


GPR*plus* in Hydrology and Hydrogeology Surveying

Contents

Introduction to Terravision

The enhanced Ground Penetrating Radar (GPR*plus*) system and Methodology

The Terravision system is a 4th generation enhanced Ground Penetrating Radar, designed for studying subsurface soil structure at depths from a few meters to hundreds of meters. The operation is based on radiation of ultra-wideband electromagnetic pulses penetrating into the subsurface medium and registration of the signals reflected at the medium interfaces or buried objects. These are primarily as a result of a change in density and/or a change in electromagnetic permeability.

Fig 1. Terravision radar using 3m antennas and 10MW transmitter. Africa 2014

Traditional GPR mechanics have been completely revised: with the pulse transmitter power increased by a minimum of 100.000 times, and the stroboscopic transformation replaced to a direct detection of signal system. The antennas use RC-Loaded dipoles to reduce interference in the received signal.

Technical parameters[1] include:

- The capacity of the EM transmitter is either: 1, 10,20, or 48MW Megawatt
- Working frequency range (MHz): 1-200
- Number of samples per scan (ns): 512, 1024, 2048,4096, 8192
- Antennas length (m): 1, 1.5, 3, 6, 10 and 15.

The device is a lightweight, highly portable system which allows for rapid mobilisation and deployment and use in arduous terrain with zero environmental impact. The radar can be pulled either by hand or behind a 4x4 vehicle along cleared profile lines.[2]

[1] Parameters can be set in a variety of modes to best suit specific geological requirements
[2] There are often no permitting requirements such as those required for drilling.

The horizontal resolution, ie the spacing of the 'radar-shots' taken along a profile is chosen according to the required scale of the target objects and in discussion with the client.

At each measurement point, the arrival time of the signal is recorded from the geological boundaries. The profile 'radargram' is formed in real time on the operator's console LCD screen in the form of a binary plot depicting radar return time of the subsurface reflections. The EM wave travel times, depending on the reflector depth and propagation velocity, vary along the profile giving a picture of subsurface layered structures in real time.

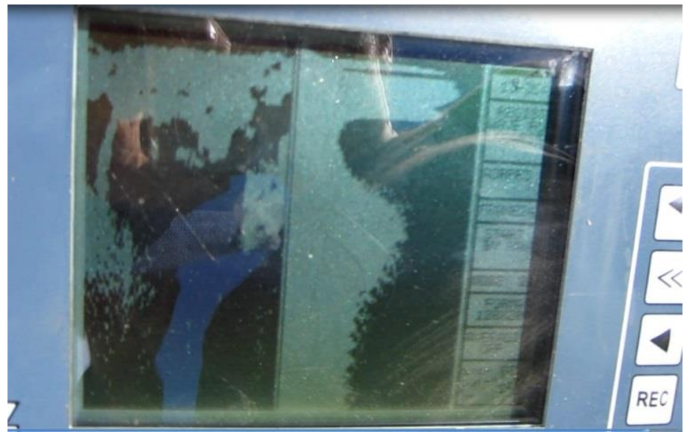


Fig 2. Console showing wave form on right and structure on left.

Data is collected and is instantly available for download and on-site analysis[3]. This real-time capability means that the operator can mark features of interest as the profile is taken.
As well as real time viewing of data, it is also possible to set up the equipment and record 2.-5-4km of profile per day, showing its ease of use and quick usage.

Fig 3. Immediate download of data to laptop for on-site analysis.

Targets and features that are commonly seen by Terravision Radar include:

- Oxide zones or alluvial cover over hard rock
- Oxide ore over fresh basement, (surficial cover and base of oxidation)
- Narrow sporadically mineralised shears
    - Small concentrations of metals, including gold create enough changes in the dielectric constant to be discerned by the Terravision system.
- Intrusions
- Pipes and dykes
- Felsic porphyry or ultramafic bodies
- Massive sulphide deposits.

[3] Further analysis will be required for full reporting.

Terravision Surveying for Water

Overview

Terravision Exploration has over 5 years of experience working in a broad range of geological settings across Africa, Asia, India, Europe and Latin America. In many cases a greater understanding of the hydrogeology; the location of the water table, fluid pathways or water defined depositional settings, has been required. The resultant profiles outlined features such as; water bodies, geological structure, location of bedrock, paleo-channels and contact zones.

GPR*plus* has thus developed its capacity to survey against such aims. The remainder of this introduces a series of case studies for these different situations. These include:

- **Searching for water:**
    a. Directly locate water bodies
    b. Locate water bearing geology
    c. Determine the structures carrying water
- **Environmental**:
    a. Locate areas of pollution in soils, especially oil contamination and pollution plumes
- **Searching over water:**
    a. Terravision can survey over water and ice to locate structures/objects of interest

Even small concentrations of water create large changes in the dielectric constant discerned by the Terravision system. GPR*plus* is also capable of penetrating c. 10 m of water to map underlying structure and geology.

All GPR*plus* data can be exported to software programs including Leapfrog, Reflex, SurPac and Arc GIS.

How Terravision Identifies water bodies

Water Table: The presence of water produces a distinct signal. Identifying the exact depth requires calibration with borehole data, the profile can then extend the water table away from the calibrated zone with confidence. To date GPR has mapped the water table down to c. 70 m depth.

Water bearing geology: For Example – palaeochannels, porous sand/impermeable clay and weathered sediment/bedrock contacts will be well defined.

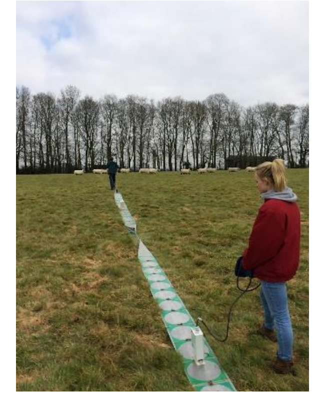
Water Bearing structures: GPR*plus* is able to map both steep and gently dipping structures, the signal indicates whether these are acting as fluid pathways.

Contaminated Land: The presence of hydrocarbons in the subsurface can be distinguished from water bodies.

Mapping over water bodies: GPR*plus* is capable of penetrating c. 10 m of water to visualise underlying geology and structure.

Case Studies

Case Study 1- Mapping Water Table - UK



Objective- Identify different geological units, identify the water table and demonstrate the effects of any present fault structures.

A borehole with the geological units and the measured water table was available at the start of the profile line. Comparing contrasts in geophysical signal with the available borehole data, allowed Terravision to interpret variation in depth of the geology and hydrology across the 750 m length profile. Variation in the depth of the geology was seen to be accounted for by five near vertical structures (black arrows). The water table was seen to be most affected by two of the structures marked by red arrows, whilst the remaining three structures appeared to not affect the vertical fluid flow.

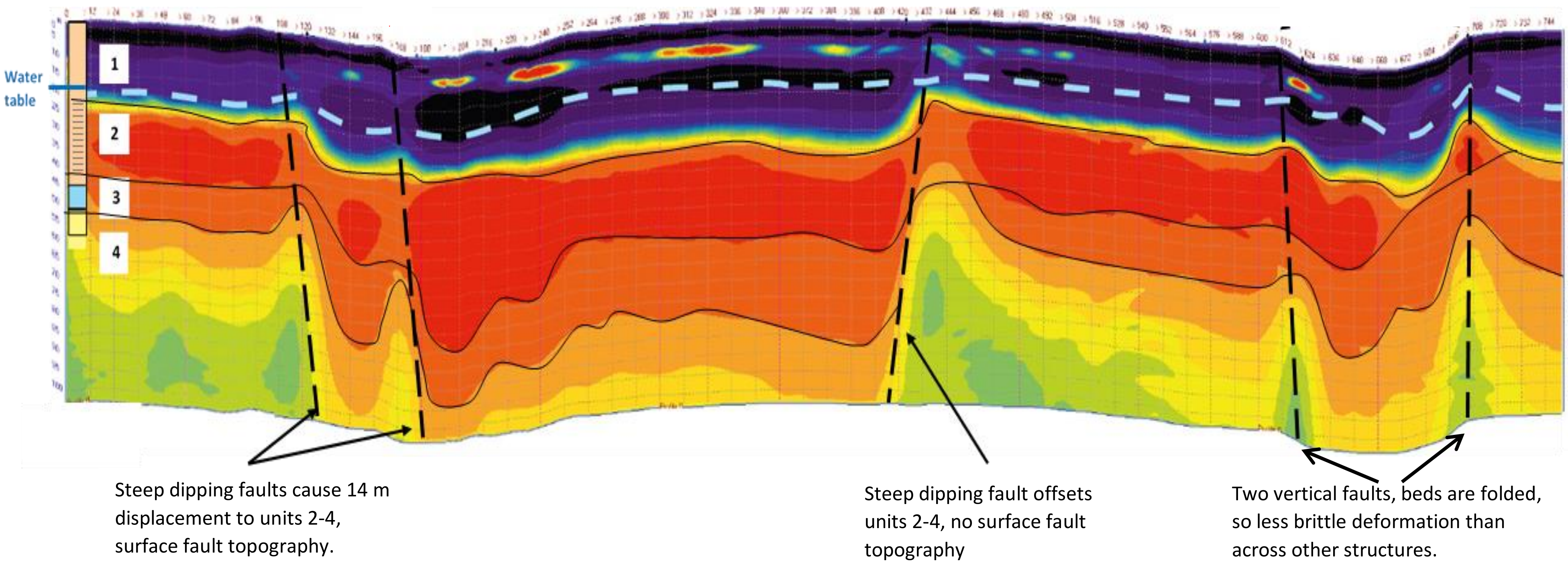


Fig 4. Radargram showing the interpretation of geological units, water table and fault structures with calibration to a borehole at the start of the profile.

Case Study 2a – Water bearing Paleo channels- Germany

Objective- Analysis across an agricultural site to identify the most suitable site for irrigation

The GPR survey was conducted at a greenfield site without borehole calibration. Whilst geological units could not be accurately understood, geological structures could be identified by way of displacement in geophysical anomalies. Analysis of the results identified the geological structures characteristic for accumulating groundwater- a paleo channel. Using this information, the borehole site was chosen for the irrigation source.

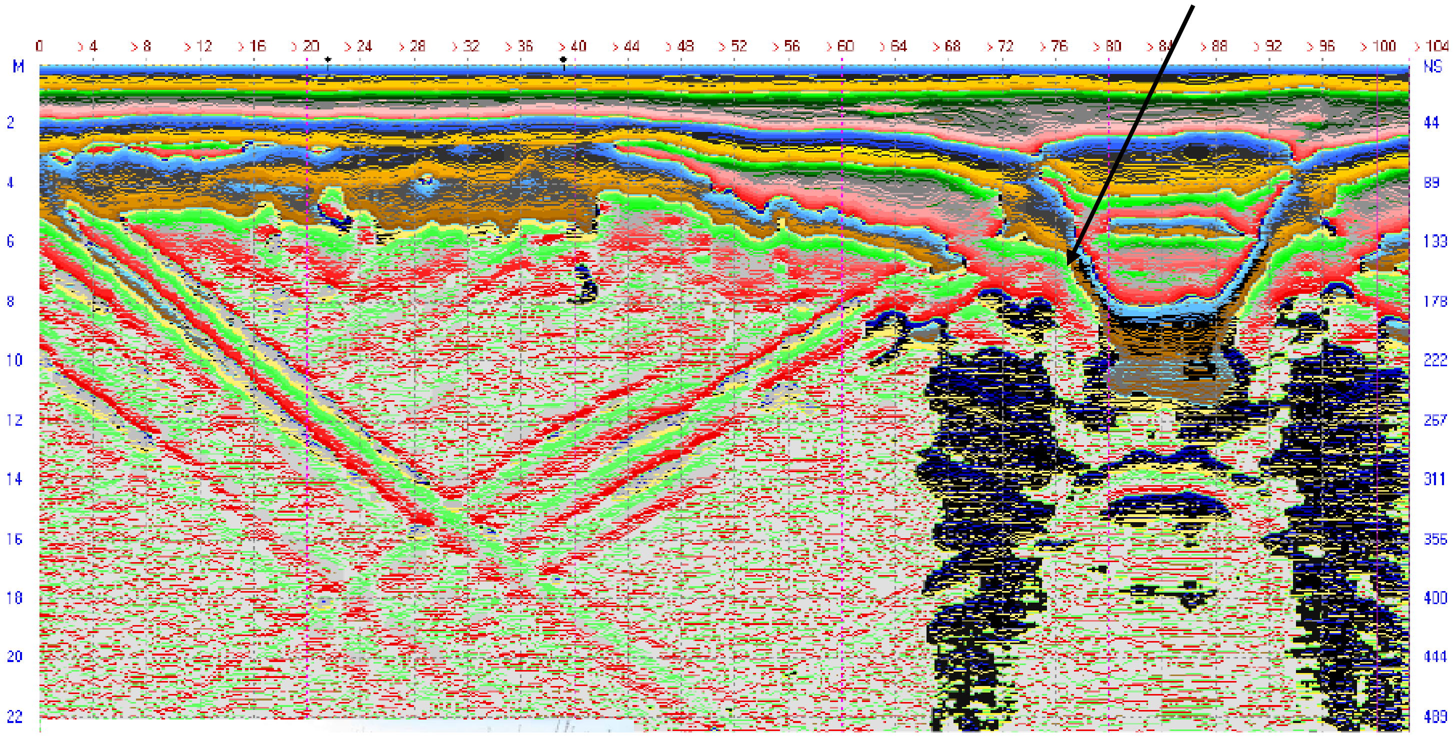


Fig 5. Radargram identifying a paleo channel that was recommended as the site for the irrigation source. Below, data collection at the site causes no disruption to the site.

Case Study 2b- Water bearing Paleo channels- Zambia

Objective- Identify a suitable site for drilling for water based upon interpreted geophysical structures.

Terravision studied the geological map of the study area to identify a suitable profile line. Analysis of the 1240 m long Radargram was conducted with the knowledge of the local geologist, the resultant geological schematic is shown below. Thickening of sedimentary cover into the centre of the profile resembles the profile of a 400 m wide and 25 m deep paleo-valley, a fault is marked in the axis of the channel. It was recommended that drilling for water was carried out into the fault at 620 m. The client found water in the borehole drilled at the recommended site.

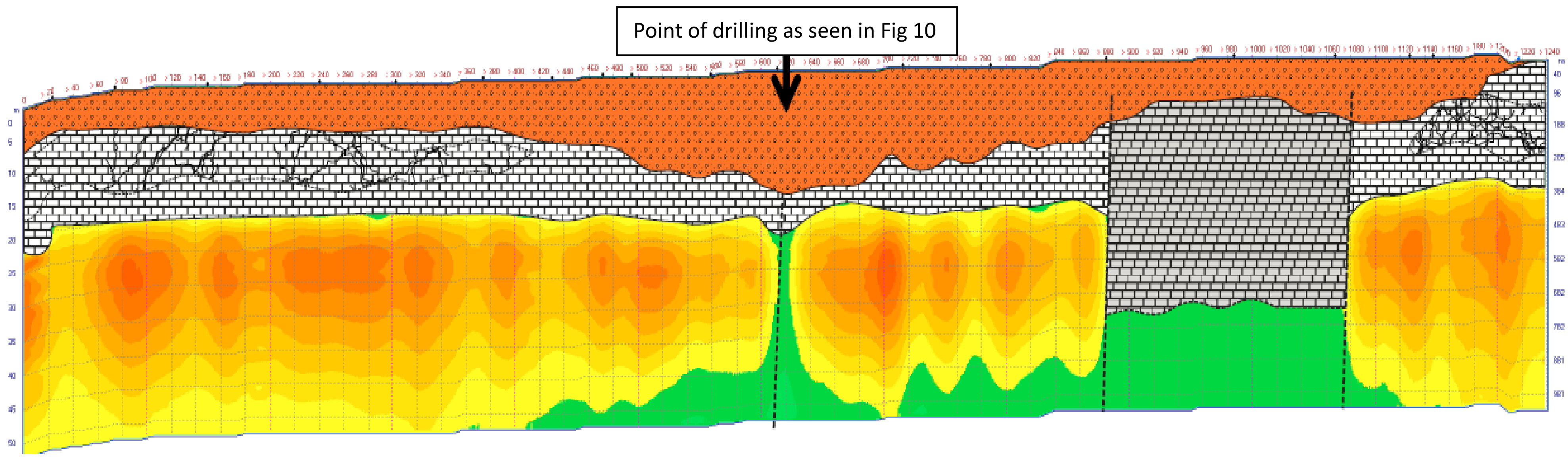


Fig 6. Geological schematic produced by Terravision from the data collection results of a GPR*plus* survey. The geological structure believed to be most conducive to water collection is identified by the black arrow. Above, the results of drilling at the recommended site.

Case Study 3 -Identifying fluid migration through structure (faults and sheer zones) - Kazakhstan

Objective- Define tectonically weakened zones which may be paths for the movement of groundwater and potentially leachate solution; thickness and contact between various geological units; depth of groundwater.

A strong anomaly in the geophysical signal is seen between 10-20 m depth (contact of purple and green unit) that correlates with the recorded water table. A deeper contrast in the signal at c. 30 m depth (contact of green to red unit) correlates with the expected depth of the weathering profile. The water table and weathering profile locally deepen or breakdown (respectively), across near vertical structures. The lower diagram demonstrates the interpreted schematic for the section. A further 8 km of profile line was collected away from the controlled area where borehole data was available. Subsequently two fractured zones where vertical structures appeared to be lowering the water table and weathering profile, were recommended to the client for further investigation by drilling.

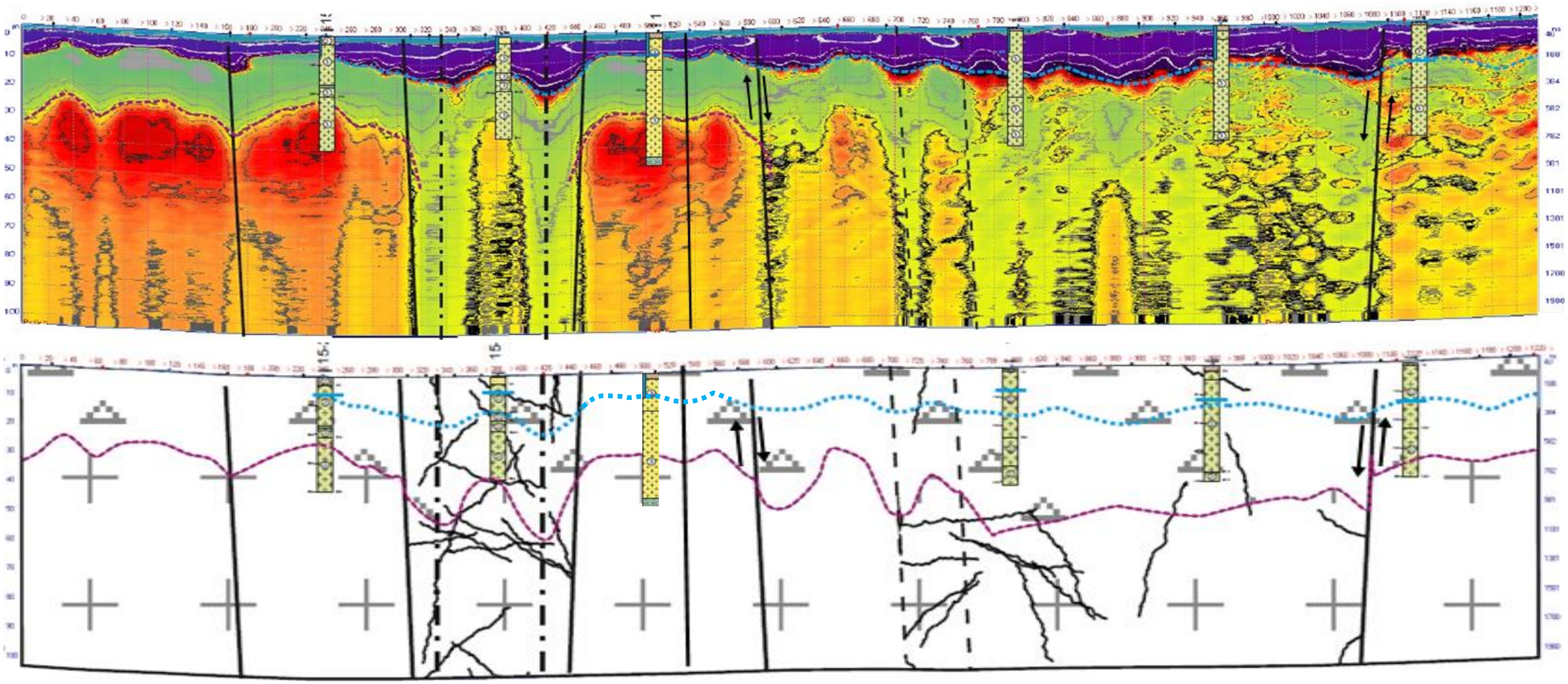


Fig 7. Radargram showing interpreted water table (blue dashed line) and weathering profile (purple dashed line) relative to available borehole data, structures are shown in solid and dashed lines. Below, schematic.

Case Study 4 – Identifying contaminated land- Russia

Objective- Identify the extent of hydrocarbon contamination in the soil.

A shallow survey was conducted, collecting results to 30 m depth. At c.4 m depth a geophysical contrast defines the contact of units 1 and 2. Unit 1 is impermeable clay, unit 2 is a sand gravel mixture saturated by oil. At c. 12 m depth the geophysical signal changes at the contact from the sand gravel mixture to clay (unit 3). Unit 2, symbolised in black, is the contaminated unit of interest to the client, the Radargram gives an idea of its thickness and how this varies along the profile.

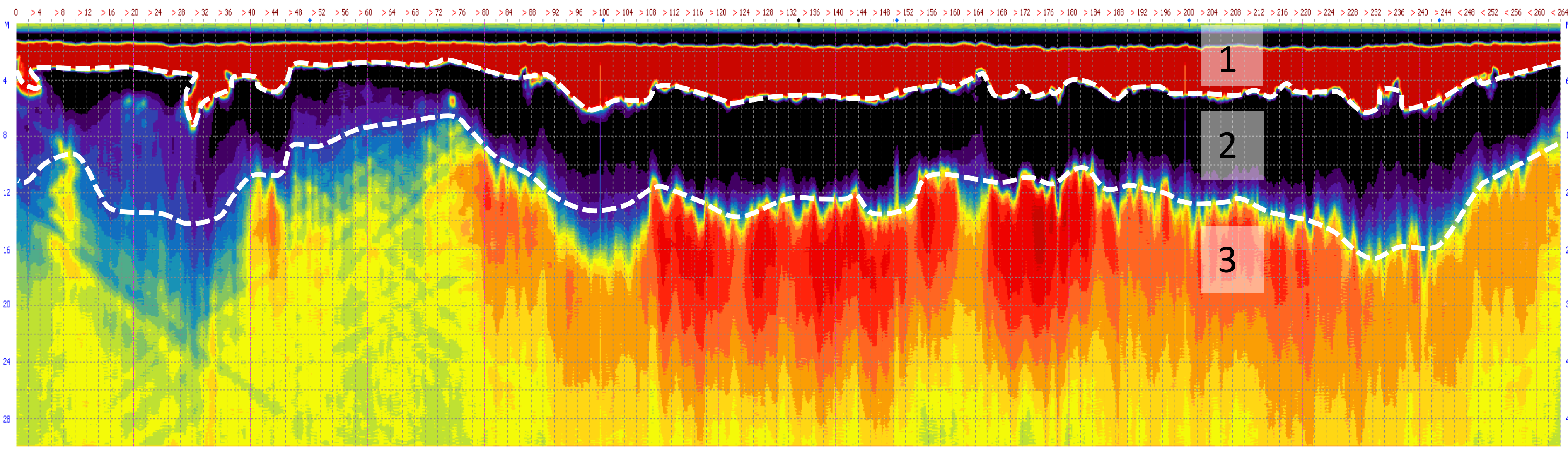


Fig 8. Data collection at the contaminated site. Below, the Radargram demonstrating the three units in the profile, boundaries are outlined by the white dashed lines.

Case Study 5 – Surveying paleo-surfaces - Russia

Objective- Correct route for planned pipeline beneath frozen river.

GPR*plus* is very effective through frozen water bodies, the wave travels well with little attenuation. GPR was able to penetrate c. 10 m of ice and water to visualise the paleo river beds <32 m below the present river bed. This can provide useful information to the client concerning variation in erosional power and load of the river as well as changes in depositional settings.

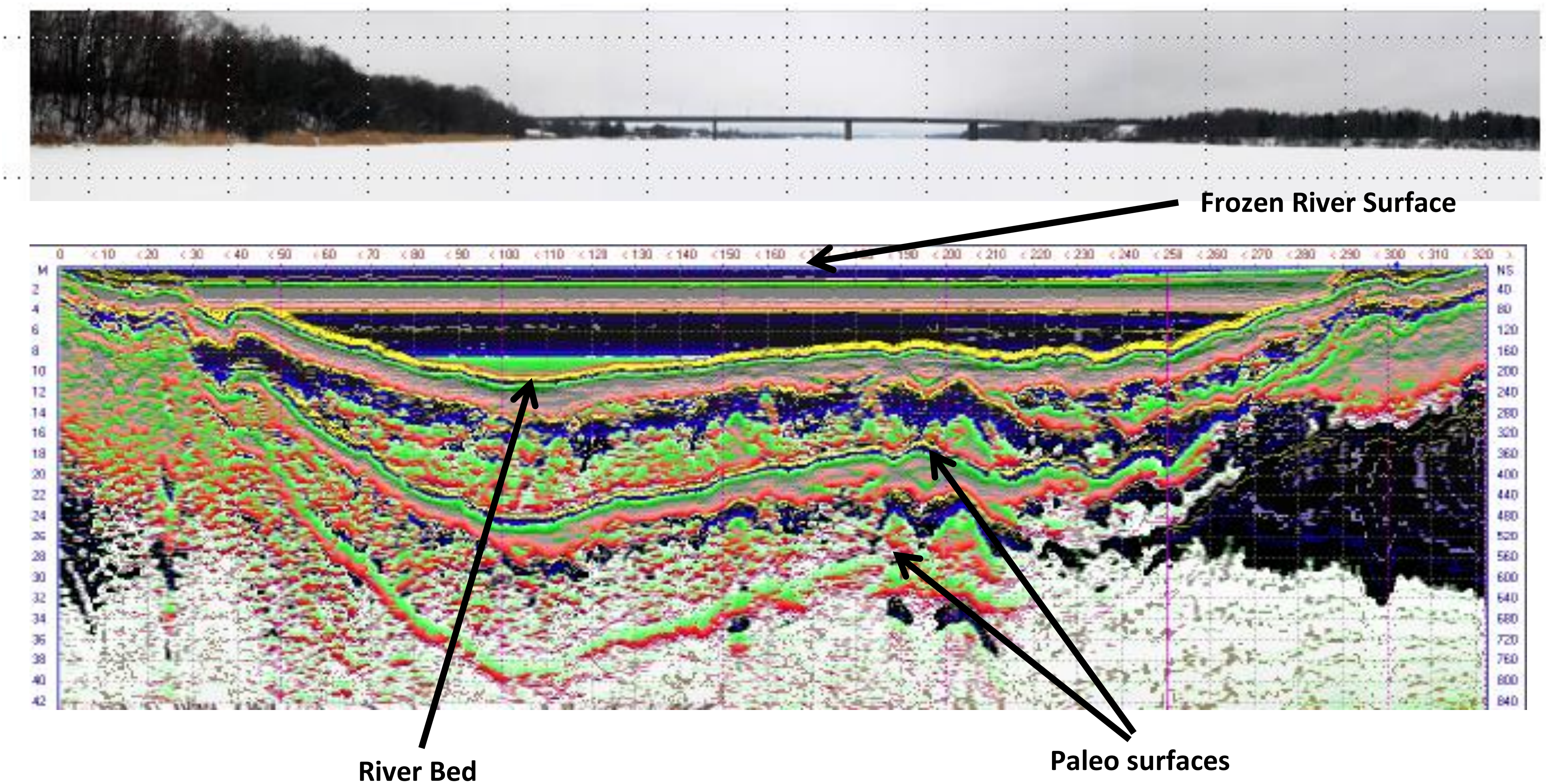


Fig 9. Radargram beneath frozen river bed.

Case Study 6 – Surveying gold tailings in a River-Russia

Objective- Identify depositional settings where the gold tailings are most likely to have collected.

The kit was floated in water proof covers either side of an inflatable raft across a fast flowing river. The signal penetrated c. 9.5 m of water, and was then able to distinguish the recently deposited sand and gravels from the bedrock. With this information the client could target their dredging programme to reprocess the tailings.

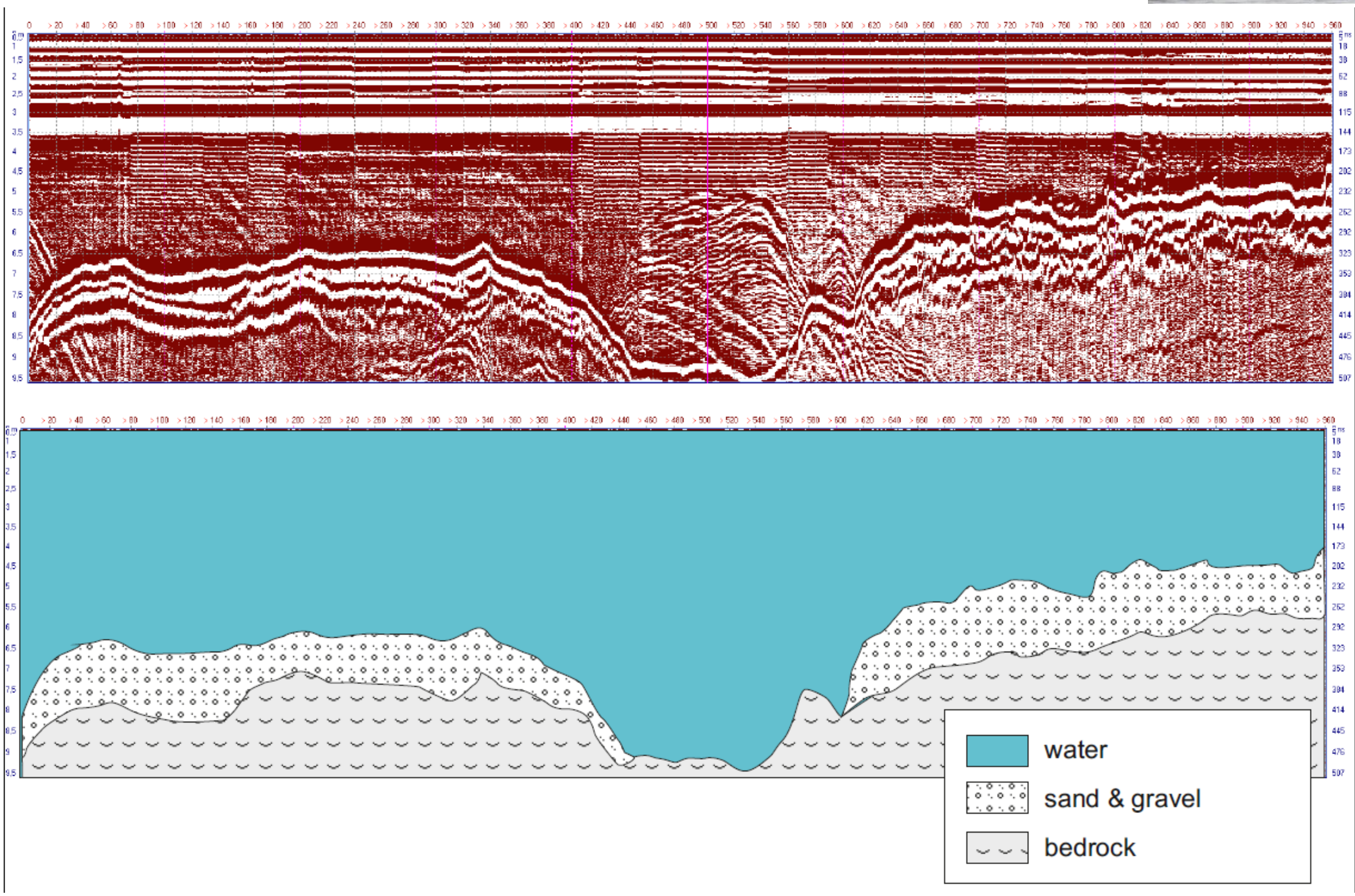


Fig 10. Radargram showing the results of the 960 m length profile line. Below, the schematic demonstrating the interpretation.

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Comparison with Resistivity Survey method

Water environment

Traditional resistivity methods may be used to identify anomaly zones where measured values for conductivity can be suggested to relate to changes in water content and clay content. Clear geological boundaries of aquifers and aquicludes, and structures responsible for variations in fluid migration are not clearly discernible.

GPRplus is able to penetrate through clay horizons and to deeper with higher resolution than those of resistivity. The results of GPR provide a clearer view of the geological situation; identifying the true scale and dimensions of geological horizons and faults and how these may affect the water bodies (Figure 11 and 12).

Operational Benefits.

- Terravision Radar - Quick, Lightweight, Real Time Feedback
- High productivity of the GPR method – 1km in 1-1.5 hours with a team of 2-3 persons.
- Intuitively clear results from the study of the sections.
- Terravision Radar plans profiling perpendicular to the strike of the geology and structures, this allows for the finding of true thicknesses and offsets.
- The profile records to the maximum depth of the study across the entire profile length. A profile line can be any desired length; this will not affect the depth readings.

General limitations for electrical geophysical methods are that interpretations can be ambiguous and need correlation with geologic controls (i.e. borehole data). In situations where there is no borehole data, GPR will clearly demonstrate structures and their sense of displacement as well as variation in the signal that may relate to changes in lithology and water content. Combined analysis of resistivity and GPR data may provide a more confident understanding of the lithology/water content variation by correlating these horizons to directly measured conductivity values (Figure 16).

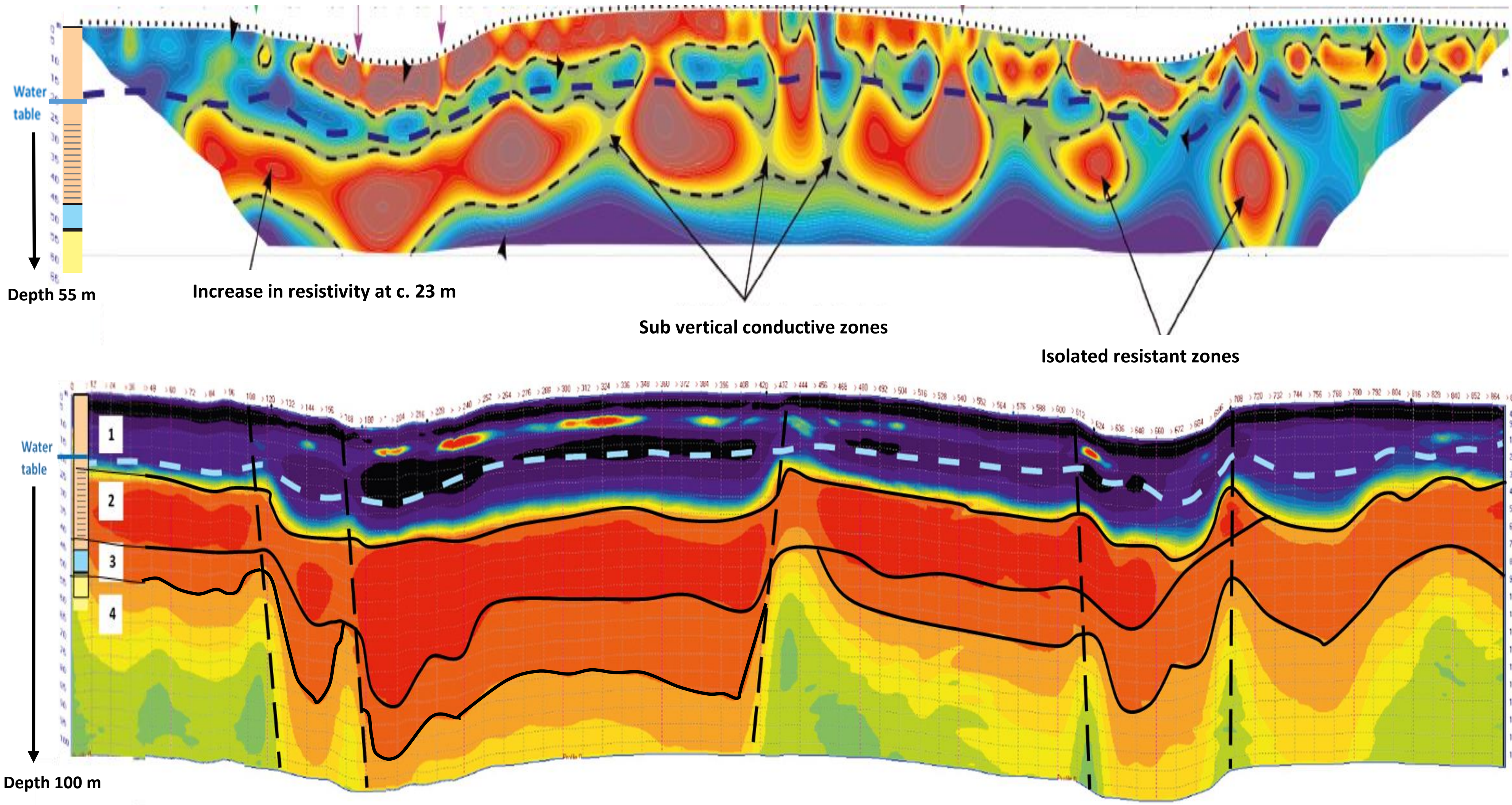

Fig 11. Above- Resistivity section showing zones of high resistivity (red) and low resistivity (blue). Below- GPR section for the same profile line showing four horizons of contrasting geophysical properties correlated to the borehole information, offset by vertical structures (black dashed lines).

In the resistivity profile, the increase in resistivity at depth has been interpreted as an increase in sand content, lateral discontinuities in this zone are identified as sub-vertical features. The water table appears to correlate to a horizon of low resistivity. In the GPR section, correlation with borehole data identifies four horizons with distinct geophysical properties. The offset of these horizons has been interpreted to relate to five vertical structures.

The water table is suggested by discontinuous zones of high geophysical contrast near to the recorded water table (20-25 m), its continuation across the profile is extrapolated using the resistivity results. GPR then shows clearly how this variation relates to the geology and structure of the section.

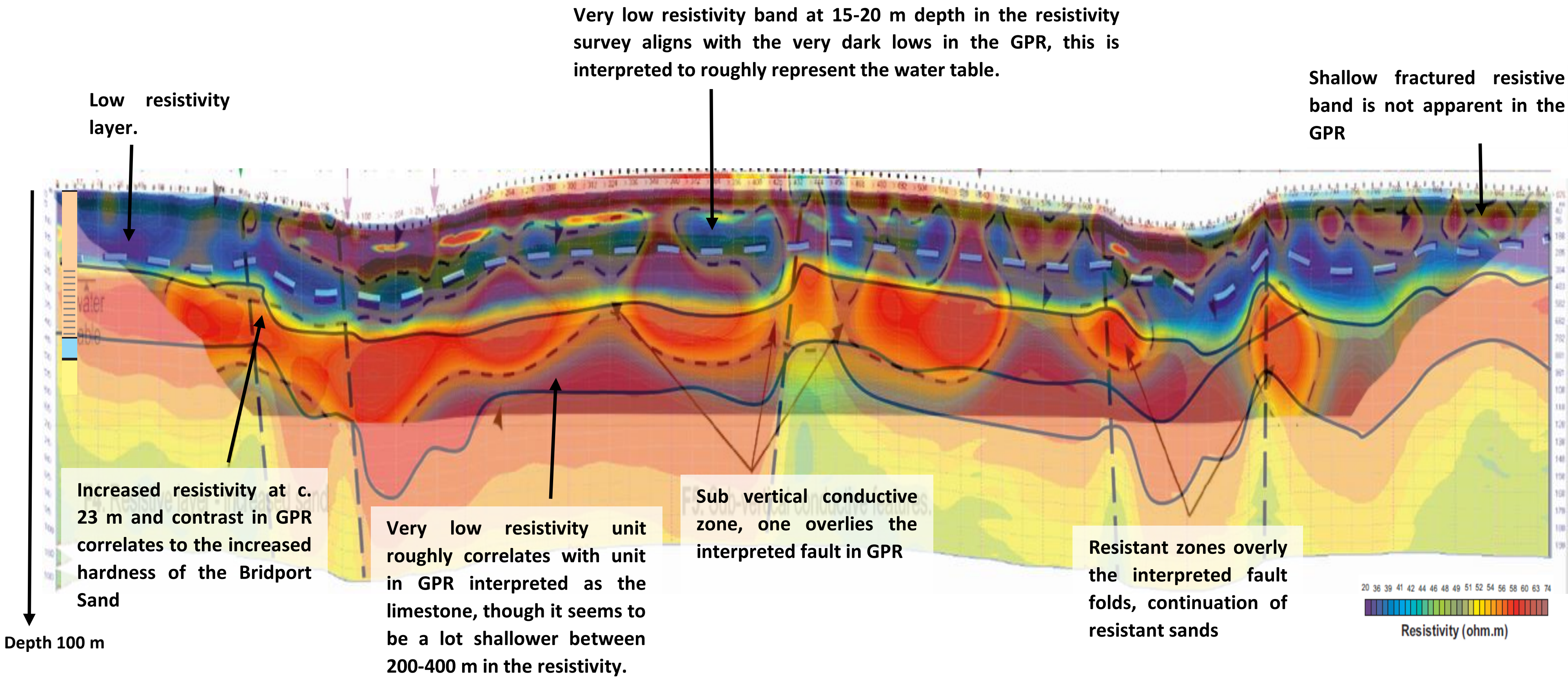

Fig 12. Resistivity survey overlaying the interpreted 6 m GPR section, annotations compare the signal where interpretations have been made, the white dashed line represents the water table

Operations and Clients

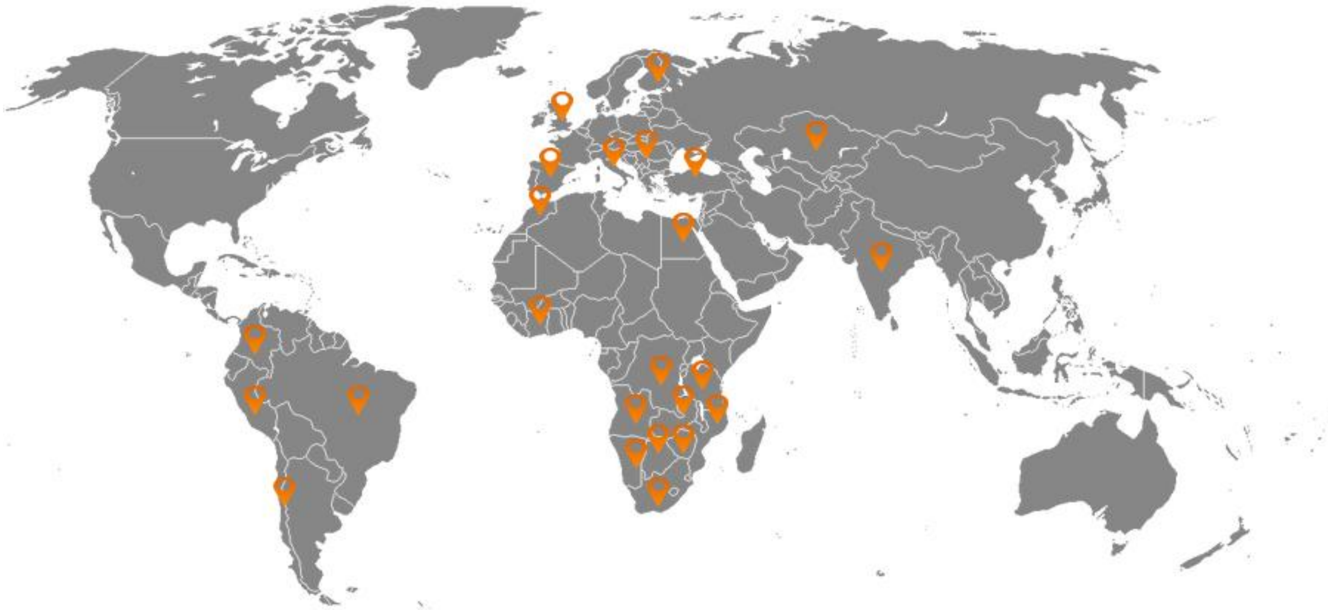

Fig 13. Terravision Operation Map

Certification:

Terravision is certified to comply with EU Directives on;

Electromagnetic Compatibility (Directive 2004/108/EC)
Low Voltage Directive 2006/95/EC

Contact

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