

REMARKS ON THE KARSTIFICATION IN THE WIDER AREA OF THE UPPER MESSINIA CLOSED HYDROGEOLOGICAL BASIN (SW PELOPONNESUS, GREECE)

I. Mariolakos and E. Spyridonos

*National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment,
Department of Dynamic Tectonic & Applied Geology, GR-15784 Panepstimioupolis Zografou,
Athens - Greece, mariolakos@geol.uoa.gr, vangelis@zedat.fu-berlin.de*

Abstract

The Upper Messinia Basin is part of the Kalamata - Kyparissia graben structure, defined by two fault zones, one of E-W direction to the north and one of N-S direction to the east. The Tripolis and the Pindos alpidic units build up the basement of the region, and are covered by post-alpidic Pleistocene and quaternary deposits. The Basin is a closed hydrogeological system. In the upper cretaceous Pindos limestones, we observe two different karst types, according to drilling results. In the western part of the basin, where the limestones appear on the surface, the merokarst type is observed and water flow is limited in separated karstic conduits. On the contrary, in the central part of the basin, where the limestones underlie the clastic post-alpidic formations, the holokarst type is observed and a rich karstic aquifer is developed. This is explained by the closed hydraulic conditions. In the western part of the basin the karstic aquifer is unconfined, while in the central part it is confined, due to the overlying impermeable post-alpidic sediments and the overall closure of underground flow to the south. It appears that the confined conditions led to the development from merokarst to holokarst in this region.

Key words: *closed hydrogeological system, aquifers under pressure, karst types, merokarst, holokarst, Upper Messinia Basin, Peloponnesus, Southern Greece.*

1. Introduction

The Upper Messinia basin is located in the SW part of Peloponnesus, 20 km NNW of the city of Kalamata (Fig. 1). It covers an area of ~295 km². The basin forms a closed hydrogeological system, as described by Mariolakos, 1988. The aim of this work is to describe the karstification types of the carbonate rocks that build the basement of the basin and investigate the interaction of neotectonics, hydrogeological conditions and karstification type.

2. Geological setting

The Messinia region, on SW Peloponnesus, is one of the most active areas in the Hellenic Arc, as it lies about 60 km from the Ionian trench, where the collision between the African and Eurasian plate occurs. By the end of the thrust movements (Middle Miocene), the largest part of the area is land and the morphogenic procedures begin. During Early-Pleistocene, when the sea transgression reaches its biggest extent, from the geotectonic point of view, the mountains of Kyparissia and Pylos belong to

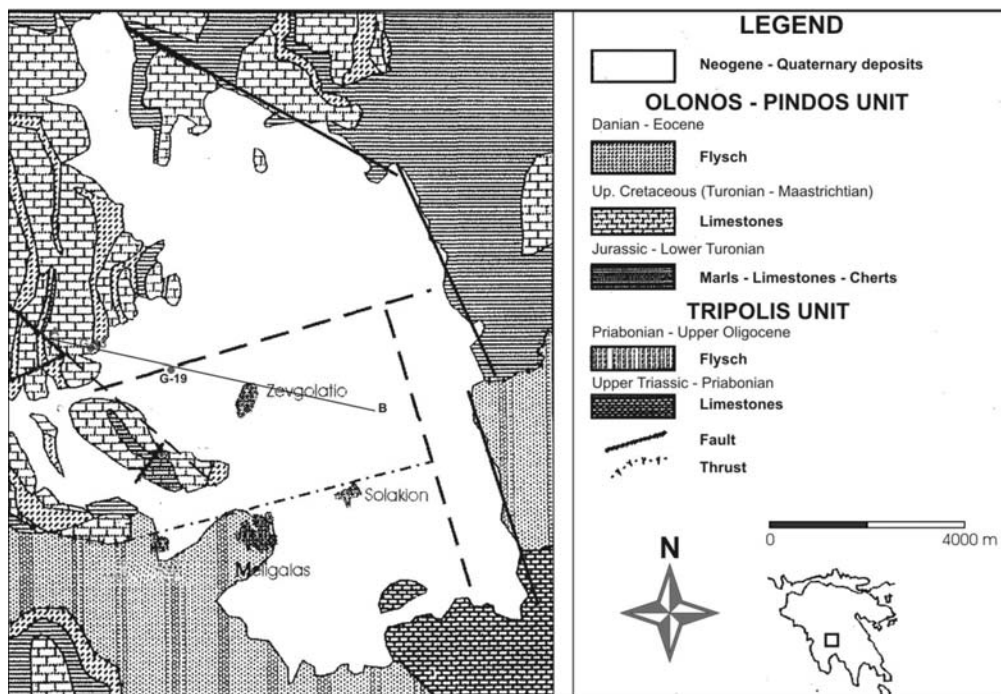


Fig. 1: Study Area position and simplified geological map (modified after Mariolakos, 1988).

the island arc (Marcopoulou - Diacantoni et al., 1989, 1991). By the end of Early-Pleistocene the area starts uplifting again. The Upper Messinian Basin remains land during this evolution, building a palaeo-isthmus between the Basins of Lower Messinia to the south and Kyparissia to the west. The post alpine deposits outcropping in the wider area can be distinguished into marine and terrestrial formations. The marine deposits occur only in the Kyparissia - Kalo Nero graben and consist of marls, sandstones and conglomerates of Late Pliocene – Lower Pliocene and Early Pleistocene age (Fountoulis, 1994). The terrestrial deposits mainly represent red-colored siliceous sands and conglomerates alternating with clay occurring in all basins.

The Neotectonic structure of the greater area of SW Peloponnese is characterised by the presence of tectonic grabens and tectonic horsts (1st order structures) striking NNW-SSE and E-W (Mariolakos et al. 1987). The Kalamata - Kyparissia graben is such a 1st order neotectonic macro-structure. At the margins or inside the 1st order neotectonic macrostructures, neotectonic structures of minor order (2nd, 3rd, ...) exist, the strike of which is perpendicular or parallel to the trends of the 1st order ones (Mariolakos et al., 1989).

The 2nd order neotectonic macro-structures inside the major Kalamata - Kyparissia graben are the Lower Messinia graben, the Meligalás horst, the Upper Messinia basin, the Dorion basin and the Kyparissia - Kalo Nero graben (Fig. 2).

The kinematic evolution of these neotectonic units is complicated since block rotation differentiates the uplift and subsidence rates throughout the margins of the neotectonic blocks. The neotectonic

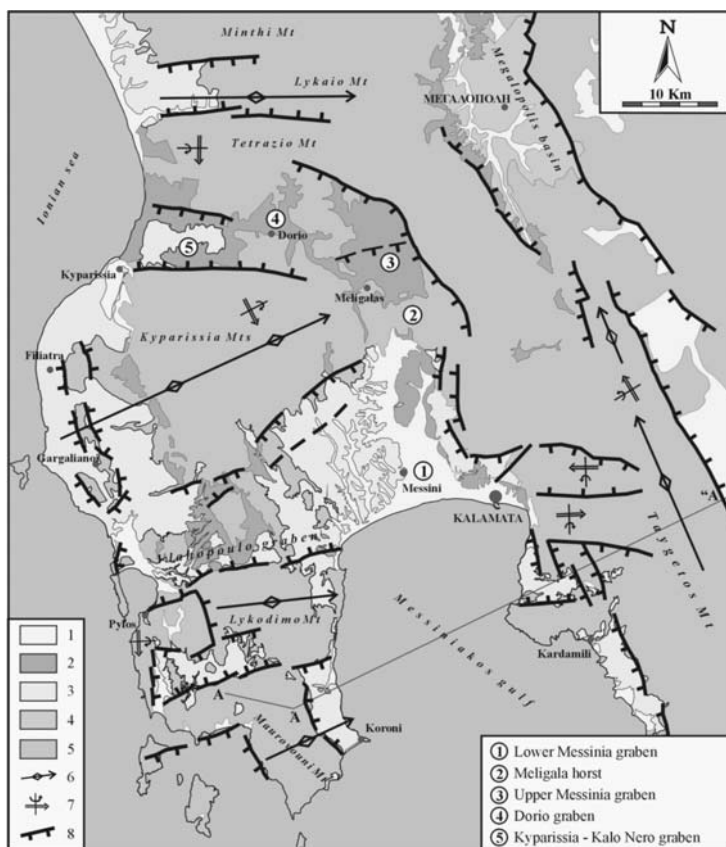


Fig. 2: Tectonic sketch map showing the neotectonic macrostructures of SW Peloponnese. 1:Holocene deposits, 2:Terrestrial deposits, 3:Marine deposits, 4:Lacustrine deposits (Megalopolis basin), 5:Pre-Neogene basement, 6:macrofold axis, 7:Rotational axis, 8:Fault zones. (from Mariolakos et al., 2001).

structures of minor order are dynamically related, as they have resulted from the same stress field but they have a different kinematic evolution. This differentiation has initiated either during the first stages of their creation, or later, during their evolution (Mariolakos et al., 1995).

The Upper Messinia basin basement consists of two alpidic geotectonic units, the Tripolis unit and the Olonos – Pindos unit (Lalechos, 1974, Katsikatos, 1980 and Mariolakos, 1988). The central part of the basin is covered by post alpidic sediments of pleiocene to quaternary age, positioned discordant on the alpidic basement. The thickness of these sediments is large related to the basin extend and in the central part it exceeds 280 m (Fig. 3) (Mariolakos, 1988).

On the western boundary of the basin the sediments are deposited unconformably on the Pindos unit rocks, mainly on radiolarites, Upper Cretaceous limestones and flysch. On the northern and the eastern part, the sediments are in tectonical contact to the alpidic formations, as a result of the action of the boundary fault zone of the Kalamata – Kyparissia Graben.

To the south, the post alpidic sediments cover the Tripolis unit flysch and to the southeast the Tripolis limestones. To the southwest the basin is connected by a narrow plain zone, covered by post-alpidic sediments of small thickness, to the Dorion - Kopanaki basin.

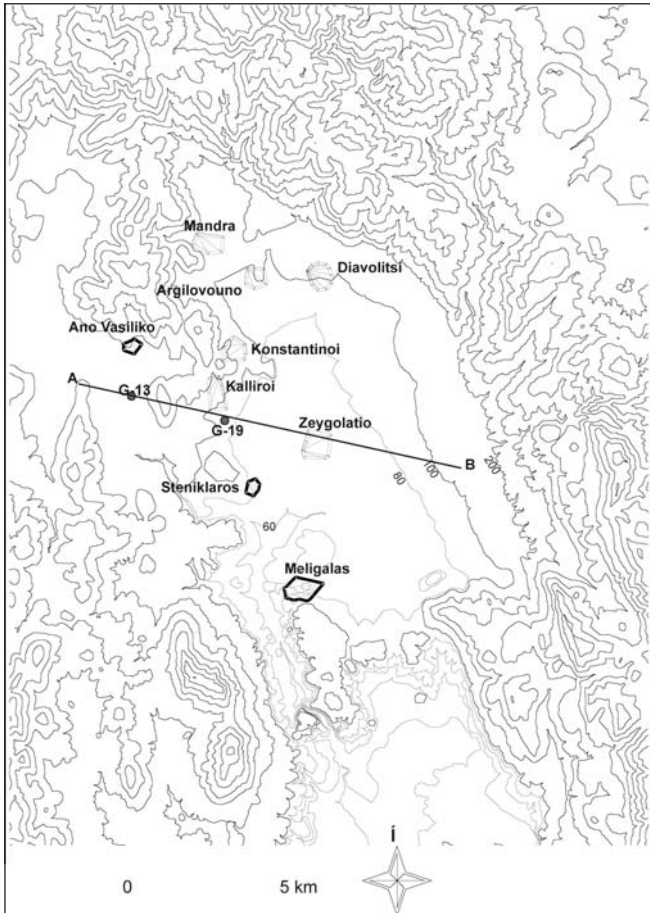


Fig. 3: Topographical map of the Upper Messinian Basin.

While the highest elevation to the East and North of the basin, on the water divide reaches 1080 & 1040 m, the central part of the basin, covered by post alpidic formations, has an average elevation of 80 m. The post-alpidic sediments extend over 81 km² and can be divided in two geomorphologic regions. To the northern and eastern boundary of the basin alluvial cones prevail with higher topographical slope and consisting of coarse grained material. The central part of the basin is flat and covered by fine grained sand and clay material of small thickness. The deeper sediment horizons consist of more coarse grained material. At a depth of 25 – to 40 m, a clay horizon exists with thickness of about 5 to 20 m.

3. Hydrogeological conditions

3.1 Surface aquifers

Two aquifers are present in the post alpidic sediments, a phreatic aquifer in the upper sediments and a second one, under pressure, below the clay horizon at the depth of 25 to 40 m. The clay horizon serves both as the base of the phreatic aquifer and the overlying confining unit of the deeper aquifer. The main inflow to these aquifers comes from the large karstic aquifers in the Tripolis limestones on the eastern boundary of the basin (Mariolakos, 1988, Spyridonos, 1994).

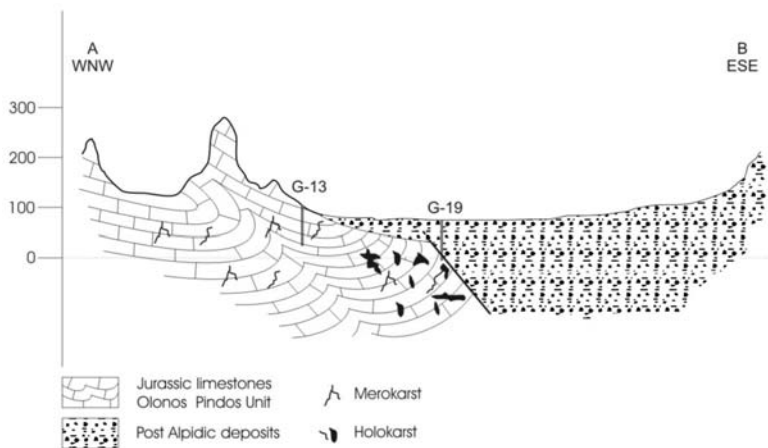


Fig. 4: Geological sketch A-B (Distance A-B 12km, elevation scale 10X exaggerated).

3.2 Deeper aquifers

The main aquifers in the area are located in the karstified carbonate formations of the Tripolis unit. The upper Cretaceous limestones at the southeastern part of the basin are part of the limestone mass that reaches northern of the city of Kalamata. In the deeper part of these limestones a large karstic aquifer is developed, which feeds the karstic springs at Pidima and Ag. Floros, on the eastern boundary of the Lower Messinia basin, southern to the study area.

The upper cretaceous limestones of the Pindos unit appear on the surface on the western part of the basin. Small temporary springs are located on the western boundary of the basin. Drilling results indicate that groundwater flow in these limestones appears in separated karstic conduits. On the contrary, under the plain part of the basin (between Mandra-Argilovouno-Zeygolatio-Kalliroi and Konstantinoi), where these limestones underlie the alpidic sediments, a large karstic aquifer is present.

3.3 Morphotectonic characteristics of the basin affecting groundwater flow

The geometrical characteristics of the basin, as a result of the neotectonic activity, are an important factor affecting groundwater flow. The northern and eastern boundaries of the basin are the fault zones that formed the Kalamata – Kyparissia Graben. To the south the basin is bounded by the Meligalas horst (Tripolis flysch). To the west the basin is bounded by the Olonos – Pindos flysch and the limestones (fig. 2).

Groundwater flows from the east through the fault zones into the sediments filling the basin, but out flow to the south is hindered by the flysch and the Pindos zone formations. So the ground water is trapped in the sediments and the only way for outflow is surficial flow, a fact that often leads to flooding of the plain region around Meligalas in the spring (Mariolakos, 1988, Spyridonos, 1994).

4. Karst description

Karstification in the Tripolis unit limestones shows all the characteristics of the holokarst type (after Cvijič, 1926): that is development of all karstic forms, in the surface as well as in depth. This explains the large water potential of the aquifers in these formations.

The limestones of the Olonos – Pindos unit appear on the northern and the western part of the basin. The karst developed in these limestones is of the merokarst type (Cvijič, 1926): that is not fully developed karst, due to preferential groundwater flow, resulting in fewer and isolated karstic conduits. This karst type develops usually in limestones with marly content or with impermeable intercalations. This kind of karstification explains the small temporary springs on the western boundary of the basin. Wells drilled in these region yielded little amounts of water, even if drilled near to springs, a fact that supports the existence of isolated conduits.

The same limestones show a different grade of karst development in the region under the post-alpidic sediments. There the karst characteristics are of the holokarst type, and the yield of wells in this region was between 120 and 200 m³/h.

This situation is clearly demonstrated in the geological section of Fig. 4: Drillhole G-13 is located less than 1 km behind the Ano Vasiliko spring and it drilled the napped Upper Cretaceous limestones of the Pindos Unit. It yielded a small amount of water, indicating that no large water reservoir is developed in the limestones and the spring is fed by linear flow through separated karstic conduits. On the contrary, drillhole G-19 drilled the same limestones under the post alpidic sediments, and met a rich aquifer developed in this formation. Pumping of this drillhole influences the Steniklaros spring, which is more than 2 km away, confirming the existence of a karstic aquifer of the holokarst type.

5. Conclusions - Results

The main aquifers of the region are located in the karstified limestones of the Tripolis and the Olonos - Pindos units.

The karstification of the Tripolis limestones is of the holokarst type, resulting in an aquifer system of large dimensions and potential, extending in the Taygetos mountain mass to the east of the study area. This aquifer system feeds the large springs of Ag. Floros and Pidima and also feeds the aquifers in the post-alpidic sediments filling the Upper Messinia basin.

The Olonos – Pindos limestones show two types of karstification. In the regions where they appear on the surface, the karstification is of the merokarst type, resulting in smaller isolated aquifers and temporary springs. On the contrary, the limestones of the same unit underlying the post-alpidic sediments are fully karstified and hosting an aquifer of large potential.

This differentiation can be explained by the hydrogeological conditions of the basin. The post alpidic sediments, especially the clay horizon, serve as a confining layer for the underlying aquifer, causing artesian conditions. This aquifer is also fed by the Tripolis limestones to the east. This results in lower flow velocities in the limestones under the sediments compared to the limestones exposed at the surface. Also, water under pressure can dissolve more CO₂ and therefore hold more CaCO₃ in solution, a fact that also helps karst evolution.

6. References

- Cvijič J. (1926). Das Karstphänomen, *Pencks geograph., Wien, Abh. 5,3*, 279p.
- Fountoulis, I., (1994). Neotectonic evolution of Central-West Peloponnesus. Phd Theses, National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, GAIA 7, 386 p.p. (in Greek with English abstract).
- Katsikatsos, G. (1980). Geological Study of the Vasiliko – Ithomi region, Messinia. I.G.M.E., *Geologi-*

- cal and Geophysical Studies*, v. XXI, Nr. 1, 176 p, 12 plates, Athens (in Greek).
- Lalechos, N. (1974). Geological Structure of Central-Western Peloponnesus. I.G.M.E., *Geological recognitions*, Nr. 53, 94 p., 17 plates, Athens (in Greek).
- Marcopoulou-Diacantoni, A., Mirkou, M.-A., Mariolagos, I., Fountoulis, I. (1991). Stratigraphic and paleogeographic observations at the post-alpine sediments of the Filiatra area (SW Peloponnesus, Greece), and their neotectonic interpretation. - *Bull. Gr. Geol. Soc.*, v. XXV/2, p. 593-608, Thessaloniki, (in Greek).
- Marcopoulou-Diacantoni, A., Mirkou, M.-R., Mariolagos, I., Logos, E., Lozios, S., Fountoulis, I. (1989). Stratigraphic observations at the post-alpine of the Thouria-Ano Amphia (SW Peloponnesus, Greece), and their neotectonic interpretation. - *Bull. Geol. Soc. Greece*, v. XXIII/3, q. 275-295, Athens, (in Greek).
- Mariolagos, I. (1988). The application of the Darcy's Law in closed geomorphological and hydrogeological systems, Example: the basin of Ano Messinia (SW Peloponnisos). In: *Proceedings of the 3rd Congress of the Geol. Soc. of Greece*, *Bull. Gr. Geol. Soc.*,v. XX/3, 77-96, Athens (in Greek).
- Mariolagos, I., Sabot, V., Alexopoulos, A., Danamos, G., Lekkas, E., Logos, E., Lozios, S., Mertzanis, A., Fountoulis, I. (1987). Microzonic study of Kalamata (SW Peloponnesus, Greece), (Geomorphology, Geology, Neotectonics). - Earth Planning Protection Organization, Report, 110q., Athens, (in Greek).
- Mariolagos, I., Fountoulis, I., Logos, E., Lozios, S. (1989). Surface faulting caused by the Kalamata (Greece) earthquakes (13-9-1986). - *Tectonophysics*, 163, p. 197-203.
- Mariolagos, I., Fountoulis, I., Marcopoulou-Diacantoni, A., Mirkou, M.-R. (1994). Some remarks on the cinematic evolution of Messinia province (SW Peloponnesus, Greece) during the Pleistocene, based on neotectonic, stratigraphic and paleoecological observations. *Munster. Forsch. Geol. Palaont.* 76, q. 371-380, Münster.
- Mariolagos I., Lozios S. And Logos E. (1995). The neotectonic macrostructure of southern Peloponnesus. The earthquakes of September 13, 1986. Seminar on active faults, XV Congress of the Carpatho-Balkan Geological Association, 51-60, Athens.
- Mariolagos, I., Fountoulis, I. & Ladas, I. (2001). The paleogeographic evolution of SW Peloponnese during Quaternary period. In: *Proceedings of the 9th Congress Geol. Soc. Greece*, *Bull. Geol. Soc. Greece*, v. XXXIV/1 pp. 37-45, (In Greek with English abstract).
- Spyridonos, E., (1994). Simulation of the phreatic aquifer of the Ano Messini basin (SW Peloponnesus) using mathematical modeling. In: *Proceedings of the 7th Congress of the Geol. Soc. of Greece*, *Bull. Gr. Geol. Soc.*, XXX/4, pp. 275-283, Thessaloniki (in Greek).