High-Resolution Airborne Thermal Infrared Remote Sensing for Geothermal Site Characterization

Geothermal Exploration at Menengai-Olbanita Prospect, Republic of Kenya

MINISTRY OF ENERGY · KenGen · GEOTHERM · BGR

Introduction

German development cooperation is supporting developing countries in geothermal energy use. The Federal Institute for Geosciences and Natural Resources (BGR) on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ) carries out the technical cooperation programme GEOTHERM.

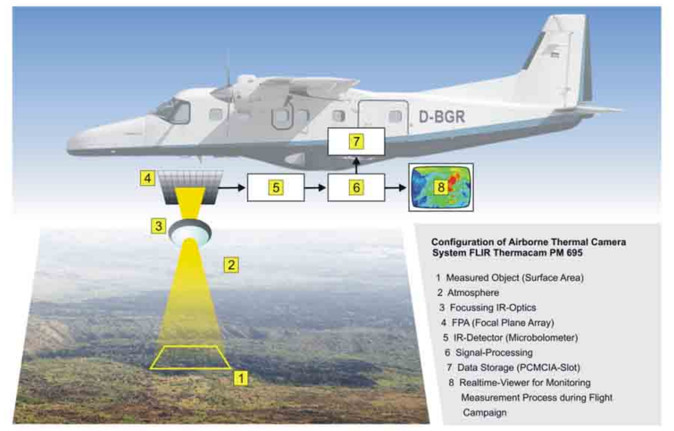
With the objective of improving the national power supply the Government of Kenya (Ministry of Energy) and KenGen (Kenya Electricity Generating Company Ltd.) are exploring the Menengai-Olbanita geothermal prospect.

These exploration activities are supported using airborne thermal infrared remote sensing techniques. A high-resolution aerial thermal imaging campaign, a large-scale stereoscopic colour aerial photography campaign and a DGPS-campaign has been carried out in the Menengai-Olbanita prospect during March and April 2005. A field campaign took place in April 2007.

Photogrammetric processing of aerial photographs using DGPS-measured landmarks led to an ortho-photomap and a digital elevation model (DEM). These products were used to rectify and to mosaick the airborne thermal images.

Goal of the thermal survey campaign was to improve the knowledge of geothermally active sites ("hot spots") in the observation area.

Further the remote sensing methods used were upgraded and aligned for use in remote and poorly explored areas.

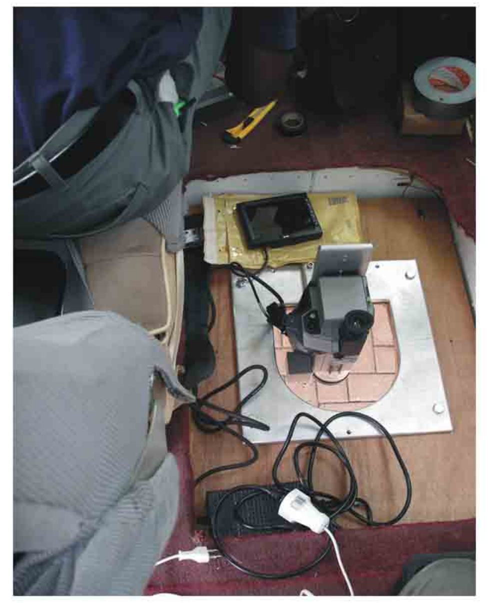


▲ Figure 1 *Configuration of airborne thermal camera system FLIR ThermaCam Pm695*

▲ Figure 2 *Aircraft PIPER NAVAJO of PHOTOMAP INTERNATIONAL was used for thermal imaging campaign at Menengai-Olbanita prospect*

Survey tasks

- **Colour aerial photography campaign:**
  Carrier: twin-engined PIPER NAVAJO;
  frame camera WILD RC-10, f= 153 mm;
  image scale 1:20,000; 7 flight lines 30 km length each.
- **Aerial thermal imaging campaign:**
  Carrier: twin-engined PIPER NAVAJO; thermal camera system FLIR ThermaCam PM 695; ground resolution 5 m; 62 flight lines15 km length each.
- **D-GPS campaign:**
  MAGELLAN GPS PROMARK X-CM and M-STAR Pro.
- **Initial field check.**



▶Fig. 3 *FLIR ThermaCam PM695 mounted on aircraft PIPER NAVAJO*

▲ Figure 4 *View into the Menengai Caldera from "Menengai View Point", looking direction SW; active thermal sites are distributed over the entire caldera area*

▲ Figure 5 *Field work and transportation inside the Menengai caldera assisted by helicopter*

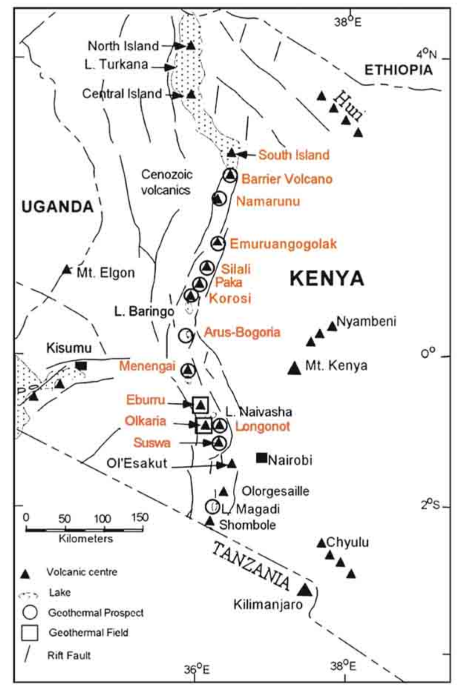
Infrared Thermography

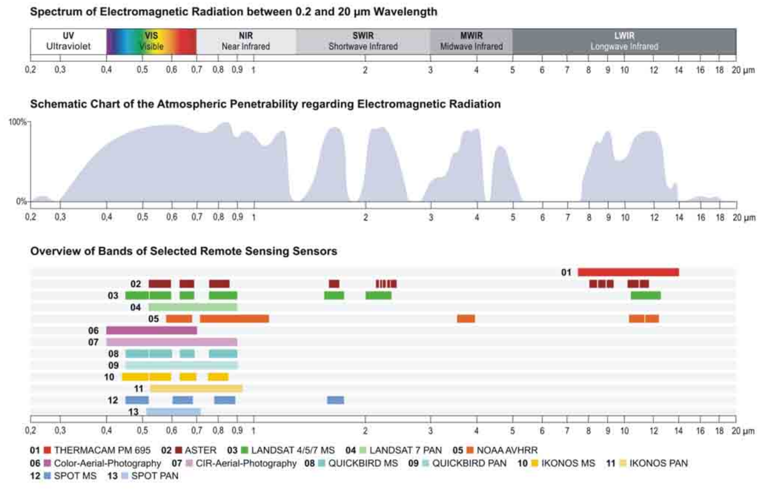
Infrared thermography is a method that detects and records energy emitted from an object at the earth surface. Chiefly utilized wavelength ranges are from 3 to 5 µm for "high temperature targets" (MWIR) and 7.5 to 14 µm for "moderate temperature targets" (portion of LWIR, ref. to figure 6).

Infrared thermography makes it possible to visualize temperature distributions over wide areas, even if the areas are of large extent and hard to access by ground-based survey methods.

The thermal camera FLIR ThermaCam PM 695 captures the energy emitted from the earth's surface in the wavelength range between 7.5 and 13 µm (ref. figure 6) and displays it as an image, which allows **high-resolution area-wide surface temperature detection and evaluation.**

Multitemporal data recording and calibration allows the monitoring of temperature in time and space.

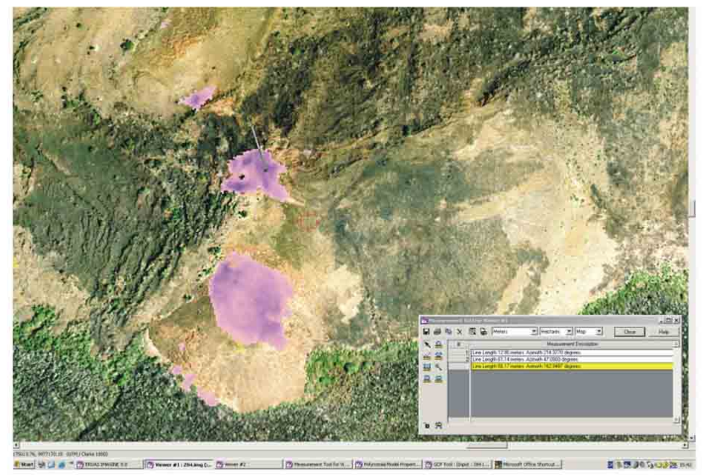




▲ Figure 6 *Spectrum of electromagnetic radiation, atmospheric penetrability and remote sensing sensors*

Tools

- LEICA ERDAS IMAGINE
- LEICA Photogrammetry Suite (LPS)
- FLIR Researcher



▲ Figure 7 *Thermally anomalous area MF2 superimposing the orthophotomap*

Workflow and Results

Master Data

- 2,400 nadir-looking thermal images, 5m ground resolution.
- 220 stereoscopic colour aerial photographs, scale 1:20,000.
- 60 DGPS-measured landmarks.

Reference Data

- KenGen already identified 8 thermally anomalous areas or "hot spots" (MF1 to MF8 in figure 8). These areas were used as references to search for additional "hot spot features" on the thermal images.
- **77 new areas could be detected and identified as further "hot spots"** (BGR T1 to BGR T77 in figure 8).

Processing and Interpretation

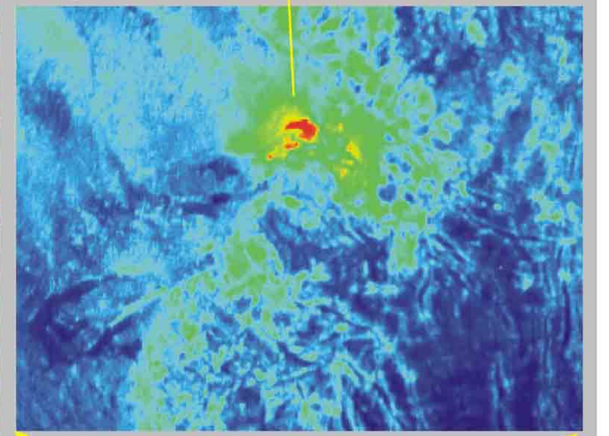
- Orthophotomap 1:25,000
- Digital Elevation Model(DEM) and topographic derivatives(ref. to fig. 12 and 13)
- Map of thermally anomalous earth surface features "hot spots" (ref. to fig. 8)

Field Check and Conclusion

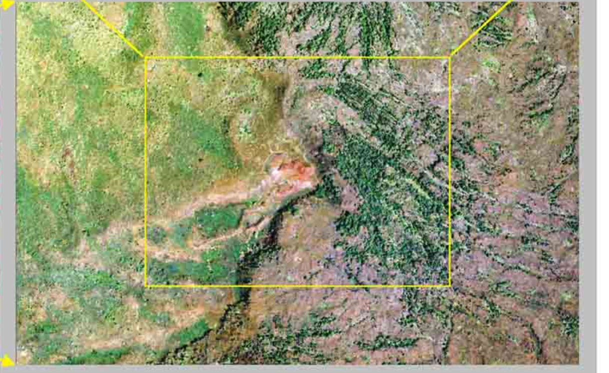
- A field check of selected thermally anomalous sites was carried out. The results of data interpretation were evaluated and assured.
- It could be shown that aerial thermal imaging contributes to improving the knowledge of geothermal conditions in the Menengai-Olbanita prospect.

▲ Figure 8 *Map of "Thermally Anomalous Earth Surface Features, Menengai-Olbanita Prospect"*

▲ Figure 9 *Photo at fumarole field MF3*



▲ Figure 10 *Fumarole field MF3 shown on airborne thermal image (reddish area)*



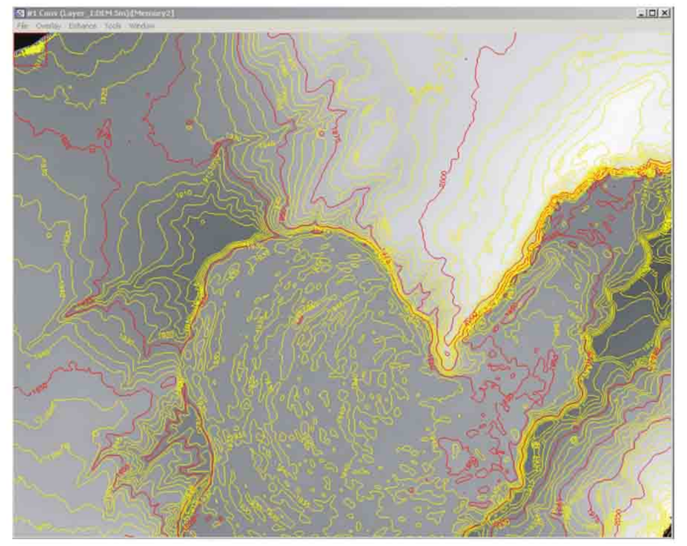
▲ Figure 11 *Fumarole field MF3 shown on colour aerial photograph (reddish area at center of image)*

Benefits

- Maps of geothermally anomalous sites (coordinates, extension and surficial temperature) provide professional information for geothermal exploration work.
- Maps of geothermally anomalous sites support the preparation of geochemical sampling work in the field.
- Up-to-date large scale orthophotomaps, digital elevation models (DEM) and topographic derivatives support to plan and to execute field campaigns as well as to recommend sites for drilling.

Outlook

The results of this integrated remote sensing approach were examined by KenGen, the public body responsible for geothermal exploration in Kenya. The benefits of this new approach were expressed, especially within the framework of future geothermal exploration work in the Northern Rift which is characterized by insufficiant geoinformation.



▲Fig. 12 *Perspective view of south-eastern part of Menengai caldera*

◀ Fig. 13 *Isolines superimposing digital elevation model*

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