CONTRIBUTIONS OF A RESISTIVITY SURVEY TO KARSTIC AQUIFERS DISCONTINUITY INVESTIGATION

BY

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The water table of some karstic areas with rough topography was contoured by means of a resistivity survey. As external concentrated input and output areas influence had been avoided, water-table geometry was interpreted only in terms of highly permeable faults and karstic cavities. It was proven that water table continuity between faults-confined blocks is seldom ensured and this happens only when faults are subjected to an endogenously derived flow in charge.

INTRODUCTION

It is customary for karstic aquifers investigations to focus on developing models that are able to fulfill the discontinuity requirements of the specific medium, which usually imply the following :

a) The existence within the reservoir of water-bearing, flooded domains, adjoining some other completely dry domains.

b) The lack of a drainage continuity between contiguous flooded domains.

In this respect, data of a resistivity survey, conducted în Pădurea Craiului Mountains, interpreted correlatively with observations performed on ground surface, in drillholes and mines, seem to contribute to an (obviously fragmentary) image of a karstic aquifer structure, in given lithologic homogeneity, tectonic style and rough topography conditions.

AREAS UNDER STUDY AND INVESTIGATION TECHNIQUES

The first investigated area is situated in Dîmbul Nițchii, on the watershed between Mniera and Poienii basins, while the other one lies in Dealul cu Clopoței, on the watershed between Sohodol-Albioara and Vida basins. No swallets, emergences, ponds or epigean water-courses were included in the surveyed areas and thus the karstic aquifer samples under study were free of either external inputs or outputs.

The aquifers include a carbonatic jurassic-cretaceous series from upper sinnemurian to lower aptian. This is underlain by a hettangian-lower sinnemurian sandstone-conglomerate complex, which may act in some places as a general impervious bed of the investigated aquifers.

The carbonatic series includes different types of limestones, all of which seem to be equally subjected to karstic processes. Only the upper malm-aptian part of the carbonate series was investigated by means of the resistivity survey.

Geophysical investigations included :

— resistivity profiling — in a square 30 m network — which was meant to provide the outcrop lines of the faults acting as drains or impervious screens ;

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— resistivity soundings — in a 30 × 60 m network — which were meant to provide water table geometry. In order to limit the noise due to relatively rough topography and to complex anomalous sources geometry, pole-dipole (Lögn) arrays were chosen that eventually proved to be more adequate than common Schlumberger symmetrical arrays.

INFORMATION ACQUIRED ON "DRAINING FRACTURES"

On both resistivity maps and sections we have outlined conductive axes the coordinates of which were consistent with a number of definite planes. As was already discussed (ORBAN, MITROFAN, 1981), in the given conditions, responsible for such a kind of anomalies are the pure shear (compressional) fractures. Their corresponding tectonic types are the strike-slip faults and the overthrusts. This kind of fracture implies the existence of a narrow strip o tensioned rock, virtually coincident with the plane of the fracture, bordered by two highly compressed rock compartments (ANDERSON, 1951, DUDA, 1965). Such an intimate structure is perfectly fitted to a drainage function. On the other hand, current observations failed to identify any penetrable karstic cavities to such faults.

In the investigated areas most pure shear fractures have low dip angles (10°— 45°) and occur in an irregular network, with separations varying from 50 to 600 m.

The resistivity survey also identified several simple shear (couple) fractures, which displace pure shear fractures planes to which they must therefore be subsequent.[1] No relationship could be established between simple shear faults and the water-table morphology, which means that they have no hydrologic function, except the already mentioned drain continuity breaking.

That is why, in order to point out the salient part played in karstic aquifers structure by pure shear fractures, we suggested that they should be defined as "draining fractures".

INFORMATION ACQUIRED ON WATER TABLE GEOMETRY

Apparent resistivity sections elaborated from vertical electrical soundings (VES) data in Dîmbul Nitchii cast light on a continuous conductive layer situated at a certain depth, usually not exceeding 100 m. The computed elevations of the top of this layer were practically coincident (a maximum 10% error), in every place where mine galleries provided accurate control with the elevations from which downward gallery walls became all at once subjected to generalized, though not severe, seepage. As a different cause could not be substantiated, it was admitted

[1] The whole pure shear as well as simple shear fractures network identified by resistivity data interpretation is satisfactorily fitting to the one interpreted from the drilling holes (in a 60 × 60 m network) data.

that at those places mine galleries penetrate under the water table of a free surface aquifer, with a continuous development, at least on the investigated area. Aquifer water table was thus contoured relying on VES data (fig. 1). Since lithology and tectonics were similar, in Dealul cu Clopoţei area, an analogous aquifer water table was contoured from resistivity data here too (fig. 3), though neither mine nor hydrogeological drillholes observations were yet available.

As shown in fig. 2, though seemingly water continuously occupies a volume, whose limits the surveyed areas could not completely reach, evidence is given that the surface confining this volume is a discontinuous function. In many places, for the same pair of coordinates from the horizontal plane, several vertically superimposed hydrostatic levels and thus several aquifer sections may exist. This phenomenon seems to be due to the vertical separation of the reservoir into several superimposed sections by the "draining fractures".

The domains on which the hydrostatic level is a continuous function are polyhedric blocks, not exceeding some hectometers in any direction, confined by the "draining fractures".

Hydraulic gradient values, as derived from the water table maps, may remarkably near 100%.

As water table drainage areas are outlined, several situations are noticed (fig. 3):

— drainage axes, always displaying hydrostatic level discontinuity, superimposed on "draining fractures" P_3, P_7 P_{18}. They prove that the latter have an increased permeability in respect to the adjoining blocks to which they provide the discharge facilities. Such "draining fractures" are seemingly subjected to a free surface, but most frequently to a diphasic (air-water) flow. The water table discontinuities in the proximity of the "draining fractures" are due to the seepage faces developing on their walls. The height of these faces is only a function of the specific permeability and yield of each of the two opposite blocks.

— Drainage axes, displaying no water table discontinuity, not superimposed on "draining fractures". Karstic cavities, penetrable, although not yet accessible may provide an explanation consistent with this phenomenon (fig. 4). They are exerting an intermediate drainage function, either bringing the water to the proximate "draining fracture" plane or perforating such planes.

— Closed water table contours, indicating a flow converging toward a point in the horizontal plane, that might represent a vertical cavity (aven) axis projection. This one would exert an intermediate drainage function, analogous to that of the horizontal cave passages mentioned above.

In their turn, recharge areas include:

— "draining fractures" subjected to flow in charge (probably giving access to remote-source waters, from depth far below), feeding the adjoining blocks, P_1, P_9, P_{11}.

— Impluvium areas, defined by closed water table contours, indicating a diverging flow toward draining axes.

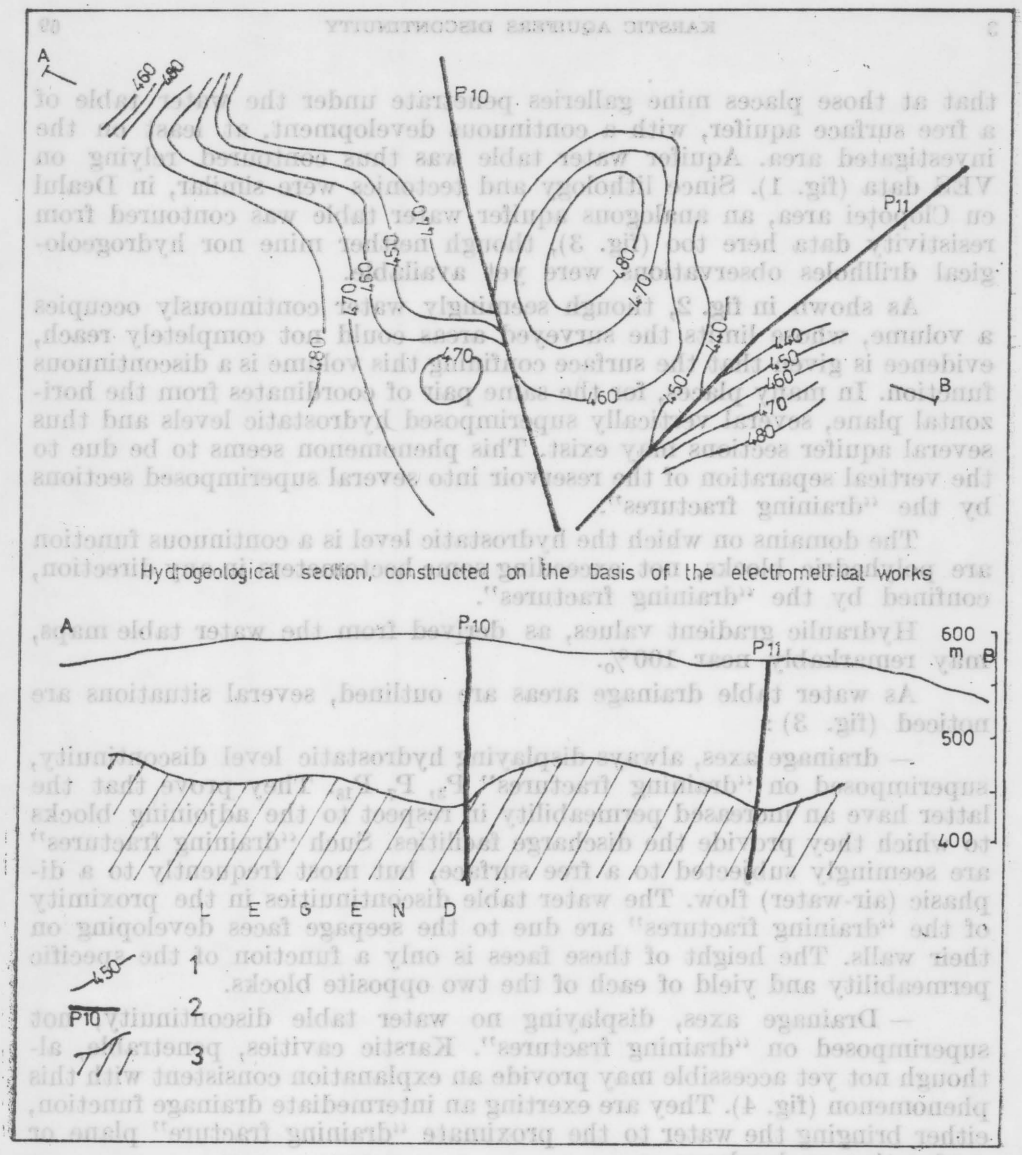

Fig. 1. — Water table map and hydrogeological section in Dimbul Nițchii area, interpreted from resistivity data : 1. water table contour (in meters). 2. draining fracture. 3. flooded area.

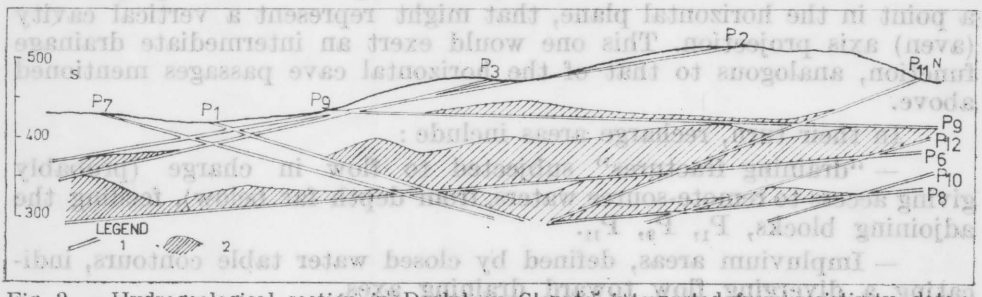

Fig. 2. — Hydrogeological section in Dealul cu Clopoței interpreted from resistivity data : 1. draining fracture, 2. flooded area.

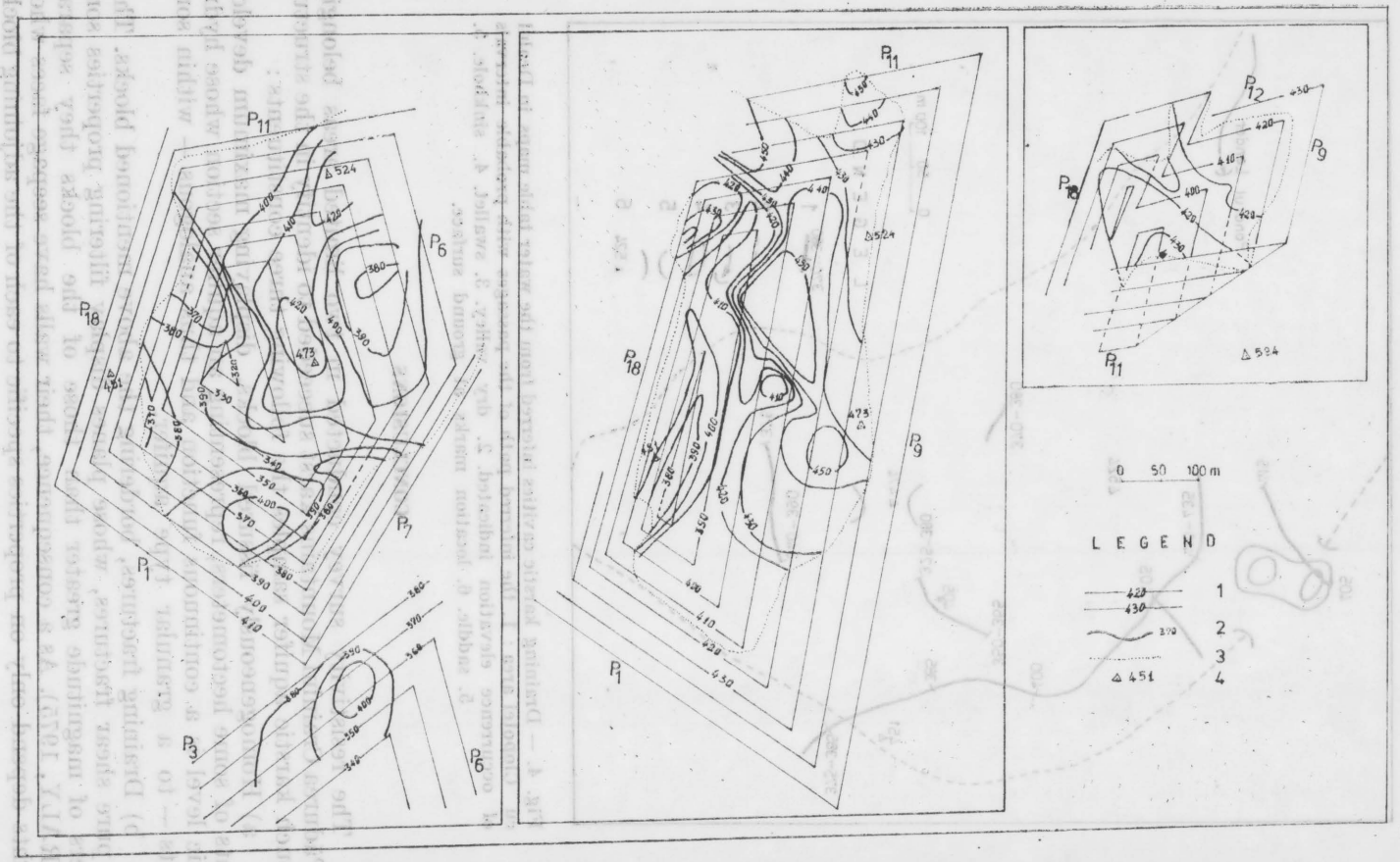

Fig. 3. — Water table contour maps for different "homogeneous" blocks in Dealul cu Clopoţei area, interpreted from resistivity data : 1. elevation contours of the draining fractures (m). 2. water table contours (m). 3. flooded area boundary. 4. location marks on ground surface

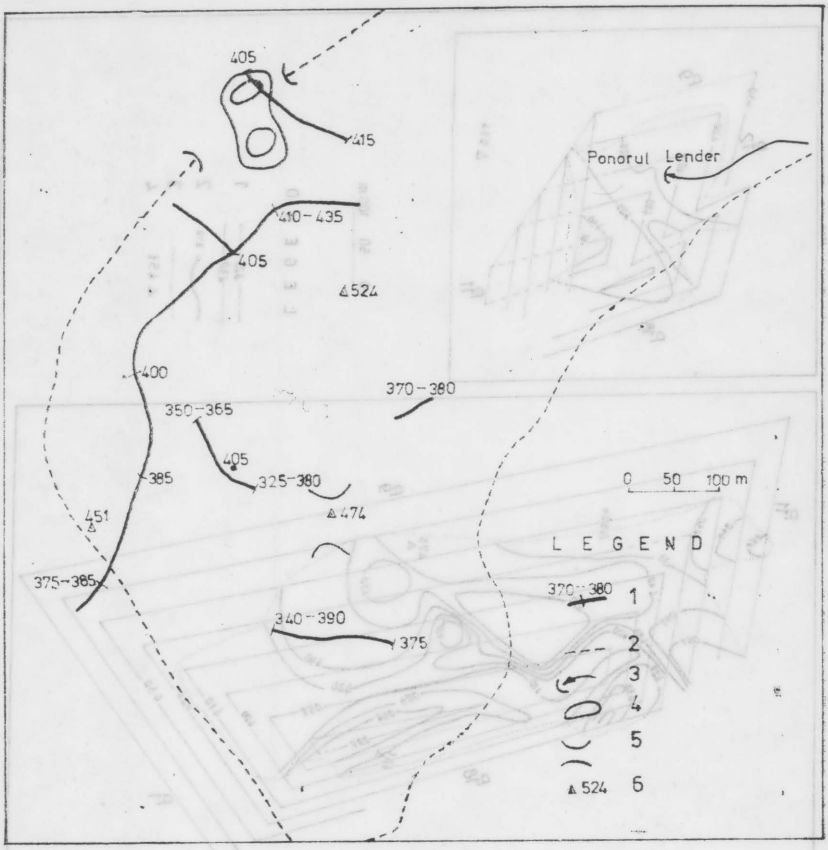

Fig. 4. — Draining karstic cavities inferred from the water table maps in Dealul cu Clopoţei area : 1. the inferred path of the passages with probable intervals of occurrence elevation indicated. 2. dry valley. 3. swallet. 4. sinkhole. 5. 5. saddle. 6. location marks at ground surface.

CONCLUSIONS

The resistivity survey conducted in two limited areas belonging to Pădurea Craiului Mountains karst succeeded to identify in the structure of such karstic aquifer samples the following three constituents :

a) Homogeneously fissured blocks, displaying maximum developments of some hectometers, representing an aquifer section whose hydrostatic level is a continuous function and thus analogous — within some limits — to a granular type aquifer.

b) Draining fractures, bordering the above mentioned blocks. They are pure shear fractures, whose planes display filtering properties some orders of magnitude greater than those of the blocks they separate (KIRALY, 1975). As a consequence, their walls have seepage faces whose heights depend only on properties specific to each of the adjoining blocks.

Thus severe water table discontinuities occur next to their planes due to the different properties, mainly yielding capability, of the opposite blocks. The fractures generally ensure the drainage of the blocks by a diphasic flow, but some of them, subjected to a flow in charge, may feed contiguous blocks too. Aquifer continuity across the "draining fractures", from one block to another is not ensured in most cases, which paradoxically may let the fractures seem impervious. Only when "draining fractures" are subjected to an ascending flow in charge, seemingly due to an endogenous source, hydraulic continuity across several blocks, on some hectometers or even kilometers is to be expected.

c) Penetrable karstic cavities —although not yet accessible. So far, available observations failed to identify any "draining fracture" to a karstic cavity. Such caves are situated inside the "homogeneous" blocks (thus restricting their assimilation to a granular aquifer), but they do not break the water table continuity. They may extend considerably upon the horizontal or the vertical but irrespective to this, they act only as drainage paths from the blocks to a confining nearby or even to a reremote preferential "draining fracture".

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