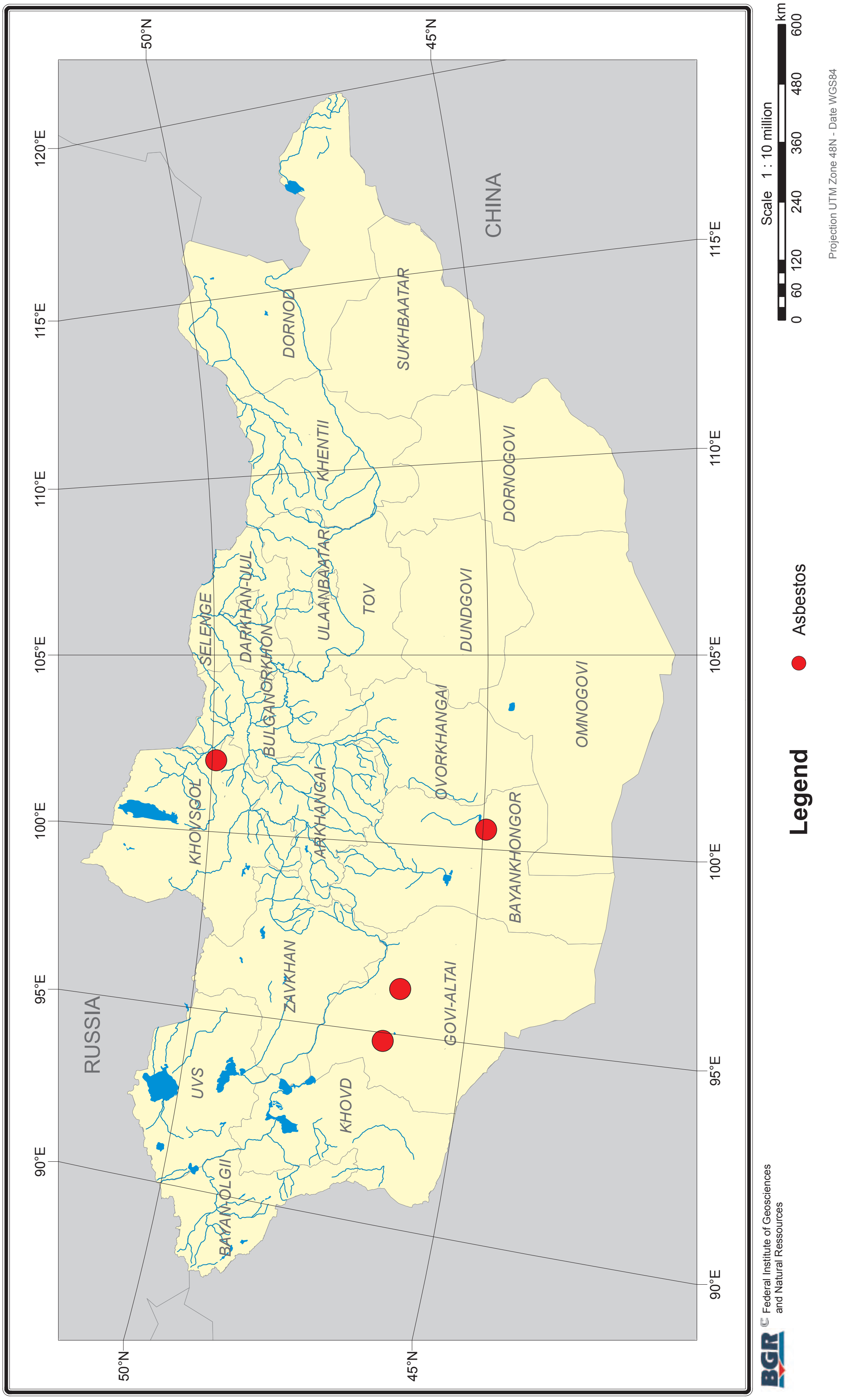
- The **Zalaat** asbestos deposit is located at the ultrabasic intrusive massif of the same name in Tarialan Soum of Khuvsgul Aimag. This deposit consists of two ore bodies with veinlets of reticulate structure. The upper ore body measures 265 x 40 m in size, dips at 70°, and is composed of small veinlets of chrysotile-asbestos with a grade of 3.7-5.3 % asbestos. The lower ore body dips at 84°, measures 120 x 25-30 m in size, and grades 3.1-3.8 % asbestos. The main ore minerals are flaky bastite, bedded antigorite, banded chrysotile and rarely magnetite. The chrysotile asbestos is of light grey to green grey colour. The length of fibres varies from 3-10 mm. Calculated resources down to a depth of 50 m amount to 42,800 tonnes of asbestos in category C1, and 26,900 tonnes in category C2. The thickness of overburden varies between 5 and 50 m.

- The **Gegeen Ovoo** asbestos deposit is located in Bogd Soum of Bayankhongor Aimag. Its mineralogy is very similar to the Alag Uul deposit. The chrysotile mineralisation is bound to a system of thin cracks, veinlets (up to 4 cm thick), and stringers (0.1-12 mm thick, 1-12 m long), resulting in highly variable grades from 0.01 to 2.5 %. The length of asbestos fibres reaches 8 mm on average. The humidity of the asbestos varies from 4 to 7.8 %. Resources were calculated by simple geometrical methods resulting in a presumed tonnage of 2.055 million tonnes of ore with a content of 46,030 tonnes of asbestos.

EVALUATION

In contrast to earlier decades, asbestos is no longer a commodity of broad interest. The deposits of chrysotile asbestos in Mongolia are rather small both according to international (<500,000 tonnes of asbestos content) and the Russian classification system (<1 million tonnes of asbestos content). They also have average grades (1-10 %) and the length of fibres varies from extremely short (<1 mm) to average (<10 mm). The deposits in Mongolia are thus not competitive compared to international markets.

Deposits of Asbestos in Mongolia



BARITE AND CELESTITE

GENERAL INFORMATION AND USES

Barite, i.e. barium sulphate ($BaSO_4$), which is mostly used to increase the density of drilling mud, but also as a filler in paint and paper, or for the production of heavy-weight concrete, is not a mineral appearing in economically interesting enrichments in known occurrences in Mongolia.

Celestite or celestine, which is strontium sulphate ($SrSO_4$), is chemically modified to strontium carbonate or strontium nitrate and then used in making glass for television screens, the production of ceramic ferrite magnets or in pyrotechnics (red colour).

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Dejidmaa et al. (2001) list ten, and Geological Information Center (2003) eleven occurrences of barite veins in Mongolia, of which only **Khatgiin Gol** near Moron town in Khuvsgul Aimag was prospected in sufficient detail to allow calculation of resources of 11,039 tonnes of barite. On the other hand, United Nations (1999) mentions **Dzurihe** 200 km south of Dalandzadgad town as the largest barite occurrence in Mongolia. It contains

Figure 11: Satellite image of Bayan Khoshuu celestite and Avdarant fluorite deposits (Photo courtesy of Google Earth).

nests of crystalline barite from 30 to 50 cm thick enclosed in a zone of Devonian marble of 500 m length and 20 m width.
The mineralised zones in the **Mushgai Khudag** volcanic-plutonic complex (cf. Rare Earths) in Mandal-Ovoo Soum of Umnugovi Aimag were analysed to contain about 0.9 % barite on average, with up to 10-15 % of barite in certain spots. P1-resources were calculated as 222,800 tonnes of barite.

Celestite in Mongolia can be found in two deposits and five occurrences (Geological Information Center 2003), or one deposit and seven occurrences (Dejidmaa et al. 2001).
One of these deposits is the **Mushgai Khudag** complex mentioned above. Besides rare earths and barite, the ores also grade 0.9-1.35 % Sr, allowing calculation of P1 resources of 220,600 tonnes of strontium. P2 resources of visible celestite, defined by ore with a minimum of 20-25 % $SrSO_4$, were calculated as 201,600 tonnes.

The other strontium deposit in Mongolia is called **Bayan Khoshuu** (44° 20' 17.1" N, 104° 21' 37.7" E, 1,228 m a msl) and is located just 4 km south-east of the Olon Ovoot gold mine, 7 km south-west of the Avdarant fluorite deposit and 28 km east of Mushgai Khudag also in the Umnugovi Aimag. The geology around Bayan Khoshuu is very complicated, and dominated by a variety of volcanic rocks, syenites and granites as well as sedimentary rocks of Silurian, Upper Jurassic, and Lower Cretaceous age. Hydrothermal veins, which occur close to old volcanic pipes, are found in two ore fields called Khumh and Cenher Tolgoi. Besides Sr, which strongly increases with depth, Ba, REO (cf. Rare Earths), and sulphides of different metals (above all MoS_2, FeS_2) are enriched.
Only the Cenher Tolgoi ore field was found to be of commercial interest. It covers an area of 32,000 m^2, is mushroom-shaped and is mineralised at least down to 200 m depth. The celestite-bearing ore is breccious and contains 50.6 % celestite, 0.5 % barite, 23.5 % quartz-feldspar-aggregates, 14.8 % feldspar, 3.6 % quartz, 3.2 % hydrogoethite, 2.6 % carbonates, 0.2 % mica, and 1.0 % other minerals on average.

Dressing tests by flotation proved very successful with a recovery rate of 75 % and a content of 87 % $SrSO_4$ in the final concentrate.
Using a cut-off grade of 10 % $SrSO_4$, total category C2 resources of 1.8 million tonnes of ore with a content of 440,000 tonnes of celestite were calculated.

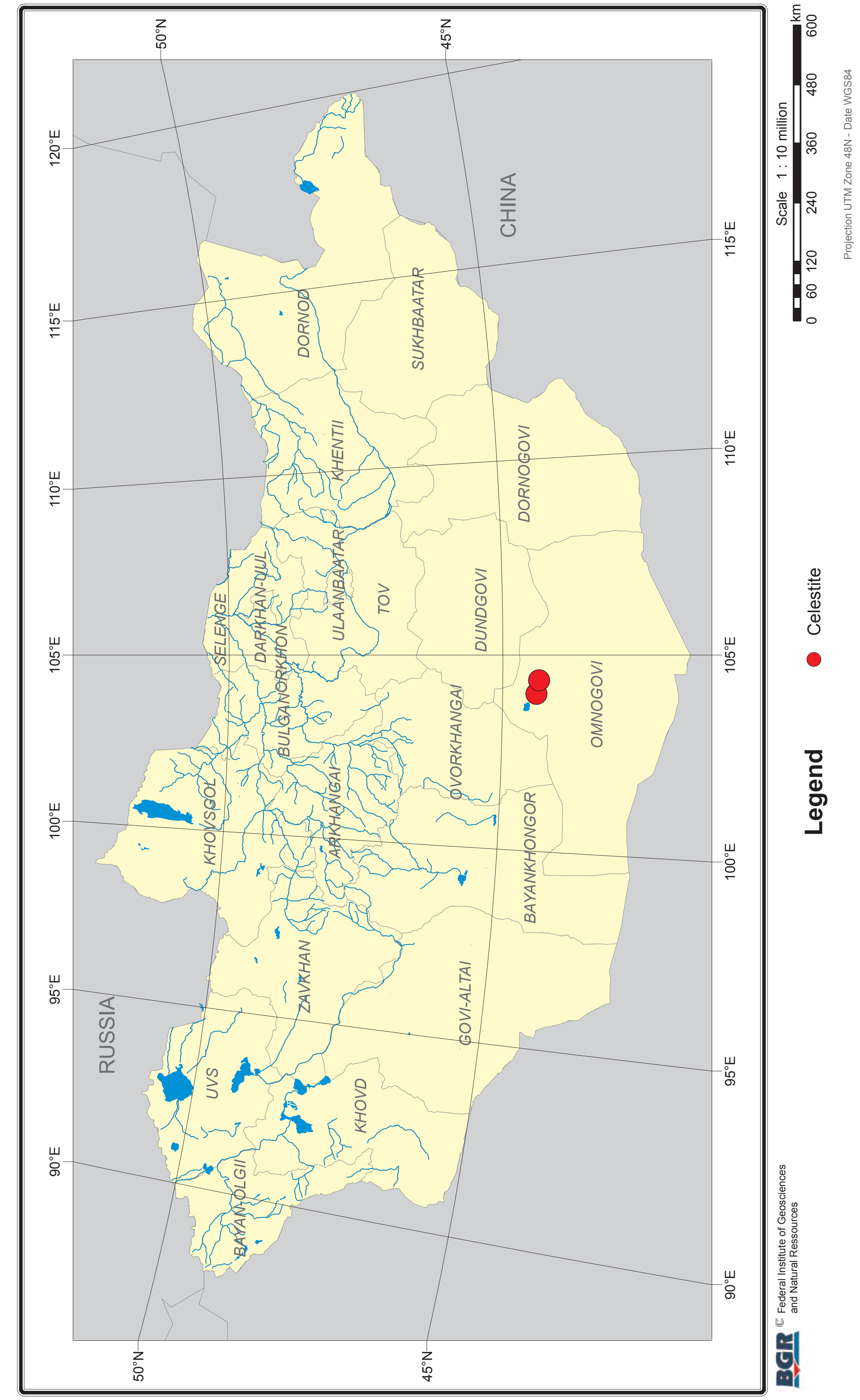
Two representative samples of celestite ore from Bayan Khoshuu taken during a field trip in 2010 yielded the following concentrations (ICP-OES and Solid Phase Mercury Atomic Absorption Analysis (Hg) analysis by BGR):

	Sr	*SrO*	*$SrSO_4$*	Ca	Hg
#1	20.62 %	*24.39 %*	*43.23 %*	0.81 %	6 ppb
#2	37.40 %	*44.24 %*	*78.42 %*	2.49 %	46 ppb

EVALUATION

Most of the barite occurrences in Mongolia have never been sampled or looked at in close detail. This means that not much is known about their quality. However, all of them seem to be rather small, with only Mushgai Khudag having some, although low potential. However, in general, the infrastructure at this location is very poor with the exception of the nearby Olon Ovoot gold mine which might serve as a centre for flotation of ores from Mushgai Khudag, Avdarant, and Bayan Khoshuu.
The strontium ores in Mongolia are also very low grade (<40 % celestite) to medium grade (40-80 % celestite) with resources categorised as medium size (100,000 – 500,000 tonnes). Dressing tests with celestite ore from the Cenher Tolgoi ore field of the Bayan Khoshuu deposit proved to be successful, but in a similar way to Mushgai Khudag, the infrastructure is very poor. In general, many more analyses have to be performed before any final evaluation will be possible.

Deposits of Celestite in Mongolia



BENTONITE AND BENTONITIC CLAY

GENERAL INFORMATION AND USES

Bentonite and bentonitic clays are sediments enriched in smectite-group clay minerals. The physical properties (namely the swelling properties) and the chemical absorption behaviours of bentonites are dominated by montmorillonite, the most prominent mineral in the smectite mineral group. Two major types of bentonite can be distinguished: swelling bentonite with high amounts of sodium, and non-swelling bentonite enriched in calcium. Bentonites enriched in potassium are usually not used.

Bentonites and bentonitic clays can be used in numerous applications, e. g. for the production of ceramics, or adsorbing materials like cat litter, the purification of vegetable oil and other liquids, in cosmetics and many other applications. High-quality bentonite is also part of some disposal systems for high-level radioactive waste and is extensively used in drilling mud. The chemical and technical properties for each application are very different and must be analysed carefully.

RELEVANT DEPOSITS IN MONGOLIA

Mongolian bentonitic clays occur at **Khunt Nuur** in Aikhan Soum of Bulgan Aimag. The Khunt Nuur deposit (48° 46' 58.1" N, 102° 15' 57.7", 1,338 m a msl) is situated in the lowermost part of a wide valley, bordered by volcanic rocks to the east. It can be identified by greenish sandy loam, which acts as a barrier to rain water (cf. Figure 12). The clays are sediments of a lake deposited in the Upper Quaternary. As the area of Khunt Nuur is a marshy landscape, the bottom of the valley must be drained before the clay could be excavated in an open pit.
During exploration in 1983, four different layers of bentonitic clays were identified. The orientation of the layers is NW to SE. Sand and silt are intercalated between the bentonitic clays.

Figure 12: The Khunt Nuur bentonite deposit as of August 2009, forming shallow ponds at the surface.

Layer	Thickness	Colour
Uppermost	0.2-0.3 m	grey
# 2	1.8-14.8 m	greenish
# 3	2.0-15.8 m	black
Lowermost	0.4-8.0 m	black-grey

The grain size of the clay is very small, with a maximum of 1.8 % >63 µm, and 37.98-50.95 % <1 µm.
According to the deposit passport, the chemistry of the deposit is quite uniform and given as: 57.92-67.52 % SiO_2, 0.36-0.78 % TiO_2,14.77-17.71 % Al_2O_3, 3.92-7.0 % Fe_2O_3, 1.05-3.25 % CaO, 1.83-2.27 % MgO, 2.83-2.94 % K_2O, 1.51-3.51 % Na_2O, 0.04-0.54 % SO_3, and 2.23-7.07 % LOI.
The amounts of iron and titanium in the clay are very high and must be reduced to an average of 1.5–2.0 % before the clay could be used as a drilling mud. Because of the comparatively high potassium and low aluminium content, the deposit presumably contains clay enriched in smectite, illite and quartz rather than a high-value bentonite. However, no reliable information about the mineralogical

composition of the clay is yet available.
The following technological parameters of the clay were determined: Marsh-viscosity: 15.5-16.5 s, water absorption: 40 ml/30 s, refractory deformation temperature: 1,160-1,200 °C. The clay was suggested for use as a drilling mud, however, the viscosity is very low.

The maximum length of the deposit is 941 m, the maximum width is 666 m, and the average thickness is 13.4 m (1.8-26.2 m). The thickness of the overburden varies from 0.1-4.9 m with an average of 1.8 m. The ratio of overburden to ore is about 1:7. Groundwater can be found below 2.0-3.4 m. Between 5.6 and 9.0 m, a layer of permafrost ice was identified. Calculated reserves/resources of bentonitic clay are 207,400 m^3 in category C1 and 381,900 m^3 in category C2.

The **Ganjuurt** deposit is located in the northeasternmost part of Choibalsan Soum in Dornod Aimag and was explored in 1987/88. The deposit is 100 m wide and 400 m long. The average thickness of the brownish-greyish clay of interest is about 8.6 m (5.5-12.0 m). While the thickness of overburden varies from 2-10 m, the ratio of overburden to clay is 1:1.5 on average. No groundwater was observed during drilling. In an area of 3,580 m^2, calculated reserves in category B are 29,714 m^3 of clay at an average thickness of 8.3 m, and an average thickness of overburden of 6.2 m. Additonally, in a larger area of 37,370 m^2, there are reserves in category C1 of 332,593 m^3 of clay with an average thickness of 8.9 m, and an average thickness of overburden of 5.6 m. The density of the clay is about 1.1-1.8 g/cm^3. The Marsh-viscosity of 20-25 s is low. On average, the clay contains 33 % <2 µm. The mineralogical composition is dominated by montmorillonite and chlorite, with small amounts of illite (hydromuscovite), quartz and feldspar. While the clay also contains high amounts of Fe-hydroxides, no further information about the chemical composition of the clay is available.

It is said that the clay of Ganjuurt could be used as a drilling mud or adsorbent; however, it is not possible to verify these applications from the available data-set. It is more likely that the bentonite of Ganjuurt is a bentonitic clay rather than a high-value bentonite.

The deposit of bentonitic clays at **Kherlen** is named after its location on the south bank of the Kherlen gol in Sumber Soum of Dornogovi Aimag (cf. Figure 13). With initial reserves/resources of 37,400 m^3 in category B, 284,000 m^3 in category C1, and 394,400 m^3 in category C2, Kherlen is one of the major deposits of bentonitic clays in Mongolia. Some 8,800 tonnes of clay were quarried before 1984. The length of the deposit is about 720 m. Its width varies from 160-360 m and its thickness from 0.6-2.3 m, with 1.7 m on average. In certain spots in the north and in the central part of the deposit >15 m of clay were drilled, however, in most places there is no overburden at all.

The colour of the clay is black or grey, in some parts greenish-grey or reddish brown, which means that it presumably contains a lot of organics. In parts, the clay may contain up to 4 % sand. Otherwise the grain size distribution is given as: 11.60-42.30 % >50 µm, 12.36-78.05 % 50-5 µm, and 10.19-46.47 % <5 µm. According to the deposit passport, the chemistry of the clay is highly variable, i.e. 34.34-57.70 % SiO_2, 12.74-21.34 % Al_2O_3, 4.50-48.45 % Fe_2O_3, 0.90-11.83 % CaO, 1.00-5.06 % MgO, 1.67-2.61 % K_2O, 2.45-4.96 % Na_2O, and 7.63-21.82 % LOI. The iron content is exceptionally high.

No information about the mineralogical composition of the clays at Kherlen is available. However, as they are slightly enriched in potassium, presumably illite (hydromuscovite) as well as montmorillonite dominates the composition.
The Marsh-viscosity of the clay is low (18.1-20 s) compared to common bentonites used in drilling mud. The density is 1.05-1.3 g/cm^3.

Because the deposit area of Kherlen is a marshy landscape during summer, it is only possible to excavate the clay in an open pit mine in winter.

ratio of overburden to clay is about 1:2.5. According to the deposit passport, both the grain size distribution (on average 63.2 % <1 µm) and the chemical composition of the

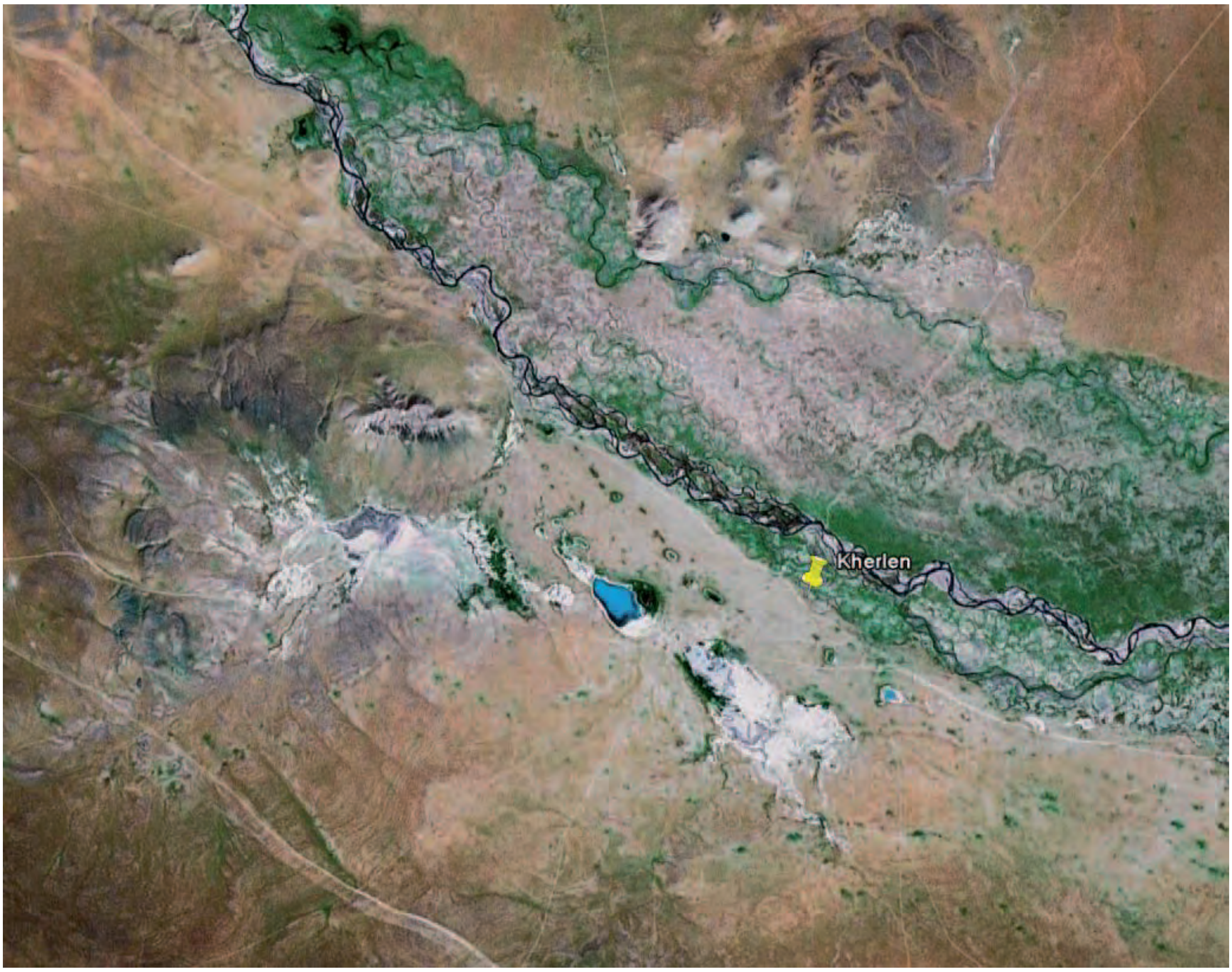


Figure 13: Satellite image of the Kherlen bentonitic clay deposit with Kherlen River to the north (Photo courtesy of Google Earth).

The **Naran** deposit is located in Sukhbaatar Aimag, just 500 m south-east of Naran village which is the Soum centre (cf. Figure 14). This area was explored in 1980 after the deposit had been discovered in 1965. Dimensions: length 200-450 m, 200 m on average, and width 100-250 m, on average 150 m. Here the thickness of the clay lenses of interest is about 8.2-18.10 m. They are covered by sand and sandy loam of 2.0-5.8 m thickness. The colour of the hard to soft plastic clays of Cretaceous age is green, dark grey, red, or brown. The clays is very uniform and not much changing with colour: 54.0-60.1 % SiO_2, 0.8-0.9 % TiO_2, 15.4-16.4 % Al_2O_3, 5.5-6.6 Fe_2O_3, 1.8-4.4 % CaO, 1.9-2.75 % MgO, 2.0-2.67 % K_2O, 0.7-1.0 % Na_2O, 0.07-0.15 % SO_3, and 6.8-7.1 % LOI.

The clay is composed of montmorillonite, illite (hydromuscovite), kaolinite and halloysite. The potassium content is slightly enriched. The deposit does not contain a high-value bentonite, but in the exploration report it is suggested that the bentonitic clay of Naran can be used for drilling mud or as expandable clay. The clay was previously quarried in an open pit and used for ceramics by a company from Ulaanbaatar. Groundwater was discovered at 28 m depth. Calculated reserves/resources are 176,700 tonnes in category B, 412,600 tonnes in category C1, and 217,900 tonnes in category C2.

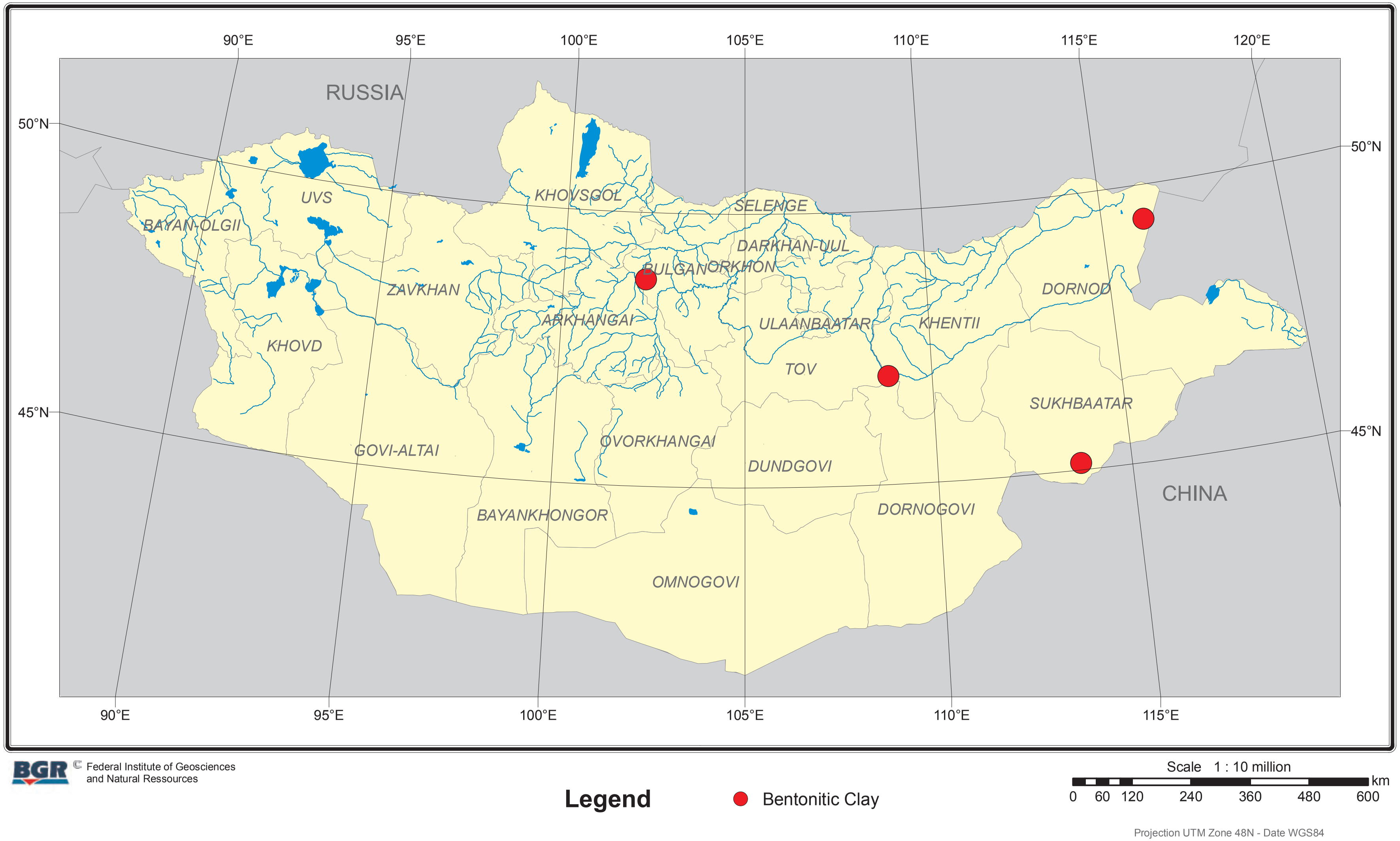
Figure 14: High definition satellite image of Naran village and the Naran bentonitic clay deposit to the south-east (Satellite image as of 8 November 2003, Altitude 2.05 km, Photo courtesy of GOOGLE EARTH).

REQUIREMENTS AND EVALUATION

For industrial use, bentonite should contain 70-80 wt-% smectite with >80 wt-% <2 µm grain size. The minimum thickness of bentonite deposits should be >0.5 m with reserves preferred to exceed 100,000 tonnes. According to the Russian classification system, bentonite deposits containing less than 10 million tonnes of bentonite should be regarded as small.

All the deposits of interest in Mongolia do not seem to contain these required amounts of smectite, although definite proof is missing. Potential investors in this commodity need to take new samples and have them analysed for mineralogy and cation-exchange-capacity (CEC) for realistic evaluation of the potential of their bentonitic clay deposit of choice.

Deposits of Bentonitic Clay in Mongolia



EARTH PIGMENTS

GENERAL INFORMATION AND USES

Earth pigments come in red, yellow, brown, black, and grey colours, made up of a variety of iron oxide minerals (hematite, limonite, goethite, maghemite, lepidocrocite, magnetite). Well-known names of natural earth pigments are ochre (red, gold, brown), umber, and sienna. Nearly all of the earth and mineral pigments of historical times have now been substituted by synthetic colours due to their lower heavy metal contents and higher uniformity. However, there are still niche markets for high-quality natural earth pigments especially for use in paints, in cosmetics, and in glass production.

RELEVANT DEPOSITS IN MONGOLIA

In the 1970's, tests for paint production were performed in Mongolia and for this reason small amounts of earth pigments are quarried at several locations. At the beginning of the 1980's with support from UNIDO and UNDP a test lab was set up in Ulaanbaatar for the production of paints for local demand from local sands and soils. These tests were supposed to run till 1990 but no final report was ever published (KAMPE 1990).

JARGALSAIHAN et al. (1996) list 15 deposits and six occurrences of "mineral paints" also stating some grade and reserve data. DEJIDMAA et al. (2001) give names of six deposits and 43 occurrences of "colored clay pigments" as well as of nine deposits and ten occurrences of "iron oxide pigments" in Mongolia. GELOGICAL INFORMATION CENTER (2003) mentions eight deposits of "pigment resources".

In the following table all of the 15 deposits mentioned by JARGALSAIHAN et al. (1996) and for which deposit passports are also available, are listed in rank of total resources calculated.

Of the pigment deposits mentioned above, Alag Tolgoi (48° 32' 53.7" N , 89° 36' 05.4" E; 2185 m a msl) and Buyant (48° 31' 59.9" N , 89° 34' 37.5" E; 2020 m a msl), both close to Buyant town in Bayan-Ulgii Aimag were visited and resampled in 2009.

The **Alag Tolgoi** pigment deposit was explored in 1983 by trenching, including sampling for granulometric, chemical, and technological analysis. The pigment deposit is rather small, having an average length of 125 m, a width of 110 m, and a thickness of 1.5-2.0 m, on average 1.75 m. The maximum thickness of overburden is 1.0 m.

The deposit consists of orange-red to brick-red fine sediments with lots of coarser clasts (15.2-56.1 %) derived from a chloritic-sericitic shale. The mineral composition is dominated by quartz with traces of muscovite-illite, feldspar, kaolinite, and hematite (XRD-analysis by BGR). According to the deposit passport, the coating capacity was determined as 67.1 g/m^2, and the oil adsorption as 33.5 g/m^3.

Calculated resources in category C1 are only 9,500 tonnes of earth pigment content meaning that the deposit is not economically mineable because it is much too small.

Figure 15: The Alag Tolgoi pigment deposit as of September 2009.

Table 1: Relevant data on earth pigment deposits in Mongolia (taken from deposit passports).

Name	Aimag	Soum	Colour	Quality	Resource (content)
Shar Shoroot	Dundgovi	Govi-Ugtaal	yellow, red, white, reddish brown	1 layer, 4 ore bodies with different colours, thicknesses, and compositions: 53.3-78.0 % SiO_2, 0.24-1.86 % TiO_2, 5.2-23.3 % Al_2O_3, 0.98-19.8 % Fe_2O_3, 0.06-3.15 % CaO, 0.01-0.16 % MnO, 0.22-3.23 % MgO, 2.55-8.20 others, fine clay, coating capacity: 62.9-237 g/m^2, oil adsorption: 33.5-40.9 g/m^3	992,975 t (C1) 112,773 t (C2) 120 t mined between 1985-1989
Erdenetsogt Erdene Tsogtyn Ovoo	Dornogovi	Altanshiree	bricky red, brown, bluish pink	3 areas, #1-pocket: silty clay, on average 135 m (100-170 m) long, 100 m wide, 4.3 m (0.6-8.0 m) thick, silty clay, #2-layer: mudstone, on average 875 m (650-1100 m) long, 275 m (150-400 m) wide, 0.9 m (0.3-1.55 m) thick, #3-body: weathered rock, on average 850 m (700-1000 m) long, 450 m wide, 10 m thick bricky red silty clay: 9.36 % Fe_2O_3, 1.22 % sol. salt, 1.7-18.7 % coarse and medium sand brown silty clay: 9.03 % Fe_2O_3, 1.27 % sol. salt, 6.31 % coarse sand and sandy loam bluish pink silty clay: 8.36 % Fe_2O_3, 1.66 % sol. salt, 5.24 % coarse sand and sandy loam mudstone: 10.3 % Fe_2O_3	# 1+2: 28,200 t (B) 32,400 t (C1) 412,600 t (C2) #3: 533,800 t (C2) Mined for several years since 1973/74 by paint factory in Ulaanbaatar (about 130-140 tpy)
Khuurai Tsahir	Umnugovi	Noyon	black, brown, ochre	24.9 % pigment grade, 75 % <0.063 mm, many large fragments	500,000 t (P)
Ulaan Del	Umnugovi	Noyon	yellow, yellowish brown, turning reddish brown upon heating	1 layer: on average 350 m long, 225 m (200-250 m) wide, and 5.7 m (2.0-9.0 m) thick, thickness of overburden 0-9.0 m, 19.08-58.8 % SiO_2, 4.5-71.8 % Fe_2O_3, 3.72-21.8 % Al_2O_3, 0.01-0.04 % MnO, 0.37-2.01 % MgO, 0.7-1.4 % CaO, 0.53-8.83 % H_2O, 78.53 % <0.063 mm, 33.5 % >0.2 mm, coating capacity: 101 g/m^2, oil adsorption: 37 g/m^3	78,300 t (B) 281,700 t (C1)
Luugariin Khudag	Ovorkhangai	Baruun Bayan-Ulaan	reddish brown	Average thickness of layered horizon 10 m, 1.4 m of overburden, 50.6 % SiO_2, 5.76 % Fe_2O_3, 14.53 % Al_2O_3, 0.11 % MnO, 0.71 % TiO_2, coating capacity: 67.9-70.3 g/m^2, oil adsorption: 26.04-62.04 g/m^3	337,500 t (C1)

Name	Aimag	Soum	Colour	Quality	Resource (content)
Guun Bariach	Govi-Altai	Khaliun	red-brown, different tinges	1 layer: 90-95 m long, 75-80 m wide, 6-25.3 m thick, overburden: 10-11 m, 4.85-12.87 % Fe_2O_3, 0.029-0.88 % MnO, 8.66-19.53 % insol., 0.02-3.92 % sol. salt, 50.2-99.6 % pigment grade, coating capacity: 66-223 g/m^2	200,400 t (C1)
Shiriin Shand	Bayankhongor	Jinst	reddish brown, turning brown upon heating	1 lens: on average 10 m thick, 62.1 % SiO_2, 7.28 % Fe_2O_3, 17.31 % Al_2O_3, 0.17 % MnO, 25.1 % >10 mm, 58 % >10 µm, contains organic matter, coating capacity: 127 g/m^2, oil adsorption: 32.3 g/m^3	178.000 t (C1)
Godiluin Bulag	Umnugovi	Khankhongor	yellow, brown	21.27-29.8 % Fe_2O_3, 0.54-1.23 % FeO, 0.01-0.12 % MnO, 0.26-3.48 % moisture, 56.54-74.54 % insol., 10-24.7 % coarse clasts	127,500 t (P) artisanal mining
Baruun Isgelen	Dundgovi	Ondorshil	green-yellow to yellow, red brown	2 areas, North: 11 % of resources: on average 260 m long, 45 m (30-60 m) wide, and 1.65 m (0.5-2.8 m) thick, overburden: 0.5-2.4 m, South: 89 % of resources: on average 340 m long, 200 m (160-240 m) wide, 1.75 m (0.6-2.9 m) thick, overburden: 0.5-1.6 m, 29.6-85 % SiO_2, 2-19.14 % Al_2O_3, 1.7-28.52 % CaO, 0.02-0.07 % MnO, 0.26-2.25 % TiO_2, 3.16-22.7 % Fe_2O_3, 0.7-8.0 % MgO, 57.1 % <10 µm, only red brown clay contains coarse clastics, coating capacity: 38.8-93.0 g/m^2, oil adsorption: 33.5-44.6 g/m^3	51,338 t (C1) 4,510 t (C2) 90 kg mined
Buyant	Bayan-Ulgii	Buyant	brownish yellow, ochre	cf. text below	37,900 t (C1) 440 t mined since 1979
Toromkhon	Bayankhongor	Bayangovi	reddish brown, turning yellow upon heating	1 layer on average 220 m long, 50 m wide, and 1-4 m thick 5.57 % Fe_2O_3, 14.22 % Al_2O_3, 0.07 % MnO, 0.84 % TiO_2, 28.0 % >10 µm	34,400 t (C1)
Khuut Bulag	Dundgovi	Govi-Ugtaal	brown, black	1 lens: 180 m long, 30 m wide, 0.2-2.8 m thick, overburden: 0.2-00.8 m, 55.02 % SiO_2, 16.05 % Al_2O_3, 1.92 % CaO, 0.1 % MnO, 1.03 % TiO_2, 8.3 % Fe_2O_3, 1.98 % MgO, 31.44 % >0.5 mm, coating capacity: 66.6-114 g/m^2, oil adsorption: 33.5-37.2 g/m^3	27,300 t (C1) 4,600 t (C2)
Shar Bugach	Bayankhongor	Buutsagaan	light yellow, turning brown upon heating	1 layer of 2 m thickness below 1 m of overburden, 42.0 % SiO_2, 9.61 % Fe_2O_3, 14.31 % Al_2O_3, 0.11 % MnO, 0.71 % TiO_2, coating capacity: 122 g/m^2, oil adsorption: 40.9 g/m^3, 58 % >10 µm	26,400 t (C2)
Alag Tolgoi	Bayan-Ulgii	Buyant	brick red	cf. text below	9,500 t (C1)
Gurvan Khairhan	Tuv	Bayan	black, black-grey	1 lens: 80-86.5 m long, 10-55 m wide, 1.5-5.0 m (avg.: 2.9 m) thick, overburden: 3.3-3.5 m, 8.1-44.0 % SiO_2, 5.0-8.0 % Fe_2O_3, 0.2-7.3 % Al_2O_3, 1.0-3.0 % MgO, 2.1-9.4 % CaO, on average 69.91 % <0.063 mm, contains coal clasts of 3-5 mm size, oil adsorption: 27 g/m^3	3,500 m^3 of ore (B1) 6,600 m^3 of ore (C1)

Unlike the Alag Tolgoi pigment deposit, the best and only extractable part of the **Buyant** pigment deposit is of yellow colour, i.e. it is an ochre pigment.

In general, the deposit is of very poor quality and is made up of mostly coarse clasts derived from partial weathering of steeply dipping intercalating strata of volcanics, conglomerates, and shales. The main component is quartz, followed by feldspar, muscovite-illite, kaolinite, and goethite as minor constituents (XRD-analysis by BGR).

Although the resource is given with 37,500 tonnes of net earth pigment (category C1) and some of the deposit was even mined after 1979, it should not be regarded as an economically mineable deposit.

Figure 16: Small quarry in partially weathered, ochre coloured rocks at Buyant pigment deposit.

Table 3: Selected chemistry of pigment ore from Alag Tolgoi and Buyant pigment deposit (XRF-analysis by BGR).

Chemistry	Alag Tolgoi	Buyant
	wt.-% / ppm	
SiO_2	64.68	60.87
TiO_2	1.00	0.75
Al_2O_3	14.92	16.31
Fe_2O_3 total	5.95	10.10
MnO	0.10	0.04
MgO	1.08	0.85
CaO	0.40	0.14
Na_2O	0.66	2.08
K_2O	1.80	2.63
P_2O_5	0.04	0.21
LOI	9.01	5.68
Sum	*99.64*	*99.64*
(As)	19 ppm	30 ppm
Co	25 ppm	20 ppm
Cr	129 ppm	201 ppm
Cu	25 ppm	14 ppm
Ni	61 ppm	127 ppm
Pb	15 ppm	<3 ppm
Th	14 ppm	16 ppm
U	<3 ppm	6 ppm
V	104 ppm	129 ppm
Zn	37 ppm	65 ppm

Table 2: Grain size analysis of pigment ore from Alag Tolgoi and Buyant pigment deposit. Analysis (data in µm) by sieving and sedigraph at BGR.

	<2	2-6.3	6.3-20	20-63	63-112	112-200	200-355	355-630	630-1120	1120-2000
Alag Tolgoi	11.8	10.2	19.4	16.6	8.9	7.3	5.8	4.8	5.6	9.6
Buyant	42.9	15.1	8.1	5.4	5.1	5.0	4.0	3.3	4.3	6.8

REQUIREMENTS AND EVALUATION

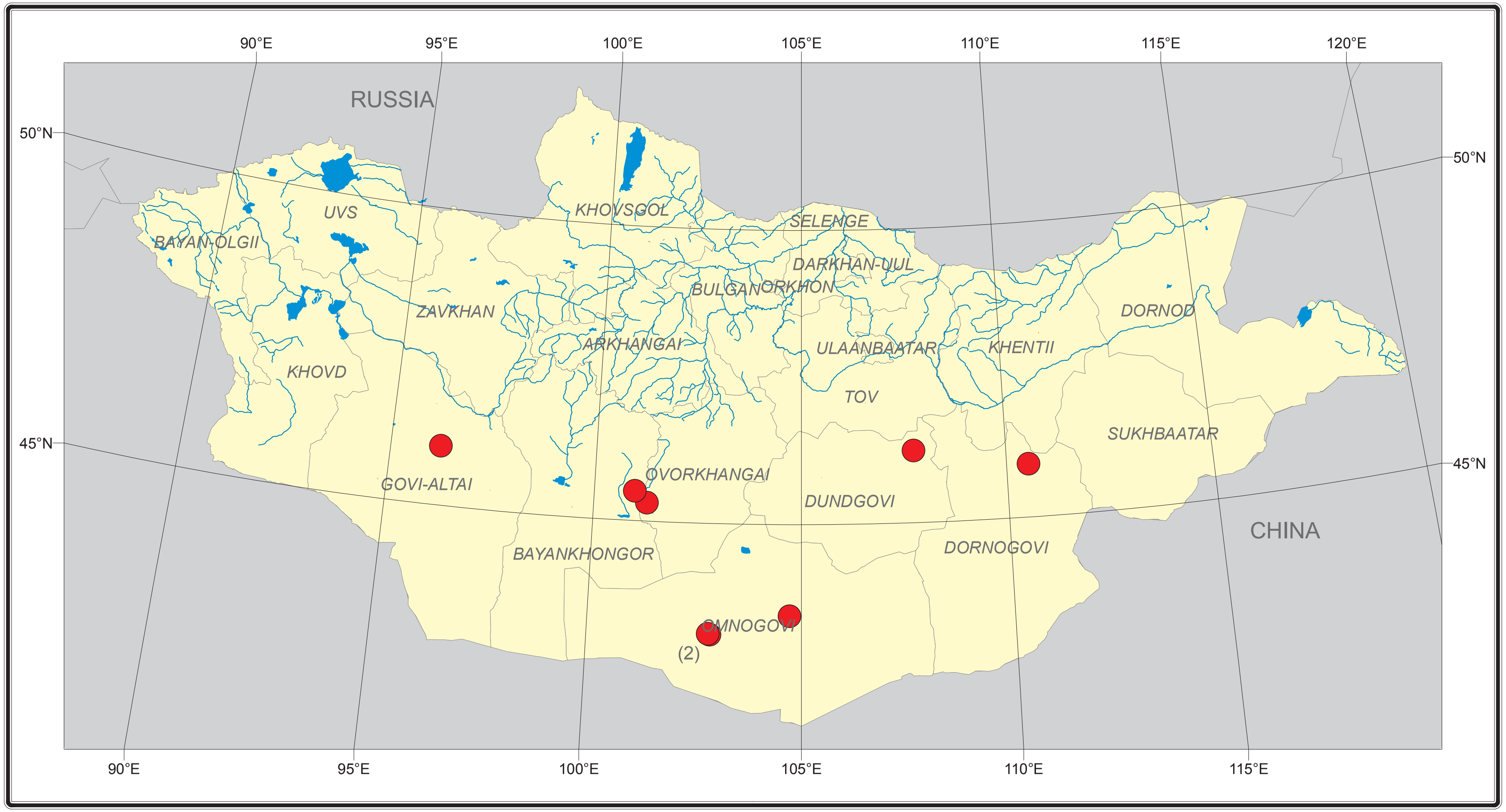
The value of an earth pigment depends on the brightness and intensity of its colour, on its texture, on its staining qualities, on its iron oxide content and on the relative proportion of oil which must be mixed with it to obtain the proper degree of fluidity for use as a pigment. The amount of soluble salts, MnO_2 and heavy metals, is strongly limited. For successful marketing it is necessary for producers to build up reputations for uniformity and high grade products.
Regarding tonnage, economically mineable small deposits normally contain 50,000-100,000 tonnes, and medium size ones up to 1 million tonnes of earth pigment content.

Regarding the earth pigment deposits of Mongolia, seven out of 15 deposits do not have to be looked at in more detail for international marketing because their resources are <50,000 tonnes. Concentrating on the remaining eight, it must be absolutely clear to potential investors, that while their resources may be sufficient, not enough is known about their quality, especially unwanted heavy metal impurities. Therefore, each deposit of interest needs to be resampled with the samples analysed for all parameters needed for definite evaluation.

RELEVANT LITERATURE

Tsogt, O. & Dorzhuren, S. (1984): Report on the results of the prospecting and first exploration works on pigment deposits in Bayankhongor and Dundgovi Aimags in 1981-1983 (in Russian): 68 pp. 10 tab.; Ulaanbaatar.

Deposits of Earth Pigments in Mongolia



BGR © Federal Institute of Geosciences and Natural Ressources

Legend

● Earth Pigments

FLUORITE

GENERAL INFORMATION AND USES

Fluorite (or fluorspar), with the chemical formula CaF_2, is the most common and important fluorine mineral. It is used in the steel, chemical, aluminium, glass, ceramics, and optical industries. According to these main applications, metallurgical-grade fluorite, acid-grade fluorite, ceramic-grade fluorite, and optical-grade fluorite can and should be differentiated.

RELEVANT DEPOSITS IN MONGOLIA

Mongolia is one of the leading producers of fluorite in the world, with abundant literature on all aspects of fluorite ores in Mongolia.

Fluorite mining in Mongolia started in 1946. During the first decades, only high-grade fluorite ore was mined and exported after hand-sorting. In 1986, mineral processing of low-grade fluorite ores, i.e. production of fluorspar-concentrates, started at Bor Ondor by MONGOLSOVTSVETMET, renamed MONGOLROSTSVETMET in 1991/92 - a Mongolian-Russian joint venture. Today fluorite ore processed at the Bor Ondor plant averages 30 % CaF_2 with an applied cut-off grade of 26-28 % CaF_2 (oral comm., 2008). Both "metallurgical-grade" (>75 % CaF_2) and "flotation-grade" = "acid-grade" (> 97 % CaF_2) fluorspar concentrates are being produced and exported by train mainly to Russia, USA, Ukraine and other CIS-states.

Figure 17: Hand-sorting of fluorite ore in the Bor Ondor plant.

In 2008, another major fluorspar processing plant (45° 55' 48.8" N, 109° 05' 16.8" E) near Dalanjargalan village was opened by a Chinese-USA (KEVIN INVEST LLC) joint venture. It focuses on buying fluorite ore from ninjas and from the recently discovered Burkhant fluorite deposit (cf. below).

Figure 18: New fluorspar processing plant at Dalanjargalan village established in 2008 with numerous bags of fluorspar concentrate ready for shipping as of September 2010.

However, more recently, not the geological abundance of fluorite in Mongolia in general but the economic viability of known occurrences and deposits has been questioned, even by leading producer MONGOLROSTSVETMET LLC (oral comm., 2008). In addition to the quality, especially the tonnage of remaining resources and thus the economic mineability of known deposits is currently being reievaluated. Additionally exploration to increase mineable reserves has picked up.

In this brochure, the interested investor in fluorspar will therefore neither find detailed information on the geology of fluorspar mineralisation in Mongolia nor a complete list and survey of known occurrences. According to Lkhamsuren & Hamasaki (1998) there are more than 600 fluorite deposits in Mongolia. Geological Information Center (2003) lists 66 fluorspar deposits and 132 fluorspar occurrences in Mongolia. Dejidmaa et al. (2001) give names of 56 fluorite deposits and 283 fluorite occurrences). In contrast, a general evaluation of economically mineable fluorite deposits in different parts of the country will be given by applying basic tonnage and grade requirements (cf. below).

Most of the fluorite deposits in Mongolia are of hydrothermal or epithermal origin. Although they occur in a huge variety of host rocks of all ages, nearly all of the fluorite has radiometric ages between 131 and 116 Ma. Based on the major minerals there are five mineral assemblage types of epithermal fluorite deposits in Mongolia:

- quartz-fluorite,
- calcite-quartz-fluorite,
- barite-quartz-fluorite,
- aduralia (orthoclase)-quartz-fluorite,
- sulphide-quartz-fluorite (sulphides: e.g. pyrite, pyrrhotite, galena, sphalerite)

The quartz-fluorite type is the most dominant. Quartz commonly occurs as chalcedony-like, fine grained or columnar crystals. Fluorite is frequently coarse grained, massive, columnar, rarely fine grained and microcrystalline or even cryptocrystalline. Fluorite occurs in various colours, e.g. violet, dark violet, green, yellow, and bluish-green. Sometimes it is pale or colourless.

The epithermal fluorite deposits occur as veins, irregular and lens-shaped, and in brecciated and disseminated shear zones. The veins are 1 to 30 m thick and 30 to 1,300 m long (along strike), exceptionally 3,000 m long in the Bor Ondor deposit. On the other hand, 60-70 m thick veins were observed in the Khongor and Bujgar deposits.

Carbonatite hosted fluorite deposits, all of them non-economic, were discovered in southern Mongolia, with Mushgai Khudag (cf. Rare Earths) being the representative deposit. Fluorite occurs in veins, dikes, and in disseminated form. There are just two mineral assemblage types:

- fluorite-apatite-magnetite-quartz,
- fluorite-calcite or celestite-quartz with feldspar, barite, dolomite, ankerite, bastnaesite or phlogopite as minor minerals.

Most fluorite deposits belong to the Eastern Mongolian fluorite belt with its subdivisions called zones, areas, knots, centres, fields and districts – depending on the author in charge. In this brochure just the district and centre subdivisons are used, with the main districts being:

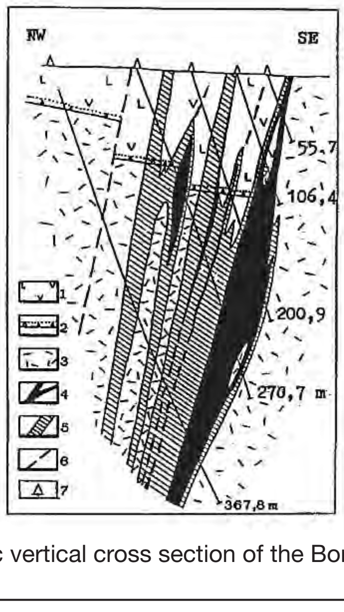


Fig. 4 Schematic vertical cross section of Bor-Öndör deposit (Koshelev, 1985). 1-2: Upper Jurassic to lower Cretaceous rock (1: Basalt and andesite, 2: Basal breccia), 3: Lower Permian quartz porphyry and tuff, 4: Quartz-fluorite vein, 5: Argillized zone, 6: Fault, 7: Bore hole.

Figure 19: Schematic vertical cross section of the Bor Ondor fluorite deposit, from Lkhamsuren & Hamasaki (1998).

Bor Ondor fluorite district:

The Bor Ondor fluorite district is the most famous and most central fluorite district in Mongolia. It is dominated by the fluorite mines and processing plant of MONGOLROSTSVETMET LLC (cf. Figure 20). In total, this district, which grades south-westward into the Khar Airag fluorite district, consists of 16 deposits, most of them in production or even mined out, and numerous occurrences.

- The huge Bor Ondor-I and Bor Ondor-II fluorite deposits were discovered as early as 1956. Mining, both open pit and underground, started up in 1982 by MONGOLSOVTSVETMET, the predecessor of MONGOLROSTSVETMET LLC. As of 2009, the remaining reserves and resources given by MONGOLROSTSVETMET LLC are 9,131,720 tonnes of ore grading 35.39 % CaF2 on average, i.e. containing 3,231,980 tonnes of CaF_2.

The **Bor Ondor-I** fluorite deposit is built up of four steeply dipping veins with main average parameters as follows: #1: 260 m length, 1.46 m thickness, 41.65 % CaF_2, #2: 135 m length, 2.04 m thickness, 34.65 % CaF_2, #3: 245 m length, 2.06 m thickness, 55.37 % CaF_2, # 4: 200 m length, 1.40 m thickness, 64.09 % CaF_2. On average the ore grades 42.51 % CaF_2. Initial estimated resources were 1,215,100 tonnes of ore grading 53.18 % CaF_2.

The **Bor Ondor-II** fluorite deposit contains about 20 steeply dipping veins of which ten (# 1, 1a, 2, 3, 4, 5, 6, 6a, 11, and 13) are of

Figure 20: High definition satellite image of Bor Ondor open pit, mine, and town. Bor Ondor is the centre of the fluorite mining and processing industry of Mongolia (Satellite image as of 21 October 2007, Altitude 4.27 km, Photo courtesy of GOOGLE EARTH).

economic importance. Individual lengths vary between 90 and 1,155 m, and individual average thicknesses vary between 2.14 and 9.07 m. Grades of CaF_2 are very homogenous varying from 39.68-41.72 % as averages. As of 1983, confirmed reserves were 10,485,700 tonnes of ore grading 43.99 % CaF_2 in category B, and 36.81 % CaF_2 in category C1 resources, i.e. 4,014,700 tonnes of CaF_2, and 1,441,300 tonnes of ore grading 37.01 % CaF_2 in category C_2, i.e. 527,400 tonnes of CaF_2.

- The also very important **Adag** fluorite deposit which lies some 10 km north-west of the Bor Ondor mine has been mined since 1988 by Mongolrostsvetmet LLC, first in a large open pit (90 m deep) and now in an underground mining operation. This deposit consists of three veins or vein systems, of which #1 and #2 are of economic importance. Vein system #1 is steeply dipping, has a total length of up to 3,640 m and an average length of individual apophyses of 2,800 m. While only small and low-grade between 100 and 240 m depth, the thickness of the individual veins varies between 0.33 and 31.01 m, with 4.37 m on average. Vein #2 also dips steeply, is 1,300 m long on average, and 1.1-8.1 m thick, on average 2.39 m thick. The average CaF_2 grade is 34.61 % in vein #1 and 38.89 % in vein #2. Using cut-off grades of 15 % CaF_2 in general, and of 24 % CaF_2 in blocks of interest, the initial calculated reserves amount to 895,000 tonnes of ore in category B, and 3,511,300 tonnes of ore in category C1, both grading 36.02 % CaF_2. Additional category C2 resources are 270,800 tonnes of ore grading 29.90 % CaF_2. 70 % of the resources of the Adag fluorite deposit are bound to vein system #1. As of 2009, the remaining reserves and resources given by Mongolrostsvetmet LLC are 1,712,780 tonnes of ore grading 43.28 % CaF_2 on average, i.e. containing 741,230 tonnes of CaF_2.

- **Dai Uul** is the name of another very big and important fluorite deposit about 25 km south-east of the Bor Ondor mine. The deposit consists of five major veins or vein systems with major parameters given in Table 4. While vein #3 is located in the central part of the deposit, vein #2 lies just 20 m north of vein #1. The composition of the ore was analysed as 24.40-56.07 % CaF_2, 39.79-63.14 % SiO_2, 0.76-2.73 % $CaCO_3$, 0.03-0.26 % P_2O_5, 0.01-3.23 % $BaSO_4$. The spectro-analytical results are 0.06 % Zn, 0.05 % W, 0.3 % As, 0.4 % Ba, and 0.02 % V. Total resources estimated down to 220 m depth are 4,641,000 tonnes of ore grading 31.95 % CaF_2.

More recent and detailed information on the Dai Uul fluorite deposit is given by Dorling (2010a). He also states analytical data from

Table 4: Main parameters of the Dai Uul fluorite deposit, taken from deposit passports.

Vein #	Average length (m)	Thickness (m)	Average CaF_2 grade
1	1,080	0.5-14.0, avg.: 6.70	31.30 %
1a	360	1.0-5.5, avg.: 1.70	30.91 %
1b	600	avg.: 1.68	29.74 %
2	640	0.3-14.5, avg.: 2.53	37.27 %
3	260	2.0-7.0, avg.: 3.33	34.64 %

Figure 21: Former Adag open pit as of May 2008. Ventilation adit of the more recent underground mine in the middle of the photo.

Figure 22: Typical mineralised drill core showing fluorite veining from the Dai Uul fluorite deposit. Photo courtesy of Lotus Resources Plc.

Figure 23: Pilot mining of fluorspar at the Dai Uul fluorite deposit. Under an exploration licence, miners extract high-grade vein type mineralisation using compressor driven jack hammers, buckets, and winches (Dorling 2010a).

Figure 24: High definition satellite image of the Zuun Tsagaan Del fluorite open pit (Satellite image as of 22 October 2007, Altitude 2.93 km, Photo courtesy of Google Earth).

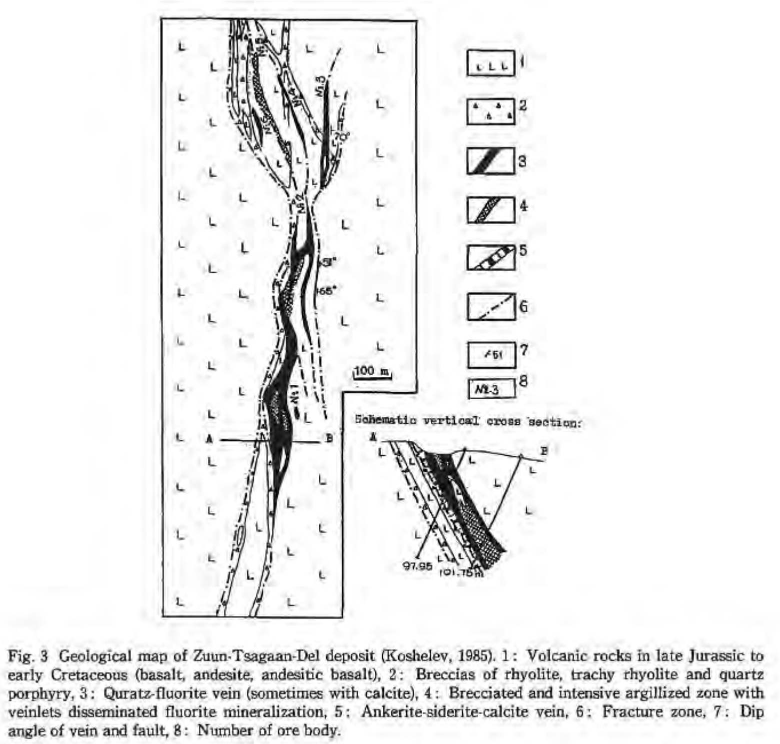


Figure 24: Geological sketch map of the Zuun Tsagaan Del fluorite deposit, from Lkhamsuren & Hamasaki (1998).

four samples taken from high-grade veins: 60.28-92.16 % CaF_2, 3.77-32.97 % SiO_2, 0.67-1.71 % $CaCO_3$, <5 ppm As, 349->2,000 ppm Ba, <1-2 ppm Cu, 0.06-0.65 % Fe, 31-643 ppm P, <2 ppm Pb, 0.07-0.14 % S, and <1-19 ppm Zn. Currently the northern part of the Dai Uul deposit is being explored in more detail and is being prepared to be mined in a shallow open pit.

- **Zuun Tsagaan Del** is another very big fluorite deposit in the centre of the Bor Ondor fluorite district. Within the deposit there are seven ore bodies of which three are lens-like and of economic importance (cf. Table 5). The typical composition of the ore is given as 30.19-35.77 % CaF_2, on average 40.26 % SiO_2, 0.72-3.83 % $CaCO_3$, 0.01-0.04 % P_2O_5, and 0.64-4.19 %, on average 2.94 % Fe. Using a cut-off grade of 15 % CaF_2, the calculated initial category B reserves are

Table 5: Main parameters of the Zuun Tsagaan Del fluorite deposit, taken from deposit passports and Koselev (1985).

Ore body #	Average length (m)	Maximum depth (m)	Thickness (m)	Composition
I	650	400	0.79-57.89 avg.: 26.89	18-61 % CaF_2, 0.59-37.60 % $CaCO_3$, 29-51 % SiO_2, 0.1-5.0 % $BaSO_4$, 0.01-2.13 % S
V	230	50	0.65-12.51 avg.: 5.28	20-45 % CaF_2, 1.28-2.68 % $CaCO_3$, 31-53 % SiO_2, 0.02-0.40 % $BaSO_4$, 0.02-0.03 % S
VII	380	260	0.65-25.58 avg.: 4.49	15-65 % CaF_2, 0.99-4.81 % $CaCO_3$, 26-51 % SiO_2, 0.20-2.14 % $BaSO_4$, 0.02-0.78 % S

1,575,300 tonnes of ore and initial category C1 reserves of 5,271,200 tonnes of ore grading 32.18 % CaF_2 on average. Additionally there were category C2 resources of 550,700 tonnes of ore grading 35.77 % CaF_2.

Mining commenced in 1978 by MONGOLSOVTSVETMET in an open pit and was stopped in 1990 when a depth of 110-115 m was reached (cf. Figure 24). As of the beginning of 1989, the remaining reserves/resources amounted to 4.5 million tonnes of ore, and as of 1995, 3.4 million tonnes of ore with about 1.1 million tonnes of CaF_2 (ALGAA 1995).

- At the **Khajuu Ulaan** fluorite deposit there are seven different ore bodies, i.e. steeply dipping veins with major parameters given in Table 6. Initial total resources calculated down to 150 m depth are 579,700 tonnes of ore grading 57.71 % CaF_2 in category C1, and 353,400 tonnes of ore grading 49.19 % CaF_2 in category C2. Surface-near parts of this deposit were mined by MONGOLROSTSVETMET in an open pit operation during the 1990s. Most probably the remaining resources – of unknown tonnage – are too small to justify an underground mining operation.

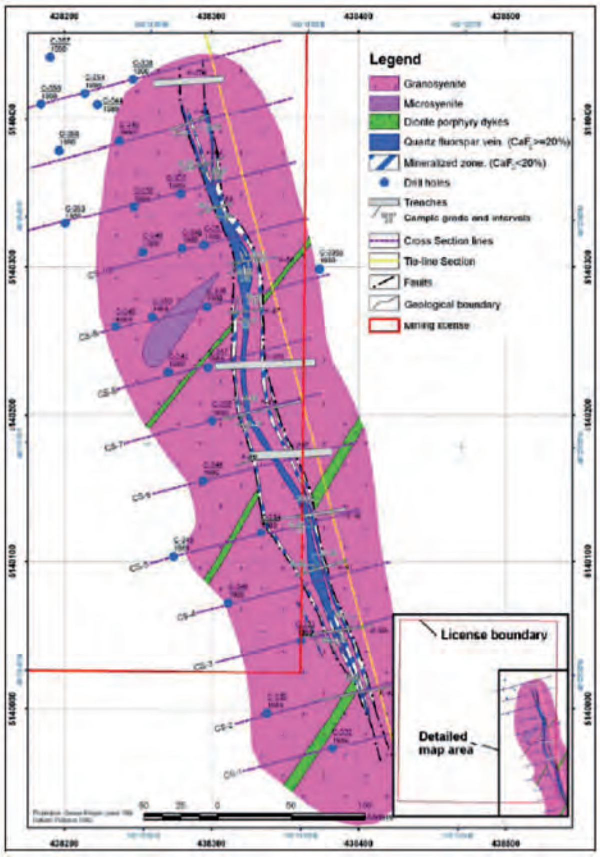


Figure 26: Geological map of the Tsagaan Chuluut fluorite deposit, from DORLING (2010 b).

- **Khamar Us** is another important fluorite deposit which was mined by MONGOLROSTSVETMET in the years after 1977. This deposit consists of five ore bodies/vein systems with a very complicated internal structure.

Table 6: Main parameters of the Khajuu Ulaan fluorite deposit, taken from deposit passports and KOSELEV (1985).

Area	Ore body #	Average length (m)	Thickness (m)	Composition
North	1	430	0.78-8.00 avg.: 3.89	58.13 % CaF_2, 32.2 % SiO_2
South	2	300	0.62-6.33 avg.: 2.99	41.99-68.35 % CaF_2, avg.: 55.57 % CaF_2
North	3	460	0.69-6.21 avg.: 3.38	avg.: 40.44 % CaF_2
North	4	310	1.80-3.92 avg.: 2.24	avg.: 43.6 % CaF_2
South	5	225	1.20-4.68 avg.: 1.53	45.8-69.66 % CaF_2
South	6	55	0.64-2.91 avg.: 1.77	56.81-75.98 % CaF_2
West	7	235	0.77-4.07 avg.: 2.56	25.58-87.34 % CaF_2 avg.: 45.42 % CaF_2

The main parameters of the ore bodies are shown in Table 7. Noteworthy average barite content is 0.33 %. Initial calculated resources applying a cut-off grade of 25 % CaF_2 were 1,589,200 tonnes of ore in category C2. Although no information on any remaining resources is available, this deposit is most probably mined out.

Table 7: Main parameters of the Khamar Us fluorite deposit, taken from deposit passports.

Ore body #	Length (m)	Thickness (m)	Average CaF_2 grade	Share of resources [1)]
I	avg.: 280	2.52-44.82, avg.: 17.15	35.63 %	24.0 %
II	avg.: 130	1.27-30.97, avg.: 7.43	38.31 %	35.1 %
III	avg.: 146	0.71-3.36, avg.: 1.05	43.38 %	4.9 %
IV	80-250	1.18-12.57, avg.: 4.21	39.31 %	13.8 %
V	45-251	0.36-8.20, avg.: 4.81		17.0 %

[1)] Original data do not add up to 100 %

- Very close to the Khamar Us open pit is the **Tsagaan Chuluut** fluorite deposit. The Tsagaan Chuluut mineralised system consists of two en-echelon mineralised zones (Zone #1 and #2), of which Zone #2 falls within the Tsagaan Chuluut deposit and Zone #1 within the nearby Baruun Barga Ovoo deposit/occurrence some 1.8 km to the south (cf. below). The width of Zone #2 is 0.1-6 m while the strike length is about 410 m. Category C2 resources estimated down to 90 m depth are 167,400 tonnes of ore grading 30.5-55.2 %, on average 45.79 % CaF_2. This resource is divided into an upper zone (block #1) ranging from surface to 50 m depth grading 40.68 % CaF_2 on average, and a lower zone (block #2) grading 55.22 % CaF_2 on average (Dorling 2010 b).

Figure 27: Small exploration and mining pits at Tsagaan Chuluut. Photo courtesy of Lotus Resources Plc.

- **Baruun Barga Ovoo** is a very small and low-grade fluorite deposit with steeply dipping fluorite veins up to 500 m long and 10 m thick. The average composition of the ore is 22.29 % CaF_2, 55.66 % SiO_2, 3.10 % $CaCO_3$, 0.05 % P_2O_5, and 0.23 % $BaSO_4$. The estimated reserves/resources are 90,000 tonnes of ore in category B, and 107,000 tonnes of ore in category P1. Because the grade is well below currently accepted cut-off grades (cf. above), this deposit should be downgraded to an occurrence only.

- **Tsagaan Elgen** is the westernmost fluorite deposit in the Bor Ondor district and has also been mined – at least partially – by Mongolsovtsvetmet. Within the deposit there are four ore bodies, i.e. steeply dipping vein systems of very different sizes (cf. Table 8). Ore body #2 is 150-200 m west of ore body #1, while the southern ore body constitutes a southern apophysis of ore body #2. IThe initial reserves were calculated as 205,200 tonnes of ore in category B, and 1,360,600 tonnes of ore in category C1, both grading 38.7 % CaF_2 on average. Resources in category C2 were 81,500 tonnes of ore grading 21.1 % CaF_2 - which is below the currently accepted cut-off grade (cf. above). Addi-

Table 8: Main parameters of the Tsagaan Elgen fluorite deposit, taken from deposit passports in Mongolian language and Koselev (1985).

Ore body #	Average Length (m)	Thickness (m)	Share of resources
1	2,000	0.62-6.01, avg.: 1.67	30.5 %
2	1,400	0.77-3.0, avg.: 1.84	12.0 %
3	1,700	0.48-6.63, avg.: 1.57	51.5 %
4 (South)	300	0.30-4.30, avg.: 1.67	6.0 %

tionally, there are even more low-grade and non-economically mineable ores of 350,400 tonnes in category C1, and 162,000 tonnes in category C2. [Attn.: In the English language deposit passport the deposit parameters are the same, the category C1 reserves are given as 606,500 tonnes of ore grading 56.04 % CaF_2 and the category C2 resources as 221,600 tonnes of ore grading 51.59 % CaF_2. Non-economically mineable resources are said to be 92,500 tonnes of ore. Similarly for ore body #1, Koselev (1985) mentions a grade of about 60 % CaF_2].

- The Saikhan Gashuun fluorite deposit is 20 km south-west of the Bor Ondor plant with a

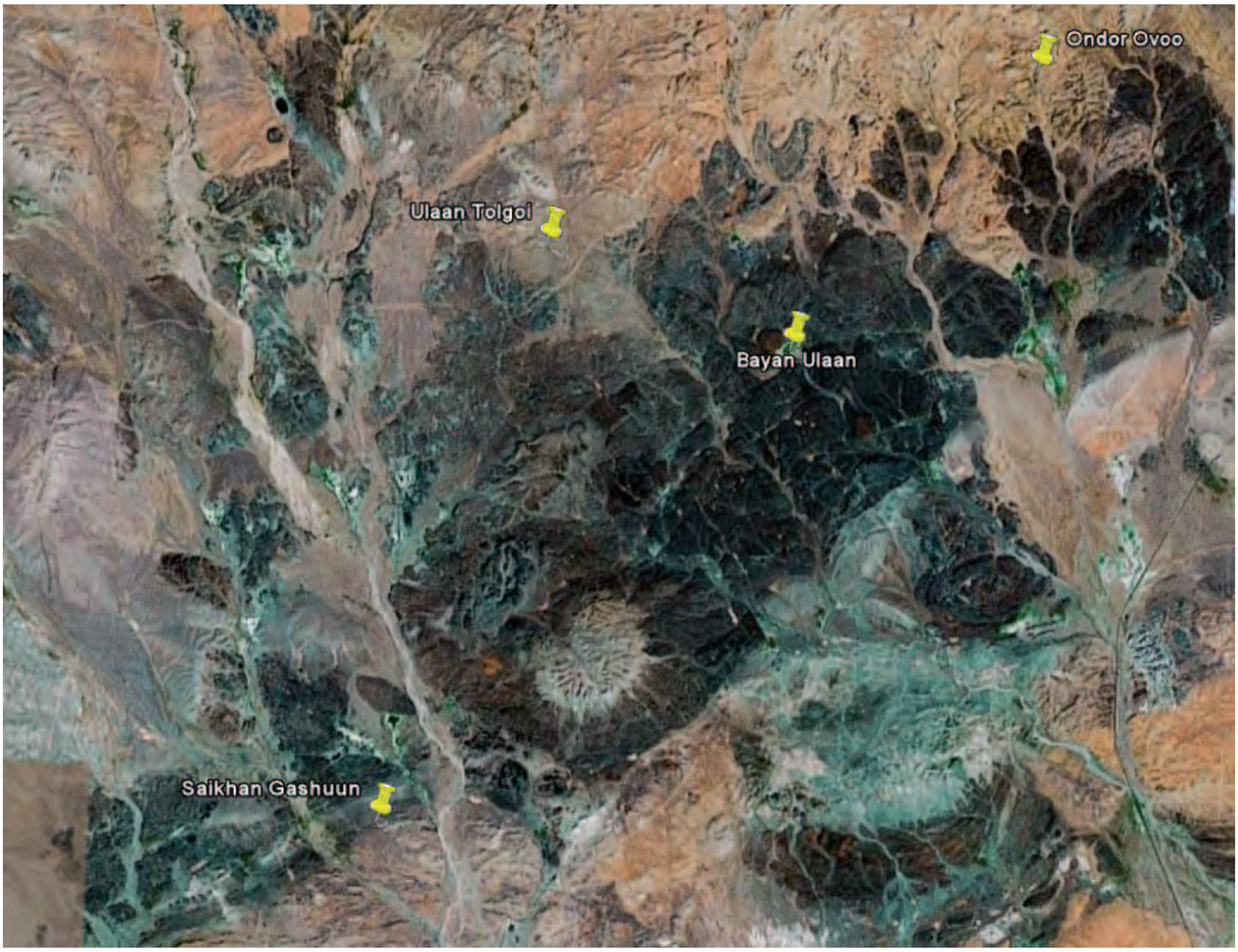


Figure 28: Satellite image of the western Bor Ondor fluorite district showing important fluorite deposits (Photo courtesy of Google Earth).

Figure 29: High definition satellite image of the former Khar Airag fluorspar open pit (Satellite image as of 8 October 2007, Altitude 1.04 km, Photo courtesy of GOOGLE EARTH).

mining licence also held by MONGOLROSTSVETMET LLC. It consists of one shallow dipping vein of 880 m length proven down to 140 m depth. The thickness of the vein varies from 0.50-4.74 m, with 1.99 m on average. The grade of CaF_2 varies from 30-75 %, with 48.16 % calculated on average. Using cut-off grades of 15 % CaF_2 in general and 27 % CaF_2 in blocks of interest, the calculated resources down to 140 m depth are 85,300 tonnes of ore grading 50.77 % CaF_2 in category C1 and 424,600 tonnes of ore grading 43.47 % CaF_2 in category C2. Between 1972 and 1973, some 7,400 tonnes of ore grading 69.4 % CaF_2 were produced by the Ministry of Defence with some further 23,000 m^3 of ore placed in five dumps.

- **Bayan Ulaan** is located about 3 km southwest of the Bor Ondor-I mine. Of the two veins in place, only vein #1 is of economic importance. It dips steeply and is tectonically fragmented into three segments of 300 m, 500 m, and 700 m individual lengths. The thickness of the segments varies between 0.37 and 10.15 m, with 2.53 m on average. The composition of the ore varies from 5.27-50.5 %, on average 37.07 % CaF_2, 37.28-83.19 %, on average 53.26 % SiO_2, 0.55-1.68 %, on average 0.82 % $CaCO_3$, 0.02-0.12 %, on average 0.06 % P_2O_5, and on average 0.01 % S, and 0.01 % $BaSO_4$. Using cut-off grades of 15 % CaF_2 in general and 27 % CaF_2 in blocks of interest, category C1 reserves are 533,900 tonnes of ore grading 31.6 % CaF_2, i.e. 168,600 tonnes CaF_2, and category C2 resources are 666,600 tonnes of ore grading 30.69 % CaF_2, i.e. 204,700 tonnes CaF_2. Additionally, there are non-economically mineable resources in category C2 of 319,500 tonnes of ore grading 23 % CaF_2 only, i.e. containing 73,500 tonnes of CaF_2. Mining these limited reserves/resources will only be possible underground, which means that Bayan Ulaan most probably cannot be mined economically.

- The **Ondor Ovoo** fluorite deposit was discovered 5 km west of the Bor Ondor plant. In this area there are several fluorite vein systems of which only #33 and #33a are considered to be of economic interest. Both vein systems are in the south-west corner of the mineralised area with #33a 50 m away from #33. Ore body #33 is 400-900 m long, on average 700 m, and 2.1 m thick, while #33a is 200 m long and 1.78 m thick on average. The composition of the ore was analysed as 10.06-63.57 %, on average 33.72 % CaF_2, 31.36-81.84 %, on average 56.12 % SiO_2, 0.71-1.49 %, on average 0.88 % $CaCO_3$, 0.03-0.17 %, on average 0.06 % P_2O_5, and on average 0.30 % S, and 0.01 %, as maximum 0.07 % $BaSO_4$. Taking into account a cut-off grade of 15 % CaF_2 and an explored depth of 310 m, category C1 reserves are 258,300 tonnes of ore grading 36.39 % CaF_2, i.e. 94,000 tonnes CaF_2, while category C2 resources are 518,700 tonnes of ore grading 22.97 % CaF_2, i.e. 119,100 tonnes CaF_2. Analogous to the Bayan Ulaan deposit, mining the Ondor Ovoo fluorite deposit will only be possible underground, which means that the Ondor Ovoo deposit also cannot be mined economically.

- The **Bor Khujir** fluorite deposit is 40 km north-west of the Bor Ondor mine. There is just one vein of 660 m length and 25-28 m thickness, on average 26.5 m. The grade of CaF_2 varies from 25.8-36.1 %, while average grades are 34.9 % CaF_2, 0.46 % $CaCO_3$, and 0.15 % S. Using cut-off grades of 15 % CaF_2 in general, and 27 % CaF_2 in blocks of interest, mineable category C1 reserves down to 170 m depth were calculated as 1,126,000 tonnes of ore grading 38.74 % CaF_2. Non-mineable resources in category C2 are 94,400 tonnes of ore grading 43.37 % CaF_2. Judging by satellite imagery from Google Earth, this deposit was or is being quarried in a large open pit operation.

- The **Tsagaan Ondor** fluorite deposit lies 25 km north-east of the Bor Ondor mine with two ore bodies in place. Ore body #1 is a vein in the middle of the deposit area with an average length of 530 m and a width of 0.66-28.88 m, on average 6.86 m. The average grade of CaF_2 is given as 29.45 %. Ore body #2 is also a vein in the western part of the deposit. It is smaller, having an average length of 200 m and a width of 2-3 m. The average grade of CaF_2 is 30.4 %. In general, the composition of the ore varies from 18.12-47.55 % CaF_2, 43.1-61.85 % SiO_2, 0.81-1.05 % $CaCO_3$, and 0.06-0.16 % P_2O_5. Calculating with cut-off grades of 15 % CaF_2 in general, and 27 % CaF_2 in blocks of interest, resources amount to 542,500 tonnes of ore grading 31.18 % CaF_2 down to 120 m depth in category C1 and to 1,095,200 tonnes of ore grading 28.72 % CaF_2 down to 230 m depth in category C2. Additionally, there are 161,700 tonnes of non-economically mineable ore. At the end of 2003, ore body #1 was assessed by MRAM to be ready for mining in an underground mine. However, because the reserves/resources of CaF_2 are limited, mining the Tsagaan Ondor fluorite deposit has to be regarded as marginally economic, and at low fluorite prices may not be economic at all.

- **Gal Shar** is the northernmost deposit in the Bor Ondor fluorite district. The deposit consists of four steeply dipping quartz-fluorite veins with parameters as follows: #1: average length 520 m, depth in the east 30-40 m, depth in the west 85-95 m, thickness 0.39-5.05 m, #2: average length 230 m, depth up to 70 m, thickness 0.40-6.62 m, #3: average length 250 m, depth up to 70 m, thickness 1.00-4.57 m, on average 2.35 m, #4: average length 200 m, not explored to depth, thickness 0.44-1.48 m, on average 1.00 m. The ore grades 57.9-81.3 % CaF_2, 9.27-20.51 % SiO_2, and 0.35-19.68 % $BaSO_4$, which means that barite (together with pyrite and galena) is a common (and unwanted) component. Mn, Pb, and Cu also occur in low concentrations. Taking into account minimum grades of 20 % CaF_2 in general, and 40 % CaF_2 in blocks of interest, the originally calculated reserves/resources down to 80 m depth amount to 132,900 tonnes of ore in category B, and 185,300 tonnes of ore in category C1 category C1, grading 60.78 % CaF_2 on average. Additionally, there are category C2 resources of 14,800 tonnes of ore grading 51.50 % CaF_2 on average. Between 1963 and 1973, some 145,800 tonnes of ore with some 88,600 tonnes of net CaF_2 were quarried in an open pit with a depth of about 30-40 m. Thus, the remaining resources amount to 187,200 tonnes of ore, which can only be mined underground – which cannot be done economically.

- Little is known about the patchily prospected **Ulaan Tolgoi** fluorite deposit. It consists of one mineralised vein of 1,700 m length and 0.5-1.58 m thickness. Estimated resources in category C2 are 224,400 tonnes of ore grading 39.13 % CaF_2 on average.

- **Omno Baga Chuluu** is another small fluorite deposit suitable for small-scale mining only. There is one steeply dipping main vein (Undsen) of 2,250 m average length, only 0.3-0.4 m thickness, and highly variable ore composition of 1.87-92.1 %, on average 49.95 % CaF_2, 5.89-92.80 % SiO_2, and 0.27-5.46 % $CaCO_3$. 600 m to the south there is a southern vein (Omnod), and very close to the main vein a northern vein (Khoid) with two fragments of 500 m average length each. The thickness of the two fragments of the northern vein varies between 0.2 and 1.8 m, with the composition of the ore varying from 2.18-93.65 %, on average 56.74 % CaF_2, 3.26-88.10 % SiO_2, and 0.18-10.34 % $CaCO_3$. The total initial resources of the main and the northern veins down to 40-50 m depth and using cut-off grades of 20 % CaF_2 in general, and 40 % CaF_2 in blocks of interest, are 88,200 tonnes of ore grading 72.67 % CaF_2 on average in category C1, and 80,800 tonnes of ore grading 71.53 % CaF_2 in category C2. Additionally, there were resources of low-grade ore of 22,300 tonnes. Most of the original resources of the more high-grade ore will have been mined by now by small-scale miners (“ninjas”).

Khar Airag fluorite district:
The well-known Khar Airag (also called Middle Govi) fluorite district lies in Bayanjargalan Soum of Dundgovi Aimag and neighbouring Dalanjargalan and Airag Soums of Dornogovi Aimag, and consists of 20 fluorite deposits and numerous occurrences. This district is not clearly defined and runs south-westwards into the Bor Ondor fluorite district.

- The **Khar Airag** fluorite deposit was a former small but high-grade fluorite deposit which was mined out before 1990. It consisted of two major ore bodies of 115 and 195 m average length, and 7.2 and 4.3 m average thickness. The average composition of the ore was 70.4 % CaF_2, 29.38 % SiO_2, 1.47 % $CaCO_3$, and 1.08 % Fe.

- The **Bor Tolgoi** (Omnod Khar Airag) fluorite deposit also consists of two ore bodies. In the south there is a lens of 265 m average length, and 3.0-12.67 m thickness, on average 7.22 m. With increasing depth, the thickness decreases considerably. Although the CaF_2-grade at the surface is 51.7 %, it also decreases down to 26.1 % at 80 m depth. However, the average grade during mining was estimated to be 44 % CaF_2. About 140 m to the north, there is another lens, which is much smaller (100 m average length, 0.95 m average thickness) and low-grade (23-33 % CaF_2), and therefore of no economic interest. The southern lens was mined by state organisations in an open pit between 1954 and 1980 with a total production of 147,600 tonnes of ore containing some 73,900 tonnes of CaF_2 until the end of 1990. Old dumps contain some 7,700 tonnes of low-grade ore.

- The **Khairt** fluorite deposit consists of two areas: western: with ore bodies/lenses #1-4, and eastern: 300 m away, with ore bodies/lenses #5 and #6. In the western area, the lenses are 85-310 m long, and 2.6-19 m thick. In the eastern area, the lenses are 95 m and 100 m long, and 12 m and 1.2 m thick respectively. The grade of CaF_2 is highly variable from 20-80 % with 52.1 % on average. Between 1979 and 1982, the deposit was mined in an open pit until mining had to be stopped due to water influx. After installation of pumps, mining con-

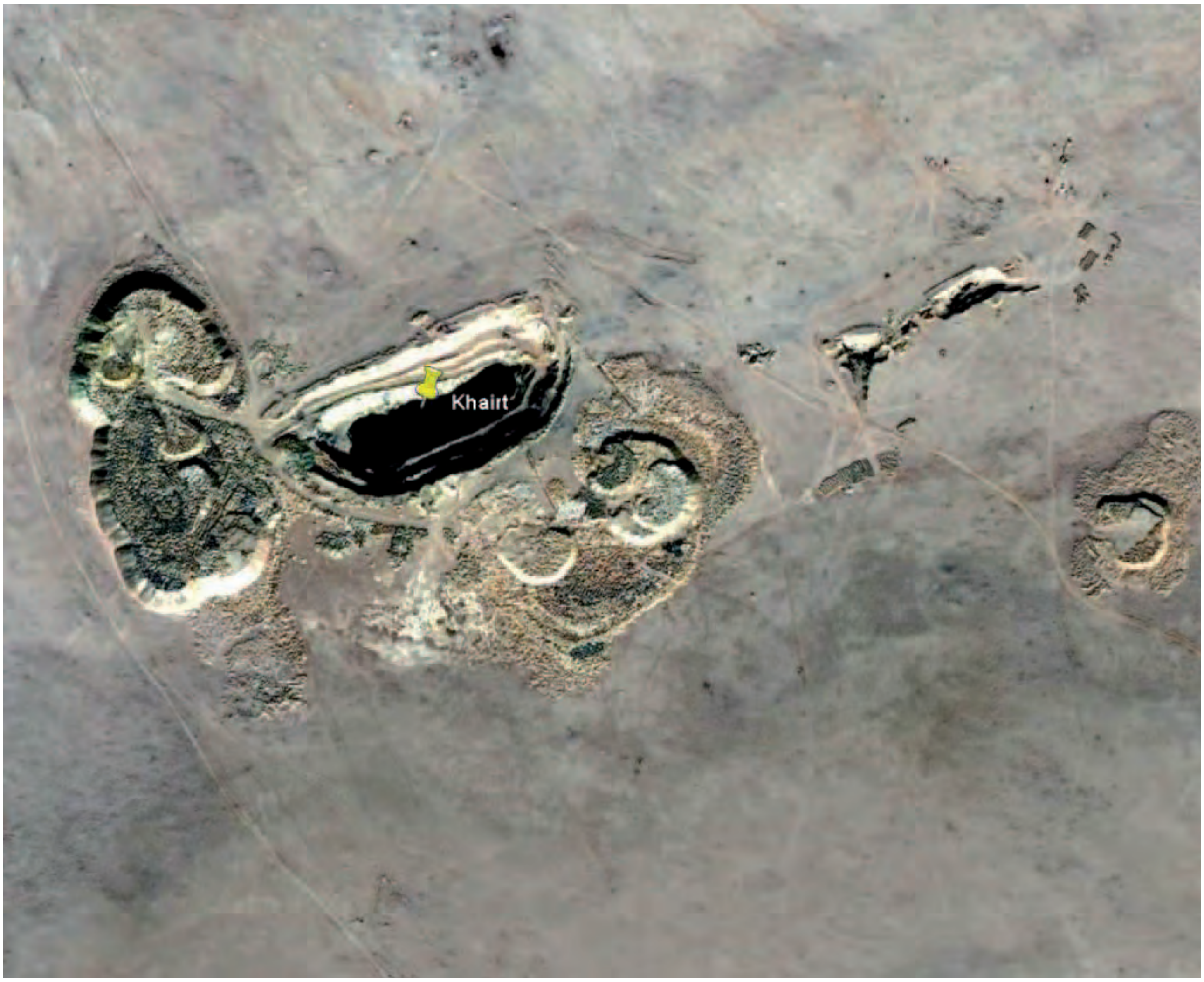


Figure 30: High definition satellite image of the former Khairt fluorite open pit (Satellite image as of 8 October 2007, Altitude 1.38 km, Photo courtesy of GOOGLE EARTH).

tinued with a maximum of about 173,000 tonnes of ore with average grades of 38-40 % CaF_2 mined and exported annually. As of the beginning of 2004, the remaining resources were just 39,300 tonnes of ore, which means that this deposit also is mined out by now.

- The **Naidvar** fluorite deposit (45° 50' 01.8" N, 109° 16' 51.1" E, 1,031 m a msl) is located 4 km north-west of Khar Airag railway station. It is made up of six ore bodies with ten veins and two lenses in total. The average lengths of veins/lenses vary between 40 and 180 m, with thicknesses reaching from 0.70-7.94 m. Taking into account the minimum grades of 20 % CaF_2 in general, and of 30.3 % CaF_2 in blocks of interest, the initial total category C2 resources amounted to 128,800 tonnes of economically mineable ore grading 33.57 % CaF_2 on average, i.e. 43,200 tonnes of CaF_2. Additionally, there were category C2 resources of 36,100 tonnes of non-economically mineable ore grading 31.6 % CaF_2, i.e. containing 11,000 tonnes of CaF_2. This deposit was mined after 1979 by Mongolsovtsvetmet with unknown tonnages quarried, and since then by numerous ninjas. It may well be totally mined out today.

- The Khongor I, -II, and -III fluorite deposits are all relatively small and are located close to each other, belonging as they do to a common volcanic structure (cf. Figure 33).

Figure 31: Naidvar fluorite deposit as of September 2010 showing extensive mining by ninjas.

- **Khongor-I** consists of one steeply dipping (63° - 80°) vein of 680 m length, 65 m depth, and 1.63-11.33 m thickness, on average 4.91 m. Grades of CaF_2 vary between 26.36 and 51.64 %. The content of $CaCO_3$ is 2.01-5.52 %, on average 3.92 %. Using cut-off grades of 15 % CaF_2 in general, and 26 % CaF_2 in blocks of interest, original category C1 reserves were calculated as 244,600 tonnes of ore grading 33.96 % CaF_2 on average, i.e. 83,100 tonnes of CaF_2. Presumably this deposit has been mined in the meantime – at least partly.

  Khongor-II is built up of 22 ore bodies of which # 1, 2, 3, 4, 4a, and 5 are the biggest ones (cf. Table 9). Between 1977 and 1990, the Khongor-II deposit was explored in more detail and successfully mined by MONGOLSOVTSVETMET. In total, 522,800 tonnes of ore with 176,100 tonnes of net CaF_2 (average grade 33.68 % CaF_2) were processed and 52,600 tonnes of low-grade ore dumped. As of 1990, the remaining reserves in category C1 were 131,300 tonnes of ore grading 32.67 % CaF_2, i.e. 42,900 tonnes of CaF_2. Additionally, there are still the previously calculated category C1 and category C2 resources from 90-120 m depth of 150,100 tonnes of ore grading 30.92 % (C1) and 36.95 % (C2) CaF_2, i.e. 45,700 tonnes of CaF_2. As these remaining reserves/resources have to be mined underground, mining cannot be done economically.

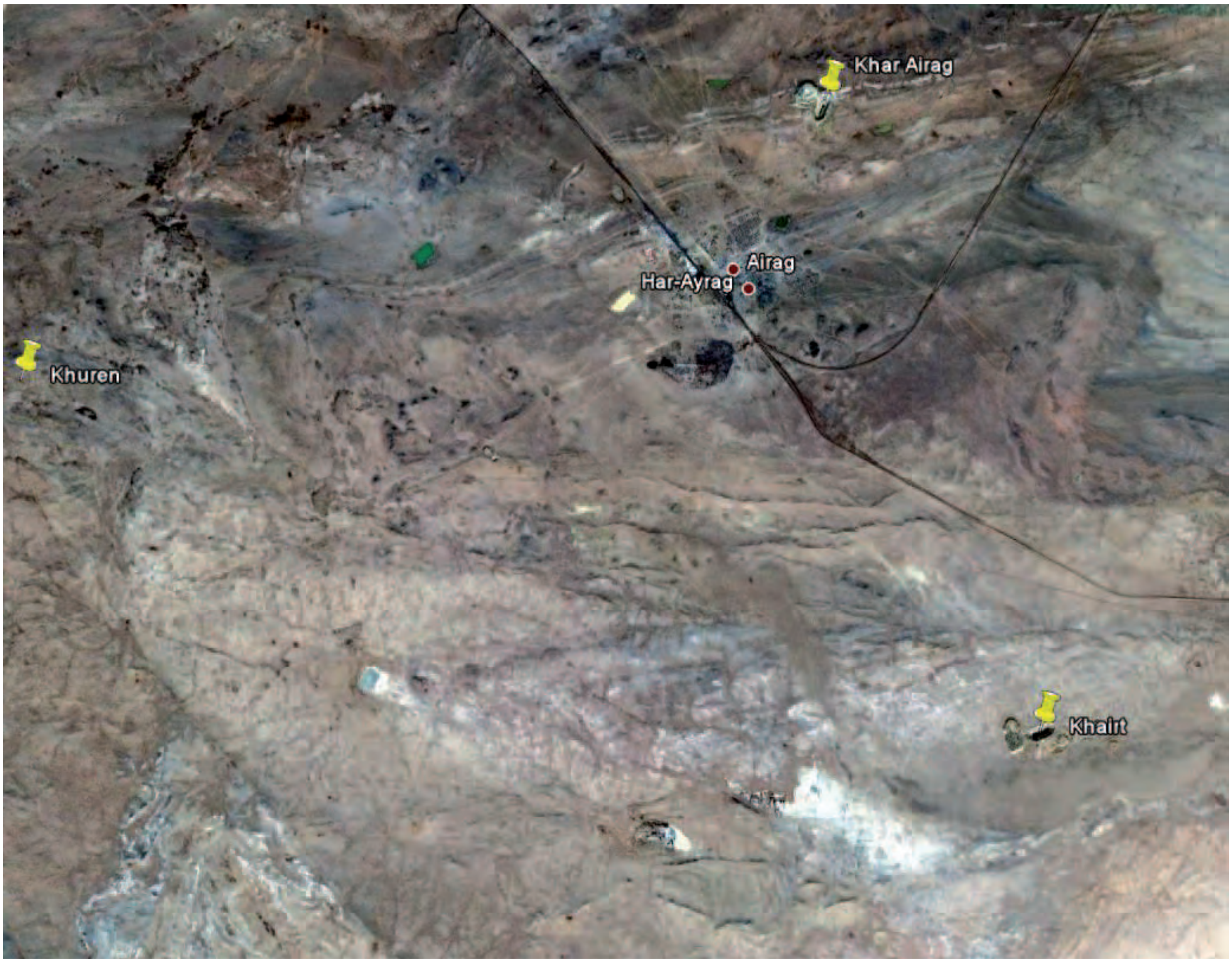


Figure 32: High definition satellite image of the central Khar Airag fluorite district with the Khar Airag, Khuren, Khairt and other unnamed fluorite open pits (Satellite image as of 8 October 2007, Altitude 13.2 km, Photo courtesy of GOOGLE EARTH).

Table 9: Main parameters of the Khongor-II fluorite deposit, taken from deposit passports.

Ore body #	Type	Average length (m)	Depth (m)	Thickness (m)	Composition	Share of resources
1	Lens	180	>230	4.14-38.47 avg.: 6.97	23.95-33.22 % CaF_2	52.1 %
2	Lens	100		1.80-20.33 avg.: 9.34	27.95-49.84 % CaF_2	18.1 %
3	Vein	100		2.29-5.55 avg.: 3.87	avg.: 54.52 % CaF_2	
4	Vein	180	130	1.25-11.75 avg.: 3.94	avg.: 29.55 % CaF_2	20.0 %
4a	Vein	90	70	1.30-5.66 avg.: 2.77	avg. 32.45 % CaF_2	
5	Vein	110	110	1.53-2.77 Avg.: 2.77	no information	

Khongor-III lies in the south-west of the Khongor area. It contains one steeply-dipping vein (680 m average length, 1.37-16.40 m thickness, on average 7.5 m, 21.25-43.0 % CaF_2), one steeply-dipping lens (115 m average length, 1.93-10.17 m thickness, on average 5.39 m, 26.83-34.72 % CaF_2), and another central vein of 100 m length, 3.2 m average thickness, and 27.04 % average grade of CaF_2. Taking into account minimum grades of 15 % CaF_2 in general, and 26 % CaF_2 in blocks of interest, the reserves down to 120 m depth were calculated as 592,700 tonnes of ore grading 33.24 % CaF_2 on aver-

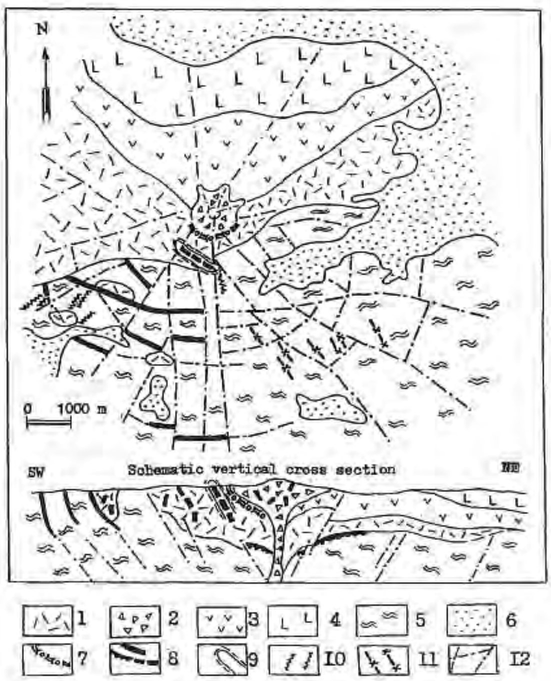


Fig. 5 Geological scheme of volcano-tectonic fluorite-bearing structure of Khongor deposit (Batjargal *et al.*, 1979). 1-4: Upper Jurassic to lower Cretaceous volcanogenic formation (1: Lava and dike of trachy rhyolite or quartz latite, 2: Dacite and dacitic porphyrite, 3: Trachy andesitic agglomerate and trachy andesite, 4: Lava and tuff breccia of basalt or andesite), 5: Precambrian mica-argillic schists with limestone interlayers, 6: Quaternary sediment, 7: Secondary quartzite, 8: Fluorite ore body, 9: Kaolinite distribution area, 10: Felsic dike and subvolcanic intrusion, 11: Mafic dike, 12: Fault and fracture.

Figure 33: Geological sketch map of the Khongor fluorite deposit structure, from Lkhamsuren & Hamasaki (1998).

Table 10: Main parameters of the Khoit Khongor fluorite deposit, taken from deposit passports.

Ore body #	Average length (m)	Depth (m)	Average thickness (m)	Composition
Western ore belt				
I	200	50	2.5	36.22 % CaF_2, 51.06 % SiO_2, 1.58 % $CaCO_3$
II	150	35	3.0	42.91 % CaF_2, 37.92 % SiO_2, 5.0 % $CaCO_3$
III	100	25	5.9	58.82 % CaF_2, 31.57 % SiO_2, 1.81 % $CaCO_3$
Central ore belt				
I	100	25	3.0	52.77 % CaF_2, 33.81 % SiO_2, 6.81 % $CaCO_3$
II	55	15	13.0	26.73 % CaF_2, 59.44 % SiO_2, 8.17 % $CaCO_3$

age, i.e. containing 197,000 tonnes of CaF_2 in category C1. 52,400 tonnes of this rather low-grade ore were mined by MONGOLSOVTSVETMET between 1977 and 1982.

- The **Khoit Khongor** fluorite deposit lies very close to the Khongor I-III deposits. During prospecting work from 1986-1988, two ore belts, with five ore bodies/veins in total were discovered (cf. Table 10). The total resources estimated in category P1 are 170,235 tonnes of ore grading 46.26 % CaF_2 and 4.67 % $CaCO_3$ on average, i.e. containing 78,700 tonnes of CaF_2.

- The Bujgar-1 and Bujgar-2 fluorite deposits lie 11 km south and 11 km west of Khar-Airag train station. The first mining period was from 1964 to 1977. As of 2008, both deposits were again being mined by MONGOLROSTSVETMET LLC in open pit operations.

Bujgar-1 consists of 12 different ore bodies, of which the parameters of the biggest ones are given in Table 11. The other ones do not contribute any significant share to the resources. The average composition of the ore varies from 33.23-50.48 % CaF_2 and 0.78-9.6 %, on average 3.12 % $CaCO_3$. The other average grades are 39.82 % SiO_2 and 1.31 % Fe_2O_3. Mining at Bujgar-1 started in 1964, with mining operations taken over by MONGOLSOVTSVETMET in 1983. (Initial?) resources were calculated as 517,300 tonnes of economically mineable ore in category C1, 245,500 tonnes of economically mineable ore in category C2, 13,900 tonnes of non-economically mineable ore in category C1, 30,300 tonnes of non-economically mineable ore in category C2, and 67,500 tonnes of ore in category P1.

Bujgar-2 is made up of five ore bodies with main parameters as shown in Table

Table 11: Main parameters of important ore bodies in the Bujgar-1 fluorite deposit, taken from deposit passports.

#	Type	Length (m)	Thickness (m)
1/1	Lens	avg.: 80	1.01-13.53, avg.: 6.02
2/1a	Lens	avg.: 160	1.15-13.65, avg.: 5.08
2/1b	Lens	99	2.03-7.81, avg.: 4.38
4	Vein	90	2.98-9.85, avg.: 5.78
5/1	Lens	180	1.10-12.34, avg.: 3.52

Table 12: Main parameters of important ore bodies in the Bujgar-2 fluorite deposit, taken from deposit passports.

#	Type	Average Length (m)	Average thickness (m)	Average composition
1	Lens	80	8.7	21.76 % CaF_2, 58.43 % SiO_2, 4.65 % $CaCO_3$
2	Lens	143	4.7	29.26 % CaF_2, 50.70 % SiO_2, 3.16 % $CaCO_3$
3	Vein	43	3.2	22.15 % CaF_2, 52.76 % SiO_2, 2.52 % $CaCO_3$
4	Vein	139	7.8	28.20 % CaF_2, 52.47 % SiO_2, 2.19 % $CaCO_3$
5	Lens	40	6.2	22.75 % CaF_2, 58.54 % SiO_2, 1.55 % $CaCO_3$

12. Some 52,800 tonnes of ore were mined from this low-grade deposit with estimated remaining category C2 resources down to 50 m depth amounting to 271,500 tonnes of probably mineable ore, 105,500 tonnes of probably non-mineable ore, and 11,400 tonnes of probably non-mineable ore due to a high $CaCO_3$-content.

- **Khuren** is a small but high-grade fluorite deposit with 16 ore bodies in four different sites. The main parameters of the 12 economically most interesting ore bodies are shown in Table 13. Total reserves in category C1 have been calculated as 65,753 tonnes of ore grading 60.8 % CaF_2 on average, i.e. 40,091 tonnes of net CaF_2. Between 1964 and 1965, 4,200 tonnes of ore were mined from ore body #1.

- **The Suul Ondor** fluorite deposit is spread over seven distinct sites some 0.5-4.5 km apart, with up to 28 veins each, of which only some are of economic interest

Table 13: Main parameters of important ore bodies in the Khuren fluorite deposit, taken from deposit passports.

#	Length (m)	Thickness (m)	Depth (m)	Average CaF_2 grade	Total CaF_2 content
1	195	avg.: 3.8	20-25	62.20 %	13,800 t
2	100	0.3-1.1, avg.: 0.9	5	72.52 %	200 t
4	100	0.4-1.5, avg.: 0.8	20	62.35 %	2,400 t
5	80	0.3-7.8, avg.: 1.0	5	66.81 %	200 t
6	20	avg.: 0.5	5	67.35 %	100 t
7	20	0.4-2.3, avg.: 1.9	5	67.69 %	100 t
9	20	1.2-2.6, avg.: 1.9	5	51.61 %	300 t
10	120	0.7-5.7, avg.: 2.2	30	66.92 %	15,900 t
11	60	1.3-4.4, avg.: 3.6	15	48.88 %	4,800 t
12	20	avg.: 2.3	5	71.65 %	500 t
13	20	avg.: 3.9	7.5	42.35 %	1,100 t
14	20	0.5-4.0, avg.: 4.0	5	44.92 %	500 t

Table 14: Main parameters of the Suul Ondor fluorite deposit, taken from deposit passports and Koselev (1985).

Site #	No of veins	Length (m)	Depth (m)	Thickness (m)	Composition
1	15	20-320	80-110	1.21-7.29 avg.: 2.77-4.60	24.8-79.13 % CaF_2, 2.44 % $CaCO_3$
2 + 3	19+19	10-240	30-100	0.97-16.90 avg. 1.62-4.91	21.76-70.38 % CaF_2, 3.65 % $CaCO_3$
4A	2	240-310	60-75	0.64-3.75 avg.: 1.27-2.69	41.85-69.04 % CaF_2, 3.22 % $CaCO_3$
4B	2 (lenses)	avg.: 60	30-40	5.67-7.16 avg.: 6.24-6.72	49.64-70.90 % CaF_2, 12.31 % $CaCO_3$
Tsagaan Ondor	1	avg.: 75	avg.: 30	2.26-3.11	41.13-77.0 % CaF_2, 11.54 % $CaCO_3$
5	11	60-140		0.5-3.0	12.5-83.0 % CaF_2
6	13	10-500		0.1-0.9	3.1-72.5 % CaF_2
7	28	20-360		0.3-0.7	2.3-25.8 % CaF_2

(cf. Tab. 14). Taking into account minimum grades of 20 % CaF_2 in general, and 30 % CaF_2 in blocks of interest, the total category C2 resources of 14 major veins/lenses amount to 1,439,300 tonnes of ore grading 41.38 % CaF_2 on average, i.e. containing 595,600 tonnes of CaF_2. Additionally, there are P1 resources of 90,100 tonnes of ore grading 45.02 % CaF_2, i.e. containing 40,600 tonnes of CaF_2. In sites #4b and Tsagaan Ondor, the grades of $CaCO_3$ are strongly elevated and may pose problems during processing.

- The **Khokh Del** fluorite deposit encompasses 21 ore bodies, i.e. veins in seven zones spread over an area of 30 km^2 (cf. Table 15). There are three different ore types: carbonate-quartz-fluorite ore grading 29.18-53.5 % CaF_2, quartz-fluorite ore grading 25.25-47.48 % CaF_2, and rich ore grading 55-65 % CaF_2. Using a cut-off grade of 15 % CaF_2, the total resources for 20 out of 21 ore bodies in category C2+P1 were estimated as 2,312,300 tonnes of ore grading 42.69 % CaF_2, but also 9.38 % $CaCO_3$ on average. Although this latter grade poses problems during processing, this deposit is currently

Table 15: Main parameters of the Khokh Del fluorite deposit, taken from deposit passports.

Zone	No of veins	Length (m)	Depth (m)	Thickness (m)	Composition
East	9	82-400	5-100	1.0-25.6	68.7 %
South-west	1	avg.: 277	avg.: 121	3.2-17.5	17.3 %
South	1	avg.: 95	avg.: 10	3.0-19.0, avg.: 11.0	0.6 %
South-east	1	avg.: 110	avg. 30	3.0-6.5 avg.: 4.48	
North	2	102.5-160	17-20	2.0-6.4 avg.: 2.15-4.95	2.0 %
Central	4	50-244	8-30	2.0-21.7 avg.: 3.4-8.79	11.4 %
Shine us	3	210-680	avg.: 40	2.0-9.5 avg.: 2.4-5.18	

Table 16: Main parameters of the Baruun Tsagaan Del fluorite deposit, taken from deposit passports.

Site #	No of veins	Length (m)	Thickness (m)	Average composition
Western	16	15-230	1.0-23.0	50.25 % CaF_2, 32.42 % SiO_2, 6.02 % $CaCO_3$
Southern	11	30-85	2.0-23.0	64.19 % CaF_2, 21.55 % SiO_2, 8.06 % $CaCO_3$, 0.4 % Fe
# 4	9 (lenses)	15-165	0.8-11.0	61.34 % CaF_2, 23.28 % SiO_2, 1.44 % $CaCO_3$, 1.67 % Fe
# 5	2	40-80	avg. 10.78	57.49 % CaF_2, 29.45 % SiO_2, 3.75 % $CaCO_3$, 0.71 % Fe
Eastern	4	avg.: 115	avg.: 9.13	No information
Nerguy	6	30-95	3.7-10.65	No information
Intermediate	2	avg.: 80	1.5-8.0	No information

also being mined by Mongolrostsvetmet Llc. Out of nine veins in the East zone (cf. Table 15) three are in operation producing about 12,000 tonnes of ore grading 75 % CaF_2 on average per year. After hand-sorting, the ore is transported about 200 km to the Bor Ondor plant.

- The **Baruun Tsagaan Del** fluorite deposit is also made up of seven sites containing 67 small ore bodies in total (cf. Table 16). Parts of this deposit have been mined since 1964 with some 197,200 tonnes of ore quarried. The remaining mineable reserves have been calculated as 99,200 tonnes of ore grad-

Figure 34: Hand-sorting and loading of high-grade fluorite ore in one of the open pits at Khokh Del (45° 30’ 31.5” N, 07° 59’ 02.8 ‘’ E, 1,149 m a msl) as of September 2010.

Table 17: Main parameters of the Ikh Narthyn Khiid fluorite deposit, taken from deposit passport.

Site #	Depth along dip-ping (m)	Average length (m)	Average thickness (m)	Average grade
Northern	30	225	2.45	58.89 % CaF_2
Middle	40	252	1.21	64.41 % CaF_2
Contact	40	180	0.80	54.55 % CaF_2
South-eastern	28	445	2.28	46.32 % CaF_2
South (Bagana)	60	8	2.40	63.71 % CaF_2

ing 51.24 % CaF_2 on average in category C1. Non-economically mineable resources (32.26 % CaF_2 on average) are 64,900 tonnes of ore in category C1, and 41,000 tonnes of ore in category C2.

- **Seeriin Bulag** is a very small fluorite deposit with one fluorite-bearing quartz dike of 1.5-2.6 km length and 1-30 m thickness cutting through granite. The estimated resources are 90,000 tonnes of ore in category C1 and 107,000 tonnes of ore in category P1. The CaF_2 grade varies between 56 and 76 %.

- **The Ikh Nartyn Khiid** fluorite deposit consists of five areas with several veins each. The main parameters are shown in Table 17. Using cut-off grades of 24 % CaF_2 in general, and 30 % CaF_2 in blocks of interest, the total category C2 resources are 90,000 tonnes of ore grading 53 % CaF_2 on average, i.e. containing about 47,800 tonnes of CaF_2.

- The Maikhant-I and Maikhant-II fluorite deposits lie 31 km and 34.5 km west-south-west of Dalanjargalan Soum centre and 18 km and 16 km south-west of train station “24” respectively.

Maikhant-I is made up of three ore bodies, all of them lens-type, stretching over some 1.5 km length. The main parameters of these ore bodies are given in Table 18. Taking into account minimum grades of 15 % CaF_2 in general, and 30 % CaF_2 in blocks of interest, the original category C2 resources of ore bodies #1 and #3 amounted to 2,474,100 tonnes of ore grading 37.7 % CaF_2 on average, i.e. 932,700 tonnes of CaF_2. Because parts of ore body #1 were mined between 1971 and 1981 (cf. Figure 35) the remaining resources are now 2,409,100 tonnes of ore with 891,700 tonnes of net CaF_2. Ore body #2 does not crop out at the surface so no resources for this ore body have been established yet. Tests to produce a fluorite concentrate by flotation processes are said to have yielded very good results.

Table 18: Main parameters of the Maikhant-I fluorite deposit, taken from deposit passports.

Ore body #	Average length (m)	Average depth (m)	Thickness (m)	Grade CaF_2	Share of resources
1	900	320	0.64-9.55 avg.: 5.50	16.7-67.2 %	93.6 %
2	300	200	1.27-3.77 avg.: 2.43	18.9-45.9 %, avg.: 54.0 %	
3	300	150	2.40-4.96 avg.: 3.68	22.1-49.6 %	6.4 %

Table 19: Main parameters of the Maikhant-II fluorite deposit, taken from deposit passports.

Ore body #	Type	Average depth (m)	Depth (m)	Thickness (m)	Grade CaF_2
1	Vein	100	40-70 avg.: 55	0.6-12.9 avg.: 6.75	17.4-31.2 %
2	Vein	200		1.2-4.3 avg.: 2.25	21.3-46.2 % avg.: 33.1 %
3	Layer	50	20-25 avg.: 22.5		avg.: 50.0 %
4	Stockwork	300	No information		

Maikhant-II consists of four ore bodies obviously of very different types (cf. Table 19). The average grade of CaF_2 is 40.2 %. Using the same parameters as the Maikhant-I fluorite deposit, category C2 resources in just ore body #2 were estimated as 197,600 tonnes of ore grading 33.1 % CaF_2 on average. More exploration is needed to verify the total resources.

- The **Tsagaan Tahilch** fluorite deposit contains four steeply-dipping fluorite-bearing

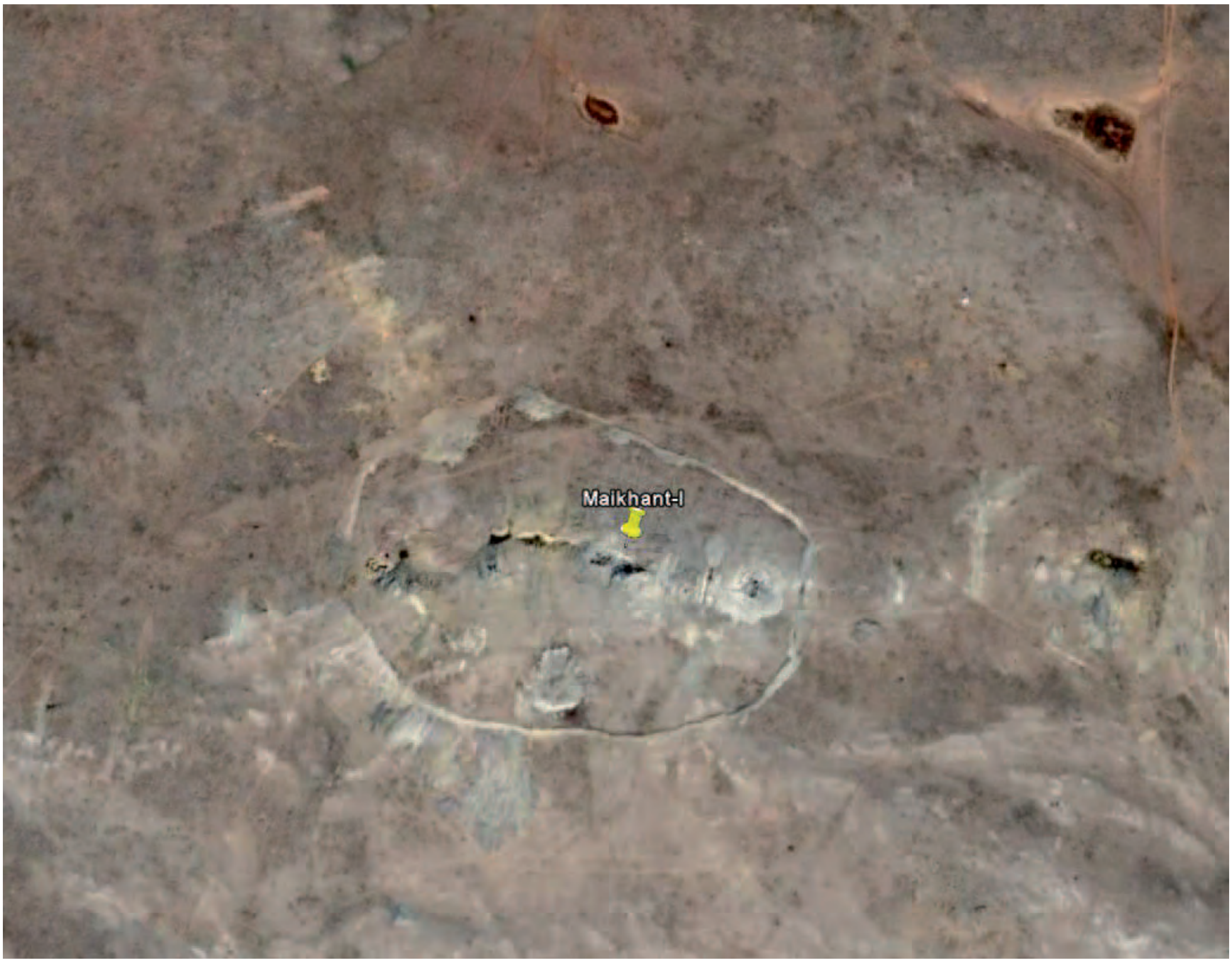


Figure 35: High definition satellite image of the Maikhant-I fluorite deposit showing old stone-fenced quarrying and trenching activities (Satellite image as of 30 August 2003, Altitude 1.14 km, Photo courtesy of Google Earth).

Table 20: Main parameters of the Tsagaan Tahilch fluorite deposit, taken from deposit passports.

Vein #	Average length (m)	Thickness (m)	CaF_2 grade
1	560	0.11-6.57, avg.: 1.81	32-52 %
1a	700	0.23-5.07, avg.: 1.24	21.2-55.3 %
1b		0.83-1.44, avg.: 1.01	
2	960	0.30-4.48, avg.: 1.66	16-72.9 %, avg.: 43.9 %

veins, of which two veins are branches of vein #1 however (cf. Table 20). A typical ore analysis shows a composition of 40.99 % CaF_2, 48.51 % SiO_2, 1.67 % $CaCO_3$, 1.12 % Fe^{total}, 0.12 % S^{total}, and 0.05 % P_2O_5. The ore is massive to breccious. Taking into account minimum grades of 20 % CaF_2 in general, and 40 % CaF_2 in blocks of interest, the total category C2 resources are 578,600 tonnes of ore grading 48.96 % CaF_2 on average, i.e. containing 283,300 tonnes of CaF_2. High definition satellite imagery by Google Earth shows no mining or exploration activities in this region (cf. Figure 36).

- The **Burkhant** East and West fluorite deposits (46° 03 14.1” N, 108° 52’ 17.6”, 1,309 m a msl) were discovered more recently by ninjas and are made up of numerous as yet geologically unexplored high-grade veins of 70 cm thickness on average. These veins are mined in a number of unstable open-pits (cf. Figure 37).

Figure 36: High definition satellite image of the north-western Khar Airag fluorite district showing the Maikhant-I, Maikhant-II, and Tsagaan Tahilch fluorite deposits like a chain of pearls, with more fluorite deposits to be expected along this chain (Satellite image as of 30 August 2003, Altitude 8.58 km, Photo courtesy of Google Earth).

Figure 37: Extensive ninja mining of fluorite ore at the recently discovered Burkhant deposit as of September 2010.

Berkh fluorite district:
The mining of fluorite in the Berkh fluorite district started in 1946. This third and also very important fluorite district lies in western Khentii Aimag with only two deposits lying southwestward in Sukhbaatar Aimag. The Berkh fluorite district encompasses some 20 fluorite deposits, most of them mined out or noneconomic, and about two dozen occurrences (Kremenetskii et al. 1987). The major problem is the distance to the nearest railway line with currently all ore transported by truck to Bor Ondor railway station 260 km away.

- Mining the **Berkh** fluorite deposit commenced in 1946 by Sovmongolmetall first in an open pit only, and from 1953/54 to 1994/95 in an underground mine by Mongolrostsvetmet or rather its predecessor company Mongolsovtsvetmet. There were two major vein systems of up to 1,100 m length along strike and with initial resources of 6.8 million tonnes of ore grading 43.61-73.22 % CaF_2. Close to the surface, the ore graded up to 91.7 % CaF_2, with the grade decreasing to 65 % CaF_2 with depth. It is said that the average processed ore graded 82-84 % CaF_2. This high-grade ore was hand-sorted, transported by truck to the railhead in Choibalsan, from where it was exported to Russia. The ore bodies were completely mined out to 410 m depth. The lower levels are flooded by now. As of 2008, the former mine workings (47° 46' 30.3" N, 111° 10' 06.7" E, 1,190 m a msl) are dilapidated (cf. Figure 38) with the site used as a storage place for fluorite ore from the neighbouring Delgerkhaan mine.

- The **Delgerkhaan** fluorite deposit is 13 km south-east of Berkh town and can easily be reached via typical unpaved tracks. The deposit is made up of eight steeply dipping veins of which four are of most economic

Figure 38: Former shaft of the Berkh fluorite mine as of June 2008.

Figure 39: Satellite image of the central Berkh fluorite district showing Berkh town and former mine, as well as the Delgerkhaan and Chimid fluorite deposits (Photo courtesy of GOOGLE EARTH).

importance (cf. Table 21). In the central part of the deposit area these four veins (# 1, 2 3/7, and 5) and vein #4 merge. Mining the Delgerkhaan fluoride deposit by MONGOLSOVTSVETMET started in 1978, first in an open pit. Later, about 168,000 tonnes of ore grading 64.2 % CaF_2 were extracted and exported each year. In 1999, the mining licence was transferred to the Mongolian Government which stopped mining in 2002 due to low world-market prices for fluoride and a water inflow. In 2006, during privatisation, the mining licence was acquired by "BERKH UUL" CO. LTD., which currently has some 30 ninjas working for it hand-picking fluorite ore which outcrops at the surface (47° 44' 37.0" N, 111° 17' 28.3" E, 1168 m a msl). In this way in 2007, "BERKH UUL" CO. LTD. was able to export some 5,200 tonnes of lump ore of "metallurgical grade" to Ukraine (75-82 % CaF_2).

Table 21: Main parameters of the four most important veins of the Delgerkhaan fluorite deposit, taken from deposit passports.

Ore body #	Average length (m)	Thickness (m)	Share of resources
1	1,280	0.40-3.08, avg.: 1.42	26.0 %
2	980	0.15-5.89, avg.: 1.99	13.0 %
3/7	1,300	0.27-10.95	54.0 %
5	130	0.30-2.10, avg.: 1.70	7.0 %

The remaining reserves at depths >150 m are stated as 3.4 million tonnes of ore grading 54 % CaF_2 on average. A fresh sample of typical ore cropping out at the surface even gave a much higher grade with no contaminants at all (cf. Table 30). Although these reserves and grades attract potential investors from all over the world, a feasibility-study with reliable data needs to be prepared first. There are hopes that a new processing plant will finally be erected either at Delgerkhaan or in Berkh.

Figure 40: Former shaft of the Delgerkhaan mine with small-scale (ninja) operations in the whole area as of June 2008.

- The **Chimid** fluorite deposit is located 15 km north-west of the former Berkh mine. Within the southern part of the deposit there are three major ore bodies as well as several smaller quartz-fluorite veins. Ore body #1 is tongue-shaped and was explored to a depth of 30-50 m on its flanks and 80-90 m in its central part. Ore body #2 is the biggest one and has an undulating form. It is 350 m north-west of ore-body #1. Ore body #3 is a more typical quartz-fluorite vein. In the western part of the Chimid deposit are ore bodies #4 to #6. Ore body #4 splits at the surface into 11 lenses but at depth it was proven to be just one vein. Ore body #5 is 150 m north of ore body #4. All ore bodies decrease in thickness (1.0-4.45 m, 2.05 m on average) with increasing depth. CaF_2 grades are known as follows: #1: 25.9-69.4 %, on average 53.18 %, #2: 31.4-47.6 %, on average 40.84 %, # 3: 10.0-33.1 %, #4: 46.3-60.5 %, #5: on average 43.67 %, and #6: on average 20 %. The initial resources were estimated as 95,020 tonnes of ore (cut-off grade: 25 % CaF_2) of which 20,200 tonnes of ore were mined in an open pit about 18 m deep after 1983. The remaining tonnage is too small to allow feasible commercial mining.

- The **Kholiin Kholboo** fluorite deposit is located 50 km north of the former Berkh mine. It was explored in part by East German state geologists between 1979 and 1987. The deposit has two areas with two major steeply dipping veins each, dipping down to 150-210 m depth (cf. Table 22). In area 1, which is the only one of economic interest, vein #2 lies 360 m north-east of vein #1. Initial resources were calculated as 380,700 tonnes of ore, of which 175,900 tonnes with a content of 123,300 tonnes of CaF_2 (70.1 % CaF_2) were mined in a 30 m deep open pit between 1985 and 1996. Additionally, 18,800 tonnes of low-grade ore were dumped. Thus, although the remaining

Table 22: Main parameters of the Kholiin Kholboo fluorite deposit, taken from deposit passports and Koselev (1985).

Ore body #	Length (m)	Thickness (m)	Grade CaF_2	Share of resources
1	avg.: 1,100	0.02-3.4	64.9-84.3 %	62.0 %
2	avg.: 350	avg.: 0.8	22.39-64.58 %	38.0 %
3	avg.: 650	0.6-3.3	21.7-84.86 % avg.: 57.5 %	
4	avg.: 400	0.2-1.6	30-40 %	

resources amount to about 239,000 tonnes of ore they cannot be mined economically as this would require an underground operation. Note that according to MARINOV et al. (1990) the ore from Kholiin Kholboo contains up to 0.2 % Ag and up to 12 % Pb, Zn, and Cu oxides.

- The Khavtgai-1, -2, and -3 fluorite deposits are located 36 km, 50 km, and 44 km northeast of the former Berkh mine or 11 km, 20 km, and 18 km north of Batnorov village.

  In **Khavtgai-1**, there is one major steeply dipping vein system of up to 1,700 m length (675 m on average), and 0.96-10.16 m thickness, on average and at the surface 2.68 m. Only the mineralised parts down to 100-150 m depth are regarded to be of economic interest. The composition of the breccious to massive ore varies from 14-87.87 % CaF_2, with 48.41 % CaF_2, 45.41 % SiO_2, and 1.01 % $CaCO_3$ on average. Taking into account cut-off grades of 20 % CaF_2 in general, and 40 % CaF_2 in blocks of interest, category C1 reserves down to 120 m depth were calculated as 252,000 tonnes of ore. Because most of these reserves can only be mined underground, this fluorite deposit cannot be mined economically. However, high definition satellite imagery by GOOGLE EARTH shows mining activity by ninjas at the surface.

  The **Khavtgai-2** deposit is made up of three steeply dipping veins which were explored in a fairly detailed way, even with galleries

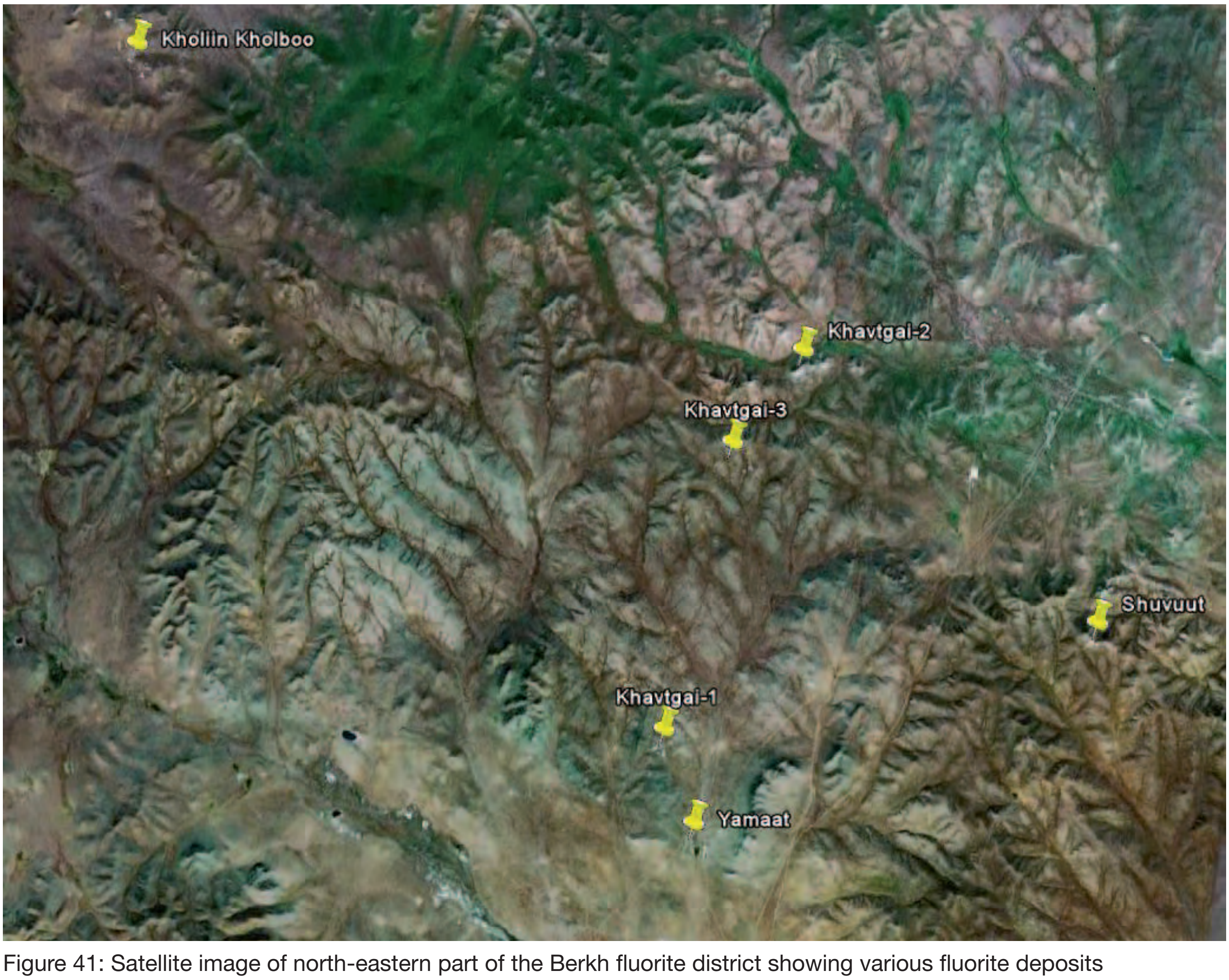


Figure 41: Satellite image of north-eastern part of the Berkh fluorite district showing various fluorite deposits (Photo courtesy of GOOGLE EARTH).

and adits. Important parameters of these veins are given in Table 23. Vein #2 is 20-50 m from vein #1, and vein #3 is 300 m east of vein #2. The grade of CaF_2 varies from 21.87-69.8 %, with 45.71 % calculated as average. Because vein #1 was mined in the 1950's to 1960's, the remaining category C2 resources of 78,100 tonnes of ore are concentrated in veins/ore bodies #2 and #3. There is no information on any of the present mining activity which is mainly carried out by ninjas.

Very similar to Khavtgai-2, the **Khavtgai-3** fluorite deposit is made up of three steeply dipping ore bodies of which ore body #2 was mined from 1976 to 1979/80 (16,700 tonnes of ore with 10,200 tonnes of net CaF_2 quarried). Ore body #1 is a lens of 150 m average length, 1.06-2.30 m thickness, and a CaF_2-grade of 26.5-61.7 %. Ore body #3 is a vein of 125 m average length, 1.18-2.71 m thickness and a grade of up to 60 % CaF_2. The total estimated category C2 resources of ore bodies #1 and #3 are 176,700 tonnes of ore grading 49.31 % CaF_2 on average. However, a different, most probably more realistic estimate is that the remaining resources after mining only amount to 9,800 tonnes of ore with a CaF_2 content of only 3,500 tonnes.

- The **Shuvuut** fluorite deposit was mined by Mongolsovtsvetmet between 1982 and 1986 which extracted some 59,500 tonnes of ore grading 68.24 % CaF_2 out of category B reserves of 84,000 tonnes of ore. Another 10,800 tonnes of low-grade ore were dumped. This small deposit is therefore completely mined out.

- The **Saikhan Uul** fluorite deposit is located 80 km north-east of Berkh. Only poorly prospected, the work led to the discovery of one tilted mineralised lens, 120-310 m length, 2.4-6.24 m thickness, and a grade of 20.1-53.6 % CaF_2, and one fluorite vein of 500-550 m length, 450 m proven depth, 1.60-9.92 m thickness, on average 5.79 m, and a grade of 20.72-43.26 % CaF_2. No resources have been estimated yet but the calculated average CaF_2 grade of only 28.66 % is close to the cut-off grade currently accepted by Mongolrostsvetmet Llc (cf. above). According to satellite imagery from Google Earth, this deposit has been quarried at the surface.

- The **Khaidelgerkhaan** fluorite deposit is in the north-western part of the Berkh fluorite district. There is just one major vein of 775 m average length, 200 m proven depth, and 0.32-6.94 m thickness, on average 2.95 m. The calculated category C2 resources are 850,500 tonnes of ore grading 40.94 % CaF_2 on average, i.e. containing 348,200 tonnes of CaF_2. According to Dejidmaa et al. (2001) this deposit is also mined out, however, there are no signs of mining activities on satellite imagery available from Google Earth.

- The **Bayan Ovoo Soum (Dojir)** fluorite deposit consists of nine fluorite-bearing veins, with veins #1 and #2 explored down to 418 m depth and shown to be branches of

Table 23: Main parameters of the Khavtgai-2 fluorite deposit, taken from deposit passport.

Ore body #	Average length (m)	Thickness (m)	Grade CaF_2
1	200	0.36-1.54, avg.: 1.31 decreasing with depth	avg.: 33.88 %
2	250	0.86-5.39, avg.: 2.63	21.87-69.48 %
3	100	1.51-6.70, avg.: 4.10	avg.: 51.6 %

Figure 42: High definition satellite image of the Bayan Ovoo Soum fluorite deposit showing significant exploration and small-scale (ninja) mining activities (Satellite image as of 2 September 2007, Altitude 805 m, Photo courtesy of Google Earth).

the same vein (ore body) #1-2. The same seems to be true for veins #4 and #6 being branches of ore body #4-6. Important parameters of these ore bodies are given in Table 24. Calculated reserves down to 212 m depth are given as 247,000 tonnes of ore grading 82.16 % CaF_2, i.e. containing 203,980 tonnes of CaF_2 in category B, and 273,600 tonnes of ore grading 77.7 % CaF_2 in category C1, i.e. containing 212,560 tonnes of CaF_2 in category C1. Commercial mining is reported from 1955 only. According to Dejidmaa et al. (2001), and similar to the Khaidelgerkhaan deposit, the Bayan Ovoo Soum fluorite deposit is now close to being mined out. In this case though, high defini-

Table 24: Main parameters of important ore bodies of the Bayan Ovoo Soum fluorite deposit, taken from deposit passports.

Ore body #	No of veins	Average length (m)	Thickness (m)
1-2	2	460	0.10-0.40
3	1	214	0.20-1.40
4-6	2	800	0.20-1.75
5	1	117	0.16-0.53
8	1	90	0.15-0.69, avg.: 0.40
9	1	160	0.10-0.50

Table 25: Main parameters of the Shalz fluorite deposit, taken from deposit passports.

Ore body #	Average length (m)	Average thickness (m)	Depth (m)	Average composition
1	750	1.32		68.72 % CaF_2, 19.33 % SiO_2, 1.8 % $CaCO_3$
2	460	1.0	40-120	48.86 % CaF_2, 2.04 % SiO_2
3	180	1.07	60-130	55.82 % CaF_2, 19.91 % SiO_2, 1.55 % $CaCO_3$
4	202	1.01 + 0.28		63.81 % CaF_2, 10.84 % SiO_2, 1.53 % $CaCO_3$
5	170	0.3	28 + 40	69.06 % CaF_2
7	80	1.53		68.88 % CaF_2, 15.6-31.56 % SiO_2, 1.33 % $CaCO_3$

tion satellite imagery from Google Earth does confirm significant mining and exploration activities at the surface (cf. Figure 42).

- The **Mal** fluorite deposit is some 28 km north-west of Berkh. Within the deposit area there are two ore bodies some 600 m apart which were explored down to 400 m depth. The southern ore body is tilted and of 280 m total length. It contains a series of lens-like quartz-fluorite veins of 20-110 m length and 0.5-2.0 m individual thickness. However, only the northern ore body is regarded to be of economic interest with an average length of 420 m and a thickness of 2.0-16.0 m. Applying a cut-off grade of 15 % CaF_2 in general, and 28 % CaF_2 in blocks of interest, the initial category C1 resources of the northern ore body only were calculated as 1,375,200 tonnes of ore grading 40.9 % CaF_2 (562,700 tonnes of CaF_2). Of this tonnage, high-grade ore (63.9 % CaF_2) accounts for 430,700 tonnes with 275,200 net tonnes of CaF_2. Because this high-grade ore of ore body #2 was especially mined in an open pit about 50 m deep after 1985, the remaining lower grade ore must be mined in an underground operation which will be only marginally economic. High definition satellite imagery from Google Earth shows only limited mining activity by ninjas.

- The **Shalz (Mogoi)** fluorite deposit is in the north-westernmost part of the Berkh fluorite district. The deposit area is characterised by a system of up to 1.6-2 km long fault zones and fracture zones which gave rise to six major but also fragmented quartz-fluorite vein systems/ore bodies. Important parameters of these ore bodies are given in Table 25. The calculated category C2 resources are 366,633 tonnes of ore grading 62.42 % CaF_2, i.e. containing 228,836 tonnes of CaF_2, of which 278,869 tonnes of ore grading 66.14 CaF_2, i.e. 183,133 tonnes CaF_2, should be recoverable. Additionally, there are category C2 resources of lower-grade ore (48.7 % CaF_2) of 34,085 tonnes, containing 16,599 tonnes of CaF_2, and P1 resources of 55,679 tonnes of medium-grade ore (52.27 % CaF_2) containing 29,104 tonnes of CaF_2. In 1969 unknown tonnages of this deposit were test-mined.

- The **Dund bulag** fluorite deposit is characterised by just one major vein with a length of 300 m. This vein consists of lenses of coarse-grained crystalline fluorite and thinly banded chalcedony. Individual lenses of fluorite are 2-3 m long and 0.66-2.5 m thick. For resource calculations, the vein was divided into two blocks. Block #1 has an average thickness of 1.83 m and contains category C1 reserves of 36,400 tonnes of

Figure 43: High definition satellite image of the Mal fluorite deposit with an open pit at ore body #2 (Satellite image as of 10 October 2005, Altitude 1.06 km, Photo courtesy of Google Earth).

ore grading 72.98 % CaF_2 (26,600 tonnes of CaF_2) on average, while block #2 has an average thickness of 1.36 m and contains category C2 resources of 44,170 tonnes of ore grading 40.26 % CaF_2 (17,780 tonnes of CaF_2) on average. This deposit is suitable for small-scale mining only.

- **Yamaat** is another small but high-grade fluorite deposit some 3.5 km south of the Khavtgai-1 deposit. Within the deposit area there are four steeply dipping veins of which #1 is the biggest and only economic vein, with 400 m (up to 680 m) average length, 200 m depth, and 1.0-4.05 m thickness, on average 1.25 m. Resources in category P only are about 123,000 tonnes of ore grading 70 % CaF_2 on average (Koselev 1985). Satellite imagery by Google Earth shows mining activities at the surface.

- The **Bulgan Uul** fluorite deposit lies 22 km south-west of the former Berkh mine. The deposit consists of three ore bodies, formed by steeply dipping veins with multiple apophyses and fine veins. Important parameters of the main ore bodies are: #1: up to 380 m length, on average 200 m, and up to 5.9 m thickness, on average 1.13 m, #2: 200 m average length, 30-50 m maximum depth, and 1.47 m average thickness, #3: 230 m average length, 110 m depth, and 2.2-3.5 m (up to 16.5 m) thickness. The ore grades 43.77-61.51 % CaF_2. Reserves established during mining between 1977 and 1983 were 94,500 tonnes of ore with 62,900 tonnes of net CaF_2 in category B+C, and 25,100 tonnes of ore with 15,500 tonnes of net CaF_2 in category C2. About 66,100 tonnes of ore containing 44,100 tonnes of CaF_2 were mined, and 6,900 tonnes of low-grade

Figure 44: High definition satellite image of the Bayankhaan and Bulgan Uul fluorite deposits (Satellite image as of 25 July 2003, Altitude 1.45 km, Photo courtesy of Google Earth).

ore put aside in dumps. The remaining resources are calculated as 29,700 tonnes of ore suitable for underground mining only, which means that they cannot be mined economically.

Figure 45: Small-scale (ninja) mining in old prospecting trenches at Bayankhaan.

- **Bayankhaan** is another quite small fluorite deposit just north-east of the Bulgan Uul deposit with a mining licence held by "Berkh Uul" Co. Ltd since 2008. Limited commercial mining is said to have occurred in 1976. The deposit consists of three ore bodies with brecciated zones and small veins. The ore bodies are fragmented, and the quartz content increases with depth. The main veins are: #2: up to 450 m, on average 350 m length and 0.2-3.4 m thickness, on average 1.52 m, #4: 350 m average length and 1.87 m average thickness, and # 7: 180 m average length and 1.60 m average thickness. The CaF_2 grade varies from 33.8-

87.0 % with 58.15 % calculated as average. The resources are quite limited with 97,200 tonnes of ore in category C2. As of 2008, some prospecting trenches within the deposit are used by ninjas for limited extraction of fluorite ore (47° 37' 46.4" N, 110° 58' 52.5" E, 1,066 m a msl) (cf. Figure 44).

- The **Serven** fluorite deposit is located 35 km south-east of the Berkh mine and was explored in detail by East German state geologists in 1976-1980. Of the several mineralised veins in place, only the main vein is of economic interest. It is over 700 m long, steeply dipping and 1.47 m thick on average. The average CaF_2 grades in the ore change considerably with depth, i.e. from 45.17 % at the surface via 35.98 % at 30-50 m depth and 24.71 % at 80-100 m depth, to 20.02 % at 140-160 m depth. The average and maximum grades in the ore are 43.98 % CaF_2, 45.08 (up to 55.22 %) SiO_2, 1.39 % (up to 1.5 %) $CaCO_3$, 0.026 % (up to 0.17 %) P_2O_5, 0.01 % (up to 0.64 %) S, and 0.1-0.04 % $BaSO_4$. Flotation tests were successful. Using cut-off grades of 20 % CaF_2 in general, and 30 % in blocks of interest, together with a minimum thickness of 0.8 m, the total calculated category C2 resources amount to 153,364 tonnes of ore grading 47.11 % CaF_2 on average, i.e. containing 72,254 tonnes of CaF_2.

- The **Anas** fluorite deposit is 120 km south-east of Berkh and comprises about 30 quartz-fluorite veins in an area of 7.85 km^2. Only three veins are of economic importance. Ore body #1 is a crooked and banded vein of 500 m average length, 0.88-7.39 m thickness, and a grade of 27.2-56.16 % CaF_2. For resource calculation the ore body was divided into three blocks of which two contain ore of good quality. Ore body #2 is located 600 m south-west of #1 and forms a complex vein system of 100-250 m length and 0.30-2.51 m thickness. The grade of CaF_2 varies from 36.92-78.4 %. Due to its limited size, ore body #2 was not included in the resource calculation. Ore body #3 is 1,000 m south-west of #1 and 400 m south-west of #3. It is a vein fragmented into two parts of 700 m average length and 0.33-1.98 m thickness at the surface. Its grade of CaF_2 was analysed as 15.5-78.25 %. The initial calculated reserves/resources were 261,500 tonnes of ore grading 44.47 % CaF_2, i.e. containing 116,300 tonnes of CaF_2 in category C1, 511,900 tonnes of ore grading 38.38 % CaF_2, i.e. containing 198,500 tonnes of CaF_2 in category C2, and 113,100 tonnes of low-grade ore containing 25,300 tonnes of CaF_2 (22.37 %). The reserves and resources of high-grade ore (59-61 % CaF_2) were also calculated. From 1988 to 1992, the Anas fluorite deposit was partially mined in an open pit by Mongolsovtsvetmet which extracted some 131,000 tonnes of high-grade ore. Afterwards, the remaining reserves were calculated as 41,300 tonnes of high grade ore (61.7 % CaF_2) in category C1, unknown resources (should be about 130,000 tonnes) of normal grade ore in category C1, and unchanged resources of normal grade ore in category C2. Thus, the total remaining resources may be some 640,000 tonnes of economically interesting ore containing about 250,000 tonnes of CaF_2. These, however, have to be mined in an underground operation, which will not be feasible without establishing new reserves at this location by renewed exploration.

- The **Khailuur Jonsh (Fluorite)** fluorite deposit is just 6 km north-west of the former Anas mine. This deposit was explored in detail in 1984 and subsequent years. Within the deposit area there are five ore bodies, of which #1, #2, and #5 represent typical hydrothermally formed quartz-fluorite veins, while #3 and #4 are lenses later formed by metasomatosis. The main parameters of these ore bodies are shown in Table 26. Ore body #1 is partly covered by >20 m of Qua-

Table 26: Main parameters of Khailuur Jonsh fluorite deposit, taken from Kremenetskii et al. (1987).

Ore body #	Average dip	Average length at surface (m)	Average thickness (m)	CaF_2 grade	Share of resources (C1+C2)
1	66°	1,100	3.25	17.64-66.23 %, avg.: 33.35 %	73.6 %
2	66°	300	6.99	24.91-51.82 %, avg.: 43.60 %	12.1 %
3	49°	100	11.18	20.68-54.70 %, avg.: 26.93 %	3.9 %
4	1°	60	3.44	24.17 %	0 %
5	84°	500	1.53	22.05-87.68 %, avg.: 44.56 %	10.4 %

ternary sediments. The average CaF_2 grade of all ore bodies is 36.93 %, with grades of CaF_2 in all veins decreasing with depth. Values of impurities found are 2.20 % (1.0-6.6 %) $CaCO_3$, 0.09 % (0.02-0.21 %) P, 1.27 % (0.90-3.74 %) Fe, and 0.01 % (traces-0.02 %) S. The total calculated resources are 340,600 tonnes of ore grading 36.85 % CaF_2 on average (125,500 tonnes of CaF_2) in category C1, and 662,100 tonnes of ore grading 36.97 % CaF_2 on average (244,800 tonnes of CaF_2) in category C2. Additionally, the calculations also indicated 56,900 tonnes of low-grade ore grading 22.14 % CaF_2 on average (12,600 tonnes of CaF_2) in category C1, 195,700 tonnes of low-grade ore grading 29.99 % CaF_2 on average (58,700 tonnes of CaF_2) in category C2, and 64,600 tonnes of low-grade ore grading 25.0 % CaF_2 on average (16,150 tonnes of CaF_2) in category P.

Dornod (Khuv bulag, North Choibalsan) fluorite district

This sparsely prospected and even less explored fluorite district is in north-western Mongolia and includes only two deposits and several occurrences, all of them in Dornod Aimag.

- The **Baruun Suuj** fluorite deposit lies in Dashbalbar Soum about 50 km south-west of the Soum centre and 7 km north-west of the former uranium mining town of Marday which is connected to the railway line to Russia (cf. Figure 46). The deposit includes nine major and nine minor fluorite-bearing veins with parameters shown in Table 27. All the veins were explored down to 150 m depth. The total resources in category C2 to this depth only, amount to 3.094 million tonnes of ore grading 43.0 % CaF_2 on average, i.e. containing some 1.331 million tonnes of CaF_2. High definition satellite imagery from Google Earth shows extended exploration activities around the deposit.

- The **Khuv Bulag** fluorite deposit is located 130 km north-west of Choibalsan and 50 km south-west of Gurvanzagal village, i.e. in Gurvanzagal Soum. The deposit covers an area of 2 km^2 and can be divided into two parts, west and east. The western part contains 18 veins, of which only five are fluorite veins, while the others are quartz or quartz-fluorite veins. In the eastern part, four fluorite veins were discovered. The largest vein in the western part is #2. It was explored down to 58 m depth, has an average length of 280 m, and an average thickness of 0.80 m (0.32-1.10 m). Its ore grades 86.80 % (64.56-96.39 %) CaF_2 on average, as well as 2.77-55.3 % SiO_2, 0.13-0.16 % CaO, 0.54-0.57 % F_2O_3 and 0.54-0.74 % other oxides. The largest vein in the eastern part is #19 which was explored to 111 m depth. It has an average length of 1,000 m and a thickness of 0.15-3.14 m, on average 1.17 m. Its ore grades 40.78 % CaF_2 (19.03-95.54 %) on average, with 2.75-69.74 %

Figure 46: High definition satellite image of the Baruun Suuj fluorite deposit with former railway-connected uranium mine and mining town of Marday to the south-east (Satellite image as of 17 August 2004, Altitude 7.84 km, Photo courtesy of Google Earth).

SiO_2, 0.03-0.49 % CaO, 0.62-1.69 % Fe_2O_3, 0.11-1.0 % Al_2O_3, and 0.79-12.44 % other oxides. The total resources calculated for all veins #1-22 are 315,850 tonnes of ore grading 30.0 % CaF_2 on average (94,700 tonnes of CaF_2) in category C1. Additionally, some new veins numbered #26-33 were discovered after more exploration. They contain about 1,470,000 tonnes of ore with about 417,900 tonnes of net CaF_2 (28.43 % CaF_2) in category C2. Shallow parts of this deposit were mined in a very shallow open pit (3-5 m) in 1968-1969, with initial resources most probably close to untouched.

Table 27: Main parameters of major fluorspar-bearing veins in the Baruun Suuj fluorite deposit, taken from deposit passport

Ore body #	Average length (m)	Thickness (m)	Average CaF_2 grade	Category C2 resources (tonnes)	
				Ore	CaF_2
South	1,050	0.28-3.82 avg.: 1.13	47.96 %	658,300	315,700
1	600	0.30-3.42	45.78 %	363,680	166,490
2	710	0.64-3.69	37.80 %	693,680	262,200
4	240	0.46-1.84	41.15 %	115,320	47,450
5	320	0.38-5.17	37.94 %	216,000	81,900
8	480	0.86-5.12	29.93 %	262,200	78,500
10	700	0.38-5.57	48.26 %	645,800	311,700
13	320	1.35-1.57	48.39 %	138,970	67,250

Chuluut Tsagaan Del fluorite centre:
This small fluorite centre, some 130 km south of Ulaanbaatar, in Bayantsagaan Soum of Tuv Aimag, contains one fluorite deposit and various fluorite occurrences. The latter ones are of no commercial interest.

- The **Chuluut Tsagaan Del** fluorite deposit (sometimes confused with Zuun Tsagaan Del, a totally different deposit in the Bor Ondor fluorite district) consists of eight ore bodies, with 87 % of all fluorspar resources contained in bodies #2 (lens of 430 m length, 10-95 m depth, 70 m thickness, and average grade of 55.65 % CaF_2) and #5 (lens of 700 m length, 220 m depth, 40 m thickness, and average grade of 48 % CaF_2). $CaCO_3$ contents are given as 2.3-16.0 %.

  Using cut-off grades of 17 % CaF_2 in general and 30 % CaF_2 in blocks of interest, the total category C1 reserves in ore bodies #2, #5, and #8 amount to 1,107,600 tonnes of ore grading 51.78 % CaF_2 on average, i.e. containing 573,300 tonnes of CaF_2. Additionally, the category C2 resources were calculated as 388,900 tonnes of ore grading 47.30 % CaF_2, i.e. containing 184,000 tonnes of CaF_2. Between 1981 and 1990, ore body #2 (46° 56' 12" N, 107° 14' 41" E) was quarried by MONGOLCZECHOSLOVAKMETAL with 629,000 tonnes of ore containing 334,900 tonnes of CaF_2 taken out. The mined crude ore was hand sorted to produce higher-grade lump fluorite ore, which was exported to the former Czechoslovakia. Some 20,300 tonnes of non-commercial ore were dumped.

  After mining, the remaining category C1 reserves were re-calculated as 590,500 tonnes of ore grading 49.9 % CaF_2 on average, i.e. containing 294,700 tonnes of CaF_2. Renewed calculation of category C2 resources gave 276,400 tonnes of ore grading 46.2 % CaF_2, i.e. containing 127,700 tonnes of CaF_2.

Figure 47: Satellite image of the Chuluut Tsagaan Del fluorite deposit and former mine (Photo courtesy of GOOGLE EARTH).

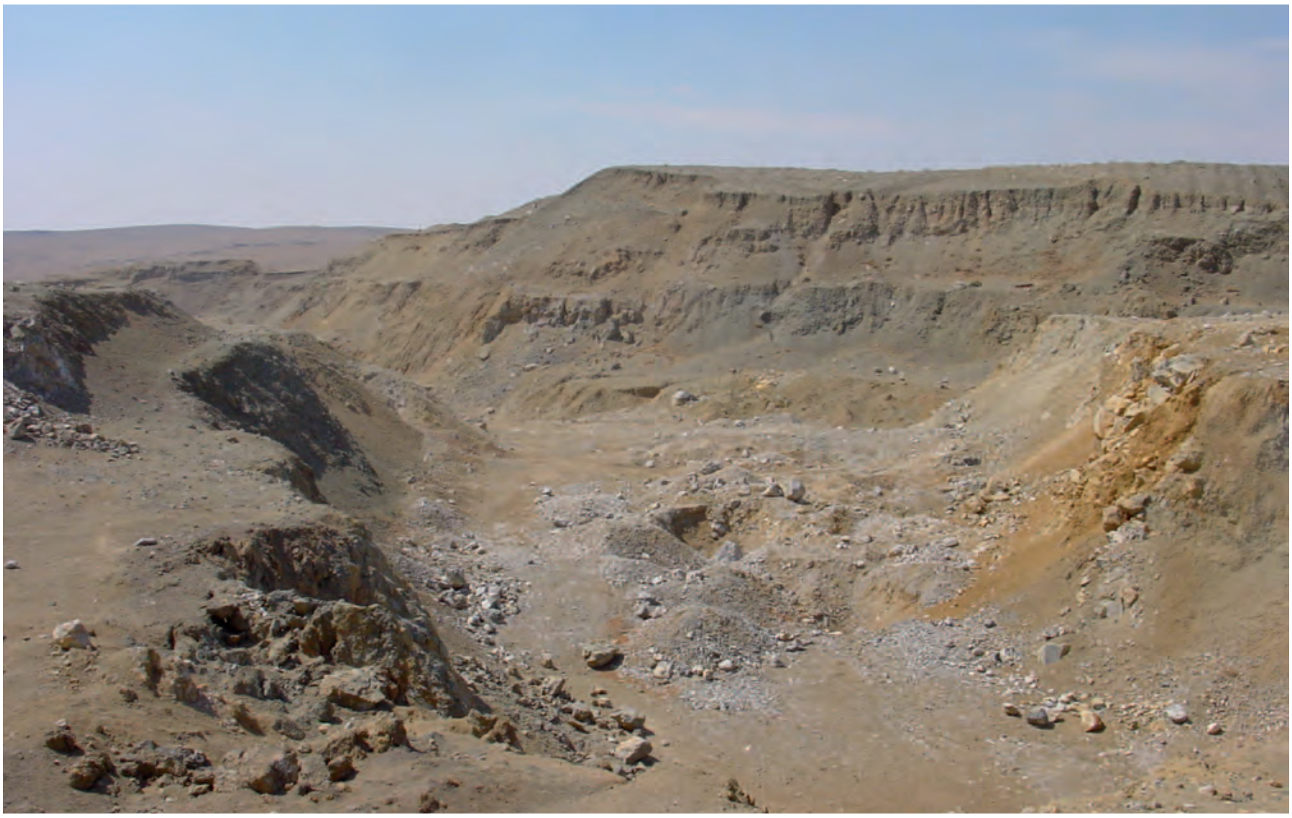


Figure 48: Former open pit mine at Chuluut Tsagaan Del operated by Mongolczechoslovakmetal. Photo taken in May 2008. The pit is about 600 m long, 100 m wide and 30 m deep.

Figure 49: Mining at Chuluut Tsagaan Del on behalf of Mongolczechmetal Llc in May 2008.

Meanwhile, Mongolczechoslovakmetal was restructured to Mongolczechmetal LLC which by means of a local contractor started mining fluorite ore again in October 2004. Since then, every year some 10,000-15,000 tonnes of "high-grade" ore only is quarried by dozers and excavators in very shallow open pits (46° 57' 03.9" N, 107° 14' 41.8" E) and transported by truck to the main railway line some 50 km away. Here it is upgraded by hand-sorting and transported via China to Ukraine, Czech Republic and other countries.

One sample of typical "high-grade" ore taken in May 2008 gave a rather low grade of just 34.34 % CaF_2 with slightly elevated values of arsenic (cf. Table 30).

Orgon fluorite centre:
This important fluorite centre covering 12 km^2 lies in the far south of the Eastern Mongolian fluorite belt in Orgon Soum of Dornogovi Aimag about 60 km south of the town of Sainshand. It was discovered by the Choir Geological Team in 1981-1983 and contains several ore bodies of economic interest. The initial resources calculated in 1990 are given in Table 28. Meanwhile, the total geological resources are estimated as ten million tonnes of ore. While low-carbonate ores (on average 47.0 % CaF_2, 45.0 % SiO_2, and 4.7 % $CaCO_3$) compose the bulk (80 %) of the ore bodies, high-carbonate ores (on average 28.5 % CaF_2, 34.7 % SiO_2, and 30.7 % $CaCO_3$) are difficult to process and have to be blended with low-carbonate ores before processing (Jargalsaihan et al. 1996).

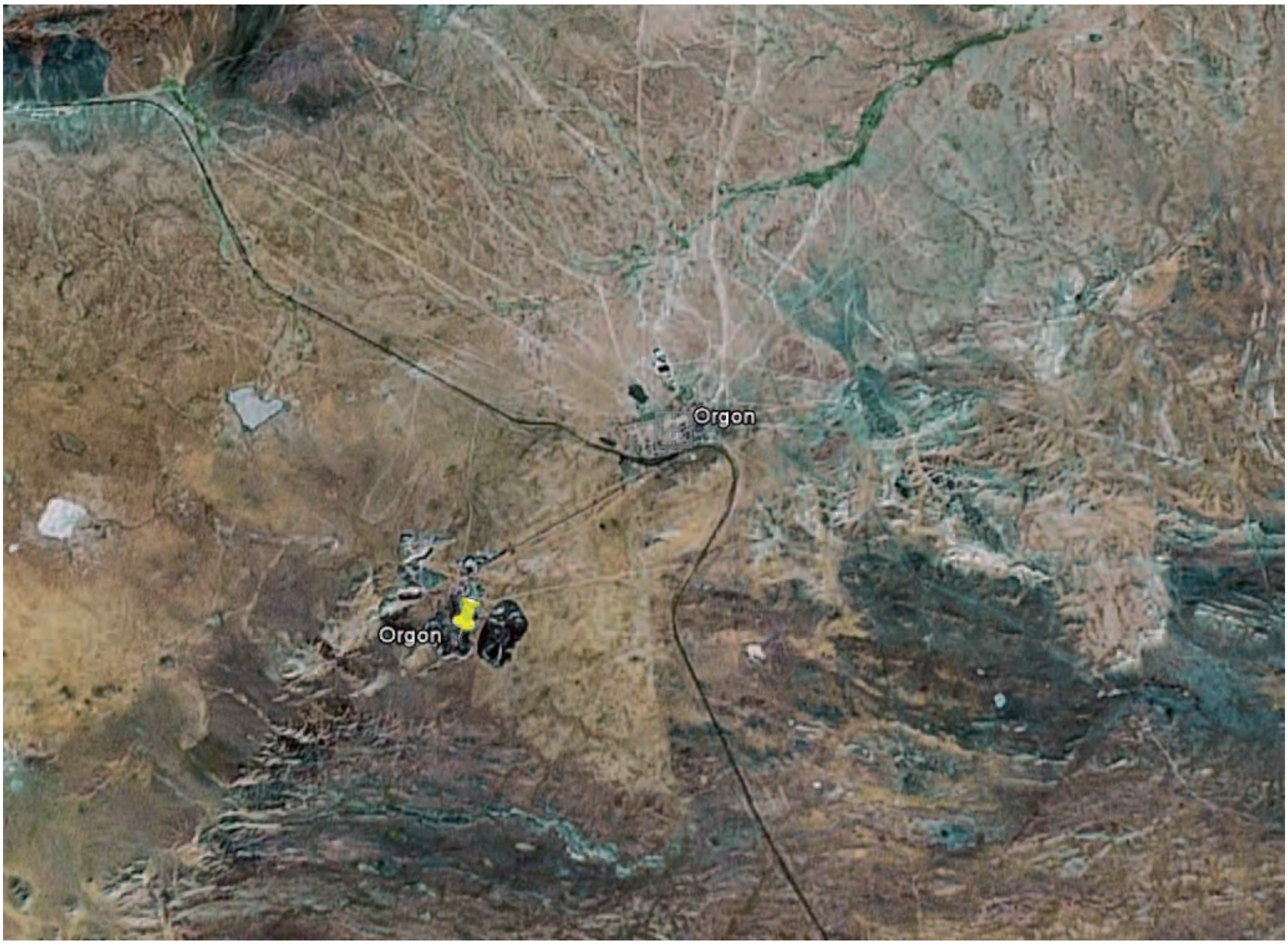


Figure 50: Satellite image of the Orgon fluorite mine only 4 km south-west of Orgon village and major railway line (Photo courtesy of Google Earth).

Table 28: Initial resources (in tonnes) as of 1990 calculated for the Orgon fluorite deposit, taken from deposit passports.

Mining method	Economic				Non-economic	
	C1	C1	C2	C2	C1+C2	
	Ore	CaF2	Ore	CaF_2	Ore	CaF_2
Open pit	1,831,800	772,432	16,924	4,498	1,224,446	441,964
Underground	418,797	193,102	14,808	7,530	3,506,774	1,419,527

- **Orgon (Ore body # 9)** (44° 42’ 12.6” N, 110° 44’ 39.3” E, 973 m a msl) and also ore body #14 (44° 42’ 32.0” N, 110° 44’ 04.9” E, 983 m a msl) have been quarried by MONGOLSOVTSVETMET, now MONGOLROSTSVETMET LLC, since 1988. Ore body #9, which is of lower quality, extends for 520 m along the strike on the surface and 370 m downdip. About 90,000-120,000 tonnes of ore are being quarried every year with the majority of this tonnage transported to the Bor Ondor plant for further processing. The ore bodies are of calcite-quartz-fluorite type with veins of 5-105 m thickness becoming narrower at a depth of 113 m. As of 2009, the remaining reserves and resources given by MONGOLROSTSVETMET LLC are 4,137,600 tonnes of ore grading 42.98 % (18.6-61.3 %) CaF_2 on average, i.e. containing 1,778,200 tonnes of CaF_2. The bulk of these reserves and resources are bound to ore body #9, with ore body #14 being close to being mined out.

Figure 51: Open pit mining of Orgon fluorite ore body #9 as of September 2010.

- **Chuluut (Ore body # 10)** is currently being explored. It appears to be made up of three small mineralised lenses and one larger and less regularly shaped body of >30 m true thickness. The latter dips north-westerly and plunges at about 60° to the west. A very rough resource estimate down to 145 m depth is 170,000 tonnes of ore grading 40.5 % (30.1-53.1 %) CaF_2 on average (Anonymous 2010). Because 80 % of these resources can only be mined underground, mining of the Chuluut ore body may not be feasible.
- The **Bilgekh Uul (Bilk)** fluorite deposit consists of three areas with several ore bodies/veins each. Area I contains 16 veins, of which 12 are of economic importance. Within these veins, the grade of CaF_2 varies from 33.54-68.8 % with 42.19 % on average. In area II, there are 28 veins, while in area III there are 23. At a depth of 40-50 m, the thickness of the veins decreases but the veins could be followed down to 100-250 m depth. The total prognosed resources are estimated as 1,625,900 tonnes of ore, while prognosed resources in area I down to 40 m depth only (= suitable for open pit mining) were re-estimated as 732,500 tonnes of ore grading 42.19 % on average, i.e. containg 309,000 tonnes of CaF_2.

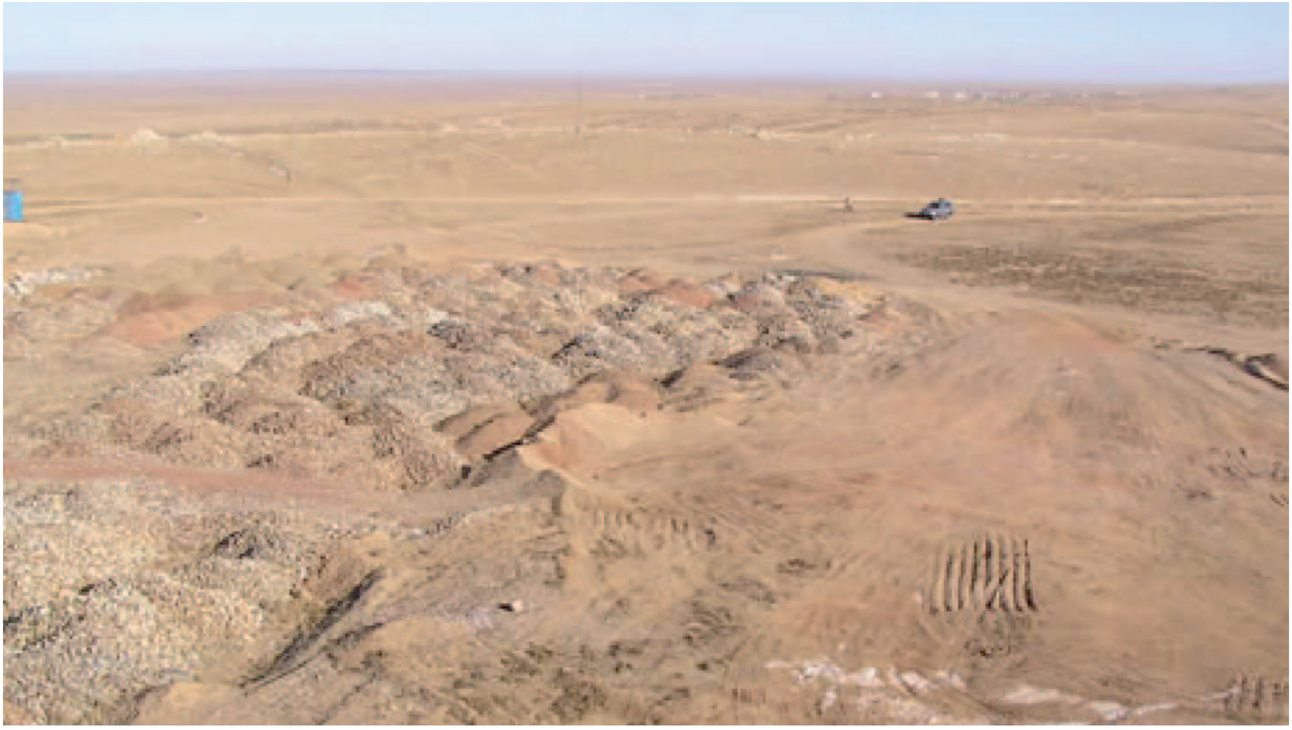


Figure 52: View looking north onto the Chuluut fluorspar ore body. Photo courtesy of Lotus Resources plc.

Central Dundgovi fluorite centre:
This newly defined fluorite centre lies in the centre of Dundgovi Aimag, and consists of just one fluorite deposit in Gurvansaykhan Soum and numerous surrounding fluorite occurrences. All of the latter ones are very poorly studied and most probably do not constitute deposits of commercial interest.

Northern Umnugovi fluorite centre:
This fluorite centre, which lies south of the East Mongolian fluorspar belt, is also newly defined, and has just one fluorite deposit of interest discovered so far.

- The **Avdarant** fluorite deposit (44° 21' 47.9" N, 104° 26' 25.2" E, 1,278 m a msl) lies in Mandal-Ovoo Soum and has been poorly prospected. However, the chances for increasing reserves by more exploration are rated as high. Additionally, it is located just 8 km east of the beneficiation plant of the Olon Ovoot gold mine, which means that the infrastructure is very good . The deposit covers 5 km^2 in size, with eight ore bodies found so far, of which one seems to have the biggest economic potential. This vein has a length of 1,700 m and a thickness of 0.5-11 m. The average grade in the ore of this vein close to the surface is 76.6 % CaF_2, while in boreholes, an average grade of 71.98 % (44.49-88.26 %) CaF_2 was determined. $CaCO_3$ ranges from 0.1-2.62 %. The total estimated resources are 709,600 tonnes of ore in category C2 (veins #1-#3) and 2,289,800 tonnes of ore in category P1 (veins #4-8).

Figure 53: Old exploration trenches at the Avdarant fluorite deposit as of September 2010. Photo courtesy Majigsuren Yondon.

Table 29: Main parameters of the Jandai fluorite deposit, taken from deposit passports.

Area #	Length (m)	Depth (m)	Thickness (m)	Composition
1	187	62	10.0-11.6	59.5-84.9 % CaF_2, 11.5-64.4 % SiO_2, 0.82-2.77 % $CaCO_3$
2	220	73	2.3-7.2	62.0-74.8 % CaF_2, 2.6-42.0 % SiO_2, 0.92-4.37 $CaCO_3$
3 a-e	30-215	10-120	0.8-11.0	42.5-68.8 % CaF_2, 4.36-41.16 % SiO_2, 1.37-36.75 % $CaCO_3$
4	109	36	2.0-8.0	43.5-75.5 % CaF_2, 20.4-50.2 % SiO_2, 1.07-3.02 % $CaCO_3$

West Khuvsgul fluorite centre:
This newly defined fluorite centre lies far north-west of the Eastern Mongolian fluorite zone in Tsetserleg Soum of Khuvsgul Aimag and consists of the Jandai fluorite deposit and several small occurrences.

- **Jandai** is a typical hydrothermal fluorite-quartz vein deposit consisting of four areas with a total of ten major veins (cf. Table 29). The total resources in area 3 are 175,279 tonnes of ore in category C2. With 519,119 tonnes of ore in all areas in category P1. Several of the fluorite deposits mentioned above were visited by a field team of BGR and MRAM geologists in 2008 and 2010. Representative samples were analysed at BGR laboratories with results shown in Table 30.

REQUIREMENTS AND EVALUATION

Because investment costs, especially for underground mining, are high, the basic tonnage requirements for fluorite deposits are:
- >1,000,000 tonnes of recoverable CaF_2-content (both underground or open pit) for international investors new to Mongolia
- >500,000 tonnes of recoverable CaF_2-content (underground) for established mining companies in Mongolia
- >100,000 tonnes of recoverable CaF_2-content (open pit) for established mining companies in Mongolia
- >10,000 tonnes of recoverable CaF_2-content within high-grade ore (open pit) for small-scale miners trying to establish longer-lasting contacts with established buyers or mining companies.

While deposits with resources less than 10,000 tonnes of recoverable CaF_2-content may still be mineable, they do not constitute serious investment targets.

According to the Russian classification system, all fluorite deposits with less than 2 million tonnes of fluorite content should be termed as small, with medium-size ones containing 2-5 million tonnes of fluorite, large ones containing 5-10 million tonnes of fluorite, and very large ones containing more than 10 million tonnes of fluorite.

As everywhere in Mongolia, the infrastructure should also be a big issue when evaluating fluorite deposits.

Table 30: Selected chemistry of typical ore and concentrates from Mongolian fluorite deposits (bulk rock analysis by XRF and for Hg by Solid Phase Mercury Atomic Absorption Analysis).

Chemistry	Chuluut Tsagaan Del	Bor Ondor		Delger-khaan	Avdarant			Orgon				Burkhan	Limits / Ranges for applications
	Ore	Ore	Conc. 3)	Ore	Ore #1	Ore #2	Ore #3	Vein14 #1	Vein14 #2	Vein9 #1	Vein9 #2	Ore	
wt.% / ppm / ppb													
(F)	13.08	27.42	43.45	43.88	47.90	8.32	45.41	28.86	26.38	27.22	32.79	45.41	
SiO_2	61.71	30.28	1.55	1.54	0.43	63.51	3.07	31.95	36.91	34.52	24.96	3.90	(<2)<5-<6(<15) (metallurgical grade) <1.0-<1.5 (acid grade) <2.5-<3.0 (ceramic grade)
Fe_2O_3 total	0.51	0.08	0.08	0.02	<0.01	0.29	<0.01	0.08	0.15	0.04	0.03	<0.01	(<0.005)-<0.50 (acid grade)
CaO 1)	26.99	50.03	71.85	72.42	71.14	20.33	69.24	47.83	44.23	45.68	53.02	68.13	
CaO 2)	24.67	45.67	62.81	66.20	71.58	19.67	70.10	47.68	45.28	46.75	54.86	68.78	
MgO	0.06	0.09	0.06	0.04	0.04	0.19	0.03	0.06	0.04	0.07	0.08	0.04	
MnO	0.004	0.002	0.005	<0.001	0.001	0.009	<0.001	0.001	0.001	0.002	<0.001	<0.001	
(SO_3)	<0.01	<0.01	0.02	<0.01	0.12	0.01	0.05	0.02	0.01	0.05	0.03	0.06	
P_2O_5	0.01	0.02	0.06	0.01	0.05	0.02	0.05	0.05	0.07	0.02	0.03	0.01	<0.03-<0.20 (acid grade)
LOI	2.38	1.97	0.95	0.47	0.27	2.82	0.97	2.46	2.45	2.37	1.85	1.07	
(As)	17 ppm	<3 ppm	<3 ppm	<3 ppm	4 ppm	7 ppm	4 ppm	6 ppm	8 ppm	6 ppm	5 ppm	3 ppm	(<5)-<10-12 ppm (acid grade)
Cu	7 ppm	8 ppm	7 ppm	<3 ppm	4 ppm	13 ppm	<3 ppm	6 ppm	6 ppm	6 ppm	8 ppm	<3 ppm	

Table 30: Selected chemistry of typical ore and concentrates from Mongolian fluorite deposits (bulk rock analysis by XRF and for Hg by Solid Phase Mercury Atomic Absorption Analysis).

Chemistry	Chuluut Tsagaan Del	Bor Ondor		Delger-khaan	Avdarant			Orgon				Burkhan	Limits / Ranges for applications
	Ore	Ore	Conc. 3)	Ore	Ore #1	Ore #2	Ore #3	Vein14 #1	Vein14 #2	Vein9 #1	Vein9 #2	Ore	
	wt.% / ppm / ppb												
Hg	14 ppb	<1 ppb	5 ppb	<1 ppb	<1 ppb	<1 ppb	<1 ppb	3 ppb	2 ppb	<1 ppb	<1 ppb	<1 ppb	
Pb	<3 ppm	<3 ppm	<4 ppm	<4 ppm	<4 ppm	10 ppm	<4 ppm	<4 ppm	<3 ppm	<3 ppm	<3 ppm	<3 ppm	<2,500-<5,000 ppm (metallurgical grade)
U	<4 ppm	<4 ppm	<4 ppm	<4 ppm	<4 ppm	<4 ppm	<4 ppm	<4 ppm	4 ppm	<4 ppm	<4 ppm	<4 ppm	∑<500 ppm for any commodity
Th	9 ppm	15 ppm	15 ppm	18 ppm	11 ppm	5 ppm	9 ppm	6 ppm	9 ppm	9 ppm	9 ppm	13 ppm	
Zn	3 ppm	6 ppm	8 ppm	6 ppm	<2 ppm	13 ppm	2 ppm	7 ppm	4 ppm	2 ppm	6 ppm	6 ppm	
	Calculated												
CaF_2 2)	34.34	65.57	87.43	92.15	99.67	27.39	97.61	66.40	63.05	65.08	76.38	49.16	>60(>70)->80 (metallurgical grade) (>92)->97 (acid grade) (>85)->95 (ceramic grade)
$MgCO_3$	0.12	0.19	0.12	0.08	0.08	0.40	0.06	0.12	0.08	0.15	0.17	0.08	<1 (metallurgical grade)
$BaSO_4$	212 ppm	54 ppm	150 ppm	<10 ppm	<10 ppm	581 ppm	<10 ppm	22 ppm	8 ppm	187 ppm	25 ppm	17 ppm	<5,000 ppm (acid grade)

[1] by XRF, [2] calculated from ICP-OES analysis, [3] although this sample was taken under supervision and with permission from the production line just before packing, it obviously does not represent a typical sample as Mongolrostsvetmet Llc guarantes better values to customers

Table 31: Summary of reserves/resources and CaF2-grades in economically mineable fluorite deposits in Mongolia, after deposit passports

District	Name	Resource of ore @ grade	CaF_2-content
Bor Ondor fluorite district	Bor Ondor-I [3) 4)] Bor Ondor-II [3) 4)]	9,131,720 t @ 35.4 % (A-C2)	3,232,000 t (A-C2)
	Adag [3) 4)]	1,712,780 t @ 43.3 % (A-C2)	741,200 t (A-C2)
	Dai uul	4,641,000 t @ 31.9 % (C2)	1,482,800 t (C2)
	Zuun Tsagaan Del [5)]	3,400,000 t @ 32.2 % (C1)	1,100,000 t (C2)
	Tsagaan Chuluut	167,400 t @ 45.8 % (C2)	76,600 t (C2)
	Tsagaan Elgen [6)]	205,200 t @ 38.7 % (B) 1,360,600 t @ 38.7 % (C1)	79,400 t (B) 526,600 t (C1)
	Saikhan Gashuun	77,900 t @ 50.8 % (C1) 424,600 t @ 43.5 % (C2)	39,500 t (C1) 184,600 t (C2)
	Bor Khujir [2) 3)]	1,126,000 t @ 38.7 % (C1)	436,200 t (C1)
	Tsagaan Ondor [5)]	542,500 t @ 31.2 % (C1) 1,095,200 t @ 28.7 % (C2)	169,100 t (C1) 314,500 t (C2)
	Ulaan Tolgoi	224.400 t @ 39.1 % (C2)	87,800 t (C2)
	Subtotal	*~24,000,000 t*	*~8,500,000 t*
Khar Airag fluorite district	Khongor-I [2)]	244,600 t @ 34.0 % (C1)	83,100 t (C1)
	Khongor-III	550,300 t @ 33.2 % (C1)	182,900 t (C1)
	Khoit Khongor	170,235 t @ 46.3 % (P1)	78,700 t (P1)
	Bujgar-1 [2)]	517,300 t @ 33.2-50.5 % (C1) 245,500 t @ 33.2-50.5 % (C2) 67,500 t @ 33.2-50.5 (P1)	~200,000 t (C1) ~100,000 t (C2) ~25,000 t (P1)
	Bujgar-2 [1)]	271,500 t @ 21.76-29.26 (C2)	~65,000 t (C2)
	Khuren	61,500 t @ 60.8 % (C1)	37,400 t (C1)
	Tsagaan Tahilch	578,600 t @ 49.0 % (C2)	283,300 t (C2)
	Suul Ondor	1,439,300 t @ 41.4 % (C2) 90,100 t @ 45.0 % (P1)	595,600 t (C2) 40,600 t (P1)
	Khokh Del [1) 3)]	2,312,300 t @ 42.7 % (C2+P1)	987,100 t (C2+P1)
	Baruun Tsagaan Del	99,200 t @ 51.2 % (C1) 64,900 t @ 32.3 % (C1) 41,000 t @ 32.3 % (C2)	50,800 t (C1) 20,900 t (C1) 13,200 t (C2)
	Seeriin Bulag	90,000 t @56-76 % (C1) 107,000 t @ 56-76 % (P1)	~60,000 t (C1) ~70,000 t (P1)
	Ikh Nartyn Khiid	90,000 t @ 53 % (C2)	47,800 t (C2)
	Maikhant-I	2,409,100 t @ 37.7 % (C2)	891,700 t (C2)
	Maikhant-II	>197,600 t @ 33.1 % (C2)	>65,400 t (C2)
	Subtotal	*~9,600,000 t*	*~3,900,000 t*

Name		Resource of ore @ grade	CaF_2-content
Bor Ondor fluorite district	Delgerkhaan [5)]	3,400,000 t @ 54 % (C1)	1,836,000 t (C1)
	Khavtgai-2 [2)]	78,100 t @ 45.7 % (C2)	35,700 t (C2)
	Serven	153,400 t @ 47.1 % (C2)	72,200 t (C2)
	Khaidelgerkhaan [2)]	850,500 t @ 40.9 % (C2)	348,200 t (C2)
	Dojir [2) 5)]	247,000 t @ 82.2 % (B) 273,600 t @ 77.7 % (C1)	204,000 t (B) 212,500 t (C1)
	Mal [5)]	~1,000,000 t @ 40.9 % (C1)	~400,000 t (C1)
	Shalz	366,600 t @ 62.4 % (C2) 34,100 t @ 48.7 % (C2) 55,600 t @ 52.3 % (P1)	228,800 t (C2) 16,600 t (C2) 29,100 t (P1)
	Dund Bulag	36,400 t @ 73.0 % (C1) 44,200 t @ 40.3 % (C2)	26,600 t (C1) 17,800 t (C2)
	Yamaat	123,000 t @ 85-90 % (P)	~100,000 t (P)
	Bayankhaan	97,200 t @ 58.1 % (C2)	56,500 t (C2)
	Serven	153,400 t @ 47.1 % (C2)	72,200 t (C2)
	Khayluur Jonsh	340,600 t @ 36.85 % (C1) 662,100 t @ 36.97 % (C2) 195,700 t @ 29.99 % (C2)	125,500 t (C1) 244,800 t (C2) 58,700 t (C2)
	Subtotal	*~8,100,000 t*	*~4,100,000 t*
Dornod fluorite district	Baruun Suuj	3,094,000 t @ 43.0 % (C2)	1,331,000 t (C2)
	Khuv Bulag	315,800 t @ 30.0 % (C1) 1,470,000 t @ 28.4 % (C2)	94,700 t (C1) 417,900 t (C2)
	Subtotal	*~4,900,000 t*	*~1,800,000 t*
Fluorite centres	Chuluut Tsagaan Del	590,500 t @ 49.9 % (C1) 276,400 t @ 46.2 % (C2)	294,700 t (C1) 127.700 t (C2)
	Orgon [3)]	4,137,600 t @ 43.0 % (A-C2)	1,778,200 t (A-C2)
	Bilgekh Uul	1,445,800 t (P) 732,500 t @ 42.2 % (P1+P2)	309,000 t (P1+P2)
	Jandai [1)]	>175,300 t @ 42.5-84.9 % (C2) 519,900 t @ 42.5-84.9 % (P1)	~100,000 t (C2) ~300,000 t (P1)
	Avdarant	709,600 t (C2) @ 72 % 2,289,800 t (P1) @ >30 %	510,900 t (C2) >700,000 t (P1)
Grand total		*~57,500,000 t*	*~22,400,000 t*

[1)] partly very high grades of $CaCO_3$, [2)] may be mined out, [3)] in operation, [4)] reserves/resources given by Mongolrostsvetmet Llc as of 2009, [5)] suitable for underground mining only, [6)] after the Mongolian deposit passports

The minimum grades of fluorite in underground veins (of minimum 0.3-0.4 m thickness) before beneficiation are 40-50 % CaF_2, while the grades in open pits must be much larger than 15-20 % CaF_2. Currently, MONGOLROSTSVETMET LLC applys a cut-off grade of 26-28 % CaF_2. For medium-scale to small-scale mining, the grades must surpass 30-40 % CaF_2. For commercial use, a minimum grade of 60 % CaF_2 in lump fluorite ore is required. With respect to the different applications, there are also different chemical requirements. E.g. the $CaCO_3$ content after beneficiation must be <3 % in metallurgical-grade fluorite and <1 % in acid-grade or ceramic-grade fluorspar. In general, both acid-grade and ceramic-grade fluorite have to be very pure. Optical-grade fluorite has to be even purer, colourless and translucent. Some more information is given in Table 30.

For any investment decision, it is vital that potential investors keep in mind that all the resource information given in this brochure is based on available data, i.e. historic data. There is a great deal of fluorite mining activity going on in Mongolia, not only by large mining companies, e.g. MONGOLROSTSVETMET LLC, opening and closing old and new pits and mines every few years, but also by medium-size Chinese mining companies and small-scale miners (ninjas). Fluorite deposits may be exhausted within a very short time (at least in shallow parts), and occurrences can turn into deposits after (but also without) detailed exploration. Examples of these activities are given by CHIMID-ERDENE & GRAYSON (2009).

Table 31 is a summary of the total reserves and resources of Mongolian fluorspar deposits which are economically mineable. As can be seen, the total tonnage is still huge despite a long history of fluorite mining, surpassing 57 million tonnes of ore with more than 22 million tonnes of net CaF_2. Of these tonnages, only a small part is categorised as prognostic. This puts Mongolia 4th place in terms of global fluorite reserves/resources, behind China, Republic of South Africa and Mexico. Investors may well be able to profit from this natural mineral wealth!

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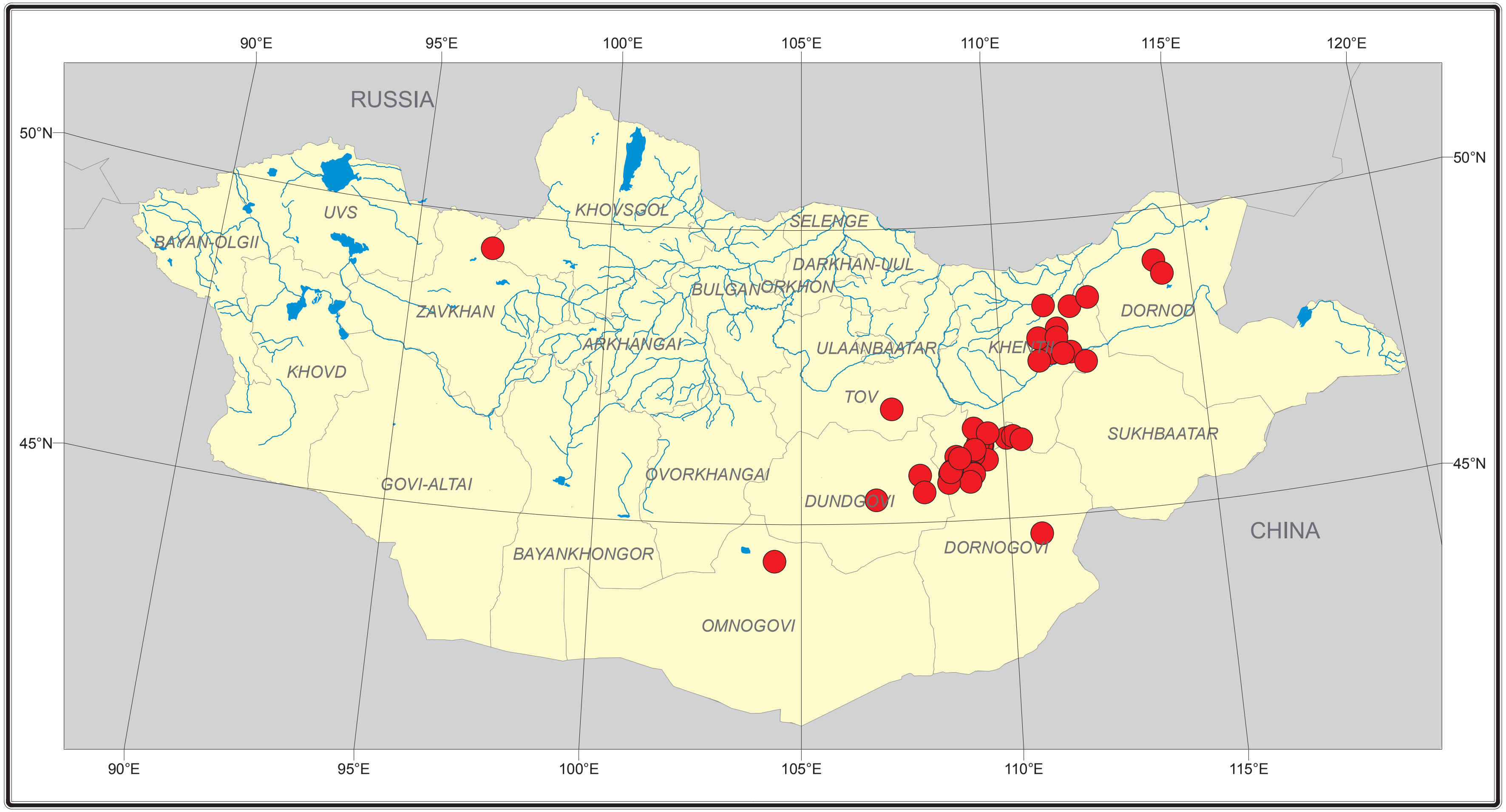
Economically mineable deposits of Fluorite in Mongolia



BGR © Federal Institute of Geosciences and Natural Ressources

Legend

● Fluorite

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

GRAPHITE

GENERAL INFORMATION AND USES

Graphite is one of the two crystal modifications of pure carbon, C, the other being diamond. Graphite which is a black, very soft, and greasy mineral is very typical of metamorphic rocks whose organic content has been metamorphosed to graphite. There are three modifications of graphite in nature. The most common is disseminated flake graphite. The second is massive vein graphite which is very rare, currently only being mined in Sri Lanka. The third is amorphous graphite formed by the metamorphism of coal beds.
Graphite is a high-tech industrial mineral. Because it is highly refractory, it is not only used in pencils, but also in crucibles, fireproof products, brake linings, and carbon brushes. Graphite is an important constituent in powder metallurgy, in self-lubrication, in batteries and in fuel cells. It is also used in the production of special plastics and graphite dispersions.

RELEVANT DEPOSITS IN MONGOLIA

Jargalsaihan et al. (1996) mention Zulegtei as a graphite mine, which is said to have been mined by “Titem Company” (United Nations 1999). Jargalsaihan et al. (1996) rank three other graphite ore bodies as deposits (Khargana Gol, Jargalant, Itgel Naidvar) and seven as graphite occurrences. Dejidmaa et al. (2001) also accept three deposits (Zulegtei, Khargana Gol, and Khutul Ulaan, which is another name for Itgel Naidvar), while 46 graphite occurrences can be summed up. Finally, Geological

Figure 54: Satellite image of the southern part of Khuvsgul National Park with Hatgal town and the Khargana Gol graphite deposit (Photo courtesy of Google Earth).

INFORMATION CENTER (2003) lists four graphite deposits (Zulegtei, Khargana Gol, Jargalant, Urd Khujiriin Gol) and 22 graphite occurrences. Urd Khujiriin Gol is most probably a misprint because in other publications this location is only mentioned as a gold deposit.

PROF. DR. LKHAMSUREN JARGAL (oral comm.) from the Mongolian University of Science & Technology only considers the Khargana Gol deposit to have some commercial potential.

Taking these statements into account, Khargana Gol, and also the Zulegtei graphite deposits but possibly also the Jargalant and Itgel Naidvar/Khutul Ulaan deposits/occurrences have to be looked at in more detail.

- The **Khargana Gol** graphite deposit (50° 23' 23.8" N , 100° 01' 50.8" E; 1,820 m a msl) lies just south-east of Khuvsgul National Park at the end of the Khargana gol side valley. It was already explored in 1931 by trenching and adits. It is a skarn type graphite, having formed at the contact between a Middle Devonian hornblende syenite dike intruding into Lower Cambrian limestone. The graphite-bearing limestone bed is 600 m long and 100 m wide. The graphite lenses are from 14 up to 20 m long and 1 to 2 m thick. Although the graphite ore looks soft, analysis proved it to be hard, most probably requiring blasting upon mining. According to old analyses, the graphite contains 56-58 % C, 15-40 % ash, 0.06 % S and some calcite. The graphite flakes are rather small in size (max. 0.2 mm) and therefore the quality is assumed to be poor. The typical chemistry of the graphite ore is given as 58.72 % SiO_2, 1.12 % TiO_2, 1.16 % P_2O_5,

Figure 55: View from old trench at the Khargana Gol deposit towards the Khargana River and further on to Khuvsgul main valley.

11.84 % Al_2O_3, 7.44 % Fe_2O_3, 8.83 % CaO, 3.75 % MgO, 7.54 % Na_2O+K_2O, 0.06 % S, and 43.77 % ash.

The new graphite ore samples taken in summer 2009 were analysed by Graphit Kropfmühl AG, Germany. The results of the analysis confirmed the old analytical data. The amount of volatiles is 1.1 wt.-%, which is quite low. The C-content between 50 and 60 wt.-% is exceptionally high and very positive. However, only a very limited number of small flakes were detected, so the graphite from Khargana Gol is not a typical flake graphite but a microcrystalline graphite. It is highly metamorphosed, approaching anthracite grade. Therefore it also cannot be used for high price purposes but only as a carbon booster or in foundry applications.

In the publications mentioned above, the reserves of graphite at Khargana Gol are given as only 320 tonnes in category A, 15,000 tonnes in category B, and 60,000 tonnes in category C1.

- The **Zulegtei** graphite deposit is located in Bayan Soum of Tuv Aimag, some 100 km south-east of Ulaanbaatar close to the main railway line, 20 km south-east of Maant railway station. It covers an area of 1.2 km^2 (other sources: 2.4 km^2). Because the reported coordinates vary (47° 04' 50" N / 47° 04' 20" N / 47° 04' 00" N ; 107° 39' 05" E / 107° 39' 40" E / 107° 40' 10" E), it could not be found during a field trip in 2008. According to Kampe (1997, 2000), the graphite at Zulegtei is bound to graphite-bearing layers of quartzite (0.22-7.0 m thick) and graphite-bearing garnet-skapolite skarn layers (0.1-6.8 m thick), which occur in bedded strata of biotite gneisses, garnet-sillimanite-biotite schists, diopside skarns and marbles. There are about 30 lens-like layers of graphitic quartzite which have variable thicknesses, lengths of up to 150 m, and graphite contents between 1-15 %. The average graphite content is close to 10 %, while the average S-content is 0.04 %. Graphite appears in the form of tiny crystals and small flakes of 0.05-1 mm, and 0.01-0.4 mm sizes. In the graphitic skarns, graphite is bound to 1x1 mm clusters of flakes of 0.05-0.07 mm size. The graphite content in the skarns varies between 5-20 % with average contents in different strata determined as 10.65 % and 12.74 %. The S-content varies between 0.005-0.12 %. For 20 high-grade (9.61-12.35 % C-content) ore layers with a total thickness of 40 m down to 50 m depth, the estimated prognosed resources total some 9 million tonnes of ore with 905,000 tonnes of graphite. An additional 32 million tonnes of low-grade (3 % C-content) ore amount to an additional 960,000 tonnes of net graphite.

  Jargalsaihan et al. (1999) also mention grades of 6.28-10.65 % of graphite and possible graphite resources of 900,000 tonnes.
  In the deposit passport of the Zulegtei deposit graphite, the grade is reported as 0.05-11.8 %. On the other hand, the C-content is reported to vary between 7.4-14.9 %. The ore was found to be easily flotable but the quality of the attained graphite was poor. The number of ore bodies varies between 7 and 16, with thicknesses of individual ore bodies varying between 1.5-18 m. Using a cut-off grade of 5 % C in general, and of 10 % C in blocks of interest, the resources were calculated as 29,400 t of ore with 3,100 t of graphite in category C1, 188,000 t of ore with 10,200 t of graphite in category C2, and 121,400 t of ore with 4,200 t of graphite in category P.

- **Jargalant** is the name of a graphite deposit in Bayanjargalan Soum of Tuv Aimag. The deposit was explored in detail between 1991 and 1993 and consists of six ore bodies of 500-1,500 m length, and 1.5-15 m width. Graphite occurs in flakes, crystals, and grains of 0.05-1.5 mm length and 0.01-0.1 mm width. The average grade of graphite is 12 % with estimated resources of 637,900 tonnes of graphite in category P2.

- **Khotol Ulaan** or **Itgel Naidvar** is a graphite deposit located in Dalanjargalan Soum of Dornogovi Aimag. Because the railroad line passes nearby, this location is quite favourable. The ore body at Khotol Ulaan is 200 m long, on average 60 m wide, and at least 120 m thick. It contains from 1.13-12.41 % C, but on average 2.5 %. The amount of volatiles is only 0.005-0.6 %. The sulphur content varies from 0.002 to 0.35 %. Graphite is bound to quartz-graphite-andalusite-sericite schists of Precambrian age, which were intruded by Permian granitoids and gabbro-diorite dikes. Resources of ore using a cut-off grade of 2.6 % C for an ore zone of 200 m x 60 m x 40 m size are 200,800 tonnes in category C2, i.e. about 5,000 tonnes of net graphite. However, as graphite is widespread in this area, the geological resources are estimated as 1 million tonnes of graphite-enriched ore. It must be mentioned, however, that the Khotol Ulaan deposit could not be found during a field trip in September 2010 at the coordinates given in the deposit passport.

Not formally deposits but occurrences of potential economic interest are:

- **Ovor Maraat** in Alag-Erdene Soum of Khuvsgul Aimag. This occurrence was formed at the contact between Early Devonian alkaligranites and calcareous shales as well as limestones of Early Cambrian age. It consists of seven ore bodies of 7.5-1,900 m in length, and 0.6-350 m in thickness. While there is no precise data on the size of the graphite flakes, the graphite grade varies between 10.3 and 12.9 %. The ash content is highly variable, i.e. between 6.6 and 71.3 %. Sulphur was analysed as 0.1-0.22 %. Prognosed resources for two ore bodies only were estimated as 1.54 million tonnes of ore.

- **Tuvshin Uul-1** in Tsenkhermandel Soum of Khentii Aimag. Here marblised limestone and widespread quartzitic quartz-mica schists contain a graphite-rich contact zone of 1-1.5 km length, 100-500 m width, and 0.2-2.5 m thickness. The graphite partly occurs as 2-3 mm large flakes and partly finely disseminated. Its grade varies between 6.9 and 40.7 % resulting in a resource of 18,443 tonnes of net graphite. Tuvshin Uul is another, but much smaller occurrence close nearby.

- **Tomortein Ovoo** in Bayanjargalan Soum of Dundgovi Aimag. Because this occurrence was only prospected roughly, information is limited to its shape (lens of 500 m length, 250 m width, and 25 m thickness), volume (3,125,000 m^3), grade (35-40 % graphite), impurities (pyrite, goethite, and limonite), and the size of the graphite flakes (0.009-0.18 mm).

REQUIREMENTS AND EVALUATION

The minimum reserves for deposits of flake graphite to be quarried in open pits are 1,000 tonnes of graphitic carbon. To be suitable for mining, weathered graphite ore with large flakes should contain >2 wt.-% fixed carbon C, and unweathered ore should contain >5 wt.-% C. For underground mining, the minimum C-content is 20 wt.-%. Sulphides like pyrite or pyrrhotine, and intergrowths of mica and graphite are undesirable and need to be separated out during beneficiation. Analyses and application tests of graphite ores should always be performed by experienced graphite mining and processing companies only.
All raw graphite ores have to be milled and flotated after mining. Graphitic ore should therefore be made up of just one of the three graphite types mentioned above, because

a mixed ore cannot be separated by flotation, and the concentrate will have unusual parameters after dressing. While there will presumably also be customers for such mixed concentrate, marketing will be difficult and time-consuming.

Graphit Kropfmühl AG, Germany, which is a very experienced graphite mining and processing company, judges the Kharganal gol graphite as very low quality. Russian geoscientists exploring this deposit in 1931 came to a similar conclusion. And because the reserves are also quite limited, this deposit is not worth mining.

The parameters quoted by Kampe (1997) for mining the Zulegtei graphite deposit are also unfavourable. The graphitic ore is compact, which means difficult separation and even reduction of already very small grain sizes of graphite. Graphite attained by flotation tests during previous exploration campaigns was also of poor quality.

While the Tomortein Ovoo graphite occurrence was reported to be of very large volume, the graphite flakes found are of extremely small size, and impurities seem to be abundant.

The parameters determined for the Jargalant and Khutul Ulaan/Itgel Naidvar deposits as well as for the Ovor Maraat and Tuvshin Uul-1 occurrences look much more favourable. However, no detailed and conclusive analysis by an experienced graphite mining and processing company has been performed yet, and are absolutely necessary before final evaluation.

RELEVANT LITERATURE

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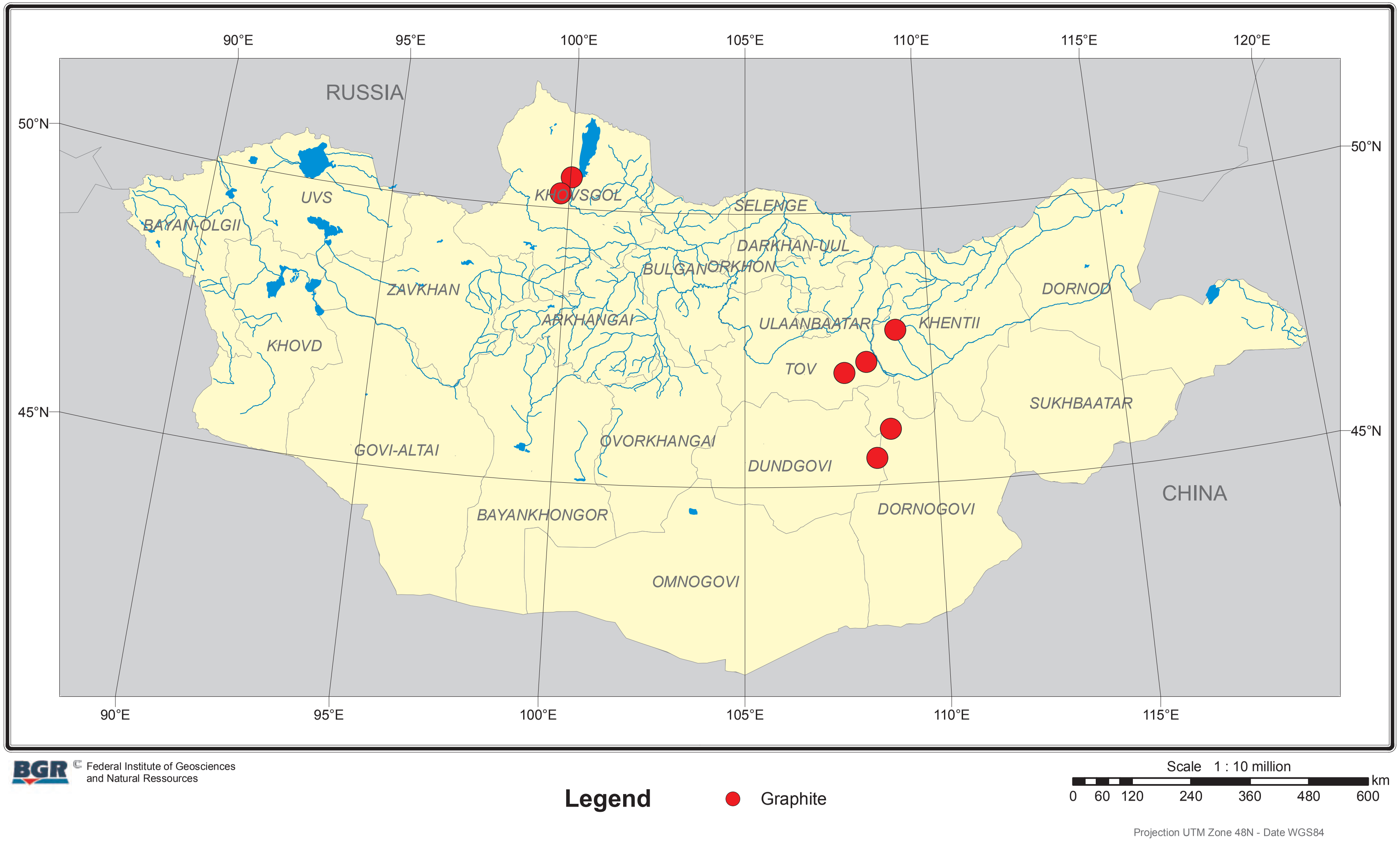
Deposits and important occurrences of Graphite in Mongolia



GYPSUM

GENERAL INFORMATION AND USES

Gypsum, $CaSO_4$ x $2H_2O$, is a very important industrial mineral and used in a variety of building materials, like gypsum wall boards and plaster of Paris. Gypsum is also needed as a retarding agent when grinding cement clinkers, and this is also the most important application in Mongolia. Some 15,000 tonnes of gypsum per year are estimated to be needed in Mongolia for this use only. However, gypsum can also be used as a fertilizer, as a carrier substance in the chemical industry, or as a special filler in the paper and paint industries.

RELEVANT DEPOSITS IN MONGOLIA

Jargalsaihan et al. (1996) list Unegt Uul, Baruun Tserd, and Taragt as gypsum mines, as well as Shire Uul, Modon Us, and Tavan Tolgoi as gypsum deposits. Five other locations are ranked as occurrences. Dejidmaa et al. (2001) rank Baruun Tserd, Shiree Uul, Taragt, Tavan Tolgoi, Modon Us, Tsagaan Tsaviin Khudag, Tsagaan Ergiin Khudag and Unegt Uul as deposits (8), while 35 gypsum occurrences are named. Geological Information Center (2003) also mentions eight gypsum deposits (Baruun Tserd, Biger, Shiree Uul, Shiree Uul-II, Taragt, Tavan Tolgoi, Modon Us, and Ongot/Unegt Uul), together with 36 gypsum occurrences.

In the 1980's gypsum from Unegt Uul and Taragt deposits were mined and transported to Darhan for cement production. Because transportation costs rose sharply after 1990, mining stopped soon afterwards (Kampe 1997).

In this brochure, the Baruun Tserd, Shiree Uul, Taragt, Tavan Tolgoi, Tsagaan Ergiin Khudag, Tsagaan Tsaviin Khudag, Modon Us, Biger and Unegt Uul gypsum deposits/occurrences will be evaluated for their potential.

- The **Baruun Tserd** gypsum deposit lies in Sagil Soum of Uvs Aimag at 50° 25' 42.2" N , 91° 46' 47.0" E; 1,107 m a msl, just 6 km east of the main asphalt road from Ulaangom to the Russian border and can be reached via a good side track. The deposit was explored in 1976 by trenching and drilling. However, drilling and reserve calculation was restricted to a depth of 60 m as severe cut-off requirements were applied at that time: good quality gypsum, minimum 3 m thickness of gypsum, and ratio of overburden to ore of <2 to 1. By applying these requirements only two gypsum lenses of interest were finally identified: one 150 m long in the west, and a second 250 m long in the east. The thickness of gypsum in these lenses varies from 4 to 15 m. At Baruun Tserd, the gypsum lenses dip 30-50° to the north. More, but non-economic lenses, were found further to the east and west. Total reserves down to a depth of 60 m were calculated as only 236,000 tonnes in category A+ B, 173,300 tonnes in category C1, and 47,500 tonnes in category C2.

However, as can clearly be seen on the satellite image (cf. Figure 56), the Baruun Tserd gypsum deposit lies at the southern edge of a large box fold, sheared off in the east. And as the gypsum is of marine origin it is not restricted to lenses but to a massive horizon. And as this horizon is dipping to the north in the south of the box fold, it should be traceable by more exploration all around the box fold and in the centre of the box fold at greater depth, too. Horizontal layering of the strata can be expected between depths of 1,500 m (30° dip) or even 2,800 m (50° dip) below surface. At these great depths, however, gypsum might be converted to non-valuable anhydrite. Nevertheless, it all suggests that Baruun Tserd is just a small outcrop in the south of a presumably huge gypsum deposit. The total geological gypsum resources therefore may easily reach several hundred million tonnes.

Figure 56: High definition satellite image of a large box fold north of Ulaangom, sheared off in the east (now a river). The road from Ulaangom to the Russian border enters the image in the lower left corner. The Baruun Tserd gypsum deposit lies in the south of the box fold with strata dipping 30-50° to the north (Satellite image as of 4 May 2005, Altitude 15.03 km, Photo courtesy of Google Earth).

The gypsum layer at Baruun Tserd is of Lower Devonian age. It is fine-grained and massive, but weathered to fibrous or cavernous gypsum where it crops out at the surface. The colour is whitish-grey to transparent and partly yellowish. Analyses of four different samples of massive gypsum rock, together with one sample of fibrous gypsum from the surface, gave extremely similar and very promising results (cf. Table 32). This data is confirmed by analysis of one typical sample from the Baruun Tserd gypsum deposit by Knauf Gips KG, Germany, which states that this gypsum can be used for all purposes (cf. Table 33).

On the other hand, the old analytical data from exploration is much more variable, which may be due to the sampling of disturbed or non-massive gypsum rock in low-grade layers.

Figure 57: Layer of massive gypsum in the north wall of a small abandoned quarry at Baruun Tserd.

Table 32: Selected chemistry of bulk rock analysis from Baruun Tserd gypsum. Analyses results of gypsum in lenses according to deposit passport. All other samples, XRF analysis by BGR.

Chemistry	Western lens	Eastern lens	Gypsum rock (n=4)	Fibrous gypsum	Limits / Ranges for applications
	wt.-%				
SiO_2	1.06-7.52	3.1-20.96	0.70-1.12	1.26	
Al_2O_3	0.18-1.81	0.64-4.35	0.15-0.25	0.26	
Fe_2O_3 total	0.11-0.63	0.25-2.61	0.07-0.12	0.09	
MgO	0.1-1.41	0.1-1.21	0.003-0.007	0.004	<0.1(<0.05) (gypsum wall boards)
CaO	29.46-39.99	24.41-32.71	32.218-32.719	32.169	
Na_2O	n.a.	n.a.	<0.01	0.02	<0.06
K_2O	n.a.	n.a.	0.007-0.014	0.068	
(SO_3)	38.55-51.45	26.41-43.44	44.04-44.94	44.88	
(Cl)	n.a.	n.a.	6-13 ppm	8 ppm	<0.01
Sr	n.a.	n.a.	721-1113 ppm	186 ppm	
LOI	7.66-18.80*	11.21-17.91*	20.94-21.45	21.06	
total				*99.819*	
Calculated					
$CaSO_4 \times 2H_2O$	82.90-110.64	56.79-93.42	94.71-96.64	96.51	>80 (gypsum wall boards)
					>70 (retardant in cement making)

* = H_2O

Table 33: Wet chemical analysis from Baruun Tserd gypsum rock by Knauf Gips KG, Germany.

Analytical Report Hand sample									
Sample from:		**Baruun Tserd (Mongolia)**							
Crystalline water (%)	$CaSO_4$ $*2H_2O$ (%)	$CaSO_4$ (%)	$CaCO_3$ (%)	$MgCO_3$ (%)	HCl (%)	Na_2O (%)	K_2O (%)	Chloride (%)	Swellable clay (%)
20.0	95.6	0.6	1.3	0.4	1.3	0.01	0.02	12	<0,2

- The remote **Shiree Uul** gypsum deposit is one of the largest gypsum deposits in Mongolia. It has a low grade however. It is located in Delgerkhangai Soum of Dundgovi Aimag and is made up of gypsum concretions intermingled with clay minerals. The almost horizontally layered gypsum-bearing beds contain layers of concretions up to 1 m thick and with varying clay contents. Gypsum also occurs in the form of lenses of variable thickness and length. Other sediments found are sand, gravel, and marls, which were all deposited in a lagoon during Middle to Upper Oligocene time. The average combined thickness of the lagoonal sediments is 10-15 m.

The deposit can be divided into a northern (Khoit) and a central (Tuv) ore body which lie 1.5 km apart. On average, the northern ore body is 2.9 m thick, 300-400 m wide, 800 m long, and is covered by 1.8 m of overburden. The average grade of gypsum in the ore body is 45 %, and 84 % in the concretions. It contains estimated gypsum reserves of 566,000 tonnes in category C1.

The central ore body is covered by 1.9-2.0 m of overburden, is 6.5-9.0 m thick, 500-600 m wide, and 1,100 m long on average. Initial estimated gypsum reserves are 717,000 tonnes in category B, and 3,167,600 tonnes in category C1. The average grade of gypsum in the ore body in category B is 50.1 %, and 45.7 % in the category C1, and in the concretions 83.5 %. All reserve calculations are based on a cut-off grade of 36 % gypsum, and a minimum thickness of 1.0 m of the gypsum-bearing layer.

The average chemical composition of the gypsum was analysed as 28.46 % CaO, 0.38 % MgO, 40.48 % SO_3 and 11.31 % insolubles, i.e. 86.7 % $CaSO_4$ x $2H_2O$.

- Close nearby to the Shiree Uul deposit lies the equally remote **Taragt** gypsum deposit. It was first mined in 1989 with some 1,500 tonnes of waste rock, and 35,000 tonnes of gypsum quarried, the latter having been used for cement production. As of 2010, limited mining by excavator can be reported both from the Taragt and Shiree Uul deposit sites. The Taragt deposit is of Upper Cretaceous age and of non-marine origin. It is made up of irregular concretions of gypsum from 10-15 to 20-30 cm in diameter. These are concentrated in two ore bodies called Taragt and East (Zuun Khereg).

  Gypsum-bearing beds in the Taragt ore body (1,100 m long x 750 m wide) dip gently 5° to the southwest, are 0.25-8.0 m thick, on average 2.5-3.0 m, and are covered by up to 3.0 m of massive, dense, weathered brown clay. The average chemical composition of the gypsum was analysed as 7.68-15.50 % SiO_2, 0.06-0.15 % TiO_2, 0.60-1.32 % Fe_2O_3, 26.01-28.85 % CaO, 0.65-1.07 % MgO, and 34.32-40.42 % SO_3, i.e. 73.8-86.9 % $CaSO_4$ x $2H_2O$.

  The eastern ore body is elongated in a north-easterly direction, has aclinal beds of 5-7.8 m thickness, and is covered by only 0.2-1.2 m of overburden. The grades of $CaSO_4$ x $2H_2O$ vary between 44.7 to 74.5 %. Total initial reserves calculated at a minimum grade of 65 % of gypsum were 17,800 tonnes in category A, 174,200 tonnes in category B, 588,800 tonnes in category C1, and 4,900 tonnes in category C2. Re-calculation after the first year of mining, i.e. 1989, gave remaining total reserves of 699,200 tonnes of gypsum in A+B+C1 categories.

- The **Tavan Tolgoi** “gypsum deposit” is located in Tsogttsetsii Soum of Umnugovi Aimag. It was well explored in 1981-1982 by mapping, trenching, drilling, and a range of sample analysis. The gypsum occurs in the form of small chips and thin veins in bluish to black-grey clays of Upper Cretaceous age. The average chemical composition of the clayey gypsum was analysed as 47.37 % SiO_2, 8.99 % Al_2O_3, 4.13 % Fe_2O_3, 14.54 % CaO, 1.29 % MgO, 23.12 % SO_3, and 2.6 % LOI, i.e. only 37.1 % $CaSO_4$ x $2H_2O$. This quality was recognised as being not suitable for cement production.

  The layers of gypsiferous clay have a combined length of 1,200-1,300 m, widths of 350-700 m, on average 450 m, and a thickness of 5.5-6.7 m. The average thickness of the overburden is 2.3 m (1.3-7.6 m). The total resources of gypsum were estimated as 1,979,500 tonnes in category C1. Resources of other commodites discovered in the same deposit area were estimated as 77,760 tonnes of Na_2CO_3, 15,552 tonnes of $NaHCO_3$, and 41,797 tonnes of NaCl.

- The **Tsagaan Ergiin Khudag** "gypsum deposit" is located in Mandakh Soum of Dornogovi Aimag. Here, covering an area of 2,500 m length and 100-400 m width, coal-bearing sandstones of Upper Cretaceous age contain a thin seam of 1.5 to 21 cm thickness, on average 15 cm, made up of 4-18 thin stringers of gypsum, lying beneath 1.9 m of overburden. The stringers contain gypsum in the form of flakes and crystals from 1-5 cm in size. Although chemical analysis gave contents of between 76.4 to 97.7 % $CaSO_4$ x $2H_2O$, the reserves are definitely too small (24,000 tonnes in category A+B, and 20,000 tonnes in category C1) and the overburden too thick, to allow any realistic thoughts of economical mining at all.

- **Tsagaan Tsaviin Khudag** is another rather small gypsum deposit also lying in Mandakh Soum of Dornogovi Aimag. It was explored in 1970 by trenching, digging, drilling, and chemical analysis. The gypsum content is highly variable (50.1-81.9 % $CaSO_4$ x $2H_2O$) and is bound to translucent and small crystals in a layer of gypsiferous clay of Upper Cretaceous age. This layer is 1,300 m long, 18-19 m wide, and 0.2-1.9 m thick, on average 1.5 m. The average thickness of the overburden is 1 m. This deposit contains estimated resources of 62,500 tonnes of gypsum in category C2 only.

- The **Modon Us** "gypsum deposit" is located in Olziit Soum of Dundgovi Aimag. Gypsum makes up 91 - 98 % in 26 different gypsum bearing beds which belong to Lower Cretaceous terrigenic sediments. These beds crop out in northern (7) and southern (19) parts of anticlinal folds, each area of outcrop covering around 2 to 25 km^2. The gypsum-bearing beds are 0.1-1.0 m thick, 24-560 m long, 1.0-4.0 m wide, and dip at 4-9^o in the northern, and 10-15^o in the southern parts of the folds. The estimated reserves are 3,478 t of gypsum in category B, and 5,703 tonnes in category C1. Because these reserves are extremely small, Modon Us should not be called a gypsum deposit but rather an occurrence.

- The **Biger** "gypsum deposit" can be found in Biger Soum of Govi-Altai Aimag. It is made up of gypsum concretions within gypsiferous clays of Oligocene age. The calculated category C2 resources in 1996 amount to 12,423 tonnes of concretions grading 90.99 % $CaSO_4$ x $2H_2O$ and 6,344 m^3 of clay grading 25.56 % $CaSO_4$ x $2H_2O$ only.

- Finally, there is the **Unegt Uul** (Ongot Uul) gypsum deposit which is also located in Dornogovi Aimag, but in Saikhandulaan Soum. It was discovered in 1958/59 and explored in 1970 and 1975 by extensive trenching, digging, and drilling. Like the majority of the other gypsum deposits in Mongolia, it is of Cretaceous age and of terrestrial to lagoonal origin. Thus the gypsum occurs within clay, sandy loam, sand and loam, i.e. in the form of crystals of selenite of 1-2 cm size. The grade of $CaSO_4$ x $2H_2O$ varies from 23.2-68.0 %.
  The deposit consists of three layers: the main layer is located in the northern limb of an anticline. It is 4,000 m long, 20 m wide, and 2.5-19.7 m thick. The average overburden thickness is 2.3 m. The main layer contains 51 % of the reserves. The southern layer is located in a dome-like fold. It is 600 m long, 20-30 m wide, and 7 m thick. The average thickness of overburden is 2.3 m. The northern layer is located in the northern part of the northern limb of the anticline. It reaches 1,200 m in length, and 0.8-8.0 m in thickness, and is also covered by 2.3 m of overburden.
  The initial calculated total reserves of gypsum were 129,800 tonnes in category B, 347,300 tonnes in category C1, and 53,500 tonnes in category C2. During a first period of mining between 1971 and 1975, the complete southern layer was mined out (96,000

tonnes). After 1976, another 112,200 tonnes were mined from the northern layer, leaving resources of only 19,700 tonnes in category C2. Also after 1976, 176,900 tonnes were taken out of the main layer, leaving some 500,000 tonnes (after recalculation) of gypsum in category C2. These resources were most probably not mined, because mining them is not possible economically.

REQUIREMENTS AND EVALUATION

Gypsum should be a highly sought after and valuable commodity in Mongolia because the demand for cement production is rising steadily and imported gypsum is quite expensive. Good quality gypsum will always fetch a good price in Mongolia!

For use as a retardant, a minimum of 70 wt.-% $CaSO_4 \times 2H_2O$ has to be guaranteed at all times. Fe_2O_3, chloride, sodium, and any other soluble salts are undesirable. MgO has to be <3 wt.-%. For the production of gypsum wall boards, the $CaSO_4 \times 2H_2O$ content has to be >80 wt.-%. Neither anhydrite, free quartz, soluble salts nor clay minerals should be present. The content of swelling clays must be <1 wt.-%. The carbonate content has to be low. Chloride must be <100 ppm, and Na_2O <0.04 wt.-%. For all applications, a steady supply of material of constant quality is desirable. Thus reserves should contain at least 100,000 tonnes of mineable raw gypsum.
Taking these requirements into account, the known gypsum deposits in Mongolia can be evaluated as follows:

Potential investors should focus on the already known gypsum deposits at Baruun Tserd, Shiree Uul, and Taragt. While only Baruun Tserd may be suitable for large-scale commercial mining, it needs much more exploration. It also lies in the north-westernmost corner of Mongolia. On the other hand, the Shiree Uul and Taragt gypsum deposits, both located in entral Dundgovi Aimag, are obviously suitable for small-scale mining. However, both deposits need hand-picking of the gypsum concretions.

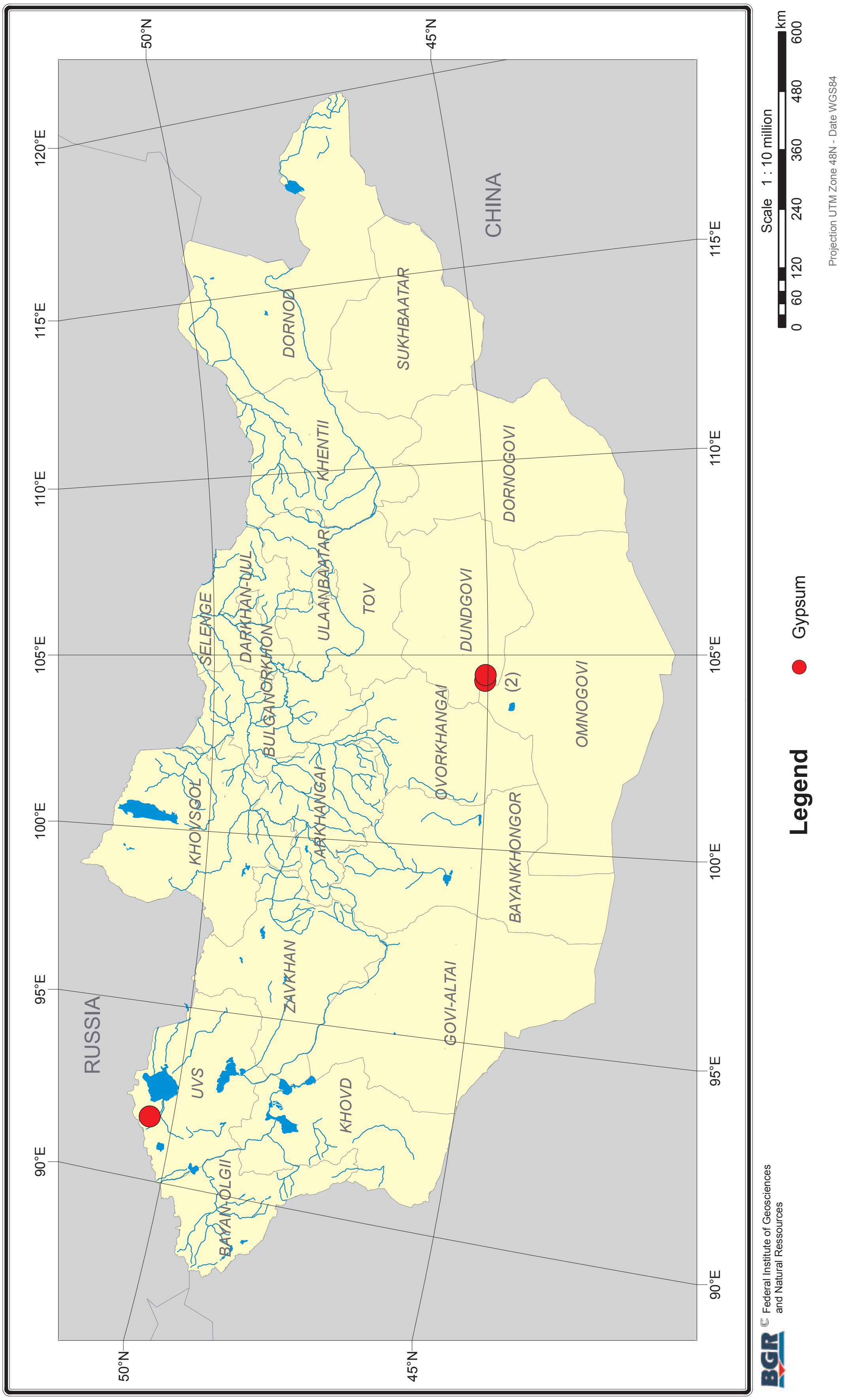
Table 34: Evaluation of gypsum deposits in Mongolia.

Name	Size	Grade	Form of gypsum	Evaluation
Baruun Tserd	Very large	Very high	Massive, thick beds	Presumably world-class deposit
Shiree Uul	Medium	Very low	Concretions	Suitable for small-scale mining and processing only
Taragt	Medium	High	Concretions	Suitable for small-scale mining and processing only
Tavan Tolgoi	Medium	Very low	Chips, thin veins	Occurrence. Not economically mineable
Tsagaan Ergiin Khudag	Very small	High	Thin seams	Occurrence. Not economically mineable
Tsagaan Tsaviin Khudag	Very small	Medium	Crystals	Occurrence. Not economically mineable
Modon Us	Very small	Very high	Massive, thin beds	Occurrence. Not economically mineable
Biger	Very small	High	Concretions	Occurrence. Not economically mineable
Unegt Uul	Small	Medium	Crystals	Mined out.

RELEVANT LITERATURE

Ganbaatar, T. & Majigsuren, Y. (2009): Mineral composition, geological structure and special uses of gypsum (in Mongolian).- 99 pp., 42 fig., 17 tab., Ulaanbaatar.

Deposits of Gypsum in Mongolia



KAOLIN AND KAOLINITIC CLAY

GENERAL INFORMATION AND USES

Kaolin, also known as china-clay when occurring in primary deposits, is a commodity made up primarily of clay minerals of the kaolin group. These minerals, the most important being kaolinite, are very rich in silica, alumina and water. Kaolinite is fine-grained, chemically inert, white, coating, soft, non-abrasive, plastic, and refractory. Kaolinitic clays are also called ball clays. The primary use of kaolin is in the production of paper, as it is a key ingredient in creating glossy paper. It is also used in ceramics, medicine, bricks, coated paper, as a food additive, in toothpaste, in cosmetics, and in numerous other applications. Kaolinitic clays are used in ceramics, as feed additives for animals, and as fillers in chemicals.

RELEVANT DEPOSITS IN MONGOLIA

Information on kaolin resources in Mongolia is quite limited, with one kaolin occurrence and six kaolin deposits mentioned by Jargalsaihan et al. (1996). These deposits are Tsogt Ovoo, Mandal Ovoo, Ulaan Nuur, Elgen Govi, Bayanduureh and Tavan Tolgoi. Dejidmaa et al. (2001) agree on the first four ones and also name Tsagaan Khotgor.

The **Tsogt Ovoo** kaolin deposit is located along a NW-SE trending fracture zone within granites in Tsogt Ovoo Soum of Umnugovi Aimag, some 80 km north of Dalanzadgad town. The deposit was explored in 1966/67 and 1986/87. According to these exploration campaigns, the lenticular kaolin lens is 100-200 m wide, on average 142 m, 150-420 m long, on average 324 m, and 1.3-11.0 m thick, on average 5.0 m. The kaolin is covered by 4-15 m of overburden. While the kaolin-rich clay is light or yellow in colour, there is also a black to dark-grey plastic clay with a characteristic H2S smell. Analyses prove that the various colours are caused by different mineralogical and chemical compositions (cf. Table 35).

The kaolin is composed of kaolinite, quartz, grains of feldspar, illite/mica and some calcite. The yellow kaolin is enriched in illite. 25-61 %, on average 37.2 % of the components are <63 µm, 38-74 %, on average 62.8 % are >63 µm.

The calculated reserves and resources are 109,300 tonnes of raw kaolin (38,500 tonnes of washed net kaolin) in category B, 237,500 tonnes of raw kaolin in category C1, and 616,600 tonnes of raw kaolin in category C2. In 1966, small quantities of the kaolin were used by a porcelain factory in Ulaanbaatar.

The **Mandal Ovoo** kaolinitic clay deposit is situated 8 km south-east of Mandal Ovoo village in Umnugovi Aimag. It was prospected in 1966/67 and 1985. The clay is of Lower Cretaceous age with three layers spread over an area of 500 x 1,000 m, and separated by layers of conglomerates and gravel-rich clay. Layer 1 has 25-160 m width, 3.0-13.0 m thickness and is covered by 0.0-6.4 m of overburden. Below 0.1-4.2 m of coarse-grained material, layer 2 has 1.9-27.7 m

Table 35: Chemical composition (in %) of kaolin-rich clay from the Tsogt Ovoo kaolin deposit, after deposit passports.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	H_2O	LOI
Light kaolin	47.9-50.5		31.8-35.0	1.0-1.2	1.4-1.7	0.3-0.5			0.1-2.7	
Yellow kaolin	47.0-49.0		35.5-36.6	1.5-1.8	0.5-0.8	0.3			0.3-1.3	
Average	50.29	0.86	31.98	1.34	0.85	0.32	2.25	0.47	0.66	11.47

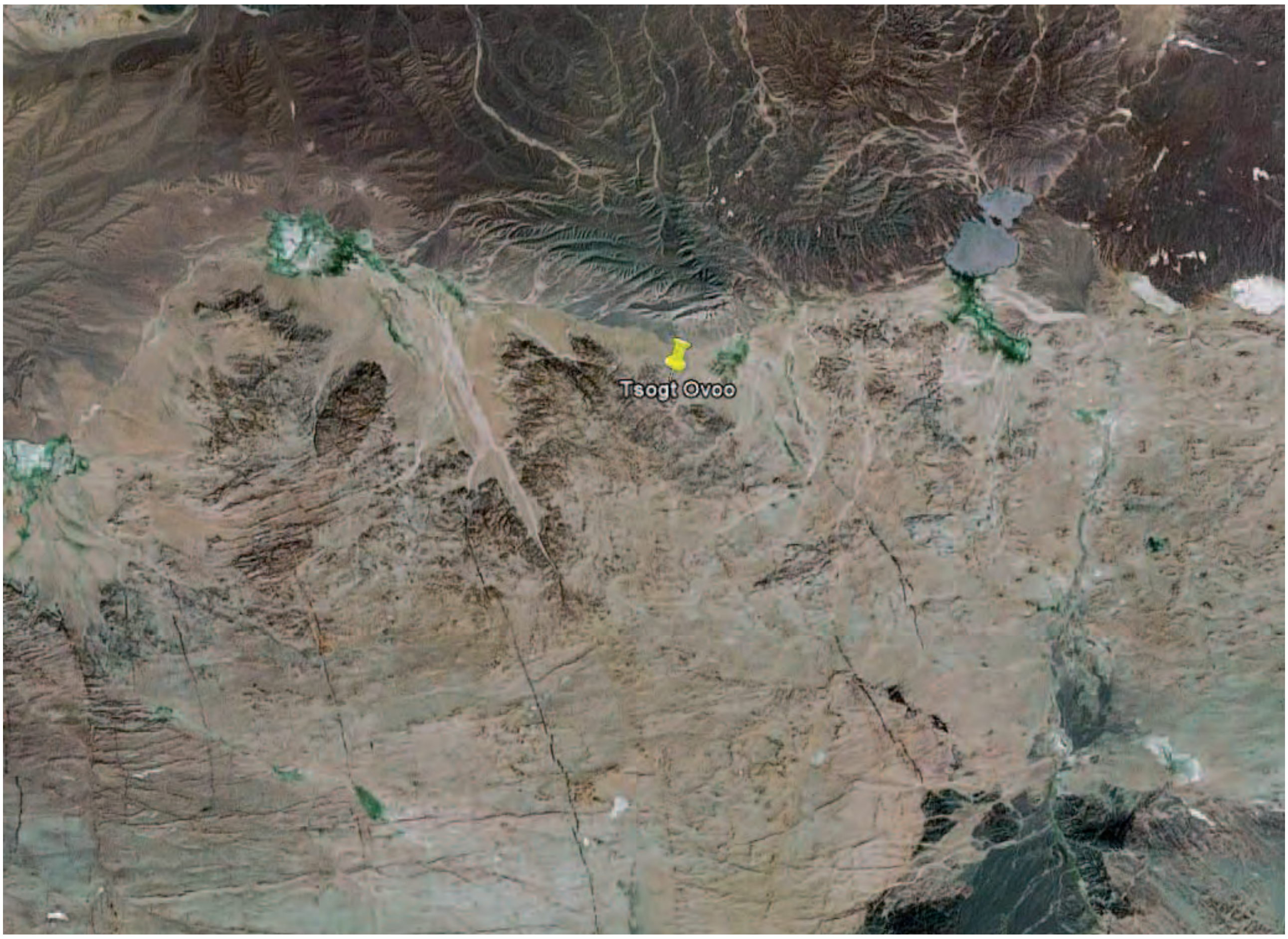


Figure 58: Satellite image showing a huge and fractured granite plateau in Umnugovi Aimag with the Tsogt Ovoo kaolin deposit at its northern boundary. Photo courtesy of Google Earth.

thickness, underlain by another intermediate coarse-grained layer of 0.0-6.4 m thickness and layer 3, which is 3.0-11.6 m thick. Ground water was not detected down to 35 m depth

The colour of the clay is grey, in some parts yellow or reddish where enriched with iron (cf. Table 36).
Mica, kaolinite, quartz and feldspar are the dominant minerals. 75.71-98.94 % of the clay falls in the grain size fraction <50 µm. The calculated reserves are 1,886,800 m^3 (or tonnes?) in category C1, and 1,863,000 m^3 (or tonnes?) in category C2.

The kaolinitic clay deposit of **Ulaan Nuur** is located in Bayanjargalan Soum of Dundgovi Aimag in the proximity of Ulaan nuur. The clay is bound to four major and two minor lenses of effusive-sedimentary rocks of Jurassic age

Table 36: Chemical composition (in %) of kaolin-rich clay from the Mandal Ovoo kaolinitic clay deposit, after deposit passport.

	SiO_2	$TiO_2 + Al_2O_3$	Fe_2O_3	CaO	MgO	$K_2O + Na_2O$	LOI
1st Layer	63.97	23.71	2.01	1.02	1.05	0.73	
All Layers	61.14-68.19	20.0-25.0	0.52-3.46	0.52-1.75	0.32-2.67	0.1-3.6	
Average	65.68	21.44	1.66	1.07	1.17	1.28	6.09

and coal-bearing beds of Lower Cretaceous age. The main parameters of these lenses are given in Table 37.

According to the deposit passport, the chemistry of the clays is: 53.1-63.9 % SiO_2, 0.43-1.15 % TiO_2, 10.8-15.8 % Al_2O_3, 1.16-4.05 Fe_2O_3, 0.7-1.0 % CaO, 0.4-0.8 % MgO, 0.88-2.1 % K_2O, 0.68-1.3 % Na_2O, and 8.6-25.7 % LOI. The preliminary mineralogical composition is given as kaolinite, metahalloysite, illite, and minor montmorillonite. The comparatively high SiO_2 content is an indication of the existence of quartz. On average, the grain size of the clays is 49.85 % >60 µm, 11.4 % 60-10 µm, 9.35 % 5-1 µm, and 26.05 % <1 µm.
The clays are of light grey colour, but contain a lot of organics. They alternate with lignite and can only be quarried as a by-product of lignite production. Ground water was discovered 7.4-22 m below surface. The calculated reserves and resources are 349,100 tonnes of clay in category B, 566,100 tonnes of clay in category C1, and 503,700 tonnes of clay in category C2.

Kaolinitic clay also was reported to occur in or on top of the lignite/coal deposits of Elgen Govi (Tsagaan Ovoo), Bayanduureh, Tavan Tolgoi and Khotgor. Because the clay within or on top of these, and most probably many other coal deposits, has either not been analysed or does not show typical characteristics of kaolinitic clay, these potential deposits are not dealt with in this guide.

REQUIREMENTS AND EVALUATION

To be economically mineable, reserves of deposits of raw kaolin or kaolinitic clay must be larger than 500,000 tonnes. According to the Russian classification system, kaolin deposits with <5 million tonnes of net kaolin should be grouped as small. The higher the percentage of kaolinite and the lower the grain-size, the higher the value of the kaolin. Chemically, the contents of all soluble salts and all other elements besides silica and alumina should be very low. LOI must be <14 wt.-%. Except for the production of paper, extremely low levels of toxic elements like F, Mn, Cu, As, Cd, Pb, and Hg have to be guaranteed.

According to Kampe (1997), premium quality kaolinitic clays do not exist in Mongolia. The amount of kaolinite is not sufficient, and the illite, iron and carbonate contents are higher than in the most common kaolinitic clays. Re-evaluating the potential of the kaolin deposits in Mongolia, the Tsogt Ovoo deposit might have the highest economic potential as it seems to be of the best quality; however, it is located far from any infrastructure and 440 km south of Ulaanbaatar.

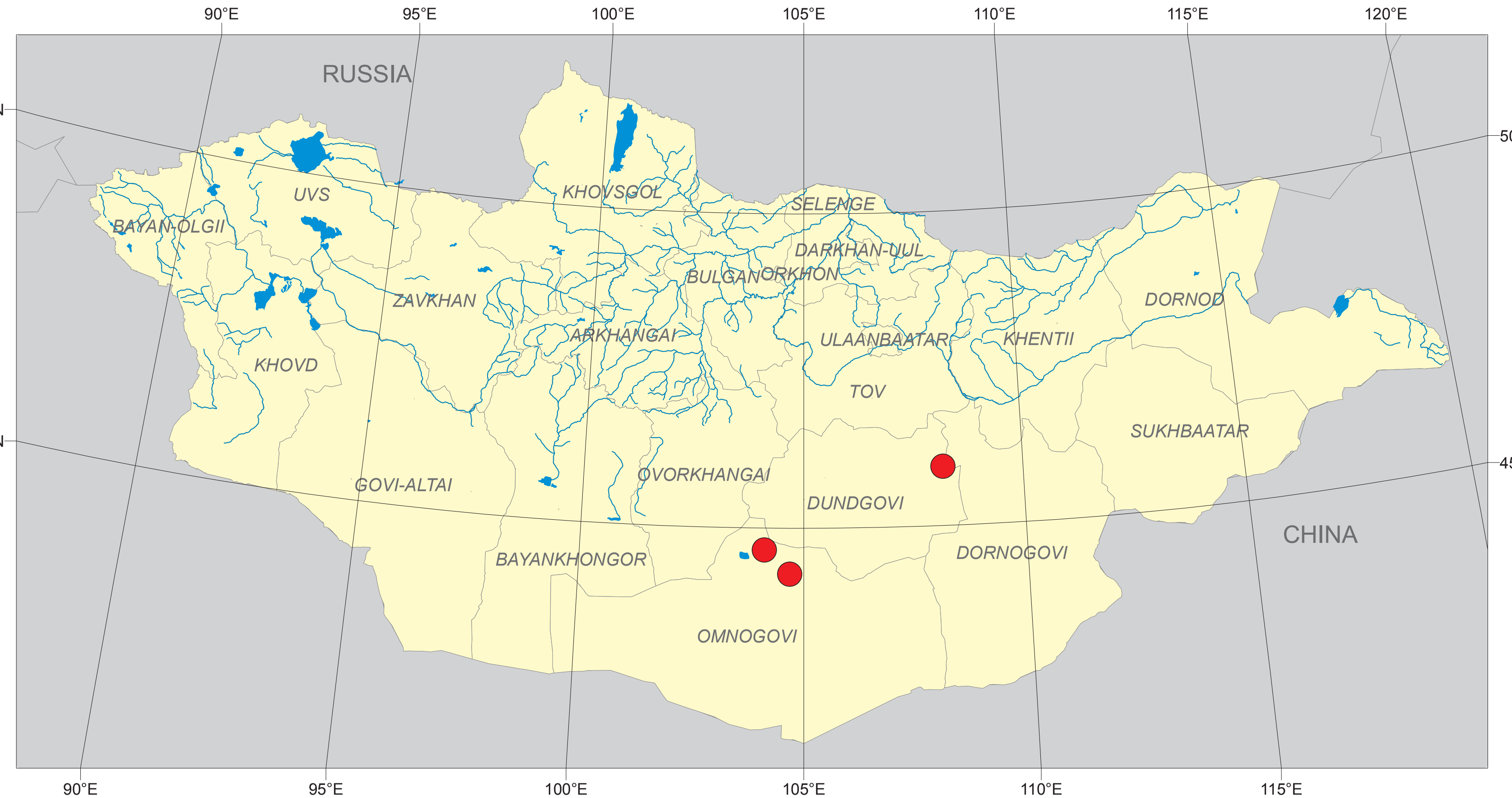
Based on the chemical composition, the clays of Mandal Ovoo can possibly be used in the ceramics industry, but to ensure this, further information is needed. The aluminium content seems to be very low for the production of refractories. However, this deposit is very large.

Table 37: Main parameters of clay lenses of the Ulaan Nuur kaolinitic clay deposit, taken from deposit passport.

Lens #	Average length (m)	Width (m)	Thickness (m)
I	820	28-82, avg.: 55	avg.: 3.7
II	1,000	12-60, avg.: 36	1.3-5.0, avg.: 3.15
IIa	94	32-50, avg.: 41	avg.: 2.75
IIb	220	36-86, avg.: 61	1.4-2.7, avg.: 2.05
III + IIIa	25	avg.: 100	1.0-2.0 + 1.5-2.6

The clays at Ulaan Nuur might be used for heavy clay ceramic production, but the aluminium content also seems to be much too low for the production of refractories. Additionally, quarrying this kaolinitic clay deposit is dependent on lignite mining.

Deposits of Kaolin and Kaolinitic Clay in Mongolia



BGR © Federal Institute of Geosciences and Natural Ressources

Legend

● Kaolin and Kaolinitic Clay

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

MAGNESITE

GENERAL INFORMATION AND USES

Magnesite, chemically $MgCO_3$, is a magnesium carbonate, which in nature very often occurs together with other carbonates, like calcium carbonate (calcite), iron carbonate (siderite), or magnesium-calcium carbonate (dolomite). While magnesite only refers to the natural, unburned mineral extracted by mining, magnesia is the name of the calcined processed product. Raw magnesite can be used as a soil improver, as an additive in glass and ceramics manufacture, as a filler/extender in paints, paper, plastics and rubber, or as an anti-caking material in cooking salt and ammonium-nitrate fertilizer. However, most magnesite is used in calcined form (caustic magnesia, burning temperature 600 – 1,000 °C) and dead-burned form (sinter magnesia, burning temperature 1,700 – 2,000 °C). Caustic magnesia has similar and additional uses to raw magnesite, e.g. as a magnesia binder in the construction materials industry. Sinter magnesia is an important refractory material and can even be "fused" at 2,800 – 3,000 °C to get fused magnesia, which is a very special high-temperature refractory material.

RELEVANT DEPOSITS IN MONGOLIA

According to all relevant sources, there is just one magnesite deposit in Mongolia: Bideriin Gol in Taishir Soum of Govi-Altai Aimag. On the other hand, the number of magnesite occurrences given vary from two (United Nations 1999) to five (Jargalsaihan et al. 1996) or six (Geological Information Center 2003) and even up to twelve (Dejidmaa et al. 2001).

Magnesite at **Bideriin Gol**, some 50 km southeast from the Aimag centre of Govi-Altai Aimag, was discovered in 1987. Prospecting and exploration campaigns followed soon after. Refining and technical tests were performed in Romania and were successful.

The magnesite is hosted by ultrabasic rocks of Lower Cambrian age. Similar to most magnesite occurrences in Mongolia, it was formed by the alteration of serpentines which means that the boundary between magnesite and serpentinite is not sharp but slightly undulating. According to exploration findings, the deposit can be divided into five independent areas, i.e. Central, North-west, Western, Holin, and South-east, which lie 130-450 m apart. The only areas with economic potential are Central and North-west.

In the Central area, magnesite deposits reach 435 m length, 110-140 m width, and 5.1-25.8 m thickness, on average 8.1 m. The average thickness of the overburden is 0.8 m. The magnesite contains 45.54 % MgO, 45.53 % CO_2, 0.82 % SiO_2, 0.42 % Fe_2O_3, 0.04 % Al_2O_3, 0.08 % P_2O_5, and 0.01 % SO_3 on average.

In the North-west area, the magnesite ore body reaches 400 m length, and 40-206 m width. It is highly fractured. There are two magnesite horizons, the first having a thickness of 2.2-40.2 m, the second a thickness of 4.2-60.7 m. The average thickness of the overburden is 2.6 m. The average magnesite composition is 45.34 % MgO, 45.45 % CO_2, 1.41 % SiO_2, 0.38 % Fe_2O_3, 0.06 % Al_2O_3, and 1.33 % P_2O_5, i.e. apart from silica and phosphorous, it is very similar to magnesite in the Central area.

In general, the magnesite at Bideriin Gol is unweathered and white in colour; only weathered rock turns yellowish-white.
The total magnesite reserves/resources for both the Central and North-west areas are given as 1,439,500 tonnes in category B, 1,038,500 tonnes in category C1, and 644,700 tonnes in category C2.

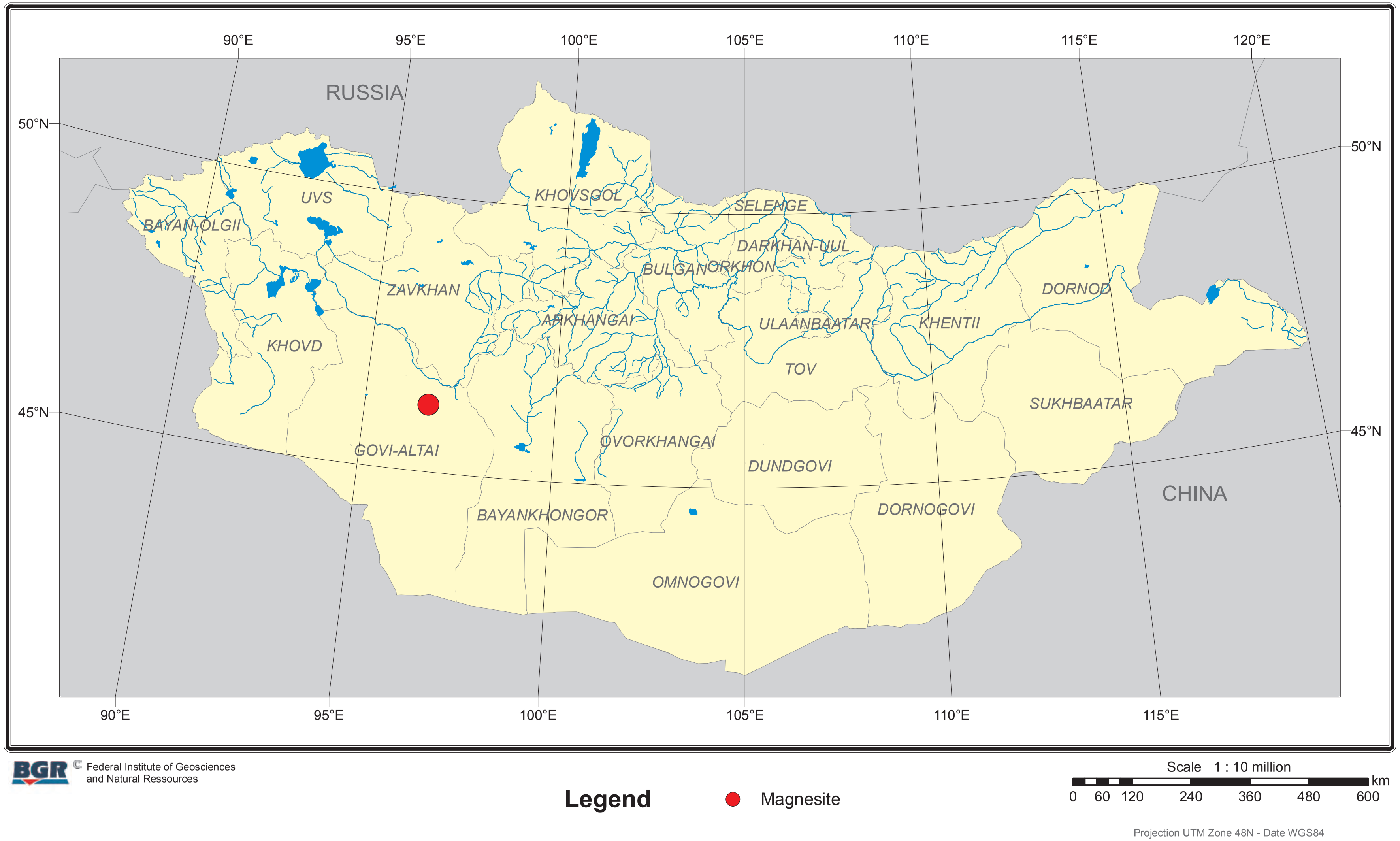
Chemically pure magnesite has a composition of 47.8 wt.-% MgO, and 52.2 wt.-% CO_2.

REQUIREMENTS AND EVALUATION

Raw magnesite should contain >40 wt.-% MgO, and <1.5 wt.-% Fe_2O_3. Hand-picked magnesite intended for the production of sinter magnesia must contain >46.8 wt.-% MgO. Because magnesite is a low-price commodity, deposits should generally contain reserves of >10 million tonnes. According to the Russian classification system, deposits containing <30 million tonnes of magnesite should be termed as small.

While the quality looks promising, the reserves of the only magnesite deposit in Mongolia are rather small. Therefore, there is only a very limited chance that this magnesite deposit might be used as a commercial source for the large-scale production of caustic or sinter magnesia. Potential investors might rather focus on the local production of magnesite as a soil improver (when finely ground for use in acid soils), as an additive in glass or ceramics production, or as a filler in paints, paper, and rubber for the local industry.

Deposits of Magnesite in Mongolia



MICA

GENERAL INFORMATION AND USES

There are several minerals in the mica group, of which only muscovite and lepidolite are of any importance to Mongolia.

Muscovite, also called sericite when very fine, is a silvery glittering light mineral occurring in many rocks. It has perfect basal cleavability and a pearly shimmer. Although it comes in light yellowish, light greenish, and light reddish colours, most often it has a silver colour when thick, and is colourless when very thin. The best quality mica in the world is said to come from Bihar in northern India and is called ruby mica. Muscovite can only be used when occurring in pegmatites where big sheets can reach more than 1 m in diameter.
Muscovite has always been mined and beneficiated by hand. It has a high dielectric strength and excellent chemical stability, making it a favoured material for manufacturing capacitors for radio frequency applications. Sheet mica has also been used as an insulator in high voltage electrical equipment. Because it is also birefringent, it is commonly used to make quarter and half wave plates. Because muscovite is resistant to heat, it is used for insulation purposes, and can be used instead of glass in the windows of stoves and kerosene heaters. Scrap mica produced when beneficiating sheet mica is used as an active filler in numerous applications, like asphalt, paints and lacquers, drilling mud, plastics, rubber and special paper.

Another mineral in the mica group, lepidolite, was once an important raw material for the beneficiation of lithium. Besides lithium (3-4 % Li_2O), lepidolite often contains rubidium and caesium (3-5 % Rb_2O+Cs_2O), which makes it a valuable source of rare alikali metals, above all lithium. Lithium is a light metal, which is used in batteries, in medicine, in pyrotechnics, and in the aerospace and nuclear industries.
Today, most of the lithium used comes from brines in Chile, Argentina, USA, and other countries. Currently unprocessed lepidolite ore is still used as a lithium-bearing flux in the ceramics and glass industries, e.g. in the production of heat-resistant flint and opal glass, and also as the basis for the manufacture of flux suitable for the welding of aluminium. In general, high freight costs preclude exports of unprocessed ore without prior processing by hand-sorting.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Most mica occurrences in Mongolia are of a muscovite-quartz-feldspar mineral type. According to United Nations (1999), four groups of muscovite-bearing pegmatites have been identified so far. These incorporate the large Bodochin group in the Mongolian Altai, the Hanhuhey group of two occurrences in Hanhuhey ridge of north-western Mongolia, the Batuin Gol group of nine occurrences on the right bank of the Tuul River west of Ulaanbaatar, and the Shariin Gol group of five occurrences in the Sharin River basin.
In contrast, Geological Information Center (2003) names 12 muscovite occurrences, while Dejidmaa et al. (2001) list 19. However, all the authors agree that if there is any muscovite deposit in Mongolia at all, it is Bodonch in Altai Soum of Khovd Aimag.

The **Bodonch** muscovite deposit is located some 40 km north-east of Altai town in the large Bulgan pegmatite zone on the southern slope of the Mongolian Altai. The length of this zone is 300 km; the width varies from 6 to 8 km. Besides muscovite, the pegmatites also contain elevated grades of Be, Ta, and Nb. The Bodonch muscovite deposit is built up of ten different pegmatite dikes. Reserves have been calculated for eight of these. Single pegmatite dikes vary in thickness from 1-20 m, and reach 230 m in length. The dikes dip between 45° and 90°. The muscovite is of light brown to black brown to grey colour, forming near-to-perfect cleaving crystals, which are fractured, however. Biotite is known as an unwanted impurity. The size of crystals is 4x5 to 7x8 cm. The total resources of muscovite calculated during preliminary exploration in 1964 were 348 tonnes in category C1, and 654 tonnes in category C2. However, after mining 231 tonnes in 1969 and the years thereafter and recalculating the volume of muscovite in place, the remaining resources stand at 106 tonnes in category C1, and 207 tonnes in category C2.

Regarding lepidolite, very nice specimens of large sheets of lepidolite are on display in the Museum of Geology and Mineral Resources at the Mongolian University of Science & Technology in Ulaanbaatar. According to its director, Prof. Dr. Lkhamsuren Jargal (oral comm.), they all stem from the Khokh Del Ulaan lithium occurrence (45° 59' 26.5" N, 108° 49' 39.5" E, 657 m a msl) which is in Dalanjargalan Soum of Dornogovi Aimag (cf. Figure 60). In this region there are 23 pegmatite dikes, of which 15 were first discovered in 1968 during an extensive prospecting campaign. The pegmatite dikes are 1.0-9.8 m wide and 30-700 m long. The pegmatites are of Late Devonian age and come in two groups: a) quartz-lepidolite-albite dikes with multicoloured tourmaline, and b) quartz-biotite-albite dikes with black

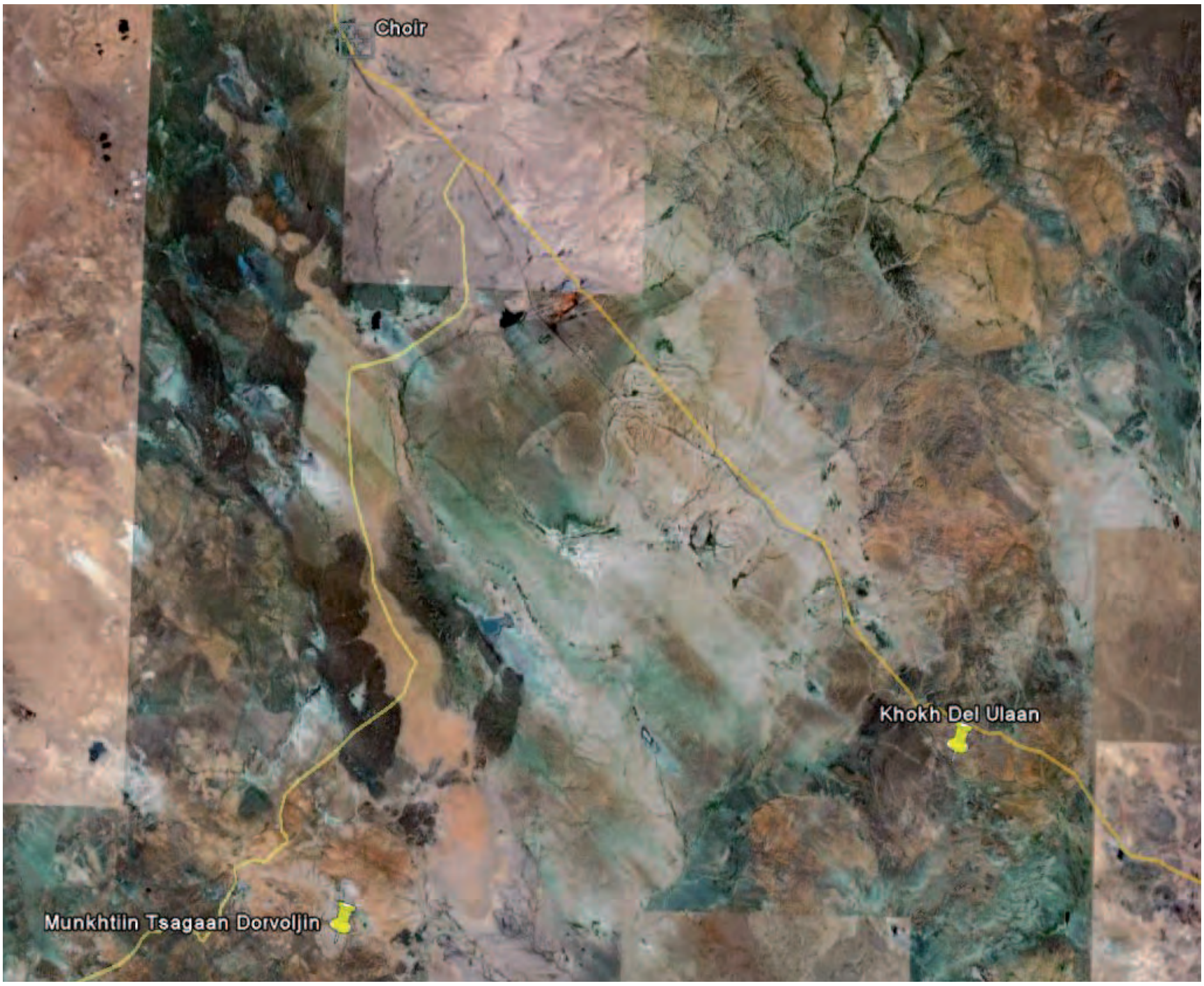


Figure 60: Satellite image of the Munkhtiin Tsagaan Dorvoljin and Khokh Del Ulaan lepidolite occurrences with main roads as yellow lines and Choir town to the north (Photo courtesy of Google Earth).

tourmaline. The pegmatites are made up of coarse-grained, block-like crystals of quartz, plagioclase (albite, albite-oligoclase), and microcline in decreasing order. Minor minerals are muscovite, tourmaline, garnet, amphibole, lepidolite, lithium-bearing biotite, and andalusite. Accessory minerals are topaz, fluorite, beryl, rubelite, cleavelandite, cassiterite, sphene, zircon, magnetite, columbite-tantalite, and ilmeno-rutile. As noticed during a field trip in September 2010, cassiterite is strongly enriched in nests in some of the pegmatites and may even be suitable to artisanal mining and separation (cf. Niobium and Tantalum). Epidote, chlorite, hematite, and calcite occur as secondary minerals. The highest grades of lepidolite are found along the axes of the pegmatite dikes with individual crystals up to 1.5 x 3 cm in size.

Because the pegmatite dikes at **Khokh Del Ulaan** have a low volume in total with a low rare metal content, they were not proposed for further exploration. The available information on grades and sizes of individual pegmatite dikes is summarised in the following table:

Table 38: Size and chemical analysis of pegmatite dikes of the Khokh Del Ulaan lepidolite occurrence (taken from occurrence passport).

Number	Length (m)	Thickness (m)	Li_2O	BeO (ppm)	Ta_2O_5 (ppm)	Nb_2O_5 (ppm)	Sn (ppm)
# 1	250	5.1	0.11-0.51	430	25-112	38-151	200
# 2	230	4.1	0.37	420	10-80	10-90	200
# 3	270	3.3	0.24	900	15-75	15-75	200
# 4	60	0.6-0.8	0.62	600	25-70	20-75	300
# 5	330	4.8	0.44	490	100	100-120	250
# 6	190	5.0	0.36	290	40	20	800
# 7	160	6.0	0.15	450	20-175	25-150	100
# 8	360	5.0	0.58	350	20-99	90	200
# 9	320	5.0	0.23	600-700	30-80	38-75	40-80
# 10	200	3.5-4.0	0.45	38-9,200	15	25	1,000
# 11	60	1.5	0.13-0.41	240	20-50	12-50	40-200
# 12	320	10.0	-	120-720	22-130	31-190	100-300
# 13	100	3.9	0.06-0.28	80-980	5-55	12-156	-
# 14	550	3.5	0.19-1.2	240-1,500	20-85	18-125	100-1,400
# 17	120	9.8	-	440	31	72	700
# 18	100	3.0	[1]	30-200			
# 19			0.14	600	30	62	100
# 20	60		0.24-0.41	730	20-22	12-75	300

[1] 24.6 % CaF_2, 4.4 % $CaCO_3$, 57.2 % SiO_2

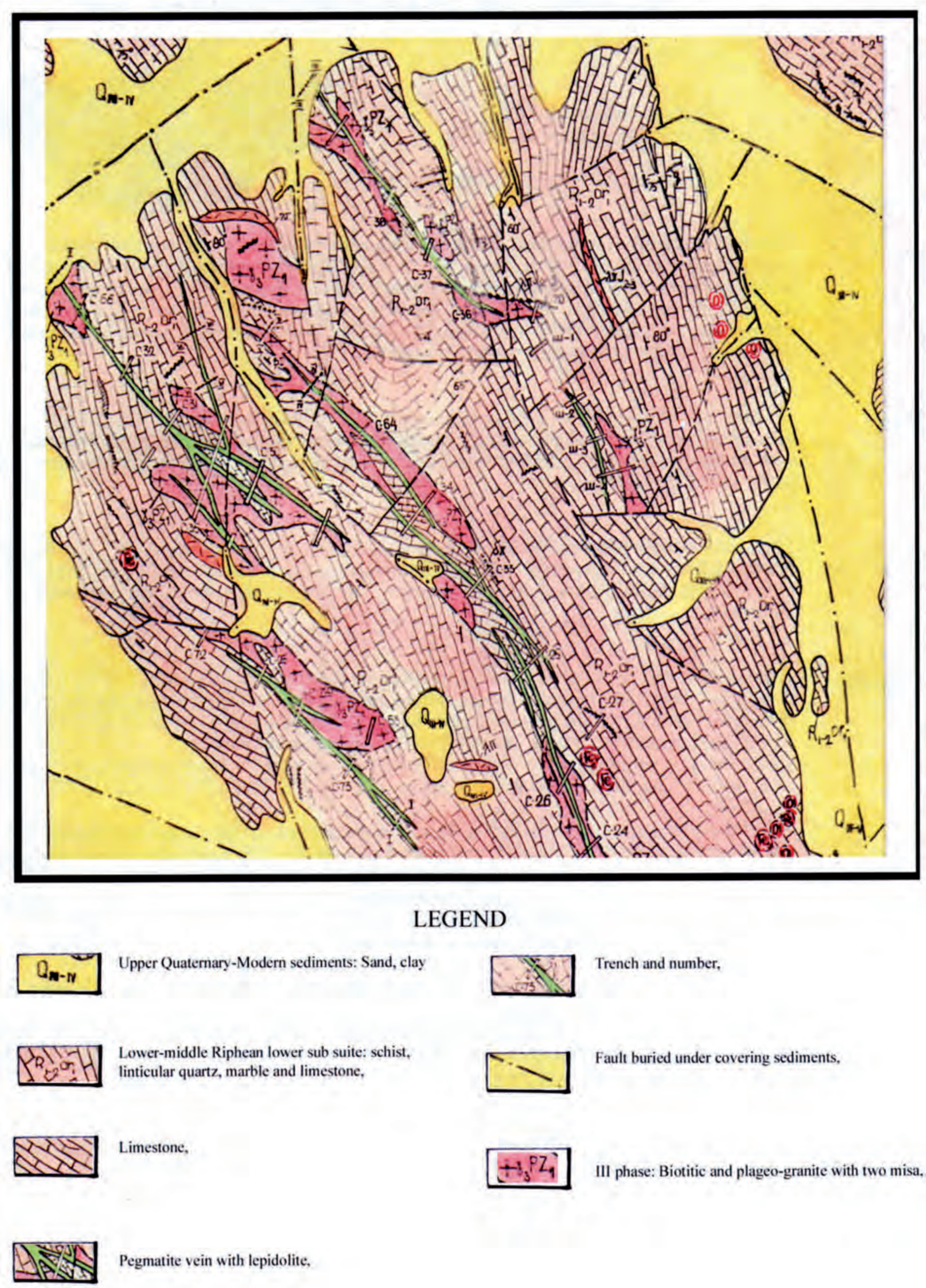


Figure 59: Geological map of the Munkhtiin Tsagaan Dorvoljin lithium deposit (Anonymous 2002).

The total resources of just four dikes, down to 20 m depth, were calculated as 89,890 tonnes of ore with an average grade of 0.43 % Li_2O, i.e. 362 tonnes of Li_2O content.

Just 40 km to the south-east, and some 50 km south of Choir in Bayanjargalan Soum of central Dundgovi Aimag, lies the **Munkhtiin Tsagaan Dorvoljin** lithium occurrence (45° 53' 22.4" N, 108° 22' 20.2", 1,216 m a msl) (cf. Figure 59). Here several pegmatite bodies were noted in a 3 km^2 area within marbles and limestones, with zones called Central, East, North-east, West, and North-west. The available information on the sizes and grades of pegmatite dikes in these zones is given in table 39.

Individual dikes were found to be 1.5-15 m thick, and 20-750 m long. Li-bearing minerals are lepidolite, spodumen, and petalite. Beryl and cassiterite are mentioned as other interesting minerals. The average ore grades according to old analyses are 0.53 % Li_2O (according to deposit passport: 0.43 % Li) , 0.1 % Rb_2O, 0.06 % Cs_2O, and 60 ppm Ta_2O_5, resulting in net resources of 36,244 tonnes of Li_2O, 6,569 tonnes of Rb_2O, 841 tonnes of Cs_2O, and 76 tonnes of Ta_2O_5.

The Munkhtiin Tsagaan Dorvoljin lithium occurrence was checked in the field in September 2010 revealing only limited trenching and no clear drilling activities. Although lithium mineralisation is obviously of pegmatitic-pneumatolytic origin, not all of the mapped dikes are pegmatites, and definitely not all of them bear lithium minerals. On the other hand, strong lithium mineralisation occurs outside the dike systems. Thus, Munkhtiin Tsagaan Dorvoljin needs more exploration, above all by drilling before any realistic genetic model can be stated and definite conclusions about resources can be reached.

Three typical lithium-bearing rock samples taken at the Munkhtiin Tsagaan Dorvoljin lithium occurrence in 2010 proved to contain mostly microcrystalline lepidolite (cf. Table 40), which is therefore not suitable for typical hand-sorting and further beneficiation (cf. below).

Table 39: Size of pegmatite zones and grades of pegmatite dikes of the Munkhtiin Tsagaan Dorvoljin lepidolite deposit (taken from Anonymous 2002).

Zone	# of pegmatite dikes	Width (m)	Length (m)	Grades
Central	7	15-40	1,300	up to 1.6 % Li_2O, 0.01-0.27 % Rb_2O, 0.09-0.11 % Cs_2O
East	several smaller, one main	8-12	390	0.03-1.0 % Li_2O
North-East	2	3.5	550	0.08-1.32 % Li_2O, 0.1-0.27 % Rb_2O, 0.09-0.11 % Cs_2O
North-West	4	7-15	850	0.03-2.27 % Li_2O
West	6	n.a.	n.a.	0.05-1.0 % Li_2O, 0.03-0.19 % Rb_2O

Table 40: Selected chemistry (data in wt.-% and ppm) of typical Li-bearing rock samples from the Munkhtiin Tsagaan Dorvoljin lithium occurrence. Bulk rock analysis by XRF, Li_2O analysis by ICP-MS, both by BGR)

Chemistry	# 1	# 2	# 3
Li_2O	2.43	2.02	1.29
SiO_2	68.86	69.40	66.76
TiO_2	0.01	0.01	0.01
Al_2O_3	16.91	16.71	19.84
Fe_2O_3 total	0.03	0.01	0.01
MnO	0.22	0.22	0.12
MgO	0.02	0.03	0.10
CaO	0.16	0.41	0.29
Na_2O	0.30	0.61	0.20
K_2O	6.15	5.74	6.47
P_2O_5	0.11	0.16	0.20
(F)	2.90	2.44	1.73
LOI	2.18	2.39	2.97
Total	97.88	98.15	98.73
Cs	1518 ppm	1312 ppm	890 ppm
Ga	125 ppm	112 ppm	129 ppm
Rb	5999 ppm	5448 ppm	4895 ppm
Sn	144 ppm	326 ppm	175 ppm
Th	11 ppm	13 ppm	4 ppm
U	<3 ppm	<3 ppm	<3 ppm
W	93 ppm	100 ppm	113 ppm

REQUIREMENTS AND EVALUATION (MUSCOVITE)

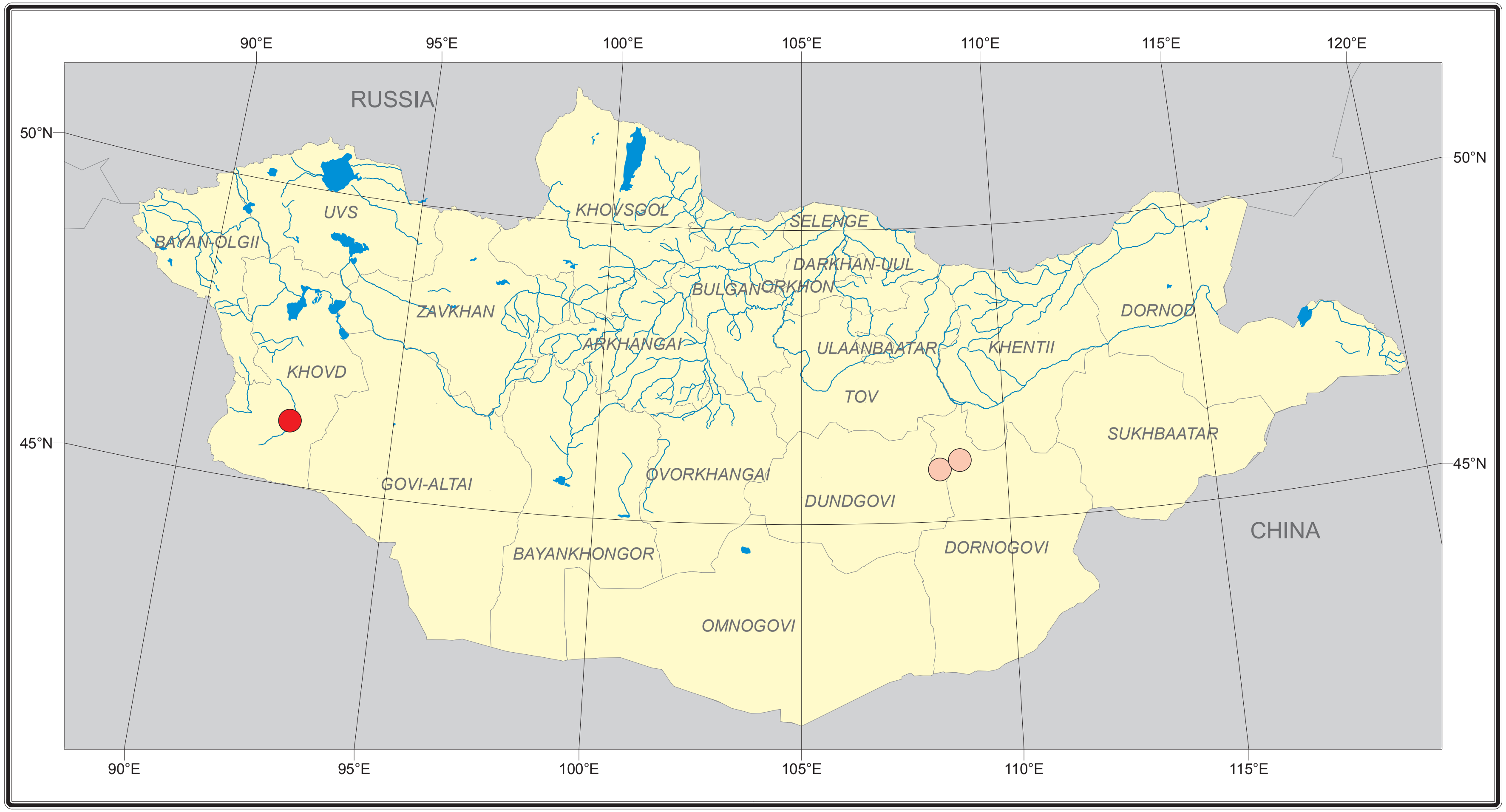
Sheet mica, e.g. muscovite, should have as few colour zonations, fractures, cracks or textures, stains or spots as possible. It should not have any inclusions of air or other minerals. Sheets must be plain and hard. Colourless or transparent sheets are preferred. The best quality sheets must have a useable size >645 cm^2, with the shortest size >10.2 cm. The lowest quality sheets must have a useable size between 4.8 and 6.4 cm^2, with at least one size having a length of >1.6 cm. Deposits should have mineable reserves of >500 tonnes muscovite. According to the Russian classification, mica deposits with <5,000 tonnes of recoverable muscovite are small ones.

Potential investors must therefore clearly recognize that the quality of muscovite from Bodonch is insufficient for the production of sheet mica, and the remaining resources are too small for commercial production. Also, this deposit is nearly mined out. The remaining muscovite might be suitable for the production of low-quality scrap mica, which after cleaning, crushing, grinding or milling might be used as a filler in the local paint industry.

REQUIREMENTS AND EVALUATION (LEPIDOLITE)

Lepidolite very often forms white to pale pinky-mauve sheets, and can therefore be rather easily identified in the field. After quarrying, the lepidolite has to be hand-sorted, and can be further upgraded by milling, magnetic separation, heavy media separation, or flotation. The concentrate needs to contain at least 3.5-4.0 % Li_2O but less than 0.1 % Fe_2O_3. Typical reserves of economically mineable lithium-bearing pegmatites are between 1 and 50 million tonnes of ore, with grades between 1.3-2.9 % Li_2O, i.e. a mineable deposit should contain a minimum of some 30,000 tonnes Li_2O. This means that while the Khokh Del Ulaan lithium occurrence is of interest to mineral collectors only, Munkhtiin Tsagaan Dorvoljin is a small sized, but more importantly, too low grade lepidolite occurrence. Most probably it will not be of interest to potential investors wishing to supply the glass and ceramics industries. However, more exploration is definitely needed before realistic resources and grades can be established.

Deposits of Mica in Mongolia



BGR © Federal Institute of Geosciences and Natural Ressources

Legend

Lepidolite

Muscovite

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

NEPHELINE SYENITE

GENERAL INFORMATION AND USES

Nepheline syenite is a magmatic rock made up of nepheline, orthoclase, albite, and small amounts of mafic and other minerals. Because it is high in alumina and alkalis, it is mainly used as a substitute for feldspar as a source of alumina and alkalis in glass and ceramics manufacture. In glassmaking, alumina retards the devitrification of the finished product, and in ceramics it provides durability and inertness. The alkalis act as a flux in both processes. The main advantage of using nepheline syenite in ceramics is that it has a slightly lower melting point (1,140-1,170°C) than sodium feldspar (1,170-1,200°C) and therefore requires a shorter firing time and less energy. In glassmaking, however, the high alumina content of nepheline syenite is a disadvantage, as it makes it slower to melt than feldspar, thus lengthening the time required to heat the batch. Despite these technical factors, the main criteria for choosing either nepheline syenite or feldspar is its price and local availability.

Only in north-easternmost Russia, on the Kola Peninsula, where there is a huge apatite-nepheline deposit, is nepheline concentrate (28.5 % Al_2O_3) mixed with limestone used for

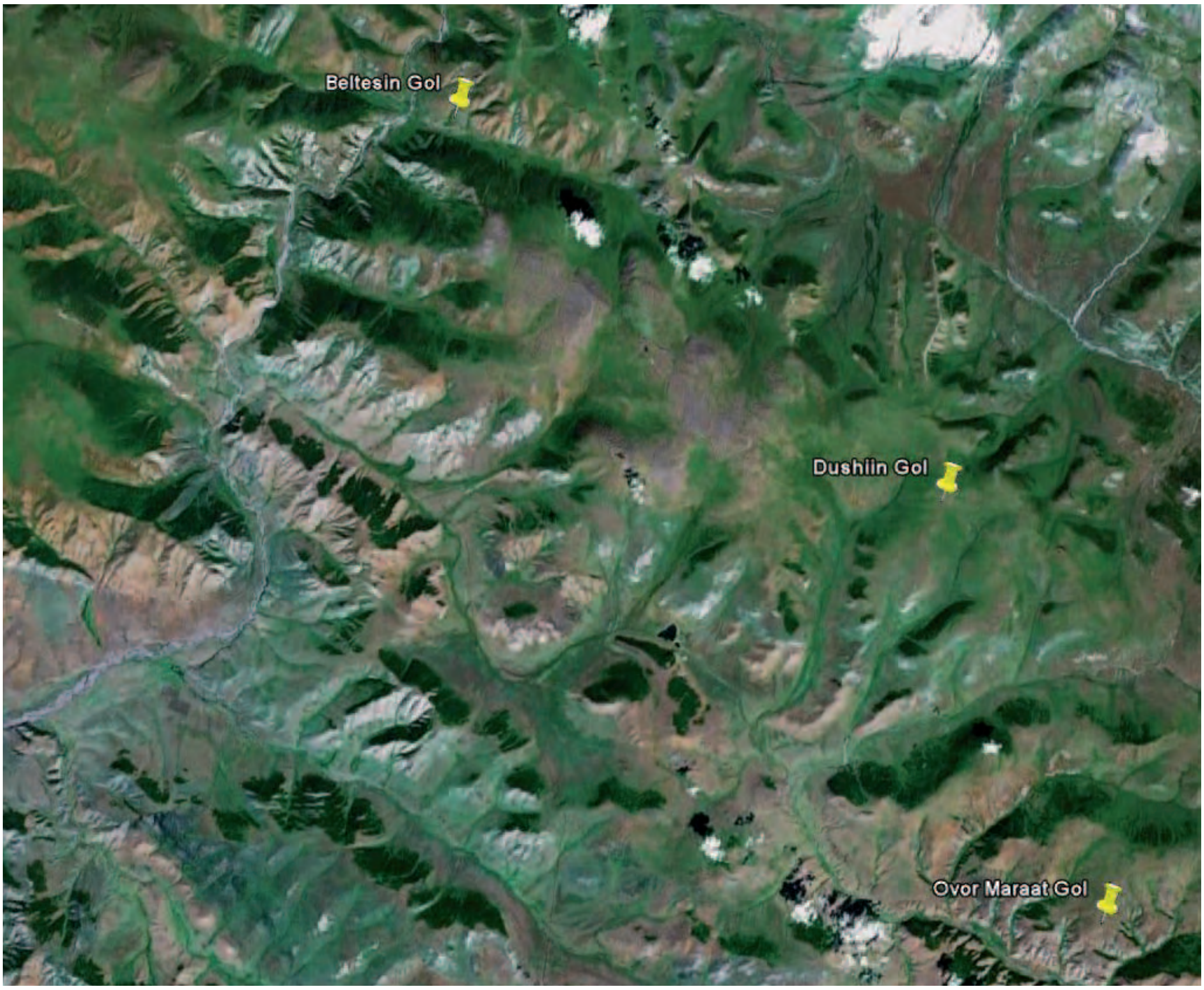


Figure 61: Satellite image of mountain ranges in Alag-Erdene Soum of Khuvsgul Aimag showing locations of nepheline syenite deposits (Photo courtesy of Google Earth).

the production of alumina – with Portland cement, soda, and potash as by-products. Other minor but direct uses of nepheline syenite are as a filler in paints, laquers, rubbers, and plastics.

RELEVANT DEPOSITS IN MONGOLIA

In Mongolia, there are numerous occurrences of nepheline syenite, of which only three are ranked as deposits. All three of them are located in the mountain ranges of Alag-Erdene Soum of Khuvsgul Aimag, west of the famous Khuvsgul National Park.

The **Dushiin Gol** deposit occurs in the watershed of the Udzhigin and Berhin Rivers and is represented by a long series of small bodies of 3 km length made up of urtite, ijolite-urtite, ijolite, and teralite, i.e. different varieties of nepheline syenite. Nepheline makes up between 60 and 90 vol.-%, and titanium-augite between 10 and 40 vol.-% of the rock assemblages. Hornblende, diopside, sphene, apatite, and magnetite are present in accessory quantities. The highest nepheline contents were recorded from two northern rock bodies measuring 600 x 200 m, and 150 x 150 m, both containing mainly urtite. A chemical analysis of a typical urtite sample is shown in Table 41 (United Nations 1999).

The Dushiin gol deposit can be divided into a northern and a southern part, both being oval in form. The northern part (Khoit) covers 0.54 km^2 and contains an ore body of 10-18 m thickness, 18-36 m length and a dip of 50^o. The resources in category P2 down to 125 m depth and an area of 0.40 km^2 were estimated as 136 million tonnes of nepheline.
The southern part (Omnod) consists of three ore bodies of 0.8-3.5 m thickness, and 800 x 300-500 m size. Estimated resources in category P2 and an area of 0.238 km^2 are given as 80.5 million tonnes of nepheline.
Other estimates of total resources in category P1 are 400 million tonnes of urtite + ijolite-urtite, resulting in some 300 million tonnes of nepheline.

Table 41: Chemical analyses (data in wt.-%) of nepheline syenite deposits in Mongolia (taken from deposit passports and United Nations (1999)).

<table>
<tr><th rowspan="2"></th><th colspan="3">Dushiin Gol</th><th>Ovoor Maraat Gol</th><th colspan="2">Beltesiin Gol</th></tr>
<tr><th>Typical urtite</th><th>North</th><th>South</th><th>Average</th><th>North</th><th>South</th></tr>
<tr><td>P_2O_5</td><td>0.16</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>SiO_2</td><td>46.38</td><td>43.6</td><td>45.0</td><td>50.43</td><td>42.6</td><td>42.7</td></tr>
<tr><td>TiO_2</td><td>0.40</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fe_2O_3</td><td>0.81</td><td>2.1</td><td>2.6</td><td>0.87</td><td rowspan="2">7.6</td><td>1.8</td></tr>
<tr><td>FeO</td><td>2.55</td><td>6.4</td><td>5.3</td><td>2.91</td><td>4.4</td></tr>
<tr><td>Al_2O_3</td><td>28.83</td><td>27.2</td><td>26.5</td><td>26.52</td><td>21.6</td><td>24.9</td></tr>
<tr><td>MnO</td><td>0.13</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CaO</td><td>5.0</td><td>6.4</td><td>5.3</td><td>2.77</td><td></td><td></td></tr>
<tr><td>MgO</td><td>0.88</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Na_2O</td><td>10.68</td><td rowspan="2">11.1</td><td rowspan="2">10.9</td><td>9.55</td><td>10.1</td><td>11.3</td></tr>
<tr><td>K_2O</td><td>3.3</td><td>4.57</td><td></td><td></td></tr>
</table>

The **Ovor Maraat Gol** deposit was discovered in a triangular massif of urtite of 5.6 km length, and 1.5 km width in the valley of the Udzhigin River. This deposit is 24 km west as the crow flies from the Moron to Hatgal road, which is currently being upgraded and paved. The rocks contain some 70-80 vol.-% nepheline, and 10-12 vol.-% micro-perthite. Accessory minerals are aegirine-augite, sphene, apatite, and hedenbergite. Secondary minerals are biotite, albite, cancrinite, hastingsite, and calcite. The nepheline is of brown to green colour, partly evenly disseminated, the other parts forming nests, and sometimes banded layers. The estimated resources down to 150 m (P2) and 200 m (P3) depth are 2.1 billion tonnes of nepheline in categories P2+P3. Other estimates of resources in category P1 are 1.7 billion tonnes of urtite + ijolite, containing some 1.3 billion tonnes of nepheline.

Finally, the **Beltesiin Gol** deposit can be observed in a bluff of ijolite traceable over a distance of 300 m in the valley of the Beltesiin River. The deposit consists of two ore bodies, North (Khoit), and South (Omnod), which are 5 km apart. The North ore body covers an area of 2 km^2. The South body covers an area of 3.8 km^2 and has a circular-shaped zonal structure. The outer zone is 75-150 m wide and consists of ijolite. The middle zone is 100-250 m wide and is made up of ijolite-urtite. The inner zone has a diameter of 50-100 m with rocks passing from urtite to nephelinite. The nepheline content in ijolite is 30-35 vol.-%, and the pyroxenite content is 60-85 vol.-%, while apatite, amphibole, garnet, epidote, and calcite occur as secondary minerals.
The total estimated resources of both ore bodies, North and South, down to 100 m depth, and covering an area of 3.5 km^2 are 945 million tonnes of nepheline ore in category P2. Another estimate, also in category P2, is 2.6 billion tonnes of urtite + ijolite-urtite with some 1.9 billion tonnes of net nepheline ore.

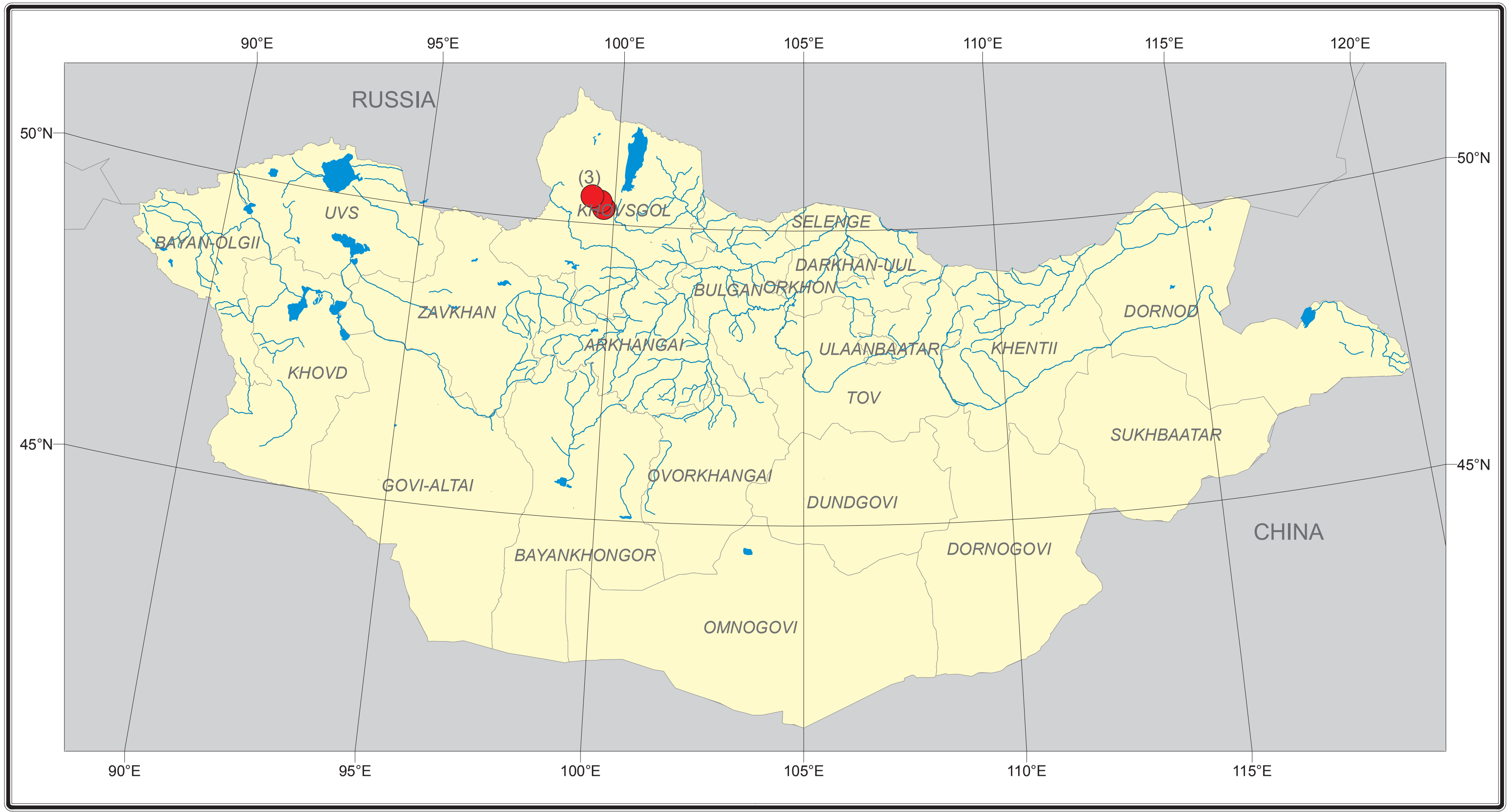
REQUIREMENTS AND EVALUATION

For industrial use, nepheline syenites should contain not less than 60 vol.-% foids/feldspars and not more than 5 vol.-% accessory minerals. Ore and heavy minerals of any kind are not wanted and need to be separated. In general, dressing considerably reduces Fe_2O_3 and TiO_2. After dressing, nepheline syenite needs to contain >23 % Al_2O_3, <0.1 % Fe_2O_3, <1.3 % CaO, <0.1 % MgO, and >14 % K_2O+Na_2O. For glass manufacture, there are also limits on Ba, Sr, and P. For use as a filler, there exist numerous technical specifications. Reserves need to encompass at least 500,000 tonnes of recoverable material. Reserves of >100 million tonnes are preferred. These international requirements comply well with the Russian classification system.

Although huge deposits of nepheline syenite can be found all over the world, for glass or ceramics manufacture, this kind of rock is currently only being mined in Canada, Norway, and Brasil. On the Kola Peninsula in north-eastern Russia, apatite rich rocks are being mined mainly for their apatite content, with large amounts of nepheline concentrate accumulating during flotation. Just 10 % of these flotation wastes are used for the production of alumina. Keeping these proportions in mind, the chances of establishing a working nepheline syenite quarry in Mongolia are rather limited.

Of the three deposits mentioned, Ovor Maraat Gol has the best quality because both Al_2O_3, and Na_2O+K_2O are high enough, while Fe_2O_3 should be reducable during processing. Also, the resources of nepheline ore are more than sufficient. Of course more exploration is needed to determine economically mineable reserves and a full knowledge of the ore chemistry. Potential investors in local glass or ceramics industries especially should keep in mind this Mongolian raw material potential.

Deposits of Nepheline Syenite in Mongolia



Legend

● Nepheline Syenite

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

PERLITE

GENERAL INFORMATION AND USES

Perlite is an acid, glass-rich volcanic rock with perlitic structure, which means that on crushing it separates into numerous tiny spheres or "pearls". Upon weathering it shows onion skin peeling. Upon heating, perlite foams up and expands considerably.

The main applications of expanded perlite are as a lightweight additive in various building materials, in filter manufacture, as a soil aerator, in thermal and acoustic insulation, as a filler for plastics, as a carrier for fertilizers, and as an additive in the production of certain paints and laquers. Raw perlite is used as an abrasive, as a flux in the ceramics and hollow glass industries, and also as a filler.

RELEVANT DEPOSITS IN MONGOLIA

According to Geological Information Center (2003) there are 18 perlite deposits in Mongolia, of which Gurvan Ovoot Tolgoi is counted twice – but could not even be found in the field after extensive searching.

Dejidmaa et al. (2001) are much more critical and name just three deposits, but 32 occurrences of perlite in Mongolia. The names of these three perlite deposits mentioned in rank of total volume of resources are:

- **Elgen Bulag** in Bayan Soum of Tuv Aimag. The Elgen Bulag deposit lies some 7 km east of the main road from Ulaanbaatar to Sainshand and amidst a large prospecting area for uranium in volcanics of Lower Cretaceous age. It was prospected in 1962 by digging and trenching, while exploration by drilling followed in 1975. As can easily be seen in both an old pit (46° 51'26.4" N, 107°

Figure 62: High definition satellite image of Elgen Bulag area with old quarry and more recent quarry to the south-east (Satellite image as of 30 September 2007, Altitude 801 m, Photo courtesy of Google Earth).

53’48.3” E, 1,403 m a msl, cf. Figure 62) and in a more recent outcrop (46° 51’09.3” N, 107° 54’00.7” E, 1,408 m a msl, cf. Figure 62) perlite only occurs in the form of clasts in a chaotically layered, probably repeatedly redeposited volcanoclastic sequence of ash, tuff, scoria, obsidian, pumice, bombs, and ignimbrites (cf. Figure 63). In the older pit, mining proved unsuccessful – which led to a larger area already cleared from overburden not even being mined as a consequence.
“Ore body #3” which was explored best has a length of 680 m, a width of 220-250 m and a thickness of 6.3-14.2 m. The thickness of the overburden is very low reaching 1 m maximum. The mineralogical-petrological composition was determined as 55-90 % volcanic glass, 15-25 % crystallites, 3-33 % potassium feldspar, and as accessory minerals: zircon, quartz, plagioclase, biotite and orthite. Secondary minerals are chlorite, pelite or perlite (?!), iron-oxides, as well as zeolites.

The total reserves/resources at Elgen Bulag were estimated as 277,000 m^3 in category B, and 409,000 m^3 in category C1. Ore body #3

Figure 63: Volcanoclastics of all sizes, but with little perlite in Elgen Bulag old quarry.

contains additional resources of 322,000 m^3 in category C2. After 1982, the deposit (old quarry) was used by a ceramics factory in Ulaanbaatar, which is said to have taken out 14,400 m^3 of material. Because the perlite content in both the existing quarries is obviously very low (<1 vol.-%), the material quarried can only be used for general filling purposes or after crushing, as an unspecified lightweight aggregate dominated by pumice

- **Bayan Ondor** in Bayantsagaan Soum of Tuv Aimag. The Bayan Ondor deposit was prospected in 1964 and 1975 by trenching, digging, and drilling. The deposit is made up of coarse-grained Lower Cretaceous vitroclastic tuff of massive texture. Its mineralogy was analysed to be dominated by montmorillonite, quartz, and feldspar. The tuff contains impurities of (volcanic?) sand and liparite pebbles. The deposit area can be divided into three parts – Western, South, and North-east – totalling 150-350 m length, 500 m width, and 10-11 m thickness. The thickness of the overburden varies between 0.3-1.9 m. The reserves (of tuff?) were calculated as 50,000 m^3 in category B, and 700,000 m^3 in category C1. In the deposit passport no information on the perlite content is given.

- **Zamiin Ulaan** in Tsagaandelger Soum of Dundgovi Aimag. This perlite deposit was discovered in 1950 during geological mapping, prospected between 1975 and 1977, and explored in 1986/1987. It is located 12 km south-east of Tsagaandelger village in a large area of felsic volcanic rocks of Middle to Upper Jurassic age, dominated by rhyolithic lava sheets, lava breccias, and volcanic domes of 10-100 m height, of which vitroclastic tuffs were ejected (cf. Figure 64). These vitroclastic tuffs cover an area of 2 km length and 800 m width. The thickness of the tuffs varies from 11.5-30.4 m, with 22.3 m on average. The thickness of the

overburden varies from 0.2-3.0 m. Groundwater was found in six boreholes at depths between 22.2 and 33.2 m.
The tuffs are composed of 70-75 % massive rhyolithic perlite of greenish, grey, and sometimes reddish colour, 10 % volcanic glass, and 10-25 % quartz and volcanic microlites.
The chemical composition was determined as: 68.50-70.68 % SiO_2, 11.47-13.91 % Al_2O_3, 0.71-1.36 % Fe_2O_3, 0.36-1.0 % FeO, 1.12-2.24 % CaO, 0.20-1.01 % MgO, 0.05-0.07 % MnO, 2.0-5.85 % Na_2O, 3.0-5.10 % K_2O, 0.02-0.35 % P_2O_5, 0.03-0.17 % SO_3, 0.11-0.59 % CO_2, 0.02-2.27 % H_2O, and 4.50-7.30 % LOI.

The grain size distribution is highly variable and given as: >10 mm: 9.0-80.4 %, 10-7 mm: 0.2-15 %, 7-5 mm: 0.2-16.7 %, 5-3 mm: 1.4-21.4 %, 3-0.5 mm: 4.7-86.2 %, and <0.5 mm: 3.2-35.0 %, which means that the raw tuff needs sorting before use. The bulk density of the coarse-grade tuff (pebble-size fraction) is 0.62-0.88 g/cm^3, while the bulk density of the fine-grained tuff (sand-size fraction) is 0.47-0.70 g/cm^3. At 1,200-1,250 °C, the expansion coefficient is 1.9-2.6. The reserves/resources of perlite suitable for use as lightweight aggregate were calculated as 1,753,000 m^3 in category B, 3,883,000 m^3 in category C1, and 8,455,000 m^3 in category C2.

Relevant information for economic evaluation of other potential perlite deposits in Mongolia is given in Table 42.

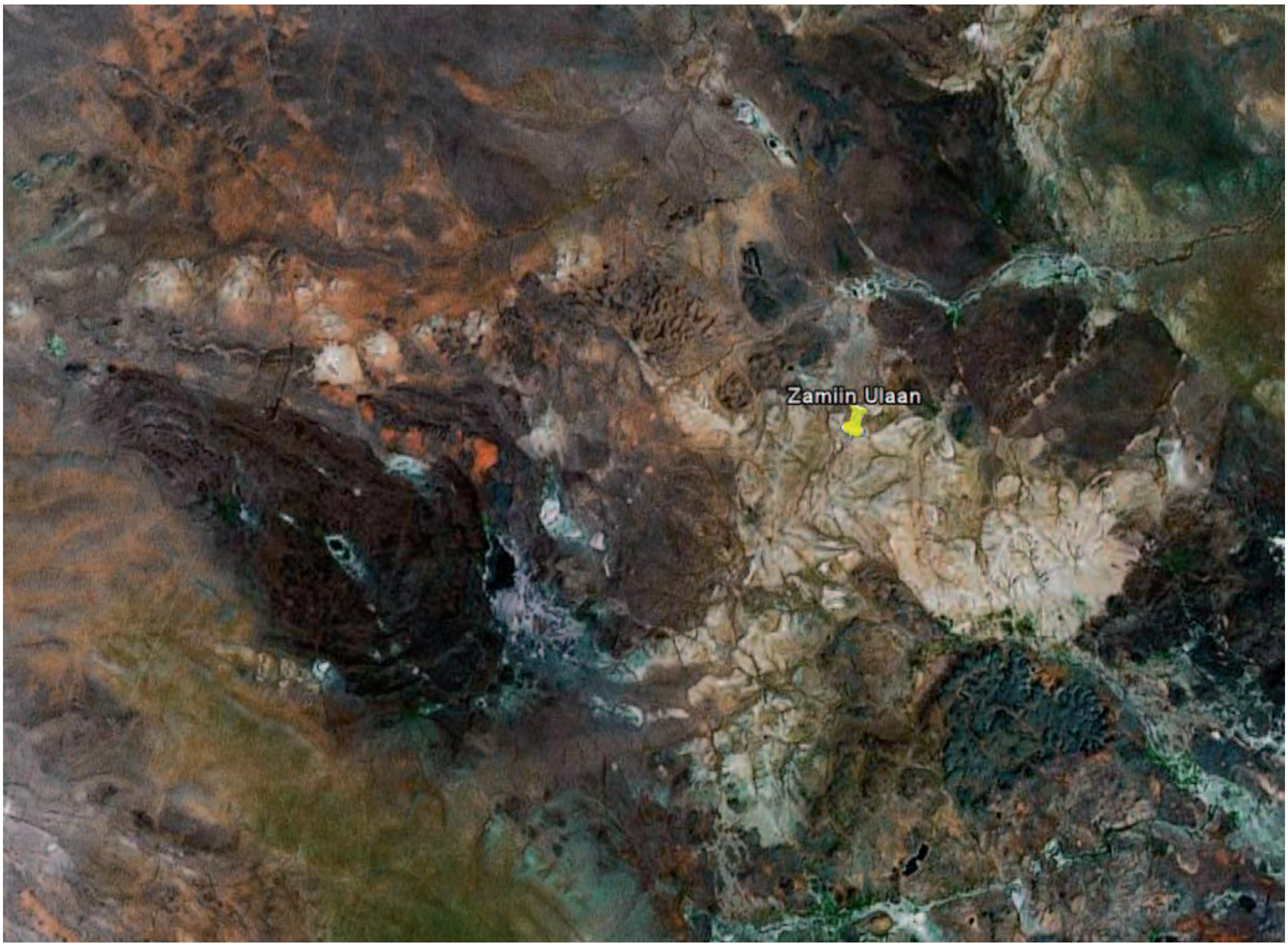


Figure 64: Satellite image of the Zamiin Ulaan volcanic area about 47 km west of Choir town. (Photo courtesy of Google Earth).

Table 42: Relevant data on selected perlite deposits in Mongolia (taken from deposit passports).

Name	Aimag	Sum	Size	Grade / Quality	Resources
Tsakhiur Uul	Bulgan	Bayan-Agt	Top of mountain: 100-150 m length x 300 m width x 15-20 m thickness	Expansion coefficient: 1.3-3.3, 1.6-3.0 % Fe_2O_3, 0.1-0.45 % H_2O	3,000,000 m^3 (C2)
Tsagaan Ovoo	Umnugovi	Tsogttsetsii	Body: 1,500 m length x 50-30 m width, steeply dipping	No information	1,000,000 m^3
Tsavchiriin Zuun	Dundgovi	Tsagaandelger	Lens: 400-800 m length x 4-5 m width x 50 m thickness	1.67 % Fe_2O_3, 0.91 % FeO, 0.46 % H_2O	52,000 m^3 (P)
Tsavchir	Dundgovi	Tsagaandelger	4 lenses: 10-70 m length x 2-5 m width x 5-20 m thickness	1.46 % Fe_2O_3, 0.98 % FeO, 0.33 % H_2O, quartz grains of 1-3 mm size	10,150 m^3 (P)
Altan Khuree	Dundgovi	Tsagaandelger	Layer: 50-80 m length x 1-2 m width x 20 m thickness	1.50 % Fe_2O_3, 0.98 % FeO, 0.91 % H_2O	4,200 m^3 (P2)
Tsagaan Nuur	Dundgovi	Govi Ugtaal	Layer: 3,500 m length x 15-40 m width	Water content 0.64-1.59 %, humidity 0.25-1.03 %, porosity 0.85-2.25 %	No information
Khetsuu Teeg Uul	Umnugovi	Bulgan	Layer: 1,500 m length x 3-20 m width	No information	No information
Unnamed (#16)	Ovorkhangai	Bogd	Layer: 450 m length x 70-100 width	No information	No information
Oortsog Ovoo	Khentii	Galshar	Laye: 10-12 m width	No information	No information

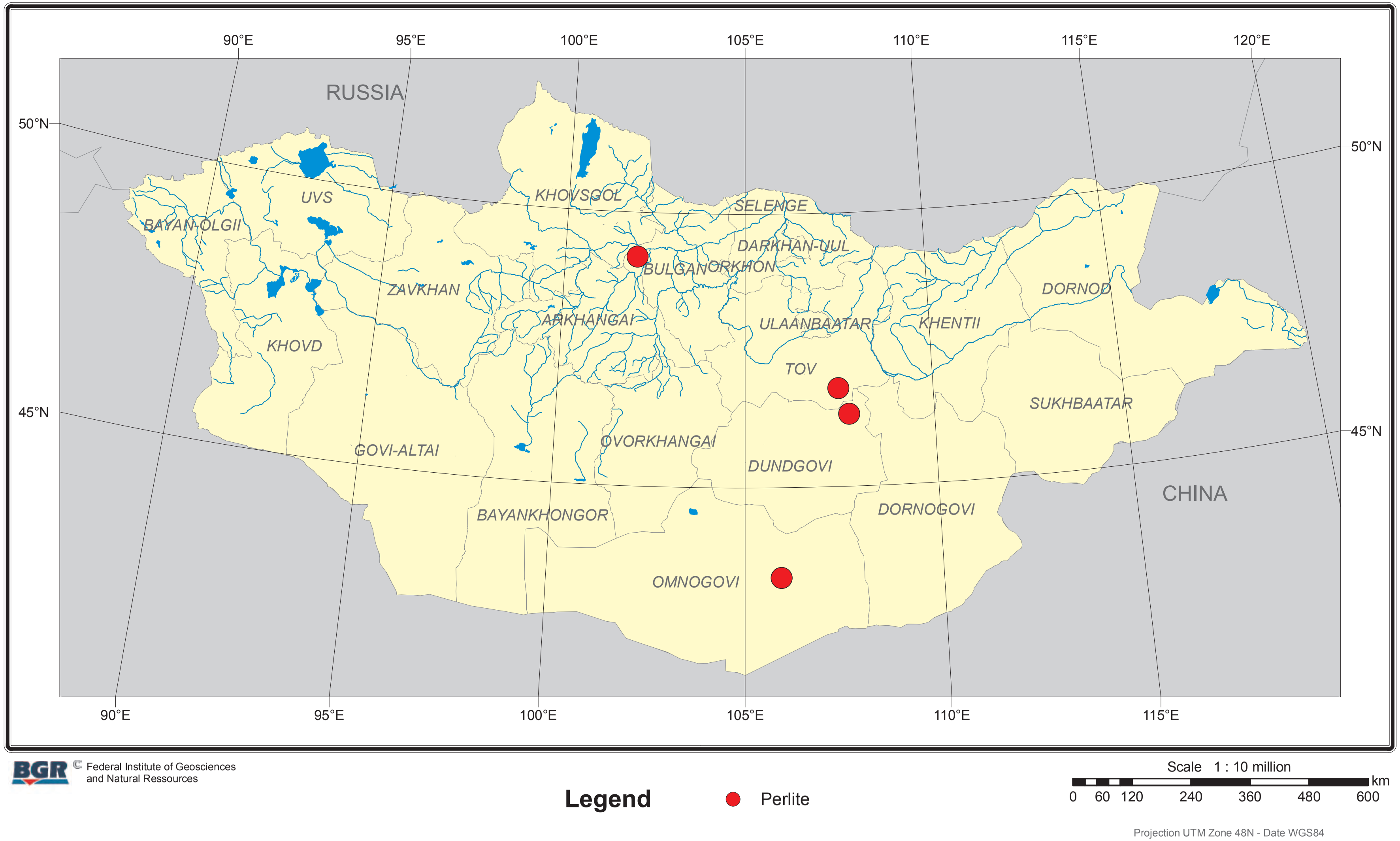
REQUIREMENTS AND EVALUATION

Most requirements for perlite refer to expanded perlite only. Raw perlite should be free of inclusions and rock fragments (<2 %), but rich in glass (>98 %). Upon heating – by blow-pipe or even matches – the perlite should expand considerably; maximum expansion is 20 times. Crushed perlite should separate into spheres of 0.5-2.5 mm diameter, but not into perlite dust <0.3 mm. Good quality raw perlite contains very limited amounts of organic material, clay and Fe_2O_3. It should however contain 2-5 % bound water.

Perlite is a low price, high-volume material, which therefore needs a good infrastructure. Minimum reserves of mineable perlite should surpass 1 million tonnes. According to the Russian classification system, small perlite deposits contain <5 million m^3 of perlite content. On the other hand very large deposits cover areas of several km^2, with strata reaching thicknesses of 30 m and volumes surpassing 200 million m^3.

The assessment of the bigger deposits of perlite in Mongolia, i.e. Elgen Bulag, Bayan Ondor, and Zamiin Ulaan suggest that only the last might be suitable for larger scale production of good-quality perlite. While this deposit obviously contains the highest grades and high resources of perlite, it still does not fulfil the international requirements for raw perlite deposits neither by quality (low expansion coefficient) nor infrastructure (none at all).

Economically mineable deposits of Perlite in Mongolia



PHOSPHATE

GENERAL INFORMATION AND USES

Phosphate ores can be of magmatic or sedimentary, both marine and terrestrial, origin. Deposits of economic importance are made up of calcium-phosphate minerals, like apatite, or guano (which is dung formed mainly by birds or bats) or phosphorite, which is a fine-grained phosphorus-rich mixture of various minerals, mainly formed offshore.
The grade of phosphate deposits is given in wt.-% P (= phosphorus), wt.-% P_2O_5 or wt.-% BPL (bone phosphate of lime) which is equivalent to TPL (triphosphate of lime) or TCP (tricalcium phosphate).

	P	**P_2O_5**	**BPL (= TPL, = TCP)**
1 wt.-% P	1	2.2914	5.0072
1 wt.-% P_2O_5	0.4364	1	2.1852
1 wt.-% BPL (TCP, TCL)	0.1997	0.4576	1

Phosphorus is essential for plant and animal life, so nearly all mined phosphate ores are used for the production of nitrogen-phosphorus-potassium fertilizers. Although there are some other very minor uses of phosphates, they are of little economic relevance. In general, all phosphate ores, with the exception of guano, have to be processed for further use and should not be used as fertilizers in crude form.

RELEVANT OCCURRENCES IN MONGOLIA

All phosphate deposits of economic interest in Mongolia are of marine origin with phosphate ores in the form of phosphorite.

Because there have been several prospecting and exploration campaigns for phosphorites in Mongolia, the distribution and potential of this commodity is well known. However, because most areas rich in phosphate are very remote and therefore difficult to reach, all of the known deposits need more exploration and evaluation before any attempt at mining.

The Khuvsgul phosphate basin in northern Mongolia stretches into southern Siberia and is one of the largest phosphate-bearing basins in the world. It has a length of some 300 km and a width up to 170 km. Within the basin, there are two phosphate belts (east and west, cf. below) with several discrete phosphate deposits and occurrences in each. The total number and names of the deposits/occurrences varies from author to author. Because the names and coordinates of deposits are not clearly defined, there is great confusion among stakeholders, which may be a big obstacle to future mining as there are plans to ban (the as yet non-existant) phosphate mining north of the 50^{th} parallel for fear of environmental pollution. However, restricting mining to the phosphate deposits in the eastern phosphate belt and north of Hatgal town, i.e. close to Khuvsgul Lake and within the Khuvsgul National Park (where all mining is prohibited anyhow) might interfere with tourism and nature reserve protection.

Most of the phosphate deposits in the Khuvsgul phosphate basin have been prospected quite well by Russian and Mongolian expeditions, with the exception of those which are so remote that they cannot be reached by normal expeditions – and are therefore not suitable for mining anyhow!
Geologically there are two phosphate-rich horizons:

1. The lower horizon (Lower phosphate unit, Hesen Formation) in the lower part of the Khuvsgul Group (Khuvsgul Series) of Early Cambrian age, consisting of up to five phosphate horizons. The lower horizon has a highly variable thickness of 25-90 m, with individual phosphate horizons reaching up to 15 m in thickness. These horizons consist of banded carbonates (15-20 % dolomite,

1-30 % calcite), chalcedony and quartz, chemically precipitated phosphorites, as well as other minerals, e.g. limonite, sericite, various heavy minerals, hydromicas, and organic matter (0.5 %, rarely up to 5 %). The total rare earth element content is <300 ppm only (Ilyin et al. 1986). The P_2O_5-content in the lower phosphate horizons reaches up to 29 %, with an average of 20-22 %. Phosphorites occur in two types:

- Isotropic fluor-apatite with finely disseminated carbonate and quartz as well as organic substances. The fluorine content reaches 1-2 %.
- Fine-crystalline low-thermal apatite.

2. The upper horizon (Upper phosphate unit, Erhel Formation) is also in the lower part of the Khuvsgul Group. This upper horizon is of much lower thickness (10-15 m) and made up of transported siliceous and carbonaceous clastic fragments and clastic phosphorites overlying a thick dolomite bed (Main Dolomite). The average P_2O_5 content in the upper horizon varies between 13.5 and 21.5 % on average.

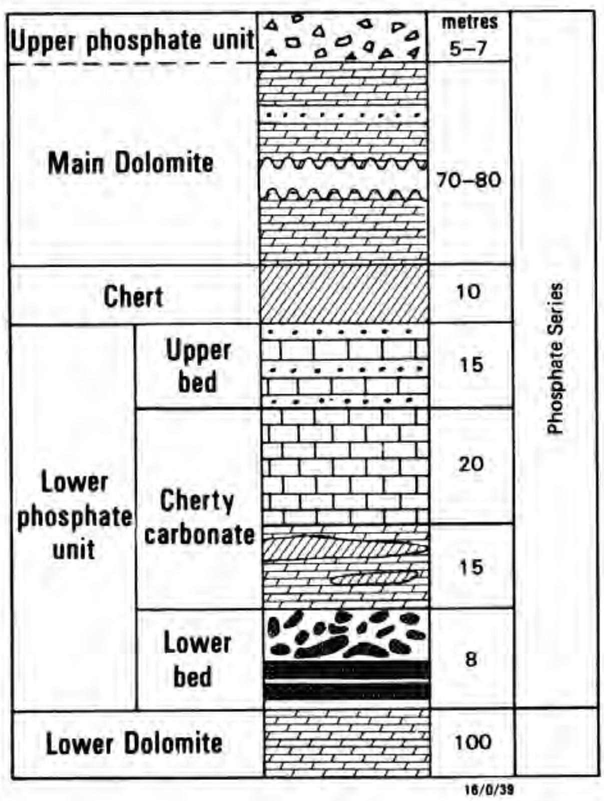


Figure 65: Stratigraphic section of the phosphate series of the Khuvsgul Group showing the Lower phosphate unit and Upper phosphate unit above the Main Dolomite (Ilyin et al. 1986).

The chemically precipitated (primary) phosphorite of the lower horizon formed in an offshore upwelling area south of the Siberian craton in Early Cambrian time. The upper horizon was most probably formed by reworking the phosphorite from the lower horizon.

All phosphate deposits at the southern end of the Khuvsgul Basin, i.e. near Moron town, belong to the Upper phosphate horizon, while the phosphate deposits further north can be correlated with the Lower phosphate horizon.

During the Caledonian orogeny, the whole Khuvsgul Group of sedimentary rocks was strongly folded, faulted and fractured. Thus, the Khuvsgul Group today is found in a big synclinorium which is dissected by numerous faults into major and minor blocks with a considerable amount of displacement. Additionally, the Khuvsgul Basin was intruded by granitoides and alkaline intrusions.

Within the huge synclinorium of the Khuvsgul phosphate basin, the two phosphate horizons described above are bound to its periphery, i.e. to two N-S-trending folded belts. Due to the strong relief, there are numerous outcrops where prospecting and sampling has started.

Within Mongolia, the eastern phosphate belt (Khuvsgul zone) reaches 250 km length and 10-15 km width. All of the bigger phosphate deposits and occurrences belong to this eastern belt. The most famous phosphate deposits within this eastern belt are Burenkhaan (in the south) and Khuvsgul sensu lato (in the north); especially the latter one with several satellite deposits and occurrences in tectonically fragmented blocks. The western belt (Darkhat zone) only reaches 200 km length and 10 km width. The western belt is so remote that it has only been poorly

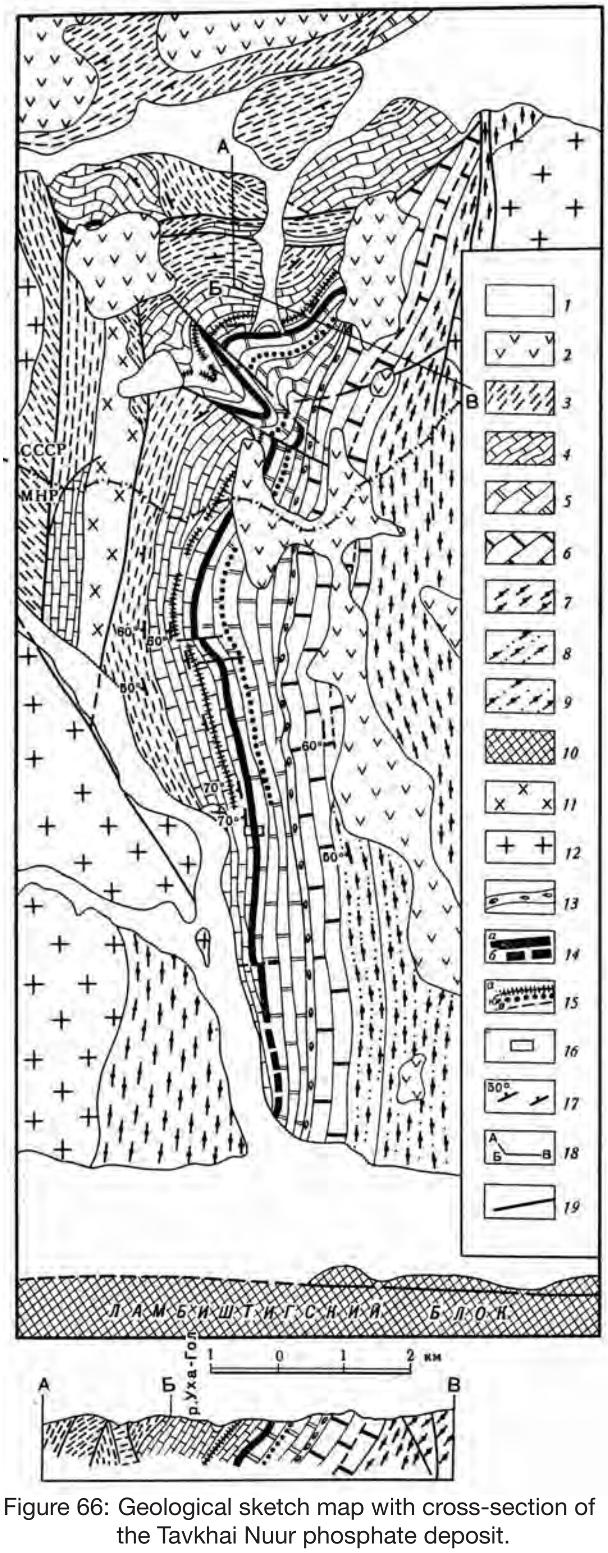


Figure 66: Geological sketch map with cross-section of the Tavkhai Nuur phosphate deposit. Phosphorite-bearing layers (14 = main layer, 15 = other layers) in black (Ilyin 1973).

studied to date. Due to the total lack of infrastructure, it does not contain any phosphate deposits which are economically mineable in the foreseeable future.

The relative geographical location of deposits and major occurrences in the Khuvsgul phosphate basin from north to south is given in Table 43.

The Ukhaa Gol or **Tavkhai Nuur** phosphate deposit is located right on the state border to Russia and is built up of argillaceous microsphorites containing small grained quarz detritus and granular or pelletal phosphorites.

The black phosphorites are found both in light-coloured carbonaceous rocks (2.5-10.0 m thick) and within a 80-100 m higher, upper layer of quarzites or cherts (3-5 m thick). On Mongolian territory, the phosphorite-bearing layers of commercial interest are within a narrow belt of 9.5-10 km length and 14 m width (cf. Figure 66). The phosphate-rich (13.9-27.71 % P_2O_5) horizons were found to continue far to the north and north-east, with

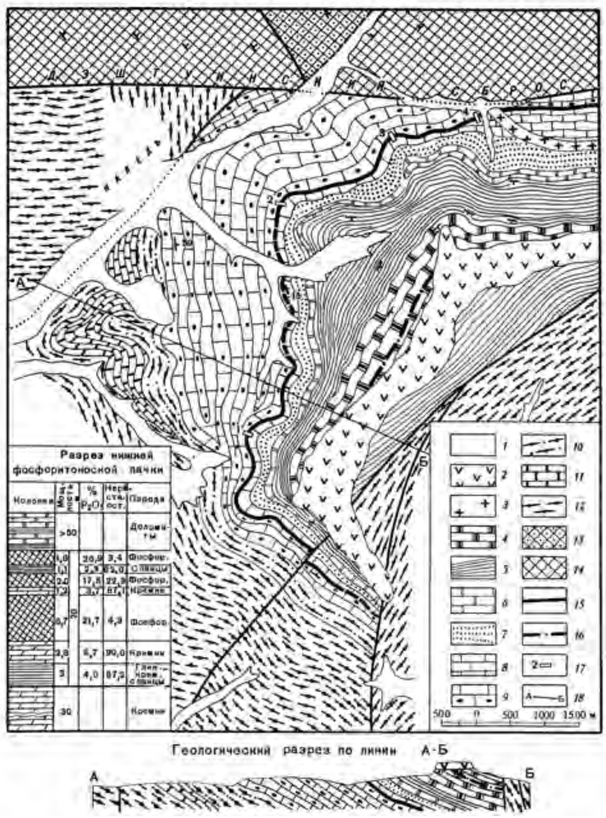


Figure 67: Geological sketch map with cross-section of Oliin Davaa phosphate deposit. Phosphorite-bearing layers (15 = upper main horizon, 16 = lower horizon) in black (Ilyin 1973).

phosphorite changing to sandy phosphorites and phosphatic carbonaceous sandstone and breccia. The resources of these low-grade ($7-9\ \%\ P_2O_5$) rocks are thought to be as large as 2-3 billion tonnes. A more recent calculation of the resources in the Tavkhai Nuur

Table 43: Relative location of phosphate deposits and major phosphate occurrences in the Khuvsgul phosphate basin from north to south (taken from deposit passports, Ilyin 1973, and Byamba 1987). Not all coordinates and names of deposits/occurrences are clearly defined.

Deposit	Satellite deposit	Occurrence
Eastern phosphate belt – north of Hatgal town (within Khuvsgul N.P. – ecologically sensitive)		
Ukhaa Gol = Tavkhai Nuur		
Ulein Davaa = Oliin Davaa		
		MaratUinnulin = Maraat Uul
Chzhiglig = Jiglig = Chiglel		Tashint
		Khava Gol
		Kharausu Gol = Khar Us Gol
Khuvsgul (sensu lato)		Ikh Tsagaan Gol
	Saikhan Gol	
	Khoit Uran Do’sh	
	Uran Do’sh	
		Doloon Tsagaan Khad
	Baga Tsagaan Gol	
	Bayanzurkh	
	Nuurtyn Am	
	Ulaan Khad	
	Ongolog Nuur	
	Khuvsgul (sensu stricto)	
	Zhinhai = Djinkhain = Jankhai	
		Asan group
Eastern phosphate belt – south of Hatgal town (not within Khuvsgul N.P.)		
		Berhimu Ulin = Berkhem Ukhaa
		Huren-Nurin = Khuren Nuur
Manhanulin = Maikhan Uul		
		Hitaingol = Ikhtsakhir
		Suul Tolgoi
		Dorozhnoe = Shirenget (?)
Burenkhaan		
		Tsaganuruus = Baga Tsagaan Uul
Western phosphate belt (total lack of infrastructure)		
		Dertrug Gol
		Targalulin
		Tuv Tengesin
		Utsegen
		Habhain = Khavkhain = Ust Khabkhai
		Horgorgain = Khogorgoin Gol
		Dood Nuur
		Harmain = Kharmain
Tsagaan Uul = Tsagaan Nuur		
		Khuikhen Gol = Khugen Gol
		Bayan Gol
		Temensultin
		Khunkh

deposit sensu stricto is 10.245 million tonnes of ore grading 23.24 % P_2O_5, i.e. 2.38 million tonnes of P_2O_5 in category C2 and 20.742 million tonnes of ore grading 23.23 % P_2O_5, i.e. 5.064 million tonnes of P_2O_5 in category P1. The thickness of permafrost in the Tavkhai Nuur region is 0.2-0.3 m in the north, and 0.5-0.7 m in the south.

Some 50 km south of the Tavkhai Nuur deposit, on the east bank of the Usan Khuchir River lies the Ulein Davaa/**Oliin Davaa** phosphate deposit. There the thickness of permafrost is also only 0.4-1.0 m. The Oliin Davaa phosphate deposit was prospected only roughly by digging three trenches and analysing three samples. The main phosphorite-bearing layer is bound to the upper, silicified and brecciated part of a limestone (70.09-74.08 % $CaCO_3$, 3.4-5.3 % $MgCO_3$, 15.9-16.9 % insol.) which stretches over a length of 2,500 m, a width of 16 m and attains a thickness of 5-12 m (cf. Figure 67). Estimated resources are 15.3 million tonnes of ore grading 20.2 % P_2O_5, i.e. 3.0 million tonnes of P_2O_5 in category C2 and 149 million tonnes of ore grading 3.09-16.1 %, on average 15.55 % P_2O_5 in category P.

The **Chiglel** phosphate deposit is located 15 km north of the Khuvsgul phosphate deposit on the west shore of the Chiglel River. It is made up of thin layers of phosphorites 2-3 mm in diameter and phosphorite-rich limestone, as well as sandstone. In total there are four phosphate horizons of 27 m total thickness stretching for 2 km. The grade of P_2O_5 varies from 15.64-19.88 % with resources of 17.5 million tonnes of ore estimated in category P2.

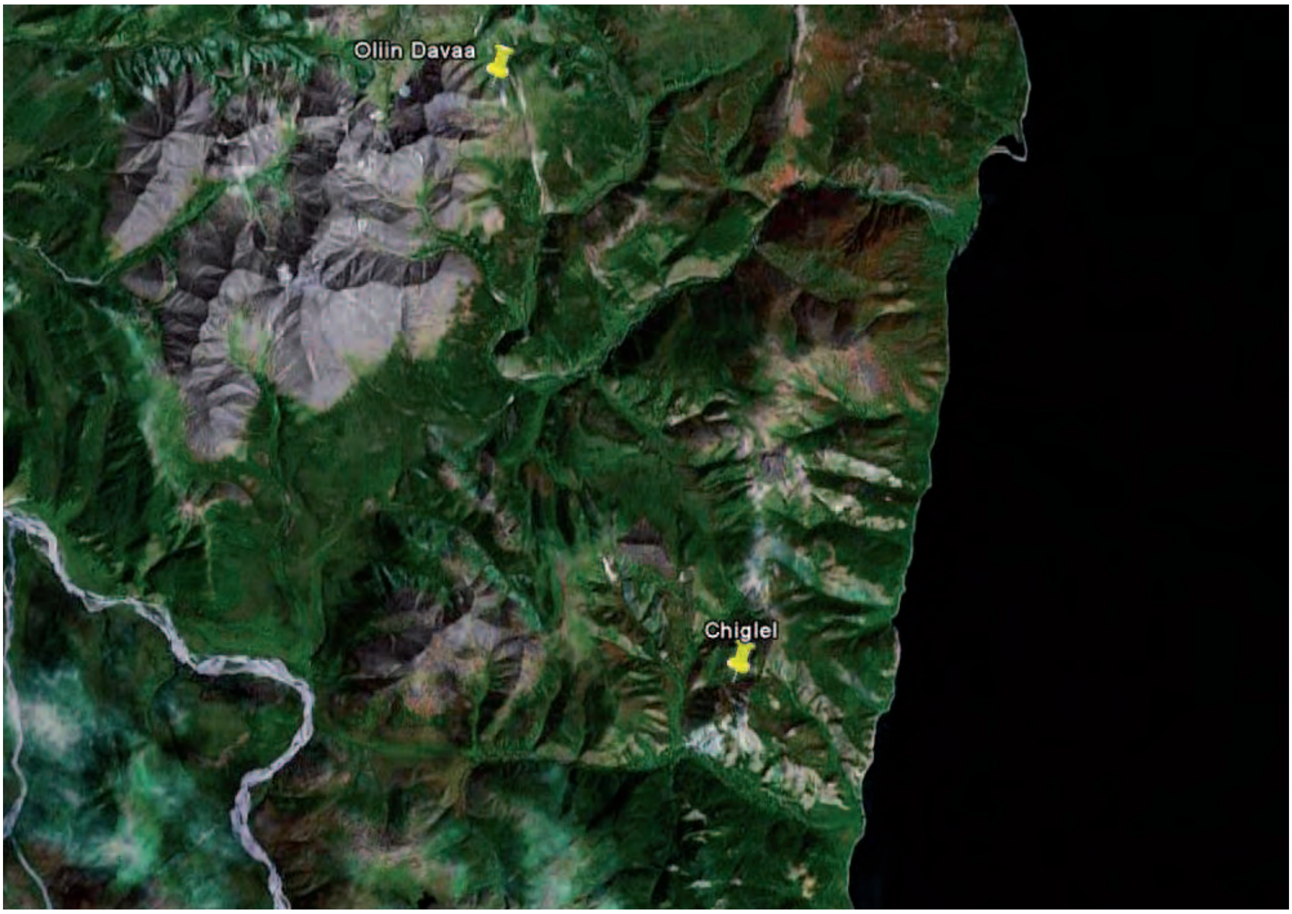


Figure 68: Satellite image showing the Oliin Davaa and Chiglel phosphate deposits with Khuvsgul Lake (in black) to the west (Photo courtesy of Google Earth).

The **Tashint** phosphate occurrence surrounds the peak of Tashintyn Mountain and covers 16 km^2. This occurrence is built up of limestone, dolomitic limestone, and phosphate-rich dolomite. There seems to be just one phosphate horizon of 7.5 km length and only 1.5 m thickness. The average grade of P_2O_5 is 16.59 %, resulting in estimated resources of 3 million tonnes of ore with about 0.5 million tonnes of net P_2O_5.

The huge Khuvsgul phosphate deposit (sensu lato) together with its satellite deposits and occurrences stretches about 30 km along Khuvsgul Lake. It was explored repeatedly in different years and campaigns with the main activity in 1974/75 and 1986/87.

About 7 km north of the Saikhan Gol phosphate deposit is the **Ikh Tsagaan Gol** phosphate occurrence. Covering an area of 18 x 4 km there are carbonates, quartzites, and dolomitic schists, partly enriched in phosphate (up to 30.7 % P_2O_5) and highly fractured. Phosphorite is mainly bound to an 18 km long, 4 km wide, and 20-40 m thick middle layer of dark limestone and dolostone dipping at 60-70°. Within this carbonate layer, there are three phosphorite horizons 1.0-6.5 m, on average 2 m thick. The average P_2O_5 content is 19.44 % with grades varying from 13.37-21.8 %. Vivianite is a common secondary mineral. The estimated resources of phosphorite ore are 1.5 million tonnes. This occurrence is extremely hard to reach due to its remoteness, elevation, and long periods of rain. Permafrost also poses a substantial problem to potential mining.

The north-westernmost deposit in the Khuvsgul phosphate deposit sensu lato is the **Saikhan Gol** phosphate deposit which is about 60 km north of Hatgal village and 10 km north of the Nuurtyn Am phosphate deposit. It stretches from the north-western side of Uran Dosh Mountain to the lower part of the Saikhan River. Prospecting in 1986/87 was by trenching only and revealed a 6.5 km long, 55° dipping phosphorite-rich horizon of 4.6 m thickness in siltstone, dolomite, and dolomitic conglomerate. In calcearous quarzitic ore the average P_2O_5 grade is 19.44 %. In quarzitic ore it is 36.45 %, giving an average grade of 29.26 %. Using this average grade, estimated resources in category P are 10.5 million tonnes of ore with 3 million tonnes of net P_2O_5.

Just north of Uran Dosh Mountain and also about 60 km north of Hatgal village lies the **Khoit Uran Dosh** deposit. This deposit was prospected in 1974/75 by trenching and analysis of 12 samples. Within dark-grey dolomitic limestones there are two phosphate-rich horizons, both slightly silicified and attaining a combined thickness of 5-24 m. One horizon is 2 km long, 20 m wide, and 3-8 m thick, sometimes up to 10 m thick. The other horizon is 5 km long, 80 m wide, and with a thickness of 15 m up to 87 m. The grade of P_2O_5 is highly variable from 2.8-23.5 %, with 18.05 % on average. The estimated total resources are 99.9 million tonnes of ore grading 17.88 % P_2O_5, i.e. 17.87 million tonnes of P_2O_5 (category P).

Reachable via Davaany Gol Valley at Avgar tsagaan khad lies the **Doloon Tsagaan Khad** phosphate occurrence. Within dolomitic limestone, dolomite, sandstone, and siltstone, there is a horizon of dolomitic silicified phosphorites about 4 km long and 1.7 m thick. The estimated resources are 1.8 million tonnes of ore grading 20.69 % P_2O_5 on average, i.e. containing 0.4 million tonnes of P_2O_5. Because this occurrence lies high up in the mountains it is difficult to reach, and thus also to mine.

In the middle part of the Baga Tsagaan River area is the **Baga Tsagaan Gol** phosphate deposit, which is also said to be very difficult to reach. It was explored by trenching and drilling in 1986/87. Here limestone is present in an area measuring 15.5 x 2.0 km in which one phosphate horizon was discovered: 5.7 km long and 6.0 m thick. In this horizon, P_2O_5

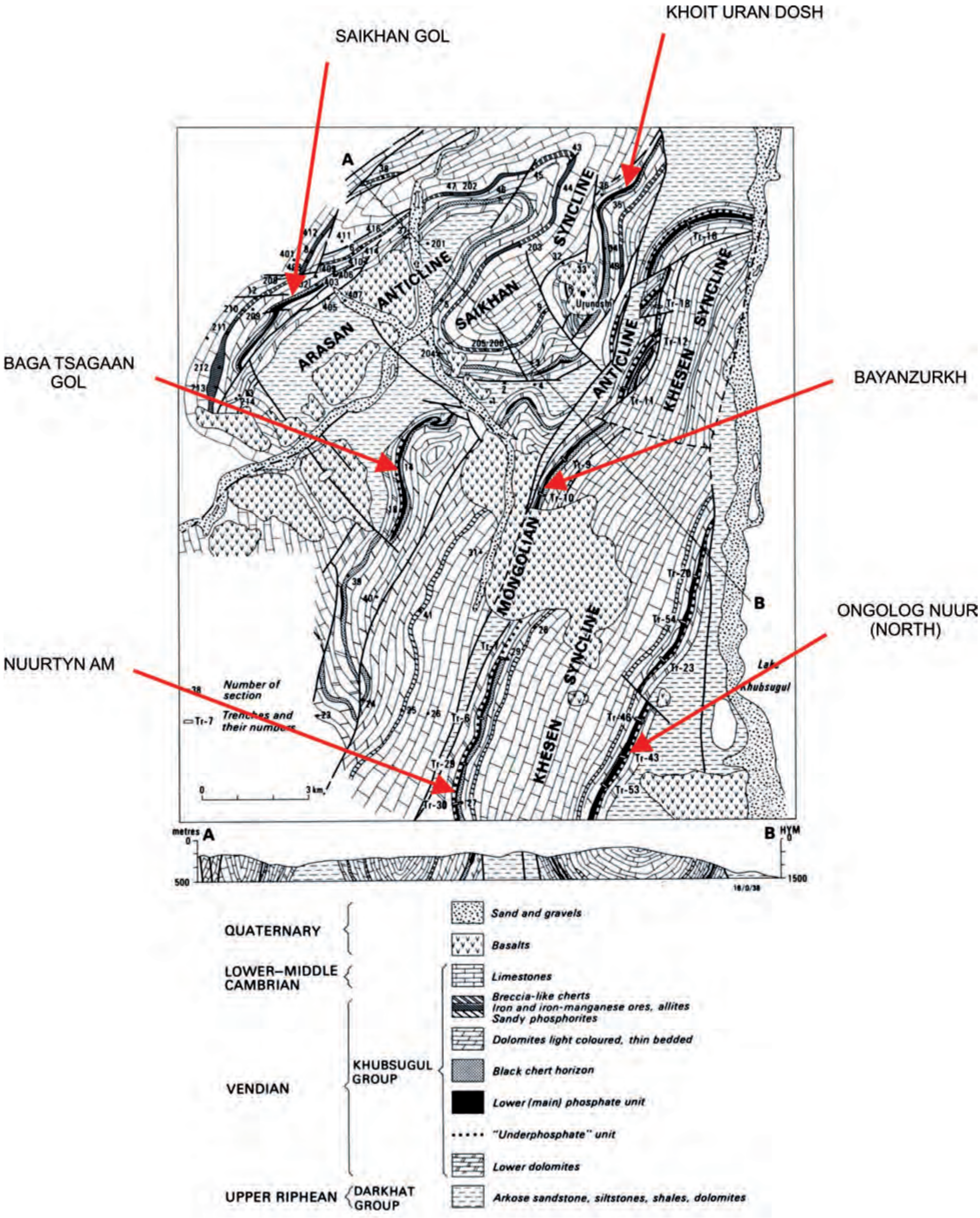


Figure 69: Geological map of the northern part of the Khuvsgul phosphate deposit sensu lato (Ilyin et al. 1986). Names of phosphate deposits assigned as far as possible (compare to satellite image in Figure 70).

grades from 11.75-26.89 % with 21.47 % on average. The estimated resources in category P2 are 20.8 million tonnes of ore with 4.4 million tonnes of net P_2O_5.

The **Bayanzurkh** deposit lies 5 km south-west of Uran Dosh Mountain and consists of two highly fractured ore bodies, North and South. Prospecting was by trenching and analysis of 30 samples. The phosphate-rich horizon in the northern ore body (on average 19.78 % P_2O_5) stretches for 2.7 km, attaining 3 m thickness. The southern ore body (Omnod Bayanzurkh) (on average 17.18 % P_2O_5) includes two horizons: the basic one stretches for 1.2 km and has an average thickness of 6.3 m, the upper one stretches for 1.5 km and has a thickness of 3-5 m, on average 4 m. Assuming a mineable depth of 150 m, the northern ore body might contain 6.4 million tonnes of ore or 1.2 million tonnes of P_2O_5, while the southern ore body contains only 3.2 million tonnes of ore with 0.6 million tonnes of P_2O_5 (category P1).

Nuurtyn Am is the name of a phosphate deposit some 50 km north of Hatgal village and 8 km south-west of Uran Dosh Mountain. Within the deposit covering 72 km² there are three phosphate horizons reaching 1.2 km average length, 50 m average width and from 13.5 to 19.4 m thickness. The average P_2O_5-grade is 23.84 %. Average grades of unwanted impurities are 17.44 % insolubles, 1.84 % Fe_2O_3, and 4.43 % MgO. The estimated resources are 70.1 million tonnes of ore with 14.8 million tonnes of net P_2O_5 (category P).

Figure 70: Satellite image of the northern part of the Khuvsgul phosphate deposit sensu lato showing various phosphate deposits, Uran Dosh Mountain and Khuvsgul Lake (in black) to the west (Photo courtesy of Google Earth).

The **Ulaan Khad** phosphate deposit lies 23 km north of Hatgal village and some 8 km south of Ikh Uul Mountain. Here phosphorite occurs in phosphorite-rich siltstone (base), limestone with silicified phosphorite (middle), and highly silicified limestone (top). There are two to three phosphate horizons reaching 300-3,000 m length and 42-45.5 m total thickness in the western limb, and one to two phosphate horizons with 47.2 m total thickness in the eastern limb of the deposit. Drilling proved phosphorite down to 200 m depth. The average P_2O_5-grade in the lowermost horizon is 26.32 %, in the middle horizon 23.74 %, and in the top horizon 21.37 %. The average grade of insolubles is 18.1 %. The estimated resources in category P1 are 7.56 million tonnes of ore grading 23.8 % P_2O_5, i.e. 1.5 million tonnes of P_2O_5. Potential mining is said to be difficult.

The biggest phosphate deposit in Mongolia is **Ongolog Nuur** with its northern end beginning some 10 km south-east of Uran Dosh Mountain and stretching southward for some 19 km. It was explored by drilling and trenching from 1984 to 1986 which revealed black phosphorite nodules of oolitic, pelitic, and breccious types, found mainly in siliceous dolomite. Typical for the southern Khuvsgul area there are up to five phosphate horizons stretching 500-19,000 m, on average 5,000-6,000 m, and with thicknesses of 1.5-50 m, on average 10-12 m. In the ore, the grades of unwanted impurities are 0.16 % Na_2O, 0.26 % K_2O, and 7 % MgO. The total resources amount to 571.652 million tonnes of ore grading 18.7 % P_2O_5 on average, i.e. 106.771 million tonnes of P_2O_5 in categories B+C1+C2, and 38.108 million tonnes of ore grading 14.8 % P_2O_5, i.e 5.629 million tonnes of P_2O_5 in category P1. Mineral processing tests were performed in the USSR showing quite satisfactory results.

In the **Khuvsgul** deposit (sensu stricto) there are five phosphate horizons of the lower phosphate unit of which layer I is the most important. It can be followed for 1.2 to 3.5 km along strike and has a thickness of 1.0-11.7 m, on average 6.2 m. The deposit is dominated by a very complicated tectonic structure with the phosphate horizons being strongly folded and fractured. Because the facies types within the phosphorite-bearing layers are highly variable, this is also reflected in the chemistry: e. g. in layer I, the P_2O_5-content ranges from 16.84-37.74 % (22.56 % on average). Besides phosphate, the ore contains impurities of 4.56 % MgO, 2.44 % R_2O_3, and 9.82 % insolubles on average. Taking into account minimum grades of 10 % P_2O_5 in general, and 16 % P_2O_5 in blocks of interest, the total resources for all five phosphate horizons amount to 9.9 million tonnes of ore, grading >16 % P_2O_5, i.e. 1.4 million tonnes of ore in categories C1+P.

In addition to the phosphate, there are also reserves of rock salt calculated as 268,500 tonnes in category B+C1.

Very similar to the Khuvsgul phosphate deposit sensu stricto, the **Javkhai** phosphate deposit, south of Jankhai Pass, consists of five phosphate horizons of which layer I has the biggest economic importance. Otherwise, the deposit consists of three areas, which are separated by fractures. The average P_2O_5 grade is 27.82 %. The resources are 15.8 million tonnes of ore with 4.4 million tonnes of P_2O_5 in category C2, and 42.1 million tonnes of ore with 11.71 million tonnes of P_2O_5 in category P2.

Ilyin (1973) estimated the (probable) resources of the whole Khuvsgul phosphate deposit sensu lato down to 200 m depth (from surface) as 432 million tonnes of ore grading 20.7 % P_2O_5 on average (i.e. 89 million tonnes of net P_2O_5). The same author estimated the resources down to lake-level (Khuvsgul Lake) as 517.9 million tonnes of ore with geological resources surpassing 1 billion tonnes of ore.
Today, resources (most of them probable) of close to 900 million tonnes of ore grading 14.8-29.3 % P_2O_5 seem to be realistic. Thus, the total P_2O_5-content is about 175 million tonnes.

The **Berkhem Ukhaa** phosphate occurrence is located some 30 km south of the Khuvsgul phosphate deposit on the border of the Khuvsgul National Park. There are three low-grade (7.1-12.5 % P_2O_5) phosphate horizons of 1.6-3 m thickness each. The total resources are estimated as 16.2 million tonnes of low-grade ore (P1).

The small **Maikhan Uul** phosphate deposit is located some 50 km south of the Khuvsgul phosphate deposit, and 20 km south of Khuvsgul Lake, i.e. just outside of the environmentally sensitive Khuvsgul National Park. Here, the main phosphorite-bearing rocks are silicified schists and quarzites. These rocks of interest occur in the two limbs of a N-S-trending anticline reaching lengths of 500-6,500 m, on average 5,000 m. The total thickness of phosphorite-bearing layers in the eastern limb is 87 m, and 31 m in the western limb. The ore grades relatively low 15.67 % (11.37-20.8 %) P_2O_5, as well as 0.88 % MgO, 2.22 % Fe_2O_3, and 2.00 % Al_2O_3 on average. In flotation tests, a phosphate concentrate grading 30.61 % P_2O_5 could be produced. Applying a cut-off grade of 10 % P_2O_5, resources amount to 9.69 million tonnes of ore grading 15.67 % P_2O_5, i.e. 1.52 million tonnes of P_2O_5 in category C1 and 41.4 million tonnes of ore grading 14.77 % P_2O_5, i.e. 6.11 million tonnes of P_2O_5 in category C2. Potential mining is expected to be difficult due to strong permafrost conditions.

15 km north of the Burenkhaan deposit, at the eastern shore of Erkhel nuur, lies the **Suul Tolgoi** phosphate occurrence. It consists of three highly tectonically fragmented ore bodies stretching 500-3,500 m, on average 2,000 m. In addition to 8.0-29.8 %, on average

Figure 71: Typical landscape with mountains and dry creek just north of the Javkhai phosphate deposit.

13.8 % P_2O_5, the ore contains 7.8 % MgO, and 6.21 % Fe_2O_3 on average. Using a cut-off grade of 10 % P_2O_5, total resources of 7 million tonnes of ore in category C2 were estimated. This occurrence is not economically mineable, especially due to the low grade.

Another rather small occurrence is **Shirenget** at the eastern side of the Egiin gol valley. In this area, one 3.8 km long horizon of highly silicified phosphorite-bearing limestone was found. The estimated resources are 2.2 million tonnes of ore of unknown grade (P1).

During a field trip in summer 2009, a small part of the important **Burenkhaan** phosphate deposit area was visited by BGR-MRAM geologists. The Burenkhaan deposit lies far south of the 50th parallel and therefore also lies far south of the Khuvsgul National Park and outside the Khuvsgul Lake drainage basin. The area visited and sampled (49° 44' 32.7" N , 99° 53' 31.6" E; 1,651 m a msl) is within one of the mining licences of Talst MArgad CO. LTD. This site can be easily reached from the town of Moron, which means that its accessibility is very good!

The Burenkhaan phosphate deposit in total is one of the 15 strategic deposits of Mongolia. Although it was explored very well in 1980, it is so huge in size (140 km^2) that it in fact consists of several interesting areas with high mineralisation (subdeposits) with even larger barren areas in between. According to the deposit passport, the Burenkhaan deposit consists of 25 ore bodies (subdeposits?) with

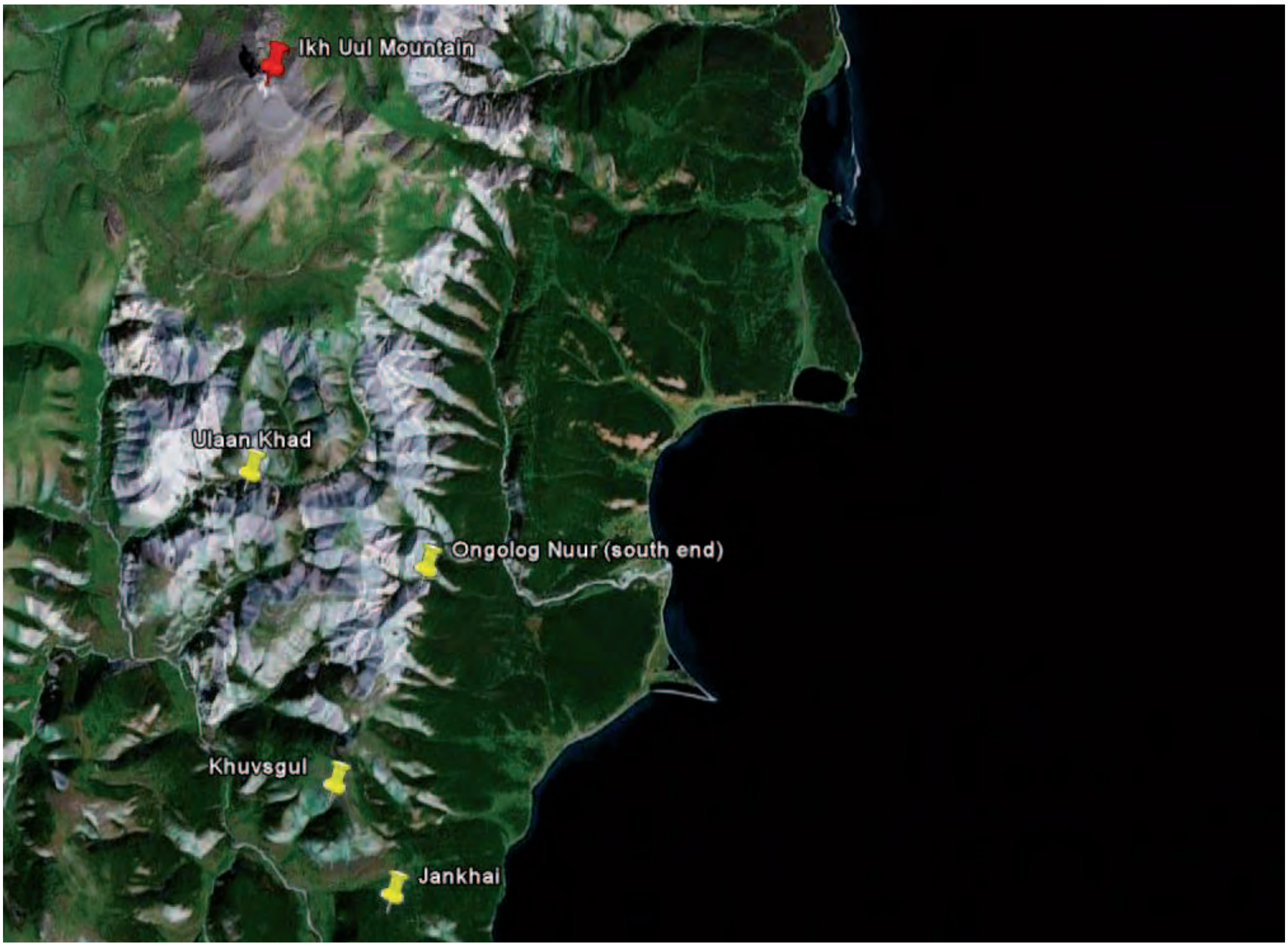


Figure 72: Satellite image of the southern part of the Khuvsgul phosphate deposit sensu lato showing various phosphate deposits with Ikh Uul Mountain in the north and Khuvsgul Lake (in black) to the west (Photo courtesy of Google Earth).

lengths of 500-3,200 m, widths of 20-100 m, and thicknesses of 2-60 m. Maximum thicknesses reflect strong folding and faulting including the stacking of phosphorite layers! Phosphorite-bearing layers are made up of variable amounts of coarse (1-2 mm), rounded to angular phosphate grains, apatite, dolomite, calcite, silica, and minor amounts of pyrite, limonite, sericite, other mica, clay minerals, organic matter, rutile and garnet.

A total of seven samples were taken by the MRAM-BGR field team from the Burenkhaan deposit. While all of them were presumed to represent typical phosphate ore, final analysis (cf. Table 44) revealed that only three of them were really phosphate ore, while the other four are more or less free of P_2O_5. This finding corresponds very well with the reports of Russian geologists, who after working on the phosphate ore in the Khuvsgul basin for several years, claimed that the phosphorite is extremely difficult to identify in the field. Similarly, Ilyin et al. (1986: 165) report: "In hand specimens, the Burenkhaan phosphorites are massive unbedded black rocks, indistinguishable from cherts".

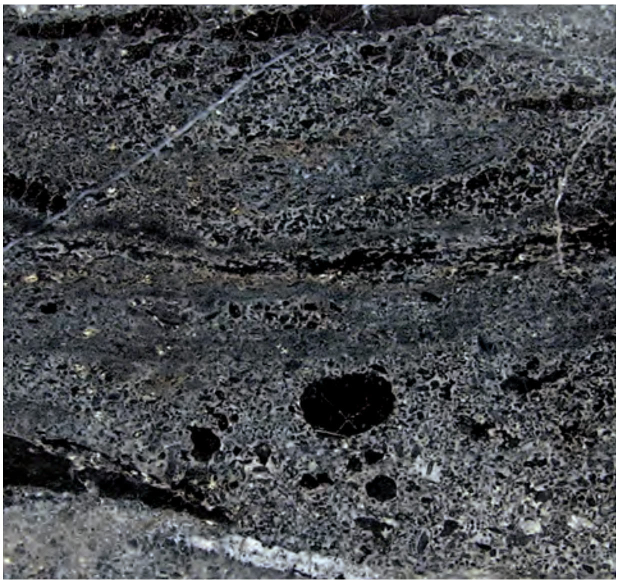


Figure 74: Photo of hand specimen (cut and polished) of typical siliceous breccious ore from the Burenkhaan phosphate deposit. Length shown is 11 cm.

Figure 73: Rolling grassland of the Burenkhaan deposit with Moron town in the far distance

Table 44: Selected chemistry of presumed phosphate ore from the Burenkhaan phosphate deposit. XRF analysis by BGR. Cd by wet chemical analysis. n.a. = not analysed.

Chemistry	Burenkhaan						
	Carbonaceous ore	Siliceous ore		No ore			
	# 5	# 1	# 4	# 2	# 3	# 6	# 7
P_2O_5	24.26	17.64	15.50	0.29	0.02	2.87	0.29
SiO_2	24.96	57.02	53.64	1.68	0.40	12.96	3.30
TiO_2	0.01	0.00	0.05	0.00	0.00	0.01	0.01
Al_2O_3	0.33	0.11	0.84	<0.05	0.06	0.18	0.25
Fe_2O_3 total	0.41	0.20	0.64	0.03	0.05	0.06	0.12
MgO	0.43	0.03	0.38	4.47	0.18	8.70	8.67
CaO	40.84	23.45	23.92	49.98	52.57	37.75	42.09
Na_2O	0.04	<0.01	0.02	<0.01	<0.01	0.01	0.02
K_2O	0.02	0.00	0.14	0.00	0.00	0.01	0.02
(SO_3)	0.04	0.05	0.05	0.06	0.04	0.05	0.11
(F)	1.58	1.08	1.03	0.10	0.11	0.35	0.11
LOI	7.40	0.39	3.78	43.28	43.30	36.85	44.79
Sum	*100.37*	*100.00*	*100.03*	*99.93*	*96.75*	*99.87*	*99.79*
(As)	11 ppm	11 ppm	9 ppm	4 ppm	5 ppm	7 ppm	10 ppm
Ba	378 ppm	880 ppm	285 ppm	18 ppm	89 ppm	236 ppm	168 ppm
Cd	1 ppm	<1 ppm	<1 ppm	n.a.	n.a.	n.a.	n.a.
Cr	29 ppm	16 ppm	50 ppm	<4 ppm	6 ppm	14 ppm	15 ppm
Cu	75 ppm	14 ppm	121 ppm	11 ppm	22 ppm	44 ppm	30 ppm
Ni	29 ppm	6 ppm	42 ppm	<2 ppm	27 ppm	40 ppm	6 ppm
Pb	<3 ppm	<3 ppm	<3 ppm	<3 ppm	<3 ppm	<3 ppm	<3 ppm
Sr	1212 ppm	556 ppm	644 ppm	467 ppm	2366 pm	475 ppm	762 ppm
Th	<4 ppm	<4 ppm	<4 ppm	<4 ppm	8 ppm	<4 ppm	<4 ppm
U	19 ppm	42 ppm	10 ppm	8 ppm	7 ppm	15 ppm	7 ppm
V	77 ppm	69 ppm	101 ppm	42 ppm	86 ppm	78 ppm	52 ppm
W	72 ppm	270 ppm	117 ppm	56 ppm	25 ppm	22 ppm	6 ppm
Zn	18 ppm	13 ppm	17 ppm	<2 ppm	39 ppm	32 ppm	6 ppm

Table 45: Chemical composition of various types of phosphate ore from the Khuvsgul and Burenkhaan phosphate deposits, after Byamba (1996). n.d. = not determined

Chemistry	Burenkhaan			Khuvsgul	
	Siliceous breccious ore	Medium-grained ore	Extremely fine-grained ore		Medium-grained ore
P_2O_5	12.56	38.20	40.05	39.26	39.60
SiO_2	51.79	2.40	0.80	0.60	1.34
TiO_2	-	-	-	-	-
Al_2O_3	4.28	0.45	0.25	1.12	0.30
Fe_2O_3	3.02	0.50	0.87	1.26	0.49
FeO	-	-	-	0.18	-
MgO	0.10	n.d.	n.d.	0.87	0.78
MnO	-	-	-	-	-
CaO	20.79	53.20	54.80	53.18	52.60
Na_2O	-	0.10	0.08	0.13	-
K_2O	-	traces	traces	0.05	n.d.
H_2O	-	-	-	-	-
CO_2	3.23	1.05	0.85	2.15	1.13
SO_3	0.04	traces	traces	-	0.50
F	-	2.75	3.04	1.75	-
others	-	2.40	1.24	-	-

Figure 75: Main phosphorite layer (black clasts) in the licence area of Talst Margad CO. LTD. in the Burenkhaan phosphate deposit.

The new chemical analyses prove the good quality of the Burenkhaan phosphate ore in general (cf. Table 44). Older analytical data are shown in Table 45.

The reserves of the Burenkhaan deposit in total (upper horizon only) were calculated in former campaigns as

- 33.09 million tonnes of ore grading 23.81 % P_2O_5 on average (7.88 million tonnes of net P_2O_5) in category B,
- 129.47 million tonnes of ore grading 20.36 % P_2O_5 on average (26.36 million tonnes of net P_2O_5 in category C1, and
- 12.95 million tonnes of ore grading 20.00 % P_2O_5 on average (2.59 million tonnes of net P_2O_5) in category C2,
- i.e. total 175.51 million tonnes of ore (36.83 million tonnes of net P_2O_5 in categories B+C.

Because two phosphate horizons of the Lower phosphate unit were also encountered in boreholes, their resources were additionally calculated as

- 28.62 million tonnes of ore grading 22.45 % P_2O_5 on average (6.65 million tonnes of net P_2O_5) in category C2 and
- 108.42 million tonnes of ore grading 20.81 % P_2O_5 on average (22.56 million tonnes of net P_2O_5) in category P.

Tsagaan Nuur is the only phosphate deposit in the western phosphate belt with any available resource data. It is very poorly studied, and consists of three phosphate-rich areas and a total of five phosphate beds. The average length of these beds is 1.5 km, with thicknesses of phosphate-rich horizons varying from 1.5 to 4.0 m. While Ilyin (1973) originally estimated

Figure 76: Satellite image showing the very remote Tsagaan Nuur phosphate deposit in the western phosphate belt of the the Khuvsgul phosphate basin (Photo courtesy of Google Earth).

resources of some 216 million tonnes of ore grading about 25 % P_2O_5 on average, more realistic approaches end up with 25 million tonnes of ore. Geological Information Center (2003) gives 37 million tonnes of ore grading 22.28 % P_2O_5 (category P). Detailed analysis proved the uranium content of this deposit to be very low (4 ppm on average) (Ilyin et al. 1986).

Besides the Khuvsgul basin, there also seems to be some potential for phosphate in the Aldarkhaan, Yaruu, and Erdenekhairkhan Soum areas of Zavkhan Aimag, i.e. in the Zavkhan basin. In this region, about 20 phosphate occurrences were discovered, mainly in limestones of Lower Cambrian age.

At **Alagin Davaa** (Alag uul) and **Tsakhir Uul** in Aldarkhaan Soum, phosphorite is bound to a 20-40 m thick layer of sandstone with the ore body stretching for some 6-7 km. The tectonic displacement is weak. The grades of P_2O_5 range from 10-32.3 % with most data plotting between 15.6-21.3 %. The estimated resources are 31.6 million tonnes of ore. Due to the lack of data, resources for the Zavkhan basin have not been calculated yet, but might well be of economic interest (Anonymous 2002).

Table 46: Summary of resources and P_2O_5-grades in phosphate deposits in the Khuvsgul phosphate basin, after deposit passports

Name		Resource of ore @ grade	P_2O_5-content
Within Khuvsgul National Park	Tavkhai Nuur	10.245 Mt @ 23.24 % (C2) 20.742 Mt @ 23.23 % (P1)	2.38 Mt (C2) 5.06 Mt (P1)
Within Khuvsgul National Park	Oliin Davaa	15.3 Mt @ 20.2 % (C2) 149 @ 15.55 % (P)	3.0 Mt (C2) 23.2 Mt (P)
Within Khuvsgul National Park	Chiglel	17.5 Mt @ 15.64-19.88 % (P2)	2.7-3.5 Mt (P2)
Within Khuvsgul National Park	Khuvsgul s.l. - Saikhan Gol	10.5 Mt @ 29.26 % (P)	3.0 Mt (P)
Within Khuvsgul National Park	- Khoit Uran Dosh	99.9 Mt @ 17.88 % (P)	17.87 Mt (P)
Within Khuvsgul National Park	- Uran Dosh	No information	No information
Within Khuvsgul National Park	- Baga Tsagaan Gol	20.8 Mt @ 21.47 % (P2)	4.4 Mt (P2)
Within Khuvsgul National Park	- Bayanzurkh	6.4 Mt @ 19.78 % (P1) 3.2 mt @ 17.18 % (P1)	1.2 Mt (P1) 0.6 Mt (P1)
Within Khuvsgul National Park	- Nuurtyn Am	70.1 Mt @ 23.84 % (P)	14.8 Mt (P)
Within Khuvsgul National Park	- Ulaan Khad	7.56 Mt @ 23.8 % (P1)	1.5 Mt (P1)
Within Khuvsgul National Park	- Ongolog Nuur	571.652 Mt @ 18.7 % (B+C1+C2) 38.108 Mt @ 14.8 % (P1)	106.77 Mt (B+C1+C2) 5.63 Mt (P1)
Within Khuvsgul National Park	- Khuvsgul s.s.	9.9 Mt @ >16 % (C1+P)	1.4 Mt (C1+P)
Within Khuvsgul National Park	- Jankhai	15.8 Mt @ 27.82 (C2) 42.1 Mt @ 27.82 (P2)	4.40 Mt (C2) 11.71 Mt (P2)
Outside Khuvsgul National Park	Maikhan Uul	9.69 Mt @ 15.67 % (C1) 41.4 Mt @ 14.77 % (C2)	1.52 Mt (C1) 6.11 Mt (C2)
Outside Khuvsgul National Park	Burenkhaan	33.09 Mt @ 23.81 % (B) 129.47 Mt @ 20.36 % (C1) 12.95 Mt @ 20.00 % (C2) LPU: 28.62 Mt @ 22.45 % (C2) LPU: 108.42 Mt @ 20.81 % (P)	7.88 Mt (B) 26.36 Mt (C1) 2.59 Mt (C2) LPU: 6.65 Mt (C2) LPU: 22.56 Mt (P)
Outside Khuvsgul National Park	Tsagaan Nuur	37 Mt @ 22.28 % (P)?	8.2 Mt (P)?

REQUIREMENTS AND EVALUATION

The main international requirements for deposits of phosphate ores of marine-sedimentary origin, i.e. phosphorites, are a minimum grade of 5 wt.-% P_2O_5 (= 11 wt.-% BPL), most often >20 wt.-% P_2O_5, and net resources of more than 5-10 million tonnes of P_2O_5 (= small deposits). Medium size deposits start at 100 million tonnes of net P_2O_5, with big and world-class deposits possessing net resources of >1.5 billion tonnes of P_2O_5.
According to the Russian classification system, small deposits also contain <10 million tonnes, however, medium sized deposits contain 10-50 million tonnes, large deposits contain 50-100 million tonnes, and very large deposits >100 million tonnes of P_2O_5.
The minimum design capacity of dressing plants is 100,000 tonnes of phosphate ore per year.

For direct use as fertilizer, i.e. without any other mineral processing besides grinding, phosphate ores should contain >15 wt.-% P_2O_5 (> 33 wt.-% BPL). 55 wt.-% of the phosphate content must be dissolvable in 2 %-conc. formic or citric acid. 80-90 wt.-% of the crude phosphate ore has to be ground to <0.1 mm.

For industrial uses, phosphate rocks, i.e. phosphate ore concentrates, need to contain >28 wt.-% P_2O_5, <11 wt.-% $CaCO_3$, <5 wt.-% SiO_2, <3 wt.-% F, <2.5 wt.-% R_2O_3, <0.25 wt.-% MgO, <0.10 wt.-% Cl, <1 wt.-% organic substance, <20 ppm Cd, as well as extremely low values of Pb, Hg, U, Cr, As, Se, and V. Phosphate rocks should also be fine-ground and dry.
For investors in Mongolian phosphate, the Burenkhaan phosphate deposit is the first and best choice. All other deposits in the Khuvsgul basin are of limited interest only, as they may be of good grade and even of medium size but are lying within the environmentally highly sensitive Khuvsgul National Park or in very remote areas.
In addition, the Zavkhain basin may contain some phosphate deposits of economic interest, however, a lot of exploration is still needed before any serious evaluation is possible.

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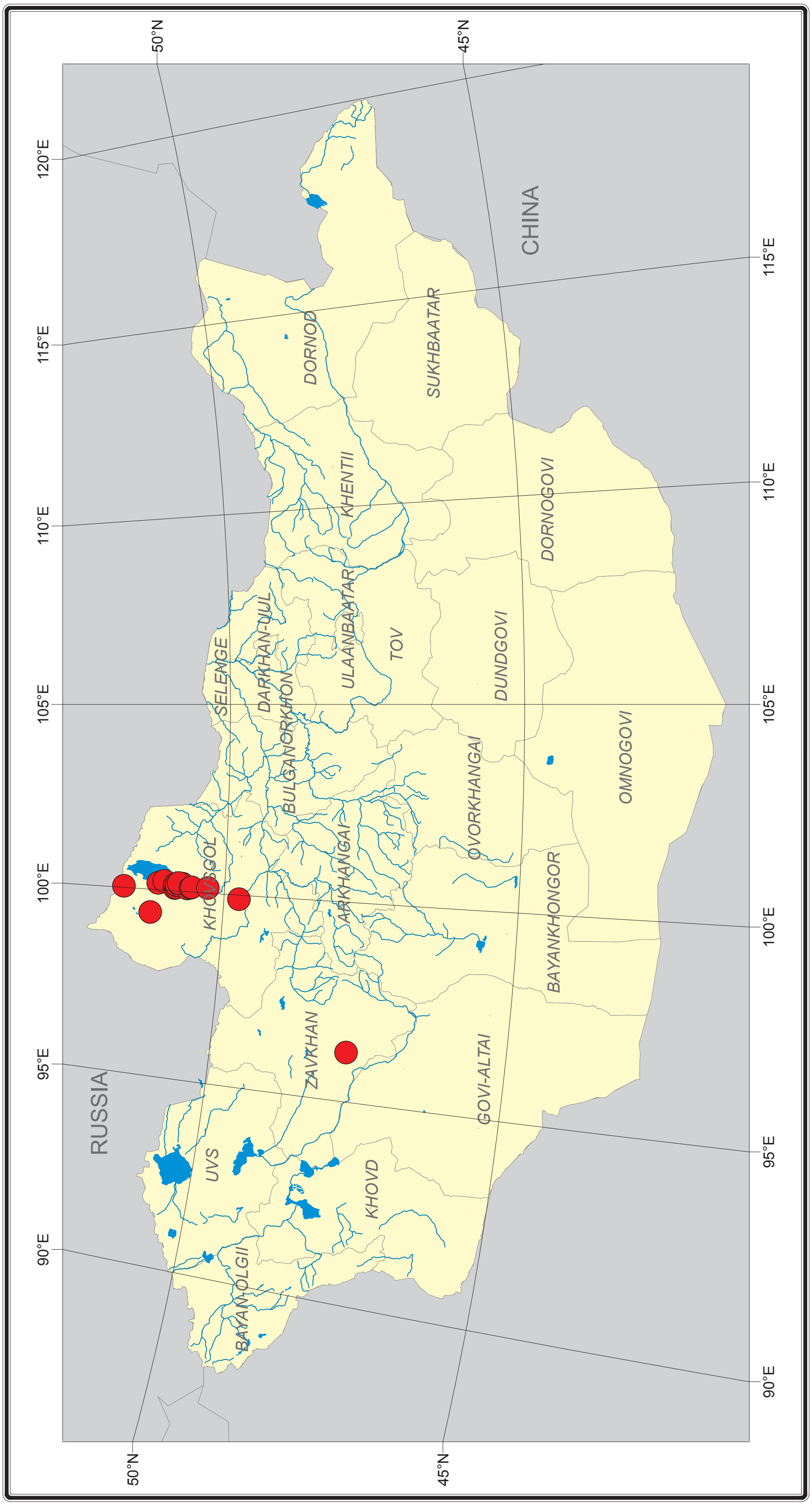
Deposits of Phosphate in Mongolia



Legend

Phosphate

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

PYROPHYLLITE (AGALMATOLITE)

GENERAL INFORMATION AND USES

Pyrophyllite is a phyllosilicate mineral belonging to the clay family. It occurs in two more or less distinct varieties, namely, as crystalline lamellae and as compact masses.
The lamellae have a pronounced pearly lustre, owing to the presence of a perfect cleavage parallel to their surfaces: they are flexible but not elastic, and are usually arranged radially in fan-like or spherical groups. This variety, when heated by a blowpipe, exfoliates and swells up to many times its original volume.
Due to its low thermal conductivity, low coefficient of expansion, low hot-load deformation, and resistance to molten metals, pyrophyllite is extensively used as a refractory. In ceramics, pyrophyllite partly substitutes for feldspar as a source of alumina and silica, to reduce shrinkage, cracking and thermal shock, and lower electrical conductivity. Similar to talc, it is also used as a pesticide carrier, anti-caking agent in animal feed, for agricultural chemicals, as a filler in wallboard, and in paints and plastics.
The compact variety of pyrophyllite is used for slate pencils and tailors' chalk (French chalk), and is carved by the Inuit and the Chinese into small images and ornaments of various kinds. Together with other soft compact minerals (steatite and pinite), the term agalmatolite is common for this kind of carvable pyrophyllite

RELEVANT OCCURRENCES IN MONGOLIA

In Mongolia there are two deposits and two occurrences of pyrophyllite – termed more correctly agalmatolite by Geological Information Center (2003).

Both deposits, Erdene, and Ikh Shankhai, are in Umnugovi Aimag and are located in the Late Paleozoic rift zone of the South Govi. They were formed by the alteration of volcanic rocks.

The **Erdene** deposit lies in Gurvantes Soum north of Erdene Uul Mountain. Here, pyrophyllite ore occurs along tectonic fracture zones in andesite porphyries and tuff horizons of Lower Cretaceous age. The ore is composed of 50-63 vol.-% pyrophyllite, 25-30 vol.-% sericite, some quartz, feldspar, and iron oxides. 13 different ore bodies have been outlined, dipping 20°-50° to the south-west, attaining 0.5-2.5 m thickness, and 20-40 m length. The largest ore body, #12, is 10 m thick and 300 m long. The estimated resources for the six ore bodies (#1-6) and down to a depth of 5 m only total 1,073 m^3 or 2,791 tonnes, out of which 5 tonnes have been quarried for testing purposes. Because this pyrophyllite ore can be easily polished and has nice decoratve features it is also quarried periodically by collectors.

At **Ikh Shankhai** in Tsogttsetsii Soum, agalmatolite occurs in a lens 25-30 m long and 5 m thick. This lens was formed between pink felsites and black to grey andesite porphyries of Upper Carboniferous age. The agalmatolite is coloured pink, yellow grey, and blue grey and is easily polishable. It has been extracted by local residents in small quantities. However, as a fracture splits the lens, many rocks are shattered and estimated resources only amount to 300 m^3 of agalmatolite.

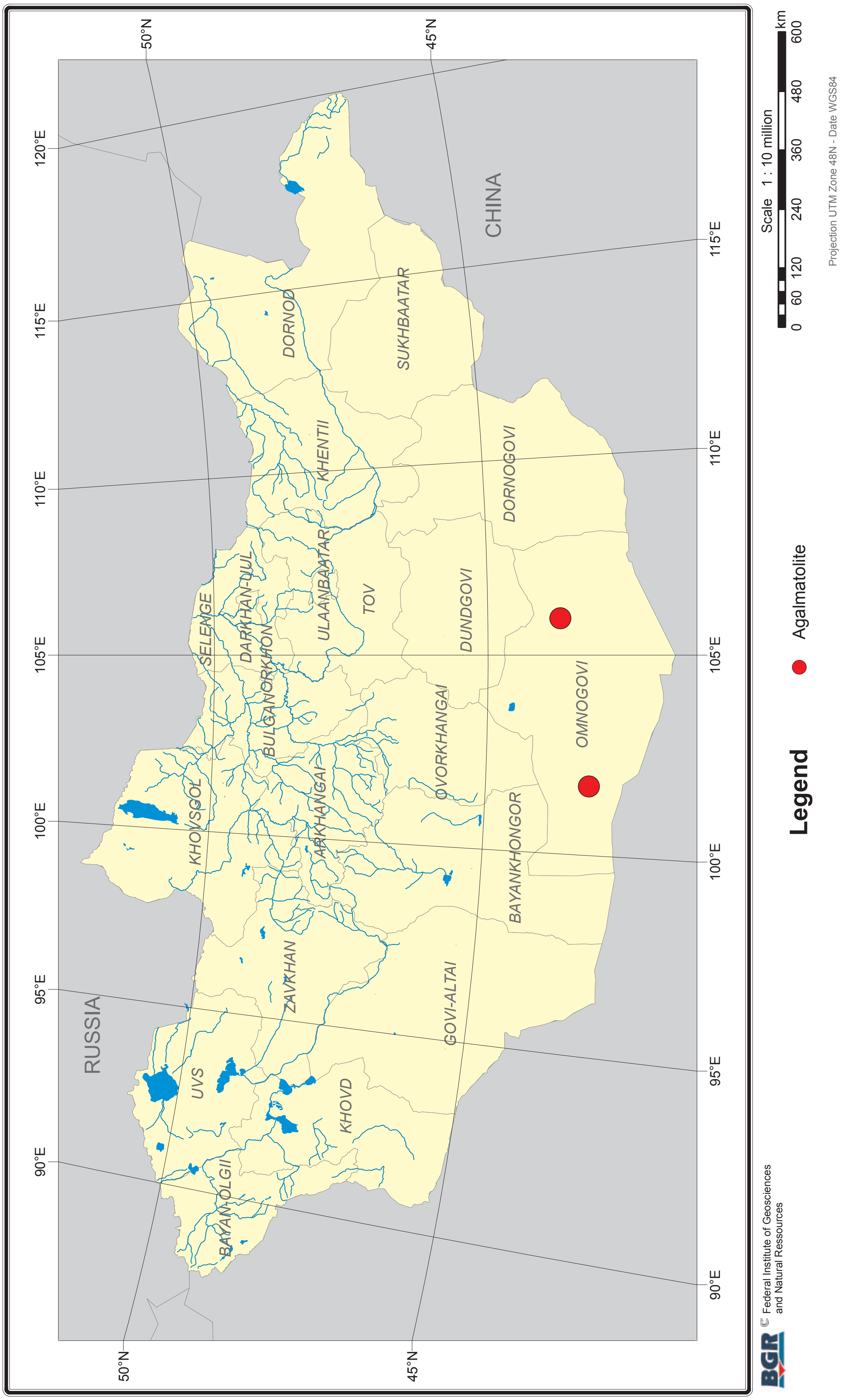
REQUIREMENTS AND EVALUATION

Depending on its application, pyrophyllite ore should be low in potassium (<0.8 % K_2O) and iron (<0.5 % Fe_2O_3). Dressing can remove most mineral impurities, very often sericite, chlorite, quartz, alunite, kaolinite, kyanite, andalusite, rutile, and other Al-rich minerals. While small but good quality deposits may contain less than 100,000 tonnes of pyrophyllite, medium size ones normally have a mineral content between 200,000 tonnes and 2 million tonnes.

Regarding agalmatolite there are no specific requirements. It just has to be carvable and have a nice colour. Of course bigger deposits are preferred.

In Mongolia there are no deposits of pyrophyllite. Erdene and Ikh Shankhai are occurrences of the mineral curiosity agalmatolite, having no economic value to investors.

Deposits of Agalmatolite in Mongolia



ROCK QUARTZ

GENERAL INFORMATION AND USES

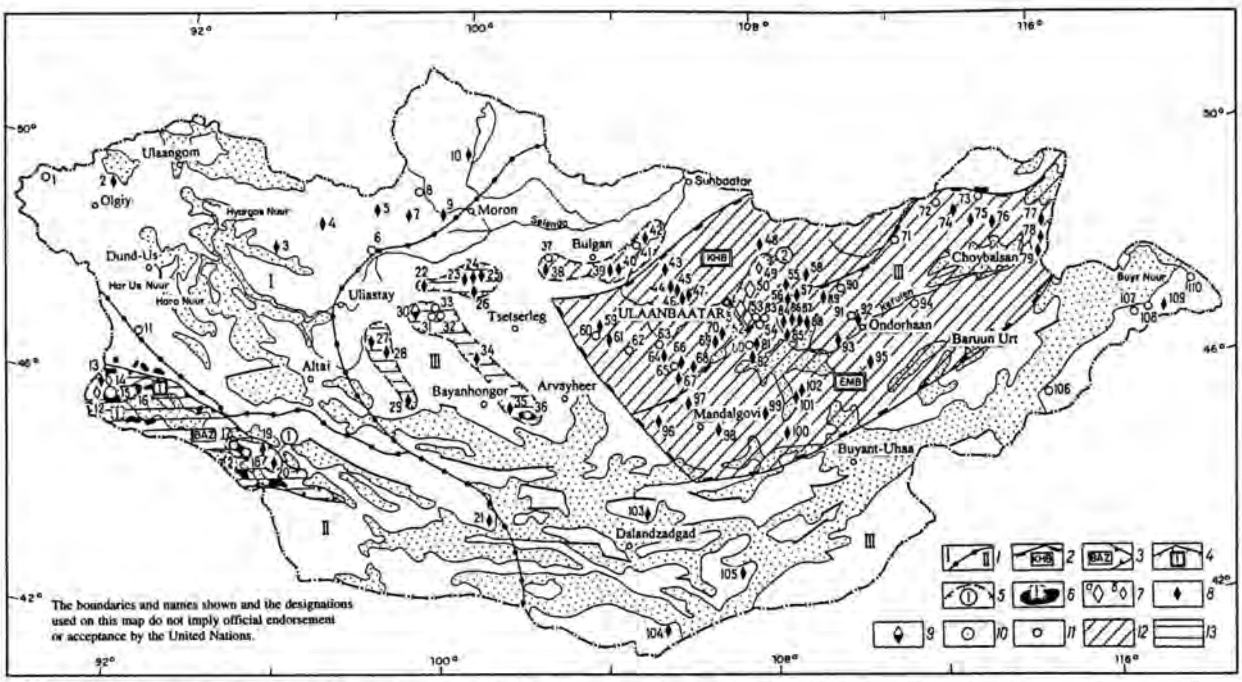
Although quartz is a ubiquitous mineral, rock quartz is a highly sought after and in some cases very valuable commodity. Other names for rock quartz or its varieties given in the Mongolian literature are crystalline quartz, crystal quartz, lump quartz, piezo quartz, optical quartz, vein quartz, and pegmatitic quartz. While crystal quartz, vein quartz, and pegmatitic quartz can be differentiated by origin, common applications are that they are all used for the production of optical glass, piezoelectric quartz, silicon, and ferrosilicon.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Occurrences of rock quartz are extremely widespread in Mongolia with the numbers of locations given by various authors varying between 40 and 109. Quartz in the form of big areas of hydrothermal quartz veins and pegmatitic quartz is common in certain granitoid massifs (100-600 km^2). The main areas of occurrences are in the Khentii Mountains east and west of Ulaanbaatar, in the Hangay Mountains, and in south-west Mongolia.

General information on major rock quartz deposits in Mongolia is presented in Table 47.

The **Gorkhi** quartz deposit lies east of Ulaanbaatar at the southern end of the Gorkhi Terelj National Park. Here, at the boundary between partly Sn-bearing and W-bearing granites of Jurassic age and neighbouring meta-sediments, pegmatites intruded. Among other rock-forming minerals, they bear gemstones (topaz, beryl, tourmaline, aquamarine, and zircon) and crystal quartz. In the 1920's, and between 1953 and 1964, big crystals of



LEGEND: Ore-bearing units: 1 - Metallogenic provinces (I - Northern Mongolian, II - Southern Mongolian, III - Eastern Mongolian); 2 - Crystalline quartz-bearing belts (KHB-Hentiy, EMB-East Mongol); 3 - Baruun Huuray-Ajbogdin zone (BAZ); 4 - Baruun Huuray quartz-bearing district; 5 - Groups of deposits and occurrences (1 - Fore-Ulaanbaatar, 2 - Ajbogdin); 6 - Quartz veins fields (1 - Baruun Huuray, 2 - Dzolen-Bogdo-Uul); 7 - Deposits of crystalline quartz of pegmatite group: (a) middle, (b) small; 8 - Pegmatite occurrences of crystalline quartz; 9 - Deposits of lump quartz/quartzite; 10 - Deposits of crystalline quartz of hydrothermal group; 11 - Hydrothermal crystalline quartz occurrences. Age of mineralization. 12 - Mesozoic, 13 - Upper Palaeozoic.

Figure 77: Map of metallogenetic provinces of Mongolia with location of rock quartz occurrences (United Nations 1999).

Table 47: Selected parameters of major rock quartz deposits in Mongolia, after deposit passports, UNITED NATIONS (1999), and BRÜNING (1966).

Name	Location	Geological setting	Main parameters
Baruun Huuray	90 km south of Bulgan (Bulgan Soum, Khovd Aimag)	The Baruun Huuray field of quartz veins contains about 1,000 quartz veins and stockworks. The field incorporates the Ond Orlog 1331 quartz deposit and several quartz occurrences.	The field contains numerous veins of 100-400 m length and up to 3 km length. At Ond Orlog 1331, 25 quartz veins were identified. 2 veins of 270 m / 150 m length and up to 23 m / 14 m thickness are reported to contain some quartz crystal bearing lenses and nests of 0.1-8.0 m^3 size. Total category C1+C2 resources are 7,421 kg of piezo quartz of very poor quality. Resources of lower quality quartz have not been stated. For chemical composition cf. Table 48.
Gorkhi	60 km E of Ulaanbaatar and 15 km NE of Nalaikh train station (Erdene Soum, Tuv Aimag)	Gorkhi granitoid massif of 104 km^2 size within Khentii mountain belt.	787 pegmatite bodies within pegmatite zone of 18 km length and 1.35 km width. Pillar-like pegmatite bodies of 3 x 6 to 25 x 30 m size containing a series of large and medium quartz crystal nests and lenses with volumes from 40 to 150 m^3. Mined out, cf. text below.
Zuu'nbayan	85 km NE of Nalaikh train station and 60 km NE of Gorkhi (Erdene Soum, Tuv Aimag)	Zuu'nbyan Triassic granitoid massif of 27 x 18 km size.	310 pegmatite bodies of vein, lens, stock or pillar shape. 143 pegmatites reportedly contain numerous quartz crystal nests and lenses of varying size and volume up to 350-450 m^3. Pegmatite veins of economic interest are 0.8-50 m long, 3-83 m wide, and 0.5-23 m thick. Most crystal quartz is black or light smoky in colour. Known defects include twinning, bedding, cracks, gas and fluid inclusions as well as inclusions of other minerals. For chemical composition cf. Table 48.
Janchivlan / Tsagaan Del	80 km SE of Ulaanbaatar and 25 km SW of Erdene (Erdene Soum, Tuv Aimag)	Janchivlan granitoid massif of 600 km^2 size.	200 pegmatite bodies localized within area of 50 km^2 size. >50 % of identified pegmatite bodies contain quartz crystals. 10 out of 80 bodies explored contain stocks, pillar-like bodies and lenses of quartz crystals of varying size and volume. The largest crystal found weighed 45 kg, was 108 cm long and 19-22 cm in diameter. Average crystals were 7-25 cm long. Mined out between mid 19th century and 1962.
Arts Gol	150 km NE of Ulaanbaatar (Erdene Soum, Tuv Aimag)	Arts Gol granitoid massif of 400 km^2 size.	23 pegmatite bodies localized within area of 4.5 km^2. Out of 18 explored bodies, 7 bodies are of lens and isometric shape, 2 are pillar-like and 9 of vein type. The quartz crystals, most of them smoky quartz, have cracks and inclusions and weigh from 500-800 g up to 25-30 kg, in rare cases up to 100 kg.

transparent and smoky quartz weighing up to 8 tonnes were mined. Quartz mining was followed by collecting pink and bluish topaz as well as aquamarine by small-scale miners. Besides lying within the Gorkhi Terelj National Park, the quartz deposit now is completely mined out, but is just visited sporadically by private mineral-collectors.

Several quartz occurrences (e.g. Salaa at Baruun-urt, Ond Orlog 1331, Tsagaan Ovoo, Zuunbayan, Tsakhir, cf. Table 48) were looked at in close detail from the mid 1960's to 1989 by the Central Institute of Inorganic Chemistry of the Academy of Sciences of the former East Germany, various state companies of the former East Germany, and the Institute for Physics and Technics of the Academy of Sciences of Mongolia. All investigations were carried out to find deposits of rock quartz suitable for use in the optical and electro-optical industries of former East Germany. Quartz samples

Table 48: Impurities in pegmatitic quartz (in ppm) from Mongolia, after Hofmann (1981) and Kraetsch (1981).

	Salaa	Ond Orlog 1331	Zuunbayan	Tsakhir
Fe_2O_3	127	9-21	3-20	3-22
Al_2O_3	284	125-180	110-190	165-330
TiO_2	13	3	10-13	11-16
CaO	45	7-10	5-17	4-11
MgO	8	2-5	2-4	2-5
SrO		1	<1	<1-1
BaO		2	<1	<1-2
Li_2O	12	2-3	27-34	26-54
Na_2O	58	30-45	4-13	8-28
K_2O	55	9-21	2-9	2-28
CuO		<1	<1	<1
NiO		<1	<1	<1
MnO		<1	<1	<1
Cr_2O_3		<0.5	<0.5	<0.5
Co_2O_3		1	1	1
B_2O_3		<1	<1	<1
V_2O_5		1	2	<1-1
ZrO_2		<1	<1	<1

of different genesis were analysed to identify raw materials for the production of enamel, and especially silica glass. Initially, 34 samples of 3-8 kg each were taken from eight occurrences, and various parameters, both chemical and technical, were analysed. The vein area at Ond Orlog 1331 produced the best results, so a larger sample was taken for additional analysis. Although the final results were never published, preliminary data showed this quartz to be unsuitable for the production of silica glass due to its high content of gas-fluid inclusions and unwanted impurities (Al, Ca, Na) (Kampe 1997).

While these findings sound very disappointing, some high-grade quartz occurrences, which nevertheless might well be of potential interest to investors, are mentioned by Geological Information Center (2003). These are **Doltai**, **Orkhon/Bayanondor**, **Kharmagtedi**, and **Bayan Uul/Zalaan Tsagaan**. E.g. the Bayan Uul quartz occurrence in Saikhandulaan Soum of Dornogovi Aimag was explored quite thoroughly, and found to contain category C2 resources of 879,000 tonnes and additional category P1 resources of 1,083,000 tonnes of quartz in three quartz veins of 255-400 m length and 2-20 m width. The quartz is obviously high-grade with 99.19 to 99.99 %, on average 99.97 % SiO_2. Maximum contents of impurities are 0.52 % Al_2O_3, 0.047 % TiO_2, 0.13 % Fe_2O_3, 0.17 % CaO, 0.023 % MgO, 0.071 % MnO, 0.405 % Na_2O, and 0.44 % K_2O. However, in general, the contents of impurites are only in the ppm-range. Although the quartz is heavily stained by Fe-hydroxides on the surface, testing showed that this coating was easily removable by thermal and chemical treatment.

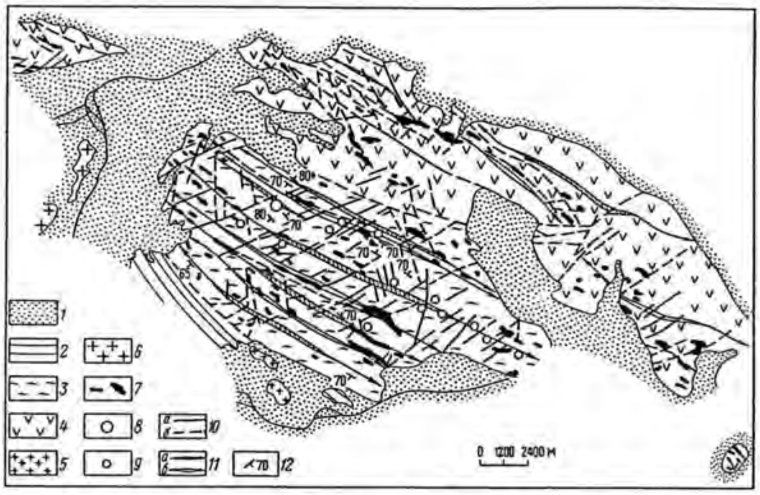


Figure 78: Schematic geological map of the Barrun Huuray field of quartz veins (United Nations 1999).

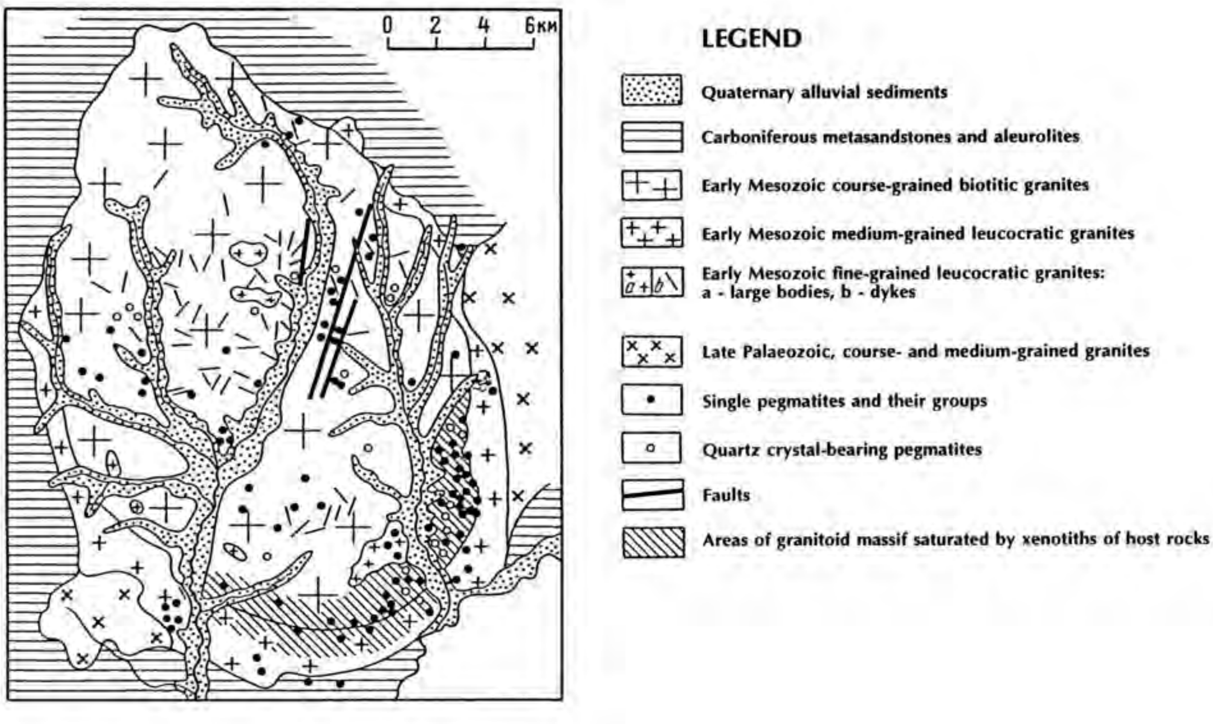


Figure 79: Schematic geological map of the Zuunbayan field of quartz veins (United Nations 1999).

REQUIREMENTS AND EVALUATION

For industrial uses, all rock quartz resources have to be exceptionally clean. For the production of quartz glass, impurities must be below 150-200 ppm, with the sum of Cu, Co, Cr, Mn, Ni, and V <5 ppm! Piezo-electric quartz must be chemically pure and may not have any inclusions, cracks or twinning. Rock crystals should weigh >125 g. For the production of electronic grade silicon, impurities are only allowed in the ppb range. However, other varieties of silicon are much easier to produce. Because these requirements are very difficult to satisfy, even small deposits of rock quartz, say half a tonne, may be worth marketing.

The geology of Mongolia is quite suitable for the occurrence of rock quartz of various genesis. While it seems that none of the bigger deposits looked at in more detail in the past are suitable for the production of piezo-electric quartz, silica glass or high-grade silicon, other quartz deposits or occurrences in Mongolia might well be used for different purposes, i.e. for the production of glass, refractories, metallurgical silicon or ferrosilicon. Potential investors should check for deposits/occurrences of both big size and excellent infrastructure, i.e. very close to a railway line, or of obviously very good quality, which needs to be verified in an experienced and well-equipped laboratory.

Figure 80: Outcrop of quartz veins in leucogranites in the middle of the steppe in Sukhbaatar Aimag (coordinates: 45°41’09.9” N, 112°06’36.4” N, 1,112 m a.s.l.).

Figure 81: Crystals of smoky quartz from mine dump in the Gorkhi Terelj National Park

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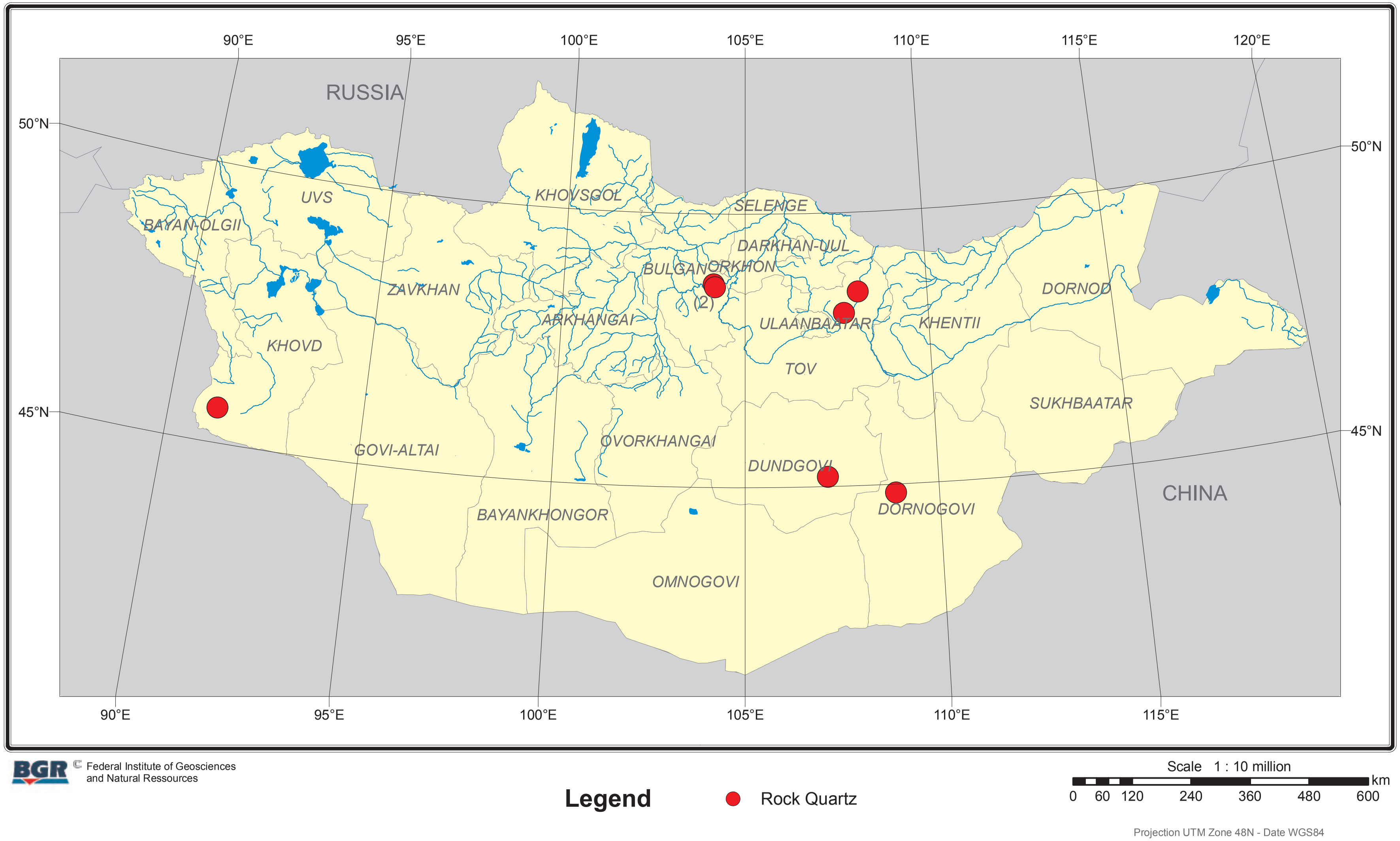
Deposits and important occurrences of Rock Quartz in Mongolia



SALT, SODIUM CHLORIDE

GENERAL INFORMATION AND USES

Common salt, which is sodium chloride, NaCl, or mineralogically halite, is essential for human and animal life. It is used for food flavouring and conservation, for the production of animal feed, for preserving skins, and for the production of caustic soda and chlorine in the chemical industry. It also finds numerous other applications in other industries. In Mongolia almost all domestic salt is produced from salt lakes, the only exception being Shuden/Davst Uul in West Mongolia which is a rock salt deposit.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Due to the arid climate there exist numerous, i.e. hundreds or even thousands of salt lakes in central, eastern, and southern, but also in north-western Mongolia.

While the number of salt lakes in Mongolia is of no interest to potential investors, they should know that most of them were only studied, if at all, many decades ago, which means that most economic parameters determined during the time of investigation are outdated. Secondly, with few exceptions (e.g. Dund bayan nuur), hardly any of the lakes or its brines in Mongolia have ever been analysed for their content of rare elements, i.e. bromium, boron, iodine, fluorine, or lithium, which today are of much higher interest to investors than common salt. Rasskasov et al. (1991) mention elevated values (without giving absolute data) of some of these rare elements in Uvs nuur (F, Br), Davsan nuur (Li, Br, B), Buult nuur (F, B), Davsan nuur (Li, Br, B), Suuj nuur (Li, Br), Borvi nuur (Li, Br), Erchel nuur (Br), Tuchmiin nuur (Li), Tsaidam nuur (F), Sumiin nuur (F), Khugh nuur (F), Angirt nuur (F),

Figure 82: Typical medium-size salt lake in Mongolia as of May 2008 with layers of mirabilite- and halite-rich salt (Olziit nuur in Bayantsagaan Soum, Tuv Aimag).

Sangiin dalay nuur (Li, Sr, Br, B), Khukh nuur (Li, Sr, Br), Utaat minjuriin (F, B), and Toson (Br, B).

Because the total number and the size of the lakes vary as a function of precipitation and evaporation, which fluctuate strongly over time, there is no general agreement on the number of salt lakes of economic importance in Mongolia. Dejidmaa et al. (2001) list 11 halite deposits, 18 mixed halite-sodium sulfate deposits, 20 halite occurrences, and 6 mixed halite-sodium sulfate occurrences in Mongolia.

The most important halite deposits in Mongolia are:

- **Gurvan Tes** in Gurvantes Soum of Umnugovi Aimag, i.e. in South Govi desert. In an area of about 2.2 km x 1 km, besides 331,000 tonnes of mirabilite and thenardite (cf. Salts, Sodium, other than Sodium Chloride) this seasonal lake contains a layer of halite about 1 m (0.2-0.5 m up to 1.4-1.6 m) thick.
  The chemical composition of this salt layer is given in Table 49. The initial reserves of halite were calculated as 233,800 tonnes in categories A+B, and 256,300 tonnes in category C1, of which 55,400 tonnes have been mined manually since the 1990's until 2003. Mining is said to continue at a limited scale for local consumption only. According to Rasskasov et al. (1991) the resources of brine (cf. Table 49) in Gurvan Tes are about 4 million tonnes.

- **Sangiin Dalay Nuur** covers an area of about 5 km^2 and seasonally up to 6.4 km^2 in Matad Soum of Dornod Aimag. While there is a 10-15 cm thick layer of “fresh” halite

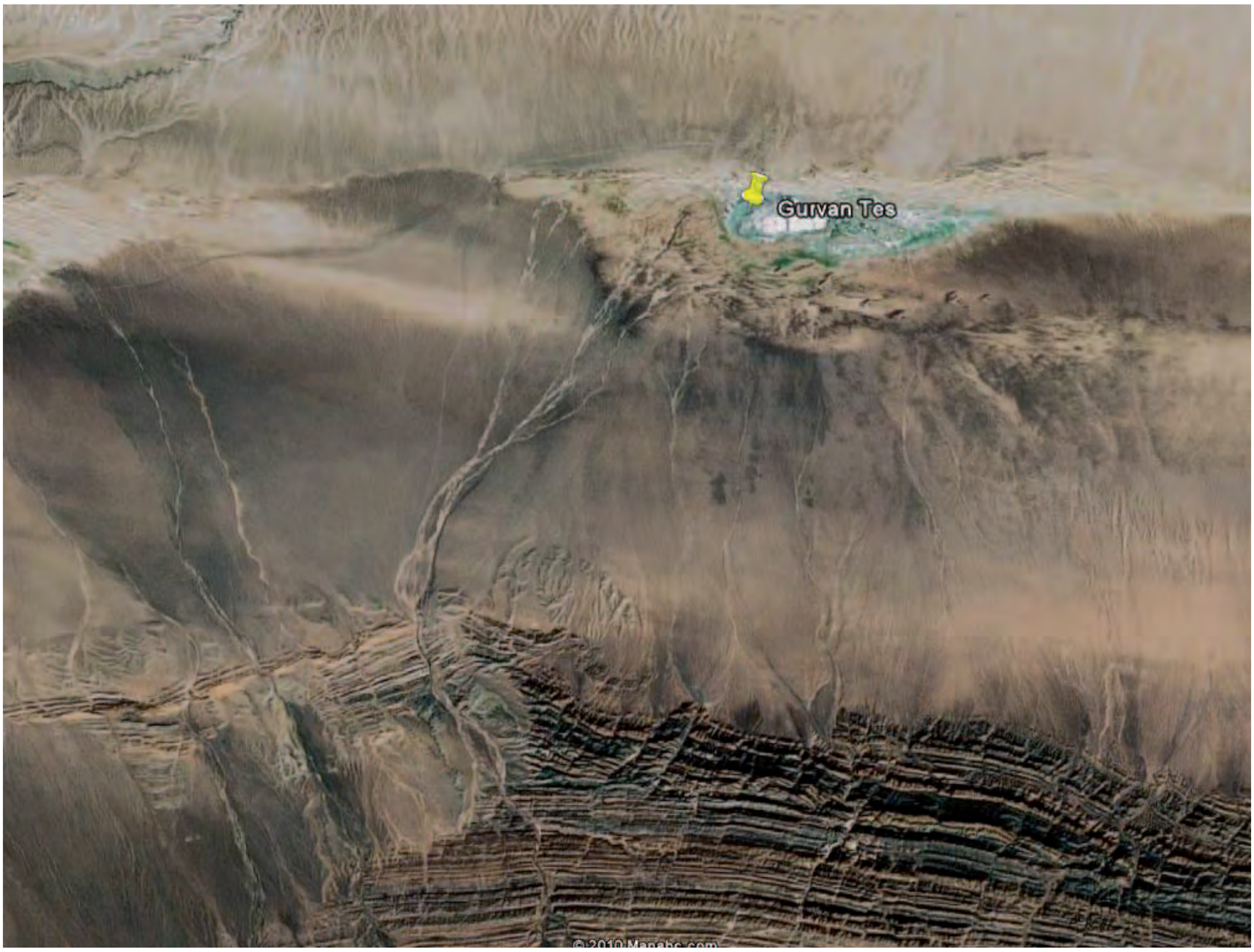


Figure 83: Satellite image showing Gurvan Tes salt lake in the South Govi desert (Photo courtesy of Google Earth).

only in the north-eastern part of the lake, the whole lake is underlain by a thin (0-10 cm) layer of clay followed by a thin (6 cm on average) layer of "fossil" halite, followed by another thin (15 cm on average) layer of mirabilite, and below a thicker layer of clay by another layer of mirabilite, about 2.5-4.0 m thick, as yet unexplored in detail. Other sources give a presumed thickness of an even deeper layer of mirabilite of up to 13 m! The chemical composition of the halite-rich raw salt and the highly mineralised brine (up to 355 g/l) is shown in Table 49. Some 53,100 tonnes of "fresh" halite were mined between 1943 and 2003 for local consumption and food preservation, leaving 167,600 tonnes of halite in categories A+B+C1. This deposit also continues to be mined for local consumption.

- **Davsan Nuur** in Tes Soum of Uvs Aimag is the name of a small and isolated hypersaline side lake measuring 270 m x 1,150 m at the eastern shore of the huge Uvs Lake (3,350 km^2), which is a state protected area and a UNESCO World Heritage Site. This side lake is only 2 m (0.4-5 m) deep on average and contains a number of shallow ponds of 2-3 m^2 up to 50 m^2 size of which about 10 % contain mineable halite. In general, "fresh" halite is underlain by "fossil" halite and two layers of mirabilite. The thickness of halite may vary from 0.09 to 1.35 m. The chemical composition of the halite-rich raw salt is given in Table 49. The original calculated resources of halite amount to 118,800 tonnes in category C1, and 288,500 tonnes in category C2. This deposit is being mined periodically by local people for fish preservation and food flavouring.

Figure 84: Satellite image showing blue pearl of Sangiin Dalay Nuur in the vast steppe of Dornod Aimag (Photo courtesy of Google Earth).

Table 49: Chemical composition (in wt.-%) of halite-rich raw salt and saline brine of selected halite deposits in Mongolia, after deposit passports and Rasskasov et al. (1991).

	Gurvan Tes		Sangiin Dalay Nuur		Davsan Nuur	Shuden Uul
	Halite	Brine	Halite	Brine *		
NaCl	96.92-98.85	16.62-23.08	74.13-98.88 (avg. 93.3)	21.51-23.46	88.59-94.95	93.74-96.03 (avg. 95.52)
KCl					0.04-0.11	
$CaCl_2$		3.32-8.82				
$MgCl_2$		0.72-5.64				
Na_2SO_4	0.14-0.37		7.17	1.44-3.90	1.52	0.08-0.26
$CaSO_4$	0.45-0.76	0.12-0.38	0.02-0.16		0.17-0.27	1.15-1.76
$MgSO_4$	0.08-0.44		0.01-0.25	2.09-2.88	0.15-0.47	
Na_2CO_3					1.10	
$CaCO_3$					0.004-0.03	
$NaHCO_3$					0.16-0.59	
$Ca(HCO_3)_2$	0.10-0.16	0.03-0.08				
$Mg(HCO_3)_2$		0.00-0.63				
Insolubles	0.06-0.36				0.75-2.80	1.95-3.19
Moisture	0.36-1.29		0.07-22.53	70.31-72.49	1.59-5.73	

* After Rasskasov et al. (1991) the brine contains elevated values of Li, Sr, Br, and B without stating any absolute values!

- **Shuden Uul (Davst Uul)** is located in Davst Soum of Uvs Aimag, 20 km north-east of Davst village and 15 km north of Uvs Lake. This strategic rock salt deposit of Middle to Upper Devonian age stretches across the border into Russia where it is called Tuz-Tag. In Mongolia, boreholes drilled in the western part of the deposit penetrated six layers or lenses of halite with lengths of 1,300 m, up to 2,000 m, widths of 150-250 m, on average 200 m, and thicknesses of 9-50 m, on average 29.5 m, dipping to the north along the flank of an anticline. Geophysical surveys proved the extension of the halite layers/lenses down to 550-700 m depth. The layers are separated by horizons of terrigenic breccious material of 2.5-15 m thickness. The chemical composition of the salt layers is shown in Table 49. Assuming a maximum depth of 80 m, a thickness of >3.5 m salt, a thickness of <2m of intercalated barren layers, a coefficient of 0.28 m^3 overburden per tonne of salt, a NaCl grade of >85 %, a content of <5.5 % insolubles, and <4 % $CaSO_4$, the initial sodium chloride reserves/resources were calculated as 1,624,400 tonnes in category A+B, 1,877,000 tonnes in category C1, 675,100 tonnes in category C2, and 72,552,000 tonnes in category P. Because the deposit has been mined, with some 804,000 tonnes taken out in an open pit since 1976, the remaining reserves in 2003 are given as 2,806,300 tonnes in categories A+B+C1.

REQUIREMENTS AND EVALUATION

The basic chemical requirements of raw unpurified salt for industrial use are: >95.5 wt.-% NaCl, <2.5 wt.-% moisture, <0.1 wt.-% Ca, Mg, K, and <0.5 wt.-% insolubles.
For human consumption (table salt), the basic chemical requirements are: >97.5 wt.-% NaCl, <2 wt.-% Ca, Mg, <16 ppm Fe, <4 ppm heavy metals (e. g. Pb), and <1 ppm As. Iodised salt should contain 60-100 ppm iodine.
The typical chemical compositions of table salt are: 99.3-99.5 wt.-% NaCl, 0.05-0.08 wt.-% moisture, 0.3-0.6 wt.-% Na_2SO_4, 0.04-0.06 wt.-% insolubles, 0.03-0.05 wt.-% Ca, and 0.008-0.015 wt.-% Mg.

The resources of net halite in deposits of rock salt or salt lakes have to surpass 50 million tonnes for potential industrial use both according to Russian and international requirements. Thus potential investors in common salt production in Mongolia have a very limited choice as only the Shuden Uul rock salt deposit offers enough potential for larger size investments. All other halite occurrences in Mongolia should be left to local people for private use.

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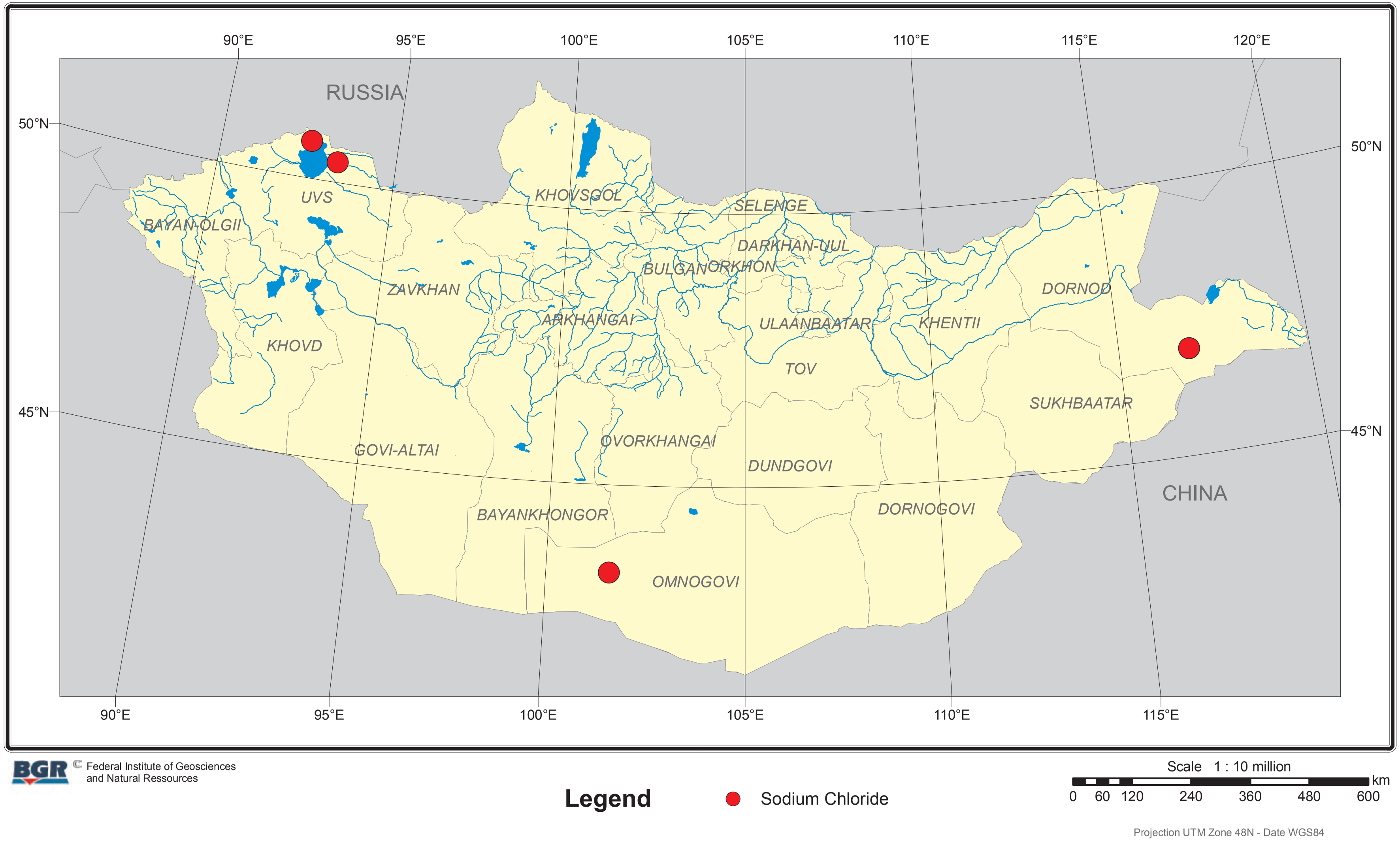
Deposits and important occurrences of Salt (Sodium Chloride) in Mongolia



SALTS, SODIUM OTHER THAN SODIUM CHLORIDE

GENERAL INFORMATION AND USES

Other economically important salts of sodium other than sodium chloride are
- Sodium carbonate or soda, also called natron (Na_2CO_3 x 10 H_2O),
- Trona ($Na_2HCO_3CO_3$),
- Nahcolite ($NaHCO_3$),
- Sodium sulphate or thenardite (Na_2SO_4),
- Mirabilite or Glauber's salt (Na_2SO_4 x 10 H_2O),
- Sodium nitrate or saltpetre ($NaNO_3$),
- Sodium phosphate (Na_3PO_4)

All sodium carbonates are very important raw minerals for the chemical industry. They are also used as fluxes in the production of glass and enamel, as well as soap and detergents. Other applications can be found in industries such as paper, pulp, textiles, steel, energy, and food production. Sodium sulphates are mainly used in the production of paper and pulp, detergents, and glass. Saltpetre is an important fertilizer, while sodium phosphate is mainly used in the production of soap and detergent.

RELEVANT DEPOSITS IN MONGOLIA

Because sodium salts are very typical for saline lakes in general, they are also quite typical and well-known in the brines and salt crusts of the numerous salt lakes in Mongolia. Sodium salts other than sodium chloride are even more widespread in Mongolia than common salt.

Table 50: Relevant data of selected mirabilite deposits – ranked in terms of resources - in Mongolia, after deposit passports.

Name	Location	Size	Minerals, grades in raw salt and resources (salt content)
Baruun Shavar	Khukh gol Soum Dornod Aimag	19.38 km² x 2.48 m	Mirabilite @ 5.69-50.54 % Na_2SO_4 (14,360,000 t C1, 13,400,000 t C2)
Sangiin Dalay Nuur (cf. Salt, Sodium Chloride)	Matad Soum Dornod Aimag	6.40 km² x 2.5-4 m	Mirabilite @ 36.89-98.83 % Na_2SO_4 (3,402,200 t A+B, 2,458,200 t C1, 1,519,400 t C2)
Shorvog Nuur	Matad Soum Dornod Aimag	5.04 km² x 2.76 m	Mirabilite @ 40.31 % Na_2SO_4 (4,305,500 t C2)
Shar Burdiin Nuur	Bayantumen Soum Dornod Aimag	4.20 km² x 2.76 m	Mirabilite @ 34.27 % Na_2SO_4 (4,015,800 t C2)
Buir (cf. Salts, Potassium and Magnesium)	Tseel Soum Govi-Altai Aimag	5.55 km² x 0.41 m	Mirabilite @ 16.62-48.39 % Na_2SO_4 (1,472,900 t C2, 776,600 t P1) Epsomite @ 18.81-32.98 % MgSO4 (781,000 t C2)
Ikh Dalai Nuur	Chuluunkhoroot Soum Dornod Aimag	2.25 km² x 0.75 m	Mirabilite @ 20.14-37.12 % Na_2SO_4 (1,625,700 t C2)
Jirmin Tsagaan Nuur	Chuluunkhoroot Soum Dornod Aimag	4.50 km² x 0.9 m	Mirabilite @ 25.37-31.06 % Na_2SO_4 (1,368,500 t C2)
Bayantsagaan	Jargalant Soum Bayankhongor Aimag	3.0 km² x 1.36 m	Mirabilite @ 36.9-77.9 % Na_2SO_4 (879,000 t C1, 1,190,200 t C2)
Dund Bayan Nuur	Sergelen Soum Dornod Aimag	0.75 km² x 3.4 m	Mirabilite @ 29.58-39.02 % Na_2SO_4 (460,800 t C1, 1,000,200 t C2)
Zuun Olzitt Nuur	Choybalsan Soum Dornod Aimag	1.95 km² x 0.97 m	Mirabilite @ 34.52 % Na_2SO_4 (676,800 t C1, 431,900 t C2)
Khokh Nuur	Khalkh gol Soum Dornod Aimag	0.57 km² x 5.8 m	Mirabilite @ 34.75-41.98 % Na_2SO_4 (1,077,900 t C2)

In the following table, only those deposits are included which will meet internationally accepted minimum size requirements (i.e. >1 million tonnes, cf. below) for deposits of sodium salts other than sodium chloride and therefore are of potential interest both to national or international investors. Salt occurrences are not dealt with in this chapter.

Of the eleven deposits of interest, four deposits, i.e Baruun Shavar, Sangiin Dalay Nuur, Shorvog Nuur, and Shar Burdiin Nuur, all in Dornod Aimag, contain resources of several million tonnes of mirabilite each. The chemical composition of the mirabilite-rich raw salt in these deposits is given in Tab. 51.

- **Sangiin Dalay Nuur** is described in detail in the chapter on sodium chloride.
- **Baruun Shavar** was explored in 1968 and 1988 by drilling down to 6.1 m depth and sampling. It is a medium-size saline lake of 19.5 km^2 size, some 20 km north of Tamsagbulag village. The thickness of mirabilite varies between 0.2 and 4.6 m, with 2.46 m on average. The thickness of overburden - a greenish-grey clay and a grey fine-grained sand - varies between 1.4 and 2.8 m, with 2.36 m on average.
- **Shorvog Nuur** is a small, mostly dry lake, which was explored in 1965 by a few 2.8-7.2 m deep boreholes. This lake is far away from any infrastructure or villages. The thickness of mirabilite discovered is highly variable between 0.7 and 5.2 m, with 2.76 m on average. The average thickness of overburden - green clays - is only 0.46 m.

Figure 85: Satellite image of Shorvog Nuur in the steppe of Dornod Aimag (Photo courtesy of Google Earth).

- **Shar Burdiin Nuur** is a small-sized and mostly dry lake about 28 km north of Choibalsan. Exploration by drilling down to 5.5 m depth also dates back to 1965. Mirabilite was found in the eastern part of the lake attaining a thickness of 1.0-5.4 m with 2.76 m on average. The salt is partly covered by dark grey clay reaching 0.1-1.5 m in thickness.

Occurrences of saltpetre in Mongolia are extemely small (up to 2,200 tonnes) and low-grade (0.22-1.54 %), and are limited to places of cattle concentration.

REQUIREMENTS AND EVALUATION

The requirements for deposits of sodium salts other than sodium chloride are met in eleven Mongolian deposits because reserves should be >1 million tonnes of mineable salts. Internationally, deposits with reserves of 5-50 million tonnes are regarded as medium size (in Mongolia: Baruun Shavar and Sangiin Dalay Nuur deposits, only), with deposits surpassing 50 million tonnes being referred to as large size. Raw mined salt should contain >90 wt.-% sodium salts other than sodium chloride. Because the industrial beneficiation of these minerals

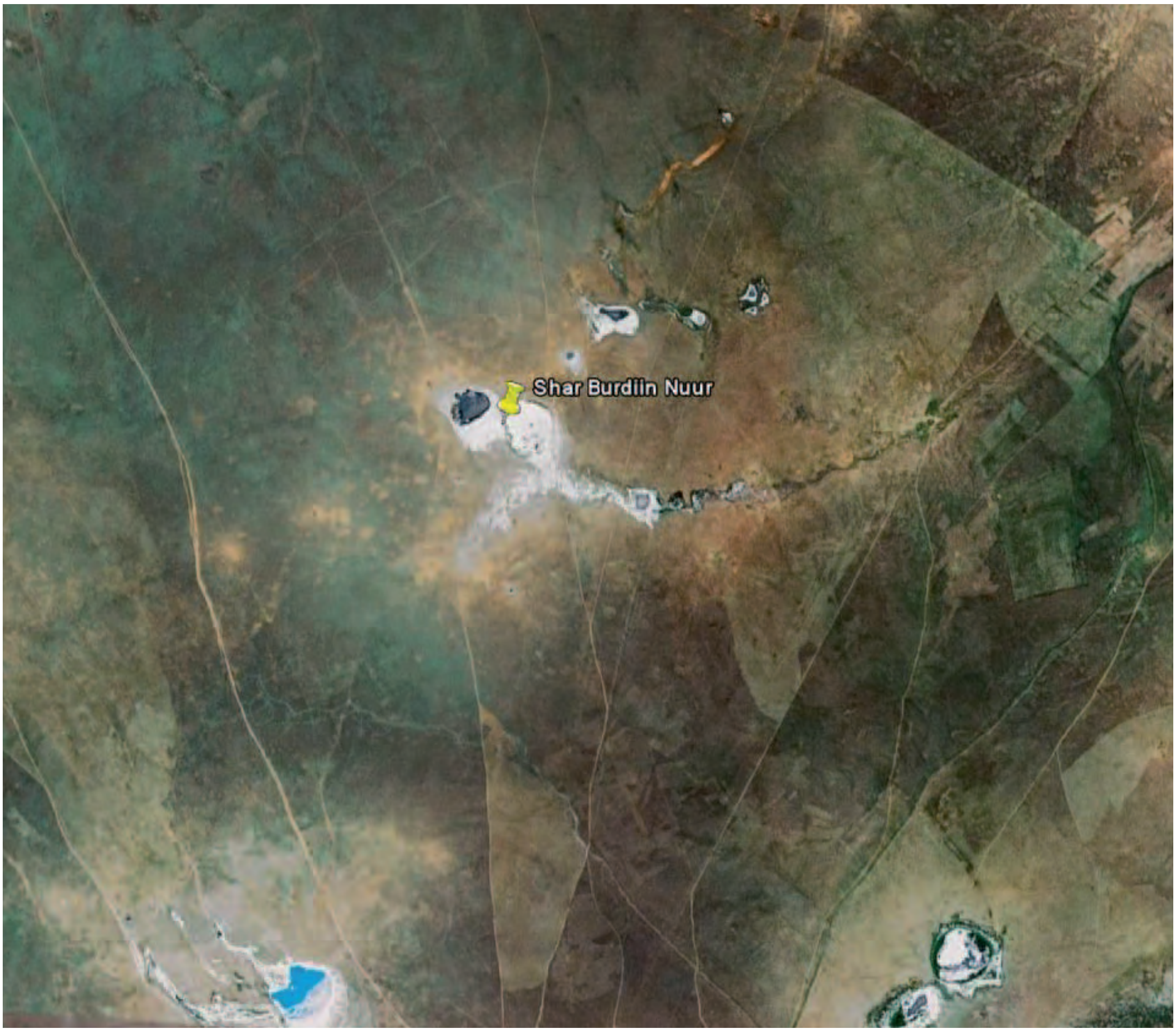


Figure 86: Satellite image of Shar Burdiin Nuur with lots of tracks leading to Choibalsan town 28 km to the south (Photo courtesy of Google Earth).

Table 51: Chemical composition (in wt.-%) of mirabilite-rich raw salt of selected mirabilite deposits in Mongolia, after deposit passports.

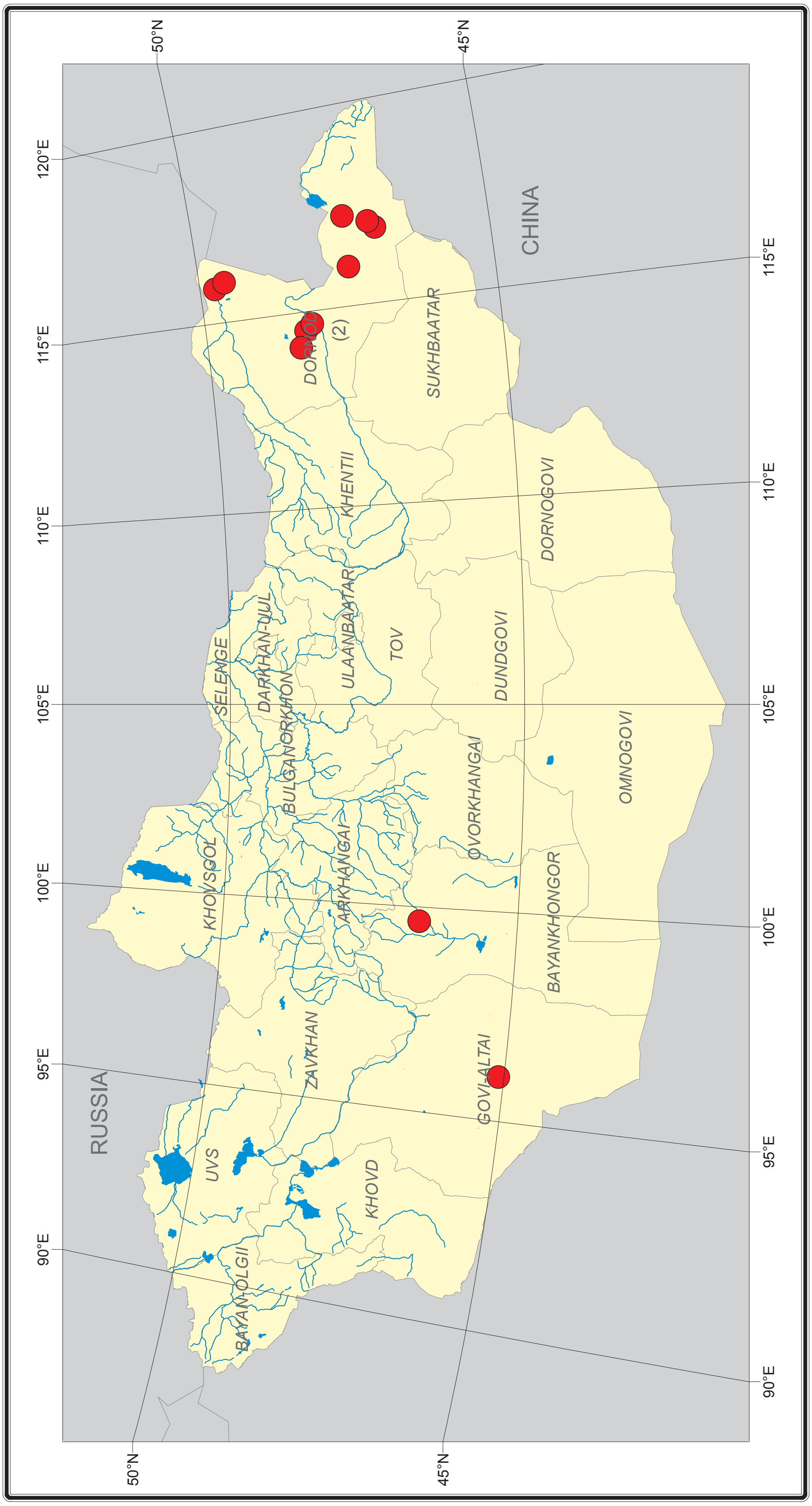
	Baruun Shavar	Sangiin Dalay Nuur	Shorvog Nuur	Tsakhir Nuur
NaCl	0.08-11.23	0.21-31.72	1.13	0.87
KCl	0.0-0.63			
Na_2SO_4	5.69-50.54 (avg. 30.36)	36.89-98.83	40.31	34.27
$CaSO_4$	0.0-0.75	0.04-1.46	0.02	
$MgSO_4$	0.0-18.19	1.34	0.2	
Na_2CO_3				6.57
$CaCO_3$	0.0-0.20		0.02	0.03
$MgCO_3$				0.03
$NaHCO_3$				1.22
$Ca(HCO_3)_2$	0.0-0.72		0.28	
$Mg(HCO_3)_2$	0.0-0.38		0.12	
Insolubles	0.69-11.91		0.27-9.45	0.01-25.71
Moisture	0.22-56.06	0.04-58.81	5.04	

first requires the removal of sodium chloride by complex fractional crystallisation, the amount of sodium chloride should be very low in the beginning. Similarly, the iron-oxide content must be very low. The final products also have to be very clean, with >99 % purity required. The mining of thin salt crusts especially poses major technological questions because the commercial scale production of sodium salts other than sodium chloride requires high investment costs and is therefore not suitable for small-scale mining. Due to these and other problems, investors should focus on lakes of low ecological importance containing thick and high grade layers of salts of mono-mineralogical composition.

RELEVANT LITERATURE

Rasskasov, A. A., Luvsandorjh, S., Sevastjanov, D. W., Zerensodnom, Z. & Egorov, A. N. (1991): Lakes of MPR and their mineral resources (in Russian).- in: Jakhontova, L.K. & Zaitsev, N.S. (eds.).- The Joint Soviet-Mongolian Scientific Research Geological Expedition, Transactions, 52: 136 pp., 28 fig., 43 tab.; Moscow.

Deposits of Salt (Sodium, other than Sodium Chloride) in Mongolia



Legend

● Sodium salt, other than Sodium Chloride

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

BGR © Federal Institute of Geosciences and Natural Ressources

SALTS, POTASSIUM AND MAGNESIUM

GENERAL INFORMATION AND USES

Salts, other than sodium, occurring naturally in Mongolia are potassium chloride or sylvite (KCl), magnesium chloride, and magnesium sulphate (Epsom salt or bitter salt). While all potassium minerals and magnesium sulphate are very important for fertilizer production, most magnesium chloride is used for the production of magnesium metal.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Unlike the salts of sodium, Mongolia is not rich in salts of potassium, but has some occurrences and deposits of salts of magnesium. The following list gives names of salt lakes in Mongolia where elevated grades of magnesium salts were detected in layers of raw salts. Thin salt crusts or lenses with elevated grades are omitted though (after deposit passports):

- Buir, cf. description below
- Khar Nuur (Zaamar Soum in Tuv Aimag): 70.43 % $MgSO_4$ (11,500 tonnes in category C2) in an epsomite-rich salt layer of 1.2 m thickness, but below up to 9.6 m of overburden
- Suujin Nuur (Umnugovi Soum in Uvs Aimag): 17.33 % $MgSO_4$ in mirabilite-rich salt layer of 0.5-1.3 m thickness
- Davsan (Tes Soum in Uvs Aimag): 3.73-6.49 % $MgSO_4$ in mirabilite-rich salt layer of 0.2-1.3 m thickness

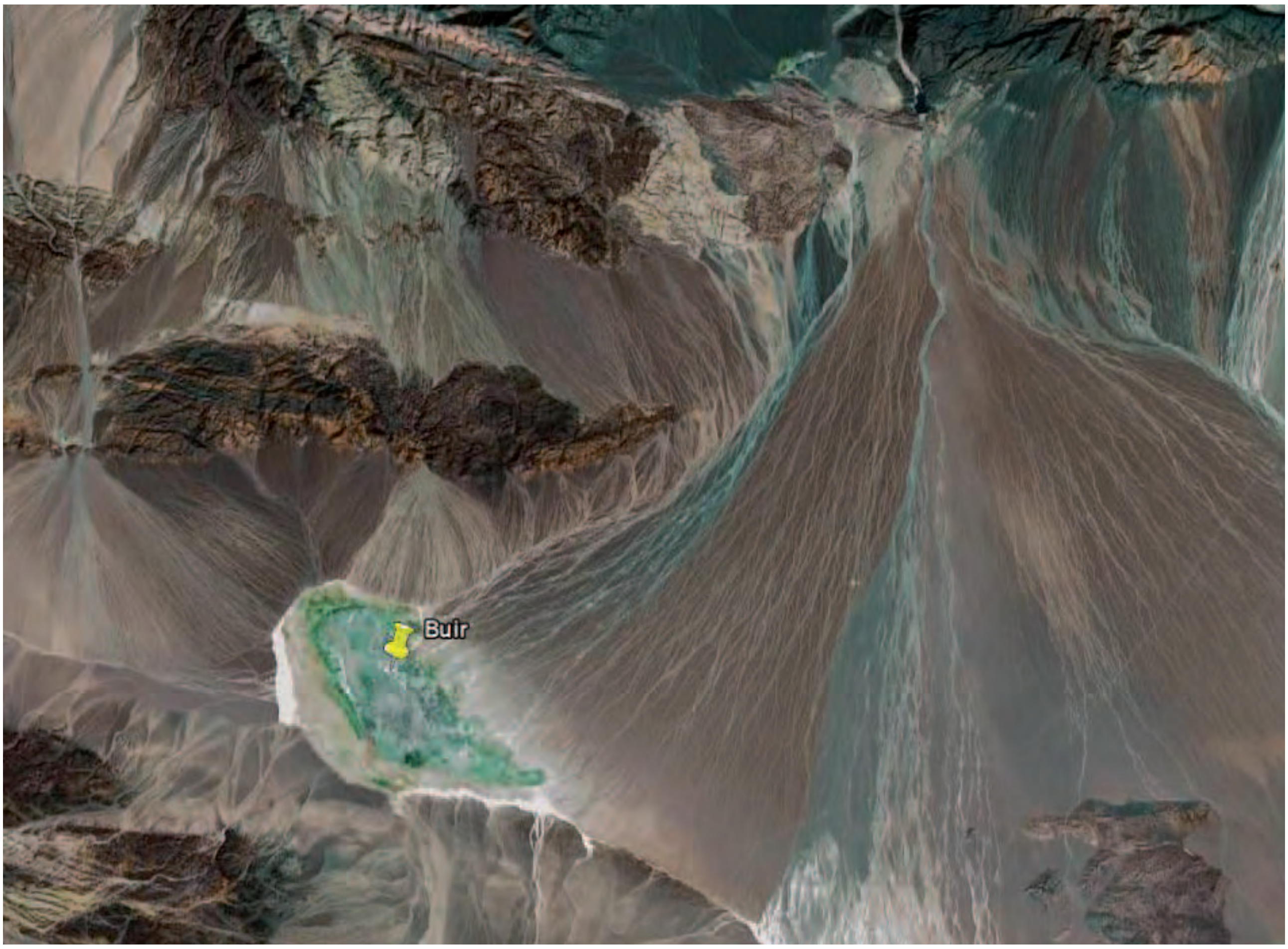


Figure 87: Satellite image of hypersaline Buir Lake lying at the south-western edge of a huge talus of magnesium-rich rock debris (Photo courtesy of Google Earth).

- Alag Nuur (Bugat Soum in Govi-Altai Aimag): 0.24-25.56 %, on average 6.02 % $MgSO_4$ in two halite-rich salt layers of 0.95 m total thickness
- Baruun Shavar (Khalkh gol Soum in Dornod Aimag): 0.00-18.19 % $MgSO_4$ in mirabilite-rich salt layer of 0.2-4.6 m thickness
- Leg Tokhom (Altai Soum of Govi-Altai Aimag): 0.04-13.41 %, on average 2.98 % $MgSO_4$ in mirabilite-rich salt layer of 1.0-3.7 m thickness
- Shuten (Khalzan Soum in Sukhbaatar Aimag): 0.45-6.24 % $MgSO_4$ in a mirabilite-rich salt layer of 0.5-1.75 m thickness. The cover of halite-rich salt crust was analysed to contain up to 15.68 % $MgSO_4$, and 12.73 % $MgCl_2$.
- Bayantsagaan (Jargalant Soum in Bayankhongor Aimag): 0.20-4.60 % $MgSO_4$ in mirabilite-rich salt layer of 1.0-1.6 m thickness

The most interesting deposit for the production of magnesium salts in Mongolia is definitely **Buir** in Tseel Soum of Govi-Altai Aimag. However, this deposit lies far away from any infrastructure, 69 km south-west of Tsel vil-

Table 52: Chemical composition (in wt.-%) of raw salt layers in the Buir salt deposit, after deposit passport.

	"Fresh" halite	"Old" halite	Epsomite	Mirabilite
NaCl	23.13-92.76 (avg. 71.76)	50.19-95.65 (avg. 80.49)	0.00-38.13 (avg. 10.36)	0.23-16.11 (avg. 4.41)
KCl	0.07-1.10 (avg. 0.41)	0.05-1.20 (avg. 0.18)	0.03-0.88 (avg. 0.29)	0.02-0.69 (avg. 0.14)
$MgCl_2$	0.0-0.75	0.04-1.46	0.02	
Na_2SO_4	0.00-20.70 (avg. 3.21)	6.0-23.64 (avg. 2.24)	0.00-11.06 (avg. 3.78)	16.62-48.29 (avg. 31.36)
$CaSO_4$	0.00-3.4 (avg. 0.43)	0.00-2.51 (avg. 0.53)	0.00-2.55 (avg. 0.80)	0.00-5.16 (avg. 0.05)
$MgSO_4$	0.65-23.76 (avg. 8.90)	0.38-18.62 (avg. 2.31)	18.81-32.98 (avg. 24.27)	0.10-14.45 (avg. 3.44)
$Ca(HCO_3)_2$	0.11-0.55 (avg. 0.24)	0.11-0.35 (avg. 0.21)	0.12-0.55 (avg. 0.36)	0.04-0.85 (avg. 0.38)
$Mg(HCO_3)_2$	0.00-0.25 (avg. 0.02)	0.00	0.00-0.33 (avg. 0.02)	0.00-0.69 (avg. 0.05)
Insolubles	0.50-8.50 (avg. 2.47)	0.76-11.53 (avg. 2.26)	1.46-10.70 (avg. 3.2)	0.37-19.41 (avg. 4.44)
Moisture	3.25-42.80 (avg. 11.57)	(avg. 86.49)	22.96-71.00 (avg. 53.72)	38.00-68.50 (avg. 52.40)

Table 53: Resources of salt minerals in the Buir salt deposit, after deposit passport.

	"Fresh" halite	"Old" halite	Epsomite	Mirabilite
A				
B	311,100			
C1	775,000*			
C2	1,293,500*	860,500	781,000	1,472,900
P1	920,000	1,203,600		776,600
P2				

*= data inconsistent

lage, 260 km south of Altai town and 105 km north of the Chinese border. The deposit is bound to a mostly dry hypersaline lake of 4.2 x 2.0 km size, of which an area up to 3.7 x 1.5 km size is underlain by a) “fresh” halite-rich salt b) “old” halite-rich salt c) epsomite-rich salt, d) mirabilite-rich salt (cf. Salts, Sodium other than Sodium Chloride), and then clay below. However, drilling between 1985 and1987 was limited to a few holes with depths of 3.2 m only. While the halite-rich salt has a combined thickness of 0.8-1.4 m, on average 0.57 m, the mirabilite-rich salt has a thickness of 0.38-0.45 m, on average 0.41 m. The average thickness of the epsomite-rich salt was not determined. The chemical composition of the various raw salts is given in Table 52 with resources information summarised in Table 53.

Because the chemical composition of brines of Mongolian salt lakes may be of importance to future investors, the very limited information available on this subject in old reports is compiled in Table 54. For the chemical composition of brines in Sangiin Dalay Nuur and Gurvan Tes, cf. Table 49.

REQUIREMENTS AND EVALUATION

Although any potassium occurrence would be of interest to the Mongolian economy as a potential source for fertilizer production, the beneficiation of purified potassium chloride from layers of mixed salt and brines is rather difficult, i.e. expensive, and resources in Mongolia are quite small. For the economic production of muriate of potash (KCl-product), the minimum concentration of KCl in brines is 1.6 wt.-%. The total reserves of sylvite should be >5 million tonnes.

For salts of magnesium there are no internationally accepted minimum requirements for

Table 54: Chemical composition of brines in Mongolian salt lakes, after deposit passports.

Name	Zeeg Nuur	Shavar Nuur	Khujryn Togoo	Buult	Dund Bayan Nuur
Location	Dashbalbar Soum Dornod Aimag	Sukhbaatar Soum Sukhbaatar Aimag	Ondorshil Soum Dundgovi Aimag	Tes Soum Uvs Aimag	Sergelen Soum Dornod Aimag
NaCl		24.10 %	7.91 %	1.09 %	15.88 %
KCl		0.25 %	0.29 %	1.09 %	
$CaCl_2$	13.88 mg/l				
K_2SO_4	19.59 mg/l				
Na_2SO_4	317.52 mg/l	4.95 %	12.58 %	5.29 %	1.00 %
$MgSO_4$		19.03 %	2.75 %		2.29 %
Na_2CO_3				13.32 %	
$MgCO_3$		0.53 %		0.05 %	
$NaHCO_3$				2.58 %	
$Ca(HCO_3)_2$	20.09 mg/l		0.15 %		0.18 %
$Mg(HCO_3)_2$	8.24 mg/l	0.17 %			0.26 %
B_2O_3					60-120 mg/l *

* Only absolute data available on rare element content of any of the Mongolian salt lakes!

grades in salt lakes. However, a minimum content of 50 million tonnes of recoverable magnesium sulphate is regarded as a minimum by international salt producing companies (K+S AG, Germany, oral comm.). Similarly, according to the Russian classification system, small deposits contain <10 million tonnes of MgO. After processing by complex fractional crystallisation, bitter salt fertilizers should contain >45 % $MgSO_4$.

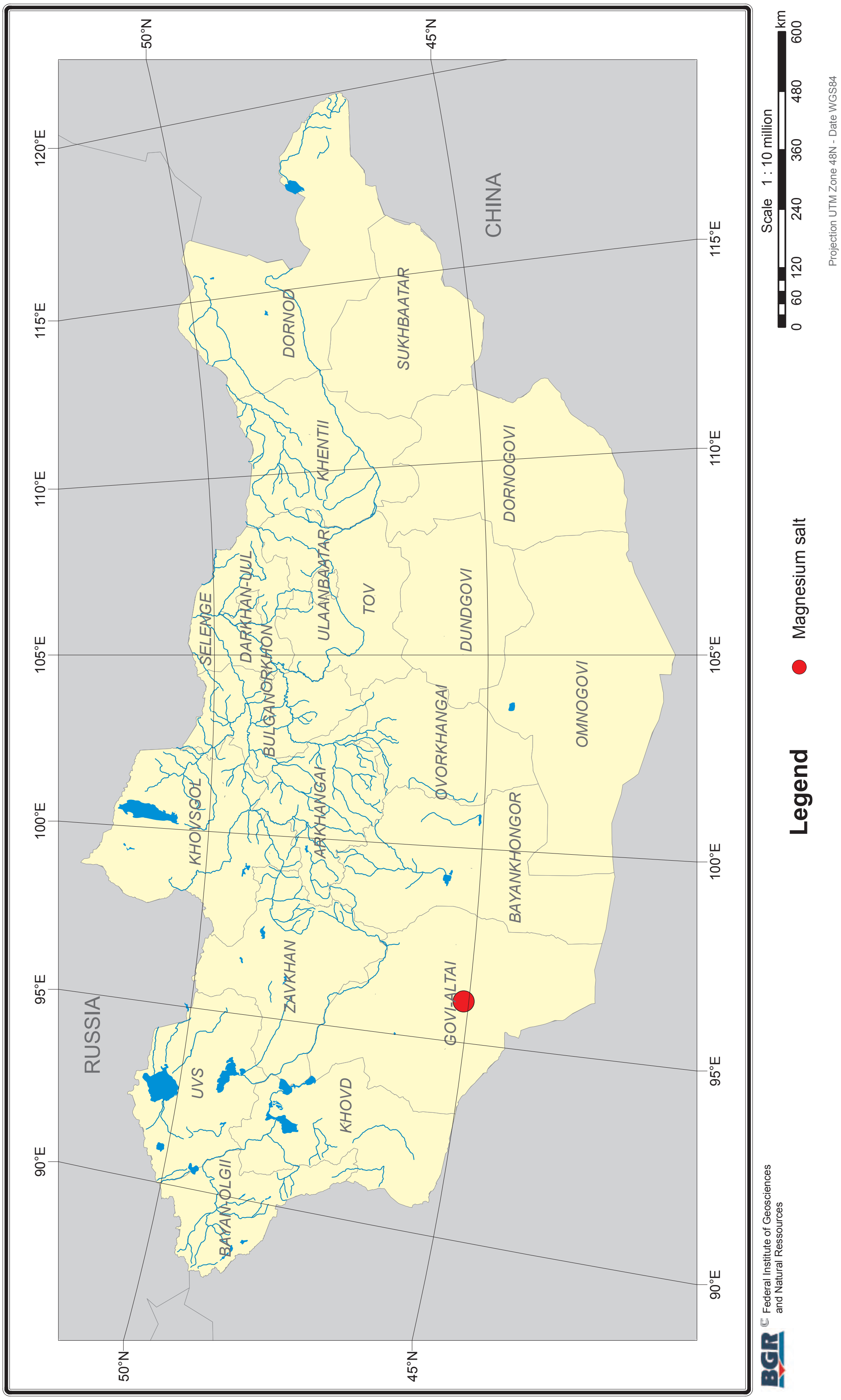
Buir salt lake is the best choice by far for any investor in magnesiums salts in Mongolia. However, more exploration is needed to determine the grades and tonnages of extractable minerals. Potential customers for this deposit have to be sought in China though.

Rare element contents must be analysed in any future exploration campaigns!

RELEVANT LITERATURE

RASSKASOV, A. A., LUVSANDORJH, S., SEVASTJANOV, D. W., ZERENSODNOM, Z. & EGOROV, A. N. (1991): Lakes of MPR and their mineral resources (in Russian).- in: JAKHONTOVA, L.K. & ZAITSEV, N.S. (eds.).- The Joint Soviet-Mongolian Scientific Research Geological Expedition, Transactions, 52: 136 pp., 28 fig., 43 tab.; Moscow.

Deposits of Salt (Magnesium) in Mongolia



SILLIMANITE AND RELATED MINERALS

GENERAL INFORMATION AND USES

The rock-forming aluminosilicates sillimanite, andalusite, and kyanite all have the same chemical composition, Al_2SiO_5, and possess the same economic value as refractories, but only after being heated to form the new mineral mullite. Minor uses are in casting, abrasives, and ceramics, and perhaps in future as a substitute for refractory bauxite. Two criteria are most decisive to determine whether any of these minerals are worth mining. Firstly, the volume of reserves available, secondly, the transportation costs to the nearest customer or port.

RELEVANT DEPOSITS IN MONGOLIA

According to Dejidmaa et al. (2001) there are 19 occurrences and two deposits of aluminosilicates in Mongolia. The only two deposits mentioned are Tomor Malgai in Tsagaannuur Soum and Sukhbaatar in Sukhbaatar Soum, both in Selenge Aimag, i.e. in north-central Mongolia. Like most of the 19 occurrences, their host rocks are highly metamorphosed gneisses, schists and migmatites of Lower Proterozoic age.
There are also some minor occurrences of kyanite in Mongolia which are only of interest to mineral collectors.

The **Sukhbaatar** deposit, located north-east of the town of the same name and close to the Mongolian-Russian border, consists of a monoclinal layer of sillimanite schist with a thickness of 2 to 4 m, on average 3 m, distributed over an area of about 1 km^2. It is hosted by a highly metamorphosed volcano-sedimentary sequence of Lower Cambrian age, made up of biotite-hornblende gneisses, and complex migmatites. The content of sillimanite in the schists has not been determined yet. An old chemical analysis reveals 17.85-32.5 % (on average 25 %) Al_2O_3, 50.6-69.4 % SiO_2, 0.9-1.4 % TiO_2, and 4.8-6.85 % Fe_2O_3. The estimated resources are around 7.5 million tonnes of ore with a yet unknown grade of sillimanite. A sample from this sillimanite schist was kindly provided for analysis at BGR (XRF+XRD) by Mrs. Majigsuren Yondon from the Museum of Geology and Mineral Resources at the Mongolian University of Science & Technology in Ulaanbaatar. This sample contained 27.13 % Al_2O_3, 67.42 % SiO_2, 1.09 % TiO_2, 0.54 % Fe_2O_3, 0.40 % Na_2O, 1.20 % K_2O, 1.56 % LOI, 17 ppm Th, and 5 ppm U. Mineralogically it was made out of 45 % quartz, 30 % sillimanite, 20-25 % muscovite, with traces of chlorite and microcline.

The **Tomor Malgai** deposits I+II lie 42 km south-west of Tsagaannuur village on the east bank of the Shorongiin River. The deposits consist of highly metamorphosed gneisses and granites in two ore bodies of 45-65 m width, a length of 360 m, on average 170 m, dipping at about 10-40° to the SE. These ore bodies contain from 25 to 90 vol.-% sillimanite and fibrolite. However, neither the chemical composition nor the resources have been determined yet.
The Tomor Malgai deposit IV is situated on the east bank of the Sharyn River. Here the metamorphosed body of interest has a length of some 1,500 m and a width of 90-150 m. The sillimanite content varies from 65-95 vol.-% with 70 vol.-% on average, resulting in estimated resources of about 7 million tonnes of net sillimanite.

REQUIREMENTS AND EVALUATION

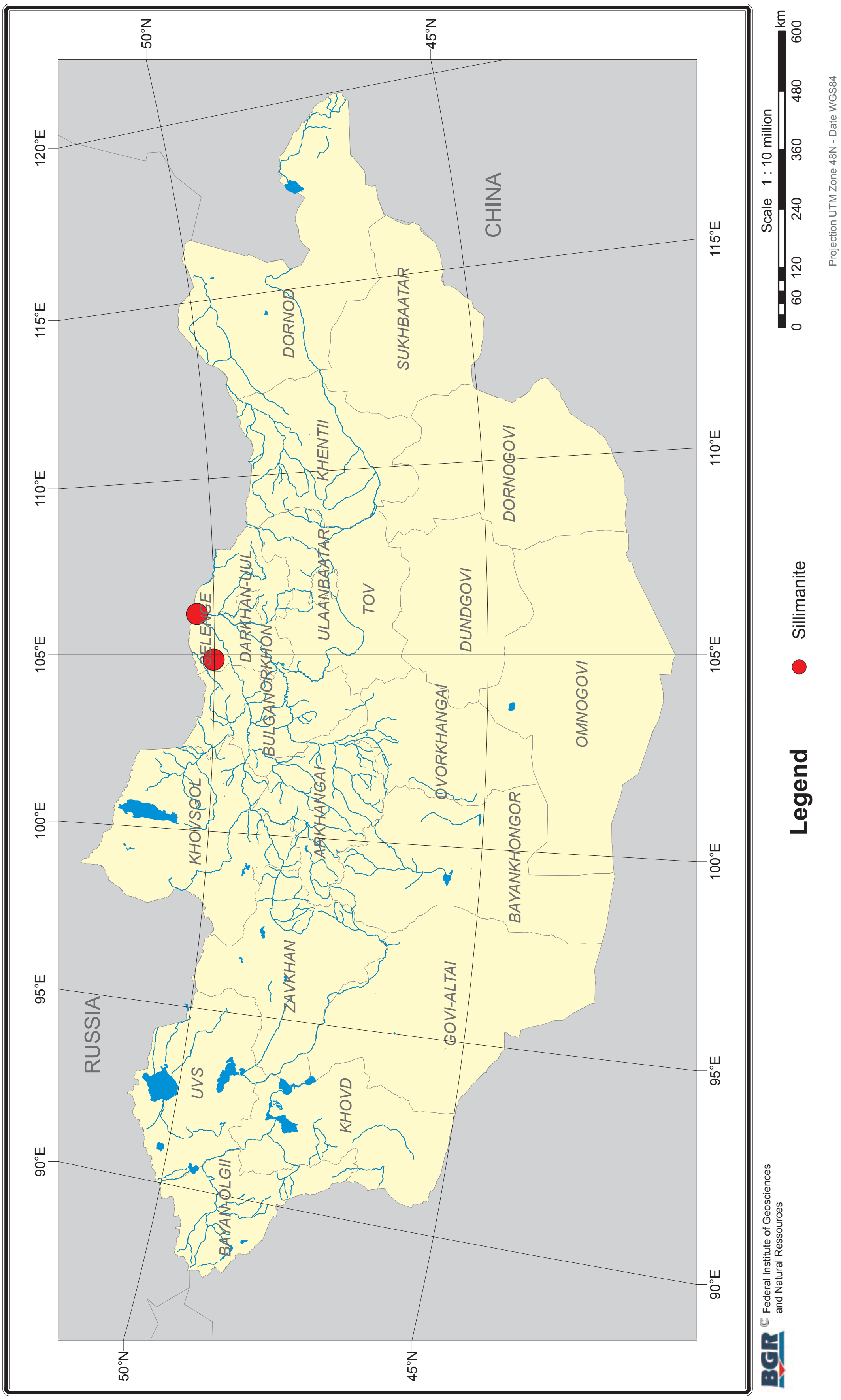
For industrial use, crude sillimanite ore has to contain >60 % SiO_2, >10 % Al_2O_3, <2.5 % Fe_2O_3, <3.0 % TiO_2, <1 % CaO+MgO, and <1 % Na_2O+K_2O. Harmful impurities in solid rock deposits of sillimanite minerals are muscovite, biotite, kaolin, silica, Fe minerals and rutile. The sillimanite content in ore should surpass 15 vol.-%, but much better 35 vol.-%.

The total reserves of sillimanite must be >0.5 million tonnes, while large deposits contain >5 million tonnes of aluminosilicates.

Concentrated sillimanite should possess >57 % Al_2O_3 and <0.8 % Fe_2O_3 to be of commercial interest as a refractory material.

Clearly, the sillimanite deposits in Mongolia are of medium to large size and, with the exception of Sukhbaatar, appear to be of good quality. The infrastructure also seems to be no problem as the main railway line is nearby. However, much more exploration with a full array of analysis, technical-physical testing and dressing tests is needed before final evaluation is possible.

Deposits of Sillimanite in Mongolia



STONES, DIMENSION

GENERAL INFORMATION AND USES

Dimension stones are hard, non-slatey natural stones either mechanically and/or manually worked into more or less regular geometrical shapes with specific dimensions. If they have more or less irregular decorative shapes and are for artistic purposes they are called ornamental stones. The uses of dimension stones today are dominated by facade slabs ("facing stone"), gravestones, window sills, stair treads, kerbstones, floor tiles, and wall tiles. Waste from light marble is processed in various ways including into terrazzo slabs (frequently mixed with dark rocks) as well as used for improving plasters.

RELEVANT DEPOSITS IN MONGOLIA

When evaluating dimension stone deposits in Mongolia, it is again first worth looking at previous author's listings. Jargalsaihan et al. (1996) mention two "facing stone mines", i.e. Tsagaan Chuluut (marble) and Avdarant (amazonitic granite). Dejidmaa et al. (2001) name Tsagaan Chuluut (marble), Avdarant (granite), Kharhorin (granodiorite), Mandalgovi (granite), Shirevger (granite), Shohoin Tsahir (marble), Zamt (granite) as "decorative stone deposits", and numerous other locations as "decorative stone occurrences". According to United Nations (1999), a variety of dimension stones are being produced in Mongolia, especially four kinds of granite: "Red granites are being quarried 300 km east of Ulaanbaatar, near Karakhorum; black granites are being produced 100 km north-west of Erdenet; green granites (amazonite) and pink granites are being quarried 150 km west of Ulaanbaatar. Other dimension stones include white marble and slate."

More information is given on the **Avdarant** amazonitic granite deposit: In Mongolia amazonite occurs in granite as crystals of light to dark green feldspar, which make up from 20-30 % of the rock. Amazonite is associated with clear quartz and dark hornblende. Unpolished amazonite granite is used as kerbstones and entrance stairs for important buildings in downtown Ulaanbaatar. Polished amazonite granite retains its lustre and is widely used in

Figure 88: Avdarant amazonitic granite quarry, from Kynický et al. (2006).

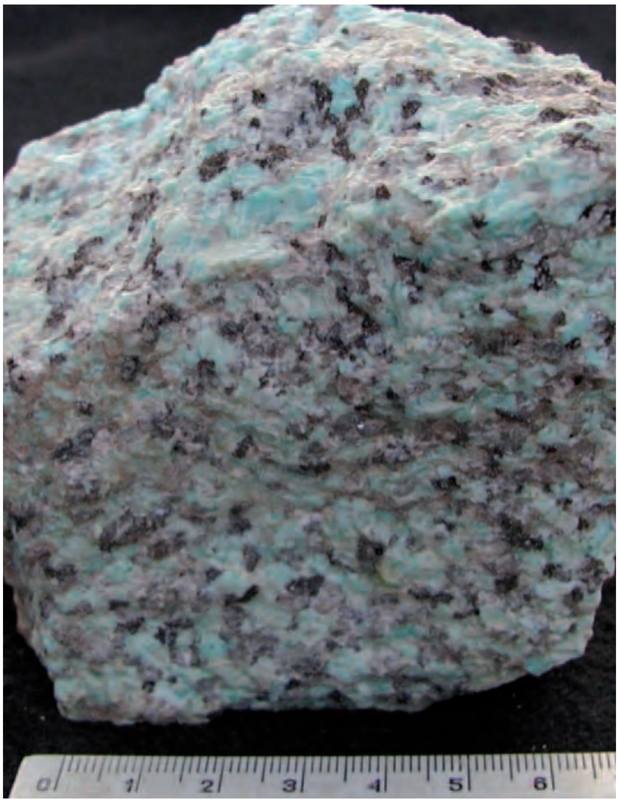


Figure 89: Typical amazonitic granite from Avdarant, from Kynický et al. (2006).

decorating hotels and office lobbies. Petrological details and photos of this amazonitic granite are given by KYNICKÝ et al. (2006). The quarry lies 200 km north-west of Ulaanbaatar in Tuv Aimag at 48° 37´ 25.9" N, 109°26´59.9" E at about 1,800 m a msl and was opened in 1989 (cf. Figure 88). It is operated temporarily by the Department of Justice. Estimated resources amount to 1.25 million m^3 of granite.

Another dimension stone deposit is said to occur at **Togostoi Uul** (47° 46' 00" N - 47° 46' 17" N , 107° 54' 45" E - 107° 55' 10" E; 1,800 m a msl) some 7 km from Erdene Soum in Tuv Aimag. Here light grey granite was tested to have physical-mechanical parameters suitable for external and internal use. The blocking and polishing characteristics also are said to be good. However, it is understood that no blocks of commercial quality have been produced yet. The resources are estimated as 19.9 million m^3 of granite in category C2 (ANONYMOUS 2002).

The **Tsagaan Chuluut** marble deposit lies south-west of the Khuvsgul National Park on top of a mountain, which is very remote from any infrastructure or settlements (50° 21' 49.4" N , 99° 46' 13.2" E; 2,351 m a msl). The deposit was discovered in 1946, and mapped after 1964. Detailed exploration by drilling started in 1984. After building a gravel road to the mountain, a quarry was opened in 1988. However, it was closed down some time before 2002, most probably in the early 1990s after the Mongolian economy changed to market economic conditions. Although it is said that the marble is of excellent quality and it is the biggest marble deposit in Mongolia (reserves and resources of 3,245,400 m^3 in categories A+B, and 17,138,200 m^3 in category C1), the site of the quarry is so remote, with such demanding weather conditions that commercial mining can never have been feasible!

The marble deposit stretches over a length of 1,200 m and a width of 300 m. The direction of

Figure 90: Abandoned Tsagaan Chuluut marble quarry as of August 2009. Note the strong fracturing.

strike is 230-260° and the angle of dip is 18-35°. It is a calcite marble with up to 40 % dolomite in certain banks. The weathering zone extends down to 8 m depth from the surface. The general thickness of the overburden is 8.0-11.7 m, with an average of 9.0 m. Various colours of marble, light brown, whitish brown, greyish brown and pure white have been found while drilling to a depth of about 150 m. The percentage of fractured rocks determined by drilling is 45.93 %. In the quarry, the marble also shows strong fracturing with schlieren and fissure fillings of iron-oxides and chlorite. This means that while the marble can be perfectly polished and may yield nice slabs and tiles, no big blocks can be quarried which meet international requirements for blocks of dimension stones.

No information is available on any of the other "decorative stone deposits" mentioned by Dejidmaa et al. (2001). According to Kampe (1997), due to the harsh climate, all mining for dimension stones in Mongolia is restricted to the summer months and is only done sporadically.

Figure 91: Typical marble of better quality in Tsagaan Chuluut marble quarry.

As of 2010, there is no active dimension stone mining operation in Mongolia.

REQUIREMENTS AND EVALUATION

While there are several requirements for dimension stone deposits, the most important is the beauty of the stone and the size of the blocks which can be quarried. While beauty is subjective, the rocks should be homogenous in structure and colour. For export purposes, unusual material should be looked for because dimension stones for the mass market are already supplied in large amounts and very cheaply by Indian and Chinese producers. Extractable blocks must have a minimum volume of >1.5 m^3, with lengths >1 m, widths >1 m, and thicknesses >0.4 m. Blocks for export should have a volume of 1.5 to 6 m^3, with lengths >2-3 m, widths >1-2 m, and thicknesses >0.5-1 m. Other requirements are good sawing or cleavage properties, very high weathering resistance, low water absorption, adequate frost resistance, high compressive and tensile strengths, low thermal expansion, uniform relative density, high polishing capacity, and possibly also good adhesion of protective coatings. These geotechnical requirements have to be proven by certified labs or by the customer.

Reserves should be >100,000 tonnes, or rather > 30,000 m^3. In general, only very high-value rocks, like sodalite or pink marble, can be transported over long distances, i.e. across Mongolia.

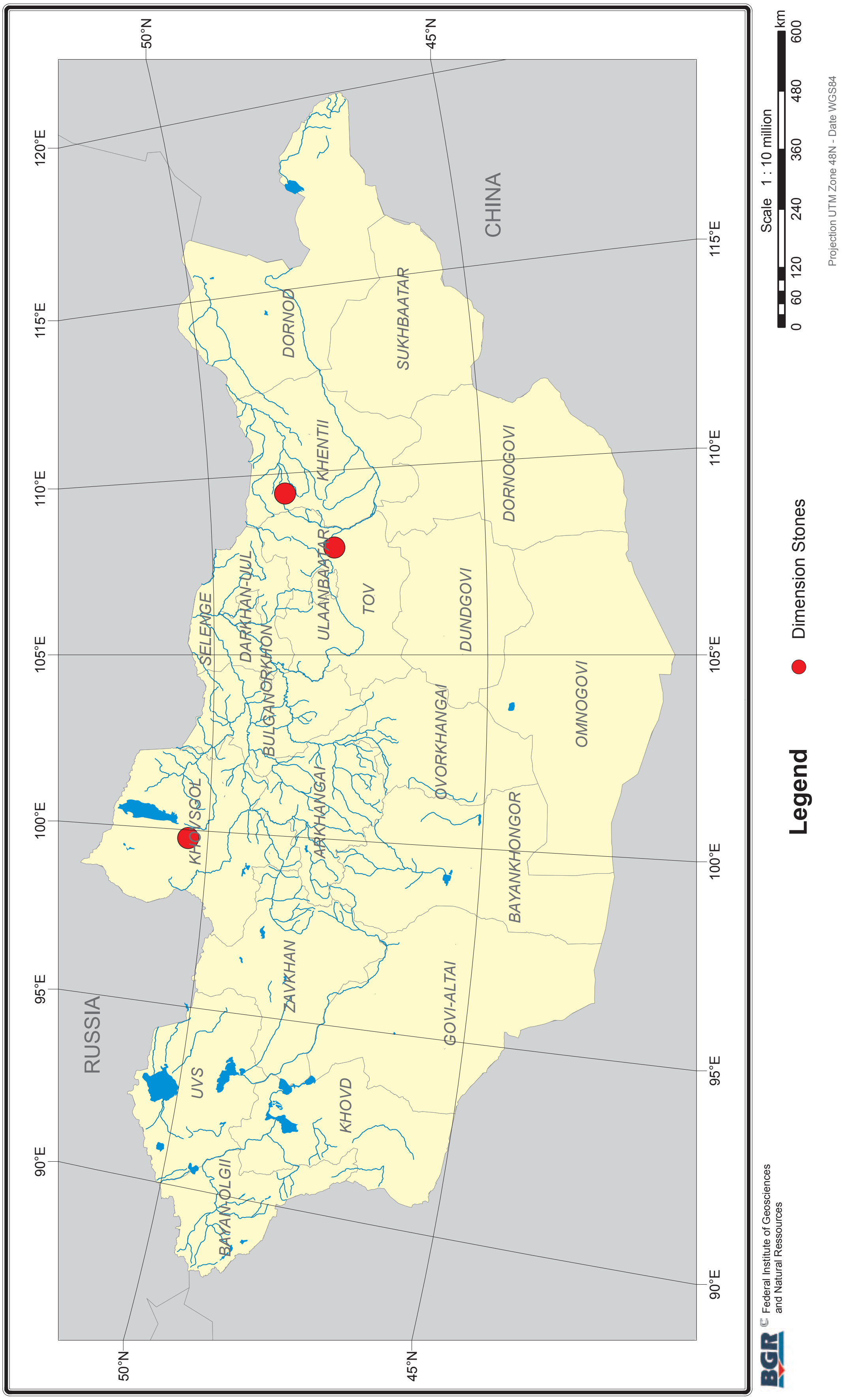
Potential investors in dimension stones first have to identify a suitable deposit. To do so it may be worth paying a visit to the Museum of Geology and Mineral Resources at the Mongolian University of Science & Technology in Ulaanbaatar. This museum has a large display of minerals and rock specimens from all over Mongolia.

Costs for drilling, cutting, sawing and hauling equipment for a reasonable mining operation are about one million US-$. Subsequent transportation of blocks will become a major issue, because a 1.5 m^3 block of marble for instance weighs about 4 tonnes, and a 6 m^3 block weighs about 16 tonnes! Even if these problems can be overcome, in Mongolia there will be additional problems with the harsh climate and the supply of water.

RELEVANT LITERATURE

KYNICKÝ, J., JAROŠ, O. & SAMEC, P. (2006): Mineral association of the miarolitic amazonite massif of Avdarant (in Czech).- Czech-Slovenian Gemmological Association: 1 p, 4 fig.; Brno (http://www.csga.wz.cz/clanky/avdarant.html).

Deposits of Dimension Stones in Mongolia



TALC

GENERAL INFORMATION AND USES

Talc is a chemically inert, oil-absorbent, flaky, and very soft mineral, which makes it an important commodity. It is used as a non-toxic, white and adsorbent filler in plastics, rubber, paper, paint, asphalt, cosmetics, ceramics, pharmaceuticals, textiles, fertilizers, and insecticides. It can also be used for the insulation of wood-burning stove fittings.
Because talc is not a rare mineral, only high-grade talc is actively traded internationally.

RELEVANT DEPOSITS IN MONGOLIA

Two types of talc mineralisation are known in Mongolia: low-ferriferous carbonate talc, and ferriferous-serpentinite talc. The carbonate talc is related to hydrothermally-altered shear zones in limestone and marble of Upper Proterozoic age. Most of the talc occurrences, however, belong to the ferriferous-serpentinite type that occurs in ultramafic rocks that have undergone intensive serpentinisation. Associated minerals are carbonate, serpentine, chlorite, chromite, genthite, and magnetite. Talc veins formed as the result of the hydrothermal-metasomatic replacement of alpine-type ultramafic rocks (Dejidmaa et al. 1999).

According to Geological Information Center (2003) there is one talc deposit – Tsagaan Gol – and 12 talc occurrences in Mongolia. Jargalsaihan et al. (1996) also calls Tsagaan Gol a talc deposit and reports the names of eight occurrences. Dejidmaa et al. (2001), however, do not even accept Tsagaan Gol as a deposit, just naming 23 occurrences.

The **Tsagaan Gol** deposit under dispute is an example of hydrothermal-metasomatic replacement and formed along the deep-seated Ikh-Bogd fault zone, 90 km south of the Govi-Altai Aimag centre and 17 km south-east of Khalium, which is the Soum centre. Talc-brennerite lenses found at the boundaries of an ultrabasic intrusive cover an area of 700 m length and 50-200 m width. They are characterised by intensive serpentinisation. The talc content is about 50 vol.-% on average with the talc having a typical chemical composition of 30.48 % SiO_2, 31.98 % MgO, 5.49 % FeO, and 0.93 % Al_2O_3. Because resources have not been determined yet, this potential deposit needs further exploration.

REQUIREMENTS AND EVALUATION

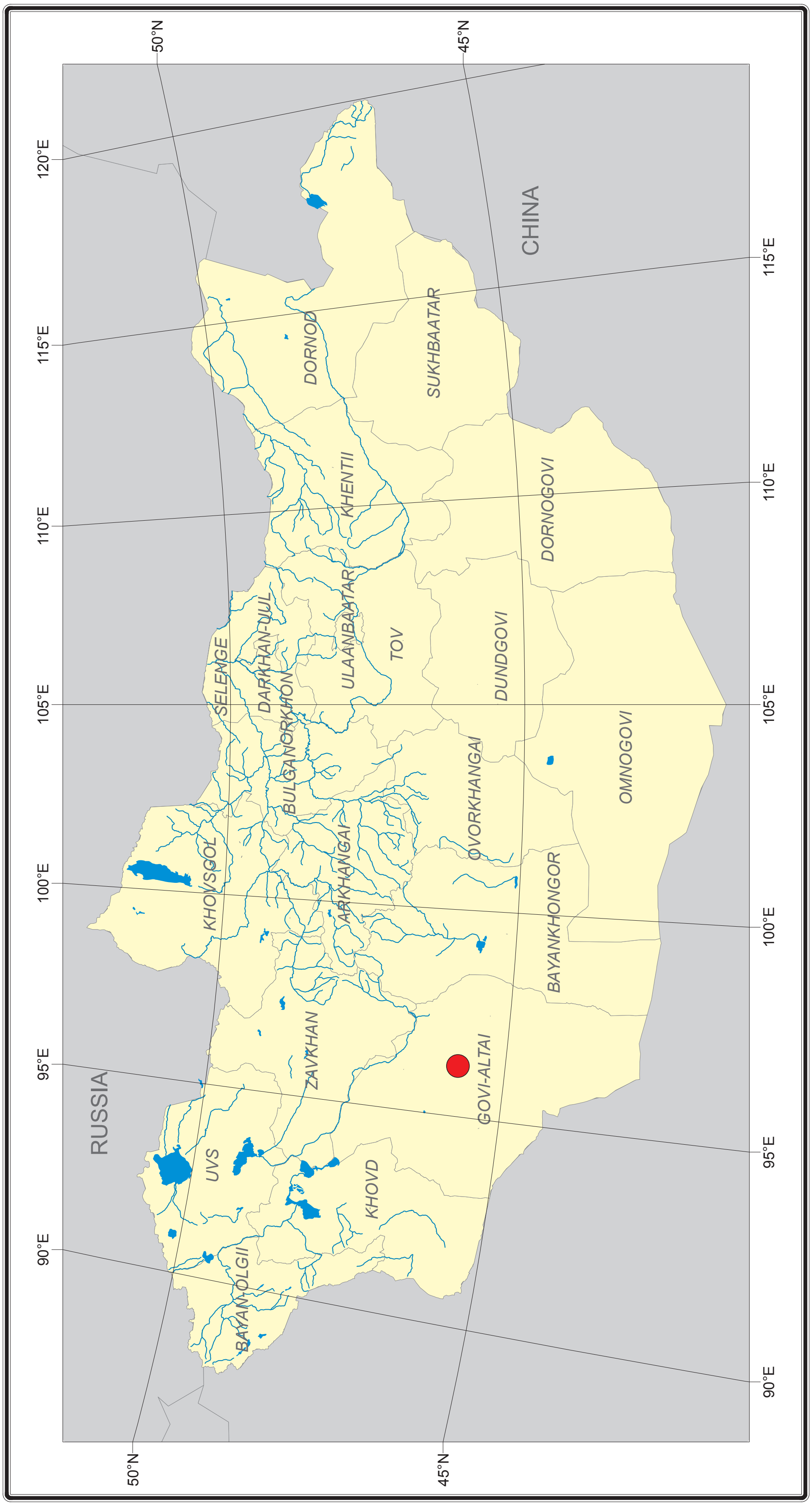
To evaluate their quality, talc deposits have to be explored with closely spaced surveys. Talc ore has to be analysed for its chemical and mineralogical composition. Technical tests of at least the specific surface, whiteness, and abrasion and oil adsorption properties are required. Asbestos fibres are unwanted impurities in most applications. Talc deposits should contain a minimum of 35 vol.-%, better 50 vol.-%, of talc with proven reserves exceeding 200,000 tonnes of net talc. However, according to the Russian classification system, a talc content of 30,000 tonnes is sufficient.

According to KAMPE (1997), there are no deposits of talc which can be utilised in Mongolia. Moreover, talc was never mined or even investigated in Mongolia.

RELEVANT LITERATURE

Dejidmaa, G., Dorjgotov, D., Gerel, O., Gotovsuren, A. & Ariunbileg, S. (1999): Preliminary description of mineral deposit models (types) for Mongolia.- in: Nokleberg, W. J., Naumova, V. V., Kuzmin, M. I. & Bounaeva, T. V. (eds.): Preliminary publications book 1 from project on mineral resources, metallogenesis, and tectonics of northeast Asia.- USGS Open-File Report, 99-165: 1-28, 1 tab.; Reston, VA.

Deposits of Talc in Mongolia



Legend

● Talc

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

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ZEOLITE

GENERAL INFORMATION AND USES

Zeolite is the name of a group of about 50 minerals, which form by the reaction of pore water with volcanic rocks or clays. While only eight of these minerals can be found in commercial deposits, all of them have large open “channels” in their crystal structure that provide a large void space for the adsorption and exchange of cations. Due to this property, zeolites are increasingly being used in aquaculture, agriculture, horticulture, the chemical industry, waste management and for domestic use. While the chemical industry prefers artificial zeolites to natural zeolites, due to their more uniform structure and properties, in the agricultural field nearly all zeolites can be used as animal feed additives, as soil and compost additives, as potting media, and as a medium for nitrogen capture, storage, and slow release.

RELEVANT DEPOSITS IN MONGOLIA

According to common understanding, there is just one major and economically mineable zeolite deposit in Mongolia, which is Tsagaan Tsav in Saikhandulaan Soum of Dornogovi Aimag. However, JARGALSAIHAN et al. (1996) add: “There are several zeolite deposits and occurrences of industrial importance (Tsagaantsav, Tushleg etc.). Spatially concentrated in the eastern Mongolian volcanic belt, they belong to a distinctive type of zeolites of igneous-limonitic genesis dating back to the Upper Jurassic and Early Cretaceous periods. The main mineral of the zeolite group is clinoptilolite. In some cases, zeolite occurrences include significant quantities of chabazite, heulandite, analcime, and ferrierite.

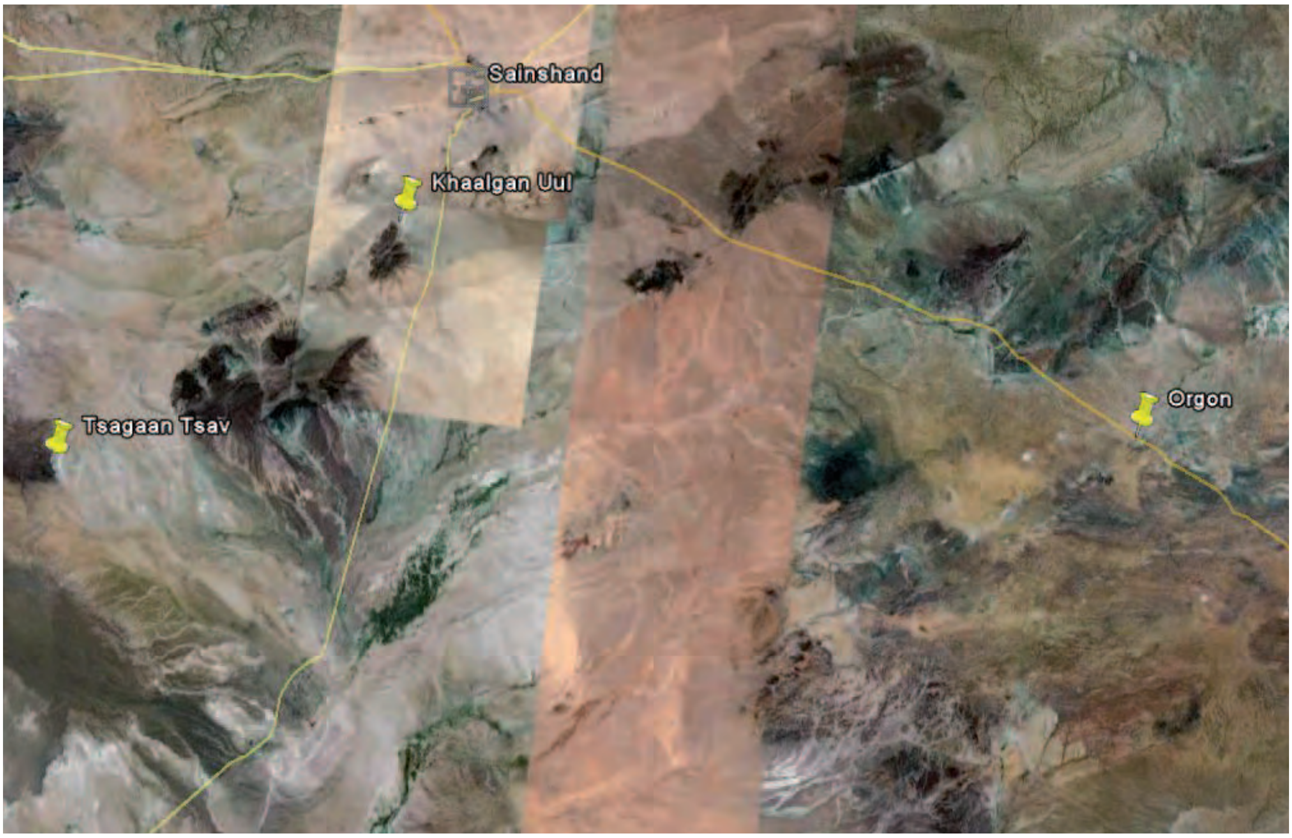


Figure 92: Satellite image of central Dorngovi Aimag showing major zeolite deposits, Sainshand town, the main road from Ulaanbaatar to the Chinese border (in orange), and major tracks (in yellow) (Photo courtesy of GOOGLE EARTH).

The mean content of the valuable component in zeolites is 40-90 %."
Dejidmaa et al. (2001) suggest that Tsagaan Tsav, Orgon and Khaalgan Uul/Tushleg be given deposit status.

South-west and south-east of Sainshand, several zeolite occurrences and deposits are known (cf. Figure 92) of which **Tsagaan Tsav** was visited and resampled during a field trip in May 2008. The Tsagaan Tsav deposit (44° 37' 36.4" N, 109° 48' 16.0" E, 944 m a. msl) is situated some 38 km south-west of Sainshand and was explored in detail between 1986 and 1988. Here, during the Jurassic, rhyolithic magma ascended along a graben side fault between Carboniferous meta-sediments and Mesozoic to Cenozoic rocks. Tuffs which were expelled at that time were later hydrothermally altered forming zeolites, especially clinoptilolite. Today, zeolites partly cover an area of some 1.6 km^2. Clinoptilolite occurs in dense, white to light greyish, partly laminated layers intercalating with clayey beds and pure tuffs. Individual zeolite layers reach 1,600 to 1,800 m in length, 50 to 140 m in width, and 20 to 30 m in thickness. Resources in category C1 were estimated as 6.8 million tonnes of zeolite, subdividable into 6.16 million tonnes of high-grade ore with 61-90 vol.-% of zeolite, and 0.72 million tonnes of low-grade ore with 20-60 vol.-% of zeolite.

United Nations (1999) mention that Tsagaan Tsav zeolite was used for environmental clean-up after the Chernobyl disaster in Ukraine in 1986. In the years after 1994, it is said to have been used for limited pig and chicken feeding in Mongolia. In 2007, a different Mongolian company took over. After mining by excavator, the crude zeolite is now trucked to the nearest railway station 35 km away and then transported to the Darchan cement factory 700 km down the line. There it may be used as a silica additive. In 2008, the rate of mining was about 50 tonnes per day, i.e 15,000 tonnes per year.

Figure 93: Wide landscape at Tsagaan Tsav with sequence of tuffs, sandstones, and zeolites (light).

Figure 94: Mining for zeolite at Tsagaan Tsav as of May 2008.

Figure 95: Finely laminated zeolite from Tsagaan Tsav.

Tsagaan Tsav zeolite deposit is mentioned in the appendix of the list of strategic deposits of Mongolia.

A more significant use of the clinoptilolite, e.g. as a soil conditioner, feed additive, or in small, but high-price amounts as a remedy, should be tested. Analyses of three fresh samples did not show any contaminants, but no beneficial characteristics either. The intercalated clay proved to be a smectite, i.e. a bentonite of low quality (cf. Table 55). However, more clay samples must be taken to produce verifiable results.

Table 55: Selected chemistry, cation exchange capacity, and mineralogy of zeolite and clay samples from the Tsagaan Tsav zeolite deposit (bulk rock analysis by XRF and XRD).

Chemistry	**Tsagaan Tsav**			
	Zeolite-1	Zeolite-2	Zeolite-3	Clay
	wt.-% / ppm			
SiO_2	66.15	64.45	65.11	61.68
TiO_2	0.21	0.13	0.22	0.51
Al_2O_3	12.53	12.14	13.15	14.33
Fe_2O_3 total	0.82	0.58	1.38	3.76
MnO	0.00	0.00	0.01	0.02
MgO	0.61	0.52	0.75	2.41
CaO	1.08	1.89	1.01	1.20
Na_2O	2.81	3.04	2.47	1.75
K_2O	3.71	3.06	4.40	3.63
P_2O_5	0.05	0.04	0.05	0.13
(SO_3)	<0.01	0.03	<0.01	0.02
(Cl)	0.01	0.01	0.01	0.01
(F)	<0.05	<0.05	<0.05	<0.05
LOI	11.78	13.81	11.17	10.32
Sum	*99.72*	*99.65*	*99.69*	*99.72*
(As)	2 ppm	2 ppm	<2 ppm	9 ppm
Ba	272 ppm	521 ppm	551 ppm	298 ppm
Ce	73 ppm	75 ppm	78 ppm	84 ppm
Pb	20 ppm	9 ppm	13 ppm	26 ppm
Sr	526 ppm	638 ppm	502 ppm	198 ppm
Th	23 ppm	24 ppm	28 ppm	26 ppm
U	<3 ppm	3 ppm	3 ppm	3 ppm
Mineralogy	Clinoptilolite and quartz with traces of biotite, feldspar, and smectite	Clinoptilolite with traces of quartz, biotite, and feldspar	Clinoptilolite, quartz, and feldspar, with traces of biotite and smectite	Smectite, quartz, and feldspar, with traces of clinoptilolite, biotite, and christobalite
Cation exchange cap. (meq/100 g)	12.9-15.0	11.2-14.6	17.6-20.0	32.2-35.8

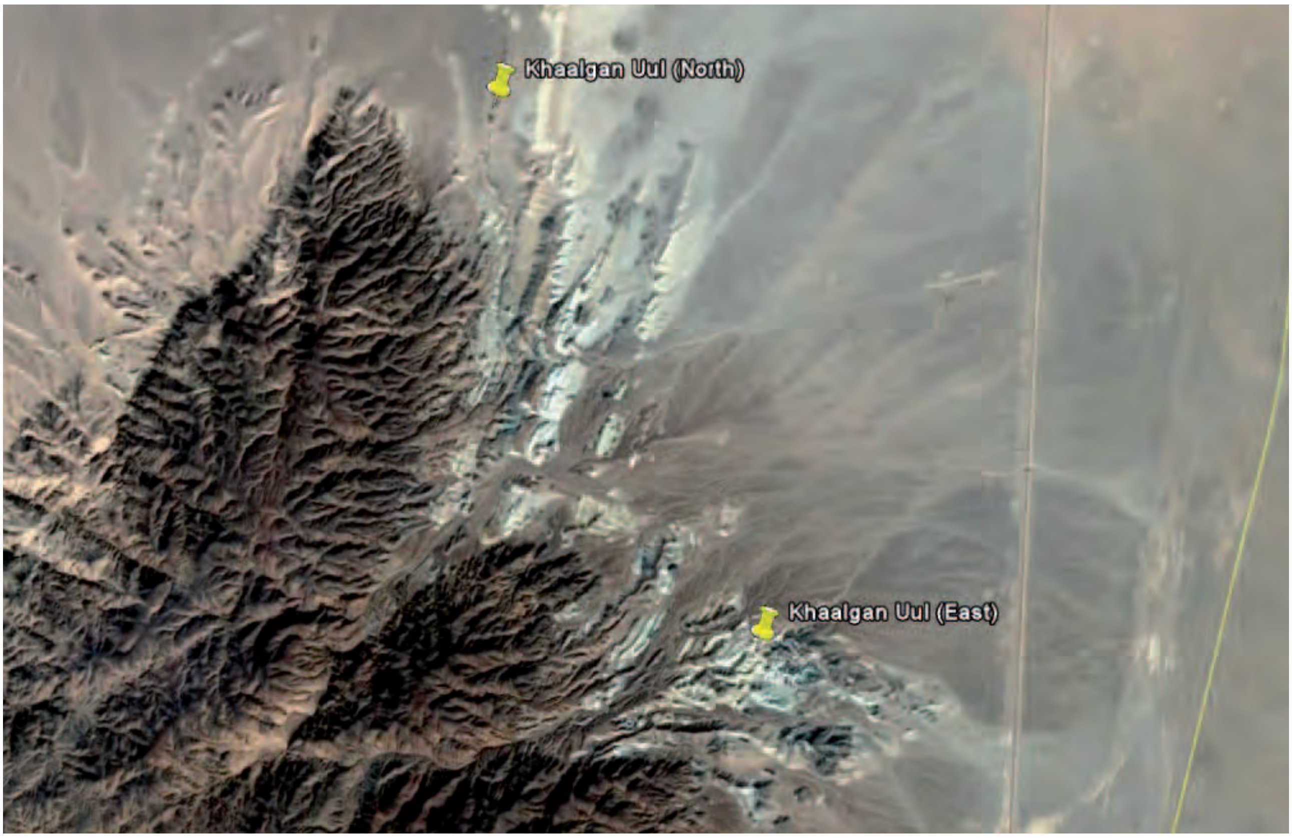


Figure 96: High definition satellite image of the Khaalgan Uul zeolite deposit, located 10 km south-south-west of Sainshand town (Satellite image as of 16 March 2006, Altitude 4.07 km, Photo courtesy of GOOGLE EARTH).

The **Khaalgan Uul** zeolite deposit consists of one layer of zeolite-rich tuff, which is distributed in three areas:

East: 3 km long x 350-400 m wide x 15-20 m thick, dip 15-20°, zeolite content 30-40 vol.-%

North: 1.2 km long x 300 m wide x 7-8 m thick, dip 15°, zeolite content 60-90 vol.-%, on average 80 vol.-%

North-West: 700-800 m long x up to 100 m wide x 4-19 m, on average 12 m thick, zeolite content 30-40 vol.-%

The zeolite-rich layer is tectonically fragmented. Zeolites are said to be dominated by clinoptilolite and ferrierite, while other authors name chabasite. The resources in category P1 are estimated as 50.9 million tonnes of zeolite ore, subdividable into 6.6 million tonnes of high-grade ore with >60 vol.-% of zeolite, and 44.3 million tonnes of low-grade ore with <60 vol.-% of zeolite. The Khaalgan Uul zeolite deposit with zeolite outcrops distributed over vast areas south-west and south of Sainshand was visited in September 2010. New representative samples of typical rocks in this area were taken and analysed at BGR (cf. Table 56 below).

Below the village of **Orgon**, zeolite occurs in pores and aureoles of tuffitic sandstone. The exploration licence for this zeolite deposit as of 2010 was held by MONGOLROSTSVETMET LLC which took a bulk sample for technological testing some years ago. Because the results of the tests are not available, two new representative samples from the old test pit, now used as a waste disposal site (cf. Figure 97), were taken in September 2010 and also analysed at BGR (cf. Table 57).

Table 56: Selected chemistry and mineralogy of various rock samples from the Khaalgan Uul zeolite deposit (bulk rock analysis by XRF and XRD).

Chemistry	Khaalgan Uul			
	Zeolite-1	Rock-2	Rock-3	Rock-4
wt.-% / ppm				
SiO_2	62.56	70.17	62.67	66.79
TiO_2	0.35	0.32	0.41	0.41
Al_2O_3	13.55	12.16	12.30	13.08
Fe_2O_3 total	1.75	1.95	2.69	2.64
MnO	0.01	0.04	0.03	0.04
MgO	1.00	1.01	2.71	1.89
CaO	1.71	1.64	1.68	1.15
Na_2O	3.75	0.92	2.13	0.88
K_2O	2.82	7.44	4.33	6.07
P_2O_5	0.10	0.10	0.13	0.11
(SO_3)	0.03	0.06	0.19	0.02
(F)	<0.05	0.06	<0.05	<0.05
LOI	11.97	3.90	10.42	6.60
Sum	*99.67*	*99.81*	*99.75*	*99.75*
(As)	4 ppm	10 ppm	4 ppm	7 ppm
Ba	436 ppm	269 ppm	268 ppm	328 ppm
Ce	68 ppm	78 ppm	99 ppm	81 ppm
Pb	22 ppm	22 ppm	22 ppm	26 ppm
Sr	1,068 ppm	120 ppm	309 ppm	104 ppm
Th	17 ppm	19 ppm	14 ppm	18 ppm
U	<3 ppm	<3 ppm	5 ppm	<3 ppm
Mineralogy	Heulandite or clinoptilolite with traces of quartz, feldspar, and biotite	Quartz with traces of feldspar and quartz	Quartz with traces of clinoptilolite, feldspar, biotite, and smectite	Quartz and smectite, with traces feldspar and biotite

Figure 97: Old test pit within zeolite at Orgon as of 2010 used as a waste disposal site.

Table 57: Selected chemistry and mineralogy of zeolite samples from the Orgon and Durvun Dert zeolite deposit (bulk rock analysis by XRF and XRD).

Chemistry	**Orgon**		**Durvun Dert**
	Zeolite-1	Zeolite-2	Rock-1
wt.-% / ppm			
SiO_2	63.35	63.48	64.38
TiO_2	0.24	0.33	0.15
Al_2O_3	13.22	13.75	12.92
Fe_2O_3 ^{total}	1.67	1.93	1.18
MnO	0.01	0.02	0.05
MgO	1.03	0.93	1.15
CaO	1.65	1.28	1.40
Na_2O	2.79	3.14	4.05
K_2O	2.23	2.69	2.06
P_2O_5	0.12	0.09	0.09
(SO_3)	<0.01	0.01	0.05
(Cl)	<0.01	<0.01	<0.01
(F)	<0.05	<0.05	<0.05
LOI	13.25	11.94	12.26
Sum	*99.56*	*99.63*	*99.76*
(As)	5 ppm	8 ppm	12 ppm
Ba	1,519 ppm	1,084 ppm	284 ppm
Ce	60 ppm	65 ppm	85 ppm
Pb	6 ppm	10 ppm	43 ppm
Sr	1,021 ppm	891 ppm	297 ppm
Th	15 ppm	15 ppm	33 ppm
U	<3 ppm	<3 ppm	10 ppm
Mineralogy	Heulandite or clinoptilolite, with traces of quartz, feldspar, biotite, and smectite		unknown mineral, resembling chabasite with traces of quartz

The distribution of zeolite is said to be bound to a basin 950 m long, 50-132 m wide, and 200 m deep. On average, the tuffitic sandstone contains 65 vol.-%, up to 85 vol.-% of zeolite, resulting in estimated category P1 resources of 15.2 million tonnes of zeolite.

Another zeolite deposit is **Durvun Dert**, some 30 km south of Mandal-Ovoo Soum centre in Umnugovi Aimag. This deposit has not been explored in detail yet, but it is said that there is one zeolite layer of about 2.5-30 m thickness dipping 20-25°. A sample from this zeolite was kindly provided for analysis by Mrs. MAJIGSUREN YONDON from the Museum of Geology and Mineral Resources at the Mongolian University of Science & Technology in Ulaanbaatar (cf. Table 57).

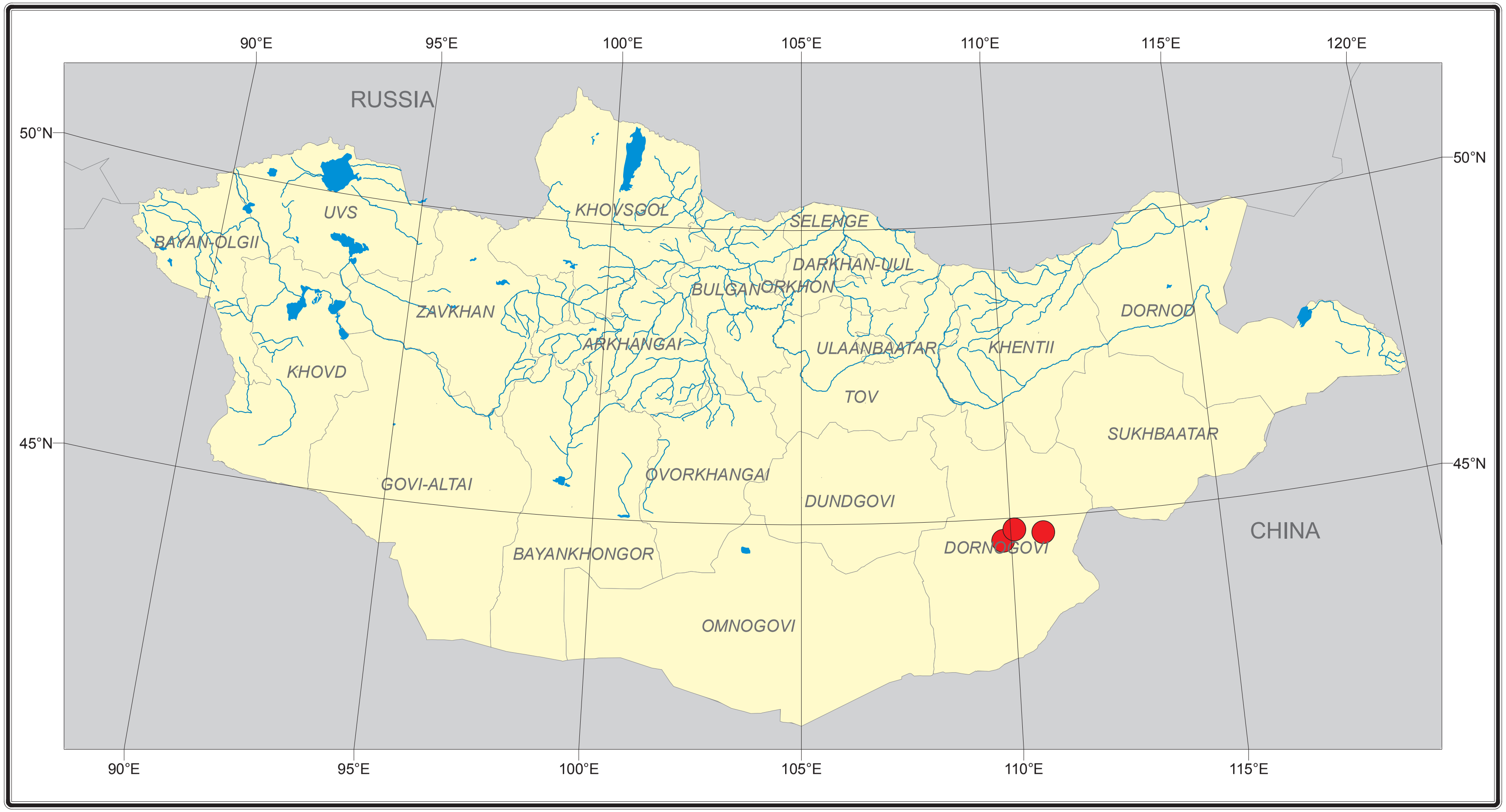
Figure 98: Outcrop of zeolite at Durvun Dert. Photo courtesy of Majigsiren Yondon.

REQUIREMENTS AND EVALUATION

For potential mining, the overburden of zeolite deposits should be low (<4 m) with layers of zeolite more than 20 cm thick. Deposits should contain >100,000 tonnes of zeolite (several million tonnes of zeolite according to the Russian classification system) contained in high-grade ore, i.e. the grade of ore has to be >60-70 vol.-%.

Mongolian zeolite deposits can easily meet these requirements. Tsagaan Tsav has already been sampled and analysed in detail several times and is already being mined. However, not enough is known about the other deposits and major occurrences which also need to be checked and tested for their quality. However, in general Khalgaan Uul seems to be of low quality while Orgon and Durvun Dert might also suitable for mining. Potential investors should therefore keep these deposits in mind when looking for business opportunities. The Central Geological Laboratory in Ulaanbaatar may be suggested as a possible evaluation partner because they have a lot of experience in analysing zeolite.

Deposits and important occurrences of Zeolites in Mongolia



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Legend

● Zeolites

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

SELECTED RARE METALS IN MONGOLIA

BERYLLIUM

GENERAL INFORMATION AND USES

Beryl and bertrandite are the two important commercial minerals of beryllium, which is a high-strength, lightweight metal with a high resistance to corrosion. It is used amongst other things in the nuclear industry and in high-tech alloys (especially with copper) in the electronic, aeronautic, and aerospace industries. Bertrandite most often forms small and transparent crystals. Beryl comes in various forms, sizes, and colours, and is therefore also extremely difficult to identify in the field. Because beryl is an important gemstone (emerald, aquamarine, heliodor, chrysoberyl, morganite, and golden beryl) it is grouped among the industrial minerals.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

Beryl is a very common mineral in pegmatites, W-Mo-greisen, as well as W-Mo-vein occurrences in Mongolia. Geological Information Center (2003) lists 21 different beryl occurrences in Mongolia, most of them pegmatites. Dejidmaa et al. (2001) report 32 beryllium-bearing pegmatite occurrences and numerous greisen and vein/stockwork occurrences containing beryl.
Noteworthy other minerals in beryllium-bearing pegmatites include columbite, cassiterite, euxenite, spodumen or fluorite.

The bulk of the beryllium-bearing pegmatite dikes in Mongolia were discovered in the Baruunhurai basin in the southern part of the Mongolian Altai. There beryllium is not only found in pegmatites but also in wall rock schists, and here it sometimes occurs in higher-than-normal concentrations. Thus, in the host schists of the Alag Tagtin pegmatite field, the BeO content reaches 0.3 % which is ten times the grade of pegmatites.
Small but beryl-rich pegmatite bodies are also encountered at the Bayan Uul occurrence (20-30 % Be, total resources 1.3 tonnes) in the area of the Yeguzer Mo-W deposit and at the Shine-Ider occurrence on the right bank of the Nuhtiyn River (Jargalsaihan et al. 1996).
Another beryllium occurrence is Munkhtiin Tsagaan Dorvoljin in Bayanjargalan of central Dundgovi Aimag. It is the name of a rare metal bearing occurrence of pegmatitic-pneumatolytic origin containing elevated grades of Li, Rb, Cs, Ta, as well as 0.2-0.4 % Be. Total estimated resources comprise 36.2 t of beryllium. For more information on this occurrence cf. Mica.

The biggest W-Mo-Be vein/stockwerk occurrence is said to be the **Buraat Uul** occurrence in Bugat Soum of Bayan-Ulgii Aimag. This occurrence is located 36 km north-east of Ulgii town and 6 km south-west of the important Ulaan Uul tungsten deposit (cf. Tungsten). At Buraat Uul, beryl is a minor component in ten quartz-beryl veins with a length of 50-200 m, on average 100 m, a thickness of 0.3-1.0 m, on average 0.85 m, and 50 m extension to depth. The veins dip 70-85° NW. The grades of BeO vary from 0.22-1.38 %, with 0.5 % on average. Other important minerals to be found are molybdenite, wolframite, columbite, and tantalite. The total resources of BeO are said to be 301 tonnes.

Low-grade but high-volume resources of beryllium are the Yeguzer and Ondor Tsagaan W-Mo greisen deposits (cf. Tungsten for details). At **Yeguzer**, beryl (0.086 % BeO; 40,000 t BeO-content) occurs both within greisen as well as within quartz veins together with wolframite, molybdenite, fluorite, topaz, aquamarine, and heliodor. One small sample of beryllium ore with visible beryl was analysed to contain 2.89 % Be or 8.02 % BeO (ICP-MS analysis by BGR) (cf. Table 77).

Similarly, the huge **Ondor Tsagaan** deposit was found to contain about 0.03 % BeO in stockwerk ore resulting in resources of 43.913 tonnes of BeO in category C1 and category C2 combined. Recovery by flotation was tested and varied between 40 and 67 % BeO.

At Dorvon Dert and Teg Uul in Umnugovi Aimag, beryllium bearing tuffs were discovered which consist of bedded and graded-bedded tuff containing fragments of ongorhyolite, rhyolite, quartz, feldspar, fluorite, and Be-bearing bertrandite. The Be content averages about 0.05 %.

Another rather rare beryllium mineral in Mongolia is phenakite (5-30 vol.-%). However, there seems to be just one occurrence in the Dulan Ovoo granite massif in central Mongolia where this Be-silicate occurs in the form of small crystals (0.3-1.5 mm) together with fluorite (20-60 vol.-%) in a quartz-feldspar-fluorite vein of 0.4 m thickness.

REQUIREMENTS AND EVALUATION

According to Prof. Dr. Lkhamsuren Jargal (oral comm.) from the Mongolian University of Science & Technology, the beryllium occurrences of Mongolia have only once been investigated in detail, i.e. by a Russian expedition in the 1950's with unpublished findings.

Geological Information Center (2003) states grades of beryllium in pegmatites in Mongolia as between <0.001 to 13.3 % Be (or rather BeO) with individual resources varying between 0.9 to 12.0 tonnes of Be (or rather BeO) content.

The international cut-off grade of beryl (10-14 % BeO, 3.6-5.0 % Be) in pegmatites is given between 0.2 and 0.5 % (= 0.007-0.025 % Be). The minimum BeO content for individual deposits is 10 tonnes. Medium size deposits start at 100 tonnes of BeO, and large ones at 5,000 tonnes.

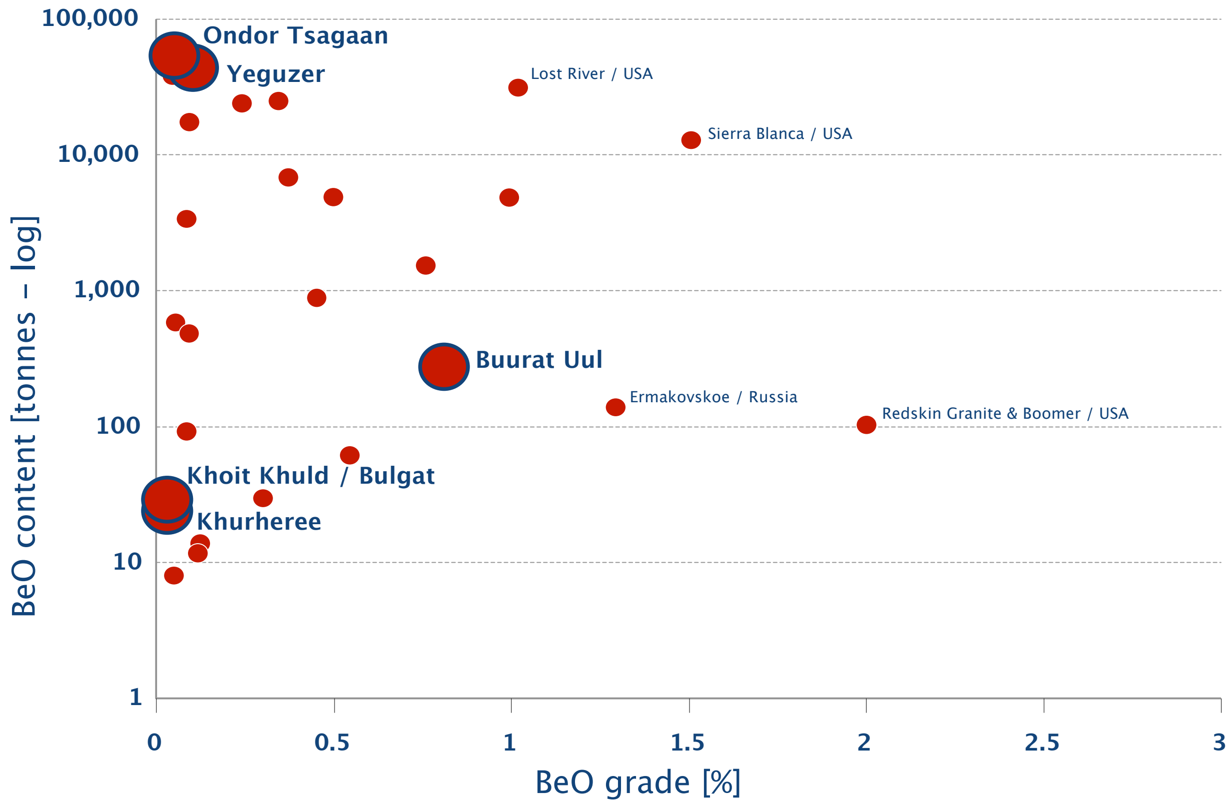


Figure 99: Grade-tonnage diagram of world-wide beryllium projects and mines with emphasis on Mongolian deposits.

However, according to the Russian classification system, beryllium deposits must be much bigger, with small deposits containing <1,000 tonnes of BeO, medium size deposits containing up to 5,000 tonnes of BeO, large deposits containing up to 20,000 tonnes of BeO, very large deposits containing up to 50,000 tonnes of BeO, and giant ones containing even more. Hand-picked concentrate should contain more than 8-13 % BeO.

Because several of the Be pegmatites in Mongolia fulfil the international requirements given above, they all represent deposits of potential interest to international investors. These are mainly:

- **Buurat Uul** in Bugat Soum of Bayan-Ulgii Aimag (0.22-1.38 % BeO, 301 tonnes BeO)

but also

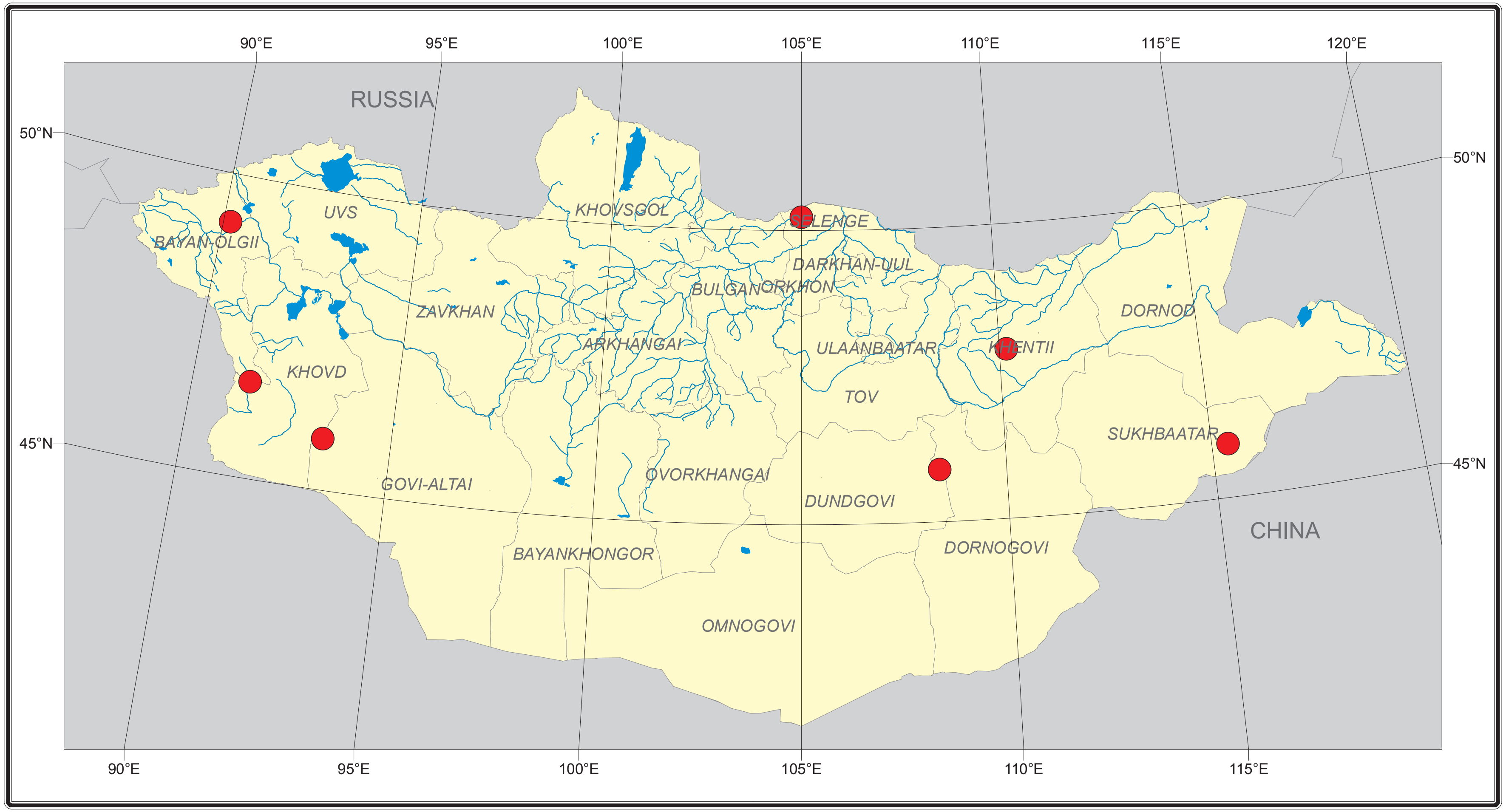
- **Bulgat** in Deluun Soum of Bayan-Ulgii Aimag (0.02-13.3 % BeO, 12.2 tonnes BeO)
- **Khoit Khuld** in Tolbo Soum of Bayan-Ulgii Aimag (0.01 % BeO, 33.3 tonnes BeO), and
- **Khurheree** in Tushin Soum of Selenge Aimag (0.015 % BeO, 27.7 to BeO)

It might be worthwhile to collect some fresh samples in the field and to obtain a personal impression. However, it should be kept in mind that beryl may occur in nearly all colours and can easily be confused with other minerals, like quartz or feldspar. The use of a field beryllometer for exploration is recommended.

The cut-off grade for bertrandite in large deposits is 0.2 %, which means that the Be tuffs of Mongolia are not worth mining.

Nevertheless, in pegmatites and tuffs, beryllium potentially constitutes a very important by-product in the W-Mo deposits of Mongolia with resources reaching world-class sizes.

Deposits and important occurrences of Beryllium in Mongolia



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Legend

● Beryllium

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

RARE EARTHS

GENERAL INFORMATION AND USES

The rare earth elements (REE) comprise the element yttrium (Z = 39), and a group of 15 elements, called the lanthanides (Z = 57 to 71). Due to its geochemical similarity, scandium is sometimes also included under the term rare earths. REE occur in significant amounts in many accessory minerals either as oxides, phosphates or carbonates, and are often formed by hydrothermal fluids.
In modern technologies, REE play an important role due to their special optical, biochemical, electronic, magnetic and other physicochemical properties. About 29 % of the REE are used in the glass and ceramics industry as glass-polishing compounds, decolouring agents, UV absorbers and anti-browning agents, glass and ceramic colouring agents, additives to structural ceramics and in optical lenses and glasses. Roughly 20 % of REE produced worldwide are used in catalysts, mainly in the refining of crude oil. Another 18 % are used in metallurgy as alloying agents to desulphurise steel, as a modularising agent in ductile iron, as lighter flints and as alloying agents to improve the properties of alloys and superalloys. Further important applications of REE are in batteries as mischmetal (a mixture of REE) and in phosphors. Also REE-alloys forming permanent magnets are being increasingly used in industrial, military and aerospace applications, or as less costly permanent magnets used in automobile starting and accessory motors, medical magnetic-resonance-imaging devices, industrial motors, wind energy turbines, compact disc players, computer disc drives, personal stereos, and camera motors.

RELEVANT DEPOSITS IN MONGOLIA

There are four deposits of rare earths in Mongolia, together with a number of occurrences which have no commercial value as they are either of very low grade or very small. E.g. the Tsagaan Chuluut placer deposit in Omnodelger Soum of Khentii Aimag contains only 758 tonnes of monazite.

Three of the four rare earth deposits known were revisited and resampled during field trips in 2009 to 2010. The new samples taken and analysed confirm the old analytical data, allowing final evaluation of the deposits in international comparisons.

Khalzan Burged
Sample Summit: 48° 24’ 23.8” N , 91° 56’ 56.7” E; 1962 m a msl
Sample 1907 m: 48° 24’ 21.5” N , 91° 56’ 53.9” E; 1907 m a msl
Sample 1854 m: 48° 24’ 21.9” N , 91° 56’ 46.8” E; 1854 m a msl
Sample 1805 m: 48° 24’ 28.8” N , 91° 56’ 47.5” E; 1805 m a msl
Sample 1755 m: 48° 24’ 30.3” N , 91° 56’ 40.5” E; 1755 m a msl
Sample 1701 m: 48° 24’ 31.5” N , 91° 56’ 27.2” E; 1701 m a msl

The Khalzan Burged rare earths/rare metals deposit lies some 45 km north-east of Khovd town and some 15 km by track off the main road from Khovd to Ulaangom, i.e. in Khovd Aimag.

The deposit was discovered in 1983 and explored in detail in the years thereafter. It is part of the lake zone of western Mongolia, which contains several rare metals/rare earths deposits of Middle Devonian age. Khalzan Burged is the largest deposit with an age of 393 Ma (K-Ar). The genesis of all of these deposits can be traced back to alkaline basic to acid intra-plate magmatism. The alkaline magma rose along extension zones at an active continental margin (Schwarz et al. 2009).

The Khalzan Burged deposit lies within a mountain range of alkaline plutonic rocks of the same name (cf. Figure 100). These rocks intruded into an ophiolite complex of Neo-Proterozoic to Early Paleozoic age and represent a shallow crustal to subvolcanic intrusion facies. The rare earths/rare metals mineralisation at Khalzan Burged most probably goes back to several phases of intrusion with the participation of other magmatic and metasomatic processes.

According to the geological exploration results, the mineralised alkaline granites intruded into barren nordmarkites and were thus affected by extensive metasomatic overprinting linked to mineralisation by rare earths and rare metals. Important for this mineralisation is the quartz-albite metasomatosis of the alkaline granites.

The granites and nordmarkites are cut by basaltic and pegmatitic dikes. All the rocks are highly fractured. There is an extensive low-grade but large mineralisation of rare earths and rare metals in the central part of the mountain range, covering an area of 0.81 km^2 (other sources: 0.91 km^2) together with a similar satellite body of 0.19 km^2 to the north-west.

Earlier exploration campaigns discovered that the higher the radioactivity of the rocks (U, Th, K) and the higher the elevation, the higher the grade of mineralisation. Above 1,900 m, ZrO_2 is said to reach 2.18 % and Ta_2O_5 0.254 %. Between 1,900 and 1,800 m all the rocks are mineralised but the grade is lower. Between 1,800 and 1,700 m the grades decrease even more (ZrO_2 up to 1.16 %, Ta_2O_5 >0.05 %) with some areas of the mountain being unmineralised. Below 1,700 m, the mineralisation is patchy.

The findings of the most recent exploration campaign including data from re-sampling and analysis of REO-bearing rocks by BGR are given below (cf. Tab. 58 and Evaluation)

Figure 100: Summit (1962 m) of Khalzan Burged with main road (yellow line) from Khovd to Ulaangom to the west (Photo courtesy of GOOGLE EARTH).

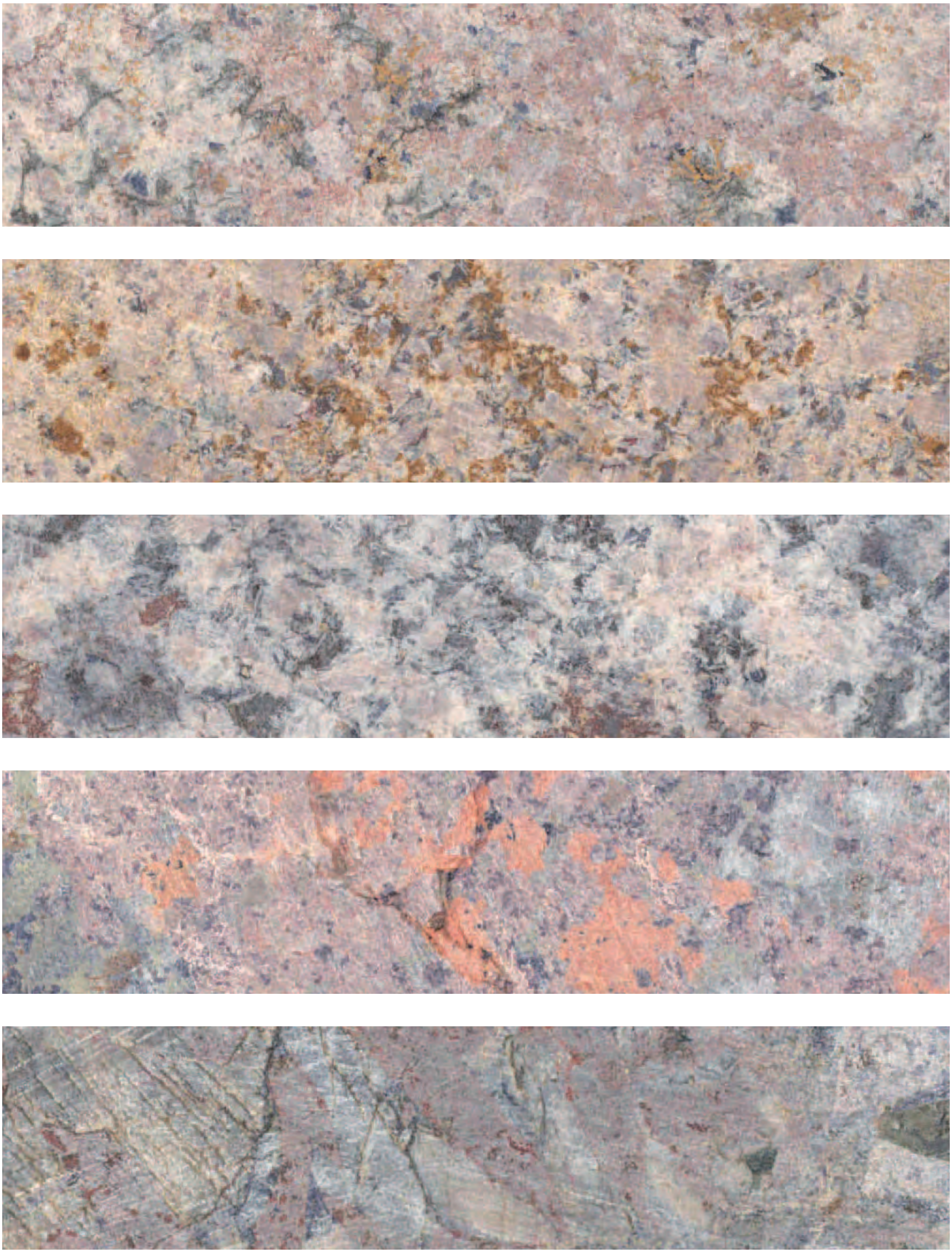

Figure 101: Rock varieties from Khalzan Burged. Lowermost picture is from pegmatite found at 1,927 m above msl, cf. Tab. 58.

Table 58: Selected chemistry of bulk rock analysis (XRF, data in wt.-% or ppm) from Khalzan Burged. Samples were taken from solid rock outcrops at different elevations as well as from pegmatite and loose boulders of various rock types from elevations above 1,927 m. All analyses by BGR. * RE analysis by ICP-MS + RE analysis by XRF

Chemistry	Elevation (m above msl)						Pegmatite	Boulders (n=3)
	Summit	1907 m	1854 m	1805 m	1755 m	1701 m	1927 m	1940-1945 m
SiO_2	67.63	67.24	72.48	74.16	71.88	70.82	63.85	61.26-66.99
TiO_2	0.66	0.44	0.42	0.14	0.20	0.08	0.26	0.26-0.84
Al_2O_3	10.24	11.52	11.33	11.10	11.90	9.47	12.72	10.94-14.54
Fe_2O_3 total	5.07	3.43	2.61	3.65	3.23	5.71	1.87	1.73-4.98
MnO	0.16	0.03	0.02	0.18	0.16	0.06	0.30	0.02-0.11
MgO	0.06	0.07	0.03	<0.01	0.02	0.02	0.08	0.02-0.06
CaO	4.23	3.91	2.06	0.11	0.12	4.29	3.17	3.60-4.41
Na_2O	4.51	4.37	3.36	3.39	4.77	3.35	1.24	3.86-5.80
K_2O	3.72	4.08	3.61	3.96	2.58	3.11	9.38	3.28-3.69
(F)	0.98	0.72	0.08	<0.05	<0.05	0.79	0.16	0.68-0.91
REO total *	0.45	0.78	0.53	0.25	0.20	0.26	0.38	0.32-0.68
LOI	1.68	2.47	2.26	0.92	0.96	2.01	1.14	1.91-2.62
Sum	*98.98*	*98.34*	*98.31*	*97.63*	*95.90*	*99.75*	*94.20*	*95.51-98.38*
ppm								
Ce +	1,234	2,806	2,049	840	404	686	565	763-1,813
Ce *	1,058	2,478	1,644	742	282	720	266	572-1618
Er *	80	74	57	16	19	23	232	30-110
Eu *	7.8	9.9	11.5	4.4	1.7	4.3	4.2	3.4-13.2
Dy *	162	175	108	42	32	71	202	54-272
Gd *	141	178	149	67	24	84	60	44-256
Hf	27	22	49	284	637	8	691	53-733
Ho *	30.5	31.6	19.8	6.4	6.5	11.5	58.0	10.8-46.9
La +	499	1,195	773	362	154	372	186	327-895
La *	387	959	546	298	110	361	79	265-855
Lu *	5.5	3.9	4.3	0.9	1.5	1.0	40.4	2.7-6.4
Nb	2,291	3,398	3,304	1,246	1,204	366	2,266	1,354-2,940
Nd +	565	1,242	959	334	167	365	159	340-935
Nd *	475	1,067	787	292	116	345	90	234-825
Pb	373	329	465	84	225	29	82	9-263
Rb	395	498	628	428	347	278	1,223	326-376
Pr *	123	290	202	78	30	84	25	64-208
Sm +	143	229	216	78	32	68	<15	73-229
Sm *	135	226	205	75	28	81	32	48-238
Sn	170	191	174	102	151	43	210	146-250

Table 58: continued

Chemistry	Elevation (m above msl)						Pegmatite	Boulders (n=3)
	Summit	1907 m	1854 m	1805 m	1755 m	1701 m	1927 m	1940-1945 m
Sr	578	375	198	74	29	118	271	51-279
Ta	163	254	247	95	81	22	192	77-197
Tb *	26.0	30.8	20.6	9.2	4.6	13.0	20.7	8.3-46.0
Th	192	151	149	110	77	87	73	71-605
Tm *	9.8	8.2	8.0	2.0	2.6	2.3	42.4	4.1-12.2
U	43	44	72	52	78	10	121	71-187
W	169	128	129	172	165	211	251	128-151
Y +	1,012	887	631	392	928	348	1,700	1,247-1,317
Yb *	51	38	44	10	14	10	303	23-58
Zn	1,169	1,532	578	999	616	383	1273	204-1,346
Zr	1,042	1,113	2,034	1.119 %	2.482 %	329	3.317 %	0.2-2.91 %

Primary ore minerals are: pyrochlore, columbite, elpidite-armstrongite, bastnaesite, zircon, and Zr-silicates.
Secondary ore minerals are: polylitionite, monazite, thorite, orthite, xenotime, synchisite, hematite, hetite, limonite, and rarely abukumalite, milarite, fluorite, and apatite.

Mushgai Khudag
The Mushgai Khudag rare earth deposit (Khuren Khad ore zone, cf. below at 44° 23' 05.6" N; 104° 00' 41.4" E, 1,166 m a msl, High grade ore zone, cf. below at 44° 23' 40.1" N; 104° 00' 00.5" E, 1,158 m a msl) was discovered in 1975, prospected in 1983/84, and explored in more detail between 1989 and 1994. The most recent exploration campaign took place between 2007 and 2009. The deposit is located in Mandal-Ovoo Soum of Umnugovi Aimag some 32 km south-west of Mandal Ovoo village, 55 km north-east of Bulgan village, and 100 km north of Dalandzadgad town. Road access is bad, with no infrastructure present at all, with the great exception of the nearby Olon Ovoot gold mine.

The Mushgai Khudag rare-earths-enriched carbonatite lies on the western part of the prominent Mushgai uplift and is surrounded by sedimentary and volcanogenic rocks of Silurian to Devonian age. The Mushgai Khudag volcanic-plutonic complex forms a ring structure of 27 km in diameter and consists of Late Jurassic (142 ± 3 Ma) alkaline intrusive and subvolcanic rocks. The alkaline rocks are composed of syenites, granosyenite porphyries and shonkinite porphyries, which form small bodies, dikes, and stocks from several tens of m^2 to 1 km^2 in size. Controlled by north-east, sublatitudinal and north-west trending faults, the mineralisation is dominated by P, Ba, Sr, REE, and Fe, and spatially and genetically related to the syenite intrusions. Lead ores are also known from the Mushgai Khudag complex (Samoylov et al. 1984).

At least 17 different ore bodies, spaced 100-1200 m apart, of various shapes, structures, and composition are known. In particular:
- steeply dipping lenticular and pillar-like pipes 900 m in extent and 200 m thick;
- stock-like and irregularly shaped bodies 10-30 m x 20-70 m in size;
- vein-like bodies up to 3 m thick and up to 100 m extent;
- stockworks up to 30 x 200 m size
- subhorizontal volcanic sheets 0.3 x 0.5 km^2 in size and up to several tens of m thick

They can be traced 50-150 m downdip without phase-out (Jargalsaihan et al. 1996). Seven ore bodies were found to be more highly mineralised and were studied in more detail.

In general, four types of mineralisation can be distinguished:
1. Mineralized breccia with carbonate cement
2. Mineralized carbonatite
3. Magnetite-apatite ore
4. Apatite ore

Apatite-bastnaesite carbonatite ore ("carbonatitic ore") and apatite ore ("phosphatic ore") are the most important ores, as they are most enriched in rare earths.

- Apatite-bastnaesite carbonatite ore appears in two different types, i.e. in the form of veins and in the form of mineralised breccias. Both types consist of calcite and dolomite (50 %), celestite and barite (up to 10-15 %), fluorite (up to 10 %), apatite, and a wide range of rare earth minerals (REO total up to 3.5 %, on average 1.5 %). Bastnaesite is present in the form of fine-grained crystals (<0.5 mm).
- Six different types of apatite ore can be differentiated:
  1. Magnetite-apatite ore
  2. Fluorite-celestite-magnetite-apatite ore
  3. Apatite ore
  4. Phlogopite-apatite ore
  5. Feldspar-apatite ore
  6. Syenites with schlieren of apatite (REO total 2.6 % on average

Quartz-carbonatite-fluorite ore is also widely distributed in the whole area. It usually occurs in veins and breccias. The main minerals in this type of ore are fluorite (up to 40 %), calcite, quartz, celestite, apatite, monazite, and barite. Cerrusite is the main lead mineral. The REO content reaches 4.6 % (Samoylov et al. 1984).

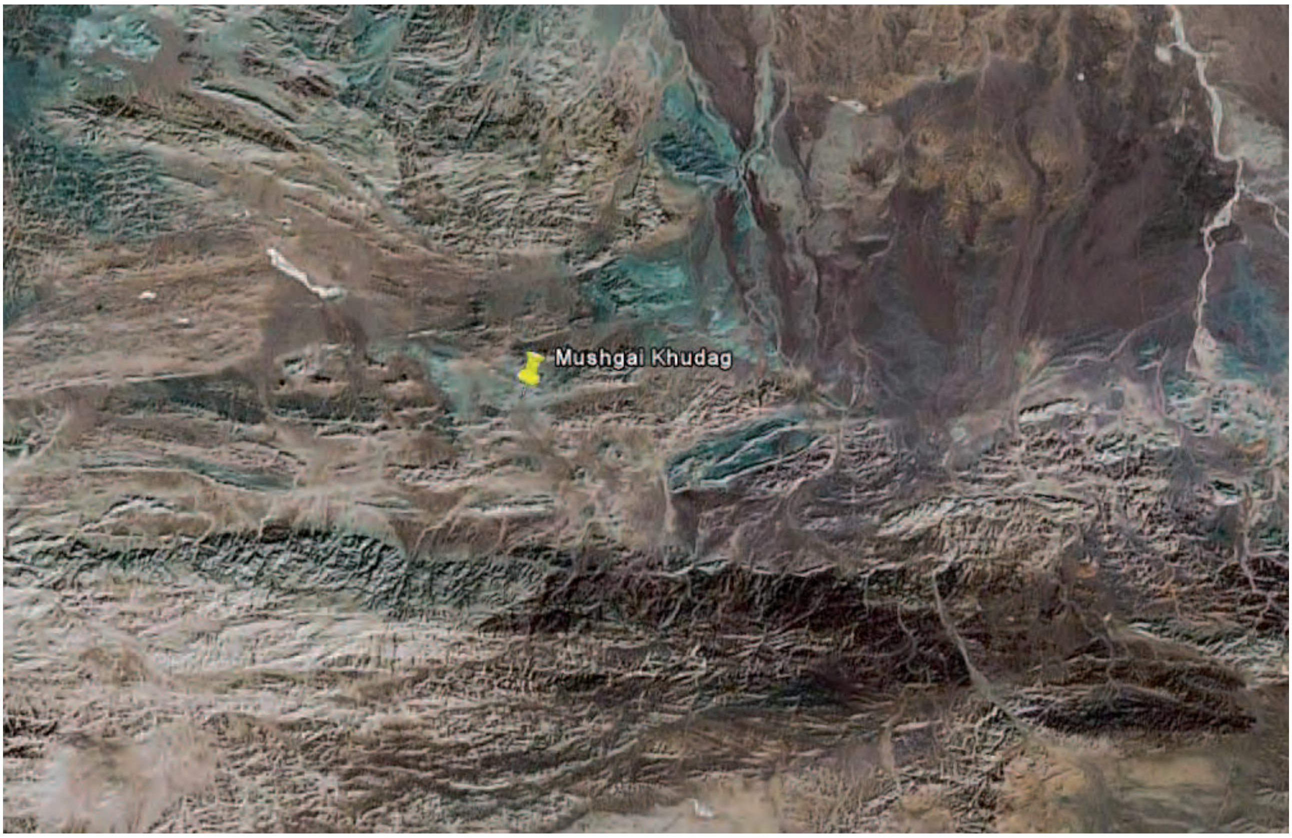

Figure 102: Satellite image of Mushgai Khudag area in Umnugovi Aimag (Photo courtesy of Google Earth).

Mineralised skarn is found in the central area only and consists of pyroxene-carbonate aggregates with fine and irregular impregnations of parisite.

In all types of ore mentioned above, the main rare earth minerals present are bastnaesite, apatite, perrierite, parisite, and synchysite, together with some iron-phosphate and monazite.

Initial calculated resources amount to
- 21,885,097 tonnes of ore (>0.5 % REO) grading 0.88 % REO on average, i.e. 192,448 tonnes of net REO in the main ore body,
- 1,752,162 tonnes of apatite ore grading 3.11 % of REO on average, i.e. 54,492 tonnes of net REO, both in category C2, and
- 1.6 million tonnes of ore grading 0.63-0.65 % of REO, i.e. 24,700 tonnes of net REO in category P1.

This adds up to a total of 23,637,259 tonnes of ore and 246,940 tonnes of net REO in category C2.

The category P1 or P2 resources of other non-economically mineable commodities found at Mushgai Khudag are:
- 5.2 million tonnes of ore with 35 % of gypsum or anhydrite
- 1.2 million tonnes of ore with 35-40 % Fe
- 441,600 tonnes of ore with 0.88-1.45 % P_2O_5
- 222,800 tonnes of ore with 0.85-0.95 % $BaSO_4$
- 220,600 tonnes of ore with 0.9-1.35 % Sr
- 201,600 tonnes with visible $SrSO_4$ (20-25 %)

Figure 103: View towards the Khuren Khad ore zone with prominent outcrop at the Mushgai Khudag rare earth deposit.

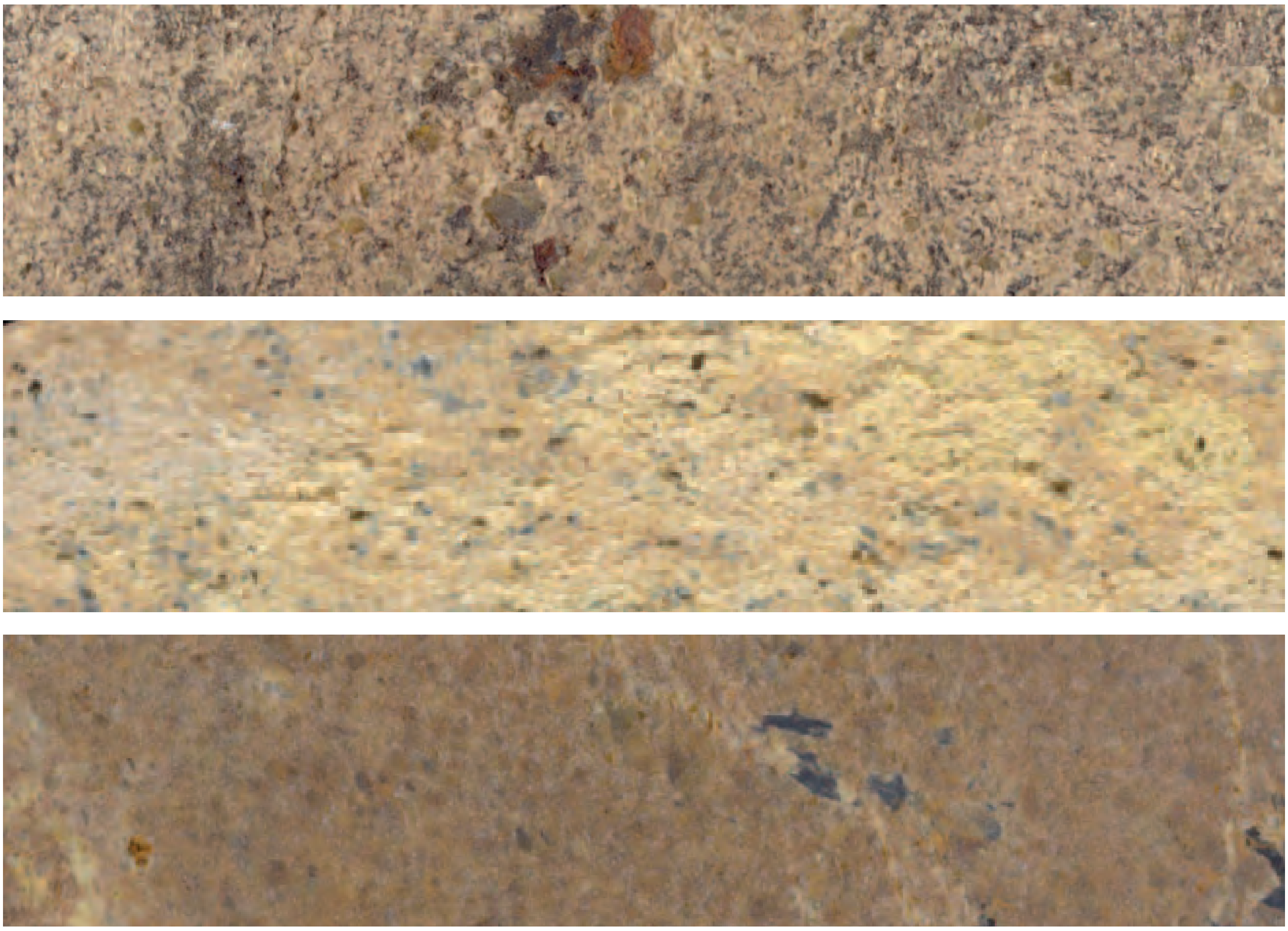

Figure 104: Rock varieties from the Mushgai Khudag – Khuren Khad ore zone, from top to bottom, samples #1, #6, and #8, cf. Table 60.

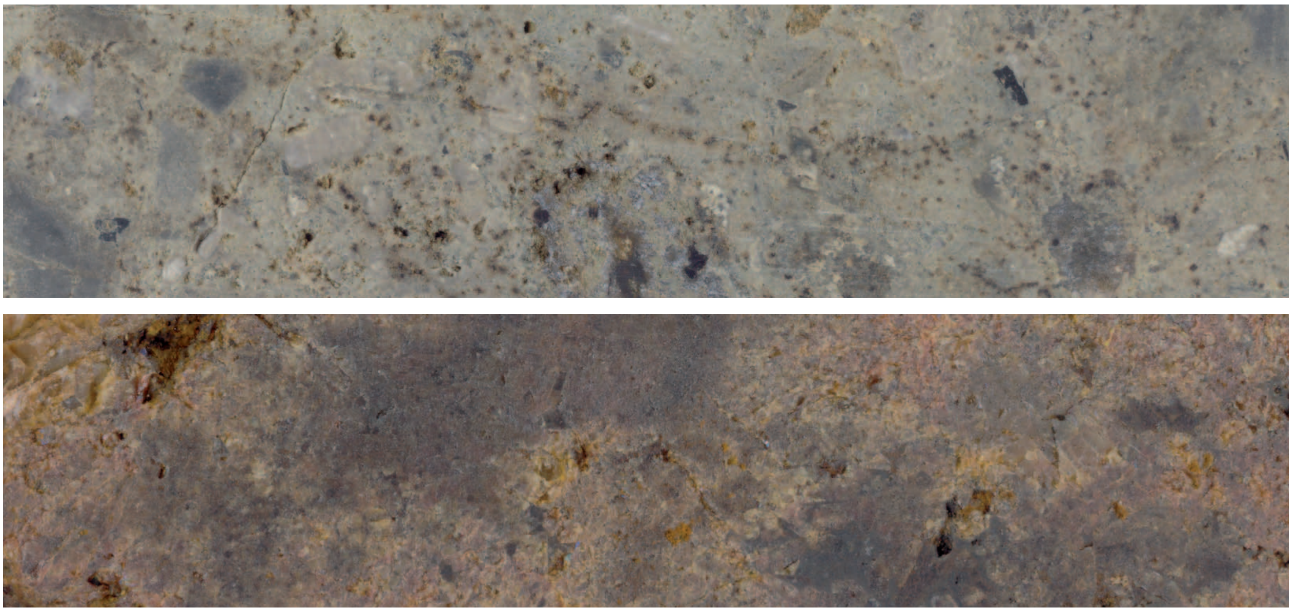

Figure 105: Rock varieties from the Mushgai Khudag – High grade ore zone, from top to bottom ore zone samples #1 and #2, cf. Tab. 60.

Table 59: Chemical composition of quartz carbonatite-fluorite ore, apatite ore and magnetite apatite ore (in % and ppm) of Mushgai Khudag, taken from Samoylov et al. (1984).

Chemistry	Quartz-carbonatite-fluorite ore n = 1	Apatite ore (surface) n = 11	Magnetite-apatite ore (surface) n = 3
SiO_2	42.71	3.09-18.23	1.57-2.06
TiO_2	0.27	n.d.-0.35	3.14-3.91
Al_2O_3	5.15	0.13-6.78	1.36-2.43
Fe_2O_3 total	5.40	7.06-33.36	66.60-74.54
FeO	n.d.	n.d.-0.70	5.21-8.44
MnO	0.03	0.07-0.13	0.21-0.53
MgO	0.33	0.03-0.19	0.26-0.33
CaO	19.98	26.26-38.61	3.64-7.62
BaO	1.64	n.d.-0.96	0.27-0.42
Na_2O	0.80	0.26-0.93	0.30-0.34
K_2O	3.19	0.02-0.05	0.25-0.36
P_2O_5	1.42	16.02-28.17	2.80-5.84
(F)	13.00	1.46-2.68	0.10-0.90
REO total	4.63	4.53-13.90	0.59-1.54
LOI	2.48	1.83-5.41	0.96-2.54
Ce	2.00 %	0.40-6.60 %	n.a.
Er	50 ppm	40-230 ppm	n.a.
Eu	150 ppm	170-460 ppm	n.a.
Dy	120 ppm	130-530 ppm	n.a.
Gd	240 ppm	320-1200 ppm	n.a.
Ho	37 ppm	35-110 ppm	n.a.
La	1.70 %	1.50-3.30 %	n.a.
Nd	0.50 %	0.55-2.30 %	n.a.
Pr	2500 ppm	2300-7800 ppm	n.a.
Sm	520 ppm	800-2500 ppm	n.a.
Sr	0.24 %	0.53-2.41 %	0.06-0.10 %
Y	690 ppm	900-4000 ppm	n.a.
Yb	41 ppm	35-210 ppm	n.a.

Table 60: Selected chemistry of bulk rock analysis (XRF, data in wt.-% or ppm) from RE rich rocks from Mushgai Khudag. All analyses by BGR. * RE analysis by ICP-MS + RE analysis by XRF

Chemis-try	Khuren Khad Ore Zone								High Grade Ore Zone	
	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2
wt.-%										
SiO_2	4.04	19.61	3.84	36.91	4.41	42.46	9.43	15.39	56.97	14.25
TiO_2	0.01	0.09	0.01	0.02	0.01	0.04	0.06	0.13	0.89	0.01
Al_2O_3	1.31	0.43	0.13	0.41	0.24	0.19	0.24	0.65	16.19	<0.05
$Fe_2O_3^{total}$	13.23	1.54	10.76	16.75	4.57	10.03	10.39	2.65	4.50	7.48
MnO	0.06	0.06	<0.001	<0.001	0.04	<0.001	0.02	0.07	0.13	0.12
MgO	0.09	0.26	0.05	0.02	0.03	<0.01	0.07	0.82	1.24	0.08
CaO	38.01	40.06	23.57	3.39	40.69	1.59	27.97	40.95	3.70	39.11
Na_2O	0.17	0.35	0.27	<0.01	0.26	<0.01	0.98	0.40	4.74	0.14
K_2O	0.04	0.10	0.09	0.08	0.02	0.06	0.05	0.33	6.23	0.01
P_2O_5	25.82	29.48	15.59	15.72	28.58	13.33	25.45	30.03	0.63	24.79
(SO_3)	2.67	1.14	11.10	0.47	2.92	0.75	2.33	1.45	0.29	2.14
(F)	2.24	2.63	0.90	0.35	2.41	0.55	2.10	2.80	0.10	2.88
REO^{total}	6.23	2.43	5.16	8.59	7.54	12.59	8.72	2.43	0.16	7.34
LOI	4.21	1.57	27.21	14.59	6.33	12.02	7.41	1.35	3.15	1.06
Sum	*98.14*	*99.75*	*98.70*	*97.29*	*98.07*	*96.61*	*95.26*	*99.48*	*98.94*	*99.42*
ppm										
Ce +	28,340	10,890	23,370	38,490	35,590	57,620	40,690	10,780	703	35,520
Ce *	29,760	11,152	24,591	41,190	36,177	60,465	41,977	11,155	743	36,384
Cu	113	13	250	150	89	88	92	12	39	121
Er *	77.7	60.4	62.5	86.7	90.1	105.0	95.2	62.7	3.1	97.4
Eu *	212.6	94.8	178.6	269.5	254.4	369.2	294.0	97.1	5.5	197.6
Dy *	200	157	165	234	237	303	246	164	6.7	229
Gd *	478	340	388	579	550	775	584	347	12.8	520
Ho *	32.1	25.4	26.4	36.4	37.6	46.1	39.5	26.3	1.1	38.1
La +	17,160	5,074	14,990	25,610	22,470	39,790	26,860	5,023	459	20,780
La *	17,624	4,919	14,939	25,939	21,565	39,084	25,886	4,856	454	19,906
Lu *	7.55	5.31	5.76	8.87	8.30	10.10	9.18	5.70	0.48	10.60
Nd +	8,946	4,974	7,143	11,040	10,840	15,830	11,780	4,943	207	10,510
Nd *	8,895	4,782	7,249	11,345	10,607	16,023	11,579	4,834	219	10,206
Pb	147	19	60	97	59	143	101	25	100	109
Pr *	2,873	1,335	2,346	3,764	3,424	5,370	3,860	1,333	72.9	3,401
Sm +	766	561	626	947	934	1327	963	564	19	861
Sm *	918	623	753	1,162	1,096	1,618	1,173	633	24	1,016

Table 60: continued

Chemistry	Khuren Khad Ore Zone								High Grade Ore Zone	
	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2
	ppm									
Sr	13,490	6,975	6,407	15,840	12,720	41,410	34,090	8,887	1,997	3,092
Tb *	46.0	35.3	38.1	55.1	54.1	73.0	56.6	36.3	1.4	51.4
Th	229	387	177	279	201	457	228	453	32	454
Tm *	9.64	7.26	7.74	11.0	11.3	13.3	12.0	7.88	0.45	13.0
U	158	23	132	274	227	321	364	27	10	420
Y +	1,076	725	812	1,224	1,179	1,612	1,285	746	39	1,326
Yb *	54.4	40.8	43.4	63.0	62.2	73.5	67.3	42.9	3.0	76.1
Zn	470	50	63	173	96	93	560	80	110	118
Zr	57	73	47	345	56	418	192	44	511	87

Table 61: Average rare earth oxide distribution (%) in different ores and minerals in the Mushgai Khudag rare earth deposit, after Samoylov et al. (1988).

Ore	Mineral	n	TREE	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Ho	Er	Yb	Y
Magnetite-apatite	**Apatite**	10	5.59	22.1	40.1	6.2	20.3	3.0	0.5	1.9	1.5	0.1	0.3	0.2	3.6
Apatite	Apatite	7	8.54	25.6	47.2	5.4	14.7	2.6	0.3	1.0	0.5	0.1	0.2	0.2	2.2
Magnetite-fluorite-celestite-apatite	Apatite	2	5.01	19.8	40.9	8.8	18.7	2.8	0.6	2.1	0.9	0.1	0.3	0.2	4.7
Carbonatite	Apatite	2	4.03	20.7	41.0	7.9	19.9	2.6	0.5	2.0	0.8	0.1	0.3	0.1	4.0
Carbonatite	Calcite	2	0.44	29.2	36.0	6.5	22.5	1.8	0.3	0.5	0.4	-	-	0.1	2.7
Carbonatite	Fluorite	2	0.66	32.0	36.6	7.0	18.3	1.5	0.3	0.6	0.5	-	-	0.1	3.1
Mineralised breccia	70 % bastnaesite concentrate	2	46.8	36.2	41.7	4.5	13.9	1.6	0.5	-	-	-	-	-	1.7

n = number of samples analysed

Lugiin Gol

The Lugiin Gol rare earth deposit (centre at 42° 57’ 46” N; 108° 35’ 12” E, 1,080 m a msl) is located in Hatan bulag Soum of Dornogovi Aimag. It lies 58 km north of the Mongolian-Chinese border and 175 km north-west of the world-famous and giant Bayan Obo rare earth deposit in northern China. The Hatan bulag Soum centre is 60 km away.

Within the boundaries of the Lugiin Gol massif, a first carbonatitic vein was discovered in 1971 by Russian geoscientists. From 1984-1987, a joint Mongolian-Polish geological expedition carried out an extensive exploration campaign for these carbonatites, which was followed by even more exploration work until 1989 and numerous visits by interested stake-holders, mainly from Japan, in the years thereafter. The most recent exploration campaign took place from 2005-2009, in general confirming all the previous data.

The Lugiin Gol massif consists of the Lugiin Gol nepheline syenite complex of Lower Triassic age (50 %), a 300 to 1300 m wide contact zone made out of hornfelsed shale (35 %) and surrounding host rock, which is black shale of

the Lower Permian Lugiin Gol Formation (15 %). This massif forms a pseudocaldera with an almost circular structure and eroded surface.
The Lugiin Gol nepheline syenite complex consists of a nepheline syenite stock and equivalent dike rocks. The stock crops out in an area of approximately 12 km^2, and has a circular outline with a diameter of 3.5 km. The stock is composed of nepheline-bearing syenite, alkali nepheline syenite and nepheline-bearing melasyenites. Similarly a vast variety of different rock types were encountered in drill cores.
The dikes are attributed to two stages: “pre-dikes” and “post-dikes”. The “pre-dikes” intruded the sedimentary country rocks before intrusion of the nepheline syenite stock, while “post-dikes” intruded both sedimentary rocks and the nepheline syenite stock. An alkali granite porphyry dike 20 m in width and 3.5 km in length crosscuts the Lugiin Gol complex. The oxidation level is about 25 m below the surface.
Carbonatite occurs in the form of about 200 to 400 dikes and small veins at the contact zone to the host rock, mainly in the northern, eastern and western parts of the Lugiin Gol Complex. 21 ore bodies with several dikes and veins have been outlined. The dikes and veins range in width from a few centimeters to 2.5 metres (on average about 35 cm), and up to more than 1,000 m length. The carbonatites are mainly coarse to medium-grained massive rocks, mostly composed of calcite, ankerite, fluorite, synchysite, quartz, mica, dolomite and pyrite. Rare earths are mainly bound to synchysite and rarely parisite, which are finely dispersed or form small nests of tiny crystals (average grain size 0.3 mm). Various sulphides (Fe, Pb, Zn, Cu, Mo, and Mn) occur as accessories.

The initial calculated resources in different categories according to Sodbaatar (2008) are

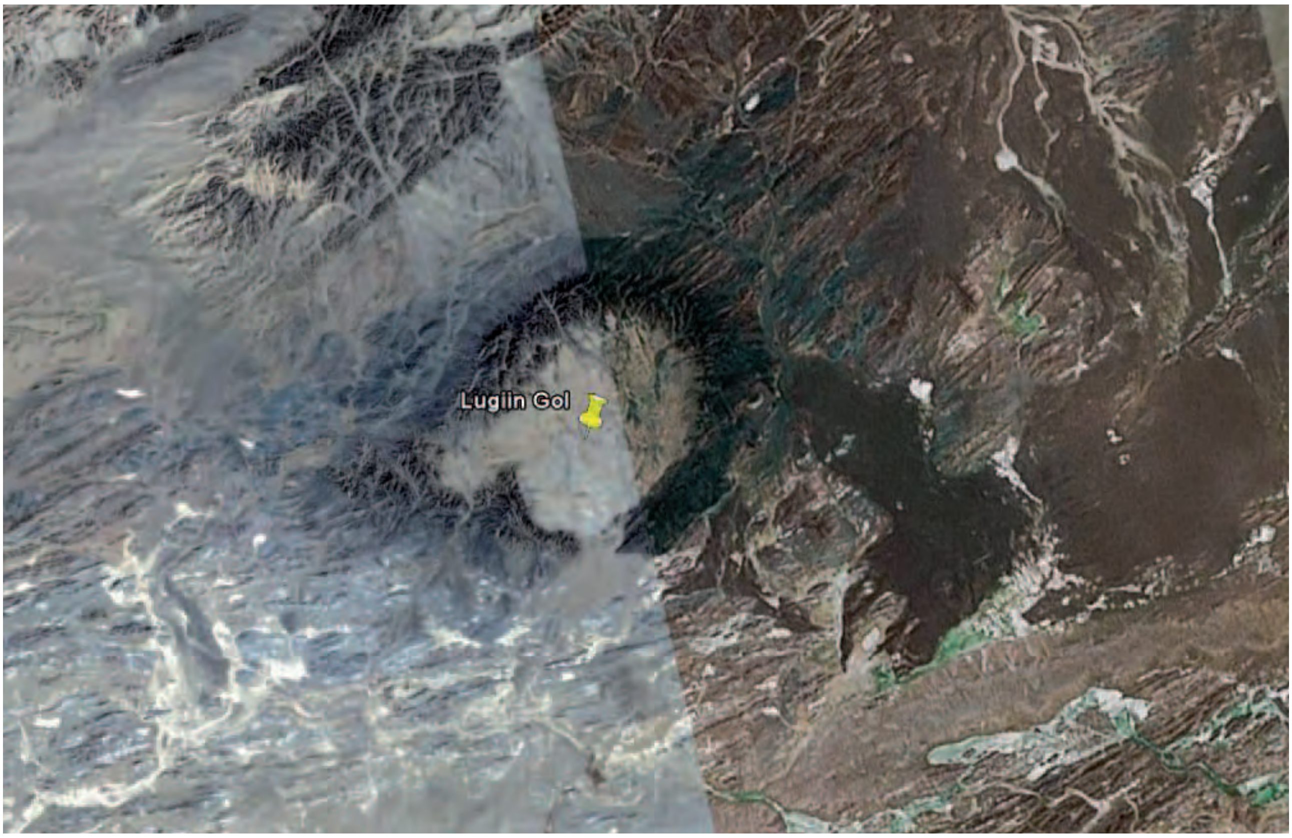

Figure 106: Partly high definition satellite image of the Lugiin Gol massif in southern Dornogovi Aimag (High definition satellite image as of 11 October 2007, Altitude 16.14 km, Photo courtesy of Google Earth).

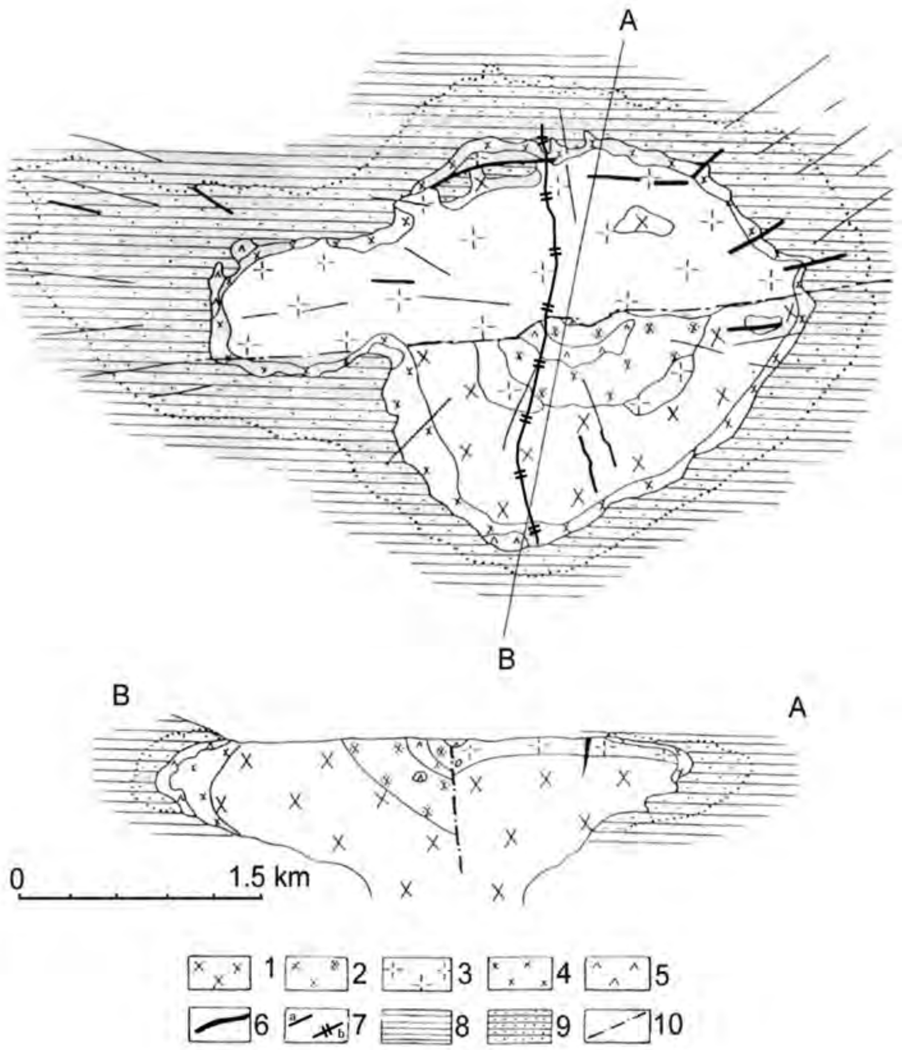

Figure 107: Geological map of the Lugiin Gol complex, modified after Batbold (1997)
1: Unaltered nepheline syenites; 2: Pseudoleucitic syenites; 3: Autometasomatic altered syenites;
4: Contact syenites; 5: Melanomonzonites and ijolites; 6 : Carbonatite veins;
7: Vein magmatic rocks (a) and alkali granite porphyry dike (b); 8: Upper Paleozoic schists;
9: Contact hornfels; 10: Faults

as follows (compare Table 62):

- 102,619 tonnes of ore grading 3.65 % REO on average, i.e. containing 3,744 tonnes of REO (category C1)
- 333,744 tonnes of ore grading 2.63 % REO on average, i.e. containing 8,761 tonnes of REO (category C2)
- 172,244 tonnes of ore grading 2.2 % REO on average, i.e. containing 3,787 tonnes of REO (category P1)
- 244,721 tonnes of ore containing 7,663 tonnes of REO (category P2).

The category C1+C2 resources and grades of other commodities found at Lugiin Gol are:

- 60,100 tonnes of oxidised ore grading 0.06 % ThO_2, 0.23 % SrO, 0.14 % BaO, and 0.87 % MnO, as well as
- 346,200 tonnes of primary ore grading 0.17 % ThO_2, 4.77 % SrO, 0.10 % BaO, and 3.46 % MnO.

Table 62: Average rare earth oxide distribution and resources (categories C1+C2) of total and selected rare earth oxides (REO) in the Lugiin Gol rare earth deposit, after BATBOLD (1997).

	Total REO		Ce_2O_3	La_2O_3	Nd_2O_3	Pr_6O_{11}	Sm_2O_3	Eu_2O_3	Gd_2O_3	Rest of Y-group
Average composition	3.20 %		49.5 %	32.4 %	9.8 %	5.1 %	0.9 %	0.40 %	0.20 %	1.7 %
Ore body #		Resources (C1 + category C2) (in t)								
I	4.17 %	1,140	564	370	112	58	9.8	4.6	2.4	19.1
II	2.69 %	Not available								
III+IIIa	2.06 %	1,215	600	394	120	62	10.4	4.9	2.6	20.3
IV	2.16 %	1,030	510	334	101	53	8.9	4.1	2.2	17.2
V	4.47 %	186	92	60	18	9.6	1.6	0.7	0.4	3.1
VI	4.30 %	4,110	2,035	1,333	404	210	35	16	8.6	69
VII	4.30 %									
VIII+VIIIa	2.71 %	2,585	1,280	838	254	132	22.2	10.3	5.4	43.2
IX+IXa	4.26 %	78	39	25	7.7	4	0.67	0.3	0.16	1.3
X	6.59 %	134	66	43	13	7	1.1	0.53	0.3	2.2
XI	1.50 %	253	125	82	25	13	2.2	1	0.53	4.2
XII	3.21 %	226	112	73	22	12	1.9	0.9	0.5	3.8
XIII	3.23 %									
XIV	1.01 %									
XV	5.07 %	203	100	66	20	10	1.7	0.8	0.4	3.4
XVI	1.82 %	299	148	97	29	15	2.6	1.2	0.6	4.9
XVII	4.11 %	Not available								
XVIII+XVIIIa	3.08 %	897	444	291	88	46	7.7	3.6	1.9	15
XIX	3.35 %	150	747	49	15	7.6	1.3	0.6	0.3	2.4
XX	2.23 %									
XXI	3.70 %									
Total	3.20 %	12,505	6,191	4,055	1,229	639	108	50	26	209

However, analogous to Mushgai Khudag, none of these commodities can be mined economically as the grades are much too low.

It should be mentioned that crystals of blue to dark blue non-gem quality sapphire (up to 0.8-1 cm in diameter), black garnet (up to 2.5 cm in diameter), zircon, pyrite (up to 5-6 cm in diameter), magnetite (up to 20 cm in diameter), leucite (up to 25 cm in diameter), and iridescent feldspar were reported from the Lugiin Gol nepheline syenite complex (ANONYMOUS 2002). However, apparently all of those minerals are extremely rare.

Khotgor

The recently (2005-2009) explored Khotgor rare earth deposit lies 68 km north-east of Dalandzadgad town in Khankhongor Soum of Umnugovi Aimag. The rare-earth bearing carbonatite bodies at Khotgor are of Upper Jurassic age, are related to nepheline syenites, have a tube-like form, and are made up of apatite, phlogopite, magnetite, hematite, fluorite, and celestite.

Very similar to Mushgai Khudag, two different types of apatite ore can be differentiated:
- Magnetite-apatite ore
- Fluorite-celestite-magnetite-apatite ore

which both come in veins and breccious form.

Individual REO bearing ore bodies are 1-30 cm thick and can be followed over 10-150 m along strike. The average composition of the REO ore is:

Ce_2O_3	La_2O_3	Pr_2O_3	Nd_2O_3
48.64 %	24.95 %	4.65 %	14.78 %
Sm_2O_3	Eu_2O_3	Gd_2O_3	Tb_2O_3
1.78 %	0.52 %	1.13 %	0.13 %
Dy_2O_3	Ho_2O_3	Er_2O_3	Tm_2O_3
0.44 %	0.07 %	0.17 %	0.02 %
Yb_2O_3	Lu_2O_3	Y_2O_3	
0.14 %	0.02 %	2.56 %	

According to the exploration report submitted to MRAM, the calculated reserves and resources in different categories applying a cut-off grade of 1 % REO are as follows:

- 24,779,890 tonnes of primary ore grading 1.26 % REO on average, i.e. containing 312,230 tonnes of REO (category B)
- 2,083,470 tonnes of oxidised ore grading 1.27 % REO on average, i.e. containing 26,460 tonnes of REO (category B)
- 12,452,860 tonnes of primary ore grading 1.15 % REO on average, i.e. containing 143,210 tonnes of REO (category C)
- 434,870 tonnes of oxidised ore grading 1.11 % REO on average, i.e. containing 4,830 tonnes of REO (category C)

Thus total reserves and resources in categories B+C are 39,751,090 tonnes of ore grading 1.22 % REO on average, i.e. containing 486,720 tonnes of REO.
Applying a lower cut-off grade of about 0.75 % REO, the total reserves and resources (B+C) rise to 96,606,140 tonnes of ore grading 0.76 % REO on average, i.e. containing 726,970 tonnes of REO.
Additionally, there are prognosed resources of 11,507,630 tonnes of low-grade ore grading 0.41 % REO, i.e. containing 47,180 tonnes of REO.

EVALUATION

For reasons of comparison and to allow evaluation, a grade-tonnage diagram of known worldwide rare earth deposits was prepared at BGR showing key data on the Mongolian deposits.

Khalzan Burged
Results of analyses of samples taken during a field trip by BGR and MRAM geologists are in the range of the analytical results from previous studies. All analyses clearly show that the mineralisation at Khalzan Burged is rather low-grade (cf. Table 63). The total rare earth element (REE) content only reaches 0.65 %, with average rare earth oxide (REO) grades and total REO contents calculated as about 0.60 % and 300,000 tonnes. In several samples yttrium was enriched, which may be of interest to investors. In contrast to former campaigns, zirconium (including hafnium) was shown to be mainly concentrated at elevations below 1,850 m. Grades for all other elements of interest, except for tantalum and niobium at and above 1,850 m elevation, are well below the internationally accepted cut-off grades (cf. Tantalum and Niobium). The high radioactivity due to the elevated thorium content will pose problems during mining. Therefore, Khalzan Burged is mainly a marginal economic tantalum-niobium deposit, which may not be suitable for economic mining (cf. Table 63). Mineral processing might also be a major problem because it is well known that all the rare earths/rare metals in Khalzan Burged are found in various minerals which are heavily intergrown and sometimes of very small size.

Table 63: Recalculation of volume, tonnage and metal content of ore from different elevations from Khalzan Burged, after SCHWARZ (pers. comm. 2009).

Elevation	Volume [m³]	Tonnes (@ 2.5 t/m³)	REE	Ta	Nb
1825-1875 m	12,407,139	31,017,848	0.44 % 136,479 t	247 ppm 7,661 t	0.33 % 102,359 t
1875-1925 m	6,144,847	15,362,118	0.65 % 99,854 t	254 ppm 3,902 t	0.34 % 52,231 t
1925-1962 m	1,112,765	2,781,913	0.37 % 10,293 t	110 ppm 306 t	0.23 % 6,398 t
Total	19,644,751	49,161,879	246,626 t	11,869 t	160,988 t

Mushgai Khudag

During the most recent exploration campaign at Mushgai Khudag from 2007 to 2009 four different ore zones could be delineated:

- Tumurtui ore zone
- Khuren Khad ore zone
- Main ore zone
- a newly discovered High grade ore zone.

The updated reserves and resources of the Mushgai Khudag deposit were calculated by kriging (cf. Table 64).

The average REO grade in Mushgai Khudag is 1.41 % and even reaches 6.15 % on average in the newly discovered High grade ore zone. The total REO content is 231,808 tonnes. On an international scale this makes Mushgai Khudag a rather size deposit which currently may not be economically mineable. Additionally, Geiger counter readings in the field partly reveal strongly evevated radioactivity (U+Th), which will pose severe problems during mining.

Table 64: Reserves and resources of the Mushgai Khudag rare earth deposit, after exploration report submitted to MRAM in 2010.

Category	Volume [m³]	Tonnes (@ 2.6 t/m³)	Average REO [%]	REO [t]
Main ore zone				
B	3,997,500	10,393,500	1.02	106,014
C	746,368	1,940,557	0.82	15,912
B+C	4,743,868	12,334,057	0.99	121,926
Khuren Khad ore zone				
B	1,296,812	4,020,117	2.20	88,443
Tumurtei ore zone				
C	414,136	1,283,822	1.67	21,440
TOTAL				
B	5,294,312	14,413,617	1.35	194,456
C	1,160,504	2,017,021	1.85	37,352
B+C	6,454,816	16,430,638	1.41	231,808

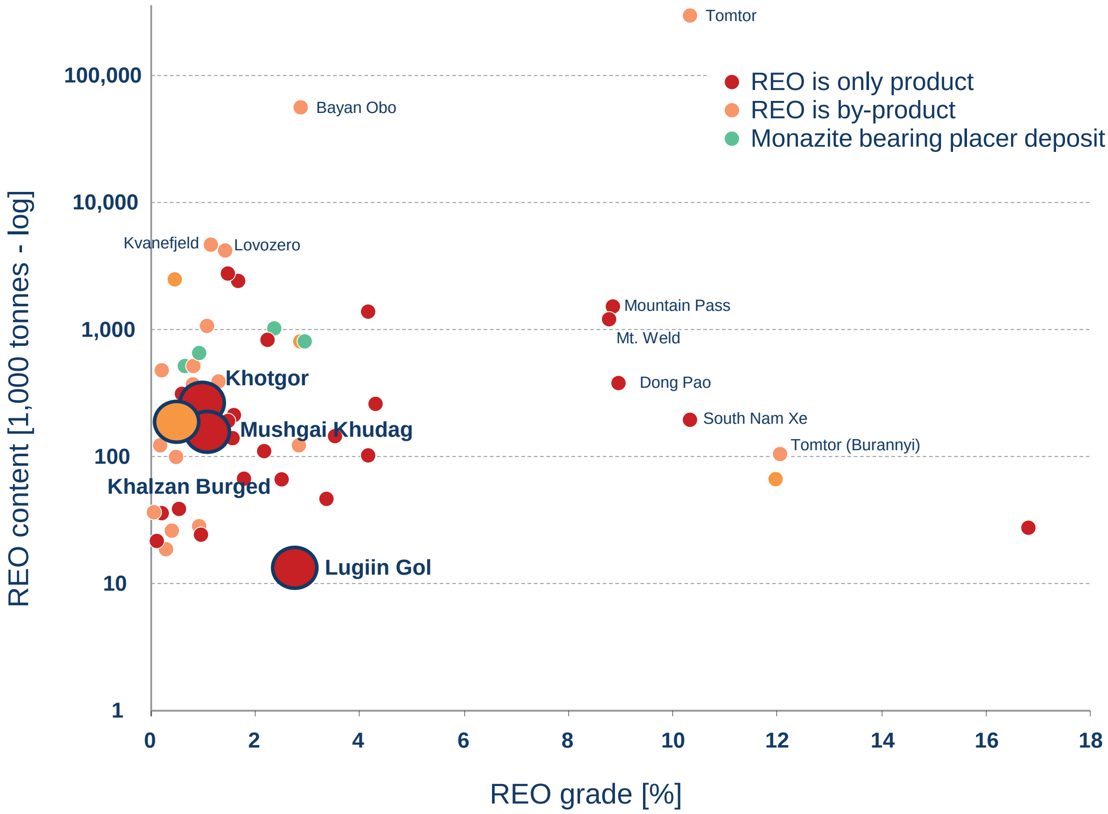

Figure 108: Grade-tonnage diagram of world-wide rare earth projects and mines with emphasis on Mongolian deposits.

Figure 109: Numerous cores from the Lugiin Gol rare earth deposit laid out during the Lugiin Gol exploration campaign September 2010.

Lugiin Gol

The Lugiin Gol complex is built up of hundreds of mineralised veins and dikes, of which 21 have been identified to be of potential economic use. However, their average thickness is just 35 cm. According to the findings of the most recent exploration campaign between 2005 and 2009, the total resources amount to 505,822 tonnes of ore grading 2.67 % REO on average, i.e. only containing 13,505 tonnes of REO.

Khotgor

Similar to the Mushgai Khudag deposit, the average REO grade in the Khotgor rare earth deposit is 1.22 %. The total REO content is also very similar with 486,720 calculated tonnes of REO. While this makes Khotgor the biggest REO deposit in Mongolia, on an international scale it is still only a small to medium size deposit which currently also may not be economically mineable.

Summary

While Mongolia is rich in rare earth occurrences of very small to small sizes and low grades, only three deposits, i.e. Khalzan Burged, Mushgai Khudag, and Khotgor are of potential commercial interest. However, while their average REO grades look promising at an international scale, all of them are of rather small size. Taking into consideration the huge investment costs in mining, and above all the separation of rare earths of 0.5 to >1 billion USD, individually they do not constitute economically mineable rare earth deposits at present.

However, both the Mushgai Khudag and Khotgor deposits could serve as raw material sources for the production of REO-enriched concentrates by flotation, with the concentrates later trucked to China for further processing. As an alternative, concentrates **from both** sites (Mushgai Khudag **and** Khotgor, i.e. 720,000 tonnes of REO content in total) could be processed at a central location within Umnugovi Aimag.

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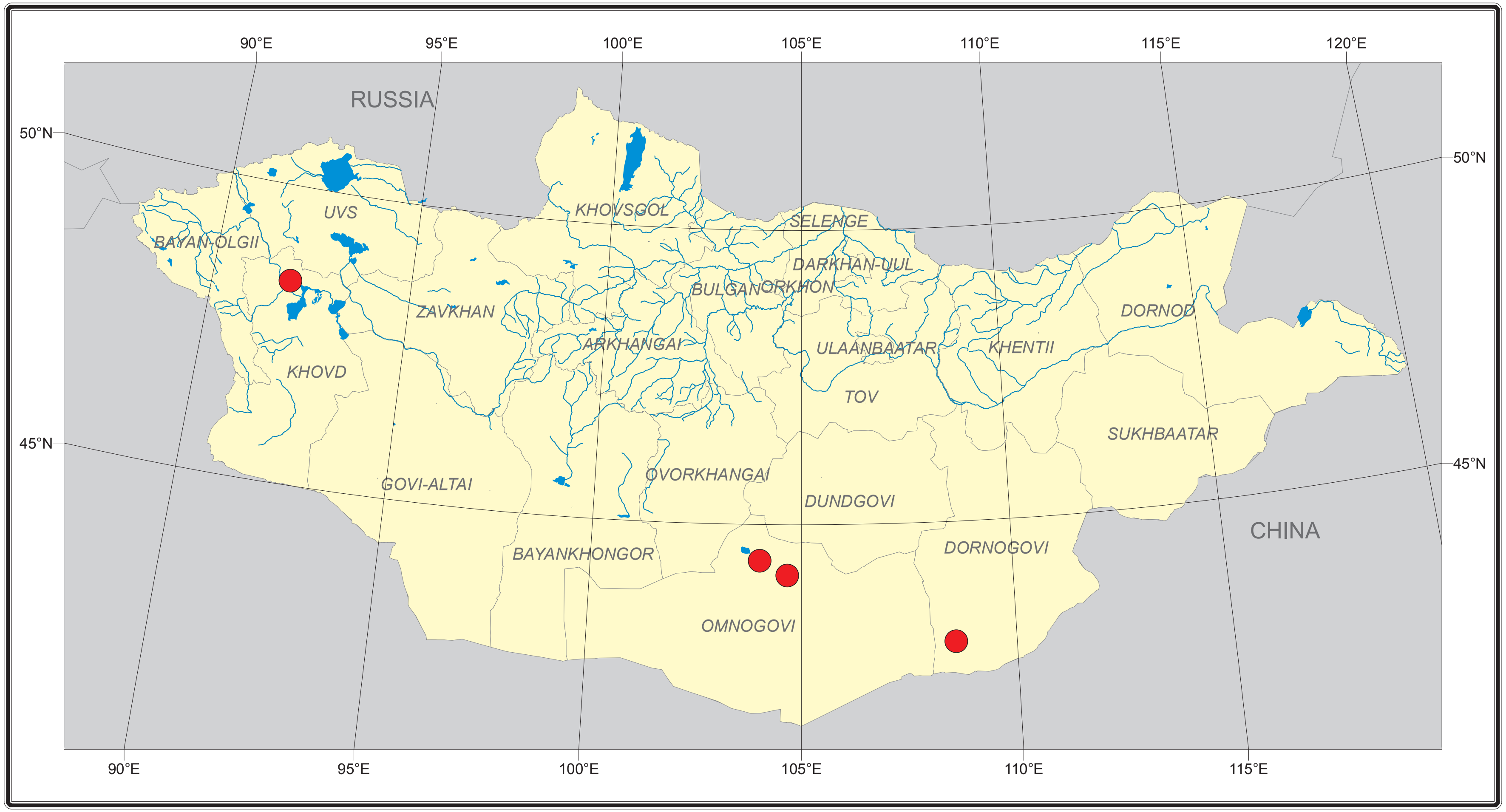
Deposits and important occurrences of Rare Earths in Mongolia



Federal Institute of Geosciences and Natural Ressources

Legend

Rare Earths

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

TANTALUM AND NIOBIUM

GENERAL INFORMATION AND USES

Important tantalum-niobium minerals are tantalite, $(Fe,Mn)Ta_2O_6$, the Ta-rich final member, and columbite or niobite, $(Fe,Mn)Nb_2O_6$, the Nb-rich final member of the solid solution columbite-tantalite series. Because these final members do not occur in a chemically pure state in nature, mining geologists commonly use the collective terms columbite-tantalite or columbotantalite or the abbreviation "coltan". Tantalum also occurs in pyrochlore, $(Ca,Na)_2(Nb,Ta)_2O_6(O,OH,F)$, the most important niobium mineral.

Columbite-tantalite is enriched in mineable amounts in granites and pegmatites. Coltan occurs – mostly associated with cassiterite and/or monazite – in placers currently being mined in Nigeria and the DR Congo, China (Provinces of Guangdong and Hunan), Western Australia, Malaysia, Thailand and other countries in the tin belt of South-Eastern Asia. The grades of coltan concentrates normally range between 30-45 % Ta_2O_5 and 5-45 % Nb_2O_5. Important secondary raw materials for the production of tantalum and niobium are cassiterite smelting slag. Typically the slags contain 2-9 % Ta_2O_5, 2-15 % Nb_2O_5 and also 0.5-2 % Sn.

Pyrochlore occurs as an accessory mineral in nearly all magmatic rocks. In carbonatites and alkali rocks, pyrochlore is frequently enriched and is then usually mineable.

Applications for niobium are:
- metal alloy ores for making pipes, car bodies, and ships, for tool steel and railroad tracks,
- Nb-oxide (high index of refraction, high dielectric constant and transmitted light optimisation) for camera lenses, computer screen coatings and ceramic capacitors (substitute for tantalum),
- Nb-carbide for tool and cutting steels as well as welding filler material,
- Nb-powder for conductors in electronic circuits,
- metal in the chemical systems industry, defence engineering, jewelry industry and minting industry
- alloy additive with Ti and Sn for superconducting magnetic coils,
- alloy additive with Zr for sodium discharge lamps and chemical plant engineering,
- high-purity Fe-Nb and Ni-Nb for the manufacture of super alloys in turbine manufacture and furnace construction.

Tantalum is used as:
- powder for very small capacitors with high capacity in micro-electronics, e.g. for hearing aids, pacemakers, airbags, ignition control and engine control units, GPS, ABS, laptops, cell phones, video cameras, playstations etc.,
- metal alloy ores and accessory for refractory and high-strength alloys, mainly with W,
- Ta-carbide for tool and cutting steels,
- Ta-oxide (high index of refraction, good abrasion resistance) for camera lenses and ink jet printers as well as with Y and P in x-ray films for reducing the duration of exposure and image quality optimisation,
- metal in the chemical systems industry, in gas turbine engineering, in vacuum furnace construction and increasingly for medical implants.

Niobium and tantalum can be substituted in part by each other, otherwise very difficult, and then only with a deterioration in quality.

RELEVANT DEPOSITS IN MONGOLIA

Tantalum-niobium mineralisation has been reported from many areas in Mongolia, but normally the grades and tonnages are very low.

The main tantalum-niobium occurrence in Mongolia is **Khalzan Burged**. At Khalzan

Burged, tantalum and niobium mineralisation occurs within a mountain range of alkaline plutonic rocks (cf. chapter Rare Earths). Pyrochlore and columbite are disseminated in stock-like bodies of alkaline granite. The higher grades were found at topographic elevations above 1,800 m. Above 1,900 m Ta_2O_5 is said to reach 0.254 %. Between 1,900 to 1,800 m also all the rocks are mineralised but the grade is lower. Between 1,800 to 1,700 m the grades are decreasing even more (Ta_2O_5 >0.05 %) with some areas of the mountain being not mineralised at all. Below 1,700 m the mineralisation is patchy. BGR-samples from the top to the 1,800 m level grade between 0.2 % and 0.3 % Nb and between 0.015 and 0.025 % Ta. According to the most recent calculations by Schwarz (pers. comm., 2009) the total resources are about 160,000 t Nb and 11,000 t Ta.

The **Shar Tolgoi** occurrence lies about 130 km from Khalzan Burged. Roskill (2009) reported estimated resources of 22,500 t of Ta_2O_5 in ore grading 0.02 % Ta_2O_5. Other niobium-tantalum bearing alkaline intrusives are **Ulaan Tolgoi**, which is located about 120 km north of Shar Tolgoi, and **Tsahir**, about 60 km NNW of Khalzan Burged, but information is scarce (Jargalsaihan et al. 1996).

At **Khokh Del Ulaan**, lithium pegmatites have a low volume in total as well as a low tantalum content (cf. chapter Mica). Individual dikes are 1.5-15 m thick, and 20-750 m long. Li-bearing minerals are lepidolite, spodumen, and petalite. Beryl and cassiterite have been mentioned as other interesting minerals. Average ore grades are 0.006 % Ta_2O_5, resulting in net resources of 76 tonnes of Ta_2O_5. As noticed during a field trip in September 2010 cassiterite is strongly enriched in several 3-5 m large nests in two of the pegmatites extending towards the railway line. Cassiterite crystals are up to 3 cm in size and are located in surface outcrops of pegmatite and in one trench. Columbite-tantalite grains of 20-30 microns in size also occur within quartz of these nests. Artisanal mining of these zones could be a valuable source of income. The extension to depth is not yet known.

Further granite hosted, pegmatite, and metasomatic occurrences as well as geochemical anomalies of very limited potential include Altan Boom (two veins, 300 m long, <0.01 % Ta_2O_5 and 0.01 % Nb_2O_5), Tsakhir (<0.01 % Nb_2O_5), Dargia Uul (Nb and Ta geochemical anomalies, 800 m long and 150-300 m wide greisen zone, up to 0.037 % Nb), Ar Khanant (100-300 m long and 1.5-2.0 m thick pegmatite dikes, up to 0.06 % Ta and 0.07 % Nb), and Buural (300 m long and 1.0-3.0 thick metasomatic zone, 0.14 % Nb, up to 0.5 % Nb).

Two syenite hosted niobium geochemical anomalies are reported from Ondorkhangai (occurrence 64) and Khag (2 km long and 100-300 m long pyrochlore-bearing metasomatic zone). In addition, tantalum anomalies occur in dyke-shaped “ongonites” of 150-200 m length (Fetherston, 2004). Ongonites are topaz-bearing rhyolitic rocks enriched in lithium and fluorine which contain around 0.005 % Ta_2O_5. In places the grades may increase to 0.016 % Ta_2O_5.

Tantalite and columbite are rather rare in placer deposits and occurrences in Mongolia. The **Urt Gozgor** placer in the Janchivlan-Elstein area is 2.0-2.5 km long and about 60-300 m wide (cf chapter Tin). It has an irregularly distributed and 0.5-2.5 m thick heavy mineral bearing layer. The cassiterite grades of the placer average 286 g/m^3, in places they may reach >1,000 g/m^3. However, established reserves of 80-286 t Sn (220 t Sn) are too small to allow commercial mining. Tantalum grades at Urt Gozgor average 25 g/m^3 indicating 34.4 t Ta reserves, which is too low even for small scale mining.

REQUIREMENTS AND EVALUATION

The following cut-off grades apply to tantalite deposits:

- hard rock: >0.008 % Ta_2O_5 (typical : 0.013-0.015 (0.02) % Ta_2O_5)
- placers: >0.003 % Ta_2O_5 (typical 0.015 – 0.02 (0.05) % Ta_2O_5 = 150-200 (500) g Ta_2O_5/tonne)
- placers: >300 g cassiterite +columbite-tantalite /m^3 sediment

Specifications for commercial concentrates of columbite-tantalite are as follows:

- >60 % (Ta_2O_5 + Nb_2O_5) (typical: 15-65 % Ta_2O_5, 5-45 % Nb_2O_5)
- <6 % SnO_2
- <6 % TiO_2
- <8 % MnO
- <5 % FeO
- <0.5 % ThO_2 + U_3O_8
- <1 % W
- <0.20 % P
- <50 ppm Sb

The reference values for the size classification of Ta-Nb deposits are listed in Table 65.

According to the international requirements and classifications given above, only Khalzan Burged, and possibly Shar Tolgoi, are of economic interest for tantalum and niobium. These occurrences should be further studied and economically evaluated in detail. All other occurrences, based on the information currently available, do not have any economic potential.

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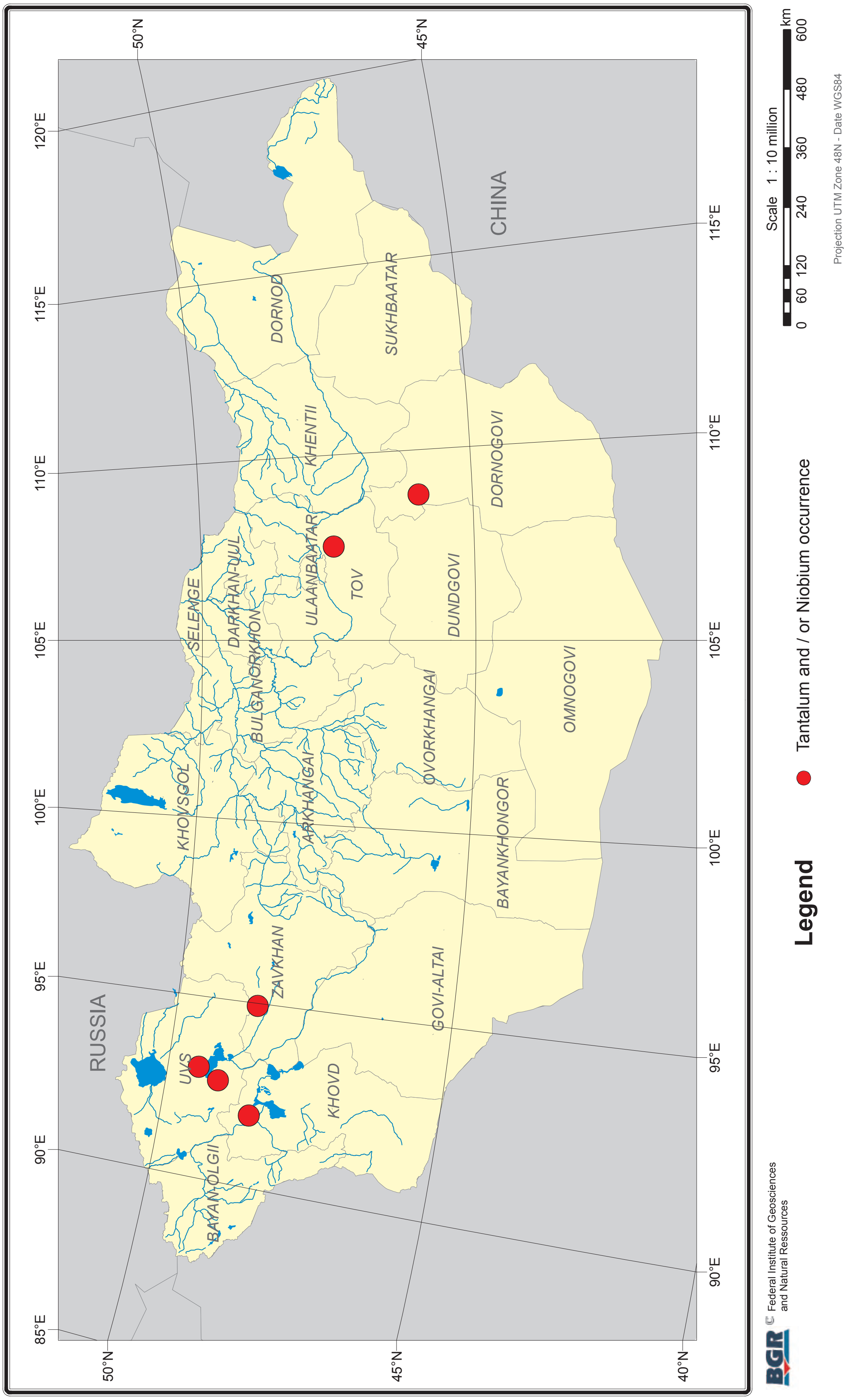
Table 65: Reference values (in tonnes) for the evaluation of the size of Ta-Nb deposits according to the National Committee of Minerals Resources of China (ZHU XUN 2002).

	Niobium deposits		Tantalum deposits	
	hard rock Nb_2O_5 content	placer mineral content	hard rock Ta_2O_5 content	placer mineral content
small	<10,000	<500	<500	<100
medium	10,000 – 100,000	500-2,000	500-1,000	100-500
large	>100,000	>2,000	>1,000	>500

Important occurrences of Tantalum and Niobium in Mongolia



TIN

GENERAL INFORMATION AND USES

Tin is a lithophile element which is enriched in the residual melt of acid magmas. Many types of granites thus contain tin in the form of the mineral cassiterite (SnO_2), which is the main tin bearing mineral of economic importance.

Cassiterite is mainly enriched within "tin granites", which contain non-economic background grades of approx. 0.0015 – 0.0050 % Sn/tonne. Cassiterite also occurs as "mine tin":

- intra magmatic: in domes of granite intrusions, in feldspar topaz granites, in rhyolites and titanomagnetite deposits. The more acidic the rock, the higher its Sn-content.
- pegmatitic: Besides cassiterite, Sn-W pegmatites contain the minerals wolframite, columbite, tantalite and lepidolite.
- pneumatolytic: "greisenisation" of granites and their adjacent rock. Contact metasomatic cassiterite mineralisations are also known. One of the largest tin deposits in the world developed metasomatically – in dolomites.
- hydrothermally: Hydrothermal veins are mineable in numerous cassiterite deposits. The individual deposits are mostly small (<4.5 tonnes of ore), but high-grade (0.7-2.3 % Sn).

Because cassiterite is very resistant to all weathering influences, is it a typical placer mineral. "Placer tin" was produced a long time before "mine tin" and traded long distances. The most important source for cassiterite is the South-East Asian tin belt (nearly 3,000 km long from Moulmein District in Northern Burma via Thailand and Malaysia to the Indonesian island of Belitung). There, the tin placers are of colluvial, eluvial (average thickness 1-2 m), and alluvial origin. Most of the alluvial placers are onshore (2/3), as well as offshore (1/3) in Western Malaysia, Thailand and Indonesia. Mining is by gravel pump "dry mining" using high-pressure water jets, floating dredge (ladder dredger or suction dredger) and quarrying, as well as secondary underground mining and artisanal mining. The estimated resources are 6 million tonnes of Sn – more than the total resources of the rest of the world.

Tin itself is a silvery white metal, very inert because of the oxidation layer, and thus singularly suitable for protection against corrosion (tin coating of sheet metal = tinplate). Tin is also used for:

- alloys: bronze, bearing metals, type metal, German silver,
- tin casting (tin figures) consisting of 60-70 % Sn and 30 – 40 % Pb,
- soldering tin,
- opaque white glazes,
- organotin compounds (tributyltin) as toxic protective paints, e. g. in shipbuilding,
- catalytic converters,
- as a stabilizer in PVC,
- together with Ca for strengthening the Pb-electrodes in batteries,
- window pane production by casting on liquid tin,
- tin halogenides as stabilizers in perfumes and soap ($SnCl_4$) or as a main component in toothpaste (SnF_2),

RELEVANT DEPOSITS IN MONGOLIA

Commercial size cassiterite deposits and occurrences in Mongolia occur as small size eluvial and alluvial placer deposits (<10,000 tonnes Sn). The major mining area in Mongolia was the Bayanmod district (Modot Valley, Khentii Aimag) but most of the cassiterite has already been mined out in the 1950´s.

Today, cassiterite is being mined on a small scale in the upper Modot Valley using excavators and jigs. At the Khujkhaan placer near Tsenhermandel, cassiterite is mined together with wolframite on a small scale. Other areas such as the Janchivlan and Elstein/East Elstein districts, which were extensively explored in the past, have not been mined and have very limited potential for small scale mining.

Cassiterite also occurs in pneumatolytic-hydrothermal vein type deposits in Mongolia, but in general the deposits are very small (<< 500 tonnes). In the past, one skarn related cassiterite deposit has been identified south-west of Choir (Ortsog Ovoo), but so far all metallurgical tests have failed to confirm economic recovery.

Stockwork and greisen type tungsten-tin bearing granites occur in many regions of Mongolia and have been studied for scientific purposes. Generally, they are of very low grade and not economically mineable. However, improvements in mining technology and high prices for wolframite, could make some deposits with low grade tungsten contents and high tonnages of commercial interest for open pit mining (e.g. at Ondor Tsagaan, Yeguzer area). If this proves to be the case, cassiterite could potentially be recovered in small quantities as a byproduct (cf. Tungsten chapter for further information).

Geological Information Center (2003) lists around 100 cassiterite deposits and occurrences in total, some of which are mined out and others too small or too low grade for commercial mining (e.g. deposits and occurrences <500 tonnes Sn).

A number of important publications devoted to tin and tungsten deposits, and mineralisation in Mongolia, were published in the past. Among these are Kovalenko (1995), Jargalsaihan et al. (1996) and Dandar (2009). A selection of publications and reports is listed at the end of this chapter.

JANCHIVLAN-ELSTEIN AREA

About 50 km SE of Ulaanbaatar, still in Tuv Aimag, lies the tin-tungsten province of Janchivlan-Elstein, which has been known for many decades. About 20 placers were explored in the past which carry between 100-600 g cassiterite/m^3, and contain about 6,000 t tin in total (B+C1+C2). Major exploration activities including drilling, trenching and sampling took place up to 1984.

The placers are located in the South Khentii region within the Khentii Northern Herlen metallogenic belt. The colluvial to alluvial placers occur in valleys with seasonal river flow. Cassiterite and wolframite bearing veins and granite greisen zones in the area, possibly also some pegmatites, are described as being the source of the placers.

Single placers extend over max. 5-10 km length, they have a width of a few tens of metres up to 500 m, and a thickness of 0.5-15 m. In the 1970s and 1980s, Russian and Mongolian expeditions explored and drilled the placers extensively. However, most of the placers are too small for commercial mining. All economic calculations for marginal reserves were based on a minimum cut-off grade for cassiterite of 150 g/m^3, reserve calculations were done using a grade of 380 g cassiterite/m^3.

Janchivlan

Six placers in the Janchivlan area were mapped and explored in the 1930s, 1950-1954, 1969-1971 and 1978-1981. The placers mainly contain cassiterite and accessory wolframite, monazite, topaz, fluorite and zircon. The overburden to ore ratio of most of the placers is around 1:1 and the bulk of the sediment is ice free during the summer season. The overburden cover is 1.3 m to 2.2 m thick, the ore layer 1.3 m to 2.0 m thick. The cassiterite grades of the ore layers vary between 403 g/m^3 and 589 g/m^3. The total C1+C2 category reserves estimated during exploration between 1974 and 1981 are 3.77 million m³ of ore containing 904 tonnes of Sn.

Elstein and East Elstein

The Elstein placer is the biggest placer in the Janchivlan-Elstein area. It consists of an upper and a lower tin-tungsten bearing layer. Both layers vary strongly in thickness and width. Indications about the depth of the placers with respect to the overburden were not found.
A total of 26,000 m of sediment drilling was done in the area. The results confirm cassiterite as the main heavy mineral, associated with wolframite, hematite, bismuthinite and arsenopyrite. According to old spectrographic analyses the cassiterite content of the placers is around 200-350 g/m³, other sources report grades between 500-600 g/m³. The overburden to ore ratio however is between 2.7 and 4.1. Based on placer sand reserves of 13 million m³, the placers contain estimated 3,000-3,500 tonnes of Sn (C1+C2).

Two placers explored in the area around East Elstein (Tuv Aimag; 47° 41' 30" N , 107° 23' 46" E; 1.400 m a msl) have a length of 3,500 m, a width of max. 170 m, and an average thickness of 1.14 m. The cassiterite grade of the sediment averages 473 g/m³ and a recovery of 80-82 % was achieved during testing. The estimated reserves are 500-700 t Sn (including Bayan Davaa), which is small for industrial mining. The total reserves of 4,288 t Sn are recorded for the Elstein and East Elstein placers. Some test mining was probably carried out between 1994 and 1995.

During a field trip in 2008, old exploration activities in the area were confirmed (cf. Figure 110). The exploration pits along two 5 km long traverses are about 0.5-1.0 m³ in volume, and about 5 m apart. The traverses are 2 km apart. The distance between traverses is around 200-400 m. Aeolian and other unconsolidated sediments cover the placers (thickness of

Figure 110: Old exploration pits crossing cassiterite placers in the area of East Elstein.

Table 66: Results of Russian and Mongolian expeditions in the area of Elstein, East Elstein and Urt Gozgor.

	Elstein		**East Elstein**	**Urt Gozgor**
	Upper Layer	Lower Layer		
Length [m]	7,850	5,980	3,500	2,000
Width [m]	60-600	40-400	20-170	60-300
Thickness [m]	0.5-15	0.5-10	0.5-1.66	0.5-2.5
Cassiterite grade [g/m^3]	500-600		253-782	268
Reserves B [m^3 sand]	2,200,000			
Reserves C1 [m^3 sand]	10,859,000			
Reserves C1+C2 [m^3 sand]			2,010,000	
Reserves B+C1+C2 cassiterite [t]	3,000-3,500		647	83-286 (220)
Col./Tantalite grade [g/m^3]				25, max. 50
Reserves Col./tantalite [t]				34.4

overburden unknown). Cassiterite and sulphide bearing granite-greisen bodies in the vicinity could be the source of the placers.

Urt Gozgor

The Urt Gozgor placer in the Janchivlan-Elstein area is 2.0-2.5 km long and about 60-300 m wide. Its heavy mineral bearing layer is irregularly distributed and is 0.5-2.5 m thick. The overburden to ore ratio is 1:3. The placer was discovered by drilling 18 boreholes ten m deep along six traverses. Another 64 sample pits along these traverses had a depth of 3.3 m. The cassiterite grades of the placer average 286 g/m^3, in places they may reach >1,000 g/m^3. However, the established reserves of 80-286 t Sn (220 t Sn) are too small to support commercial mining.

According to archive reports, the heavy mineral concentrate which was produced contained cassiterite, wolframite, columbite/tantalite, scheelite, ilmenite, zircon and monazite. Columbite/tantalite is rather rare in the Janchivlan-Elstein placers. The grades at Urt Gozgor average 25 g/m^3 and indicate 34.4 t Ta reserves, which is too low for mining (cf. chapter on Tantalum/Niobium).

Avdarant

The Avdarant group of placers in the Janchivlan-Elstein area consists of six distinct placers. The placers occur near the surface and are 1.8-4.5 km long, about 10-450 m wide and 1-2 m thick. Geological mapping and exploration work was carried out in the 1930s, 1951-1954, 1969-1971 and 1978-1981.

The cassiterite grades of the placer average 300-550 g/m^3. C1+C2 reserves total 1,8 million m^3 of ore containing 637 tonnes of Sn, with the largest placer containing 200 tonnes of Sn. Because of their small size, the placers are not recommended for commercial mining.

According to archive reports, one area with 30 and another with 15 cassiterite-bearing quartz-feldspar veins was found in a nearby granite massif. The veins are 20-350 m long, 0.1-1.5 m thick and contain up to 1.72 % Sn. However, the reported average grades are only around 0.08 % Sn.

CASSITERITE PLACERS AT MODOTIIN

In the Bayanmod area near Tsenhermandal, about thirteen cassiterite placer deposits are known. The placers are located within the Upper Triassic to Lower Jurassic Modot biotite-granite intrusive suite. The thickness of the fluvial sediment varies between 5 m and 50 m. Dumps and relicts of the former Russian-Mon-

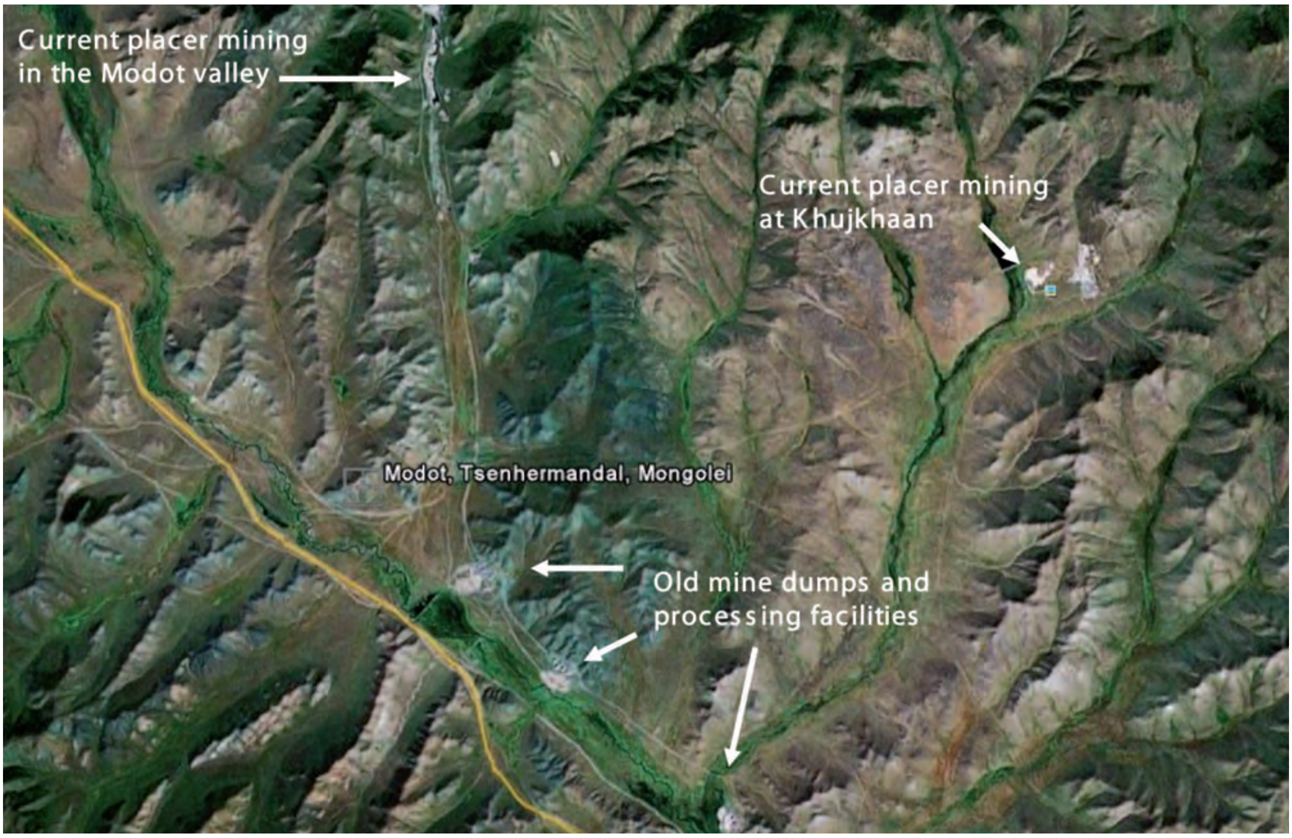


Figure 111: Satellite image with location of current placer mine sites in the Modotiin valley and at Khujkhaan, and old mine dumps and processing facilities from the Russian-Mongolian era near Tsenhermandal. Photo courtesy of GOOGLE EARTH.

golian tin processing facility for placer material from the Moditiin valley (Khentii Aimag; 47° 43' 30.1" N , 109° 04' 05.5" E; 1.461 m a msl) can still be seen from the main Ulaanbaatar – Jargaltkhaan road. The dumps as well as current placer mining activities are also visible on satellite images (Figure 111). Old mine houses are maintained in the centre of Tsenhermandal (Figure 112).

Figure 112: Old mining centre of Tsenhermandal.

Comprehensive exploration work in the area was carried out during the Mongolian-Russian Dornot-Metal Expedition (1947-1950) and the Soviet-Mongolian Metal Expedition (1950-1955), the Mongolian "Modot" expedition (1969-1975) and the Mongolian-Czechoslovakian Intergeo-Expedition (1985-1988). In the years following World War II, prisoners of war were deployed for cassiterite placer mining.

Between 1949-1955, concentrates with 8,516 t Sn and 1,297 t WO_3 content were produced from the main Modot valley, which is about 10 km long. In the period 1973-1977, the amount fell to 108 t cassiterite concentrate containing 30 % Sn. Between 1979-1990, some 712 t Sn were produced from Bayan-

Figure 113: Old dumps near Tsenhermandel left from the beneficiation of cassiterite bearing placer sediments of the Bayanmod area and remains of a former processing facility.

mod, 19 t Sn from the 12th Valley and <5 t Sn from the Medium Valley. In 1981, MONGOLCZECHOSLOVAKMETAL started mining a lower placer horizon at Modotiin (Lower Layer) and produced a cassiterite concentrate containing 50 M.-% Sn; the total concentrate production contained 476.8 t Sn and 3.5 t WO_3. The cut-off grade for all placer deposits was 100-150 g cassiterite/m^3. The tin grade of the placers varied between 170 g/m^3 and above 700 g/m^3 (often up to 450 g/m^3), the WO_3 grades ranged from a few g/m^3 to <200 g/m^3. Losses during processing were reported to be around 8-15 % for cassiterite and 87-88 % for WO_3 (in wolframite).

Old dumps:
It seems that beneficiation in the past was not very effective especially for coarse grained cassiterite: since the rise in tin prices, artisanal miners have picked coarse cassiterite

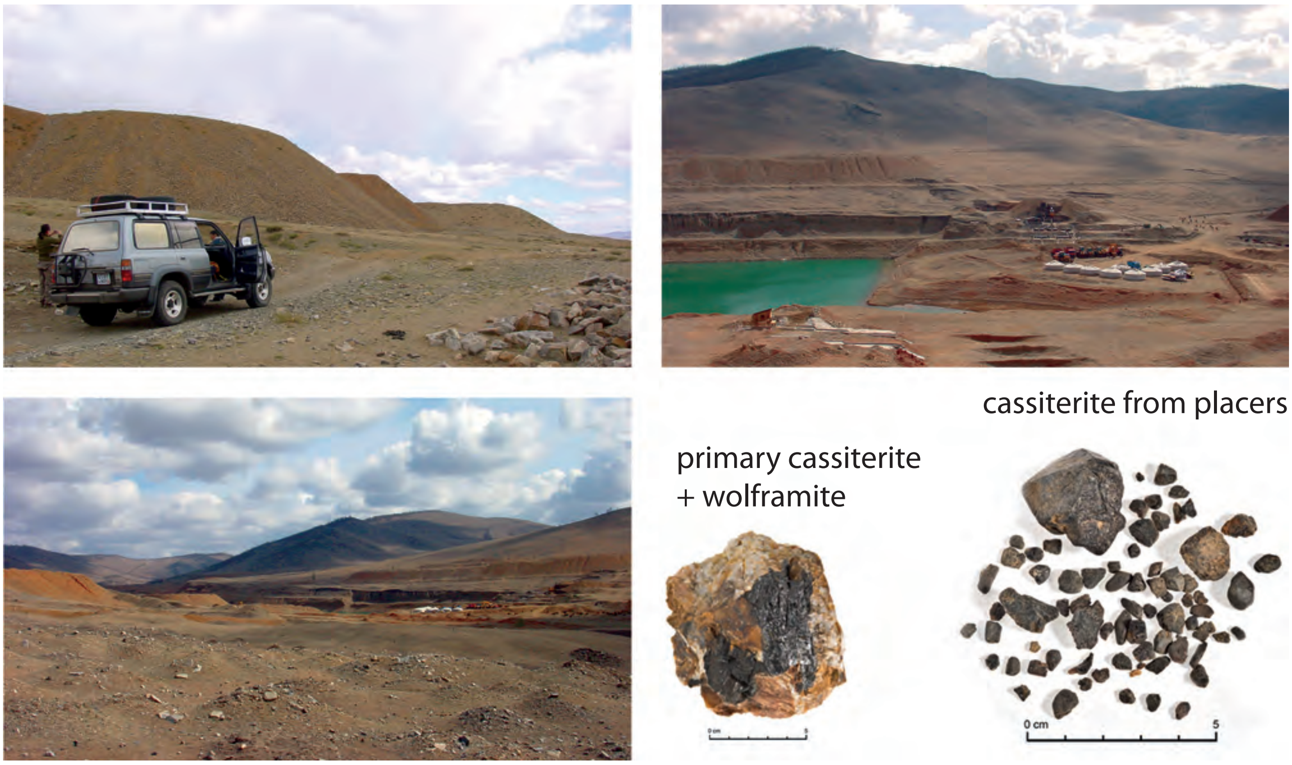


Figure 114: The Modotiin valley: Old dumps from processing facilities near Tsenhermandal (upper left), Chinese alluvial cassiterite mining in the upper Modotiin valley (upper right), remains of alluvial mining in the upper Modotiin valley (lower left), alluvial cassiterite picked from old dumps near Tsenhermandal (lower right), quartz-wolframite vein sample found in trenches along the slopes of the upper Modotiin valley.

Table 67: Chemical composition of host rock from the Upper Modotiin valley, cassiterite from dumps, and wolframite concentrate upgraded at the BGR laboratory (XRF analysis).

	Modotiin							
	Host rock						Cassi-terite	Wolf-ramite
	Dump-1	Dump-2	Dump-3	near vein	near vein	stockwork		
SiO_2	75.54	73.08	71.76	56.01	59.01	80.79	2.28	3.28
TiO_2	0.05	0.18	0.14	0.87	1.03	0.36	0.83	0.07
Al_2O_3	14.08	14.36	15.14	17.30	18.77	11.07	0.40	4.32
Fe_2O_3 total	0.71	1.46	1.14	6.55	9.23	0.93	1.46	14.47
MnO	0.02	0.03	0.02	0.39	0.12	0.01	0.17	9.02
MgO	0.35	0.25	0.30	3.09	1.59	0.53	0.16	0.12
CaO	0.46	1.66	3.87	3.60	0.34	0.19	0.21	0.35
Na_2O	3.28	3.55	2.57	0.20	0.83	1.83	0.03	<0.01
K_2O	4.24	4.15	3.32	7.00	5.87	2.61	0.08	0.04
P_2O_5	0.16	0.04	0.10	0.15	0.07	0.07	0.03	0.08
(SO_3)	0.01	0.25	0.02	0.20	0.05	0.02	<0.01	0.04
(F)	<0.05	<0.05	<0.05	1.48	0.19	0.05	<0.05	0.37
LOI	0.83	0.67	1.36	3.05	2.47	1.35	0.55	0.10
total	*99.76*	*99.74*	*99.79*	*99.89*	*99.61*	*99.83*	*6.24*	*32.27*
(As)	7 ppm	11 ppm	24 ppm	72 ppm	7 ppm	12 ppm	<6 ppm	n.a.
Ba	662 ppm	1,032 ppm	417 ppm	424 ppm	785 ppm	475 ppm	171 ppm	<12 ppm
Bi	<4 ppm	<4 ppm	9 ppm	5 ppm	<4 ppm	<4 ppm	45 ppm	n.a.
Cu	8 ppm	64 ppm	47 ppm	22 ppm	20 ppm	10 ppm	303 ppm	19 ppm
Hf	<6 ppm	7 ppm	<6 ppm	<6 ppm	14 ppm	7 ppm	98 ppm	<31 ppm
Mo	<2 ppm	<3 ppm	<3 ppm	<3 ppm	<3 ppm	<2 ppm	<11 ppm	<13 ppm
Nb	3 ppm	11 ppm	4 ppm	24 ppm	20 ppm	6 ppm	583 ppm	2,458 ppm
Pb	44 ppm	54 ppm	34 ppm	41 pppm	32 ppm	8 ppm	1,300 ppm	519 ppm
Rb	176 ppm	152 ppm	127 ppm	4,713 ppm	1,419 ppm	141 ppm	27 ppm	41 ppm
Sn	596 ppm	5 ppm	66 ppm	401 ppm	68 ppm	<4 ppm	71.89 %	633 ppm
Sr	238 ppm	405 ppm	356 ppm	56 ppm	76 ppm	41 ppm	12 ppm	<9 ppm
Ta	<4 ppm	<4 ppm	<4 ppm	<5 ppm	<5 ppm	<4 ppm	38 ppm	128 ppm
Th	9 ppm	16 ppm	19 ppm	11 ppm	35 ppm	17 ppm	<11 ppm	n.a.
U	3 ppm	<3 ppm	<3 ppm	<4 ppm	<4 ppm	<3 ppm	<11 ppm	29 ppm
V	<6 ppm	7 ppm	10 ppm	74 ppm	131 ppm	59 ppm	89 ppm	48 ppm
W	20 ppm	<4 ppm	14 ppm	34 ppm	7 ppm	41 ppm	8,288 ppm	56.47 %[1)]
Zn	29 ppm	59 ppm	46 ppm	259 ppm	297 ppm	15 ppm	43 ppm	349 ppm
Zr	12 ppm	147 ppm	65 ppm	242 ppm	206 ppm	210 ppm	304 ppm	35 ppm
Calculated								
SnO_2	757 ppm	6 ppm	84 ppm	509 ppm	86 ppm	<5 ppm	91.28 %	804 ppm
WO_3	25 ppm	<5 ppm	18 ppm	43 ppm	9 ppm	52 ppm	1.04 %	71.21 %

[1)] wet chemical analysis

Table 68: Chemical composition of host rock gravel and heavy mineral concentrate from a Chinese processing facility, Upper Modotiin valley (XRF analysis).

Chemistry	Modotiin		
	Gravel	Raw concentrate	Lab-produced heavy mineral concentrate
wt.-% / ppm			
SiO_2	68.31	43.03	18.81
TiO_2	0.48	6.77	18.44
Al_2O_3	14.95	9.92	9.37
Fe_2O_3 total	4.27	11.82	27.66
MnO	0.07	0.63	1.67
MgO	1.08	0.91	1.30
CaO	2.74	2.86	3.56
Na_2O	1.37	0.85	0.06
K_2O	3.66	1.66	0.28
P_2O_5	0.10	0.33	0.61
(F)	0.08	<0.05	0.24
LOI	2.50	0.86	-1.03
Sum	99.63	79.59	80.97
(As)	65 ppm	109 ppm	176 ppm
Ba	692 ppm	342 ppm	<122 ppm
Bi	<4 ppm	22 ppm	23 ppm
Ce	54 ppm	854 ppm	2,748 ppm
Cu	40 ppm	168 ppm	72 ppm
Hf	<6 ppm	94 ppm	131 ppm
Nb	12 ppm	238 ppm	403 ppm
Pb	58 ppm	238 ppm	188 ppm
Sn	172 ppm	15.02 %	13.03 %
Ta	<4 ppm	20 ppm	40 ppm
Th	21 ppm	191 ppm	721 ppm
U	<3 ppm	34 ppm	87 ppm
V	72 ppm	99 ppm	132 ppm
W	45 ppm	0.40 %	0.52 %
Zn	85 ppm	186 ppm	355 ppm
Zr	123 ppm	0.28 %	0.53 %
Zn	29 ppm	59 ppm	349 ppm
Zr	12 ppm	147 ppm	35 ppm
Calculated			
SnO_2	218 ppm	19.08 %	16.54 %
WO_3	56 ppm	0.51 %	0.66 %

Figure 115: Remains of alluvial placer cassiterite mining in the upper Modotiin valley.

of 0.5 up to 3 cm grain size from the dumps (Figure 114).

Therefore, re-assessing the dumps may be worthwhile to estimate the economic potential for reworking the dumps. A small mobile processing facility would yield quick results. However, some methodology for recovering oversize cassiterite also needs to be developed. As a minimum benefit, reworking the dumps could contribute to financing re-cultivation efforts.
BGR analysis of cassiterite concentrate from artisanal miners confirm its high quality (Table 67). Traces of Pb and W were detected, but the U/Th content is low.
According to archive reports, some 6,500 t Sn (in cassiterite) and 900 t WO_3 (in wolframite) reserves could be mined in neighbouring valleys such as Urgurniam, Mutun golyn deed heseg and Nerguin heseg.

Table 69: Heavy mineral composition (in vol. %) of concentrates from a Chinese processing facility, Upper Modotiin valley.

Mineralogy	Modotiin
HM total	**38.4**
Magnetite	12.4
Ilmenite	17.4
Leucoxene	7.8
Cassiterite	16.8
Sphene	+
Zircon	1.7
Garnet	31.4
Sillimanite	+
Tourmaline	2.2
Epidote	+
Topaz	1.1
Clinozoisite	2.8
Augite	+
Hornblende	0.6
Apatite	+
Quartz et al.	5.8
Sum	100.0

Current mining activities:
Chinese companies and ninja miners currently mine river sediments in the upper reaches of the Modotiin valley down to the bottom of the river bed (position 1: 47° 48' 43.1" N , 109° 03' 16.9" E; 1.520 m a msl, position 2: 47° 49' 35.1" N , 109° 03' 19.8" E; 1.590 m a msl, position 3: ninja mining: 47° 49' 52.4" N , 109° 03' 25.9" E; 1.614 m a msl). They also seem to re-work old dumps using bulldozers (Figure 114). One concentrate sample taken from a small plant yielded 38 % heavy minerals containing mainly garnet, magnetite, ilmenite, cassiterite (i.e. 15 % Sn), and elevated values of Ce and Th (cf. Table 68).
In addition to the placer deposits in the upper reaches, several 100-200 m long and 0.5-2 m thick quartz-cassiterite veins occur along the mountain slope. According to archive reports, the veins should carry 0.2-0.9 % WO_3 (Ø <0.2 %) and 0.2 % Sn in that area, and a 51 m long adit should exist. Visual inspection of the veins yielded poor mineralisation except for one site where artisanal miners found some high grade cassiterite-wolframite pockets (Figure 114). Host rock samples taken from dumps and along major veins do not point to any disseminated style of mineralisation.

CASSITERITE-WOLFRAMITE PLACER KHUJKHAAN

Exploration work at Khujkhaan (47° 46' 56.5"N, 109° 14' 03.1"E; 1,471 m a msl) was carried out during the Mongolian-Russian Dornot Metal Expedition (1947-1951) and the Soviet-Mongolian Metal Expedition (1954-1956), the Mongolian "Modot" expedition (1969-1970), the Intergeo-Expedition (1979) and in the period 1981-1985.

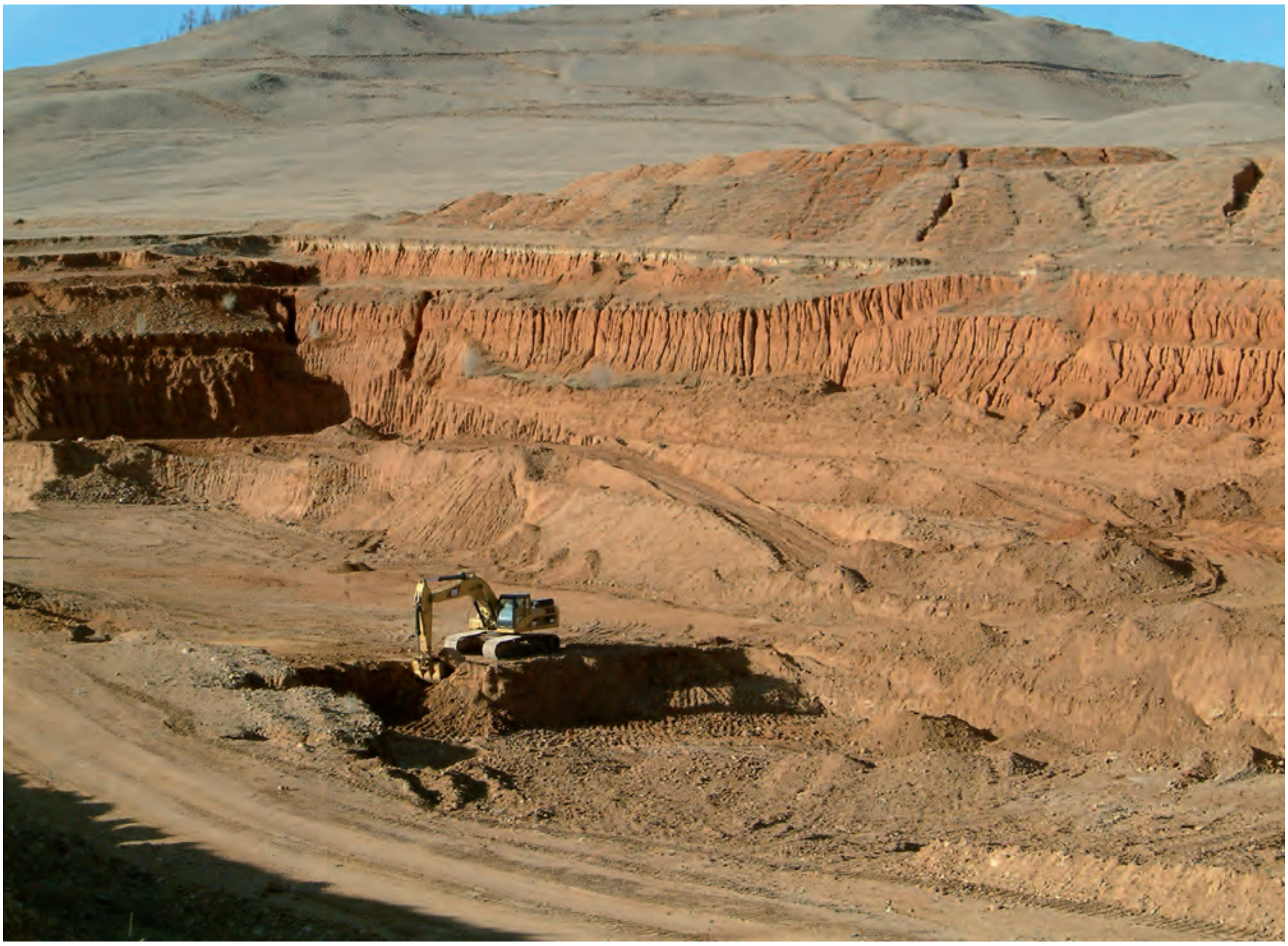


Figure 116: Open pit mining of placer sediments by National Mongolian Company, East Khujkhaan, as of June 2008.

Table 70: Chemical composition of placer sediments and concentrates from the Sn-W-placer deposit at East Khujkhaan (XRF analysis).

Chemistry	East Khujkhaan					
	Placer sediment	Ore bearing boulders	Wet mill concentrate	Cassiterite concentrate	Wolframite concentrate	Dry mill heavy mineral concentrate
	wt.-% / ppm					
SiO_2	59.66	79.98	7.81	2.20	2.53	11.50
TiO_2	0.75	0.04	2.18	0.55	2.95	1.31
Al_2O_3	17.52	10.43	1.18	0.93	0.77	2.02
Fe_2O_3 total	5.69	2.83	3.06	1.80	16.79	5.16
MnO	0.07	0.34	0.78	0.72	6.60	1.47
MgO	1.83	0.06	0.14	0.13	0.08	0.14
CaO	2.42	0.09	1.00	0.31	0.42	0.68
Na_2O	2.01	0.08	<0.01	0.05	0.02	0.17
K_2O	3.31	3.41	0.10	0.05	0.10	0.45
P_2O_5	0.19	0.02	0.25	0.04	0.08	0.06
(F)	6.02	<0.05	0.28	0.39	<0.05	<0.05
LOI	11.78	1.73	0.50	0.60	-0.12	0.73
Sum	*99.46*	*99.04*	*17.29*	*7.77*	*30.27*	*23.64*
(As)	538 ppm	434 ppm	<187 ppm	<192 ppm	n.a.	204 ppm
Bi	5 ppm	192 ppm	468 ppm	185 ppm	n.a.	765 ppm
Ce	82 ppm	56 ppm	1,185 ppm	312 ppm	226 ppm	140 ppm
Cu	115 ppm	106 ppm	119 ppm	216 ppm	932 ppm	131 ppm
Hf	9 ppm	<6 ppm	1,472 ppm	47 ppm	<24 ppm	<19 ppm
Nb	15 ppm	41 ppm	487 ppm	477 ppm	630 ppm	509 ppm
Pb	69 ppm	171 ppm	753 ppm	1,420 ppm	552 ppm	1,104 ppm
Sn	465 ppm	552 ppm	53.77 %	67.67 %	14.79 %	50.59 %
Ta	<5 ppm	<5 ppm	125 ppm	<20 ppm	37 ppm	29 ppm
Th	25 ppm	40 ppm	341 ppm	<12 ppm	n.a.	<10 ppm
U	8 ppm	7 ppm	137 ppm	<12 ppm	30 ppm	10 ppm
V	43 ppm	<6 ppm	<24 ppm	34 ppm	122 ppm	66 ppm
W	112 ppm	0.47 %	4.40 %	3.94 %	47.56 % 1)	8.65 %
Zn	320 ppm	69 ppm	125 ppm	49 ppm	307 ppm	123 ppm
Zr	305 ppm	90 ppm	5.85 %	0.24 %	0.11 %	0.16 %
	Calculated					
SnO_2	590 ppm	701 ppm	68.27 %	85.93 %	18.78 %	64.23 %
WO_3	141 ppm	0.59 %	5.56 %	4.97 %	59.98 %	10.99 %

1) wet chemical analysis

The Khujkhaan valley near Tsenhermandel is 12 km long and crosses a granite massif of 1.5 to 3.5 km diameter. Side valleys are up to 1.5 km long. During past expeditions, a total of ten placer deposits were mapped and studied. According to archive reports, marginal C1+C2 reserves for the whole area are 4.3 million m^3 sediment containing 1,725 t cassiterite and 375 t WO_3 in wolframite. Non-marginal C1+C2 reserves are 2.2 million m^3 sediment containing 400 t cassiterite and 66 t WO_3 in wolframite. Between 1949 and 1955, concentrates containing 237 t Sn and 68 t WO_3 were recovered.

Figure 117: Beneficiation plant of National Mongolian Company, East Khujkhaan.

Table 71: Heavy mineral concentrate composition (in vol. %) of weathered granite, placer sediment and concentrates from the beneficiation plant and the Sn-W placer deposit East Khujkhaan.

Mineralogy	East Khujkhaan					
	Weathered granite	Placer sediment	Wet mill concentrate	Cassiterite concentrate	Wolframite concentrate	Dry mill heavy mineral concentrate
HM total	0.4	1.1	53.1	98.0	97.4	100.0
Magnetite			1.8	0.5	1.1	+
Titanomagnetite?				10.3	1.0	
Ilmenite			11.5			2.1
Leucoxene		10.0	2.4			0.8
Cassiterite	2.7	10.0	51.5	4.9	11.2	67.9
Wolframite		20.0		82.6 [1)]	83.5 [1)]	1.7
Scheelite?					0.1	
Sphene		1.6	+			
Zircon	4.2	7.8	8.8	0.5	1.6	26.3
Garnet		1.0	0.2	+	0.2	
Epidote	+			+	+	+
Topaz		6.8	3.1		0.4	1.0
Clinozoisite		0.5				
Mica	5.0	3.9	+		+	
Augite	+				0.9	
Hornblende	21.2	34.4	6.0	+		+
Apatite	7.2	0.5	0.8		+	+
Fluorite	0.3	1.6	0.8	+		
Aggregates	58.5					
Quartz et al.	0.9	1.9	13.1	0.9	+	0.2
Sum	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

[1)] confirmed by XRD

In 2008, National Mongolian CO. began mining the East Khujkhaan tin-tungsten placer after beginning work in April 2007 and employing a staff of 54. According to old reports, the East Khujkhaan placer carries 531 g cassiterite/m^3 and 85 g WO_3/m^3 sediment on average. The marginal category C1 reserves are 700,000 m^3 containing 231 t cassiterite and 7 t WO_3. The non-marginal C1+C2 reserves are 507,000 m^3 containing 95 t cassiterite and 11 t WO_3 (cut-off grade and recovery similar to Modotiin). However, new reserve estimates are much higher: the total mineable amount of concentrate could contain 2,000 t Sn+WO_3 (company information).
Three heavy mineral layers each about 1.5 m thick are being mined in a 20-30 m deep open pit. The upper layer is low grade, and the lower two layers are high grade. The lowest layer especially at the contact to the country rock seems to have the highest grade. One strip sample of that layer yielded 590 ppm SnO_2 (about 1,000 g cassiterite/m^3, cf. Table 70) as well as elevated WO_3 and As values. From the open pit, the placer sediment is trucked to the beneficiation plant about 3 km away. According to company information, the plant processes 600 m^3 sediment/day and produces 100 t concentrate/year with a tin/tungsten ratio of 1:1. As of 2008, some concentrate fines were lost to the dumps. Beneficiation is by two separation lines consisting of sieving and jigging. The processing capacity of the plant was scheduled to be 90,000-100,000 m^3 sediment/year, the lifetime was planned to be 16 years.

The concentrates produced contain cassiterite and wolframite as well as ilmenite and another 10-15 different heavy minerals. According to BGR analysis, the tin concentrates contain 67 % Sn and 4 % W, the tungsten concentrate contains up to 15 % Sn. U/Th values are low. One heavy mineral concentrate from the second last processing step contains 5.8 % zirconium and more than 0.1 % cerium and hafnium in addition to tin and tungsten (wet concentrate, cf. Table 70).

As of 2008, the company sold cassiterite and wolframite concentrate to the Czech Republic and Switzerland with additional interest expressed by Chinese and South Korean companies. Because of the impure quality of the tin and tungsten concentrates, the National Mongolian Company was interested in technical support and investment.

FURTHER DEPOSITS/ OCCURRENCES OF TIN IN MONGOLIA

In addition to the cassiterite deposits described above, about 80 other tin deposits and occurrences are listed in the MRAM database. A crosscheck of this database showed that most of the deposits/occurrences do not seem to be of economic interest. Most data on placer deposits/occurrences indicate resources <<1,000 tonnes of Sn, most often they range between 50 to 300 tonnes Sn (or cassiterite) C1+C2 reserves. These types of deposits are of no interest to commercial mining. However, a few placer deposits may be worth re-evaluating for small-scale mining:

- Khar Moritiin Group (Omnogovi Aimag, near Chinese border): Prospecting work was carried out between 1952 and 1953, 1970 and 1971. The main cassiterite-wolframite bearing placer is 4 km long, 0.1-5.0 m thick and 24-110 m wide. Calculated category B, C1+C2 reserves are 714 t Sn (cassiterite?) at 485-3,082 g Sn/m^3 and about 20 t WO_3 at 213 g WO_3/m^3. Water shortages in the Gobi desert and poor infrastructure will pose problems for mining and processing.

- Onongin Group (Khentii Aimag, near Russian border): Prospecting occurred in 1949, 1951, 1953, and between 1971 and 1974. The four studied cassiterite-wolframite bearing placers are 3.9-6.0 km long, 0.1-6.9 m thick and 35-250 m wide. Calculated C1 reserves are 945 t Sn (cassiterite?) at 273-439 g Sn/m^3 and around 70 t WO_3 at 5.8-30 g WO_3/m^3. While the water supply is sufficient, permafrost and poor infrastructure will be the main obstacles for mining.

- Deed Kumiiriin Group (Khentii Aimag, near Russian border): Prospecting occurred in 1951 and 1953. The main cassiterite-wolframite bearing placer is 0.3-1.9 km long, 0.7-3.8 m thick and 12-298 m wide. Calculated B+C1 reserves are 874 t Sn (cassiterite?) at 110-1,041 g Sn /m^3 and around 741 t WO_3 at 668 g WO_3/m^3. Again water supply is not the problem, but permafrost and poor infrastructure are obstacles to mining.

Except for the cassiterite placer deposits mentioned above, two deposits are described as primary tin deposits:

- The Oortsog Ovoo skarn-type tin deposit (Dundgovi Aimag, approx. 80 km SW of Choir): Prospecting work was carried out between 1986 and 1989 and 1990. The four cassiterite bearing skarn ore bodies are located in Upper Proterozoic, Upper Jurassic-Lower Cretaceous rocks intruded by Late Paleozoic and Middle-Late Jurassic granites. The magnetite-rich skarn ore bodies are 75-150 m long, 1-32 m thick and 30-150 m deep. The grade varies between 0.2-1.95 % Sn, with minor amounts of Zn and Cu (<< 0.5 %, + other sulphides), and Au (0.5 ppm). Two samples were taken for technological processing (magnetic, gravimetric, flotation), but the Sn recovery was very poor (<20 %), probably due to the low cassiterite grain size of 0.01-1.0 mm. The calculated category C2 resources are 33,000 t Sn, 13,137 t Zn, 5,292 t Cu and about 1,000 t Pb. During a visit in 2010, no recent activities were observed.

- The Narsiin Hundlun deposit (Dornod Aimag, near Russian border): According to a 2008/2009 company report, this vein type tin deposit consists of four major ore bodies which are 300-400 m long and 1.25-5.1 m thick. The tin grades up to 3.72 % but averages 0.85 %. Category B+C reserves are 5,635 t Sn at 0.61 % Sn.

Tin could potentially be recoverd, also as a by-product, in minor quantities at the primary Ondor Tsagaan W-Mo-Be deposit or in the Yeguzer area (e.g. Zentr).

Figure 118: Old trench crossing a tin bearing skarn ore body at Oortsog Ovoo.

As noticed during a field trip in September 2010 cassiterite at Khokh del Ulaan is strongly enriched in several 3-5 cm large nests. The outcrops could be mined by small scale or artisanal mining methods (cf. niobium and tantalum).

REQUIREMENTS AND EVALUATION

The minimum contents (cut-off grades) for mineable cassiterite deposits are:

- underground mining: >1.0 % Sn
- mine tin: >0.5 % Sn or Sn+W
- placer tin: >0.01 % Sn (typical: 0.05 % Sn = 500 g Sn/ton)
- placer mining with floating dredge: 60 g cassiterite/m^3
- placer mining using gravel pumps: 120 g cassiterite/m^3
- large-scale industrial mining: 240 g cassiterite/m^3
- small-scale mining: 300 g cassiterite + columbotantalite/m^3

Reference values, which apply to the evaluation of the size of all types of cassiterite deposits, are as follows:

Table 72: Classification of tin deposits according to the size and tin content.

	Sn content after SUTPHIN et al. (1990)	Sn content after PETROW et al. (2008)
Small	<10,000 tonnes	<20,000 tonnes
Medium	10,000 – 100,000 tonnes	20,000 – 50,000 tonnes
Large	100,000 – 500,000 tonnes	50,000 – 100,000 tonnes
Very large	>500,000 tonnes	>100,000 tonnes

According to the above classification of tin deposits, all placer tin deposits and occurrences in Mongolia are of small size and/or low grade.

Most of the placer deposits in the Modot valley are mined out, with little activity left in the upper Modot Valley. Other areas such as the Janchivlan and Elstein/East Elstein districts, which were explored in the past, have not been mined but have very limited potential for small scale mining (e.g. Elstein). Most placer deposits/occurrences in Mongolia contain <<1,000 tonnes Sn, most often they contain <<500 tonnes Sn. Some small scale deposits which contain 500-1,000 tonnes Sn occur in very remote areas including the Gobi desert (Khar Mortiin Group) or in permafrost areas (e. g. at the Russian border, NE Ulaanbaatar), which are not of interest for commercial mining.

The most interesting area for future small-scale placer mining is Khujkhaan. The placers in that area have high cassiterite grades and also carry wolframite, which can be separated as a by-product. Further possibilities are the neighbouring valleys of the Modot valley, e. g. the Urgurniam, Mutun golyn deed heseg and Nerguin heseg valleys (>1,000 tonnes Sn+WO_3 content). Neither of these placers has been extensively explored or mined in the past.

Oortsog Ovoo is currently the largest known, medium size cassiterite deposit in Mongolia. However, metallurgical tests have so far failed to prove economic recovery from this skarn type deposit. Further testing with state of the art technology is recommended.

As a by-product, cassiterite could be recovered in small quantities from Ondor Tsagaan or in the Yeguzer area (cf. Tungsten chapter for further information).

Table 73: In situ value and size of cassiterite deposits in Mongolia (value calculated at a cassiterite price of 8,500 US$/tonne, 2009).

Value of deposit	Size of deposit	Typical size in Mongolia (Sn content)	Example	International classification
<3 Mio US$	Very small	<350 t	East Elstein, Janchivlan group	
~3-10 Mio US$	Very small	350 - 1,200 t	Modot region	
~10-30 Mio US$	Small	1,200 - 3,500 t	Khujkhaan and Elstein regions	<10,000 t Sn
~30-100 Mio US$	Small	3,500 - 12,000 t	Narsiin Hundlun	<10,000 t Sn
~100-400 Mio US$	Medium	12,000 - 50,000 t	Oortsog Ovoo	10,000-50,000 t Sn
>400 Mio US$	Large	>50,000 t	-	>50,000 t Sn

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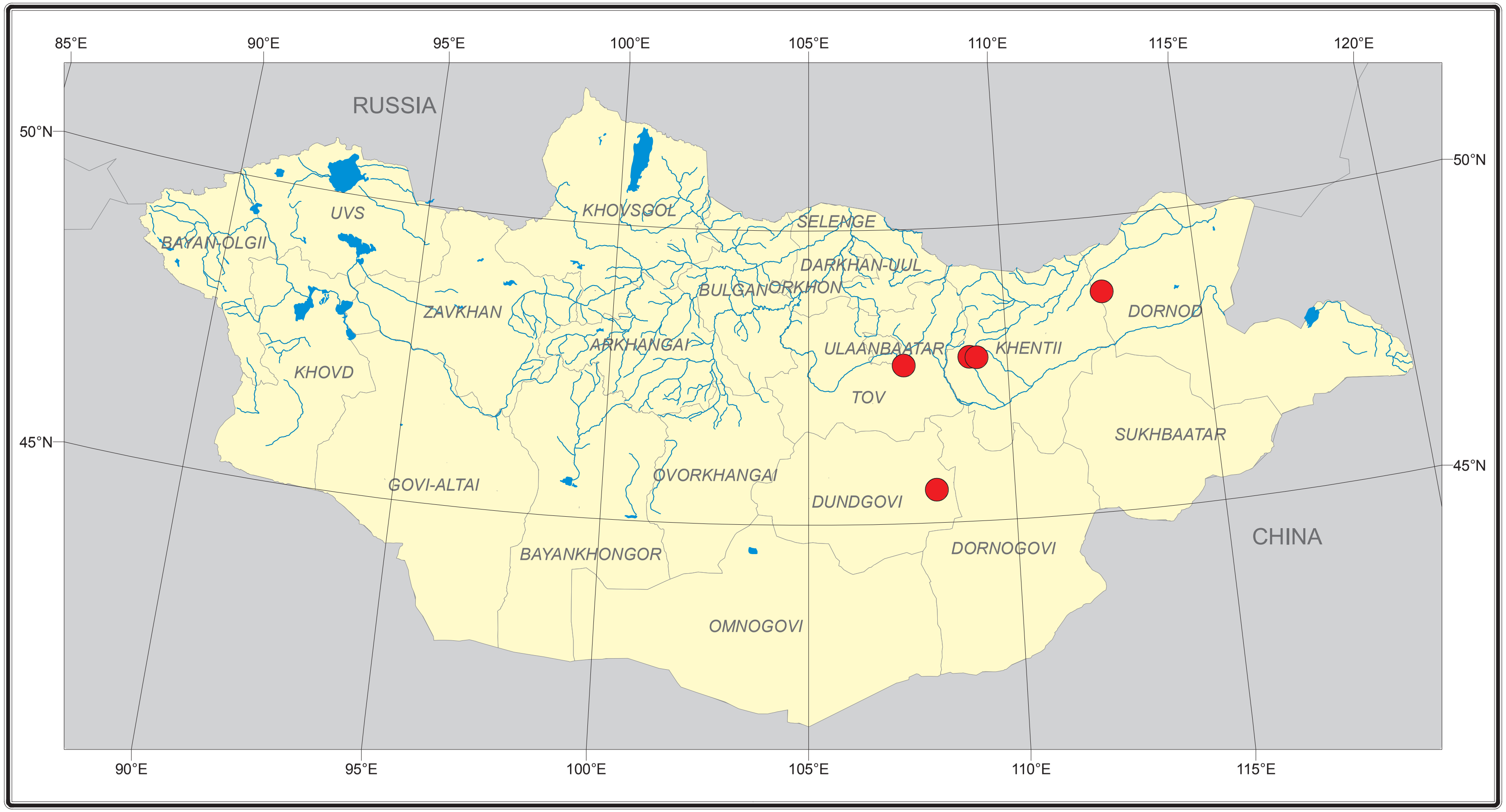
Deposits and important occurrences of Tin in Mongolia



BGR © Federal Institute of Geosciences and Natural Ressources

Legend

● Tin (reserves and resources > 1000 t Sn content)

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

TUNGSTEN

GENERAL INFORMATION AND USES

Wolframite, (Fe, Mn) WO_4, frequently contains minor amounts of Nb, Ta, Sn and Ca (<1.5 %), Sc (<0.4 %), Ti (<0.1 %) as well as traces of In, Mo, Bi, Zr, Hf, and Y. Some of these elements impede the processing of tungsten ores. The similar crystal structure of columbite-tantalite allows their incorporation in wolframite (up to 20.25 % Nb_2O_5) and vice versa, of wolframite in columbite-tantalite (up to 13 % WO_3).

The formation of wolframite, hubnerite ($MnWO_4$), and ferberite ($FeWO_4$) mainly takes place:
- pegmatitically-pneumatolitically (ferberite, wolframite),
- pneumatolitically-hydrothermally (hubnerite),
- subvolcanically (ferberite) as well as
- submarine-exhalative-sedimentary (ferberite).

Higher contents of Sc, Rare Earths, Nb and Ta indicate genesis of the wolframite in pegmatites and greisens. Low contents indicate genesis in hydrothermal lodes (Pavlu 1986).

Scheelite, $CaWO_4$, is one of the most fluorescent minerals and is prospected for in the dark using UV-light because of the fluorescent colours (bright blue, and frequently white to yellow due to traces of molybdenum).

Scheelite forms:
- in skarns (contact pneumatolitically altered), associated with garnet, epidote, diopside, tremolite, vesuvianite, fluorite, chalcopyrite and molybdenite,
- in hydrothermal quartz veins, associated with gold, cassiterite, wolframite, topaz, tourmaline, apatite, beryl, molybdenite and arsenopyrite
- strata-bound, probably submarine-exhalative-sedimentary, associated with Sb and Hg mineralisation.

Scheelite and wolframite are relatively sensitive to physical and chemical exposure. Wolframite in particular is subject to fast physical weathering because of its pronounced cleavability. Both minerals possess only limited hardness. In spite of their high density, they are rather rare as heavy minerals in placers – if present they are more likely found in colluvial and eluvial placers, but only very rarely in alluvial deposits.

Even though scheelite is mainly prospected for by detecting its fluorescence, heavy mineral analysis for scheelite and wolframite is one of the best prospecting tools for primary hard rock deposits of these two tungsten minerals.

Scheelite and wolframite are exclusively used for the extraction of the metal tungsten, which is characterized by its
- High thermal resistance (highest melting point of all metals: 3387 (3422) °C),
- High tensile strength (highest mechanical strength and smallest coefficient of expansion of all metals),
- (with C or O) very high hardness (very soft in highly pure form),
- Good conductivity, and
- High resistance to vapours and acids.

Tungsten in turn is used for the manufacture of:
- Tungsten carbide, WC and W_2C, which is mainly used for the manufacture of turning and cutting steels, but also in alloys for armour-plated projectiles because of its very high hardness and its high abrasion resistance even at high temperatures,
- Tungsten alloys, together with Co, Ni, Mo, Al, Ta, Re, Th and Zr, for special steels,
- Different tungsten chemicals for catalysts, pigments, lubricants, lasers, x-ray devices and also for glass with controllable translucence.

In addition, tungsten in metallic form is used
- in the electronics and electrical industry (light bulb filaments, cathodes, anodes, spark plugs, electric contacts in circuits),

- in high-temperature engineering (heating elements, thermo elements, electrodes),
- welding,
- in aerospace engineering (rocket nozzles)
- for building furnaces for special glass melts.

There are no mineable tungsten ores other than wolframite and scheelite and their weathered mineral product tungstite (wolfram ochre). Depending on the application, tungsten carbide, tungsten metal and tungsten chemicals can usually not be replaced by other chemicals. In the most important application, the manufacture of turning and cutting tools, substitution is possible in some cases by other metal carbides, e. g. TiC, CoC.

RELEVANT DEPOSITS AND OCCURRENCES IN MONGOLIA

INTRODUCTION

Tungsten deposits and occurrences in Mongolia are subdivided into pegmatitic-pneumatolytic and pneumatolytic-hydrothermal vein type, stockwork type and greisen type deposits. Placer deposits in Mongolia carry wolframite as well as scheelite in minor quantities which is a by-product of tin placer mining (cf. chapter Tin). In the past, wolframite and scheelite were mainly mined from vein type deposits. However, due to improvements in mining technology and high prices for wolframite and scheelite concentrates, deposits with low grade/high tonnage could become of commercial interest for open pit mining, especially in the area of stockwork or greisen type mineralisation.

Wolframite/scheelite deposits and occurrences occur throughout Mongolia and are mainly concentrated in the Bayan-Ulgii, Khentii and Suhkbaatar Aimags. In general they are associated with granitoid intrusions of Paleozoic age which occur along structural tectonic belts. Wolframite-rich placer deposits mainly occur in valleys around Khujkhaan in Khentii Aimag (cf. chapter Tin).

The possible occurrence of strata-bound scheelite deposits has been mentioned in the literature, namely in the Tseel and Govi-Altai/ Hyangan, the Bargin ovoo, and Buteelin nuruu areas. However, no assured information could be obtained for this publication. According to Prof. Dr. Lkhamsuren Jargal (oral comm.) from the Mongolian University of Science & Technology, and Prof. emerit. Dr. S. Dandar, rumours about stratabound scheelite deposits in Mongolia cannot be confirmed.

Wolframite mining and exploration in Mongolia has a long tradition, however all deposits which have been mined in the past were small scale in international terms but high grade. Exploration started in the late 1930´s by the former USSR and continued for many decades. A number of wolframite deposits are already mined out, e.g. Burentsogt, Tumentsogt, Ikh Khairkhan, Chuluun Khoroot, and Salaa. Historic mining also occurred at Yeguzer from the late 1940´s, and at Ulaan Uul, Khovd Gol, and Tsagaan Davaa since the 1990´s. Historic annual wolframite concentrate production ranged between a few tonnes and a maximum of about 350 tonnes.

Today, two wolframite deposits are still in operation in Mongolia, namely the Tsagaan Davaa deposit in Tuv Aimag and the Khovd Gol deposit in Bayan-Ulgii Aimag. Both are vein type deposits and produce around 50-80 tonnes of wolframite concentrate per year

A number of known vein type deposits, partly mined in the past, are currently being re-evaluated for potential mining. Among these are the Ulaan Uul (Kyzil Tau) and Tsunheg deposits. A number of deposits and occurrences formerly not mined but well explored have a good potential for mining (cf. Table 74). Some of them are currently being re-evaluated.
In addition to vein type deposits, a few low grade/high tonnage stockwork and greisen type deposits occur in Mongolia, which could be of interest for mining, e.g. the Yeguzer and the Ondor Tsagaan deposits. The Yeguzer de-

posit in the Suhkbaatar Aimag was mined between 1948 and 1956 by the USSR as a high grade vein type deposit. Veins occur within a large greisen zone formerly uneconomic for mining. Current exploration activity focuses on the economics of the greisen zone which could potentially be mined in a low grade/ high tonnage open pit mine. Similarly, mining of the Ondor Tsagaan stockwork type deposit in Khentii Aimag, still regarded as the biggest wolframite deposit in Mongolia, could become economic through large scale mining.

Geological Information Center (2003) lists 20 tungsten deposits in total, some of which are mined out and others being too small for commercial mining (e.g. deposits <50-100 tonnes of WO_3). In addition, a total of 98 tungsten occurrences are listed by Geological Information Center (2003), for which archive reports are available. However, the bulk of the mentioned occurrences are very small and contain <100 tonnes of WO_3 or even <10 tonnes of WO_3. While cross checking the archive reports, some interesting occurrences with obviously >500 tonnes of WO_3 content were found which might have good potential for commercial mining. In this guide, these occurrences are included in Table 74 and are also discussed in the text.

A number of important publications devoted to tin and tungsten deposits, and mineralisation in Mongolia, were published in the past. Among these are Kovalenko (1995), Jargalsaihan et al. (1996) and Dandar (2009). A selection of publications and reports is given in the reference list at the end of this chapter.

EASTERN MONGOLIA

Yeguzer

The Yeguzer deposit (45° 54’ 27.9” N , 115° 23’ 37.7” E; 1,064 m a msl) lies 3 km east of Erdenetsagaan in SE Mongolia, near the Choinon Gol in Sukhbaatar Aimag. Between 1948 and 1956, only high grade ores at Yeguzer were mined by the USSR. The mining activities focused on high-grade wolframite-molybdenite veins. During this period, concentrates containing a total of 1,255 tonnes of tungsten were extracted. In 1969, a group of former East German (GDR) geologists evaluated the deposit and took a 30 tonne ore sample for dressing tests. These were conducted at the “Forschungsinstitut für Aufbereitung” (FIA) in Freiberg, former East Germany. However, the tests did not fulfil the required recovery grade for commercial mining. Between 1971 and 1974, the USSR and Mongolia carried out a re-exploration campaign focussing on the greisen zone. Again dressing results were unsatisfactory.

Altogether the deposit has been well explored. The reserves (C1+C2) are 21.58 million tonnes of ore with 42,530 tonnes of net WO_3 and 12,030 tonnes of net Mo. In addition, considerable reserves of BeO (41,000 tonnes) and Bi (12,000 tonnes) were calculated. During exploration, approximately 13,000 m^3 of ore and rock from trenches and 10,000 m of core drilling were investigated and several stopes and shafts were driven. 314 boreholes reached a depth of more than 300 m, numerous shallow boreholes penetrated 40 m of rock and ore. The underground exploration activities were performed at a distance of 50 x 25 m and in the marginal areas of the ore body at a distance of 50 x 50 m and 50 x 100 m.

Within the deposit, there are some 120 hydrothermal-pneumatolytic quartz-wolframite veins, of which 20 were studied in detail; 11 veins have industrial importance. These were largely mined. They were 100-500 m long, 0.5 to 14.3 m thick (ore body #4: 0.8 to 41 m?) and 50-250 m deep (ore body #4: 950 m; #8: 200-500 m). The WO_3 content was very high ranging between 2 and 8 %. The veins mainly carried wolframite, molybdenite, beryl, fluorite and topaz and minor amounts of aquamarine and heliodor.

Table 74: Summary of grades and tonnages of major tungsten deposits in Mongolia according to exploration reports and additional information received by various experts.

Aimag	Deposit	Resource of ore @ grade	Tonnage
Khentii	Ondor Tsagaan	134 Mt @ 0.127 % WO_3, 0.036 % Mo, 0.03 % BeO, 0.01 % Bi (B+C)	175,990 t WO_3, 48,470 t Mo, 43,350 t BeO, 13,460 t Bi
	Narangyn Gol	43,000 t @ 0.32 % WO_3	752 t WO_3 (in 1953), 6,750 t WO_3 (revised in 1985)
Sukhbaatar	Salaa	100,000 t @ 1.34 % WO_3	1,385-2,287 t WO_3 (mined out)
	Baruun	880,000 t @ 0.28 % WO_3	2,000-3,000 t WO_3
	Tumentsogt	1,420 t @ 1.5-2.0 % WO_3 56,800 t @ 0.1-2.7 % WO_3	76 t WO_3 (partly mined by Russia between 1950-55)
	Burentsogt	0.8-1.0 Mt @ 0.36-1.63 % WO_3 47,000 t @ 0.82-1.14 % WO_3 251,800 t @ 0.129 % WO_3	~ 3,000 t WO_3 (mined out) ~ 465 t WO_3 (remaining) ~ 320 t WO_3 (in tailings)
	Erdenetsagaan area		
	Yeguzer	21.58 Mt @ 0.19-0.23 % WO_3, 0.05-0.08 % Mo, 0.08-0.12 % BeO (C1+C2)	42,530 t WO_3,12,030 t Mo, 41,000 t BeO
	Ar bayan area incl. Bayan Uul	8.3 Mt @ 0.19 % WO_3 1.2 Mt @ 0.16 % WO_3	18,900 t WO_3 (total area)
	Tov (Zentr)	3.8 Mt @ 0.13 % WO_3, 0.14 % BeO, 0.04 % Sn, 0.015 % Mo	4,990 t WO_3, 5,340 t BeO 1,360 t Sn, 530 t Mo
	Batguj	no information	150 t WO_3
	Omnod	? t @ 0.14-0.54 % WO_3	8-164 t WO_3
	Nucht/Uvurbayan	no information on WO_3	currently in production
Tuv	Tsagaan Davaa (in production)	1.2 % WO_3 90,000 t @ 0.44 % WO_3, 0.05 % Sn	~ 3,000 t WO_3 (mined out) ~ 1,000 t WO_3 (remaining) 400 t WO_3, 45 t Sn (in tailings)
	Ongon Khairhan	7.4 Mt @ 0.15 % WO_3 (C1+C2) 5.3 Mt @ 0.05-0.10 % WO_3 (C2)	11.136 t WO_3 3.993 t WO_3 (test mining by CSSR late 80´s/ early 90´s)
	Ikh Khairhan	~ 150,000 t @ Ø 1.3 % WO_3 65,200 t @ ca. 0.8 % WO_3	~ 840 t WO_3 (partly mined out) 550 t WO_3 (remaining)
	Khar Chuluut	100,000 t @ 0.66 % WO_3	697 t WO_3
Dor-nod	Chuluun Khoroot (partly mined)	18,300 t @ 0.8-1.0 % WO_3, 0.06 % Sn, 0.14 % Bi, 0.05 % Mo	255 t WO_3 (70 t remaining)
Bayan Ulgii	Tsunheg	80,000 t @ 3.33 % WO_3 (B) 405,000 t @ 2.29 % WO_3 (C)	2,682 t WO_3 9,267 t WO_3
	Ulaan Uul (Kyzil Tau) (partly mined)	285,500 t @ 1.1% WO_3 (B+C?)	3,138 t WO_3 (remaining)
	Khovd Gol (in production)	48,070 t @ 10 % WO_3 (B) 16,850 t @ 10 % WO_3 (C)	ca. 1,000 t WO_3 (mined) 4,736 t WO_3 (remaining) 1,107 t WO_3 (remaining)
	Nuuryn Gol	30,000 t @ 1.82 % WO_3 (C1?)	600 t WO_3

According to GRUNER et al. (1984), the veins at Yeguzer are surrounded by a 3,000 m long, 1,500 m wide and 150-180 m deep, economically interesting greisen zone with an average grade of 0.19-0.23 % WO_3 and 0.05-0.08 % Mo, identified in four greisen bodies and lenses. In addition, elevated levels of Bi (0.13-0.21 %) and BeO (0.08-0.12 %) were found. The mainly tectonically controlled greisen zone is located at the contact between a granite porphyry (fine to medium grained alaskite of Triassic-Jurassic age) and Ordovician metasediments (hornfels). It lies below 14-16 m of host rock cover in the dome area of the intrusion and below some 100 m of host rock down to the flanks. In the case of an open pit operation, the waste/ore ratio would be 7:1. About 90 % of the identified reserves are concentrated in one of the four identified greisen bodies measuring 600 x 40 m. The thickness of the total greisen zone averages 21 m; in the central part it reaches 84 m, and on the flanks 5-6 m. Besides wolframite, molybdenite, beryl,

Table 75: Heavy mineral composition (in %) of wolframite concentrate (cf. Table 76) from the Yeguzer W-Mo-Be deposit. Analysis by BGR.

Mineralogy	Test concentrate from the pilot plant
HM total	**67.0**
Magnetite	+
Leucoxene	7.8
Cassiterite	0.3
Wolframite	80.5
Garnet	+
Topaz	+
Mica	0.7
Clinozoisite	+
Augite	+
Hornblende	0.2
Fluorite	0.2
Quartz et al.	10.3
Total	100.0

fluorite and topaz, alteration minerals such as muscovite and feldspar also occur. The wolframite is partly oxidized and very fine-grained.

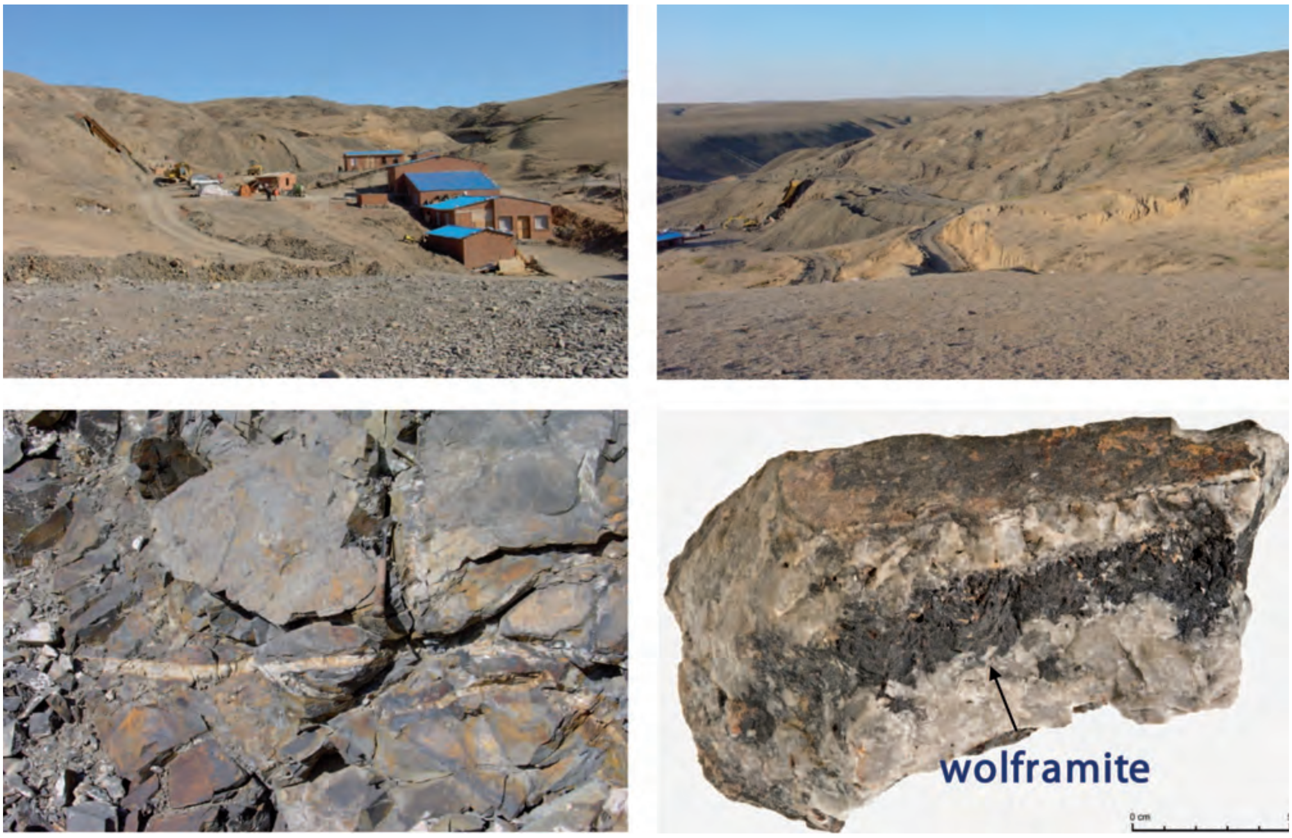


Figure 119: Yeguzer wolframite-molybdenite-beryl deposit: Processing facility of ENGUICAL CO. LTD. (top left), view of the greisen zone (top right), shallow dipping quartz-wolframite vein (bottom left), and high grade wolframite vein type ore (bottom right, scale 5 cm).

Table 76: Chemical composition of greisen ore sample and wolframite concentrates of the Yeguzer W-Mo-Be deposit (XRF analysis by BGR).

Chemistry	Yeguzer test concentrate			
	Greisen ore	Wolframite concentrate		
		From the processing facility[1)]	From ore samples[2)]	Processed concentrate at BGR[3)]
wt.-% / ppm				
SiO_2	82.36	4.18	5.29	2.10
TiO_2	0.02	0.05	0.04	0.06
Al_2O_3	8.12	0.91	0.08	0.59
Fe_2O_3 total	2.79	12.10	11.73	13.43
MnO	0.31	11.43	13.30	13.38
MgO	0.05	0.04	0.10	0.15
CaO	0.77	0.79	0.33	0.38
Na_2O	0.07	0.05	<0.01	0.02
K_2O	2.69	0.23	0.02	0.13
P_2O_5	0.01	0.07	0.06	0.10
(SO_3)	0.44	0.02	<0.01	<0.01
(F)	<0.05	<0.05	n.a.	<0.05
LOI	1.39	2.20	0.46	1.40
Sum	*99.05*	*32.07*	*31.51*	*31.74*
(As)	192 ppm	n.a.	n.a.	n.a.
Ba	20 ppm	1,522 ppm	74 ppm	<120 ppm
Bi	14 ppm	n.a.	1,506 ppm	n.a.
Cr	<4 ppm	<10 ppm	252 ppm	<12 ppm
Cu	19 ppm	2,052 ppm	61 ppm	559 ppm
Mo	591 ppm	5,846 ppm	562 ppm	1,906 ppm
Nb	171 ppm	5,756 ppm	11,796 ppm	6,675 ppm
Pb	93 ppm	n.a.	153 ppm	n.a.
Rb	870 ppm	74 ppm	32 ppm	41 ppm
Sn	205 ppm	1,068 ppm	450 ppm	672 ppm
Ta	117 ppm	<28 ppm	n.a.	n.a.
Th	24 ppm	n.a.	<17 ppm	n.a.
U	10 ppm	47 ppm	85 ppm	46 ppm
V	<6 ppm	123 ppm	54 ppm	<20 ppm
W	4,398 ppm	45.99 % [4)]	59.17 % [4)]	52.66 % [4)]
Zn	191 ppm	n.a.	982 ppm	n.a.
Zr	52 ppm	170 ppm	51 ppm	68 ppm
Calculated				
WO_3	5,546 ppm	58.00 %	74.62 %	66.41 %

[1)] Mechanical processing in a pilot plant at Yeguzer by crushers and shaking tables [2)] Mechanical processing at BGR laboratory with shaking table and pan [3)] Mechanical processing of concentrates from the pilot plant using high density liquid at BGR [4)] Wet chemical analysis; n.a. = not available

Table 77: Chemical composition of beryl ore (with visible beryl) from the Yeguzer W-Mo-Be deposit (XRF analysis).

Chemistry	**Beryl ore**
	wt.-% / ppm
SiO_2	72.83
TiO_2	0.03
Al_2O_3	11.30
Fe_2O_3 total	2.02
MnO	0.05
MgO	0.08
CaO	1.81
Na_2O	0.10
K_2O	0.32
P_2O_5	0.02
(F)	1.22
LOI	1.58
Sum	91.36
(As)	286 ppm
Be [1)]	2.89 %
Ce	117 ppm
Cs	573 ppm
Mo	61 ppm
Pb	203 ppm
Rb	137 ppm
Sc	102 ppm
Th	25 ppm
U	<3 ppm
Y	132 ppm
W	49 ppm
Zn	391 ppm
Calculated	
BeO	8.02 %

[1)] by ICP-OES

Mineralogy (XRD): Beryl and quartz with traces of muscovite-illite

As of 2008, the Mongolian company Enguical CO. LTD. has held a 79-hectare licence covering the deposit. The company started processing old mine dumps which have an average WO_3 content of at least 2 %. The small treatment plant was equipped with a jaw crusher, four cone crushers and a shaking table (cf. Figure 119). Analysis of wolframite obtained in test runs and other samples from the Yeguzer deposit are given in Table 76. The analytical results of the processed ore show that in 2008 the treatment was not optimally set up and the quality of the concentrate could be significantly improved. An elevated U-content was not found.

On behalf of Enguical CO. LTD, an Austrian consulting firm was engaged to prepare a feasibility study by the end of 2008 on the establishment of an open pit, based on the historical exploration results. For a proposed joint venture, the Mongolian MCS CO. LTD has already agreed to place an investment of 20 million US-$ for the establishment of an open pit. The name of the joint venture is "Biluut mining Company".

The Yeguzer deposit, which is already classified by the Mongolian government as a "strategic deposit", boasts significant resource potential for tungsten, molybdenum and beryllium. The project is already well developed and, regarding infrastructure developments, could benefit from the planned railway line between Baruun Urt and China.

The **Tov (Zentr)** deposit is located close to the Yeguzer deposit and comprises 38 greisen ore bodies of 20-480 m length, 1-20 m thickness and about 100-250 m depth. Another 40 lenticular bodies of 60-120 m length, but only 1-2 m thickness, were discovered during trenching in historic times. The main ore minerals are disseminated wolframite, scheelite, beryl, cassiterite and molybdenite accompanied by minor sulphides.

Based on prospecting, trenching and drilling in the late 1970s, the reserve estimates in 1980/82 were 3.8 million tonnes of greisen ore. The grade of a 3 tonne test sample for processing was 0.06 % WO_3, 0.2 % BeO and 0.08 % Sn. The average grades in category C2 were estimated as around 0.13 % WO_3, 0.14 % BeO, 0.04 % Sn and 0.015 % Mo. The total calculated reserves are 5,340 tonnes of BeO, 4,990 tonnes of WO_3, 1,360 tonnes of

Sn, and 530 tonnes of Mo. These grades and tonnages are generally too low for mining. However, if the Yeguzer greisen deposit were to be mined in future, additional exploration should be carried out at the Tov deposit to potentially increase its reserves base.

Similar deposits are located 40 km NE of the Yeguzer deposit. This area includes the **Ar Bayan** and **Ovor Bayan** deposits and the **Bayan Uul** occurrence, and covers 6 km^2. Twenty up to 120-500 m long trenches were dug, and twelve boreholes were sunk, at 100-150 m spacing. Mineralisation is confined to greisen and stockwork zones within Late Triassic-Early Jurassic granites. The stockwork mineralisation grades 0.18 % WO_3 with minor amounts of Be, Sn, Pb, Li and Ag. Elevated Mo grades of 0.03 % may also be of interest. The ore bodies are 4-40 m thick and up to 250 m long but not well defined. The calculated category C2 resources are around 8.3 million tonnes of ore at 0.19 % WO_3, with additional category P1 resources of around 1.2 million tonnes of ore at 0.16 % WO_3. The total WO_3 resources in categories C2 and P1 are 18,900 tonnes. Of these, Bayan Uul contains 2,195 tonnes of WO_3 and 2,919 tonnes of Mo. A further review of old reports and field work is recommended, however, the grades are very low.

The **Batguj** (Bat Gun, Batguai) wolframite-molybdenite deposit lies about 8 km NE of Yeguzer. According to the deposit passport, two veins of 20-60 m length may contain resources of 150 tonnes of WO_3. Some greisen mineralisation was identified, but the occurrence has not been studied in detail yet.

The remote **Omnod** tungsten deposit lies about 70 km ENE of Erdenetsagaan, close to the Chinese border. This deposit was drilled and sampled in 1954/55 and was not regarded as economic. Tungsten mineralisation is related to shear and greisen zones and occurs in 15 quartz-wolframite veins (minor molybdenite) with a length of up to 60 m, an estimated depth of up to 60 m and a WO_3 content of 0.14-0.54 %. According to the deposit passport, the estimated reserves are only 18.4 tonnes of WO_3. Other information suggests resources of 164 tonnes of WO_3. Currently this deposit seems to be too small for mining.

Nucht/Uvurbayan

During a visit in early summer 2008, the Nucht/Uvurbayan Mo-W-Sn-deposit was being developed by a Chinese-Mongolian company. The deposit (46° 02' 24.7" N , 115° 46' 25.3" E; 1,112 m a msl) is located 36 km from Yeguzer. The vein type deposit was explored in 2006 and 2007.

In 2006, two 120 m deep shafts were sunk (cf. Figure 121). According to local workers as of 2008, the production of a high grade ore containing an estimated grade of ore minerals of 5 %, was about 30 tonnes per hour. The ore partly contains massive molybdenite and pyrite as well as wolframite, cassiterite, and galena (cf. Table 78). The reserves are 1,788,500 tonnes of ore at 0.22 % Mo (4,030 t Mo, B1+B2) and

Figure 121: View of Nucht polymetallic mine in 2008

Figure 122: Flotation line as part of the processing facility near Nucht polymetallic deposit.

Table 78: Chemical composition of flotation concentrates from the Nucht/Uvurbayan polymetallic deposit, as well as of wolframite concentrates processed at BGR from the Nucht/Uvurbayan and Salaa wolframite deposits (XRF analysis).

Chemistry	Nucht/Uvurbayan		Salaa
	Flotation test conzentrate	**Wolframite concentrate of ore samples [1)]**	
	wt.-% / ppm		
SiO_2	1.63	2.04	12.10
TiO_2	0.04	0.01	0.02
Al_2O_3	0.20	0.22	<0.05
Fe_2O_3 total	4.35	3.95	7.65
MnO	<0.001	20.15	14.36
MgO	<0.01	0.09	0.15
CaO	0.09	0.04	0.15
Na_2O	<0.01	<0.01	<0.01
K_2O	0.04	0.01	0.02
P_2O_5	<0.001	0.06	0.05
(SO_3)	7.86	0.03	0.03
(Cl)	0.24	0.03	0.03
LOI	12.80	0.46	0.08
Sum	*27.27*	*27.11*	*34.67*
(As)	<30 ppm	n.a.	n.a.
Bi	1.63 %	n.a.	n.a.
Cr	<11 ppm	93 ppm	<13 ppm
Cu	1.55 %	230 ppm	<18 ppm
Mo	21.50 %	131 ppm	637 ppm
Nb	<15 ppm	2,754 ppm	3,277 ppm
Pb	24.02 %	n.a.	199 ppm
Sb	1,355 ppm	<21 ppm	<20 ppm
Sc	<2 ppm	453 ppm	44 ppm
Sn	1,621 ppm	75 ppm	<10 ppm
Ta	<14 ppm	82 ppm	79 ppm
Th	286 ppm	n.a.	n.a.
U	138 ppm	62 ppm	78 ppm
W [1)]	251 ppm	57.63 % [2)]	52.11 % [2)]
Y	115 ppm	222 ppm	135 ppm
Zn	8.29 %	479 ppm	76 ppm
Zr	53 ppm	19 ppm	33 ppm
Calculated			
WO_3	316 ppm	72.68 %	65.72 %

[1)] mechanical processing at laboratory scale [2)] wet chemical analysis, n.a.= not available

2,512,500 tonnes of ore at 0.21 % Mo (5,260 t Mo, C1). A total mine lifetime of 7 years was proposed.

In 2007, a dressing plant (46° 03' 08.6" N , 115° 43' 58.2" E; 1,071 m a msl) was built about 3 km away. According to the local workforce in 2008, the plant was still in the testing phase. It consisted of crushers, two ball mills and two flotation lines with 12 cells each (cf. Figure 122). About 60 Mongolian and 30 Chinese workers were working at the mine. No information could be obtained about the size, the reserves situation or other specific deposit parameters.

An analysis of the flotation test concentrate gave grades of 24.0 % Pb, 21.5 % Mo, 8.3 % Zn, 1.6 % Bi, and minor amounts of Cu, Sb and Sn (cf. Table 78). Wolframite was removed separately. The wolframite from ore samples shows increased contents of niobium while the uranium content is low. The produced concentrate will probably be exported to China.

Salaa

Between 1966 and 1970, the Salaa wolframite deposit (46° 48' 43.8" N , 113° 25' 35.1" E) was explored for the first time in detail by a Mongolian-Hungarian expedition. The deposit is located 8.5 km east of the town of Baruun-Urt. In 1981, two further exploration campaigns followed, namely the Dornot expedition, where some 5,000 metres of drilling was done, and the Dornot-Salaa expedition, where almost 1,700 m trenching was carried out.

Of the twelve quartz-wolframite veins at Salaa, at least three were completely mined out. MRAM even assumes that the deposit is almost completely mined out. Initial category C1+C2 resources were calculated as 103,442

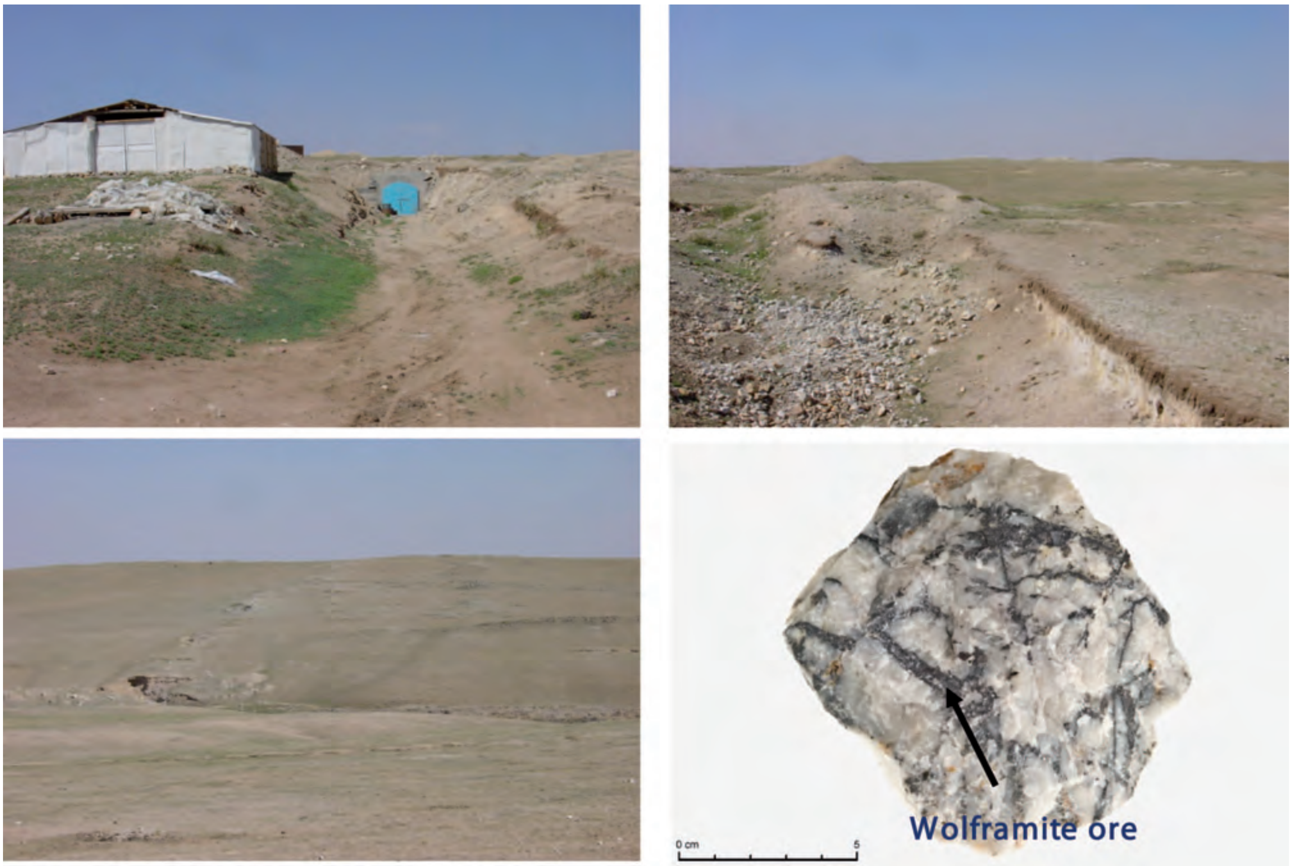


Figure 123: Impressions of the Salaa deposit: Former adit (upper left), quartz-wolframite vein outcrops (upper right and lower left), typical wolframite ore sample (lower right).

tonnes of ore with 1,385 tonnes (other sources: 2,287 tonnes) of net WO_3.

The pneumatolytic quartz-wolframite veins at Salaa occur in leucocratic porphyritic granite of Triassic age. In addition to wolframite, there is also tungstite, molybdenite, scheelite, pyrite and chalcopyrite. During a visit in 2008, three veins were examined which apparently have low wolframite grades (significantly <1 %). The veins were originally mined through a main adit and the ore was processed nearby.
The veins were 200-500 m long and 0.1 to 3.6 m thick (cf. Figure 123). Half of the reserves were bound to a 400 m long, 0.1-1.5 m thick and 120 m deep vein. The ore had an average grade of 1.34 % WO_3; the cut-off grade was 0.13 % WO_3 (marginal reserves) and 0.4 % WO_3 (industrial reserves); the minimum thickness was 0.8 m.

Gravitational tests yielded enrichment to 30-40 % WO_3 (70-75 % recovery), flotation concentrates had an enrichment of 65 % WO_3 (90-95 % recovery). Wolframite samples analysed at BGR show elevated Nb contents with the U levels again being low.
A resumption of mining operations does not appear useful without more detailed knowledge of the remaining reserves and the exploration of new reserves close by. A reassessment of the area by modern geophysical methods may be adviseable.

Ondor Tsagaan

The Ondor Tsagaan wolframite-molybdenite-beryl deposet lies in Khentii Aimag (47° 52' 37.3" N , 110° 10' 43.9" E; 1,488 m a msl) and is the largest wolframite deposit in Mongolia. It is located 80 km NW of Ondorkhaan town and was mapped between 1978 and 1979. Detailed geological mapping was accompanied by geophysical studies. Exploration was done using a number of several hundred metre long, several metre wide and deep trenches (55,355 m^3 of excavations). A total of 15,386 m were drilled (percussion drilling) and adits were driven.

Table 79: Chemical composition (in wt.-% or ppm) of wolframite concentrate from the Ondor Tsagaan wolframite-molybdenite-beryl occurrence, laboratory scale processing at BGR (XRF analysis).

Chemistry	Wolframite concentrate (Laboratory scale)
SiO_2	8.63
TiO_2	1.40
Al_2O_3	0.36
Fe_2O_3 total	16.82
MnO	4.64
MgO	0.25
CaO	2.49
Na_2O	<0.01
K_2O	0.15
P_2O_5	0.17
(SO_3)	0.05
LOI	-0.60
Sum	34.43
Ba	40 ppm
Bi	n.a.
Ce	477 ppm
La	133 ppm
Mo	706 ppm
Nb	395 ppm
Nd	241 ppm
Pb	n.a.
Sb	310 ppm
Sn	431 ppm
Sr	<9 ppm
Ta	<34 ppm
Th	n.a.
U	24 ppm
W	53.74 % [1)]
Zn	56 ppm
Zr	76 ppm
Calculated	
WO_3	67.77 %

[1)] Wet chemical analysis

Figure 124: Typical samples of wolframite-molybdenite-bearing stockwork mineralisation from dumps near the two adits at Ondor Tsagaan.

Between 1983 and 1984 the deposit was evaluated by a Bulgarian-Mongolian expedition.

Based on exploration at that time, comprehensive reserve estimates were carried out for the 1800-1900 m long, 600-800 m wide and 550-600 m thick ore body. According to these results the occurrence contains more than 140 million tonnes of ore (C1+C2) with a content of 175,102 tonnes of WO_3, 26,175 tonnes of Mo as well as beryl and bismuth (cf. Table 80). A cut-off grade of 0.10 % WO_3 was used for the calculations. In dressing tests in Mongolia, Bulgaria and the former Czechoslovakia, the recovery was 65-79 % for WO_3 (gravimetric), 74-84 % for Mo, 40-67 % for BeO (flotation) and 73-84 % for Bi (from sulphide concentrate). The ore also carries 0.07 % Li, 0.13 % Rb, 0.009 % Cs and 0.03 % Cu. A recent feasibility study basically confirms these net reserves data for WO_3, BeO, and Bi, but comes to almost double the amount for Mo (Table 80). The total estimated investment including plant and infrastructure would be around 300 million US-$.

The Ondor Tsagaan occurrence is characterised by stockwork and greisen mineralisation within metamorphic sedimentary rocks, gabbro and diabase of the Lower Devonian and Mesozoic granites of the South-Khentii block. Ore minerals comprise wolframite (mainly ferberite), scheelite, molybdenite, bismuth, beryl and fluorite.

The Ondor Tsagaan area is divided into several licence blocks held by different owners in 2008. The central mining licence, essential for establishing an open pit, was held by QGX LTD. According to a press release in April 2008, the first dressing tests of the ore were completed successfully. A recovery of 70 % WO_3 and a concentrate grade of 65 % WO_3 and higher was achieved using a grain size of 120 microns. For molybdenite recovery, flotation was recommended. In a next step, dressing tests on a larger scale were suggested. According to MRAM, QGX LTD submitted a feasibility study in May 2008 which included revised ore reserves calculations.

During a visit in 2008, the remains of the extensive exploration activities of the 1970's and 80's were observed (cf. Figure 125). Dumps in front of two adits carry metasediment-hosted ore samples with ample stockwork mineralisation (cf. Figure 124). Quartz-wolframite veins and stockwork samples contain wolframite and molybdenite grains of several millimetres in size and additional fluorite and beryl.

In general, the occurrence appears to be well explored according to old exploration reports and current field observations. Because of the high reserves, the occurrence could well be of economic interest despite the low grades. Therefore, Ondor Tsagaan was upgraded to a deposit by MRAM. However, the licence ownership situation could be a problem for mining. Due to its remote location, the investments for mining, processing and infrastructure will be very large.

Table 80: Reserves of the Ondor Tsagaan wolframite-molybdenite-beryl occurrence according to the Bulgarian-Mongolian expedition of 1983-1984.

	C1	C2	C1+C2	P1
Ore reserves [1,000 tonnes]	**24,659**	**116,335**	**140,994**	**60,000**
Grade (wt.-%)				
WO_3	0.125	0.124	0.124	0.11
Mo	0.019	0.018	0.019	0.03
BeO	0.028	0.032	0.031	0.03
Bi	0.013	0.006	0.008	0.01
W equiv.	0.167	0.167	0.165	-
Content [tonnes]				
WO_3	30,913	144,189	175,102	-
Mo	4,752	21,423	26,175	-
BeO	6,839	37,074	43,913	-
Bi	3,142	9,909	13,051	-
Reserves estimate as of 2008 by QGX Ltd.				
Reserves	134,6 Mio. t @ 1.27 % WO_3; 170,993 t WO_3			
	48,470 t Mo @ 0,036 % Mo			
	43,350 t Be @ 0,03 % BeO			
	13,460 t Bi @ 0,01 % Bi			

Figure 125: Dumps in front of two exploration sites (adits) at the Ondor Tsagaan wolframite-molybdenite-beryl occurrence and remaining trenches of former exploration activities.

Tsagaan Davaa

The wolframite mine (48° 11' 15.5" N , 106° 06' 27.0" E; 1,392 m a msl) at Tsagaan Davaa lies about 100 km north-west of Ulaanbaatar in Tuv Aimag, and went into production in 1978 after extensive exploration by Hungarian state geologists between 1969 and 1973. The main quartz-wolframite vein originally had an extension of 470 m length and 490 m depth with an average thickness of 1.4 m. Two further veins of 80 m and 175 m length with a depth of 90 m were discovered during exploration of the deposit. The initial reserves were calculated as 3,139 tonnes of WO_3 in ore grading 1.52 % WO_3 and 738 tonnes of WO_3 in ore grading 0.72 % WO_3.

After some years of standstill, mining activities resumed in 1993 by MONGOLMINMETAL LTD. The mine has been owned by Mongolian MONWOLFRAM LLC since 2003. Altogether in the last 30 years about 3,000 tonnes of wolframite concentrate were produced. According to the latest ore reserves calculation, another 1,000 tonnes of wolframite concentrate will be available for mining. In 2008, MONWOLFRAM LLC assumed a remaining lifetime for the mine of 5-6 years.

The mine is accessible via a 475 m long horizontal main adit cutting granite host rocks (Figure 126). The ore is extracted from two 0.5-2 m thick, shallow dipping quartz-wolframite veins. Another quartz vein was recently discovered. During a visit in 2008, it was possible to take samples from this newly discovered vein (block 2C1, at hole 87, 13 m above the roof of the main vein) (cf. Table 82). In places the grade increases to 10 % WO_3. Besides wolframite and cassiterite, the veins carry minor quantities of scheelite and chalcopyrite, and plenty of azurite and malachite along fractures.

In 2008, the company produced between 6,000-8,000 tonnes of ore, the ore averaging 1.2 % WO_3. The average annual production amounts to 40-60 t of wolframite concentrate containing 50-68 % WO_3, and up to 18 g Ag/t and 0.9 g Au/t, for which the company achieved a price of 18,000 US-$/tonne in early 2008. Sales were to Russia and the United States. The dressing plant (48° 14' 51.9" N , 106° 11' 17.2" E; 1,188 m a msl) comprises two stages of primary crushing, a ball mill and two shaking tables. In addition the company planned to reprocess approximately 90,000 tonnes of tailings as of 2008. The company was interested in new investments for this project and for the improvement of the dressing plant. According to BGR-analysis, one strip sample (cf. Table 82, Figure 127) of the tailings contains 0.44 % WO_3 and 0.05 % cassiterite. Therefore the tailings could contain some 400 tonnes of WO_3 and 45 tonnes of cassiterite.

Table 81: Heavy mineral composition (in %) of tailings from the Tsagaan Davaa plant.

Mineralogy	Tsagaan Davaa
HM total	1.6
Magnetite	+
Ilmenite	
Leucoxene	
Cassiterite	4.5
Wolframite	8.1
Sphene	
Zircon	+
Garnet	
Sillimanite	
Tourmaline	+
Epidote	0.6
Topaz	
Mica	35.7
Fluorite	39.8 [1)]
Hornblende	0.4
Azurite	+
Quartz et al.	7.7
Total	100.0

[1)] confirmed by scanning electron microscope analysis

Table 82: Chemical composition of tailings material and of a separated heavy mineral concentrate from the Tsagaan Davaa tailings dump, as well as a separated wolframite concentrate from quartz-wolframite vein samples from the Tsagaan Davaa mine (XRF analyses).

Chemistry	Tsagaan Davaa		
	Tailings		Wolframite
	Tailings (untreated)	Heavy mineral concentrate (produced at BGR) [1]	Concentrate (produced at BGR)
	wt.-% / ppm		
SiO_2	85.22	32.58	2.59
TiO_2	0.15	2.83	0.02
Al_2O_3	6.63	12.13	<0.05
Fe_2O_3 total	1.72	23.76	13.69
MnO	0.10	1.28	12.02
MgO	0.21	3.65	0.07
CaO	0.56	5.54	0.06
Na_2O	1.15	0.22	<0.01
K_2O	2.50	5.21	0.01
P_2O_5	0.05	0.37	0.05
(SO_3)	0.04	0.12	0.02
(F)	<0.05	0.15	0.13
LOI	2.20	5.76	-0.24
Sum	*99.28*	*93.60*	*28.50*
(As)	60 ppm	392 ppm	n.a.
Ba	201 ppm	641 ppm	474 ppm
Bi	96 ppm	1,012 ppm	n.a.
Ce	53 ppm	738 ppm	<64 ppm
Cu	314 ppm	4,835 ppm	773 ppm
Mo	25 ppm	255 ppm	<13 ppm
Nb	42 ppm	470 ppm	4,190 ppm
Pb	27 ppm	675 ppm	<16 ppm
Rb	263 ppm	1,158 ppm	33 ppm
Sn	402 ppm	1,342 ppm	362 ppm
Ta	<4 ppm	43 ppm	70 ppm
Th	19 ppm	129 ppm	n.a.
U	<3 ppm	35 ppm	58 ppm
V	12 ppm	61 ppm	90 ppm
W	3,484 ppm	3.38 %	61.48 % [2]
Zn	178 ppm	1,875 ppm	784 ppm
Zr	107 ppm	814 ppm	31 ppm
	Calculated		
WO_3	4,394 ppm	4.27 %	77.53 %

[1] Mechanical processing at laboratory scale by dense liquids [2] wet chemical analysis

Figure 126: Entrance to the adit of the Tsagaan Davaa wolframite mine.

Figure 127: Strip sampling of tailings from the Tsagaan Davaa plant.

The small but high grade Tsagaan Dava deposit definitely has good potential for further mine extension. As mentioned, a quartz-wolframite vein has recently been discovered in the hanging wall of the main vein. Intersecting smaller veins point to the complex tectonic framework of the deposit. A structural geology analysis is recommended to discover further quartz-wolframite veins. In addition, the unusually high grade of azurite and malachite in the host rocks may point to copper mineralisation at greater depth. Also a detailed study on the tungsten-tin content of the tailings dump is recommended. To generate cash flow for further exploration of the deposit, reprocessing of the tailings dump is a good option.

Ongon Khairkhan

The Ongon Khairkhan (47° 03' 00" N , 105º 10' 00" E; 1,420-1650 m a msl) deposit lies 180 km SW of Ulaanbaatar in Tuv Aimag. It was studied between the late 1960's until 1985, and consists of five ore bodies with stockwork and vein type mineralisation. The deposit is located within a Triassic and Upper Jurassic intrusive complex intruded into Middle Paleozoic sedimentary and Upper Cretaceous metamorphic rocks.

Figure 128: View of the Ikh Khairkhan tungsten deposit mined out in the 1960´s and 1970´s.

The deposit was extensively trenched and drilled in the past. The stockwork ore bodies are 200-500 m long, 40-300 m thick and 30-150 m deep (max. 300 m). Vein type ore bodies are 60-500 m long, 0.2-5 m thick and max. 20 m deep. The main ore minerals are wolframite and scheelite accompanied by minor sulphide minerals, fluorite and beryl.

The calculated resources are 7.4 million tonnes of ore grading 0.15 % WO_3 (11,136 tonnes of WO_3) (categories C1+C2) and an additional 5.3 million tonnes of ore grading 0.05-0.10 % WO_3 (3,993 t WO_3) (category C2). The total resources might reach 15,000 tonnes of WO_3. Test mining took place during a Czechoslovakian expedition in the late 80´s/early 90´s. The test pit was around 200 m x 40 m on the surface and 6 m deep and included one adit. However, the total amount of available ore and the grades are probably too low for economic tungsten mining at the current stage. Once production at Yeguzer or Ondor Tsagaan starts, pre-processed ores from Ongon Khairkhan could possibly be transported to one of these locations for further dressing.

Ikh Khairkhan

The Ikh Khairkhan deposit (46° 52’ 45” N , 105° 56’ 15.6” E; 1,360 m a msl) lies 165 km SW of Ulaanbaatar and about 30 km SE of Bayan Onjuul in Tuv Aimag. The deposit was mined underground between 1961 and 1972 after extensive exploration in the 1950´s and 1960´s.

A total of 14 ore bodies were discovered in Triassic host rocks, but only six quartz veins, 160 m to 900 m long, were regarded as economic. The major vein “4-7” is 900 m long, dips 70-80° to the NE over 550 m, and is 0.3 to 8.0 m thick. Mineralisation consists of coarse wolframite, scheelite, with minor chalcopyrite, molybdenite, tungstite, ferrotungstite, and fluorspar.

The reserves calculated in 1964/65 were about 480 tonnes of WO_3 in ore grading 1.32 % WO_3 (C1+C2) based on a cut-off grade of 0.4 % WO_3 and a minimum thickness of the vein of 0.8 m. It is probable the all the reserves have been mined out. Additionally, the mine processed ore from Ongon Khairkhan and Tsagaan Davaa so that total production increased to 1,399 tonnes of wolframite concentrate containing 60 % WO_3 (840 t WO_3). Below the 1,273 m level, some remaining 65,200 tonnes of ore containing 550 tonnes of WO_3 were estimated. However, the mine was closed in 1973. About 2008, a Chinese company started to rework the mine and probably the tailings, but during a visit in September 2010 the place was abandoned. Currently, the total amount of available ore is too low for economic tungsten mining.

Khar Chuluut

The Khar Chuluut deposit is south of Ikh Khairkhan also in Tuv Aimag (46° 51’ 32.3” N, 106° 09’ 21.6” E; 1,502 m a msl). Exploration took place in the 1960´s together with prospecting activities at Ongon Khairkhan. The prospecting trenches and boreholes cover an area of 2.65 km^2, and the trenches are still visible on site.

The deposit is located at the contact of Triassic amphibolite-biotite schists and a Jurassic granite body. Mineralisation is mainly in stockwork and greisen zones along shear zones. A total of 20 ore bodies were discovered, including six larger bodies. On the surface, their length is 46 to 321 m and the thickness varies between 0.21 m and 2.30 m. The grade varies between 0.21 % and 7.74 % WO_3, with the larger ore bodies having rather low grades. In 1964, a 26 tonne sample of the “Number 3” ore body grading 3 % WO_3 was processed yielding a recovery of 78 % and giving a wolframite concentrate grading 66 % WO_3. The category C2 resources calculated in the 1960´s are 104,900 tonnes of ore grading 0.66 % WO_3, i.e. containing about 700 tonnes of WO_3. Because of the low grade and low tonnage, the deposit is not presently regarded as economic.

Figure 129: View of the Khar Chuluut tungsten deposit with pits (front) and trenches (back) dug in the 1960´s.

Chuluun Khoroot

The Chuluun Khoroot occurrence lies 20 km north of Dashbalbar village, 250 km north of Choibalsan town, and about 60 km south of the Russian border. The deposit was mentioned in archive reports of 1943; however, major exploration was between 1950 and 1955 by "MONGOLSOVMETAL". During the exploration, three shafts and two adits were dug.

Mineralisation occurs in narrow quartz-wolframite veins within a granite stock. The main vein, which accounts for 90 % of the ore reserves, is 150-160 m long, 0.2-0.4 m thick and up to 60 m deep. The average grades are 1.36 % WO_3, 0.06 % Sn, 0.14 % Bi, and 0.05 % Mo. Wolframite clusters weigh up to 20 kg. The total calculated reserves (category B, categories C1+C2) are <500 tonnes of WO_3 with remaining reserves <300 tonnes of WO_3.

A total of 229 tonnes of WO_3 were mined up to 1955. The deposit was finally regarded as uneconomic because of high processing costs, bad transport conditions and sulphide minerals disturbing the dressing process.

WESTERN MONGOLIA

Tsunheg

The Tsunheg wolframite deposit is in Bayan-Ulgii Aimag (49° 10' 38.5" N , 90° 04' 15.9" E; 2,662 m a msl) some 29 km NE of Ulgii town. During a visit in 2009, the exploration and

Table 83: Reserve and resource estimates for the Tsunheg wolframite deposit.

Vein #	Length of ore body [m]	Thickness [m]	Grade [% WO_3]	Strike/dip [°]
71	200	0.2-0.6	3.42	20/90
72	150	0.1-3.0	3.74	40/90
73	700	0.1-0.3	2.71	17/70-85
76	800	n.a.	2.91	40/90
Old resource estimate during the 1980's				
Category C2 resources	100,400 tonnes ore at 3.38 % WO_3; 3,398 tonnes net WO_3; cut-off 0.47 % WO_3; min. thickness 0.8 m			
P1 resources	177,100 tonnes ore at 2.79 % WO_3; 4,974 tonnes net WO_3; cut-off 0.47 % WO_3; min. thickness 0.8 m			
Resource estimate as of 2006 (Baruun Mongol Metal; 2006)				
Category B reserves	80,677 tonnes ore at 2.96 % WO_3; 9,267 tonnes net WO_3; cut-off 0.24 % WO_3; min. thickness 0.8 m			
C-resources	405,137 tonnes ore at 2.29 % WO_3; 9,267 tonnes net WO_3; cut-off 0.24 % WO_3; min. thickness 0.8 m			

mining licences were held by Baruun Mongol metal. However, no major production except for some artisanal mining is recorded to date.

Tsunheg was discovered in 1974 by Mingeo Russia during the Ulgii expedition. Between 1976 and 1977, Russian geologists carried out further prospecting, followed by exploration by Mongolian geologists in 1979. A first evaluation of the deposit was done during a Mongolian geological expedition in 1983. In 1990, Russian geologists re-evaluated the deposit. During the exploration, 17 boreholes (total 3,008 m; depth?) were completed and several trenches (3,241 m^3) were dug and sampled. Between 2001 and 2005, Baruun Mongol metal carried out new reserve estimates.

The mineralisation at Tsunheg is related to a NE trending fault zone and splits off the Bayan ulgii structural belt of the Mongolian Altai fold system. The host rocks are Upper Ordovician to Lower Silurian silty schists and gabbro diabase. Wall rock alteration consists of hornfels rocks showing carbonatisation and sulfidation. The ore minerals present are wolframite and scheelite. Siderite, pyrite, chalcopyrite, chalcocite, pyrrhotite, arsenopyrite, sulfosalts and bismuth occur as accessory minerals.

A total of ten tungsten bearing quartz veins have been discovered so far. Four major veins, # 71, 72, 73, and 76, were studied in detail (Table 83). According to the old reserve estimates, the deposit contains about 3,400 tonnes of WO_3 in ore grading 3.38 % WO_3 on average. During a visit in 2009, veins # 71 and 73 were drilled by a Chinese company with vein #71 intersected at 200 m depth.

Also during the visit, wolframite veins # 71, 73, and 76 were sampled along strike. The wolframite bearing chip samples were mechanically concentrated by a pan and jig at BGR and analysed by XRF. Concentrate samples from veins # 73 and 76 have a high WO_3 grade of 73 % and contain some Nb. Additionally, the concentrate of vein # 73 contains elevated values of As, Bi, and Co. The sulphides present in the wolframite concentrate from vein #71 lead to elevated values of Cu, Mo, and Pb, while the WO_3 grade of 50 % is lower

Figure 130: Drilling rig at the Tsunheg deposit (left) and remains of artisanal mining at vein #71 (right).

compared to the concentrates from the other veins. Mechanical separation of the sulphides was not possible using the described procedure. It seems that sulphide mineralisation could be a problem for processing, although the distribution of sulphides was limited to the southern part of vein #71, only. Uranium and thorium values are low and will not cause a problem for export.

The results of a current pre-feasibility study point to a total content of more than 10,000 tonnes of WO_3 from high grade ores (Table 83). According to this study, the annual production could be 52,500 tonnes of ore and 1,000 tonnes of wolframite concentrate. Metallurgical testing points to a recovery grade of wolframite of 85 %. At this recovery grade the concentrate would contain 72 % WO_3. An increase of the recovery grade to 90 % would lower the grade to 65 % WO_3 which is still acceptable for international markets. Annual processing costs are calculated at around 2.0 million US-$, with operating costs (mining and processing) of around 1,332 US-$/tonne concentrate. The reserves and resources were confirmed by an external auditor and approved by MRAM in 2006. Thus, the Tsunheg deposit bears good potential for commercial mining.

Ulaan Uul (Kyzil Tau)

The Ulaan Uul wolframite deposit is located 50 km NE of Ulgii town (49° 13’ 41.9” N , 90° 14’ 26.8” E; 2,214 m a msl) in Bayan-Ulgii Aimag. During a visit in 2009, the mining licence was held by KainaR LLC. The mine was closed in 2008 after ten years of recorded production. Production in 2008 was some 60 tonnes of wolframite concentrate. Prospecting at Ulaan Uul started between 1974 and 1976, followed by a prospecting and evaluation campaign between 1982 and 1985. The first reserve calculations were carried out in 1986. During this period, the licence area was extensively mapped and trenched. In addition to that, exploration pits and adits were dug.

Figure 131: Ulaan Uul mine area with old trenches and mine dumps in front of an adit (center of photo).

Figure 132: Ulaan Uul mine with old crusher in front of an adit.

Figure 133: High definition satellite image of the Khovd Gol wolframite mine (Satellite image as of 7 September 2006, Altitude 744 m, Photo courtesy of Google Earth).

Table 84: Historic category C1 and C2 resource estimates for the Ulaan Uul wolframite deposit and recent results of a prefeasibility study.

Vein #	Strike/dip °	Length [m]	Thickness [m]	C1 reserves [% WO_3]	C2 reserves [% WO_3]
6th	35-40/?	240	0.29-2.0	–	1.46
7th	40/70	800	0.44	–	3.03
8th	35-40/75-80	300	0.25-2.0	–	2.61
9th	75/75	200	0.58-0.72	–	2.19
14th	40/70-75	400	0.30-0.69	–	3.42
16th	40/70	400	0.52-0.62	1.83-2.04	1.80
32th	40/75-80	700	0.36-0.71	1.89-2.03	1.89-2.30
C1 and C2 resources	C1: 1,308 t WO_3 @ 1,98 % WO_3 + 204 t @ 0.59 % WO_3; 66,100 t ore C2: 1,495 t WO_3 @ 2,10 % WO_3 + 683 t @ 1.17 % WO_3; 71,000 t ore Total: 2,803 t @ Ø 2.04 WO_3				
Resource estimate as of 2008 (Kainar LLC)					
B + C (?)	285,500 t ore @ Ø 1,1 % WO_3; 3,138 t WO_3				

The quartz-wolframite veins at Ulaan Uul occur within Upper Devonian to Carboniferous and Jurassic alaskite granite of a second intrusive suite. The granites intruded volcano-sedimentary rocks including liparites and dacites of Early Devonian age.

Wolframite grains of up to 2.5 cm in diameter mainly occur irregularly distributed in hydrothermal quartz veins. Over 100 veins and veinlets occur in the area, which is subdivided into the North-west zone (34-39 veins), the Kyzil Tau zone (34-39 veins), and the South-east zone (39-59 veins). Some of the quartz-wolframite veins are up to 2 km long and 1 m thick. 60 veins were studied in more detail, but only seven veins were considered to be of commercial interest. Mineralised zones are normally confined to a length of 200-600 m and a thickness of 0.25-0.72 m. The grades are high and range between 1.4 % and 3.4 %.

Concentrate samples (mixed sample) from artisanal miners who worked on the main vein in 2009, were analysed by XRF at BGR. The results point to a high grade wolframite concentrate containing 68 % WO_3. Compared to samples from Khovd Gol and Tsunheg, the values of uranium (up to 70 ppm), niobium (up to 0.46 %) and tantalum (up to 0.03 %), as well as As, Bi, and Cu are elevated.
The total reserves to a depth of 60 m were originally calculated as about 2,800 tonnes of WO_3 (Table 84). According to a recent pre-feasibility study, the remaining reserves are 285,500 tonnes of ore containing 3,138 tonnes of WO_3. Production is scheduled at 28,000 tonnes of ore per year resulting in about 450 tonnes of wolframite concentrate with a grade of 60 % WO_3 (recovery rate 87 %). The lifetime of the mine would be another 10 years. The deposit is therefore of commercial interest.

Khovd Gol
The Khovd Gol mine (48° 43’ 24.2” N , 88° 50’ 11.5” E; 1984 m a msl) lies some 100 km west-south-west of Ulgii town and was the only operating wolframite mine in Western Mongolia in 2009. By car it is accessible on a dirt road, and in winter time on a frozen river. In 2009, the exploration and mining licences were held by CC Mongolia LTD. Khovd Gol is famous for its extensive high grade wolframite veins containing from 5 to 30 % WO_3. During a visit in 2009, it was not possible to go underground. However, high grade samples were provided by artisanal miners who produced wolframite concentrate from ore from the mine at the nearby river.

The Khovd Gol wolframite deposit was discovered in 1980. Early prospecting followed in the periods 1982 to 1984 and 1987 to 1989. The latter prospecting campaign was led by Russian geologists involved in the Ulaan Uul expedition. A total of 467 m of core drilling was carried out, in addition to extensive trenching, sampling and 4.5 km of geomagnetic and geoelectric surveying. Open pit and underground mine production started in 1986 by the Ulaan Uul Company, followed by Kainar Wolfram in 1990. The current mining company CC Mongolia LTD. is owned by US investors. Mineralisation is related to wolframite bearing hydrothermal quartz veins which occur along thrust zones of the Tsagaan gol granite massif. The country rocks are Upper Cambrian to Lower Devonian siltstones and sandstones, which were intruded by the granite suite (plagiogranite, granodiorite, quartz diorite). The deposit is located between the Altai and Tolbo Lake deep faults which belong to the Mongolian-Altai fold belt as part of the Mongolian-Altai metallogenic province.

A total of 23 ore bearing zones have been discovered so far. The largest ore bodies have thicknesses of 450 m (vein #22), 1 km (veins #13 and 22) and 2 km (vein #19) long and 0.1-1.0 m. Other veins are generally less than 250 m long and 0.1-0.5 m thick. The main veins are shallow dipping to the NE (20-35°) and can be followed to a depth of up to 280 m. Minor amounts of antimony minerals, scheelite and carbonate minerals were recorded.

Figure 134: View of the Khovd Gol wolframite deposit (centre of photo) with mine buildings (white) in 2009.

Figure 135: Inclined shaft at the Khovd Gol wolframite mine.

Table 85: Selected chemistry (wt.-% or ppm) of wolframite from concentrate, vein samples and tailings from tungsten deposits in Bayan-Ulgii Aimag, Western Mongolia (wolframite concentrate from ninjas[1)], at BGR, mechanically concentrated wolframite from vein samples[2)], and tailings[3)]. XRF analysis by BGR.

	Ulaan Uuul		**Tsunheg**			**Khovd Gol**			
wt.-%	Conc.[1)]	Vein[2)]	Vein #71[2)]	Vein #73[2)]	Vein #76[2)]	Vein (bulk)[2)]	Conc.[1)]	Tail.[1)]	Vein.[2)]
SiO_2	4.81	0.35	1.35	1.58	0.94	28.50	12.09	82.00	2.37
TiO_2	0.04	0.05	0.03	0.02	0.02	0.04	0.07	0.14	0.03
Al_2O_3	0.78	<0.05	0.06	0.07	0.09	0.42	0.62	4.17	0.06
Fe_2O_3 total	20.17	18.25	26.30	21.12	14.44	19.30	27.36	3.68	25.77
MnO	4.70	4.63	3.69	2.90	6.62	0.45	0.85	0.11	0.98
MgO	<0.01	0.10	1.13	0.11	0.11	<0.01	0.34	0.31	0.18
CaO	0.75	2.75	6.69	2.28	4.02	0.54	2.55	1.67	0.24
Na_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.27	<0.01
K_2O	0.26	0.04	0.02	0.08	0.01	0.05	0.08	0.51	0.03
P_2O_5	0.05	0.06	0.04	0.06	0.05	0.04	0.06	0.06	0.05
SO_3	0.05	0.05	0.04	0.05	0.05	0.03	0.04	0.02	0.05
LOI	-0.64	-1.00	8.20	-1.10	-0.33	-0.58	1.40	2.50	-1.67
Sum	*31.02*	*25.36*	*37.56*	*27.22*	*26.05*	*48.84*	*45.58*	*95.47*	*28.13*
					ppm				
(As)	**253**	24	53	**219**	<7	5	59	43	<7
Ba	<11	<12	<10	13	33	120	393	125	16
Bi	920	213	389	115	37	<13	<14	<3	47
Cu	119	<13	**1.20 %**	<19	47	26	346	64	39
Mo	<12	<13	**302**	<13	<13	<9	149	23	<12
Nb	**2,776**	**4,674**	29	343	**787**	120	54	8	31
Pb	98	54	72	<16	<16	52	<12	4	<15
Rb	98	46	40	56	66	52	43	30	68
Sb	25	<20	<19	<19	<20	106	392	161	<19
Sn	320	31	16	<10	<10	<7	<7	<4	<9
Ta	215	321	<30	<36	<36	<25	<27	<6	<35
Th	<18	<19	<16	<19	<19	16	<14	<4	<18
U	55	70	35	43	33	43	36	7	32
V	81	91	72	72	82	137	193	31	165
W (%)	**54.19**	**58.46**	**40.15**	**57.62**	**58.42**	**40.52**	**42.86**	**3.46**	**57.00**
Zn	61	92	39	87	58	74	142	20	73
Zr	38	38	<13	<15	16	<11	19	43	<15
					Calculated				
WO_3 (%)	**68.34**	**73.72**	**50.63**	**72.66**	**73.67**	**51.09**	**54.05**	**4.36**	**71.88**

Historically, elevated gold grades between 0.2 and 6.0 ppm in single samples have been reported, one sample contained 94 ppm gold. According to CC MONGOLIA, and based on assay results by A.H. KNIGHT, gold has not been detected in concentrates produced to date.

Historic resource estimates came up with 32,668 tonnes of ore at 19.26 % WO_3 (6,206 tonnes W metal) (C2) and 14,788 tonnes of ore at 14.44 % WO_3 (2,135 tonnes W metal) (P2). The grades of veins # 1-4 and #8 varied between 5.1 and 30.6 % WO_3. Considering that cut-off grades of 3.3 % WO_3 for C2 resource calculations and 2.65 % WO_3 for P1 resource calculations were applied, the resources under the current economic conditions, i.e. at much lower grades, would have been much higher. The grade of the concentrate was 62.9-71.3 % WO_3 and the recovery grade for wolframite was 67.9 %.

Between 1986 and 2008, the total recorded production at the Khovd Gol mine was 5,928 tonnes of ore containing 940 tonnes of WO_3. In 2008, the reserve estimates in category B were 48,070 tonnes of ore containing 4,736 tonnes of WO_3, and in category C 16,850 tonnes of ore containing 1,107 tonnes of WO_3, both calculated with an average grade of the veins of 10 % WO_3 (!). The calculations were based on a cut-off grade of 0.3-0.5 % WO_3 and an average thickness of the vein of 0.28 m.

According to CC MONGOLIA, mine production in 2008 was 80 tonnes of concentrate with a grade of 69.9 % WO_3. The grade of the mined vein was 10 % WO_3. Planned production is 200-300 tonnes of concentrate per year giving a lifetime for the mine of 11 years. A new beneficiation plant was scheduled to be built in 2010. In addition to that, about 3,000-5,000 tonnes of tailings which contain 3.5 % WO_3 will be processed in future. A grab sample of the tailings provided by CC MONGOLIA during the visit in 2009 contained 4.36 % WO_3.

The results of the BGR analysis show that the wolframite concentrate, which was mechanically concentrated from vein samples at BGR, is high grade containing 73 % WO_3. Uranium and thorium values are low. According to the mineralogical analysis, the wolframite concentrate produced by ninjas from the tailings dump of the Khovd Gol plant contains some 79.2 % heavy minerals. These are made up of 71 % wolframite, 29 % wolframite intergrown with quartz, and traces of epidote and carbonates. Khovd Gol is probably the most interesting small-scale but high-grade wolframite mine in Mongolia. According to exploration results by CC MONGOLIA, there also seems to be potential for discovering new veins in the area.

Nuuryn Gol

The Nuuryn Gol wolframite occurrence is located 130 km west of Ulgii town near the Russian border. In 2009, the licence was held by KAINAR LLC.

Prospecting at Nuuryn Gol started in 1952 by Russian geologists, followed by a Kazakh campaign in 1971. The licence area was extensively mapped, trenched and sampled during prospecting and exploration. Between 2006 and 2007, KAINAR LLC drove a 114 m long adit and 162 m stopes into the mountain and sampled the ore body as well as placer material.

The occurrence lies in Middle to Upper Ordovician siltstones and sandstones. It is structurally controlled and located within the Mongolian Altai folded province as part of the Mongolian Altai metallogenic zone.

Two mineralized zones were identified: the longest zone is 700 m long and 50 m thick, and a second zone is 400 m long and 20 m thick. Within these zones about 100 quartz-wolframite veins and stockworks were found, of which ten veins were of further interest. These ten veins are 30 to 240 m long, 0.03 to 0.60 m thick and dip 75-90° W. The ore minerals present are wolframite and scheelite; accessories are molybdenite and other sulphide minerals, as well as beryl and fluorite. Estimated resources of the ten veins in 1952 were 790 tonnes (W or WO_3?) at an average grade of 1.38 % WO_3. Calculated resources in 1971 of the main ore zone were 3,400 tonnes of WO_3 (category P1). The resources of the ore zone in total including the vein and stockwork zone calculated for a depth of 100 m in 1971 were 5,000-6,000 tonnes of WO_3 at an average grade of 0.3 % WO_3. More recent exploration by KAINAR LLC came up with 32,000 tonnes of ore grading 1.82 % WO_3 on average, i.e. a total content of about 600 tonnes of WO_3. Additional placer material in the area contains 30 g wolframite/m^3 and 10 g scheelite/m^3 and even more in places.

Currently, the size and grade of the whole stockwork zone seems to be small for an open pit mine. The occurrence could be developed as a small scale vein type mine although the reserves seem to be limited at the present exploration stage. Placer material however could generate some initial cash flow. Considering the presence of a large vein and stockwork zone, further exploration and drilling is recommended.

FURTHER DEPOSITS/OCCURRENCES OF TUNGSTEN IN MONGOLIA

In addition to the tungsten deposits and important occurrences described above, about 100 other tungsten occurrences are listed in the MRAM database. An examination of this database showed that no further deposits/occurrences seem to be of economic interest. Most data on occurrences pointing to resources >1,000 tonnes of net WO_3 are either:

i) low grade/low tonnage, e.g. Achit Nuur (0.01-0.3 % WO_3) or Zuun Tsengel (0.1-0.2 % WO_3);
ii) an error based on confusion between data for ore quantity and WO_3 content, e.g. Buraat; or
iii) an error based on confusion of archive summary data indicating “Thousand tonnes” instead of “Tonnes” of WO_3 resources, e.g. Udav and Achit Nuur; or
iv) calculated as category P, P2 or P3 with subeconomic grades <0.5 % WO_3 and partly low tonnages, e.g. Zadgai Bulag (P), Field (Kheseg)-I (P3), Ukhaa (P2), Mushguu (P2-P3), Zuun Tsengel (P3), Khuiten Salaa Gol (P2)
v) some locations defined as deposits with C1 and C2 reserves do not have economic potential because of their low grade and tonnage, e.g. Narangyn Gol, Baruun (cf. Table 74).

In addition to this, some deposits are regarded as mined out, e.g. Burentsogt or Ikh Khairkhan, with low quantities remaining, suitable for small scale mining only. Other deposits, e.g. Chuluun Khoroot or Tumentsogt, are too small even for small scale mining.
The results of the archive research, focusing on occurences which could not be inspected, were basically confirmed by Prof. emerit. Dr. S. DANDAR of the Mongolian University of Science & Technology, who visited most of the listed locations.

REQUIREMENTS AND EVALUATION

Table 86 compiles international specifications for the chemical composition of scheelite and wolframite concentrates. Higher Sn and Mo contents in particular are undesirable, as are various sulphide minerals. Where sulphide minerals occur in vein type deposits, these areas should be avoided during mining, e.g. at Tsunheg. If sulphide minerals are present or cannot be avoided by selected mining, they have to be separated by flotation which increases the processing costs.

Table 86: International specifications for the chemical composition (in %) of scheelite and wolframite concentrates according to ANONYMOUS (1986) as well as LI & WANG (1955).

	Wolframite			Scheelite		
	General	Grade I	Grade II	General	Grade I	Grade II
WO_3	65.00-70.00	≥65	60-64.99	60.00-70.00	≥70	65-69.99[1)]
Sn	1.00-1.50	0.20-1.00	≤2.5	≤0.1		
As	0.10-0.25	≤0.20	≤0.4	≤0.10	≤0.3	
Cu	≤0.10	0.08-0.40	≤1.0	≤0.10	–	
Mo	0.04-0.40	≤0.40	≤1.0	0.05-0.40	≤2.0	≤4.0
P	0-05-0.10	0.03-0.08	≤0.25	0.05-0.10	≤0.1	
S	0.10-0.50	0.20-0.75	≤2.00	≤0.5		
Bi	≤1.00			0.05-1.00		
Sb	≤0.50	–		≤0.05	≤0.2	
Mn	0.00			≤1.00		

1) Lower Grade scheelite ores are usually converted into artificial scheelite direct at the mine or later into ammonium paratungstate, an important intermediate product of the synthesis of tungsten.

In addition to these parameters, the radioactive content of concentrates for export must be very low. All samples of wolframite/scheelite concentrates taken during the BGR-MRAM field trips had low uranium and thorium values. Therefore all concentrates will be acceptable for transport by international freight agencies.

There are no specifications on the grain size distributions of wolframite and scheelite concentrates, but normally the grain size of concentrates for metallurgical applications should be 1-2 mm. Some problems with low grain sizes were encountered at the Khujkhaan placer deposit (cf. chapter Tin). Small grain sizes of wolframite/scheelite also occur in tailings. Concentrates with small grain sizes could be sold to the chemical industry (e.g. tailings at Tsagaan Davaa or Burentsogt).

Producers and buyers often agree on customized specifications for wolframite or scheelite concentrates. Generally, wolframite or scheelite concentrates should grade >60 % WO_3. The analysed wolframite concentrate samples from various tungsten deposits in Mongolia, taken during the field trips or produced at BGR, had high WO_3 grades (>65 %), which is acceptable for export.

According to international classification after ZHU XUN (2002) and PETROW et al. (2008), all tungsten deposits in Mongolia can be classified as small (<10,000 tonnes WO_3), except for the Yeguzer (medium), Ongon Khairkhan (medium) and Ondor Tsagaan (large) deposits.

Table 87: Classification of tungsten deposits: according to the National Mineral Reserves Commission of China: Standards for Size Classification of Mineral Deposits (ZHU XUN 2002) and according to the Russian classification system by PETROW et al. (2008).

Size of deposit	WO_3 content after ZHU XUN (2002) (t)	W content after PETROW et al. (2008) (t)
Small	<10,000	<10,000
Medium	10,000-50,000	10,000-100,00
Large	>50,000	>100,00

Table 88: Size of tungsten deposits in Mongolia according to the classification after ZHU XUN, 2002.

Size of deposit	Typical size in Mongolia [WO_3*]	Examples
small	<300 t	Several occurences in Mongolia
small	300-1,000 t	Nuuryn Gol, Tsagaan Davaa, Burentsogt, Ikh Khairkhan, Khar Chuluut
small	1,000-3,000 t	Khujkhaan**
small	3,000-10,000 t	Khovd Gol, Ulaan Uul, Tsunheg
medium	10,000-50,000 t	Yeguzer, Ongon Khairkhan
large	>50,000 t	O´ndor Tsagaan

* extractable WO_3; **cf. Tin

Because Mongolia hosts several very small (i.e. <1000 t WO_3 or even <300 t WO_3) tungsten deposits, applied small scale mining techniques or cooperative/artisanal mining, organised in a socially and environmentally friendly way, could be introduced and promoted. Small but probably economic tungsten deposits currently not in production are Ulaan Uul, Tsunheg, and Nuuryn Gol. These deposits especially should be promoted. Although some deposits are regarded as mined out, e.g. Burentsogt or Ikh Khairkhan, low quantities are left for small scale mining. Other deposits, e.g. Chuluun Khoroot or Tumentsogt, may also be of interest for very small scale mining.

Yeguzer provides an opportunity to link other deposits and occurrences in the area e.g. Ar Bayan and Zentr, into a potential production center near Erdenetsagaan to increase the total available tonnage. Feasibility studies should take this into account as well as the economics of the mineable byproducts beryllium and molybdenum.

Ongon Khairkhan is a medium scale deposit and posesses reserves and resources of about 15,000 tonnes of WO_3 (medium). However, the grades are even lower than at Yeguzer, and mining and processing is most probabably not economic at current tungsten prices. Once production at Yeguzer or Ondor Tsagaan starts however, pre-processed ores from Ongon Khairkhan could possibly be transported to one of these locations for further dressing.

Ondor Tsagaan is the largest tungsten deposit in Mongolia, and could become a world class tungsten and beryllium deposit. It is a low grade but high tonnage deposit which contains the mineable byproducts beryllium, molybdenum, as well as tin. Feasibility studies have to take into account the lack of infrastructure and the current licence situation on site.

For reasons of comparison and to allow better evaluation, a grade-tonnage diagram of global tungsten deposits was prepared, also showing some Mongolian deposits (Figure 136). Due to lack of data, Chinese tungsten deposits are not shown despite the fact that they contribute almost 80 % of global tungsten production.

Figure 136 shows that at the current high prices for wolframite concentrates, a trend to explore low grade/high tonnage deposits as well as medium and small scale deposits exists, e.g. Mactung (Canada) or King Island (Australia). For each deposit, the economics are highly determined by the quality of infrastructure, legislation, mining and processing costs.

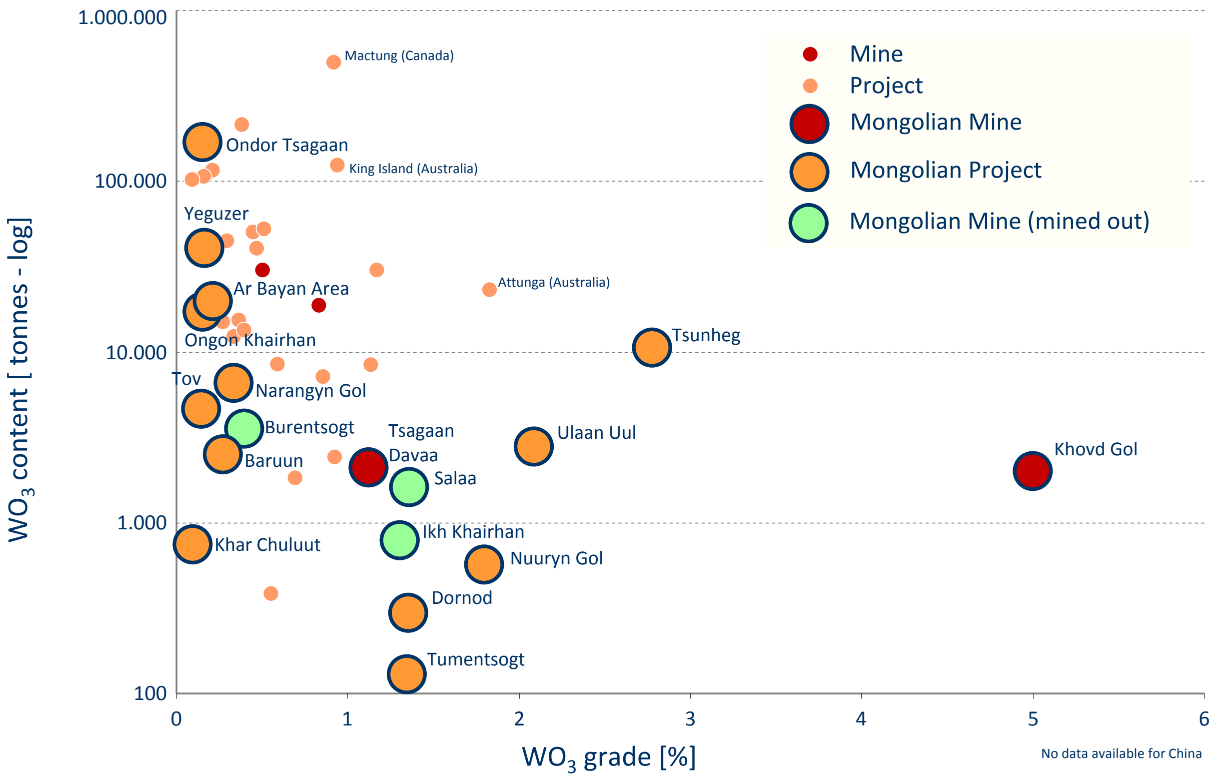


Figure 136: Grade-tonnage diagram of world-wide tungsten projects and mines with emphasis on Mongolian deposits and important occurrences.

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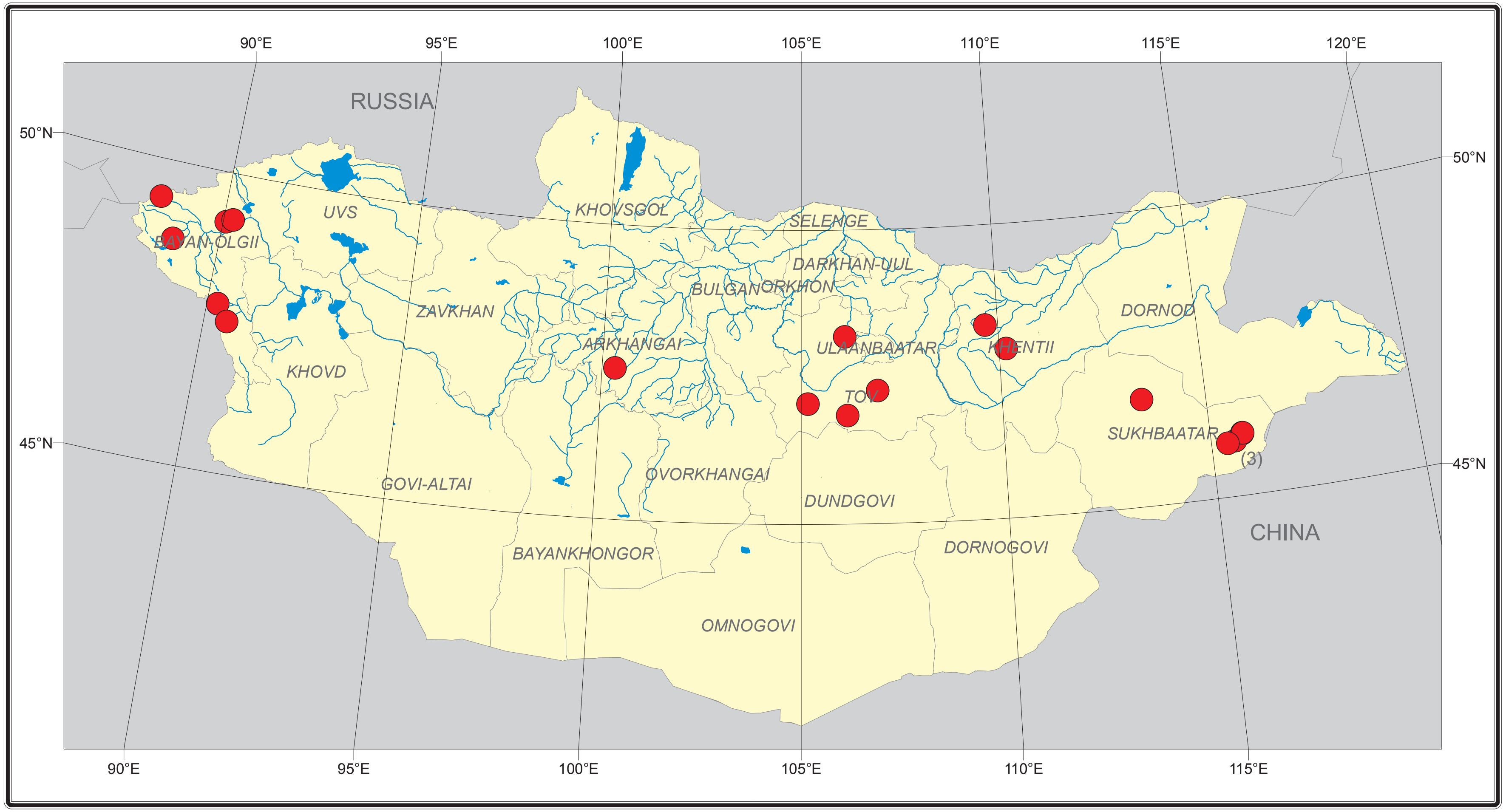
Deposits and important occurrences of Tungsten in Mongolia



Legend

● Tungsten (reserves and resources > 500 t WO_3 content)

Scale 1 : 10 million

0 60 120 240 360 480 600 km

Projection UTM Zone 48N - Date WGS84

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