High-resolution method of pulse electromagnetic probing (MPEP)

International experience of application
Fund deposits, opened from the surface, has long been exhausted and this requires use of high-performance exploration methods (with the on-line component), which are high resolution and are inexpensive and quick. Scanning geological cross-section to a depth of 300 m.

The method can be used for all types and stages of geological prospecting:

1. Small-scale regional geological survey
   1:500,000 - 1:1,500,000

2. Middle-scale geological survey
   1:200,000

3. Stage 2
   Forecasting and search geological work
   1:200,000 (1:100,000 - )

4. Large-scale geological survey
   1:50,000 - 1:250,000

5. Stage 3
   Greenfield exploration

6. Stage 4
   Exploration
Solved problems

- Stratigraphy of the geological section
- Isolation of ore zones / bodies
- Their isolation in geophysical cross-sections and tracking in space (stockworks, veins, and mineralized zones)
- Identification and mapping of faults of different genetic types
- Mapping zones of tectonic disturbances of various genetic types
- Mapping modern and buried river valleys

Technological circuit of the works - the "eyes" of one joint team

- Preliminary interpretation of satellite images and other types of remote sensing
- Geomorphological investigation
- Neotectonic investigation
- High-resolution method of pulse electromagnetic probing (MPEP)
- Magnetometer mapping

Ore minerals study

Fluid inclusions study

Structurally-geometrical analysis of fold and fault dislocation

Geological Study

Other geophysical methods

Electrophysical methods

Gravimetric mapping

Magnetometer mapping
HIGH-RESOLUTION METHOD OF PULSE ELECTROMAGNETIC PROBING (MPEP)

FIELD WORKS:
- Picture of phase-amplitude electro-physical inhomogeneities in the cross-sections

Spatial linkages selected types of anomalies

Analysis → synthesis → selection and typing anomalies

Geological interpretation of geophysical data

Create a spatial model (Geological and geophysical)
HIGH-RESOLUTION METHOD OF PULSE ELECTROMAGNETIC PROBING (MPEP)

• “MPEP" is the complex of pulse electromagnetic probing belonging to the class of geophysical devices for the exploration of subsurface ground structures at the depths of several - hundred meters depending on device model, applied aerial and the parameters of probed medium.

• The principle of operation of this equipment is based on irradiation of superbroadband electromagnetic pulses without spreading to base medium and registration of their reflections from the borders of layers separation or objects.

• Distinctive feature of the devices of this series, in comparison with well-known analogues, is big energy potential allowing to operate in high conductivity mediums, for example in loam or damp clay.
Technical properties

- Mean radiated power, mW 50
- Peak pulse voltage, kV > 5.5
- Pulse duration, ns 3-5
- Repetition rate, Hz 1000
- Radar potential, dB 120
- Sensitivity, µV 200
- Discretization rate, MHz 1000/500
- Frequency band, MHz 1-50+
- Dynamic range, dB > 95
- Registration range, ns 256, 512, 1024, 2048, 4096
- Time resolution, ns 1, 2, 4
- Registration cycle (averaging on/off), s: binary mode 0.2/0.015; full waveform mode 2.2/0.6
- Operation modes: manual; automatic with period 1s, 2 s, 3s; with user-defined period
- Number of frames (128x256 format): binary mode > 500; full waveform mode > 30 000
- Averaging over shots 16
- Two manual threshold ranges, dB ± 16
- LCD b/w 240*320
- PC connection via RS232
- Data processing PC
- Consumed power, W (not more) 3.7
- Temperature range, °C -20+50
- Dimensions (CIU with batteries), mm 260*150*160
Applying the method of pulse electromagnetic probing, it is possible to solve the following geological problems:
- At the initial stage of exploratory geological studies, the following geological problems are solved on primary deposits:
  - Detection and mapping of structural geological abnormalities;
  - Detection and mapping of geological breaks;
  - Drawing up tectonic map of works area;
  - Definition of hydro-geological conditions of works area;
  - Detection and delineation of geophysical anomalies based on variation of electric physical and electromagnetic properties;
- Detection and mapping of ore bodies;
- Detection and mapping of kimberlite structures;
At the stage of additional geological and geophysical studies of primary deposits:
- Determination of lateral extension of productive horizon;
- Detection of emptiness and karstic zones within the limits of proven deposit;
- Exploratory examination of mine boards for development of dangerous geological processes (collapses, landslips, slide-rocks, quick grounds);
- Detection and mapping of geological breaks;
- Determination of ground (underground) water level;
- Detection of drained accumulative structures;
- Determination of promising points for drilling of dewatering wells.
Geophysical support at open mines

Gol-e-Gohar, Kerman

*Detection and mapping of geological breaks
*Detection and mapping of ore bodies
*Detection of emptiness
*Detection of confining layer and base of waterbearing horizon
*Geophysical monitoring of dangerous geological processes (collapses, landslips, gaps)
Application of geophysical complex “MPEP” allows to determine efficiently the capacity of rocks overlapping ore body, to detect geological breaks and to determine structural discords.
During the works, the step between measurements is 1 m. Such detailed elaboration allows to determine very precisely the sizes and capacity of ore bodies, to determine in the most precise way the lines of geological breaks and to localize geological and geophysical anomalies.
At the depths up to 100 m, it is possible to find small emptiness. The emptiness with big dimensions (caves) are fixed at the depths up to 300 m. Timely finding of the emptiness during field development essentially reduces the risk of emergencies.
The details of the received geophysical sections allows to mark out precisely secondary ore bodies, zones of dissipated mineralization formed as a result of sulphide streams going out.
On the geophysical sections, chrome containing ore bodies are marked. Their configuration and capacity are determined, and it is undoubtedly important to make decisions about economic feasibility of mining.
Based on the geophysical operations conducted the following results were received:
- on the basis of drilling before conducted and in comparison and analysis of GPR data the appropriateness of gold concentration and content in this deposit is revealed
- the prospective areas for further drilling are revealed and mapped.
Geophysical anomalies corresponding to ore bodies, containing copper, chrome, magnetite and other types of iron ores and having contrast electric physical properties, are fixed precisely enough on georadar sections.
Geologic and geophysical exploration for minerals of lateral extension, such as coal, is one of the most active areas of application of this technology. Having contrasting electrical properties in comparison with enclosing rock, coal horizons are clearly marked out in geophysical sections.
According to its electrophysical properties the coal bed has a contrasting distinction from enclosing rocks. So the reveal of coal beds made by *pulsed electromagnetic sensing* method at depths of nearly 200 metres is possible.
The experimental and methodical operations which purpose was the demonstration of possible mapping of the **Ore-Bearing Lenses** were conducted using the geophysical system “MPEP”.

There were sharp changes detected in signal amplitude inside the lens in operation min/max while analyzing and interpreting the geophysical profile. Within the distinguished lens these amplitude changes are timed to the maximum depths.

Considering the large density of tantalite and gravitation forces the tantalite deposition and accumulation take place in the areas of maximum submersion.
As a result of experimental and methodical work done the lens beneficiated with tantalite was revealed and mapped. The control pit which has confirmed the presence of substracted lense was made in the point of minimum depth from earth surface. Thus, the geophisical system “MPEP” showed its high efficiency during the mapping of productive lenses of low thickness of up to 50 cm at depths of neatly 10 metres.
One of principal directions of the application of **pulsed electromagnetic sensing** method is the search for subsurface water and water catchment geological structures. The main tasks being solved with the help of this method were the following:

- water-bearing horizon depth test
- localization of water draining geological structures (catchers)
- hydrogeological hole drilling position finding.

- The boundaries (roof and bottom) of water-bearing horizon are revealed according to the results of **geophysical** operations conducted. The structural heterogeneities being water catchers are determined and localized. The points for hydrogeological hole drilling are marked with maximum accuracy.
The anomalies which are closed karst zones are detected in the geophysical data analysis and interpretation. In the geophysical profile three watered bearing karst zones are marked out. The Zone 1 and Zone 2 are ones of active karst development because the rock jointing and multiple little karst «windows» are fixed above them.

The geological and structural faults being the places of natural water draining into lower layers are clearly fixed in the geophysical sections.
• Spatial linkages of the ore zones

• Mapping of ore-mineralized structures (horsts)
• Interpretation of satellite images

• Spatial linkages of the ore zones
idealized model of the ore zone

Аз. пад. 15°

Аз. прост. 315-325°
Spatial model of the ore body as a result of profiling MPEP

bottom view

View from above
• Vertical fault, violates the continuity of horizontal layers and the basement, the disintegration of rocks in the fault zone

• Discordance of two type geological layers and rocks of the basement
• Three vertical fault zones
• Layered deposits, which are cover the basement rocks
quartz-sulphide vein of the ore stockwork

Quartz veins

Dikes
Ore-controlling faults and zones of silicification in them
The ore body, quartz-sulfide vein - stockwork

Ore-silicification zones in layered thicker sandstones
Ore-controlling horst (1, red) and the ore body (2, white) in it
KIMBERLITES
Allocated on geophysical sections anomalies correspond to vertical geological structures to kimberlites. Kimberlites bodies have considerable deviations of values of electrophysical properties of containing breeds. Search and detection of kimberlites bodies with use of a method of pulse electromagnetic sounding at depths up to 300 meters it is possible.
Kimberlite pipe, which intruded rocks of Precambrian crystalline basement

Above - a distinctly mapped caldera complex of the Kimberlite pipe
SEARCH OF ALLUVIAL GOLD and DIAMONDS
Applying georadar (MPEP) method it is possible to solve the following geological problems:
At the initial stage of geological exploration on placer mines:
- identification and outlining the boundaries of river paleochannels and paleovalleys;
- determination of alluvial deposits thickness;
- identification and outlining accumulative traprocks;
- building of pale morphological 3D model of river valley;
- identification of promising areas for quality testing.
large boulders, gravel and clay

medium gravel with sand

medium sand with gravel

system palaeochannels

palaeochannels

medium gravel with sand

large boulders, gravel and clay
Modern river valley and paleorelief of the buried river valley.

Gravel (3.2).

The structure of the basement rocks
• Modern river valley

• Fault zones and accompanying mineralization in the basement formations (variously manifested in different layers)
Currently, this technology is widely applied by Russian diamond mining companies for prospecting and exploration of new kimberlite structures. Design features of the geophysical system “MPEP” allows to realize the surveys in the areas not only with difficult relief, but also in the areas with dense vegetation (forest, taiga), where application of other exploratory methods is either difficult or impossible. Mobility and efficiency of this geophysical system allows exploring of geological conditions within the shortest period of time, significantly reducing the costs of exploration.
The application of georadar method may significantly reduce the time for geological exploration. Mobility and small size of georadar equipment are able to perform 3 to 10 km of linear geophysical profiles per day, which exceeds the capabilities of other geophysical methods. Specialized software also allows you to process and interpret quickly the georadar data. Depending on the complexity of the problems and geological conditions, preparation of the report may take 15 to 20 days, with the volume of geophysical profiles 30 to 50 linear km. Such efficiency allow, within the shortest time, to survey large areas, significantly increasing the efficiency of seasonal field works.

In the course of fieldworks using georadar method, detailed elaboration of the produced geological and geophysical sections increases, by reducing the spacing between the probe points. In georadars of “MPEP” series, minimum distance between the probe points, during exploration, is 30 cm. Such detailed elaboration allows to detect geological objects or shapes with small section, depending on the depth. On placer mines, it is possible to detect accumulative forms of small lateral extension, to mark out geological layers, to separate the layers by granulometric composition. According to the results of the received data, the places of confirmatory boreholes or pits are adjusted, significantly reducing their number and increasing the information content and quality of sampling.

The structural feature of georadar complex “MPEP” enables profiling in the conditions of heavy vegetation and in difficult mountainous rocky areas. Applicable aerials are composed of separate small interconnected plates. Such flexible construction follows the relief contour and does not render difficult the works in complex areas. The width of geophysical aerial does not exceed 50 cm, which in the condition of thick vegetation of jungle or bush does not require cleaning of broad band.

Georadar complex “MPEP” may be successfully applied in climatic zones with temperatures -40 to +50 °C.

Application of georadar method during geological exploration significantly reduces the costs of drilling (wells, pits), while significantly improving their quality and information content. The obtained results allow quick identification of promising area for further exploitation. As a rule, under favorable geological, landscape and climatic conditions, the price of 1 linear kilometer profiling is $ 800-1000.