Δελτίο Ελληνικής Γεωλογικής Εταιρίας τομ. XXX/5, 45-51, 1994
Πρακτικά 7ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάιος 1994
Bulletin of the Geological Society of Greece vol. XXX/5, 45-51, 1994
Proceedings of the 7th Congress, Thessaloniki, May 1994

GEOPHYSICAL INVESTIGATION IN THE DELTA OF SPERCHIOS RIVER

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ABSTRACT

The delta of Sperchios River is of great geological interest due to the intense tectonism and the great thickness of the sediments formed by the deposition of the rivers. Geophysical methods (resistivity and gravity method) have been applied in the delta, in order to detect the depth to bedrock, the existing faults, and the classification of the sediments.

The main result of the geophysical investigation was the detection of a graben along the middle-south part of the delta, made by a step-like faulting of E-W direction. The blocks in the northern part of the graben, created by 3 long faults on E-W direction, are much greater than those of the southern part. Some other minor faults have been detected. The intense deposition of Gorgopotamos, Xirias and Asopos Rivers and the tectonism of the area affect the route of Sperchios River. Finally, the relief of the bedrock has been detected in the whole area.

ΣΥΝΟΨΗ

Το δέλτα του Σπερχειού Ποταμού είναι μεγάλου γεωλογικού ενδιαφέροντος λόγω του έντονου τεκτονισμού και του μεγάλου πάχους των ιζημάτων που δημιουργούνται από τις αποθέσεις των ποταμών. Γεωφυσικές μέθοδοι (ειδικής αντίστασης, βαρυτική) εφαρμόζονται στο δέλτα με σκοπό τον εντοπισμό του βάθους του βραχώδους υποβάθρου, των υπαρχόντων ρηγμάτων και των εναλλαγών στα ιζήματα.

Το κύριο αποτέλεσμα της γεωφυσικής έρευνας είναι ο εντοπισμός μίας τάφρου κατά μήκος του μεσο-νότιου τμήματος του δέλτα, που δημιουργείται από βαθμωτά ρήγματα διεύθυνσης Α-Δ. Τα τεμάχη στο βόρειο τμήμα της τάφρου είναι μεγαλύτερα από αυτά του νοτίου τμήματος. Κάποια άλλα ρήγματα έχουν εντοπισθεί που μαζί με την έντονη απόθεση των Ποταμών Γοργοποτάμου, Ξιριά και Ασωπού επηρεάζουν τη ροή του Σπερχειού Ποταμού. Τελικά, το ανάγλυφο του βραχώδους υποβάθρου έχει βρεθεί για όλη την περιοχή έρευνας.

INTRODUCTION

The delta of Sperchios River is of great geological interest due to the intense tectonism, the presence of geothermal sources in many places and the great deposition of the rivers. The boreholes are of shallow depth and the sediments are of great thickness. Therefore, the application of geophysical methods can solve some of the problems concerning the geological status of the area.

GENERAL GEOLOGY

The Sperchios River Basin is in the Central Greece, outlined by Othris,

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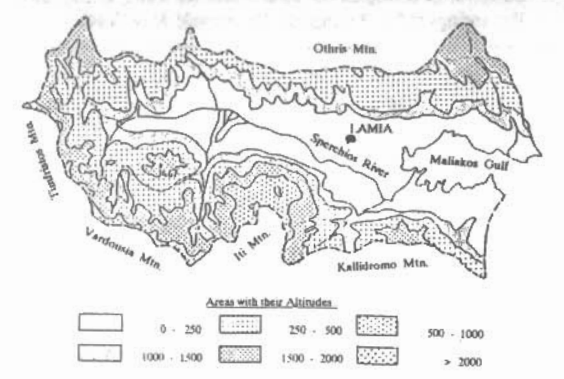

Fig. 1: Topographic map of Sperchios River Valley with the mountains around it (Kakavas, 1984).

Timfristos, Vardousia, Iti and Kallidromo Mountains (Fig. 1). The Basin is open to the sea on the East (Maliakos Gulf). The direction of Sperchios River is W-E. There are many tributaries and more important from the West to the East are Roustianitis, Vistritsa, Gorgopotamos, Xirias, Asopos.

The Sperchios River Basin is a result of a tectonic graben and it is in the transition area from the inner to the outer geotectonic zones.

The Basin is divided in two parts: the Inner Valley and the Delta of Sperchios River.

The geological map of the Delta is shown in figure 2.

Alpine Formations

North-North-Eastern of the basin there are Triassic to Jurassic limestones, flints and ophiolites. North-eastern of Lamia there are Upper Createaceous transgressive limestones and flysch. The same series are observed in Kallidromo mountain, Southeast of the basin. The areas, previously considered, belong to the "East Greece Series" that is made up by some paleotectonic series that have been homogenised by the Upper Createaceous transgression (Papanikolaou, 1986). Such series in the area under investigation are "Maliaki" and "Hypopelagoniki" series.

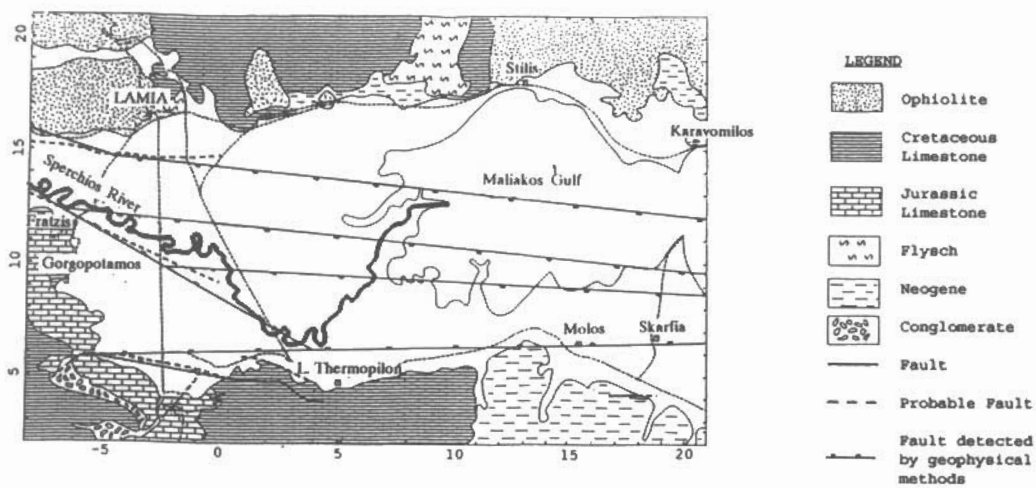

Fig. 2: Geological map with the main geological formations in the delta of Sperchios River, designed by the use of all the elements of the geological maps of I.G.M.E. (scale: 1:50000) "Lamia" and "Stilis". The faults present in the delta have been detected by the geophysical investigation. The map has the geographic co-ordinates in km.

The Sediments

The tectonic graben, as the basin was defined, is full of loose deposits of great thickness.

These deposits consist:

· Oligomiocene conglomerate.

· Pleistocene lacustrine deposits (conglomerates, sands and clays) under the alluvial deposits of Sperchios River.

· Alluvial deposits of Sperchios River (clays with intercalation of conglomerates and fanglomerates).

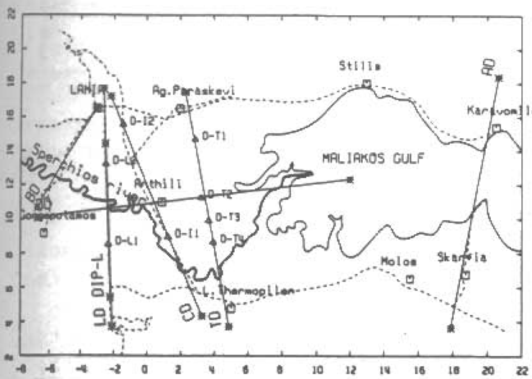

Fig. 3: Map with the gravity profiles (*BD, LD, CD, TD, DD, AD*), the dipole-dipole profile (*DIP-L*) and the resistivity soundings (*D-L1, D-L2, D-I1,* e.t.c.) in the delta of Sperchios River. The map has the geographic co-ordinates in km.

Tectonism of the Sperchios graben

The topography (steep slopes of Kallidromo Mountain, displacement of river sill and many alluvial fans) indicates intensive tectonic activity. An interpretation of this activity is based on the theory of the tectonic dipoles (Mariolakos, 1976 and Dermitzakis & Papanikolaou, 1979).

THE GEOPHYSICAL SURVEY

A gravity survey (320 stations of observation along profiles) and a resistivity survey (8 deep soundings by the use of the Schlumberger electrode configuration and a dipole-dipole profile) were carried out (Fig. 3) in the area under investigation (Apostolopoulos, 1993b). The data were processed and interpreted in order to investigate the depth of the bedrock, some intermediate layers and the faults.

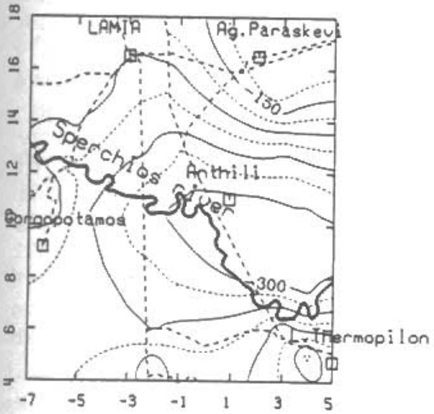

Fig. 4: Bouguer gravity map of the delta of Sperchios River (contours per 50gu). The map has the geographic co-ordinates in km.

The gravity survey

The Bouguer map of the area (Fig. 4) gives an idea of the bedrock relief. It seams that the bedrock, in the south-east part of the Delta, has the greatest depth.

The gravity interpretation, with 2-D modelling in profiles (Fig. 5, Fig. 6 and Fig. 10) and only one interface (sediments - bedrock), gave the depth of the bedrock and the position of the existing faults in the whole survey area (Fig. 7 and Fig. 2).

The aeromagnetic map

The aeromagnetic map (Residual magnetic anomaly) of figure 8, is the result of combination of two I.G.M.E. aeromagnetic maps (sheets "Lamia" and "Stilis", scale 1:50000). This map contributes in the following qualitative conclusions:

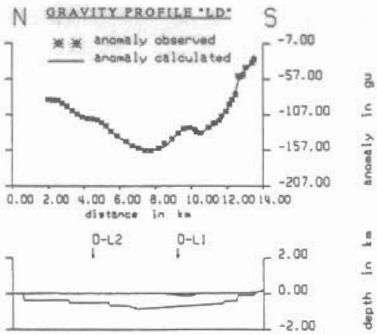

Fig. 5: 2-D gravity interpretation of the gravity profile "LD" (the position of the resistivity soundings is also marked).

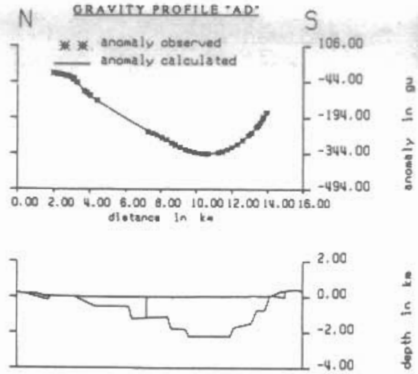

Fig. 6: 2-D gravity interpretation of the gravity profile "AD".

· The presence of certain local magnetic anomalies (maximum values) indicates that there the bedrock is ophiolite. This is confirmed by the geological map as well (Fig. 2).

· The contours and their magnitude, create a picture that confirms the position of the faults and the bedrock relief, detected by the gravity method (Fig. 2 and Fig. 7). The gravity depth section of the profile "AD" (Fig. 6) is also confirmed by the aeromagnetic map. Generally, the greatest thickness of the sediments is south of the 100γ contour.

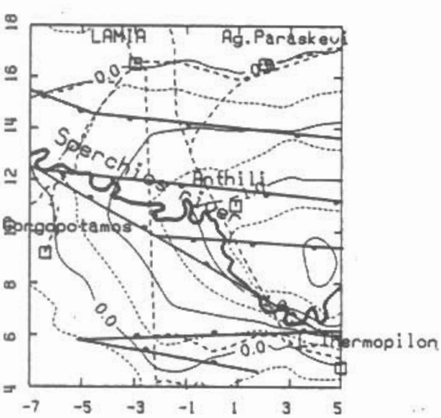

Fig. 7: Map showing the depth to the top of the basement (contours per 0.5km) and the faults in the delta of Sperchios River, as obtained by the geophysical investigation. The map has the geographic co-ordinates in km.

The resistivity survey

The apparent resistivity maps drawn for constant half current electrode distance (AB/2), give a picture of the lateral resistivity distribution in an approximately constant depth. Therefore, in the map of figure 9a (AB/2=100m) there is an area of high resistivity values that is caused by the resistive ophiolite body near Lamia, an area of intermediate values that are caused by the conglomerate made by the deposition of Gorgopotamos, Xirias and Asopos Rivers and an area near Anthili of very low resistivity values caused to the clay and the sands full of saline water. The influence of the bedrock (its depressions and uplifts) is evident in the apparent resistivity map of figure 9b (AB/2=2154m).

A first conclusion from the observation of the apparent resistivity maps is that the continuous deposition of the rivers directs the route of Sperchios River to Northeast (high apparent resistivity values) and then the depression of the bedrock to Southeast (low values).

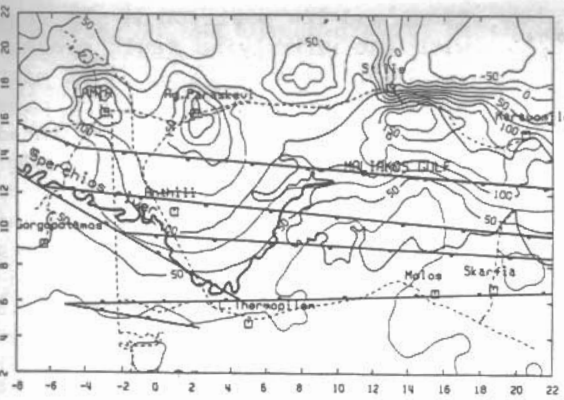

Fig. 8: Aeromagnetic map of I.G.M.E. (residual magnetic anomaly) of the delta of Sperchios River (contours per 25ã). The faults shown in the map have been detected by the geophysical investigation. The map has the geographic co-ordinates in km.

In-situ soundings gave the resistivities of the rock formations present in the area under investigation (ρ_{FL}=80-180Ωm, ρ_{OPH}=200-600Ωm, ρ_{LIM}=250-1100Ωm, ρ_{CLAY}=10-30Ωm).

The 2-D interpretation of resistivity data for the soundings D-L1, D-L2, D-I1 (Apostolopoulos, 1993a) gave sequences of layers geoelectrically defined and the position of dipping interfaces (faults). The 1-D interpretation was applied in the rest of the soundings.

The gravity and resistivity interpretation show that some of the soundings reached the bedrock some others did not. The bedrock under each sounding is, limestone for D-L1, ophiolite for D-L2, limestone for D-I1, ophiolite for D-I2.

A resistivity depth section was constructed with the guidance of the apparent resistivity section for the soundings D-T1, D-T2, D- T3, D-T4 (Fig. 10). Though these soundings did not reach the bedrock, the resistivity depth section gives a picture of the sedimentation. Therefore the resistivity sections of each sounding (Fig. 10) show, that a surface layer of sand with saline water (thickness ≈ 12m and ρ<8Ωm) is in the area of the soundings D-T1 and D-T2, underlain by a layer of clay that disappears moving to D-T3. Another layer of sand with saline water is under the layer of clay and is connected with the surface layer in the area between the soundings D-T3 and D-T4. The last layer of sand with saline water is extended in the whole profile and it has great thickness under the soundings D-T1 and D-T2 and much less under D-T3 and D-T4 (resistivity section in figure 10). The sandy layer is over a layer of clay. In the area of the sounding D-T1, the layer under the clay (ρ = 67Ωm) is weathered ophiolite, due to the high values in the aeromagnetic map (Fig. 8). The influence of the lateral inhomogeneity (ophiolite - sediments) is evident in the apparent resistivity section. Another lateral inhomogeneity is present between the soundings D-T2 and D-T3 (ρ_{D-T2}=42Ωm and ρ_{D-T3}=20Ωm) with its influence in the apparent resistivity section. The last inhomogeneity separates sediments with different compaction (different time of sedimenta-

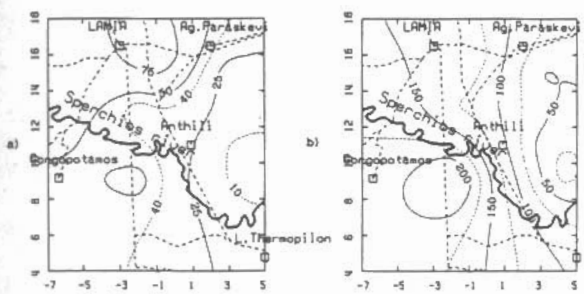

Fig. 9: Apparent resistivity maps of the delta of Sperchios River for half electrode distances AB/2=100m (a) and AB/2=2154m (b) (contours per 25Ωm and 50Ωm respectively). The map has the geographic co-ordinates in km.

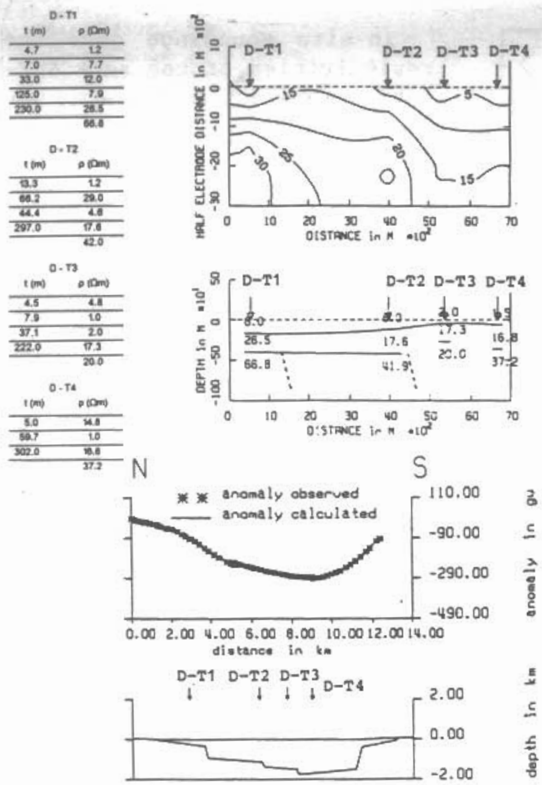

Fig. 10: Profile "DT" (apparent resistivity section with contours per 5Ùm, geoelectric section, gravity anomaly and gravity section with the relief of the bedrock). The results of 1-D interpretation for each of the soundings are shown on the left side of the figure.

tion) and its position is the same with the underlying fault present in the gravity section. It is most probable so, that the fault made after the sedimentation represented by the layer with resistivity ρ=42Ωm.

The dipole - dipole electrode configuration was applied along the gravity profile "LD" in order to detect irregularities in the bedrock relief. This configuration is very sensitive in lateral resistivity inhomogeneities (Sumner, 1976) and by the use of 1000m dipole length the detection is in the approximate depth of the bedrock. Finally, the dipole-dipole apparent resistivity section (Fig. 11) shows no irregularity in the bedrock relief and the irregularity in the gravity measurements (Fig. 5) is caused to a surface dense layer. It is probably a layer of conglomerate made by the deposition of rivers mentioned before.

DISCUSSION, CONCLUSIONS

The results of the geophysical survey can be summarised as follows:

· The great thickness and the great conductivity of the sediments did not help to reach the bedrock with the geoelectrical method. However, the relief of the bedrock has been found by the gravity method. The resistivity soundings reached the bedrock in certain places and intense anomalies in the magnetic map (Fig. 8) possibly indicate places of ophiolite. The lithological identification can be done in such places, with some doubts.

· The location of the faults and the bedrock depth anomalies found with geophysical investigations. They indicate as well, the depression of the bedrock south-east of Anthili and north of Molos.

· In the map of figure 2, three (3) successive long faults along the central part of the Delta (W-E) are located and they create blocks falling to the South. In the South, near Kallidromo Mountain, there is a step-like faulting with the smaller blocks falling to the North. Therefore, in the central and south part of the Delta a grabben is created with its section shown in the gravity depth

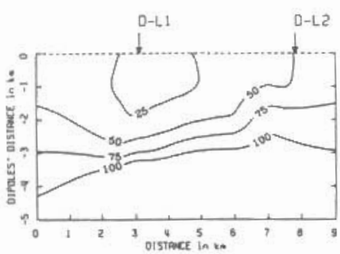

Fig. 11: Dipole-dipole apparent resistivity section of the profile "DIP-L" (contours per 25Ωm).

map (Fig. 7) and in the gravity depth section of the profile "AD" (Fig. 6).

· The continuous deposition of Gorgopotamos, Xirias and Asopos Rivers directs the route of Sperchios River to Northeast and the tectonism and the relief of the bedrock to the South.

ACKNOWLEDGEMENTS

The author thanks Professor J.Drakopoulos and Assistant Professor E.Lagios for the valuable guidance in handling geophysical data and Professor D. Papanikolaou for geological data. He also thanks Assistant Professor J.Louis and Professor A.Ikonomou for their usefull consulting in the whole project.

REFERENCES

APOSTOLOPOULOS, G. (1993). 2D interpretation (graphical method or use of composition rules) for resistivity data. *Extended Abstract, 55th Meeting of European Association of Exploration Geophysicists , Stavanger, Norway.*

APOSTOLOPOULOS, G. (1993). Geophysical studies in the Sperchios basin. *Ph.D. Thesis, Geology Department, University of Athens.*

DERMITZAKIS, M. and PAPANIKOLAOU, D. (1979). Paleogeography and geodynamics of the Aegean Region during the Neogene. VII Int. Congress Medit. Neogene, Athens 1979, *Ann. Geol. Pays Hellen hors serie IV*, 245-289.

I.G.M.E. Aeromagnetic maps (sheets "Lamia" and "Stilis", scale 1:50000)

KAKAVAS, N. (1984). Hydrological balance of the run-off basin of Sperchios River. *Ph.D. Thesis, Geology Department, University of Athens.*

MARINOS, G., ANASTOPOULOS, J., MARATOS, G., MELIDONIS, N. and ANDRONOPOULOS, B. (1963). Geological map of Greece, "Stilis" sheet, scale 1:50000. I.G.M.E., Athens.

MARINOS, G., PAPASTAMATIOU, J., MARATOS, G., MELIDONIS, N., ANDRONOPOULOS, B., TATARIS, A., BETOULIS, D., KATSIKATSOS, G., MARAGOUDAKIS, N. and LALECHOS, N. 1967. Geological map of Greece, "Lamia" sheet, scale 1:50000. I.G.M.E., Athens.

MARIOLAKOS, I. (1976). Some thoughts and aspects on certain problems of the geology and tectonism of Peloponnese. *Ann. Geol. Pays Hellen.*, 27, 215-313.

PAPANIKOLAOU D. (1986). Geology of Greece. *Eptalofos Publications.*

SUMNER, J.S. (1976). Principles of induced polarization for geo-physical exploration. *Elsevier Sc. Publ. Co.*