Subsurface Structure of Tympaki Basin (Crete, Greece) Based on Well and Geophysical Data

CONFERENCE PAPER · OCTOBER 2015

DOI: 10.3997/2214-4609.201414142

5 AUTHORS, INCLUDING:

George Panagopoulos
Technical University of Crete
19 PUBLICATIONS **6** CITATIONS

Emmanouil Manoutsoglou
Technical University of Crete
94 PUBLICATIONS **171** CITATIONS

Pantelis Soupios
Technological Educational Institute of Crete
106 PUBLICATIONS **432** CITATIONS

27176

Subsurface Structure of Tympaki Basin (Crete, Greece) Based on Well and Geophysical Data

G. Panagopoulos* (Technical University of Crete), E. Manoutsoglou (Technical University of Crete), A. Vafidis (Technical University of Crete), P. Soupios (Technological Educational Institute of Crete) & S. Bellas (Ministry of Reconstruction of Production, Environment)

SUMMARY

Tympaki basin has been studied in the past years from a hydrogeological point of view. Whatsoever, less are known on the subsurface structure of the plain part of the basin in terms of sediments thicknesses and faults existence. A way of identifying in-ferred faults is the integrated use of geophysical and well-data which finally give an insight of the subsurface within a content of a well-established knowledge of the geo-logical regime of the study area. In this paper the use of 3D geological modelling technique is described as a mean to identify fault structures and horizon depths. The data used include the digital elevation model (DEM) of the area, the boundary sur-face between geologic formations and the litho-stratigraphic data from wells, geo-physical measurements of Vertical Electrical Soundings (VES) and Transient Electro-magnetic Method (TEM). The first step was to develop a 3D stratigraphic model that approximates the subsurface position of the Plio-Quaternary and the Neogene depos-its. The inferred faults came out from this model were cross-checked with the TEM measurements providing an updated subsurface structure. All the newly identified faults and along with the depth of stratigraphic horizons give finally an overall tecton-ic pattern of the Tympaki basin.

Introduction

Tympaki basin is located in the southern part of the island of Crete in Greece. The area exhibits a pronouncedly differentiated relief, with an almost flat south-western domain proximal to the coast, and a north eastern hilly domain proximal to Idi Mountains (Figure 1). While the main tectonic features could be observed in the northern part, this case is quite difficult to the southern area where the deposition of recent sediments has formed the so called Tympaki plain.

The identification of inferred faults in plain areas is usually a difficult issue because of lack of surface evidence. In such cases, geophysical methods are regarded as a first, yet mediate, way of grossly tracking those faults. However, the interpretation of the geophysical measurements without having any surface control point might turn up to be ambiguous. At that point a well-established knowledge of the study area geological regime may considerably add to the value of the geophysical interpretation. So, the construction of a database with all the available spatial geological information in the region would significantly assist to the interpretation procedure and strengthen the final results.

There are many different software packages relative to the construction of a geological database with options in visualizing and modifying a 3D environment. Each one of those is more or less sophisticated depending on the number of options the user has and usually each software is dedicated to a specific line of expertise. The selection criteria of the best software to use should be balanced between, on one hand on the quality/quantity of the available data, the complexity of the study area and the requirements of the project and on the other hand of the cost of purchasing and updating the software and of training the users.

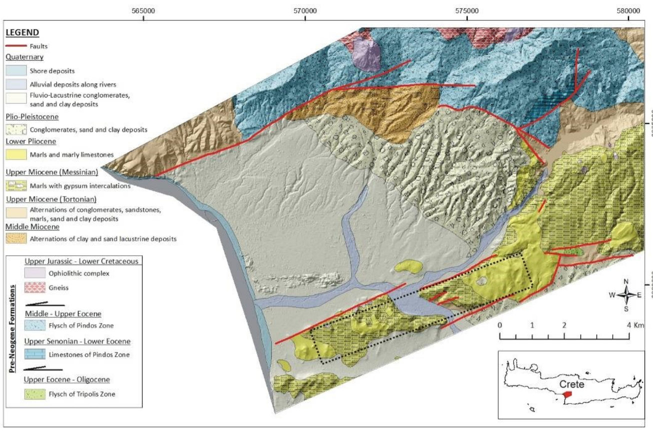

Figure 1 *Geological map of Tympaki area (after Vidakis et al., 1994 and Bonneau, 1985, modified). Dashed line delineates the Faistos horst. Recent deposits cover most of Tympaki basin, while Neogene deposits are underlain.*

Tympaki basin has been studied in the past years from a hydrogeological point of view. Faults identification is crucial for the study of the sea-water intrusion. Whatsoever, in Tympaki basin only the faults that could be detected on the surface were taken into account. This is demonstrated in previous studies based on morphotectonic observations and drilling and geophysical data (FAO, 1969; Peterek & Schwarze, 2004; Paritsis, 2005; Papanikolaou & Vassilakis, 2010). Most of the Tympaki basin, particularly the south western part, is covered by recent fluvio-lacustrine and alluvial deposits, while the north western domain is covered by fluvial deposits and alluvial fans (Figure 1). Below those deposits Neogene to Early Pliocene sediments are observed, exhibiting in a great extent marly and clayey lithologies (Bellas & Keupp, 2010).

In this paper an approach to unlock the tectonostratigraphic configuration of Tympaki basin is described. For that purpose, new and legacy surface and subsurface geological data were collected, and gathered into a single database, the spatial correlation of which ended up to the 3D tectonostratigraphic model of the basin.

Methodology

In order to construct the 3D lithostratigraphic model of Tympaki basin, a GIS geological database (in ArcGIS) was created which was used in combination with a 3D geomodeller package (Rock-Works15, RockWare, Inc). The 3D model was built based on DEM and 39 well logs with the objective of defining the boundaries of the Plio-Quaternary and Neogene Units of the basin. The second stage was to examine those boundaries and to identify any abrupt throw in absolute elevation of them. Something like that could be interpreted as a result of fault activity which cannot be observed in the surface (Panagopoulos *et al*, 2013). Such abrupt changes were located on the isodepth map (Figure 2). Based on this concept several faults were defined in a first pass interpretation. It should be mentioned that the identification of faults was restricted in the area where enough borehole data were available.

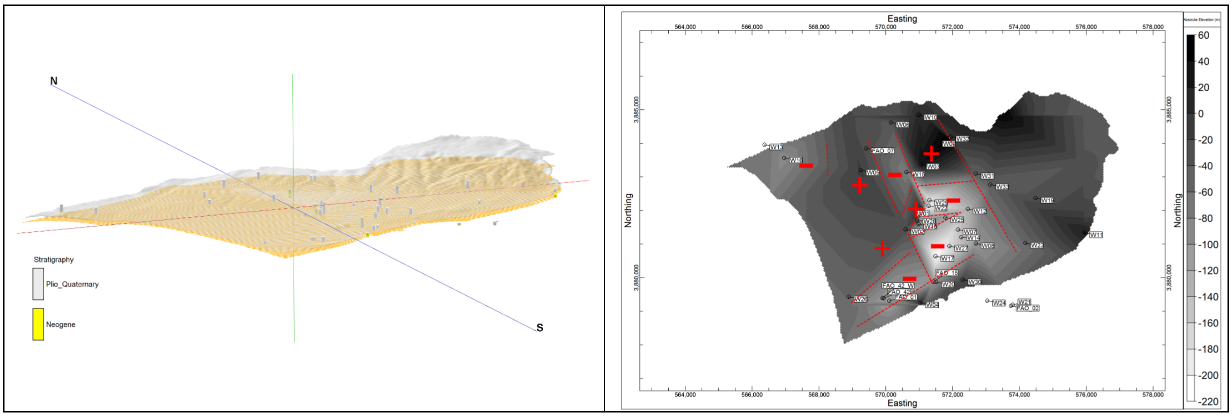

Figure 2 *On the left, the 3D presentation of the upper Plio-Quaternary surface (transparent surface) and the boundary surface between Plio-Quaternary and Neogene deposits (lower surface). The spatial position of all boreholes is also shown. On the right, the resulting isodepth map of the upper surface of Neogene deposits. Dashed lines depict inferred faults. Plus and minus symbols refer to elevated and subsided areas respectively.*

In a second phase inferred-fault interpretation was refined and cross-checked with additional pre-existing VES data and newly acquired TEM measurements. The latter were acquired in the context of a research program monitoring saltwater intrusion in the coastal zone of Tympaki. TEM survey was carried out by using a single square loop configuration (50m x 50m) allowing the detection of subsurface resistivity structures for a maximum depth of 100 to 120 m. The survey grid covers all the plain part of Tympaki basin, with a total of 367 soundings at 107 locations (Soupios *et al*., 2014). The results of this survey were used to cross-check the zones where possible faults have been identified as resulted by 3D lithostratigraphic model. Zones of low resistivity values are assigned to wet areas because of either seawater intrusion or faults hosting water. In general, the distinction between the two cases could be based on the shape the low-resistivity areas have. Elongated linear shapes is more likely to represent faulted structures, while wider flatten shapes are closer to a seawater intrusion front. Thus, the identification of elongated low-resistivity zones should be highlighted in TEM interpretation as inferred faults which should be checked in parallel with the other available spatial data.

Integrated interpretation of the subsurface structure

Having all the available data as described above, the next step was the use of them in similar way (harmonization). In other words, the different information each one of those datasets provided should be interpreted according to a common classification basis. So, all lithological logs from the boreholes and all resistivity values from the VES should be attributed to Neogene or Plio-Quaternary deposits.

As already discussed, a first approach was the recognition of potential faults in areas where abrupt changes in depth were observed. In a second stage, the indicative position of these faults were modified to honor the results of TEM, in a way that they would coincide with the positions where TEM anomalies have been observed. During this process, two additional faults were observed in areas where borehole and VES datasets could not reveal their existence but TEM anomalies could. The two additional faults, as well as, the refinements made to the rest faults can be spotted in the map of Figure 3 which is slightly different from the previous one of Figure 2.

After the new fault configuration, the Top of Miocene deposits were interpolated again using another algorithm that would honor faults existence. Usually, faults existence influences local interpolation and should be taken into account whenever an interpolation of field data takes place. In order for the predicted surface of Top Miocene horizon to honor faults existence, the input data were reprocessed in ArcGIS by using Kernel Smoothing algorithm with barriers. This algorithm interpolates irregular surfaces and predicts standard error throughout the model. By including the fault polylines as barriers, "Kernel Smoothing With Barriers" can accurately model point data within discrete subgroups, or in this specific case, discrete fault blocks (Figure 3). What's more, the same procedure can give a measure of uncertainty following the prediction. In Figure 3 the associated uncertainty is higher mainly in areas where well data are scarce, or secondly in areas close to faults.

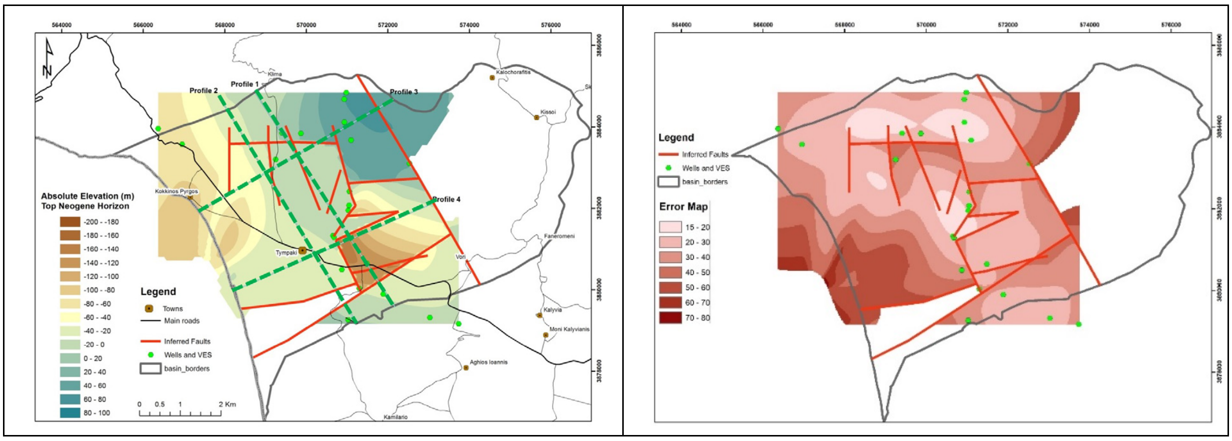

Figure 3 *Prediction map and an associated error map of the depth prediction of the depth of Top Neogene. The absolute elevation can reach a value as deep as -200m. The greatest error values are observed in the area of less control points as well as proximal to faults.*

Conclusions

Based on a series of well and geophysical data, the depth of the top surface of Neogene formations was defined and the inferred faults were identified giving an insight to the subsurface in the Tympaki basin, that could not been observed in the surface because the area is covered by recent fluvio-lacustrine deposits. The applied methodology provided strong evidences of the subsurface geology that come in an agreement with past morphotectonic studies (Peterek & Schwarze, 2004).

Two main fault directions identified through the analysis. The first one has a general direction NNW-SSE, similar to the strike direction that previous studies have proposed (FAO, 1969; Paritsis, 2005). The second one has a general direction from ENE to WSW, and it follows the strike direction of the boundary faults in the Northern and Southern basin boundary.

The available data didn't cover homogeneously the whole basin and the fault interpretation was restricted in areas where adequate data exist, while the interpolation of the Top Neogene horizon covers the major part of the study area, followed by an estimation of the associated uncertainty. No matter how much the data coverage was, all the newly identified faults give finally the overall tectonic pattern of the Tympaki basin. According to it, several tilted fault blocks in an NNW-SSE direction result in an escalated morphology of the Neogene basement deepening towards the SW. This trend of deepening is also influenced by the activity the SW-NE fault group, which seems to have a regional impact in the basin evolution from Tympaki towards Gavdos island in the SW (Figure 4).

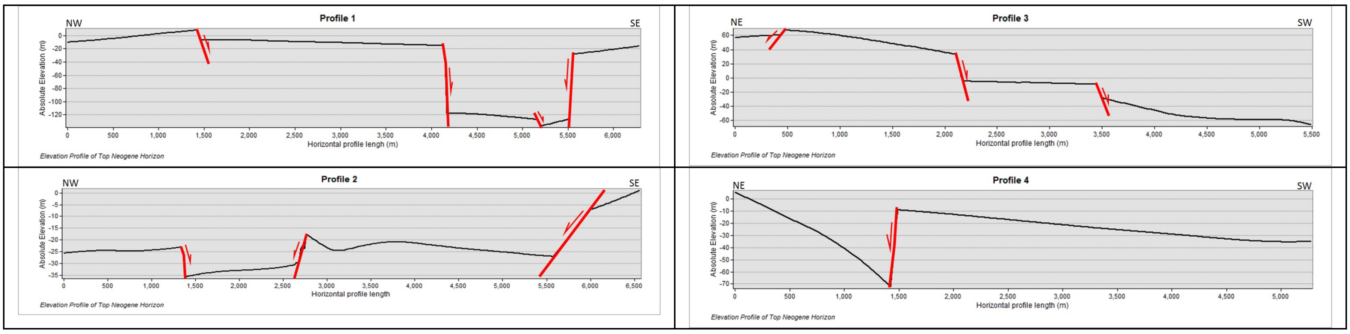

Figure 4 *Profiles of the Top Neogene Horizon in Absolute Depth (m) and the inferred faults. For location check Figure 3.*

Acknowledgements

This study is part of the work that Technical University of Crete undertakes within the Work Pack-age 1 of the BLACK SEA ERA.NET project, focusing in pollution from sea water intrusion at coastal areas (Tympaki basin).

References

Bellas, S. and Keupp, H. [2010] Contribution to the late neogene stratigraphy of the ancient Gortys Area (Southern Central Crete, Greece). *Bulletin of the Geological Society of Greece*, **XLIII**(2), 579-593.

Bonneau, M. [1985] *Geological map of Greece, 1:50.000. Melambes sheet*. I.G.M.E., Athens.

FAO [1969] *Greece: geophysical survey performed in Messara plain (Eastern Crete). Final report.* Fondazione Ing. C.M. Lerici Del Politecnico, Milan, Italy.

Panagopoulos, G., Giannakakos, E., Manoutsoglou, E., Steiakakis, E., Soupios, P. and Vafidis, A. [2013] Definition of inferred faults using 3D geological modeling techniques: A case study in Tympaki basin in Crete, Greece. *Bulletin of the Geological Society of Greece*, **XLVII**(2), 605-615.

Papanikolaou, D. and Vassilakis, E. [2010] Thrust faults and extensional detachment faults in Cretan tectono-stratigraphy: implications for Middle Miocene extension. *Tectonophysics*, **488**, 233-247.

Paritsis, S.N. [2005] *Simulation of seawater intrusion into the Tymbaki aquifer, South Central Crete, Greece.* Report within MEDIS project, Study implemented on behalf of the Department of Management of Water Resources of the Region of Crete. Heraklion, Crete, Greece.

Peterek, A., Schwarze, J. [2004] Architecture and Late Pliocene to recent evolution of outer-arc basins of the Hellenic subduction zone (south-central Crete, Greece). *Journal of Geodynamics*, **38**, 19-55.

Soupios, P., Kourgialas, N., Dokou, Z., Karatzas, G., Panagopoulos, G., Vafidis, A. and Manoutsoglou, E. [2014] Modeling Saltwater Intrusion at an Agricultural Coastal Area using geophysical methods and FEFLOW model. *IAEG XII Congress*, 15-19 Sept., Torino, Italy.

Vidakis, M., Jonkers, A. and Meulenkamp, J.E. [1994*] Geological map of Greece, 1:50.000, Epano Archanae sheet*. I.G.M.E., Athens.