The 9th International INQUA Workshop on Paleoseismology, Active Tectonics and Archeoseismology

FIELD TRIP GUIDE

Field Trip 1: Kassandra, 24 June 2018

Field trip 2: Eastern Halkidiki – Mygdonia basin, 29 June 2018

PATA DAYS 2018 GREECE

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INTRODUCTION

This field trip guide contains some brief and concise information on the stops of the two field trips that have been planned in the frame of the 9th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology. The field trips include visits to some of the main active faults of the broader Halkidiki area, as well as some sites of interest to both active tectonics research and geology in general.

The first of them (June 24, 2018) consists of an overview of Anthemountas graben and its geomorphological signature, a visit to the unique Petralona cave and a discussion about uplift and sea level changes.

The second field trip (June 29, 2018) crosses the active fault system of eastern Halkidiki, which produced the 1932 Ms = 6.9 (Ierissos-Stratoni) earthquake, as well as the epicentral area of the destructive 1978 Ms = 6.5 (Stivos) event, the 40th anniversary of which coincides with this meeting.

The geological setting, the Neogene-Quaternary stratigraphy and the main neotectonic features of the area are briefly described in the following chapters. More detailed information will be discussed during the field trips.

Thessaloniki, Greece, June 2018

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GENERAL GEOLOGY

CIRCUM RHODOPE BELT (CRB)

The Axios Massif, along with the CRB comprise the eastern segment of the Axios zone (Figure 1). It is considered (Kockel et al., 1977) as a narrow fragment of the Serbomacedonian Massif that has suffered retrograde metamorphism to greenschist facies. Several granitic intrusions of Upper Jurassic age, as well as extensive platform carbonates of similar age containing bauxite horizons, are observed within the Axios zone (Figure 2).

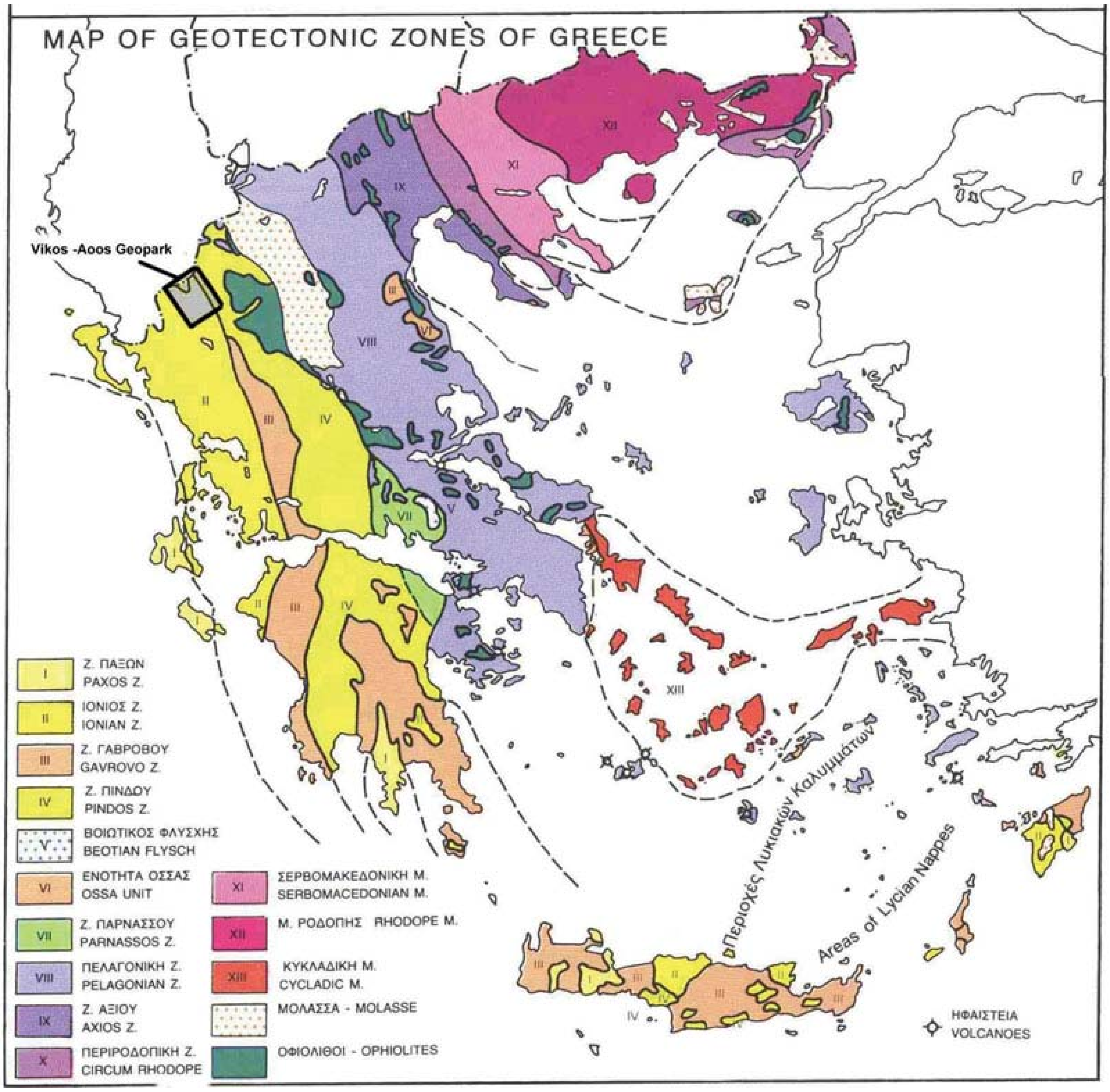

Figure 1. Generalized sketch map of the geotectonic zones of Greece.

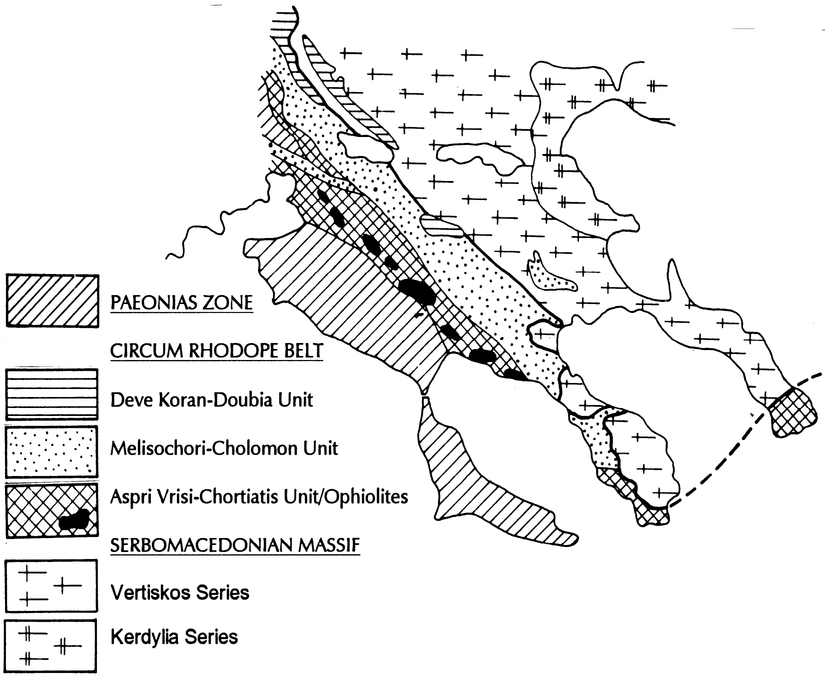

Figure 2. Structural sketch map of the Central Macedonia (Axios zone - Circum Rhodope - Serbomacedonian) (Mountrakis 1985).

The innermost part of the Axios Zone, the CRB, is thought by Kockel et al. (1977) to have been derived from the destruction of an embryonic ocean during Upper Jurassic. Zimmerman and Ross (1976) consider this belt as the suture zone of an Axios ocean, a root zone of all the Mesozoic ophiolites in Greece (Vourinos, Pindos, etc.). The lithological units of the belt record, in some detail, the formation and the subsequent destruction of a small ocean basin. They start, on top of the crystalline basement (Serbomacedonian Massif), with Permian continental sediments which grade upwards into a thick sequence of acid metavolcanics and pyroclastics. Neritic Triassic carbonates, followed by a deposition of a thick flysch succession during Lower and Middle (?) Jurassic, are observed along the central parts of the belt. A very prominent greenschist belt (K-poor diorites with dyke-like structures according to Schuneman (1986) and a dismembered ophiolite complex occupy the western part of the Circum Rhodope Belt.

SERBOMACEDONIAN MASSIF (SMM)

The Serbomacedonian Massif comprises a series of Palaeozoic and/or older rocks (Kockel et al., 1977), extending northwards into former Yugoslavia and bounded to the west by the above described Circum Rhodope Belt formations and to the east by the Rhodope crystalline basement (Figure 2).

In its Greek part, the Massif is divided into two units: Vertiskos Formation in the west and Kerdyllia Formation in the east. The contact between the two formations is poorly defined and their distinction was based on petrologic differences only.

- Vertiskos Formation is overlying Kerdyllia Formation through a fault that locally is developed into a thrust fault. It mainly consists of two-mica gneisses with

- intercalations of thin, elongated amphibolite bodies, large amphibolite blocks with gabbro/diabase remnants in their cores and abundant, small, elongated seprentinite bodies. A discontinuous but prominent ophiolite complex is observed in some parts along the Vertiskos-Kerdyllia contact.
- Kerdyllia Formation consists of migmatitic biotite gneisses, three marble horizons, hornblende gneisses and amphibolites (Demetriadis, 1974).

Carbonates, phyllites and volcanosedimentary rocks in the Vertiskos Formation are considered (Kockel et al., 1977) to have been tectonically emplaced from the CRB. Mesozoic granites (i.e., Arnea granite) and Tertiary plutonites make the rest of the Serbomacedonian massif.

K/Ar and Rb/sr isotope analyses in different lithologic units of the Vertiskos For- mation yielded ages ranging from 110 to 130 m.y. similar analyses for the Kerdyllia Formation range from 32 to 80 m.y. (Borsi et al., 1964; Harre et al., 1968; Papadopoulos and Kilias, 1985).

Although a lot of controversy has been raised about the degree of metamorphism of the SMM it seems that a metamorphic discontinuity exists between Vertiskos and Kerdyllia Formations; upper greenschist-lower amphibolite facies for Vertiskos Formation and middle to upper amphibolite facies for Kerdyllia (see also Dixon and Dimitriadis, 1984).

The bedrock has been subsequently subjected to an extensional regime, which caused its fragmentation and the formation of the main feature of the area, Mygdonia basin (Figure 3).

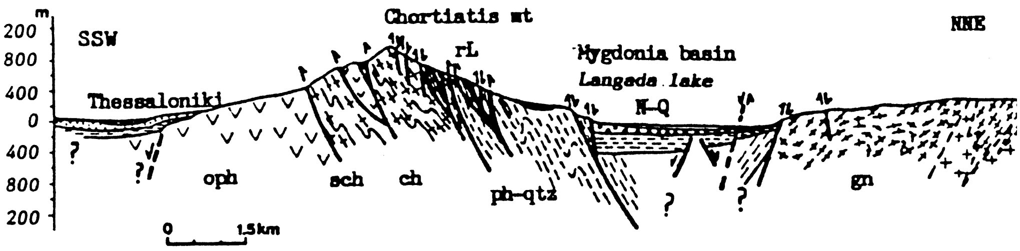

Figure 3. A NNE-SSW trending cross-section through the Thessaloniki-Mygdonia seismogenic area showing the mainly Alpide thrust structure and the post-Alpide high angle normal faulting.

NEOTECTONICS

MYGDONIA BASIN

Mygdonia basin is an angular crank-shaped graben (Figure 4 to Figure 7). Field evidence and remote sensing observations support the idea that there is a narrow fractured active zone within the Serbomacedonian massif associated with an intense seismic activity (Voidomatis et al., 1990) especially during this century.

This area is one of the most seismically active regions of northern Greece, and its proximity to the big city of Thessaloniki poses an additional socio-economic problem. Earthquake events include the 1902 Assiros (Ms = 6.6) and the 1978 Stivos (Ms = 6.5) shocks. The last one was well studied by scientists of many disciplines, since it was the first earthquake that directly affected a big city during modern times (e.g., Mercier et al., 1979, 1983a, 1983b; Papazachos et al., 1979, 1982; Hatzfeld et al., 1986, 1987). The formation of the graben has probably resulted from sinistral movements along a NW-SE oriented wrench fault zone. Some authors has interpreted the zone as Riedel shear to the North Aegean Trough system (the continuation of the North Anatolian Fault into the Aegean), while the character of the crust stress is mainly extensional (N-S stretching, Pavlides et al., 1990). It is a neotectonic structure filled up with Neogene and Quaternary clastic sediments.

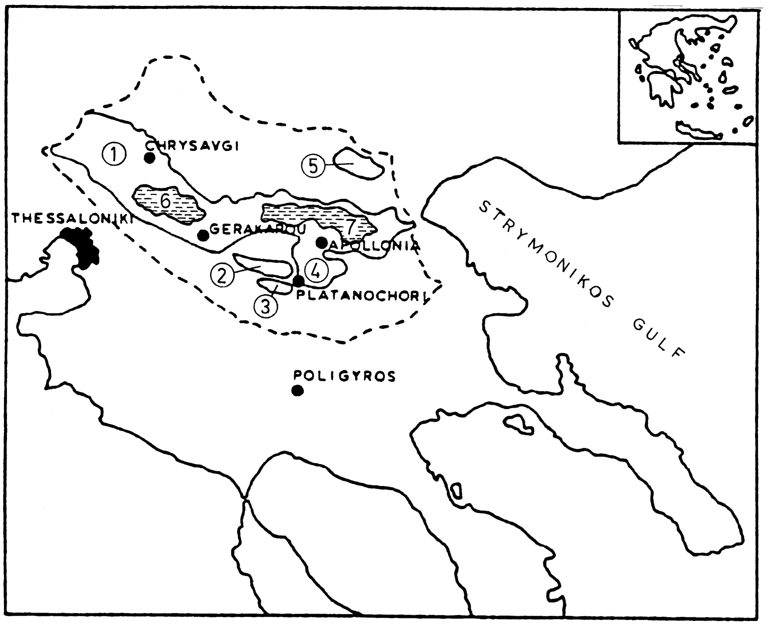

Figure 4. Sketch map indicating: (1) Mygdonia basin, (2) Zagliveri basin, (3) Doubia basin, (4) Marathousa basin, (5) Vromolimnes basin, (6) Koronia lake, (7) Volvi lake. Premygdonia basin is indicated by a dashed line (data from Psilovikos, 1977, Koufos et al., 1995).

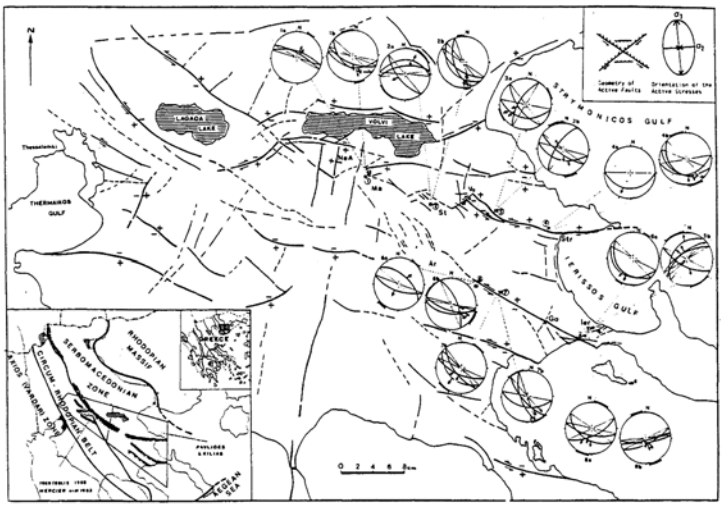

Figure 5. Structural map of Mygdonia basin and surrounding area (Halkidiki, northern Greece). Solid lines are faults that have been detected as lineaments after LANDSAT images and aerial photo analysis. Studies were accompanied by field observations, especially in the central and eastern Chalkidiki. Eight numbered representative sites are indicated as stars, while circles are equal-area projections of the corresponding faults (curves) and striations (arrows). Plus (+) and minus (-) signs indicate the relative fault motion (normal component). The location map (lower left corner) shows the geological emplacement of Mygdonia basin. Locations are: Ar: Arnea, Go: Gomati, Ier: Ierissos, Ma: Marathousa, Str: Stratoni, NeA: Nea Apollonia, St: Stanos, Va: Varvara (after Pavlides and Kilias, 1987).

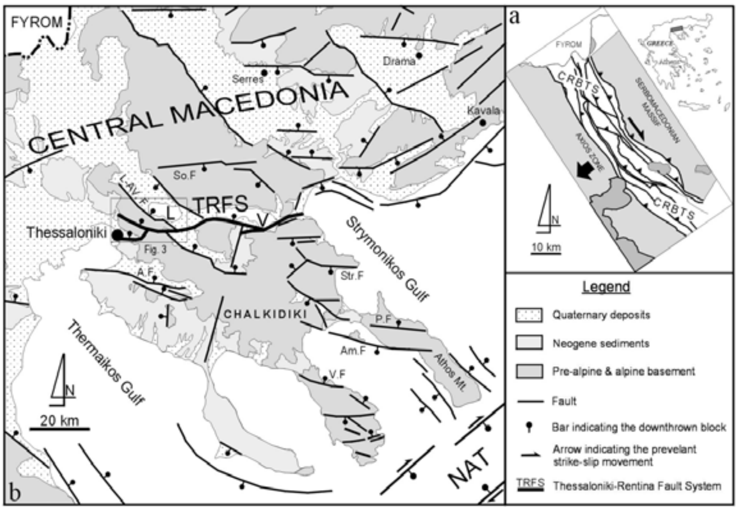

Figure 6. Generalized geological and tectonic map showing the Thessaloniki–Rentina Fault System and its westernmost part, the Thessaloniki–Gerakarou Fault Zone, in the fault-dominated area of Central Macedonia. Am. F: Amoliani Fault, A. F: Anthemountas Fault, L–AV. F: Lagina–Ag. Vasilios Fault, P. F: Pirgos Fault, So. F: Sochos Fault, Str. F: Stratoni Fault, V. F: Vourvourou Fault, L: Langadas Lake, V: Volvi Lake. The inset map in the upper right corner shows the transpressive Circum Rhodope Belt Thrust System that dominates the deformation of the pre-Alpine and Alpine basement rocks from Oligocene to Miocene times and the position of the studied area in the Greek mainland (Tranos et al., 2003).

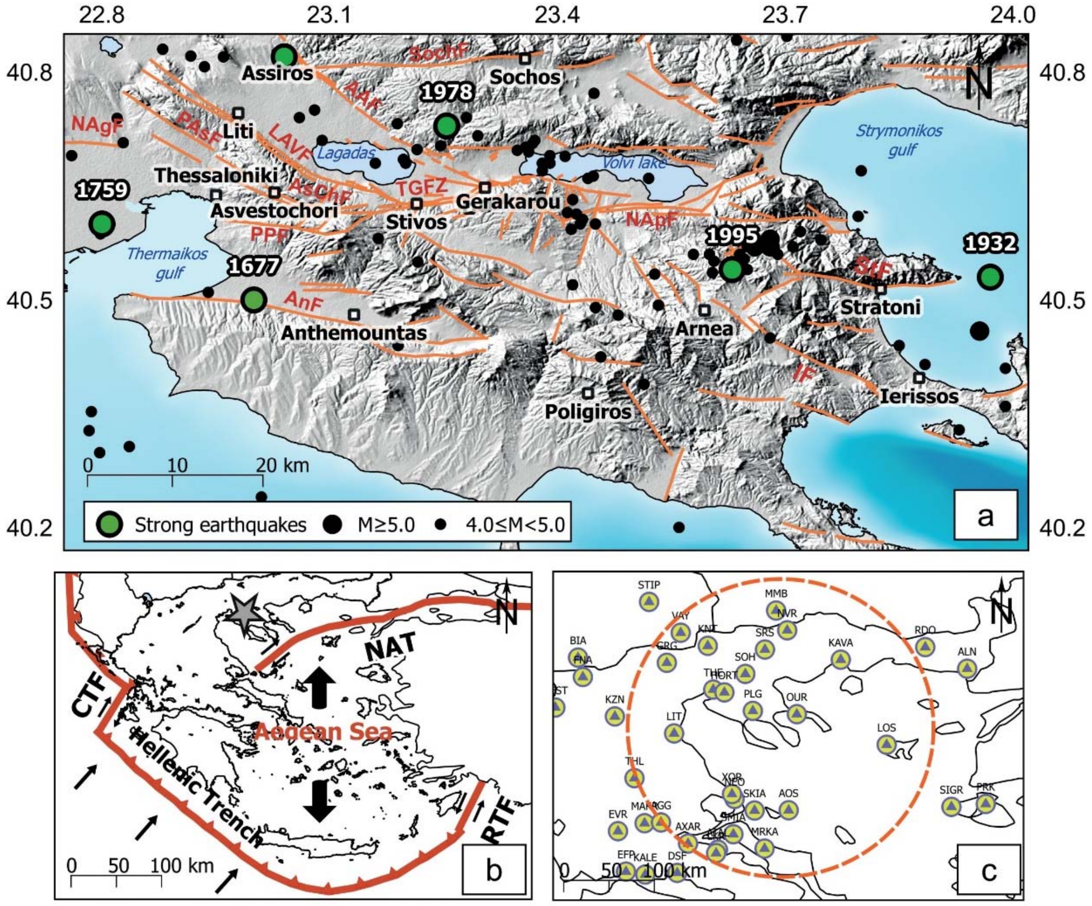

Figure 7. a) Digital elevation model for Mygdonia basin. Red lines correspond to important rupture zones, such as the E-W Thessaloniki-Gerakarou (TGFZ) normal fault zone, along with secondary fault segments described in the text (fault information gathered by Pavlides and Kilias, 1987; Tranos et al., 2003; Mountrakis et al., 2006). Green circles denote strong earthquakes (M≥6.5) and black dots depict earthquake epicentres with M≥4.0 since 1981. b) Simplified map of the broader Aegean Sea with the dominant seismotectonic features. The asterisk denotes the location of the study area, while arrows indicate the dominant plate kinematics. c) Map of northern Greece with the installed seismological stations belonging to the HUSN. The red circle encloses seismological stations employed for data re-processing using Wadati methodology and the calculation of station time delays (Gkarlaouni et al., 2015).

STRATIGRAPHY

The Neogene-Quaternary deposits of Mygdonia basin (Figure 8) have been distinguished in two main Sedimentary Groups; the Mygdonian Group and the Premygdonian Group (Psilovikos, 1977; Koufos et al., 1988, 1995). The discovery and study of several fossiliferous sites with molluscs (Koufos et al., 1992), mammals (Koufos, 1986, 1987, 1992; Koufos et al., 1983, 1989, 1992; Kostopoulos, 1996) and micromammals (Koliadimou, 1996) allowed the dating of the sediments and a more detail division in lithostratigraphic units.

PREMYGDONIAN GROUP

- Chrysavgi Fm: The so far oldest formation. Coarse clastic sediments deposited on the Pre-Neogene basement and fining upwards (Fig. 10). In the upper horizons silty-clayey beds contain micromammals of final middle Miocene (late Astaracian- Aragonian).
- Gerakarou Fm: Terrestrial-fluvioterrestrial. Red beds with large extension (Fig. 10) a rich mammal fauna from many fossiliferous sites indicates late Pliocene- early Pleistocene (Villafranchian) age.
- Platanochori Fm. Fluviolacustrine sediments (sands, conglomerates, silts, clays, marls) with fossil mammals of early Pleistocene (latest Villafranchian) age.

MYGDONIAN GROUP

Lacustrine sediments sands, clays-silts with fine horizontal bedding, in the base coarse clastics predominate while in the top appear small occurences of sandstones and travertines.

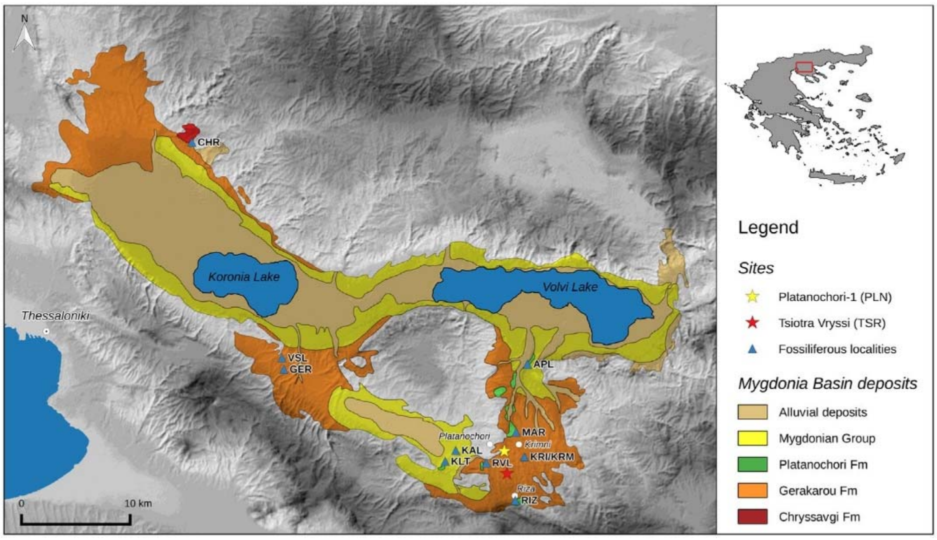

Figure 8. Geological map of the Neogene and Quaternary lithostratigraphic units of Mygdonia Basin (Konidaris et al., 2015).

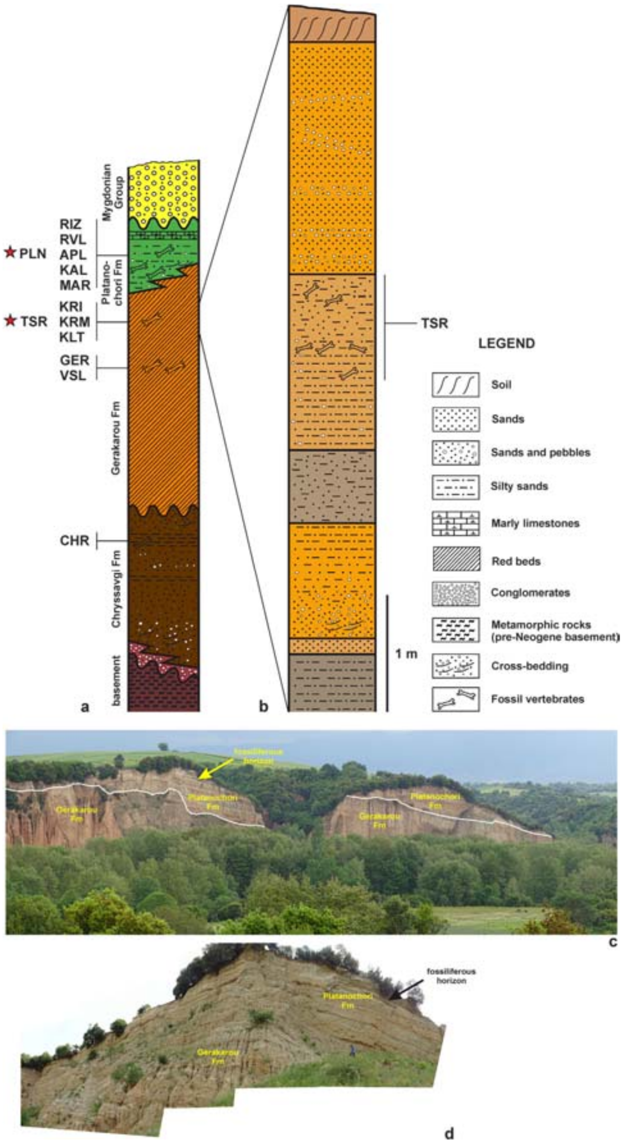

Figure 9. a: Simplified composite stratigraphic column of Mygdonia Basin indicating the position of the old and new fossiliferous localities, data from Koufos et al., 1995; b: stratigraphic column of the Tsiotra Vryssi (TSR) locality; c, d: panoramic view of the Platanochori-1 (PLN) locality in distant (c) and close (d) view (Konidaris et al., 2015).

PALEOGEOGRAPHIC EVOLUTION

Mygdonia basin as well as some other smaller surounding basins (Zagliveri, Marathousa, Doubia, Vromolimnes) are the remnants of an initial older and more extensive basin named Premygdonian basin. The initial basin was possibly created by tectonic action during late Paleogene-early Miocene. During Neogene- early Pleistocene Premygdonia basin was filled up by fluvioterrestrial and lacustrine clastic sediments up to 350-400 m thick (Premygdonian Group). A new phase of tectonic action at the end of early Pleistocene faulted the Premygdonian basin and some smaller basins (Mygdonia, Zagliveri, Marathousa, Doubia, Vromolimnes) were formed. Among them the largest one was Mygdonia basin, which was filled up by water, forming a large lake (Mygdonia Lake or Mygdonian Group).

During middle-late Pleistocene Mygdonia Lake was gradually drained up towards Strymonikos Gulf to the east, through the Rendina straits (Psilovikos, 1977; Psilovikos and Sotiriadis, 1983). The present lakes of Koronia (Langada) and Volvi are the remnants of the initial Mygdonia.

Several successive coastal lake terraces are observed in different altitudes which reflect the drying up episodes of Mygdonia Lake. The uppermost terrace indicates the maximum level of Mygdonia Lake, estimated at 135m a.s.l.

SEISMICITY

Two destructive earthquakes have occurred in Mygdonia basin in the 20th century (1902 and 1978), while some historical events are also known f(660, 667, 700, 1430, 1759) (after Papazachos and Papazachou, 1989).

Among these strong recorded earthquakes the two strongest ones have occurred in the area of the Serbomacedonian massif. The first, of magnitude Ms=7.7, (I_o=X) struck on 4 April 1904 in the Cresna area (SW Bulgaria), while the second of magnitude Ms=7.5 struck on 8 November 1905 in the area of Agion Oros (easternmost peninsula of Chalkidiki; North Aegean Trough).

The main seismic activity along the Serbomacedonian massif in the 20th century can be divided into three distinct periods. The first period started with the strong earthquake of magnitude Ms=6.6 that struck the Assyros village (I_o=IX) area on 5 July 1902. The seismic activity drifted northwards during the following years (1903-1904) with the occurrence of the above mentioned strong earthquake in the Cresna (S. Bulgaria) area and finished with the 1905 Agion Oros (Holy mountain) earthquake. The second period started with two strong earthquakes of magnitudes Ms=6.0 and Ms=6.7 respectively that struck in the Valandovo region of South Yugoslavia on 7 and 8 March 1931. The seismic activity continued towards SW in the areas of Ierissos and the Mygdonia basin also with strong earthquakes with magnitudes up to Ms=7.0 during 1932 and 1933. On 20 June 1978 a strong earthquake of magnitude Ms=6.5 (Io=VIII$^+$, Stivos village) struck in the Mygdonia basin. This earthquake is the first strong earthquake with a magnitude of more than Ms=6.0 that has occurred along the Serbomacedonian massif after 45 years of relative quietness. The main shock of June 20, 1978 was a double event (small and large) according to Papazachos et al. (1979) and Kulhanek & Meyer (1983). They were based on several long and short period data recorded by seismographs and accelerographs with high magnification to show that a second event occurred 3 to 4 seconds after the first onset.

Fault plane solutions of the main shock and the largest fore - and aftershocks show E-W striking dip-slip normal fault (Papazachos et al., 1979; Soufleris et al., 1982). Additionally, the focal mechanisms of small earthquakes six years after the 1978 sequence show a complex fault pattern (Hatzefeld et al., 1986). The aftershock epicentres were mostly not distributed along an E-W direction, but followed an arcuate trend subparallel to and about 5 to 10 km north of the surface seismic ruptures. They were also concentrated in three distinct clusters.

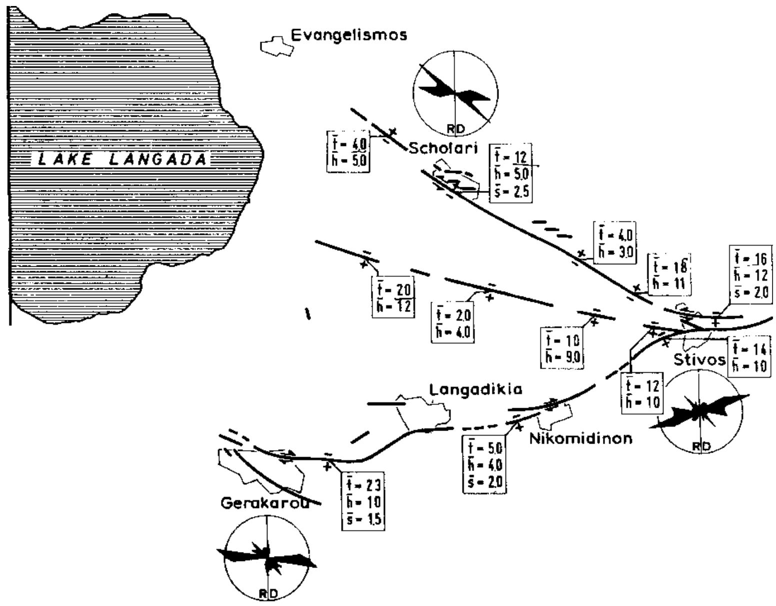

Figure 10. Surface rupture map in the epicentral area of the June 20, 1978 earthquake (Papazachos et al., 1979).

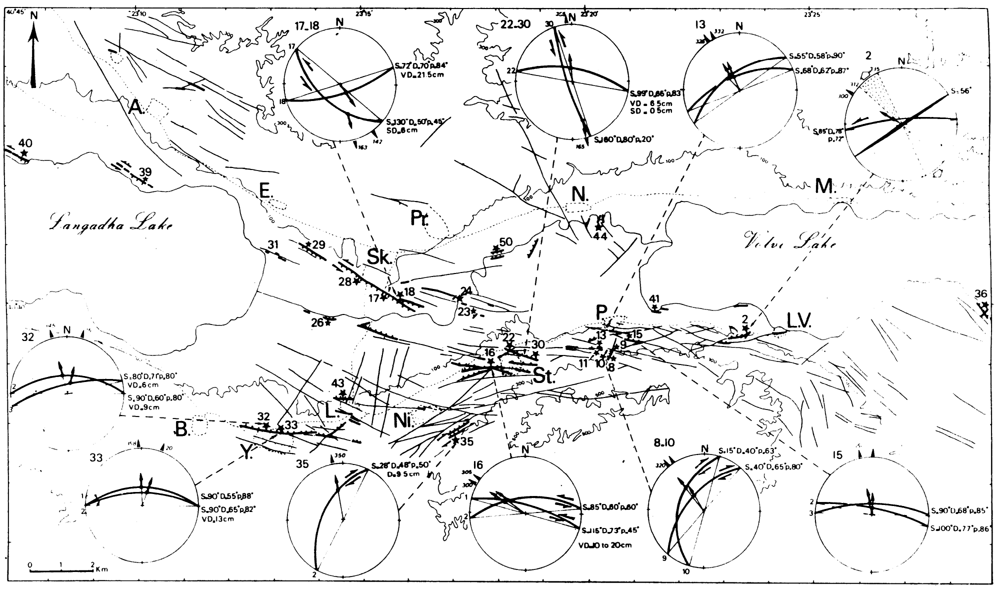

Figure 11. Detailed map of the epicentral region of the 1978 Thessaloniki earthquake (Ms=6.5): lineaments and faults observed on aerial photos (fine lines), faults and fissures of the earthquake (heavy lines dashed on the downthrown side). The numbered stars correspond to field sites. The Wulff stereo diagrams (lower hemisphere projections) illustrate: the direction (S) and the dip (Do) of the faults, the pitch angle (p) of the fault striations, the vertical (VD) and the horizontal (SD) component. The letters indicate village names (after Mercier et al., 1983a).

The 1978 event produced surface ruptures and it is one of the first Greek earthquakes where a detailed mapping of earthquake effects was carried out (Figure 10 and Figure 11). This quantitative first approach led to subsequent significant advances in earthquake geology in

Greece, such as the application for the first time of paleoseismological techniques along the 1978 ruptures.

Since 1981, when a detailed seismological study of the northern Greece domain started, a great deal of data have been collected concerning the seismicity. A first assessment is that although there was a continuous seismic activity for at least 10 years after the main Thessaloniki earthquake, strong earthquakes with magnitude Ms≥5.5 have not been recorded. Moreover, the depth of the earthquake epicentres of the area during the 1981-1985 period ranges from 5 to 15 km with a mean depth of 9 km.

On May 1995 and earthquake of Ms=5.8 occurred in the eastern Halkidiki. The microseismic investigation has revealed that the area from the Mygdonia basin to the Ierissos gulf might be characterized by relatively intense seismic activity. This area absorb high amounts of the seismic activity of the whole area and at particular times releases this energy creating rather strong earthquakes, so that this area can be considered as the largest source of seismic risk (Scordilis, 1985).

PALEOSEISMOLOGY

GERAKAROU VILLAGE SEISMIC FAULT

Across the road pavement, the trace of the 1978 earthquake which is normal with sinistral component seismic crack can be seen. This NW-SE trending crack is still active since the Thessaloniki earthquakes, and its continuous movement causes severe damages of the road, which needs restoration periodically every few months. A similar E-W normal active fault trace cuts through the country road between Gerakarou and Zagliveri villages at a distance of about 1 km southern of the previous one, and it also coincides with a 1978 earthquake crack. A spring with a small periodical flow of water is located at the continuation of the first crack into the nearby small valley. The flow reaches its maximum value during the humid months, but generally it is very low, almost zero. At this site the Department of Geology has installed an extensiometer measurement array, which confirms the fault movement, as well as a radon emanation counter array. It is well known from the literature that along active faults the ground emanation in radon and thoron is greater than in surrounding rocks. The results from this and many other measurements sites in Mygdonia basin confirm this viewpoint (Ioannides et al., 2003).

Two paleoseismological trenches have been excavated across the trace of a 1978 earthquake crack, at a small distance eastwards of Gerakarou village (Cheng et al., 1994; Chatzipetros, 1998). The first trench was located exactly across a small scarp, which until then was thought to be a fault scarp. The logging of the trench showed that no displacement or any other disturbance was present at the sediments, of the Gerakarou Formation. That led to the conclusion that the scarp itself, was not fault-generated but it was rather modificated by natural (probably lake shore erosion) and man-induced (farming activities) causes.

The second trench was excavated in such a way to contain the crack itself. It should be noted that during the summer months of 1993 the crack could be traced even in recently ploughed fields. Its length was more than 100 m and it was 2-3 cm wide. It is possible that the low water content could have intensified the phenomenon, but its primary cause is active tectonic deformation. This trench had a length of 10 m and a depth of 4 m at its maximum. The logging of its eastern wall revealed good evidence for previous reactivations of this particular fault branch, as can be seen in Figure 12. The lithological units are (from the oldest to the younger):

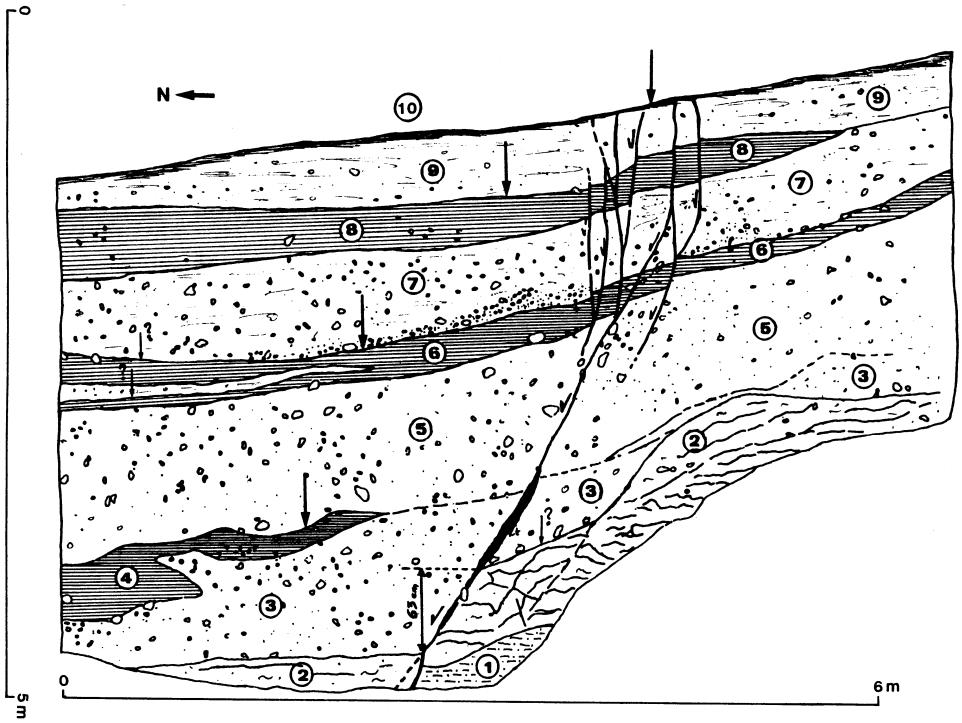

Figure 12. Log of the eastern wall of the Gerakarou trench. The lithological units are explained in the text (Cheng et al., 1994; Chatzipetros, 1998).

1. Clayey silts, 2. Coarse sands with liquefaction phenomena, 3. Clayey rubbles (colluvium), 4. Paleosoil, 5. Clayey rubbles (colluvium), 6. Paleosoil, 7. Clayey rubbles (colluvium), 8. Paleosoil, 9. Fine rubbles and modern soil.

Of particular interest are the three paleosoil units, as well as the liquefied sands (2) near the bottom of the trench. Units 4, 6 and 8 (paleosoils) contain datable organic material. Thermoluminescence (TL) dating showed that there is a regular recurrence interval of about 7,000 yrs between each deposition of the paleosoils. The formation of a soil requires a certain amount of time, since decay of organic materials is a quite slow process. In geological terms, this means that during this period the area was under tectonic quiescence; that is, non-seismic or aseismic creep processes. When an earthquake happens, a fault scarp is formed. Then the erosion causes a downslope transportation of material which smooths the scarp and give rise to deposition of generally unsorted coarse-grained sediments (colluvium). Using these data, the interpretation of the trench log along with the TL dating shows that at least four earthquakes happened and left their marks in the geological record; the 1978 shock, and three other at 7,200+600 yrs B.P., 14,000+1,100 yrs B.P. and 21,700+1,800 yrs B.P. respectively. A problem arises from the available radiocarbon (^{14}C) dating for paleosoil 8 that gives a date of 2,350+80 yrs B.P. (that is a time period spanning from 437 BC to 277 BC, with the most probable date at 357 BC). Paleosoil 6 bifurcates towards the end of the trench, indicating that maybe there were two earthquakes during a small period of time as this soil was formed.

The fault has a displacement of about 63 (+2) cm that is consistent with the number and the expected displacement of the earthquakes that were found. In addition, based on paleoseismological and historical data, the maximum expected magnitude (Ms) of a probable future earthquake could be 6.5 to 6.7.

NIKOMIDINO VILLAGE NEOTECTONIC FAULTS

At this site, close to the old cemetery of the village, various morphotectonic elements of the southern Mygdonia fault zone can be observed. A big frontal scarp (E-W trending) defines the main fault line, while some other smaller ones resulted from other tectonic events define secondary faults of different strike. Differentiated erosion at several fault scarps (different stage of scarp degradation) indicates a migration of morphostructural features towards the centre of the basin. At this site the side of a hill was artificially modified for paleoseismological purposes, but the results were not satisfactory since the material belongs to the Gerakarou formation where TL and 14C dating are impossible. Nevertheless, many small joints filled up with calcitic material ranging parallel to the main fault trace can be seen at the wall. The orientation and the opening of the joints indicate the predominant N-S extensional stress field of the area. Three radon emanation counter stations are also installed at this site, counting the -particles of radio gases released at the fault zone.

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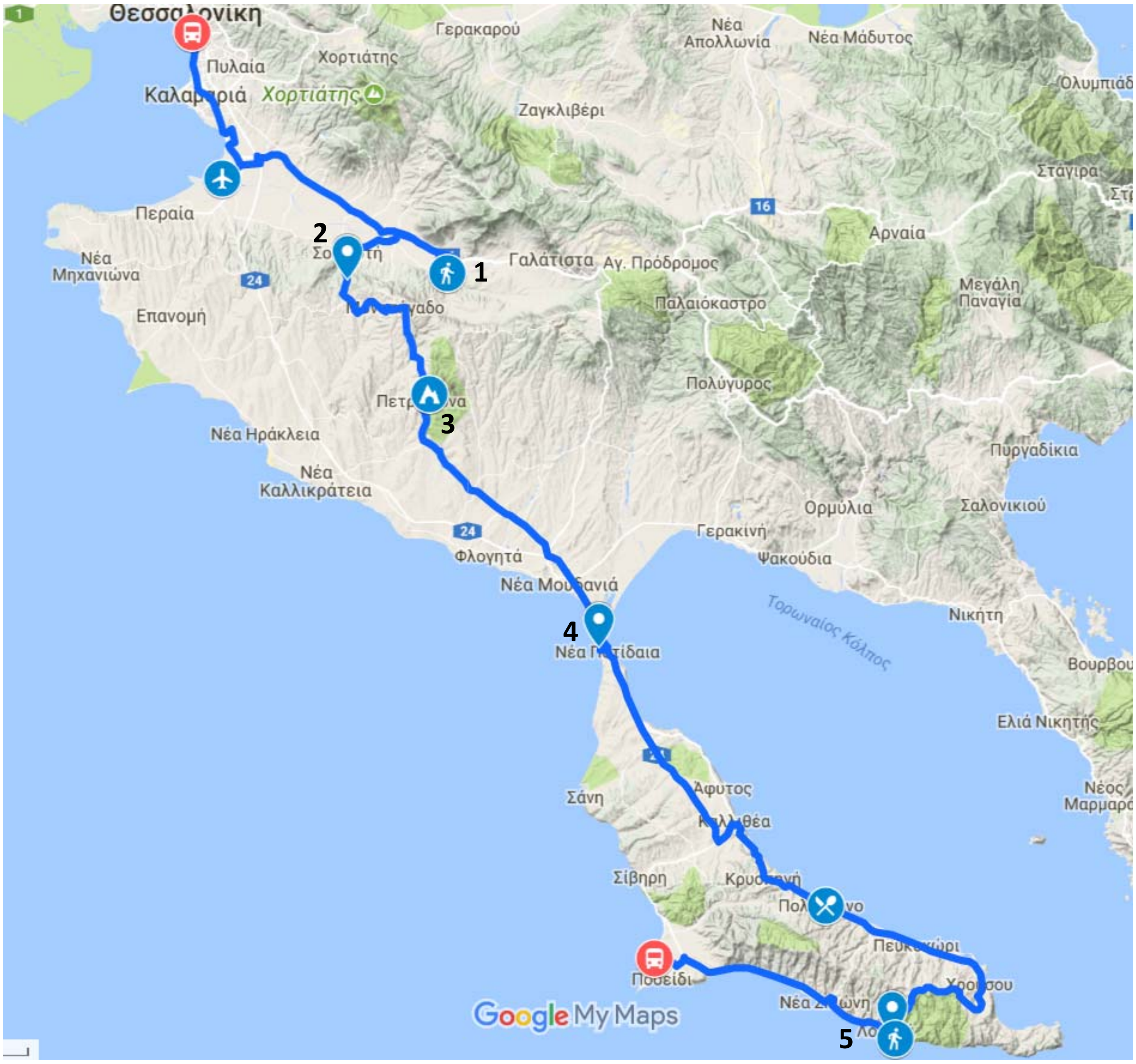
FIELD TRIP 1 – KASSANDRA (JUNE 24)



STOP 1: ANTHEMOUNTAS FAULT

- Normal fault, bounding the southern margin of Anthemountas graben.
- Possibly associated with the 1677 earthquake that destroyed Thessaloniki and caused the population to abandon it.
- Prominent geomorphological features.

STOP 2: AGIOS ANTONIOS

- Overview of Anthemountas graben.
- Deep incision due to footwall uplift.
- Stratigraphy.

Situated at the south margin of Anthemountas valley. Watershed between Anthemountas valley and west Halkidiki drainage systems.

We follow the asphalt road from Souroti village to Agios Antonios Village. The area reveals a hilly terrain in the form of tectonic terraces. Coarse grained clastic sediments (Antonios Fm. loose conglomerates and sands) of Neogene Age (Middle - Upper Miocene) dominate the area covering the pre- Neogene basement (Mesozoic Limestones). Due to tectonic uplift the area is intensively eroded (gully erosion) tending to form badlands. In this stop the contact between pre-Neogene basement and Neogene sediments is exposed. The old carstified Mesozoic limestone reveals many fissures filled with old terra rosa containinig mammal and micromammal fossils of Middle to Upper Miocene age and is covered by the Antonios Fm.

In this place a brief introduction of the geology of western Halkidiki and Kassandra Peninsula will be done.

West Halkidiki and Kassandra peninsula are situated at the east side of Thermaikos gulf. The Present day Thermaikos gulf is the relic of an older larger elongated tectonic depression trending from NNW to SSE. This depression was formed during Neogene and gradually filled up with Neogene – Quaternary sediments. They consist mainly of clastic sediments (sands, silts, clays, gravels, conglomerates) that were deposited during Middle-Late Miocene (Conglomerates, Antonios Fm.), Late Vallesian – Early Turolian (redbeds, Triglia Fm.), Latest Miocene (Late Turolian “Pontian” mollusk bearing clays, sands and limestones, Trilophos Fm.). During Pliocene (Ruscinian) clastic sediments intercalating with massive marly limestones were deposited (Gonia Fm.). Quaternary terrestrial sediments (Red beds, Moudania Fm.) formed a younger extensive cover above the previous sediments in west Halkidiki (Syrides 1990).

These sediments are deposited as alternated beds; in west Halkidiki they dip towards SSE while in Kassandra peninsula towards NNW. In western Halkidiki 4 successive cuestas are formed in the hilly terrain due to 4 intercalated limestone beds.

STOP 3: PETRALONA CAVE

- Site of one of the most important paleoanthropological discoveries in Europe: the Petralona Skull *(Homo heidelbergensis).*
- Extensive fossil fauna.
- Interaction of tectonics and carstification.

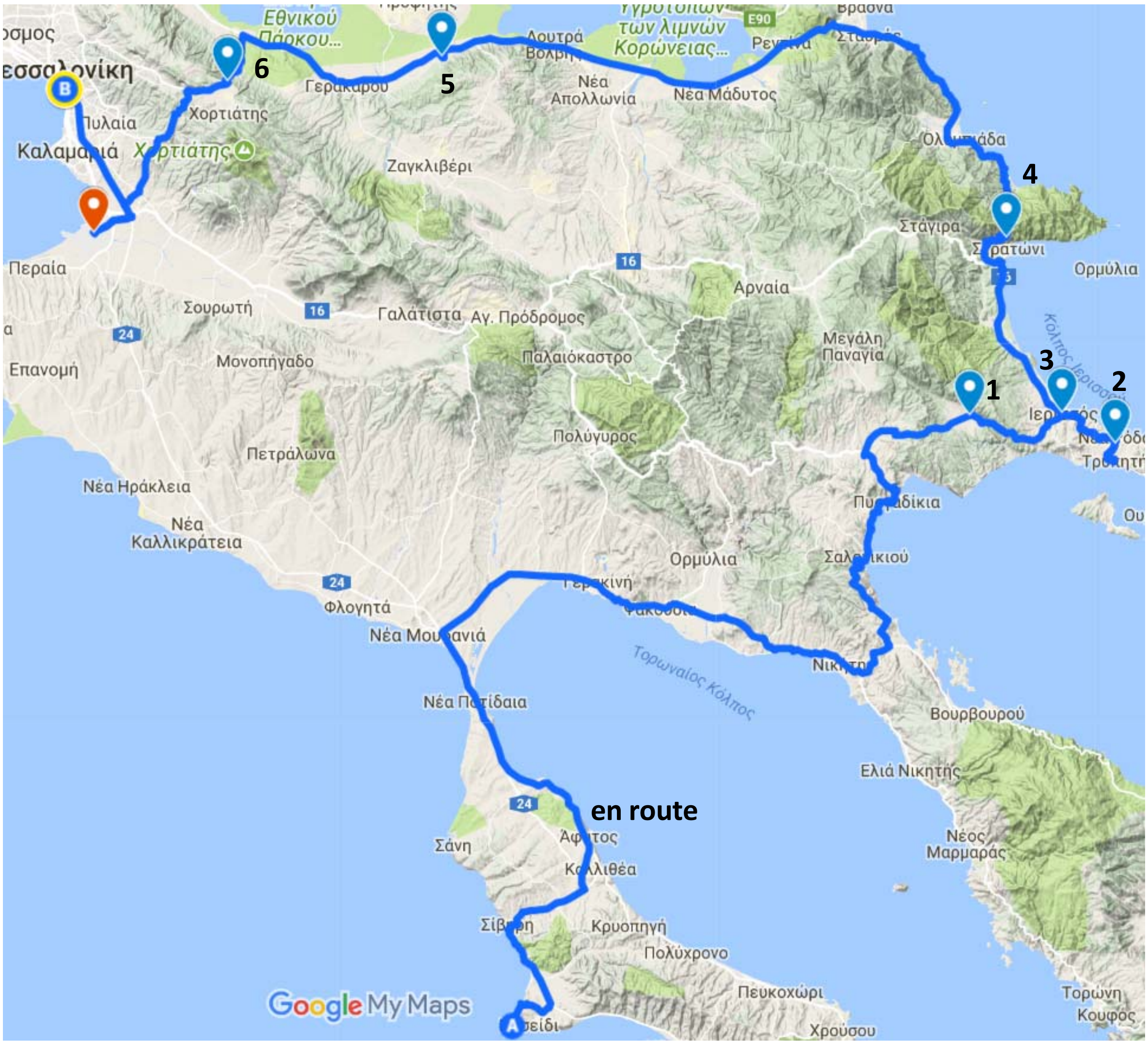
STOP 4: POTIDAEA

- Sea level change indicators.
- Coastal processes.
- The 479 BC tsunami, as described by Herodotus.
- Potidaea canal.

STOP 5: LOUTRA AGIAS PARASKEVIS

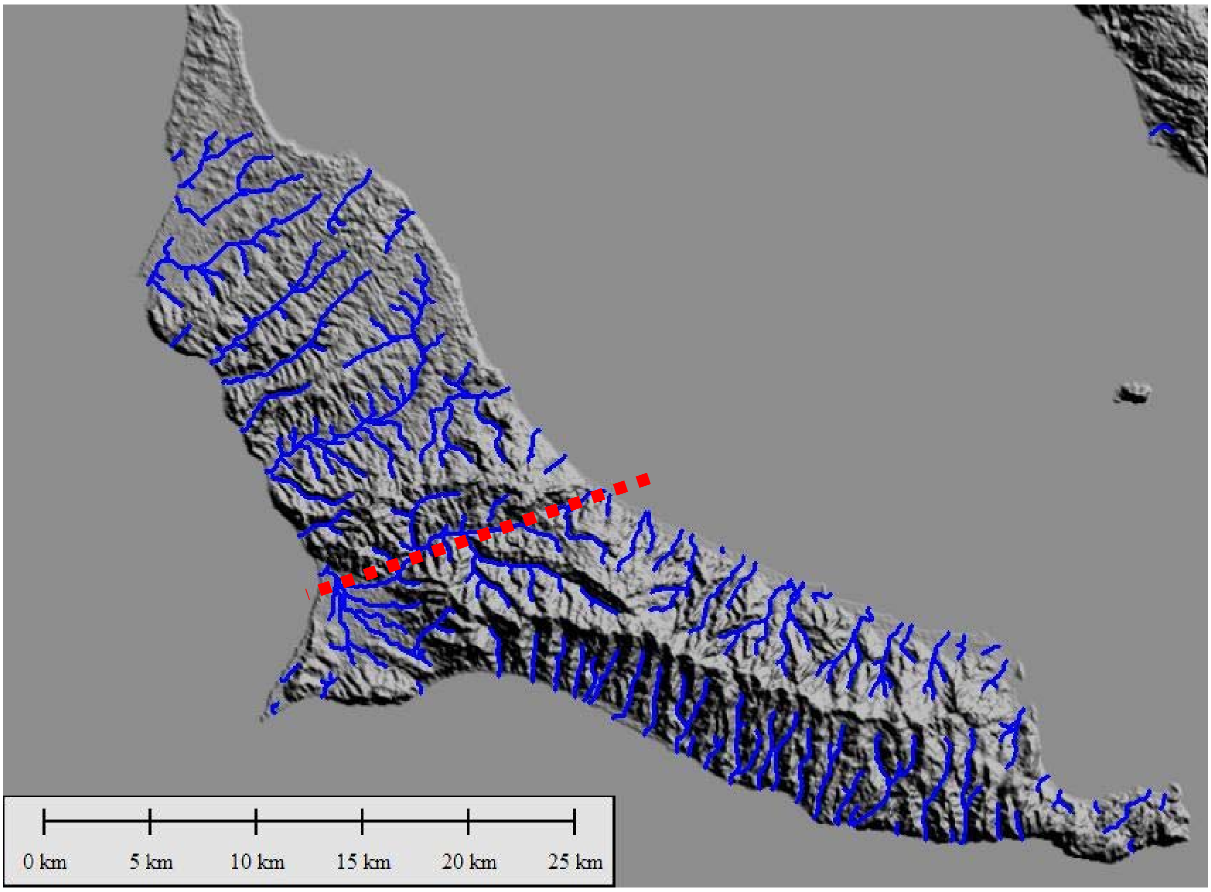
- Uplifted marine terraces.
- Coastal bedrock notches.
- The offshore Kassandra normal fault.

FIELD TRIP 2 – EAST HALKIDIKI AND MYGDONIA GRABEN (JUNE 29)



EN ROUTE: TILTED KASSANDRA PENINSULA

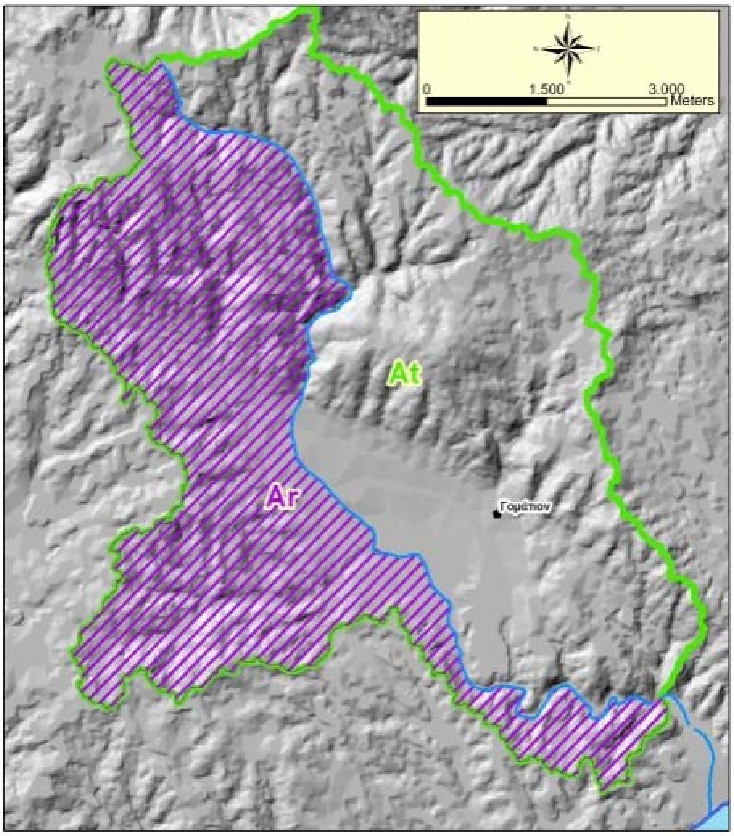
- Asymmetrical development of the drainage network.
- Two distinct geomorphic blocks, separated by a normal fault.
- Tilting features.



Drainage network of Kassandra peninsula. The northern block shows a distinctively different pattern than the southern one.

STOP 1: GOMATI FAULT

- Normal fault, part of the East Halkidiki complex fault system.
- Active geomorphology with triangular facets, deep incision, etc.



Gomati fault and the associated drainage basin (Chatzipetros et al., 2005).

STOP 2: XERXES CANAL

- Stratigraphy and geomorphology of a historic site.
- Xerxes, the Persian king, used this canal to transport his fleet's ships overland due to unnavigable rough seas around Mount Athos peninsula, as described by Herodotus.

STOP 3 IERISSOS

- Destroyed in 1932 due to the 1932 Ms 6.9-7.0 earthquake. 161 deaths and 669 injuries. The old town of Ierissos was destroyed, and it was rebuilt at a new site. Archaeological evidence provides indications that it was also active during antiquity.
- Short rest stop.

STOP 4: STRATONI FAULT

Stratoni fault is a large tectonic feature that affects the rocks of eastern Halkidiki area. Its western branches start near the village of Varvara while it gradually extends into the sea eastwards. The 1932 Ms=6.9 Ierissos earthquake is directly associated with this fault (Figure 13). The ore deposits of Stratoni have been deposited along this fault, proving that it was active during their formation. It is remarkable that such a fault is still active after such a long period. The morphological characteristics of the fault are impressive, and are expressed as triangular facets (especially to its sea-front part), step-like morphology, hanging valleys, isolated planation surfaces, etc. (Pavlides and Tranos, 1991; Chatzipetros, 1998; Michailidou, 2005; Chatzipetros et al., 2005). This fault belongs to the complex eastern Halkidiki fault system that is considered to be associated directly with the North Aegean Trough Fault System.

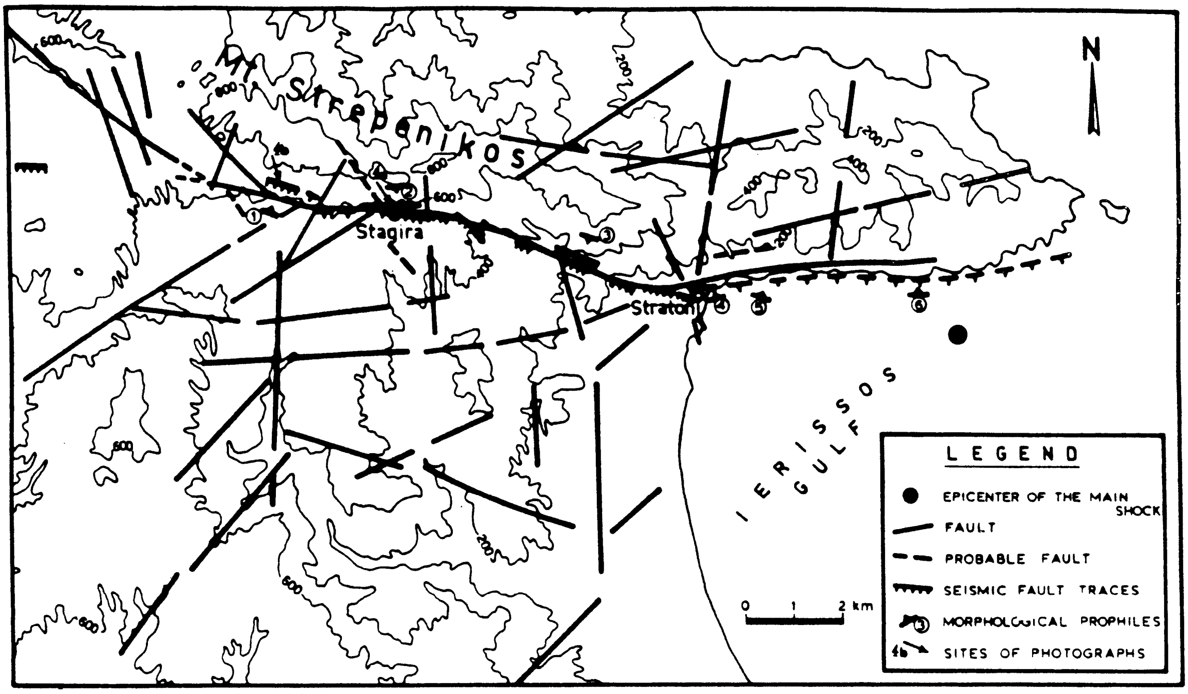


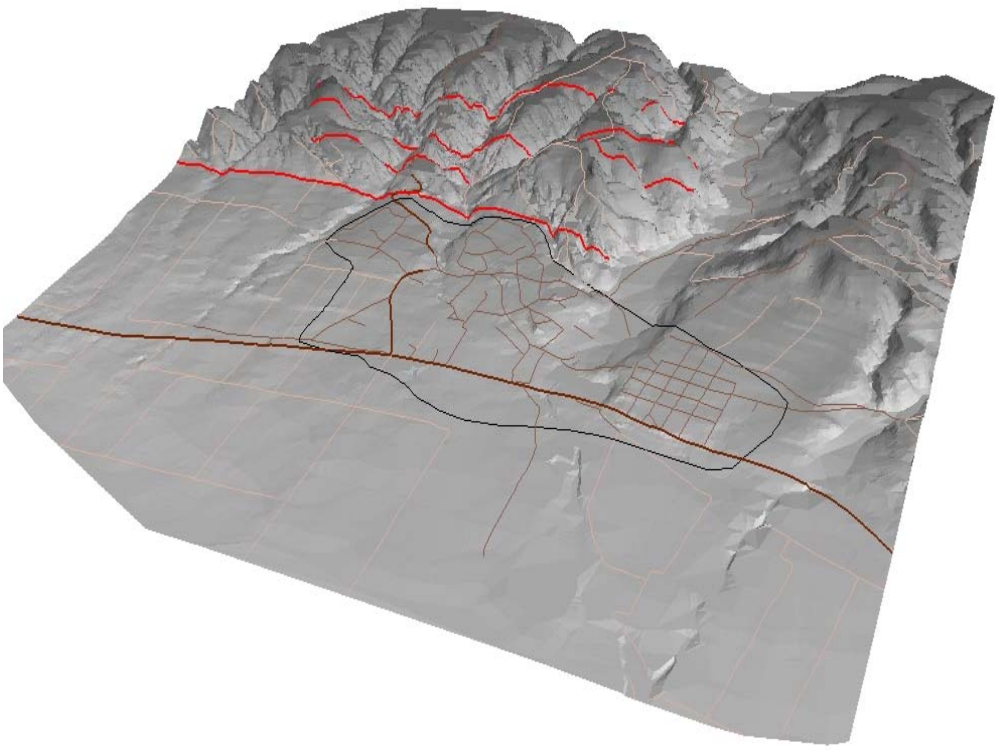
Figure 13. Structural map of SE Halkidiki peninsula (Ierissos-Stratoni region) showing the main seismic rupture or the 1932 earthquake, as well as the fault pattern of the wider area (heavy lines) (Pavlides & Tranos, 1991).

STOP 5: STIVOS VILLAGE

- Epicentral area of the 1978 M 6.5 Thessaloniki earthquake.
- Widespread damages and fatalities.
- Ground ruptures.
- Some damaged buildings are still visible.

STOP 6: MYGDONIA GRABEN

- Overview of Mygdonia graben.
- Geology, tectonics and stratigraphy.
- Geomorphological characteristics.



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