GROUND ACOUSTIC PENETRATION

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1. DESCRIPTION

Ground Acoustic Penetration (GAP) is a new ground geophysical method based on modern approaches to the interpretation of acoustic signals.

Soil/upper regolith layers are comparatively thin and their response to acoustic pulses has a very complex nature. Responses from different layers/borders are close in time, and as they interfere with each other, they create complex oscillations. To interpret this wave pattern, two significantly different approaches are used. One of them is based on the study of the frequency spectra of waves and is described in some detail by Houdzinsky (1962). The spectrum of a wave S(f), reflected from a layer, can be determined from the following equation:

$$S(f)=q(f)p(f)K(f)e^{-a(f)}k(f),$$

where q(f) is the spectrum of the impact pulse; p(f) is the filtering influence of the upper stratified medium on the waves that are going through; a(f) is the dependence of the absorption index on frequency; K(f) is frequency characteristic of the registering device, including geophone station characteristics.

The major problem of this approach is to accurately determine spectral characteristics for each of the adjustments and the problem was resolved by the developers of GAP. At present it is this approach that is used for processing and interpreting field data based on research carried out in Russia (Brekhovskikh and Godin, 1989) and other countries (Bath, 1974, Aki and Richards, 1980). The data are presented as cross-sections, which show the distribution of acoustic impedance of studied media.

Modern powerful computing equipment makes it possible to use another approach - complicated from the point of view of mathematics but more appropriate for the physics of the studied processes. It is based on finding and analysing the response from each of the reflecting borders in the time domain. At present this approach has got complete experimental verification and software for its practical implementation is being developed.

The GAP method is implemented with modern hardware and software backing, based on National Instruments' products.

2. FIELD PROCEDURES

GAP surveys are carried out along profiles with 1 to 20 m spacing between measuring stations depending on clients' requirements and local geology. The major considerations when planning the location and spacing of the stations are the size and depth of target geological features.

Subject to the spacing and ground conditions, a 2-person field team makes a few hundred measurements per day. Very portable field equipment (~6 kg including 12V batteries) makes it possible to use GAP in remote areas without expensive ground clearing and gridding. Profile and station positioning may be arranged using some standard portable GPS equipment.

Basic calibration for the area specific geology may be carried out in the field based on available geological and other data to better interpret variations in acoustic properties.

In Papp, É. (Editor), 2002, *Geophysical and Remote Sensing Methods for Regolith Exploration* CRCLEME Open File Report 144, pp 90-94.

Field quality control includes two steps:

1. evaluation of acoustic noise and spectral patterns at each station; and,

2. preliminary processing and visualisation in a field camp using laptop computers. The preliminary visualisation is available for inspection a few hours after finishing field measurements.

3. DATA PROCESSING AND INTERPRETATION

GAP profiles are presented as raster images compiled by the correlation of processed discreet records into continuous cross-sections. The cross-sections show variations in acoustic properties and may be calibrated for real depths and interpreted on the basis of available drilling data or other geological and hydro-geological information for example.

Certain processing and interpretation algorithms have already been developed for some typical geological situations and target features, eg. for diatreme structures. Such algorithms make it possible to successfully use GAP in grass-roots exploration with very limited geological information on a survey area.

4. APPLICATIONS

The technique has already been successfully used in primary and alluvial diamond exploration in Russia, Ukraine, Africa and Australia, as well as on a number of environmental and geotechnical projects, including for example, radioactive waste control and geohazard studies.

The GAP depth range is from less than 1 m to approximately 300 m. Resolution depends on surface conditions and geology, and may be adjusted for different depths using available acoustic sensors and various recording time/frequencies. The adjustment allows an indication of the general thickness of regolith and deep bedrock relief features (Figure 1) as well as internal regolith irregularities (Figure 2).

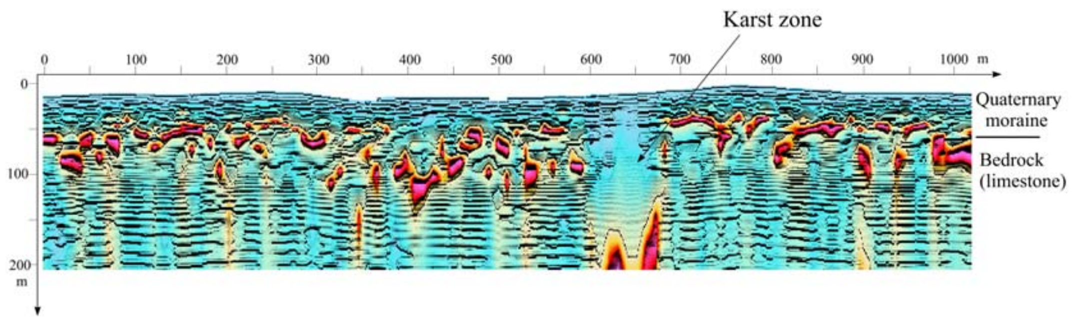

Figure 1. Regolith thickness and bedrock relief: geotechnical regolith study along the Moscow - St. Petersburg Highway 1997.

GAP may be used as a cost-effective alternative/support to traditional geophysical techniques and drilling in mining and exploration projects, in particular for the delineation of discovered geological bodies and search for their extensions, in testing magnetic/EM anomalies and palaeochannel exploration. There are also obvious GAP applications in geotechnical regolith studies (Figures 1 and 2).

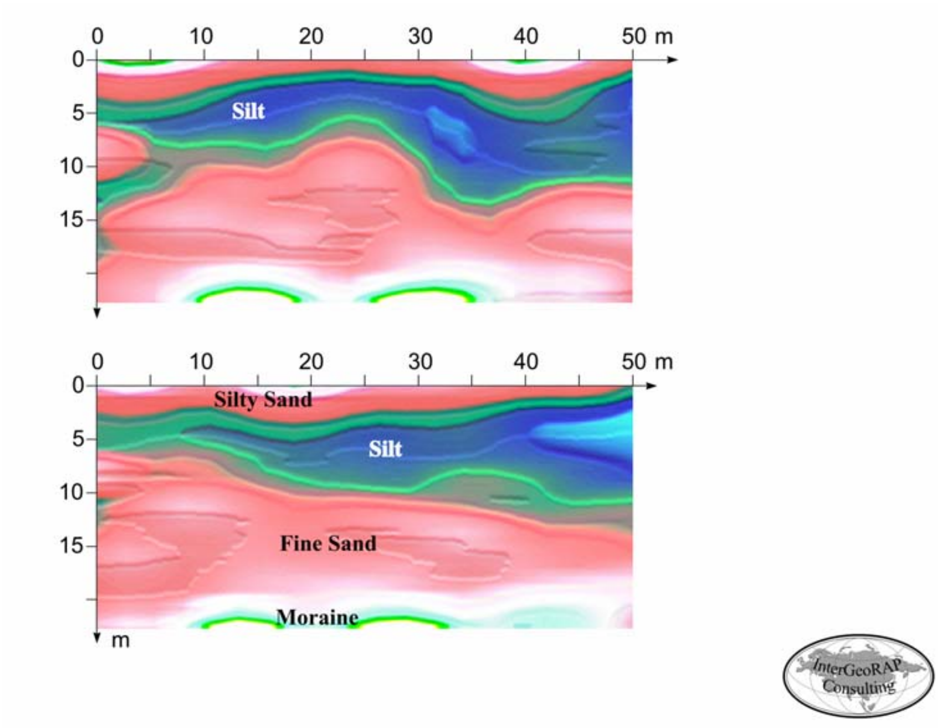

Figure 2. Regolith structure. Geotechnical regolith study at a construction site, St. Petersburg 1999.

GAP may be used in areas where conventional EM techniques and Ground Penetrating Radar fail to provide reliable results due to soil salinity and unfavourable hydrogeological conditions. Good resistance to interference makes it possible to use GAP in urban environments.

Extensive GAP trials were carried out in Australia in November-December 1999. The trials were hosted by the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME) and sponsored by Geoscience Australia and 7 major mining and exploration companies; Anaconda Nickel; Ashton Mining; Astro Mining; Great Central Mines; PacMin Mining; Placer (Granny Smith) and WMC. The technique was tested at a few regolith projects (palaeochannels, alluvial terraces, laterites and deep weathering profiles) as well as on bedrock geology (gold, diamonds) and geotechnical projects.

Following the trials, InterGeoRAP started commercial surveys in Australia in 2000. At this stage the completed commercial surveys include primary and alluvial diamond exploration, gold exploration projects and a hydro-geological study. Further geotechnical studies were carried out on laterite profiles (Figure 3).

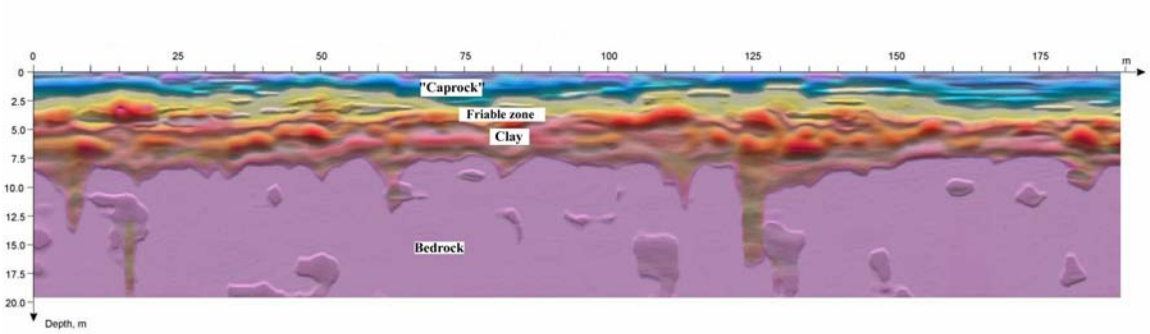

Figure 3. Example of GAP laterite geotechnical studies.

5. PROBLEMS, LIMITATIONS

GAP provides good resolution down to approximately 300 m depth. At this stage GAP involves mechanical sources of acoustic signals (eg. geopick, sledge hammer) and therefore depends on the surface conditions. Accumulating and averaging of measurements as well as additional filtering are necessary for surveys over a loose sandy or soft wet ground and heavily disturbed areas (eg. dumps, pits, rehabilitated areas) as well as over areas close to sources of acoustic disturbances. A non-mechanical source of signals is supposed to help to overcome these limitations at the next stage of the development of the technique.

6. SURVEY ORGANISATIONS

The GAP technique has been developed up to the stage of industrial applications by an independent geophysical consulting firm, InterGeoRAP Consulting, established in 1996 in St. Petersburg, Russia. The firm employs a group of geophysicists and software specialists, formerly involved in major Russian mining and exploration companies. InterGeoRAP has been developing the new ground acoustic technique and implements innovative approaches and software for the processing and interpretation of ground and airborne magnetic data. It also specialises in ground and airborne radiometrics, EM and gravity surveys.

At this stage InterGeoRAP does not sell or rent out its proprietary GAP equipment. The firm carries out field surveys and consulting assignments in Russia and internationally.

Additional information on the firm and some examples of GAP applications are presented at InterGeoRAP's web site: http://www.iinet.net.au/~tchern

Any inquires about InterGeoRAP may be addressed to firm's overseas agent in Australia:
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7. COSTS

The GAP survey costs depend on the station spacing and ground conditions and are in the order of a few hundred dollars/ line kilometre. The survey costs include both fieldwork and interpretation/reporting.

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