Helicopter-Borne Electromagnetic Investigations of Buried Valleys

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BURVAL

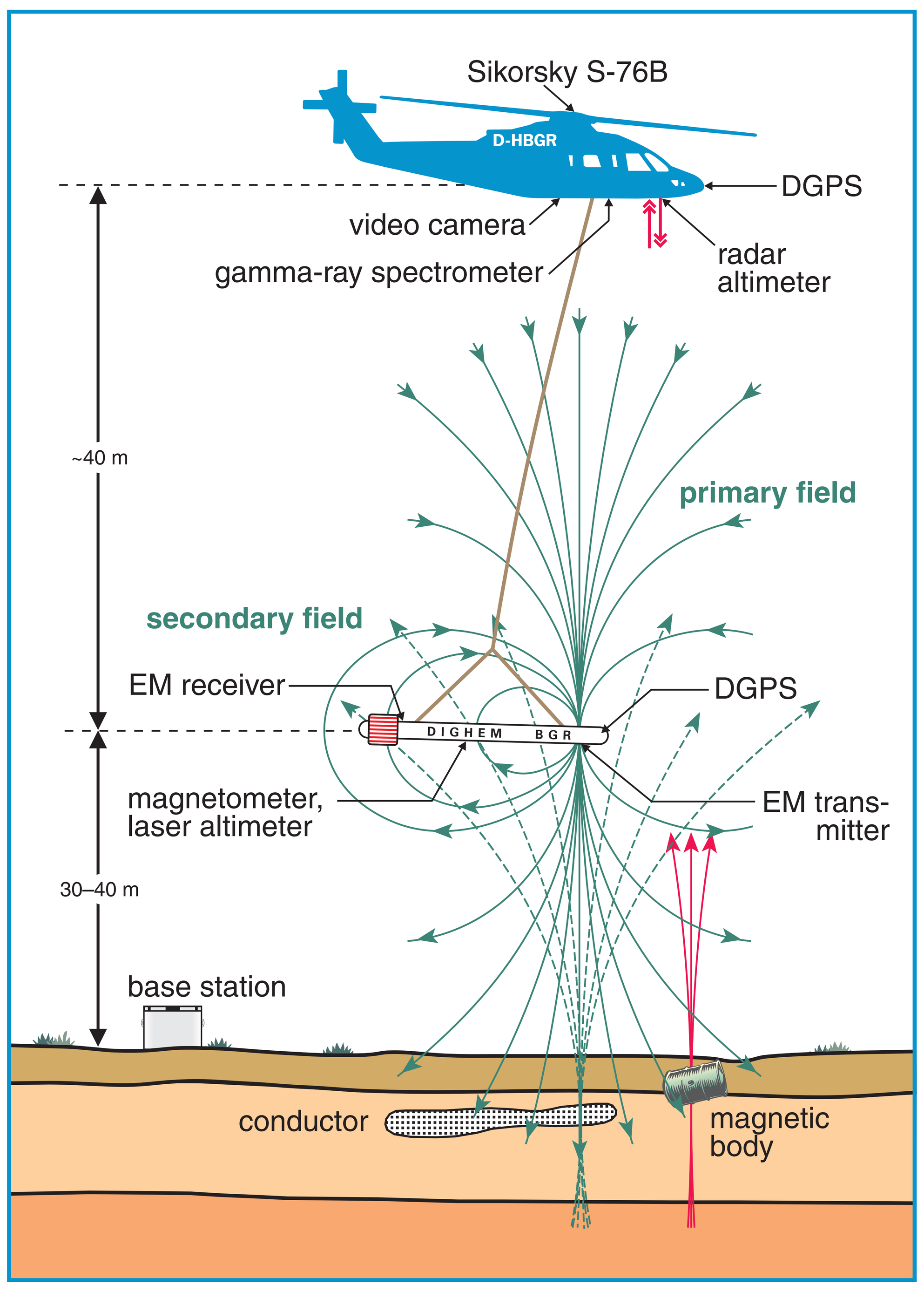
Interreg North Sea Region

Buried valleys

Buried valleys are depressions in paleo landscapes mainly caused by water flow. Today, these valleys are completely refilled and covered with sediments. From a hydrogeological point of view, buried valleys are becoming increasingly important as they host groundwater reserves which are in many cases big enough to satisfy the future demand for freshwater.

Airborne electromagnetic data sets collected during the past decades by the BGR helicopter-borne geophysical system over various geological settings show that such data sets do not only indicate layered horizontal geological features but also vertically and laterally confined structures, such as buried valleys. Indicative geological markers are either electrically conductive cover layers or conductive fills in resistive bedrock or incisions in conductive host filled with resistive materials.

The results of the BurVal pilot areas as well as the case studies shown here demonstrate that multi-frequency helicopter-borne electromagnetics is an easy, fast and cost-effective tool to identify buried valleys and to delineate their lateral extent down to about 100 m depth.

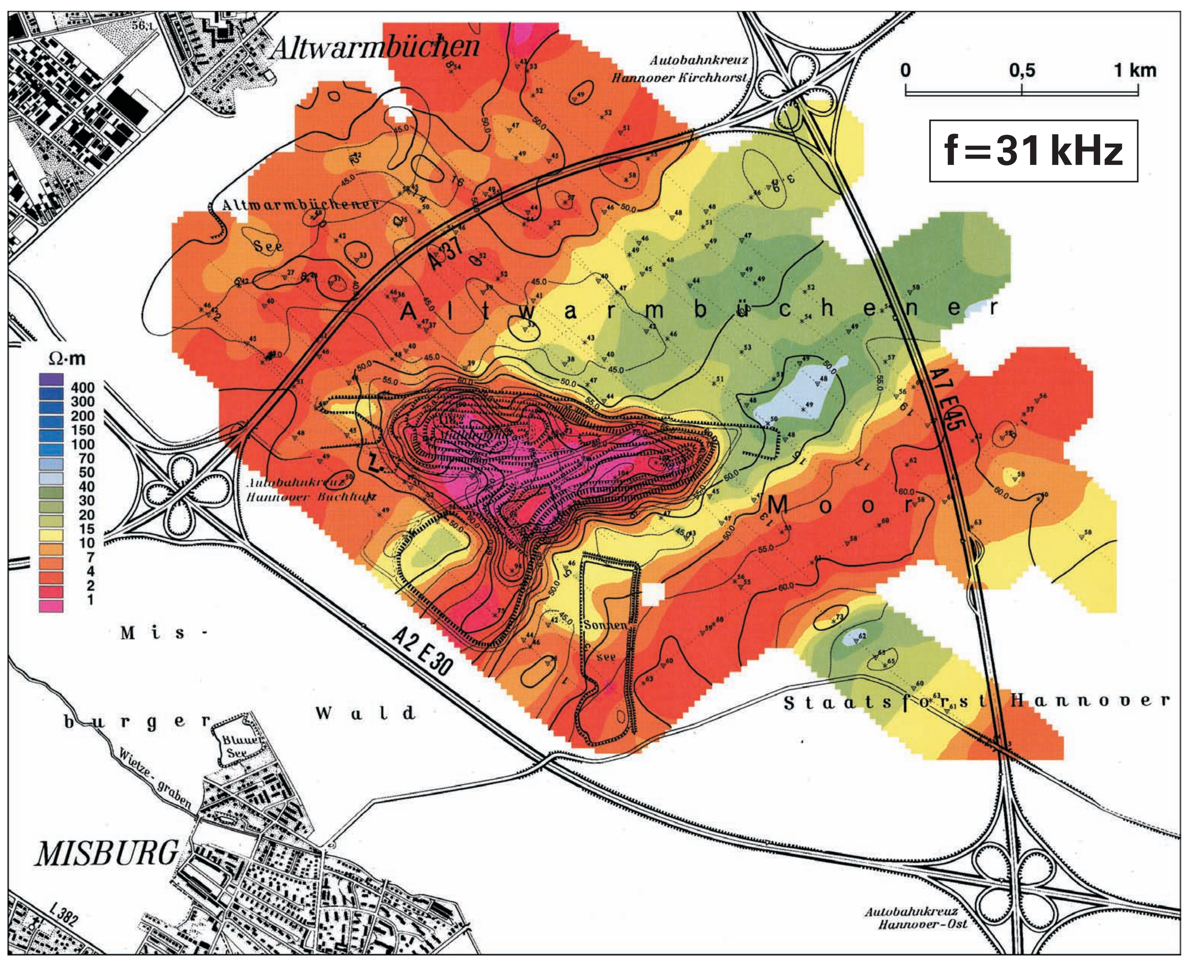


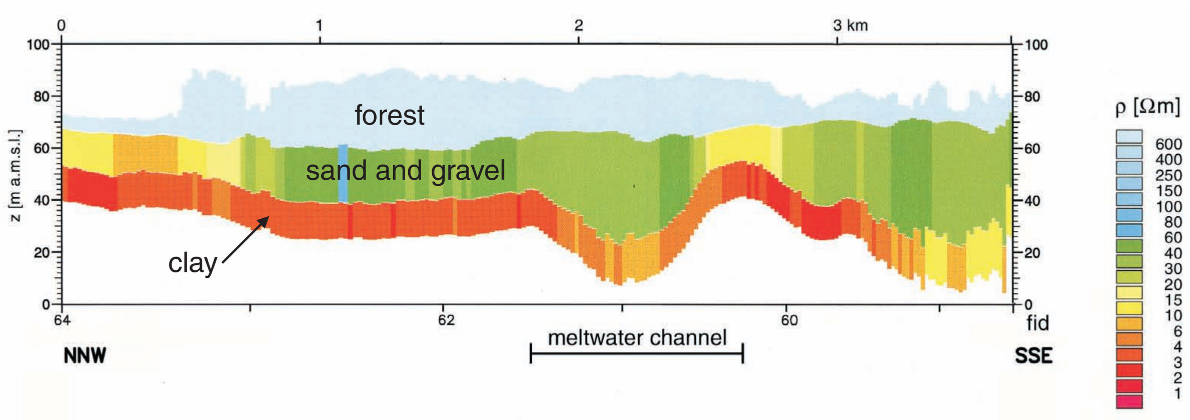
Helicopter-borne geophysical system

The helicopter-borne geophysical system includes five-frequency electromagnetics, magnetics and gamma-ray spectrometry. Navigation and positioning are based on DGPS and radar plus laser altimeters. The geophysical instrumentation, the positioning systems, the analogue and digital recording units, as well as other equipment needed for the survey flights are integrated in one system carried by a Sikorsky S–76B helicopter. The digital electromagnetic system, the magnetic sensor, the GPS antenna and a laser altimeter are installed inside a tube, called the bird, towed about 40 m below the helicopter. A ground base station records the time-variant data required to correct the airborne data.

The sampling distance is about 4 m resulting from an average flight speed of 140-150 km/h and a sampling rate of 10 Hz. The digital electromagnetic system, which consists of a set of four coils (transmitter, receiver, bucking, calibration) for each of the five frequencies (0.38-133 kHz), provides information on the distribution of electrical conductivity of the near subsurface from the surface down to a maximum depth of about 100 m.

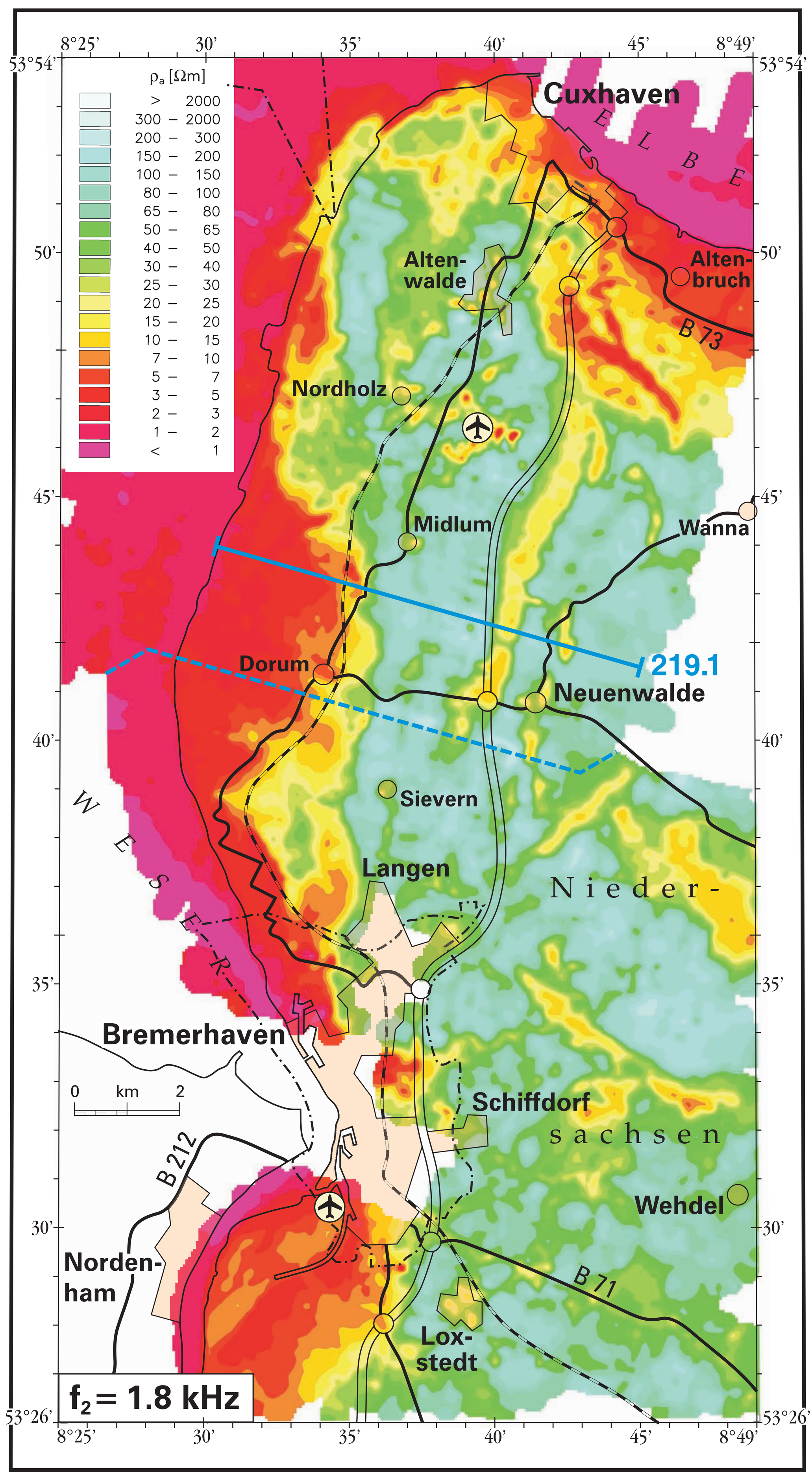
Type I: Eroded clay, refilled with sand

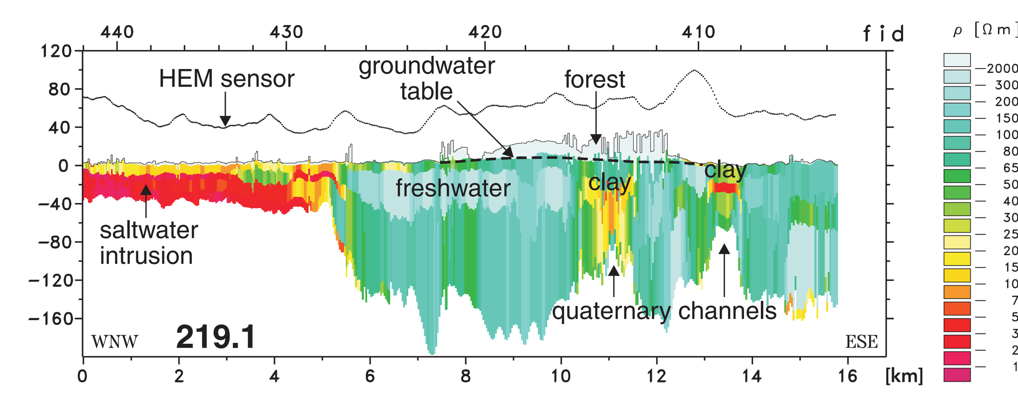




The first example flown over the outskirts of the city of Hannover, Germany, demonstrates that channel fill can readily be mapped if a contrast in resistivity between host rock and infill exists. Low apparent resistivity values appear nearly all over the 5 km by 5 km survey area except in a SW–NE-trending zone of rock material with increased apparent resistivity values as revealed on the 31 kHz apparent resistivity map. It is known from several drill holes that thick Cretaceous clay- and marlstone layers are covered by thin, mostly sandy Pleistocene sediments. The vertical resistivity section along a flight line of the north-eastern part of the survey area running NNW–SSE is in good agreement with this. It clearly demonstrates that the SW–NE-trending resistive zone can be ascribed to a channel where conductive clay- and marlstone were heavily eroded by glacial meltwaters and subsequently filled with Pleistocene sands and gravels, which are several tens of metres thick. Remarkably, a waste dump, which appears as a highly conductive feature on the resistivity map, is situated directly within this buried valley – at the most unfavourable place.

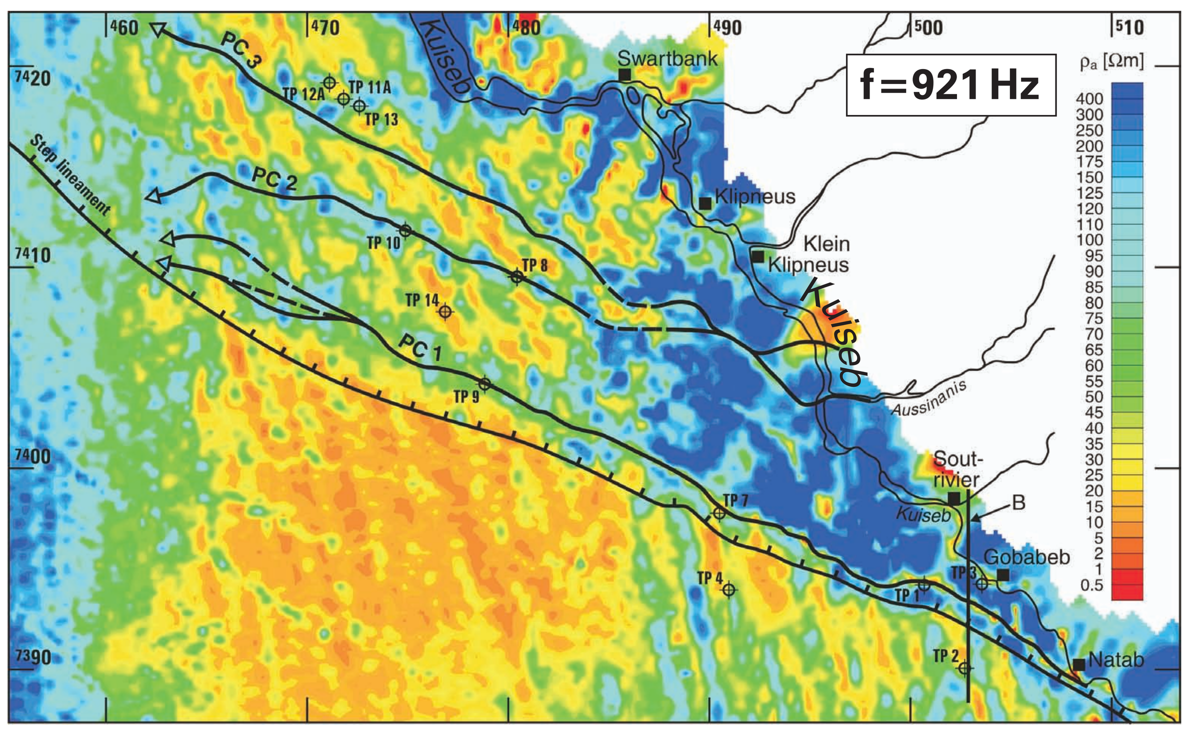
Type II: Eroded sand, refilled clay

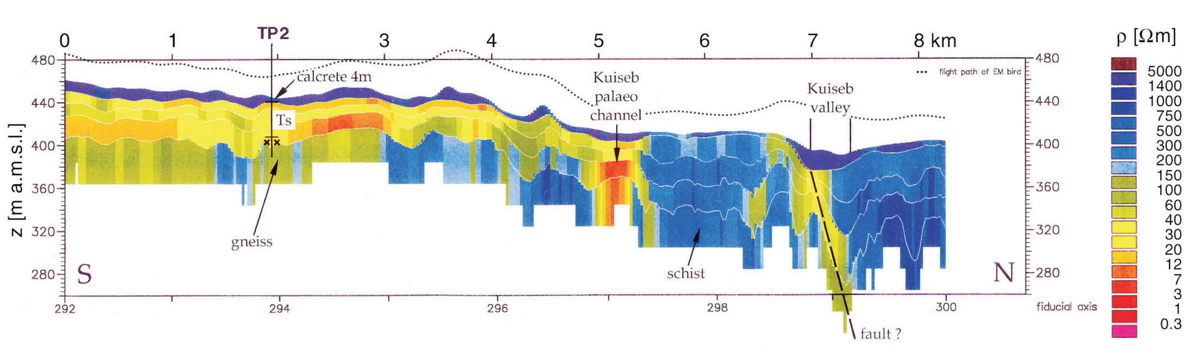




The area between the coastal towns of Cuxhaven and Bremerhaven was flown in 2000/01 in order to map glacial meltwater channels and saltwater intrusions from the estuaries of the Elbe and Weser rivers. The yellow coloured conductive zones of the 1.8 kHz apparent resistivity map can be ascribed to channels that were incised by glacial meltwater in the Pliocene land surface during Pleistocene glacial regression epochs. The channels filled with up to 300 m of coarse sands and gravels in the bottom and mostly silt and clayish materials in the upper parts are ideal freshwater aquifers. Between 10 and 14 km of the vertical section, a pair of meltwater channels are identified due to the conductive properties of the clays. It can also be noted that the depth of penetration of the HEM system is reduced within these meltwater channels due to the occurrence of the conductive clays.

Type III: Eroded hard rock, refilled with sediments





The survey over the Namib dessert to the south-east of the Namibian coastal town of Walvis Bay was flown in 1992. The 921 Hz apparent resistivity map enables to identify three paleo channels (demarcated as PC 1 to 3) below up to 100 m high sand dunes to the south-west of the Kuiseb river. Where paleo channels incised the metamorphic basement, low resistivity values reflect the channel fill. Areas where paleo channels incised Tertiary sandstone are indicated by increased resistivity in a surrounding low resistivity environment. The vertical section clearly depicts a conductive Kuiseb paleo channel fill and the present Kuiseb river at 5 km and 8 km, respectively, embedded in highly resistive terrain presumably built up by metamorphic schists.

Literature

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