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IDENTIFICATION OF BURIED ACTIVE STRUCTURES WITH PRELIMINARY GEOPHYSICAL AND MORPHOTECTONIC ANALYSIS, AT EASTERN THESSALY BASIN (GREECE)

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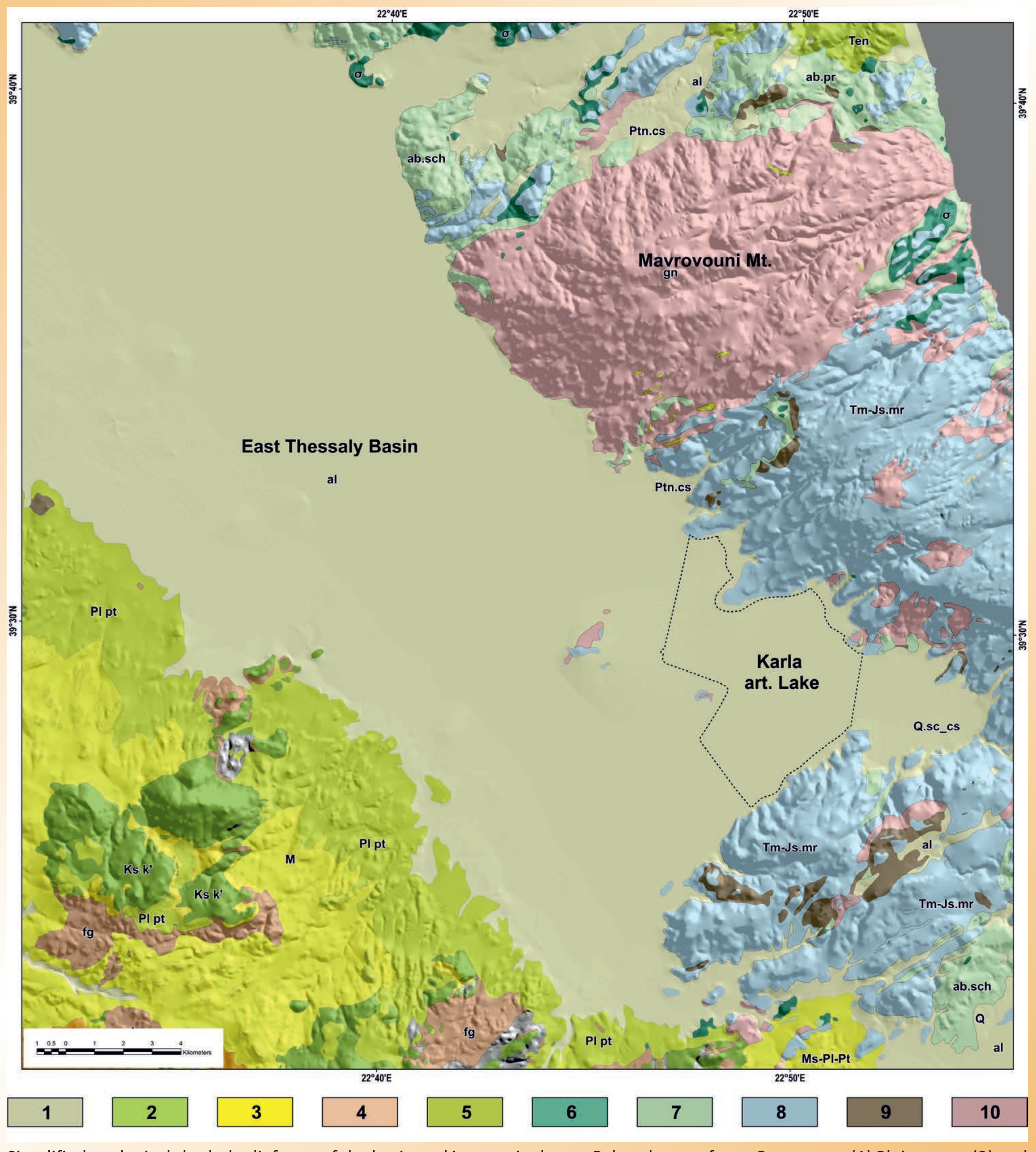
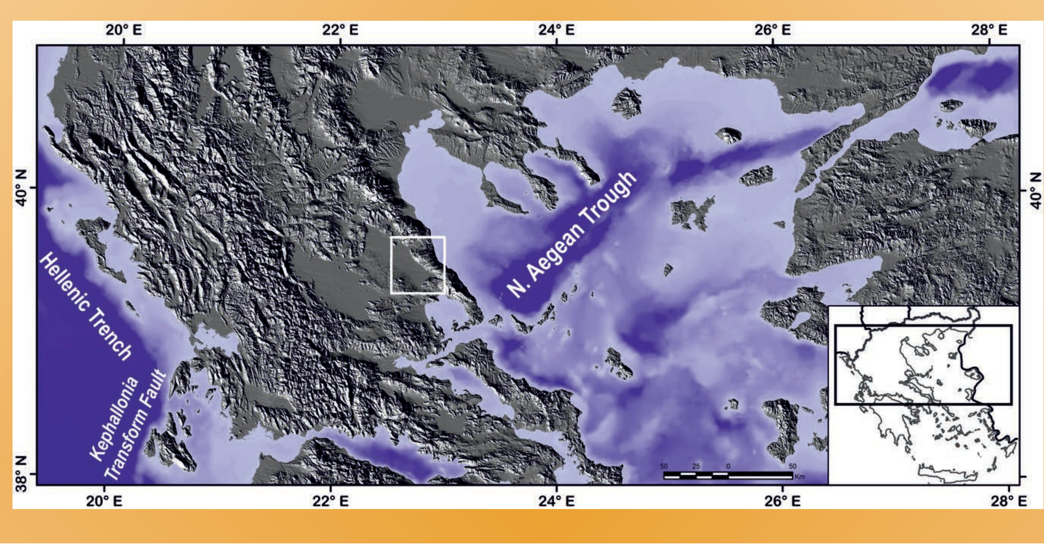
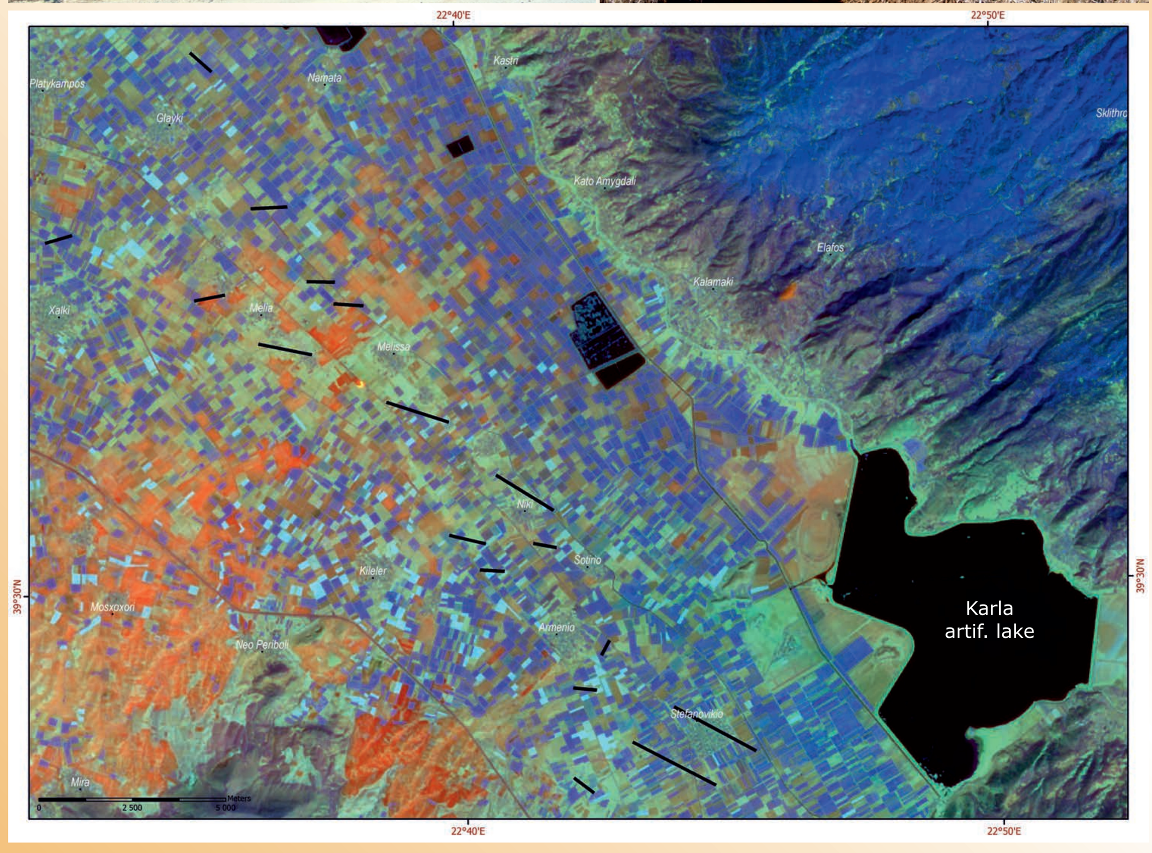


Simplified geological shaded relief map of the basin and its marginal area. Pale colours refer to Quaternary (1) Pleistocene (2) and Miocene (3) sediments, whilst intense colours refer to the alpine basement rocks, Flysch (4), Limestones (5), Ophiolites (6), Amphibolites (7), Marbles (8), Schistolites (9) and Gneiss (10). The dashed outline shows the borders of the recently filled artificial lake of Karla and west of it several basement rocks are cropping out in the middle of the basin.
The alpine basement rocks, which crop out at the eastern and southeastern margins of the eastern Thessaly basin consist of metamorphic Gneiss, Marbles, Schists, Amphibolites and Ophiolitic bodies (Migiros and Vidakis, 1979). The westernmost marginal area is comprised of Neogene continental sediments, mainly conglomerates, covering alpine flysch and limestones. The tectonic contact between the metamorphic and non-metamorphic rocks lies buried under the Quaternary fluvial and lacustrine sediments of the basin.

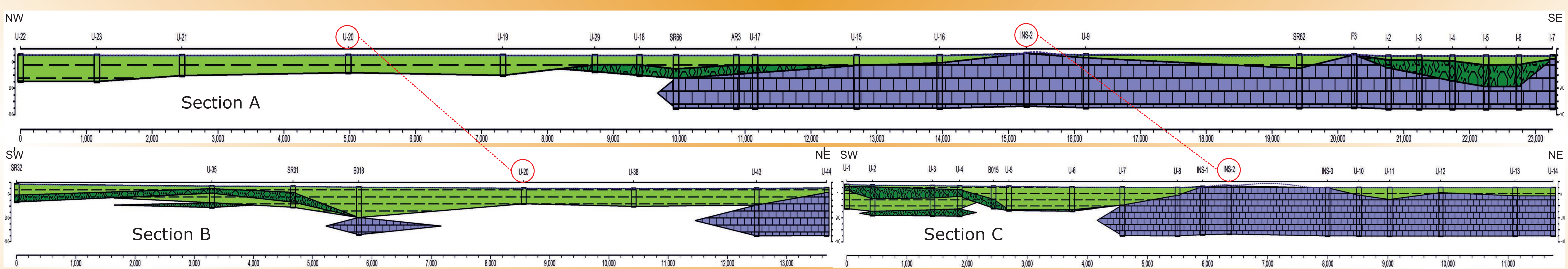
ABSTRACT

Extensive ground fissures frequently occur within the eastern Thessaly basin, in central Greece and have been since 1989. This paper aims to give a preliminary explanation for their generation reasons by interpreting the results of a dense geophysical survey along the basin. This is combined with drilling data, as well as field work tectonic measurements, morphotectonic analysis and remote sensing data interpretation throughout the marginal areas of the basin. The gathering, homogenisation and organisation of different types of geo-data by using various GIS software packages led to the discovery of the alpine basement surface, which is covered by recent sediments, and possible structures that contributed to the development of the basin. The methodology of producing a 3D basement surface model and various lithology profiles across the basin, along with sediment isopach maps by combining surface with subsurface data, is described in this paper.





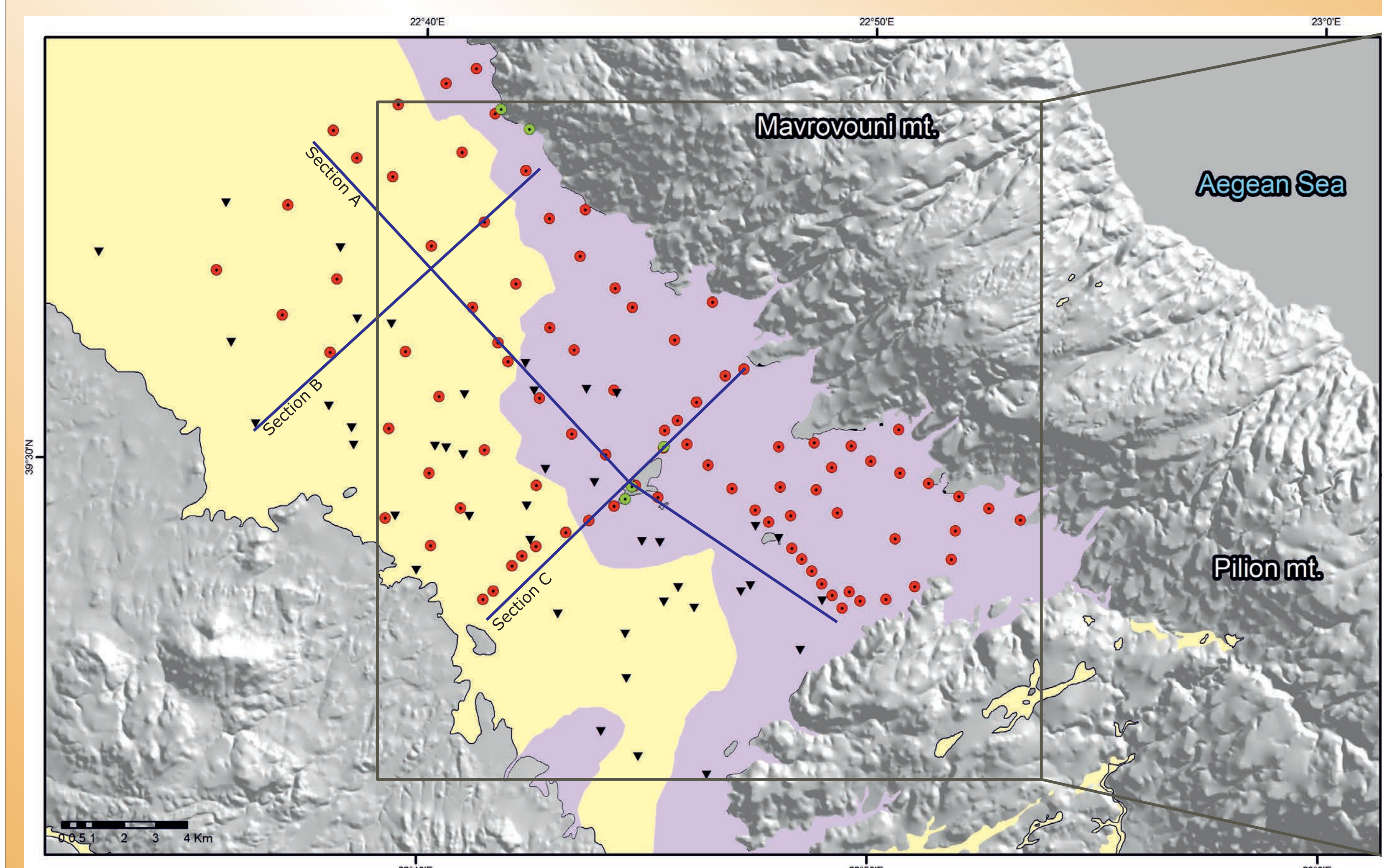
A pseudo-color (6,5,7/R,G,B) Landsat-8 image of September 2013 is used as a base map for the locations of observed ground fissures. It is obvious that most of the fissures are located in or at a small distance from residential areas, which means that there could be more fissures at the agricultural territories that did not become perceptible.
The distortions caused by frequent creeping displacements along ground fissures are obvious at the photographs above either at manmade structures or at the fields. These phenomena are implying the existence of an active transtensional geodynamic regime, which could be reinforced by the compaction of aquiferous strata due to groundwater over pumping.
Note the NE-SW linear shapes of the drainage network north of Karla artificial lake and the incision at the basement rocks comprising the eastern margin of the basin.



Three litho-stratigraphical sections were composed, based on the interpretation of the resistivity values measured by the VES as well as the borehole stratigraphic data. The section traces are displayed below and note that the vertical scale is exaggerated (x2) for best viewing results.

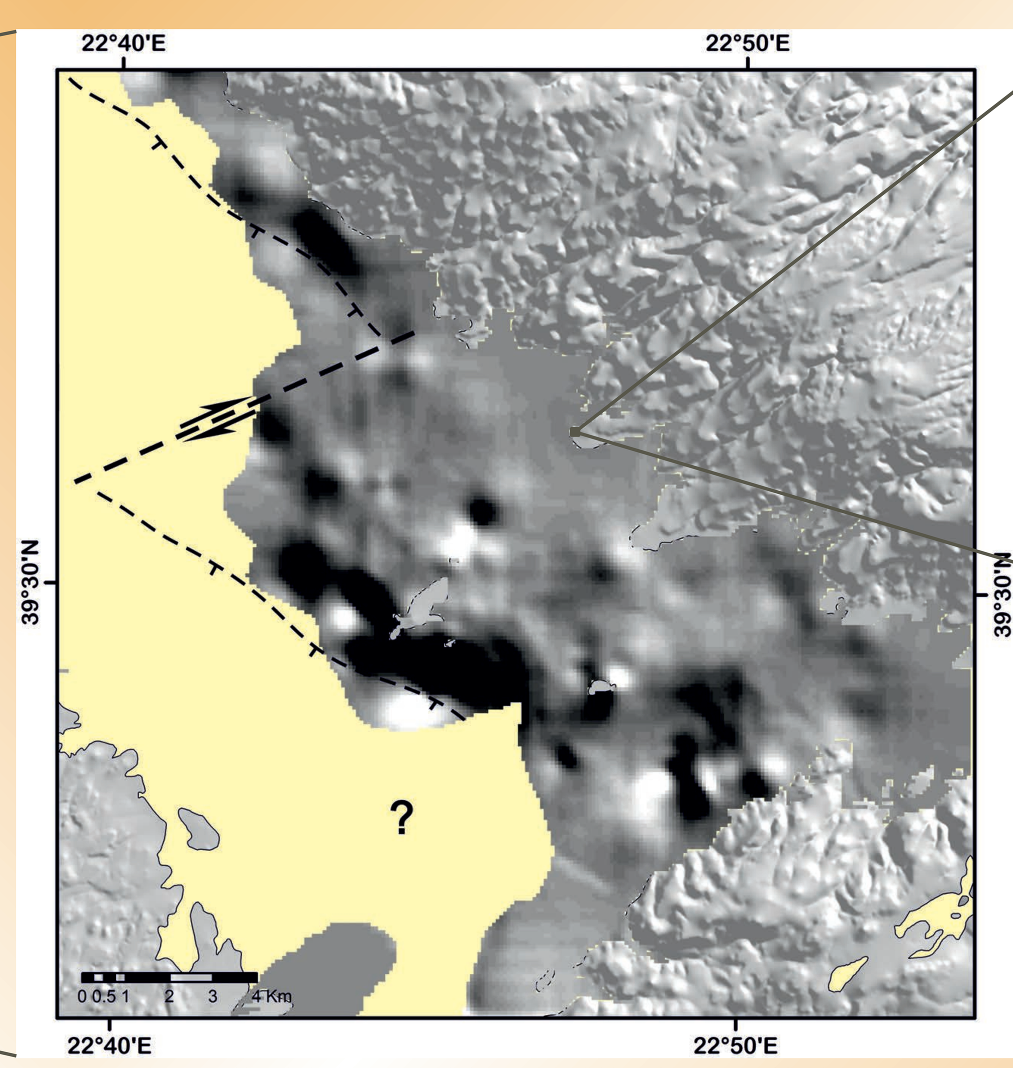
The alpine basement is presented unified (blue) and the recent sediments were separated into two formation sequences; fine grained strata with clay as the dominant material (light green) and coarser grained strata with the presence of sand, pebbles and clay (dark green).

The code names above the topography of each section refer to the data source and the depth of investigation at each location is also displayed. The red connector circles show the intersections between the sections and the common data sources.

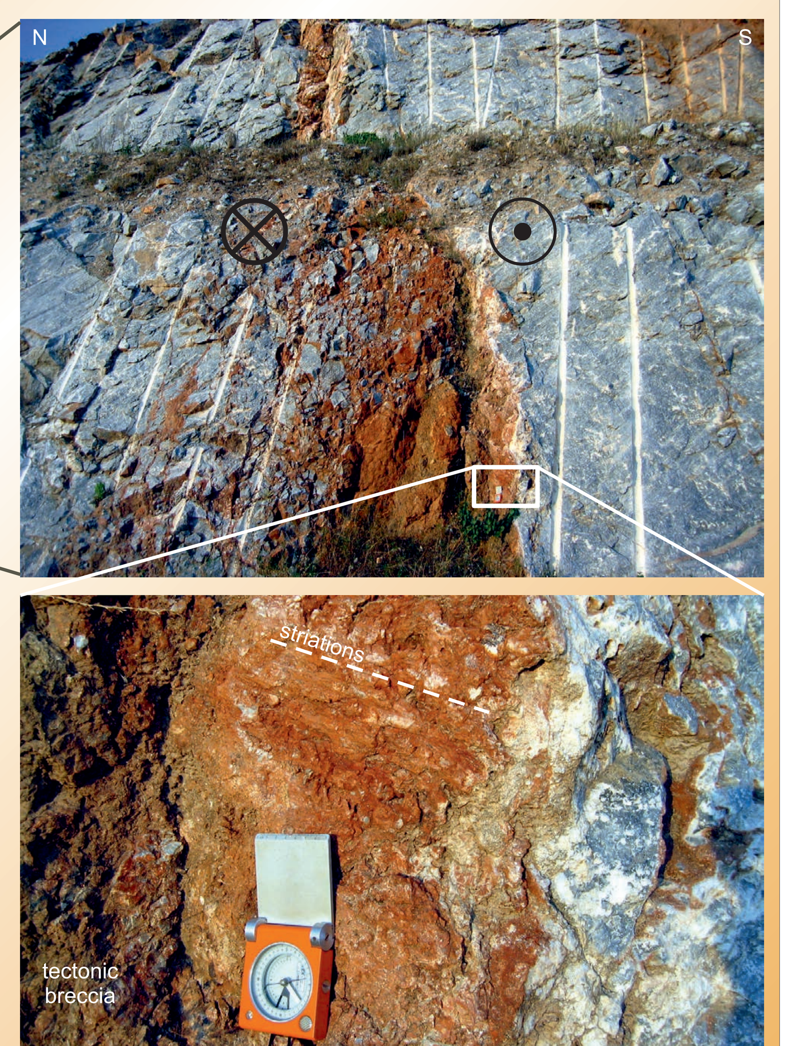


A dense grid of 61 Vertical Electrical Sounding (VES) measurements (Schlumberger array) was designed and carried out covering the entire basin area. The main objective was to investigate the boundaries between the main sediment lithologies and the upper surface of the alpine basement rocks. The geoelectrical data included five (5) "in-situ" resistivity measurements on surface outcrops of the alpine geological formations and fifty six (56) VES measurements at depths around 500 meters. Additionally, data from thirty six (36) unpublished measurements, which were carried out during early 1970's were re-interpreted and re-evaluated, increasing the quantity of data for interpretation, along with a large number of water pumping borehole stratigraphic sections data.

The location map of the VES measurements (red dots), In-situ resistivity measurements (green dots) and the boreholes (reverse triangles) the drill sections of which were used for the subsurface basement map, is displayed above. Only the Quaternary outcrops are displayed in colour as all the rest have been removed and replaced by a shaded relief. Purple color shows the areas where the alpine basement was found under the sediments at the depth of investigation. The traces of the sections presented above are also marked.
The fieldwork photographs below show VES measurements at Quaternary deposits (a), In-situ VES measurements at alpine basement outcrops (b), as well as Electrical Resistivity Tomographies *-not presented in this paper-* across observed ground fissures (c).



Based on geophysics and borehole data, a Digital Elevation Model (DEM) was created for the covered basement surface and combined with a DEM that was created from elevation data for the marginal areas, where the alpine rocks are cropping out. The single unified morphological pseudo-surface, which was synthesised, was used for further study by applying tectonic geomorphology indices and algorithms, in order to define potential blind fault zones that are buried beneath the basin material. It is quite clear that the area where the alpine basement was found in relatively shallow depths (less than 250 meters), represents the gradual subsurface continuation of the eastern marginal outcrops.
Two buried steep slopes, which can be attributed to southwest-dipping blind normal faults, could be identified at the shaded paleo-relief map displayed above. These seem to belong initially at the same fault zone, which was the main structure for the generation of eastern Thessaly basin. A third NE-SW trending structure has been probably activated at a later period and has laterally displaced the aforementioned marginal faults, separating them with a right slip movement mechanism. The question mark symbol shows lack of data at this preliminary phase of research. The systematic orientation of the observed ground fissures, even if the main cause seems to be the over-pumping and subsequently the compaction of several horizons due to the relatively sudden loss of the aquifer water, seems to be related to the large tectonic structures, which are buried under the quaternary formations.
Although no significant seismic activity has been observed in the intra-basin area, there are several clues implying that there are geodynamic procedures still going on. Based on the morphotectonic analysis the activity is concentrated more at the central area and not at its -more or less linear- margins. That is because it seems to be an asymmetric extensional basin, the active margin of which is dipping to the SW and the western margin is back-tilted towards the east along a major tectonic contact which is covered by the recent sediments.



Nevertheless, several dextral strike slip tectonic structures trending WSW-ENE, possibly related to the northern branch of the active North Aegean Trough, can be identified across the marginal range by observing the shaded relief maps. This mountain range is the highest morphological relief between the basin and the trough, the tectonic influence of which seems to affect the range and fade away more westerly in the intra-basin area, as the palaeo-relief of the alpine basement extracted by geoelectrical measurements show.
The dextral character of these cross cutting structures is clear either by examining the subsurface basement map or by observing the drainage network offset on each side of the morpho-lineaments that can be attributed to strike slip faulting.
Additionally, almost horizontal striations on vertical fault surfaces were observed at marble outcrops located at the eastern marginal area, accompanied with kinematic indicators compatible with dextral movement (see photographs above).

Acknowledgments
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