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DETERMINATION OF THE GEOTHERMAL POTENTIAL BY GEOPHYSICAL INVESTIGATIONS IN THE KARBINCI–TARINCI AREA, IN THE VICINITY OF ŠTIP

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A b s t r a c t: Geophysical methods used in the determination of geothermal potential by geophysical investigations in the Karbinci–Tarinci area included as follows: detailed reflective seismic scanning, geomagnetic profiling, geoelectric probe and electromagnetic VLF prospecting. The site investigated consists of rocks of Precambrian, Mesozoic (Jurassic), Tertiary (Paleogene Neogene) and Quaternary age. From earlier investigations carried out in the wider vicinity and from investigations carried out by the present authors, one can expect occurrence geothermal water in the area.

Key words: geophysical methods; reflective seismic scanning; geomagnetic profiling; geoelectric probe; electromagnetic VLF prospecting

INTRODUCTION

The site under investigations is situated in the River Bregalnica valley some 7 – 8 km north-east of Štip before the foot of Mt. Plačkovica.

The occurrence of warm water near the village of Krupište gave the idea for investigations of geothermal water. Also, greenhouses which use crude oil for heating are located close to the area investigation.

The investigations of the present authors may serve to discover on alternative source for heating the greenhouses – thermal water is more economic instead of crude oil.

GEOLOGIC CHARACTERISTICS OF THE TERRAIN

The site under investigations (Figs. 1, 2) is located in a terrain made up of:

– Crystalline base of the terrain is made up of gneiss and micaschist of Precambrian age with interlayer of schist, amphibolites, and marbles.

– Granite complex – alamelites, aplitoide and biotite granites intruded into the crystalline base of the terrain (probably in the Lower Jurassic) and reworked by later tectonic processes.

– An upper flysch zone (later located into Oligocene sediments) made up of slates and sandstones with interlayer of marls and limestones in the younger portion of the column:

– Pliocene erosion "rocks" left only in the upper part of the terrain near the site.

– Alluvial layer of the river Bregalnica and one alluvial-proluvial layer from the water flow at the Mt. Plačkovica site, made up of sand, pebble with dust and clay of $n \times 10$ m thick

The thickness of the sedimentary cover probably amounts to 500 or 600 m (according to data from structural drill hole near the village of Krupište).

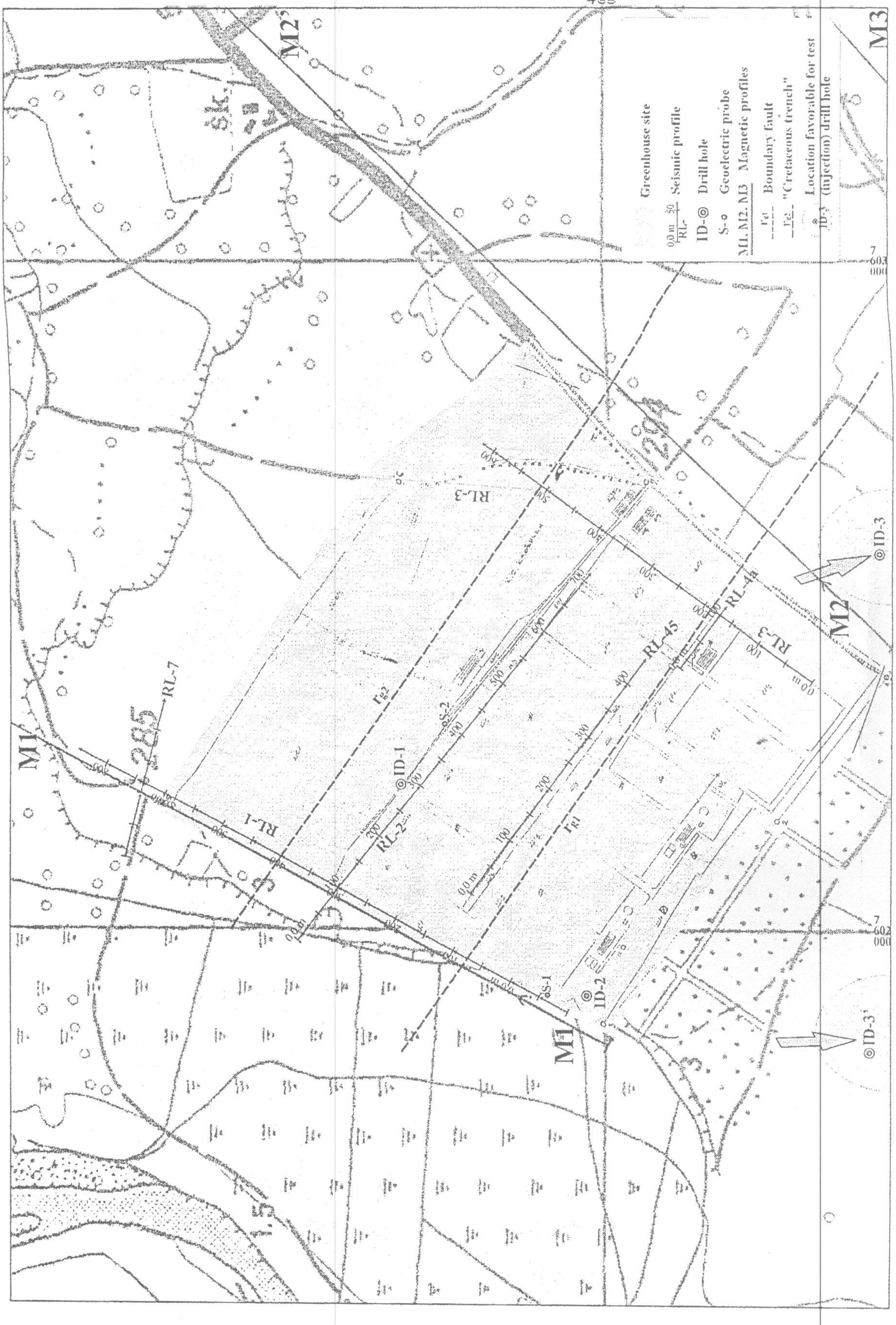
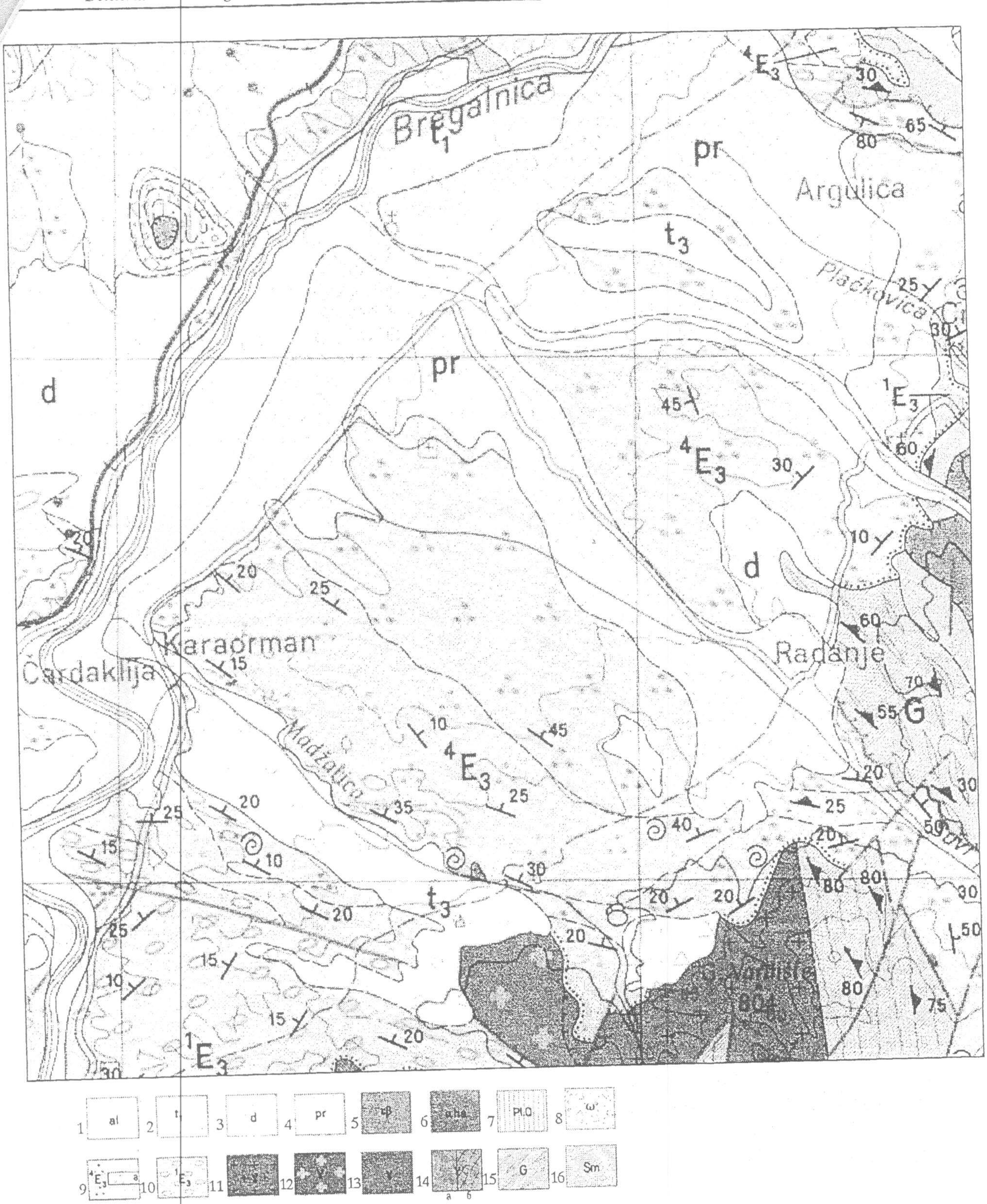


Fig. 1. Topographic base 1:5000 with location of the greenhouses



Quaternary: 1 - alluvium, 2 – river terrace, 3 – diluvium, 4 – proluvium, 5 – kayanites and basalts; **Neogene:** 6 – augite-hornblende-biotite andesite, 7 – tuffacious limestones, 8 – andesite breccias and tuffs; **Palaeogene:** 9 – upper flysh zone, slates and sand stones, marls, lime stones and sleds (a), 10 – basalts series, sand stones, marls and conglomerates; **Jurassic:** 11 – aplitoid granites, 12 – biotite granites, 13 – adamelites; **Precambrian:** 14 – granites (a), schistose granites (b), 15 – augen-amygdaloidal gneisses, 16 – micaschist

Fig. 2. Geologic map of the area between Karaorman – Radanje – Argulica (Scale: ≈ 1 : 50 000)

HYDROGEOLOGIC CHARACTERISTICS OF THE TERRAIN

Recharge with water to the site under investigations is done by gravitational inflow of atmospheric water from the higher terrain from the adjacent slope of Plačkovica.

The alluvial and deluvial cover represents a collector hydrogeologic environment with intergranular porosity that is favorable for recharge with cold water.

The Eocene (? Oligocene) Cretaceous period is characterized mainly by small intergranular porosity and pronounced low water permeability.

The complex of crystalline base with granite massif has been discovered in the upper part of the adjacent slope in Mt. Plačkovica.

Fissured granites (with fissure porosity and water permeability) are permeable to poorly permeable, depending on the intensity of fissuration and the size of the fissures. The compact granite with closed (surpressed) fissures serve as water insulanting environment.

Gneiss, particularly micaschist and other schists (based on understanding from the wider surrounding) are very water insulating environment.

Thus, the concept for the presence of hydrothermal systems in the site under investigation is based on "thermo-aquifer in cracked granites and its recharge through fissured granites".

Among the granites, the most significant are aplitoide granites (with greater fissuration) particularly from the aspect of making a drill hole. However, aplitoide granites (as vein rocks) occur at the boundary zones between gneiss and granites are characterized by small thickness of veins and small collector volume. In that regard the possibility for their indirect registrations is reduced, especially due to the sediment cover of probable thickness amounting 500 m.

The issue for the presence thermo-aquifer in the site is of interest with regard to the presence of the Kežovica hydrothermal system (some 10 km SW of the site along the river Bregalnica course) and warm water 600–650 m in depth in the drill hole near Krupište (some 5 km NE from the site – along the river Bregalnica course).

Two occurrences can be related to the granite massif in the slope of Mt. Plačkovica to the east–southeast of Štip. There are indications for the occurrence of warm water near Krupište on the basis of which it can be assumed that it originates from "thermo-aquifer" located in the closer surrounding of this location.

GEOPHYSIC INVESTIGATION

Investigations included as follows:

– Detailed reflective seismic scanning of the structural-tectonic pattern of the land of the greenhouses where 5 individual exploration profiles (RL-1 to RL-5) of 250–800 m in length, and total length amounting to 2,5 km. Scanning of the pattern was carried out with step of 5 m excite, geophone distance of 5 m and offset of 100 m.

– Geomagnetic profiling in 3 profiles for the check of the possibility for the presence of magnetic rocks in the crystalline base.

– Geoelectric probes were carried out 2: S1 with AB/2 = 700 m and S2 with AB/2 = 300 m perpendicular to each other.

– Electromagnetic VLF prospecting – 6 profiles were carried out: W-1,W-2, W-3, W-4, W-5 и W-6.

Seismic scanning was carried out by ABEM TERRALOC, geomagnetic profiling by proton magnetometers BISON and GEOMETRIX, geoelectric probes by ABEM TERRASAS and electromagnetic VLF prospecting by field prospector ABEM WADI.

The geoelectric method allows assuming that there are indications of ground water in the site with the possibility of geothermal water. In that regard, geoelectric methods were used for the support of the hydrogeological interpretation of the structural tectonic pattern with reflective seismic scanning in the terrain.

RESULTS AND INTERPRETATION

The results obtained make it possible to point out that:

– The granite massif is present in the crystalline base south of the terrain under investigation.

– The presence of "Cretaceous roof", discovered on the surface on the right side of the upper course of the River Radanska which goes further under the younger sediments towards the area. On the left side of the Radanska, mapping of confinement of the trench by overthrusting was made. This friable structure most probable play certain hydrogeological role in under ground flow. If the zone at the base of the sediments passes through the granites, it may act as water conducting zone and collector environment, and down to the lower Eocene and Cretaceous impermeable sediments as buried hydrogeologic curtain.

– Geophysical geomagnetic and gravimetric indications for the presence of faults perpendicular to the trench among which the Bregalnica strike is predominant.

Magnetometer profiles M1, M2 and M3 (Fig. 3) are almost parallel to each other, 1000 m in length, with Štip–Kočani strike, and reversed. Magnetometric profiles correspond to geologic assumption for the "Cretaceous trench".

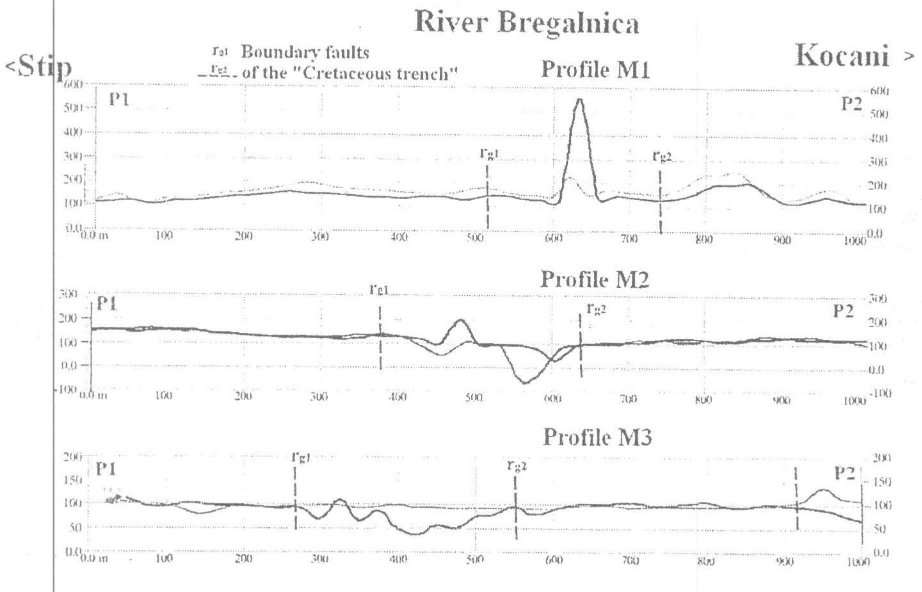


Fig. 3. Magnetometric diagram from walking mode

Reflective seismic investigations (Figs. 4 and 8) are shown in seismic sections to depth, after investigated profiles.

Reflective seismic investigations determined the structural tectonic pattern as essential for the assessment of the deep fault zones – possible routes for circulation of heated thermal water towards the surface. The hydrothermal model – recharge by cold water from the fissure system of the granites south of Štip, its heating in depth and return to the surface through deep faults.

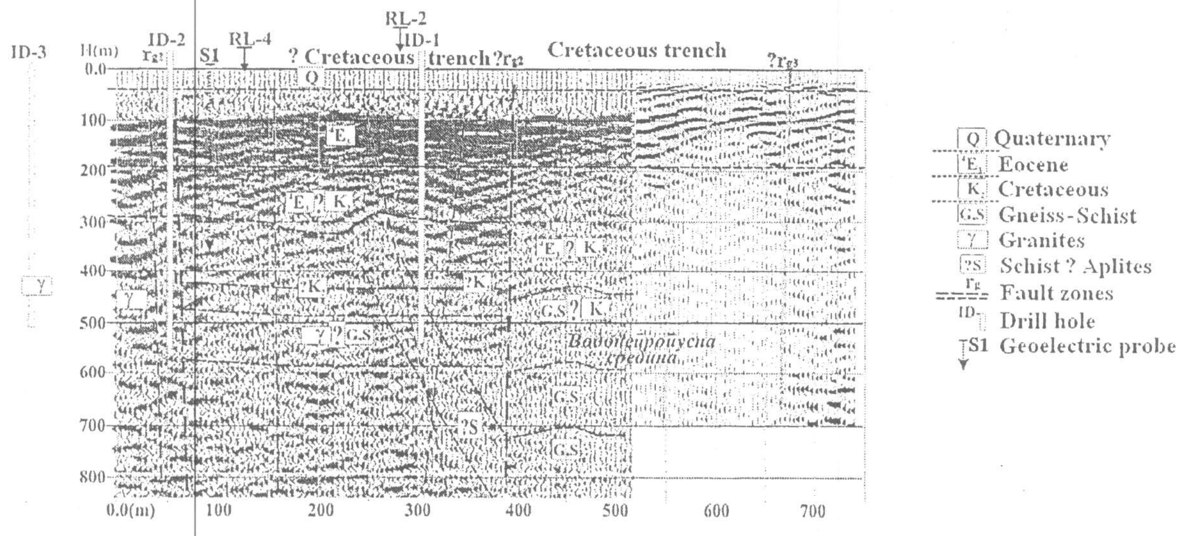


Fig. 4. Cross section RL-1 with interpretation

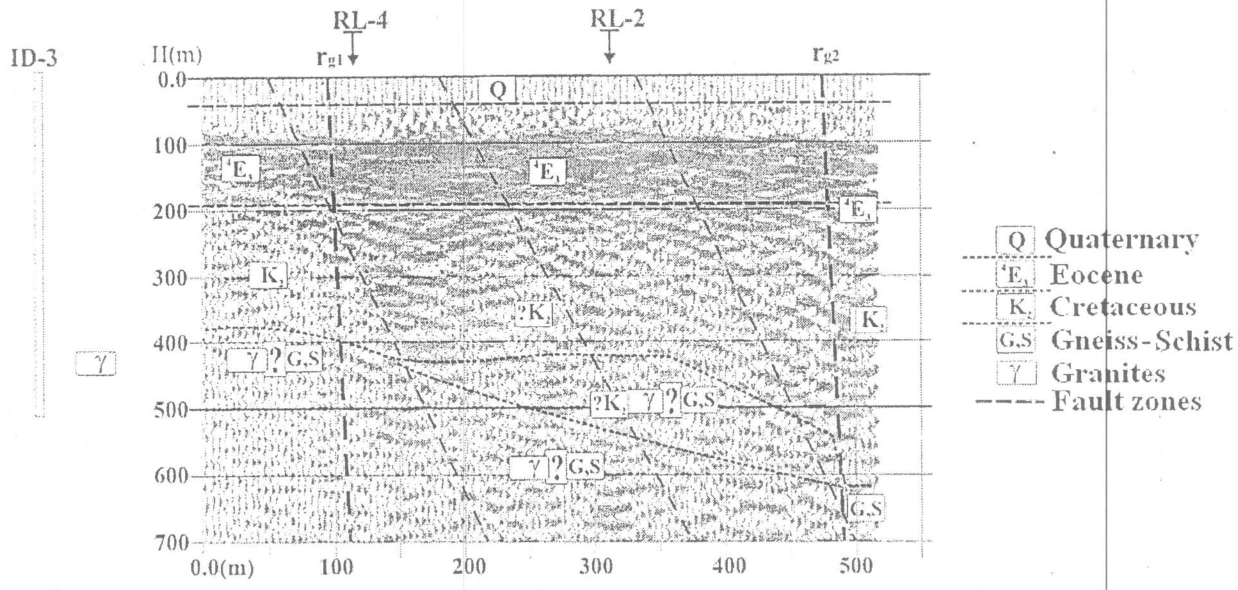


Fig. 5. Cross section RL-3 with interpretation

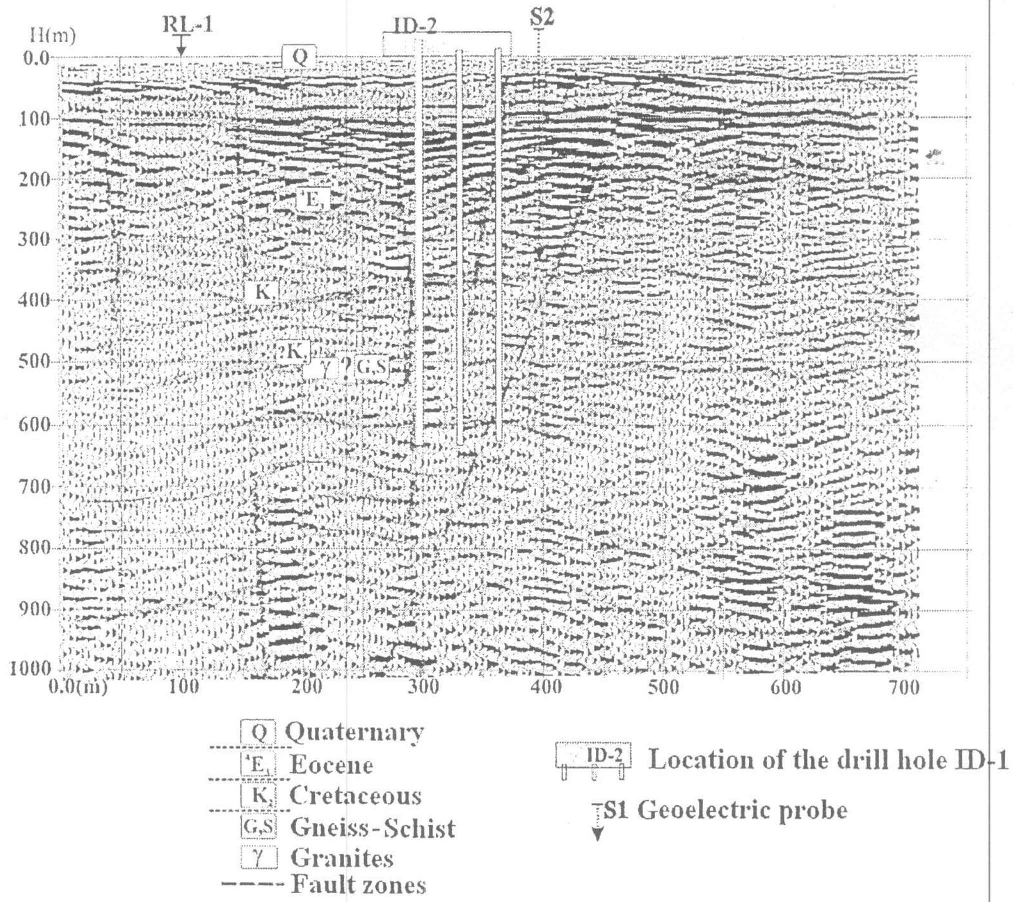


Fig. 6. Cross section RL-2 with interpretation

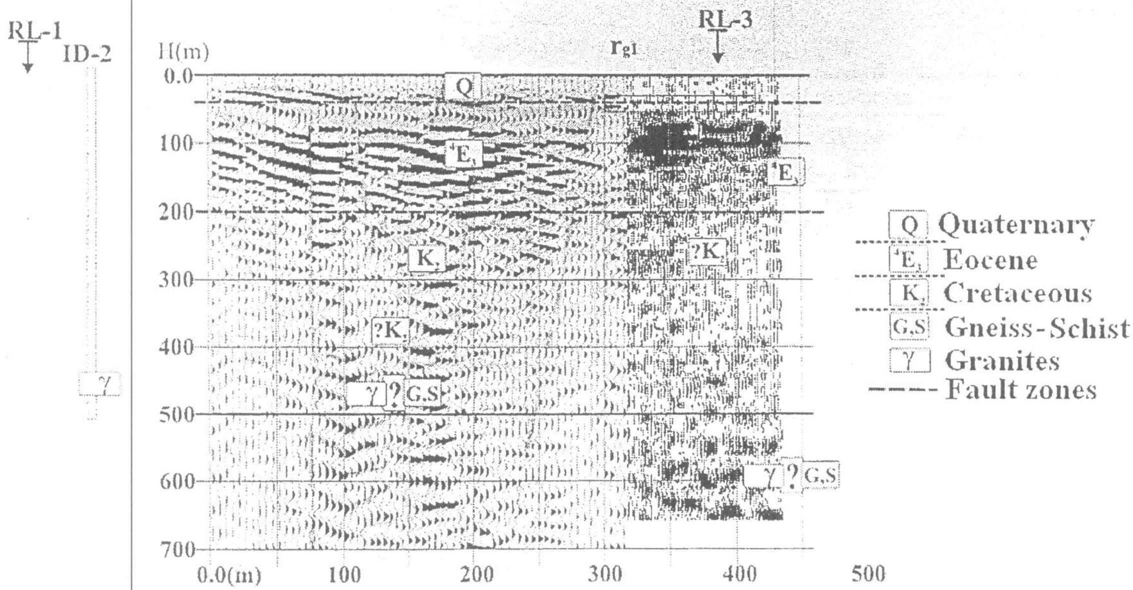


Fig. 7. Cross section RL-4 with interpretation

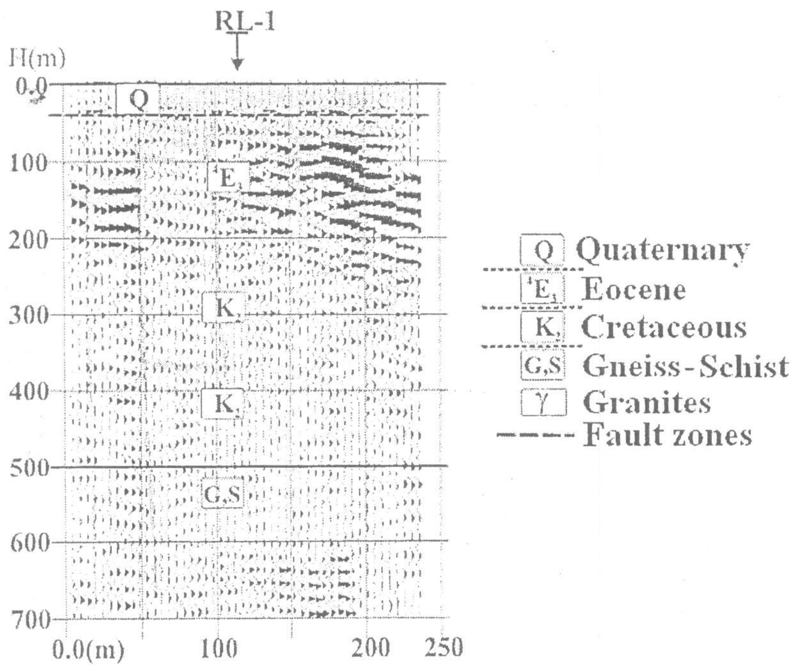


Fig. 8. Cross section RL-5 with interpretation

Two geoelectric probes (Figs. 9 and 10; Tables 1 and 2) perpendicular one to other were carried out. The first profile S1 is 1400 meters long, which means that AB/2 = 700 m, whereas potential electrodes are at distance of MN/2 = 25 meters and MN/2 = 50 meters. The second profiles S2 is 600 meters long, with AB/2 = 300 meters and MN/2 varies logarithmically, and in the second case MN/2 = 30 meters.

In order to check the results obtained for apparent specific resistivity, measurements were carried out in the reverse direction to both profiles or after the first measurements of the central point to the end of the profile. Measurements were carried out from the end of the profile to the central point. Probes are marked on the map as S1 (along RL-1) as S2 (along RL-2). More probes are necessary for precise results.

Table 1

Results from geoelectric probe S1

Geoelectric probe S1			Geoelectric probe S1 (reverse)		
AB/2 m	MN/2 m	Specific resistivity Ωm	AB/2 m	MN/2 m	Specific resistivity Ωm
50	25	34.650	100	50	16.9600
100	25	12.894	150	50	9.8150
150	25	8.8598	200	50	8.4530
200	25	7.8276	250	50	7.6794
250	25	7.3158	300	50	7.6884
300	25	7.4966	350	50	7.5680
350	25	7.2290	400	50	7.2647
400	25	7.2128	500	50	7.3598
500	25	7.3269	600	50	7.3978
600	25	7.1812			
700	25	7.4598			

Table 2

Results from geoelectric probe S2

Geoelectric probe S2			Geoelectric probe S2 (reverse)		
AB/2 m	MN/2 m	Specific resistivity Ωm	AB/2 m	MN/2 m	Specific resistivity Ωm
50	3	42.58	50	30	114.72
100	10	13.92	100	30	19.18
150	10	8.95	150	30	12.95
200	10	8.10	200	30	9.92
250	10	6.38	250	30	8.69
300	30	9.48	300	30	9.48

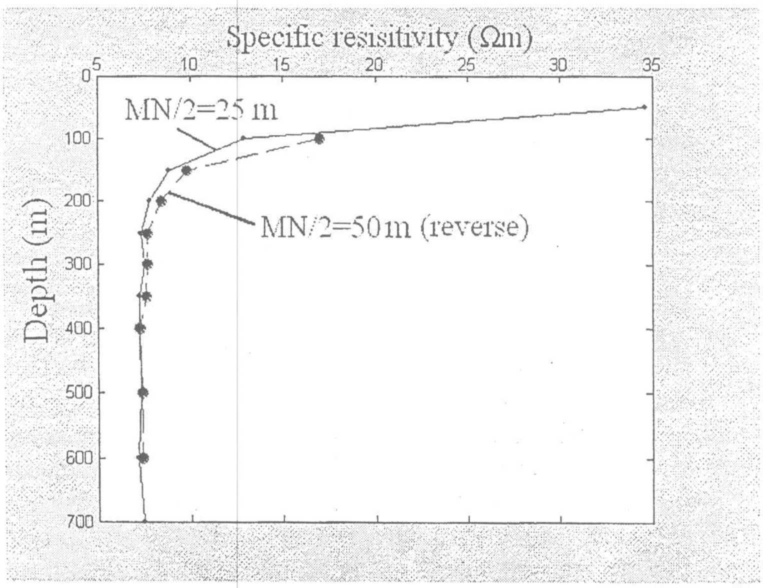


Fig. 9. Curves of geoelectric probe S1