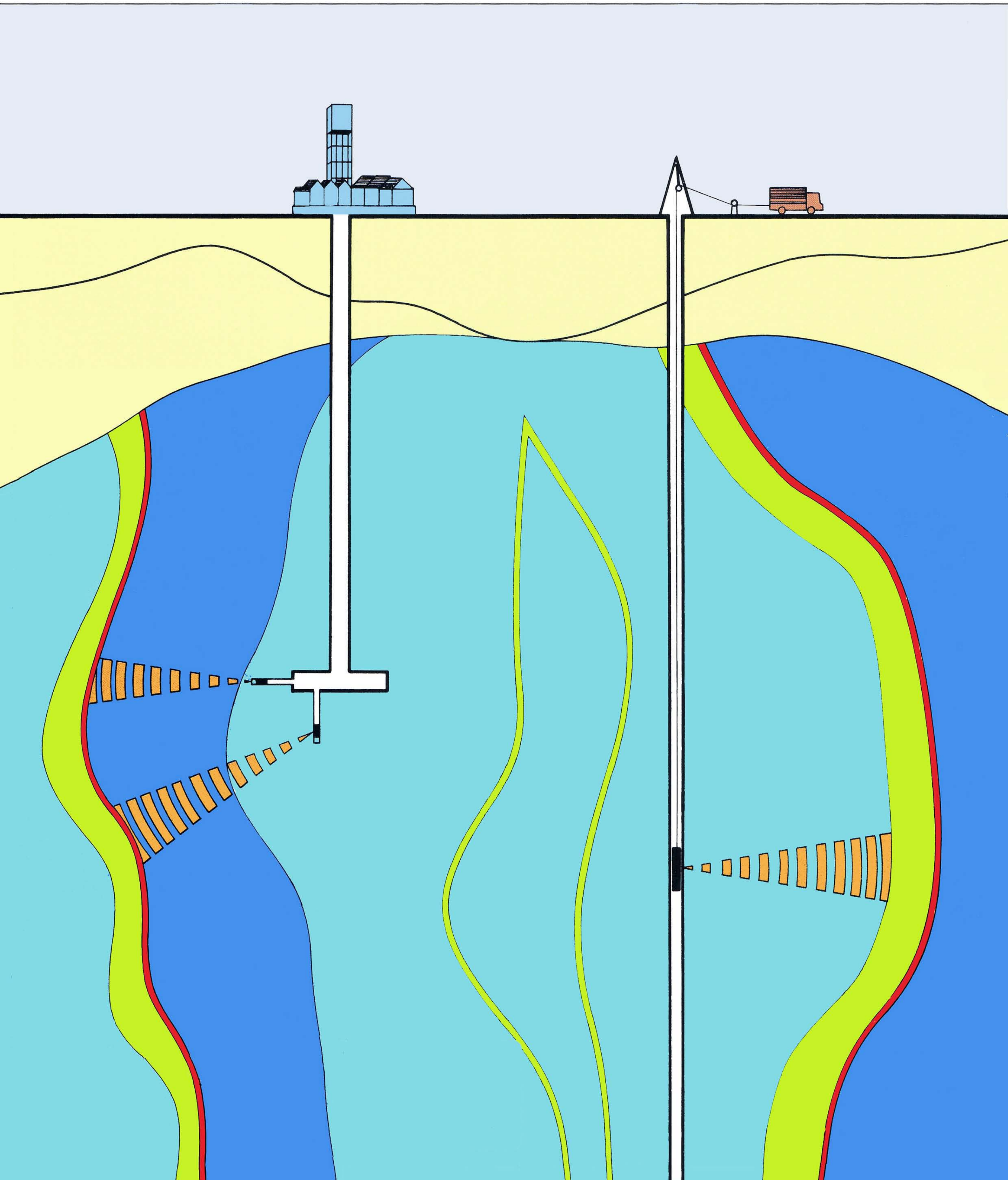
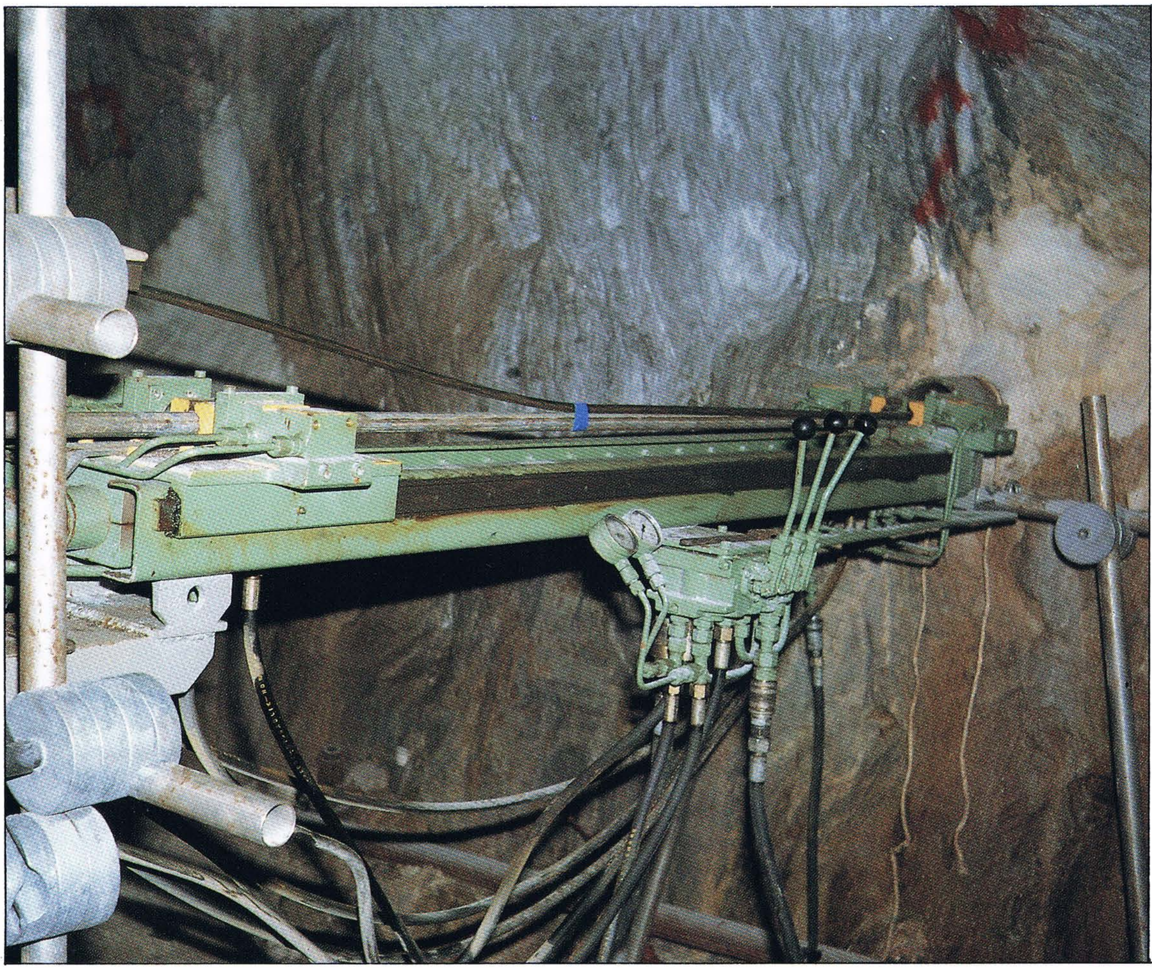
PRAKLA-SEISMOS INFORMATION No. 64

High-Frequency Borehole Radar Using a Direction-Finding Antenna System



Preparing well-radar equipment at a rig site



Pipe-moving equipment for horizontal boreholes in mining environment

High-Frequency Borehole Radar Using a Direction-Finding Antenna System

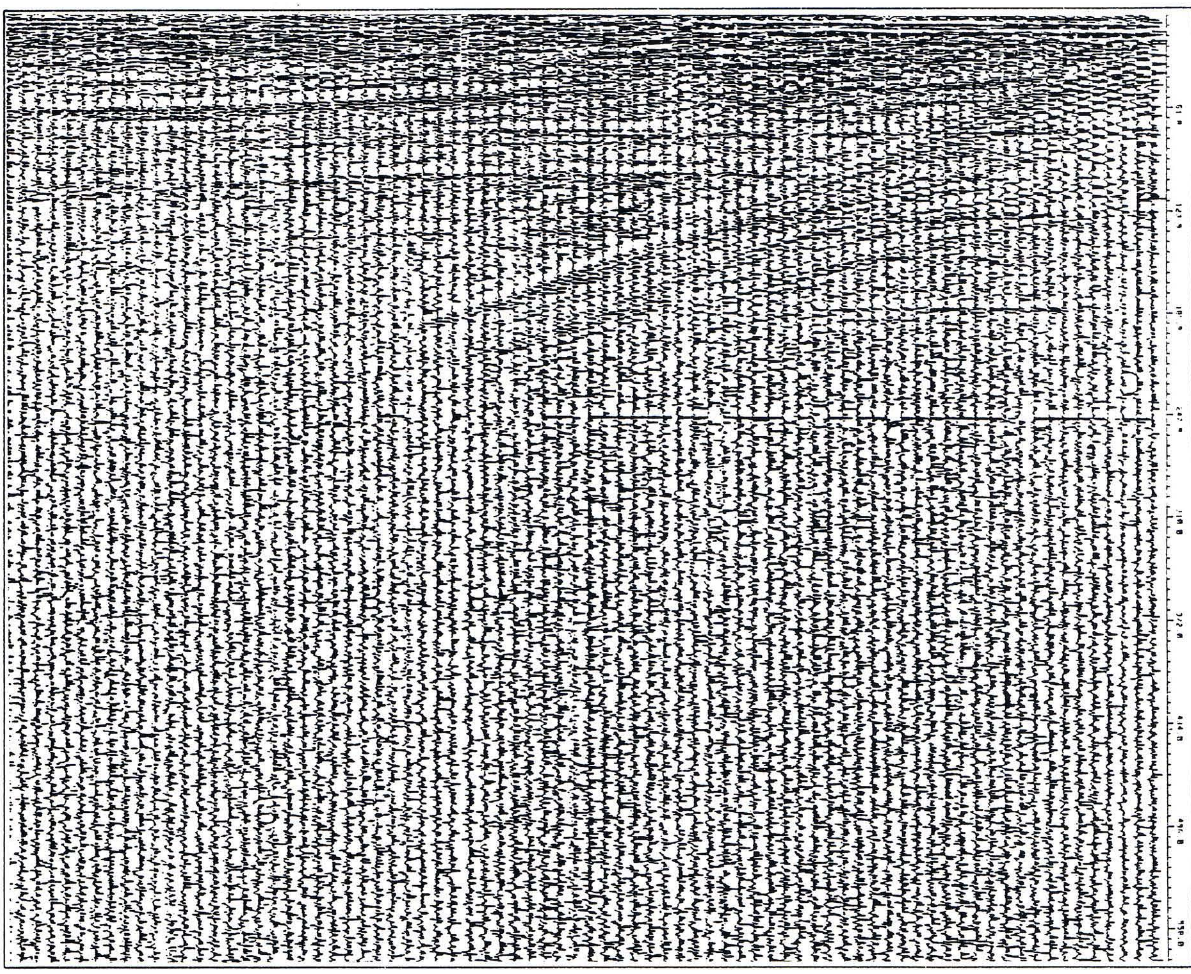
Electromagnetic reflection measurements can be made from boreholes with both transmitter and receiver antennas in the same hole separated by several metres. Normally dipole antennas are used, installed along the sonde axis. Under favourable conditions reflection signals are recorded over a range of more than 200 m. Many records have been produced in salt and rock showing numerous reflections from discontinuities.

Some of these events show continuously changing traveltimes as a function of the varying sonde depth. Traveltimes which run to zero indicate that the event crosses the borehole. The rock at this crossing point can then be analysed by orientated cores and by televiewer measurements to correlate the detected electromagnetic event to specific rock properties. Events, however, which cannot be correlated with the borehole profile in this way cannot be localized azimuthally from the records. To overcome this problem the direction from which the reflection signal returns to the receiving antenna has to be determined. Well-known techniques using directional antennas, however, cannot be realized in the borehole because of the large wavelength of the signal travelling through the rock compared to the diameter of the hole.

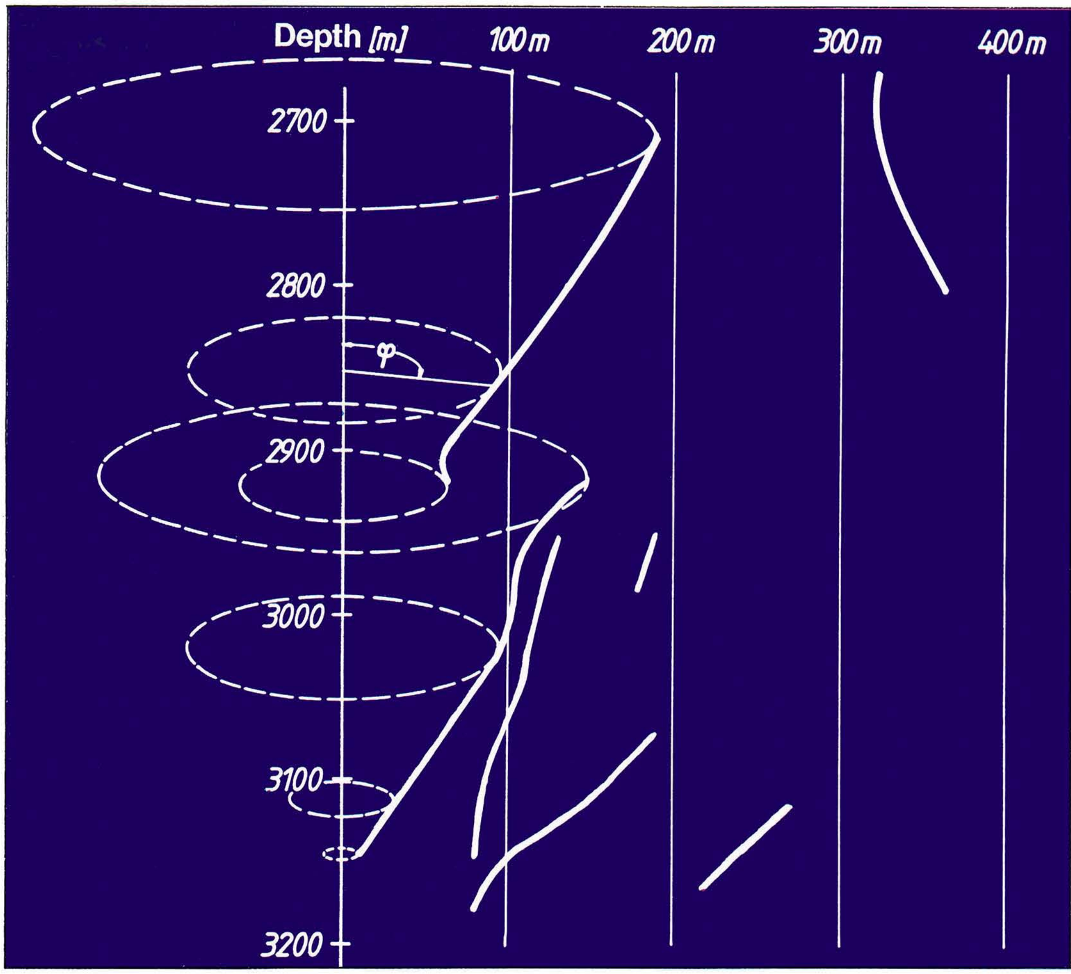
Consequently a new direction-finding technique was developed using two crossed-loop antennas to determine unequivocally the azimuthal direction of the incoming signal. With this receiver technique phase and amplitude can be evaluated as a function of direction, which can be determined with 5° accuracy. A correlation algorithm allows this procedure to be performed on site so that the direction from which a specific signal is reflected can be continuously tracked in a moving time window relative to the compass's indicated direction.

The sonde is designed not only to be lowered into holes from the earth's surface but also to be dragged through tilted boreholes, eg starting from underground mining galleries. The whole system is available in a fire-damp proof version.

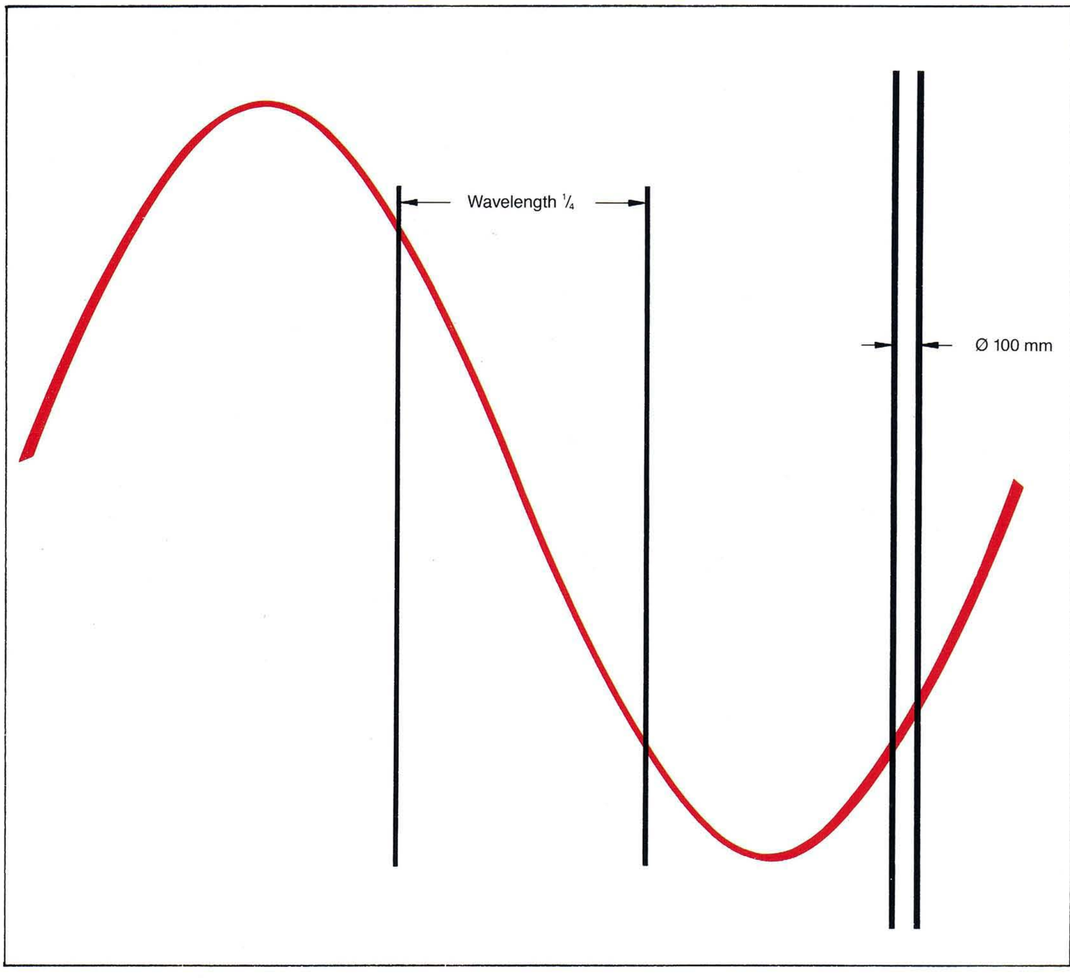
Experience has shown that the variations in electromagnetic properties and the varying conductivity of the rock material result in distinct reflection signals. This must be taken into account when tuning survey parameters to the exploration target. The technique used for the electromagnetic reflection survey system, which includes the sonde with direction-finding antenna, allows the parameters to be tuned over a wide range.



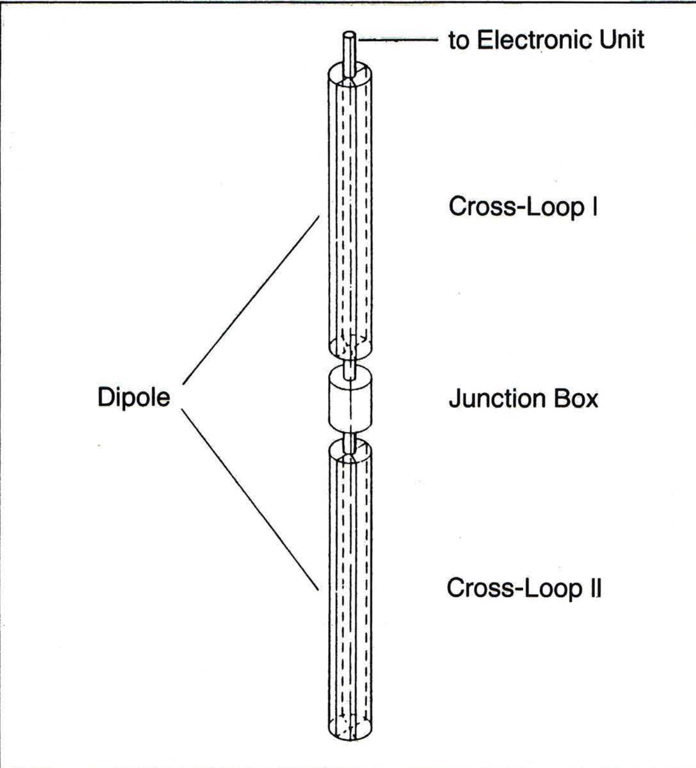
Interpretation of high-frequency radar data is similar to that of seismic data. The reflection electromagnetic (REM) cross-sections, however, differ in scale, since the velocity of radiowave propagation is 125 m/µs in rock salt.



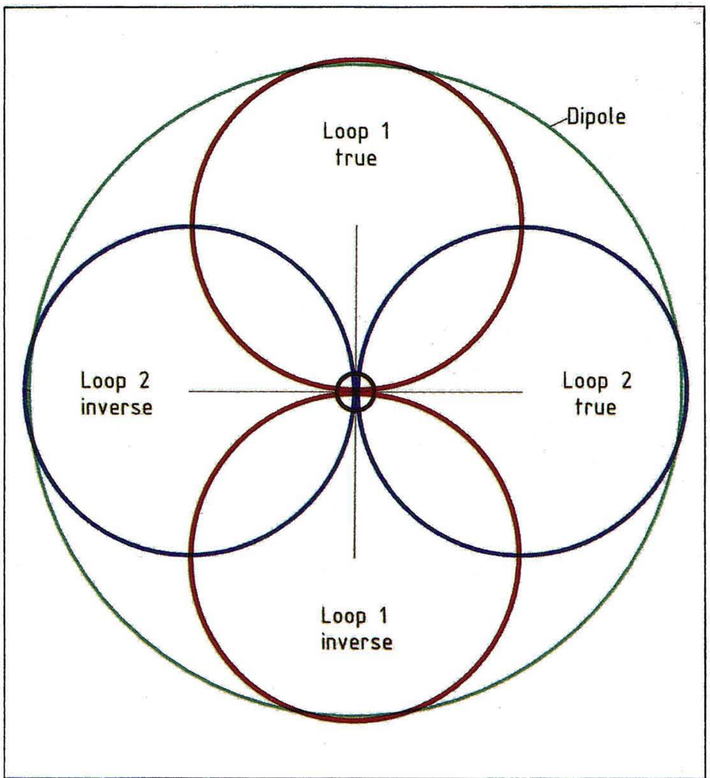
There is no information about the azimuthal position of a reflector: it may be situated anywhere on a concentric circle around the sonde in the borehole. The angle of orientation could **up to now** be derived only for reflections crossing the borehole using data from orientated cores.



To derive the angle of incidence of an electromagnetic wavefield antennas normally have to be at least 1/4 wavelength long. Since the wavelength of high-frequency radar is several metres, the realization of direction-finding antennas for use in a borehole is extremely difficult.

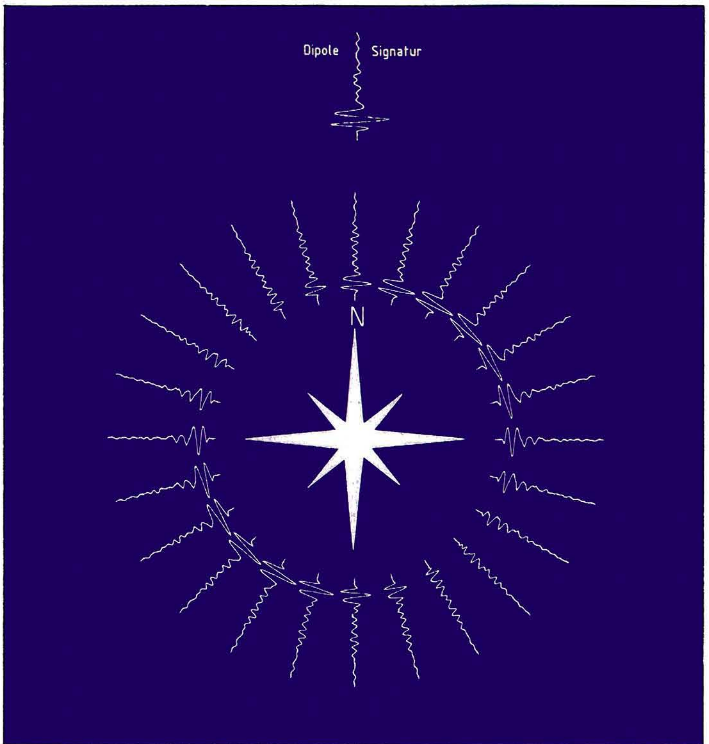


In order to solve this problem, a unique loop-dipole antenna system has been developed. The arrangement consists of two staggered crossed-loop systems. A junction box in the centre contains electrical circuits to separate the signals of the loop-dipole structure.

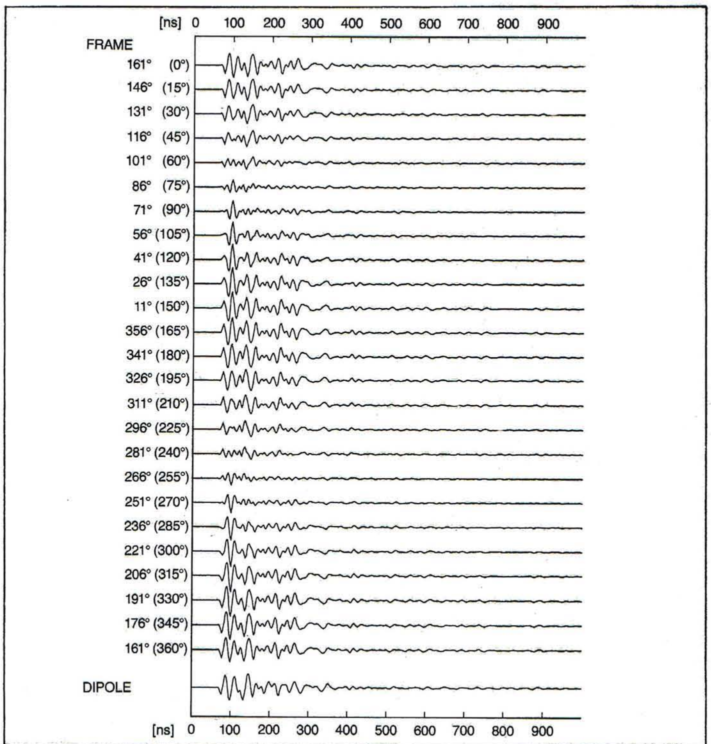


The output of this antenna has three distinct signals, which are recorded consecutively:

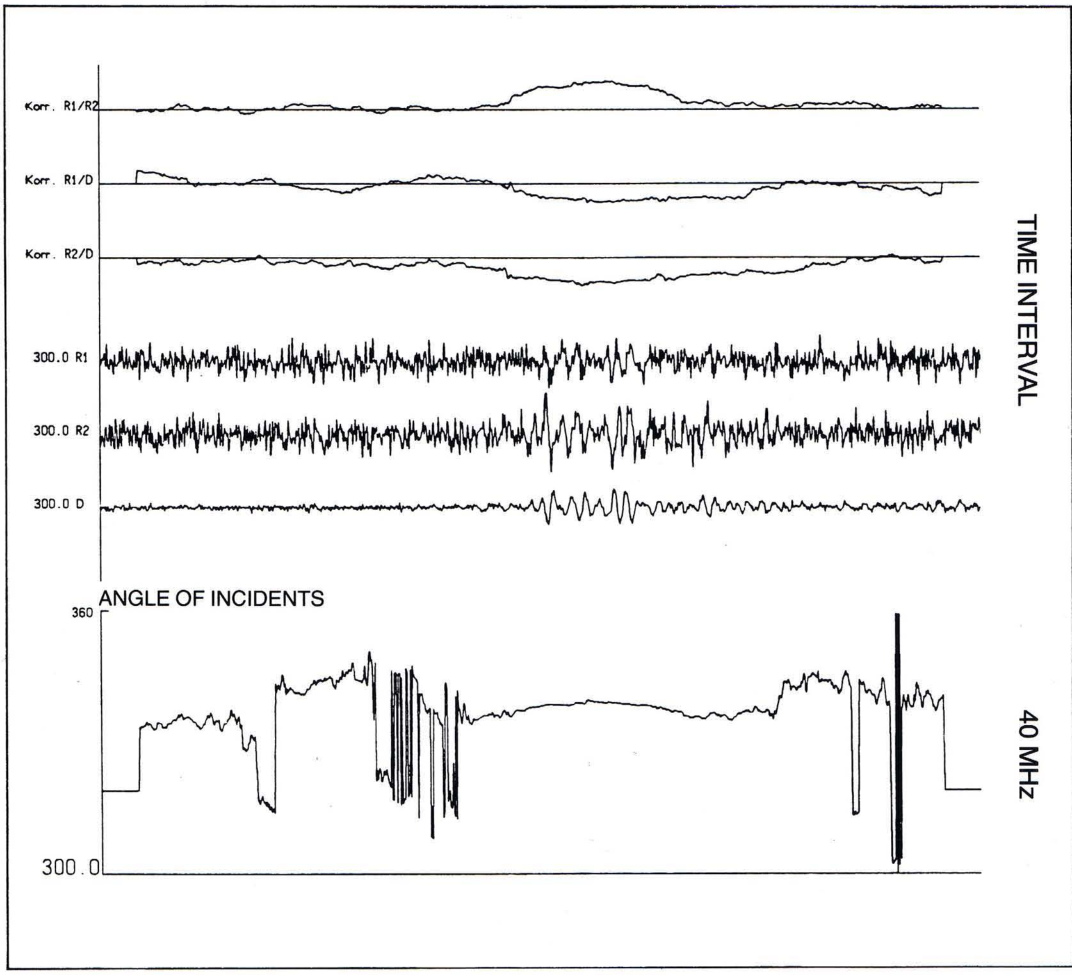
- an omnidirectional dipole signal
- a figure-of-eight loop signal
- an orthogonal figure-of-eight loop signal.



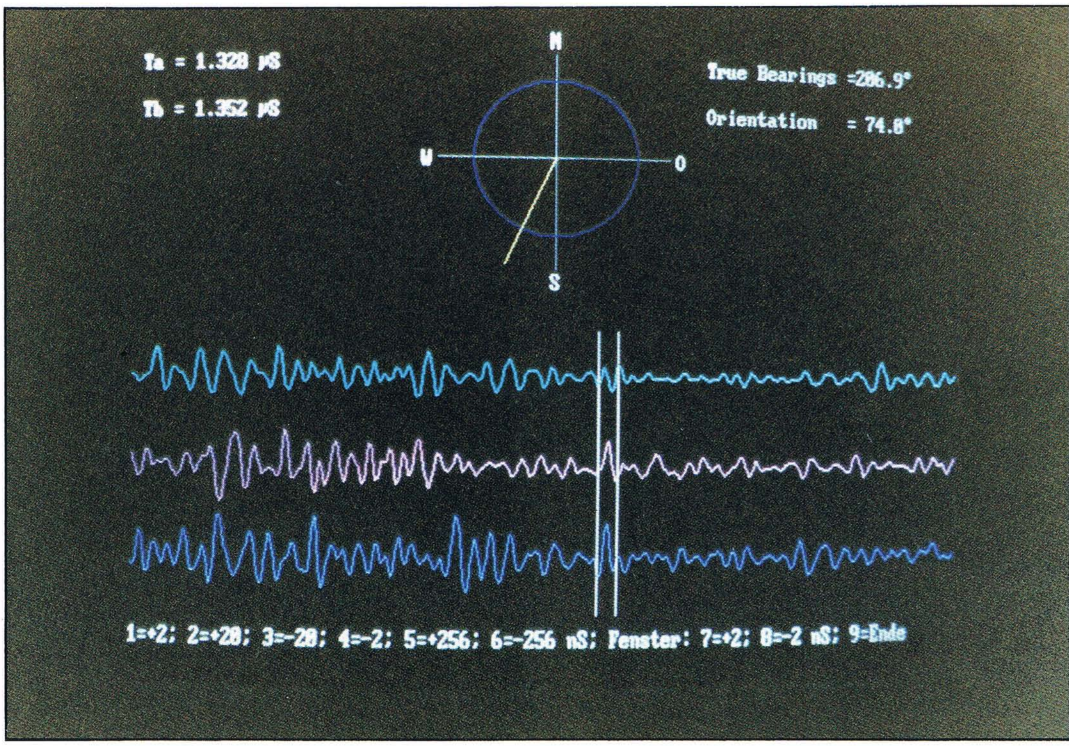
A vector-rotating algorithm allows the figure-of-eight loop-antenna pattern to be turned to any desired position in the azimuthal plane so as to simulate the mechanical rotation of a single loop. Presentation here is in a polar plane in 15° steps. Phase ambiguity is resolved by considering dipole signature.



A vertically stacked trace-by-trace presentation proves more practical. Geographic orientation of the antenna is obtained by a magnetic compass and/or an inclinometer.



A dedicated correlation-algorithm facilitates a continuous graphic display of the angle of incidence and correlation factors of loop 1 to loop 2, dipole to loop 1 and dipole to loop 2.



An interactive screen evaluation program allows a variable window to be moved on the dipole-loop-loop display and presents analog and digital directional information including correlation quality control by displaying analog vector length.

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