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Energy Conference and Exhibition 2007
Athens, Greece

Guide to Fieldtrip No. 1
14-17 November 2007

Structural Geology of the Western Greece Fold and Thrust Belt

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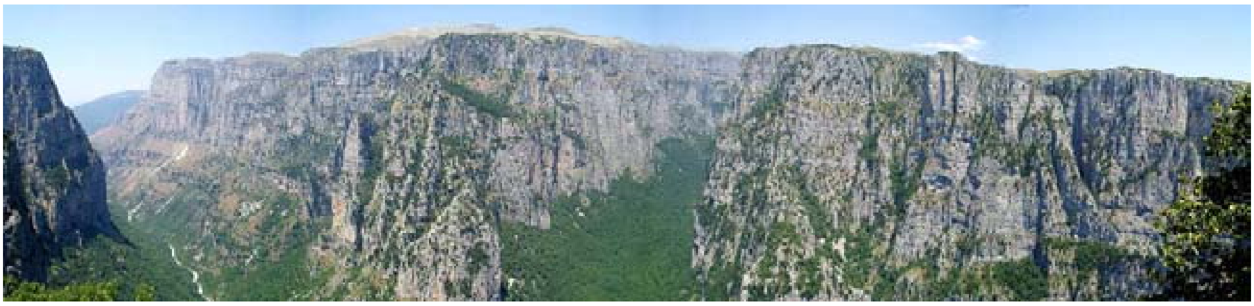

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FIELD TRIP #1 Route

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ΑΘΗΝΑ 2007

HELLENIC PETROLEUM

LEGEND

Trip route

Direction

SCALE: 30 km

FIELD TRIP GUIDE

STRUCTURAL GEOLOGY OF THE WESTERN GREECE FOLD AND THRUST BELT

DAY 1

Departure from Athens at 08.00
Travel from Athens to Delphi. Visit the archaeological site and the museum. On the way to Arta (275 Km), and more particularly between Itea and Nafpaktos, we will realize a geological section across the Hellenides, along the northern coast of Corinth's gulf. At the end of the day we will stay in Arta.
A short presentation of the geology of Epirus will be given before dinner, at the lobby of the hotel.
Dinner and overnight in Arta.

DAY 2

Departure from Arta at 08.00 and travel to Igoumenitsa (distance of 177 Km).
Several sections have been chosen for a presentation of the stratigraphy and the structure of the Ionian zone. Stops are scheduled in Eocene limestone impregnated with oil and the main source rocks (Posidonia beds) in order to discuss the petroleum system of the Ionian zone.
A short visit to the ancient theater of Dodoni has been planned, depending on the time availability and weather conditions.
Dinner and overnight in Igoumenitsa.

DAY 3

Departure from the hotel at 08:00 a.m., and travel to Ioannina (100 Km distance).
On our way to Ioannina, we will see outcrops of the Triassic evaporites, and we will examine the deformation events of the main tectonic units. We will discuss about the structural evolution of the area and the exploration of deep targets based on seismic, well data and the structural interpretation.
In the afternoon we will visit the gorge of Vikos, where the limestones of Eocene and Upper Cretaceous age will be examined.
Dinner and overnight in Ioannina.

DAY 4

Departure from the hotel at 08:00 a.m., and travel to Meteora (120 Km), where conglomeratic fans of a deltaic system have been eroded to form gigantic separated blocks, creating a unique landscape. We will examine sections of deltaic deposits and we will visit a Byzantine monastery. On our way to Meteora, we will have the chance to see a panoramic view of the Pindos overthrust and the Zagoria syncline. After lunch in Meteora, the trip will continue to Athens (352 Km distance), where it is scheduled to arrive between 20.00 and 21.00, depending on the traffic.

<u>Geology of North-Western Greece (Summary)</u>

NW Greece comprises the sedimentary sequence lying west of the Pindos Mountain chain and includes the mainland sector (Epiros and Aitoloakarnania) and offshore areas in the Ionian sea. The eastern limit of the area is Pindos overthrust which trends NNW-SSE and can be followed northward by the Dinarides and Southeastward into Turkey.

From Triassic to Late Cretaceous Western Greece constituted part of the southern Tethyan margin. At the scale of hundreds of kilometres, the whole Alpine belt can be considered as the inverted margin of the Neotethyan Ocean in response to the collision of Apulia against Europe (de Graciansky *et al.*, 1989). On a smaller scale of a few tens of kilometres, the various sub basins of the Hellenic Tethyan margin have been inverted to produce the main Hellenic thrust sheets or folded zones. This occurred successively from inner (eastern) zones to external (western) zones (Fig. 1).

Most external zones of the Hellenides are included in the geological setting of W. Greece: Paxi, Ionian and Gavrovo. They have been formed during Early Jurassic when crustal extension difeerenciated the southern Tethyan passive margin creating the Ionian basin and the shallow water platforms, Gavrovo to the east and Paxi to the west. (Fig. 2)

The Gavrovo zone

The Gavrovo zone was a persistent carbonate platform with shallow marine conditions from the Upper Jurassic to Eocene interval. From Late Cretaceous until Eocene, it can be distinguished to areas with continuous sedimentation and areas with hiatus, unconformities or reduced sequences. During Upper Eocene and Oligocene a foreland basin was formed in front of the Pindos thrust sheet into which clastic sediments (flysch) were deposited (Fig. 3).

The Ionian zone

The Ionian zone exhibits three distinct stratigraphic sequences (Karakitsios, 1995), representing a pre-rift, a syn-rift, and a post-rift stage of evolution of the Ionian realm, from a neritic platform environment to a pelagic basin (Fig. 3).

The pre-rift sequence

The older known formations of this realm are the subsurface evaporitic series of Lower – Middle Triassic age (Fig. 3). Their thickness is estimated to be more than 2000m, mainly consisting of alternating sulphate and carbonate sediments which were probably deposited in a “sabkha cotier” environment. Evaporites outcrops consist of small gypsum bodies which are always accompanied by extensive carbonate breccias, known as Triassic Breccias formation. Generally, gypsum and associated breccias crop out in areas aligned with or near to major trusts or faults.

The evaporites are overlying by the Foustapidima limestones of Ladinian – Rhetian age, followed by the shallow water Pantokrator limestones of Early Lias age. The Pantokrator limestones mainly consist of Algae, pellets and algal stromatolites with bird eyes indicating a very shallow sedimentary environment. These limestones constituted part of the vast carbonate platform extended, during the Early Lias, over the whole of western Greece. The thickness of the carbonate sequence is more than 1.500 m.

The syn-rift sequence

The beginning of the syn-rift sequence is represented by the Siniais Limestones and their lateral equivalent, the Louros limestones of Plienbachian age (Karakitisos, 1995) more than 100 m thick. These formations correspond to the general deepening of the Ionian area (formation of Ionian basin), which was followed by the internal syn-rift differentiation of the Ionian basin marked by smaller paleogeographic units. These palaeogeographic units were recorded in the prismatic syn-sedimentary wedges of the syn-rift formations, the Ammonitico rosso or Lower Posidonia beds, the Limestones with Filaments, and the Upper Posidonia beds.

Stratigraphic sections measured throughout the study area display abruptly changing thicknesses in the syn-tectonic sequences within a few kilometres. The opening of the Neotethyan Ocean was accompanied by the formation of a series of north-northwest- and east-southeast-trending conjugate faults. The Early Liassic shallow marine platform was affected by listric block faulting, which was recorded in the differential subsidence within each small palaeogeographic unit. The directions of syn-sedimentary tectonic features indicate that deposition was controlled by structures formed during the extensional tectonic phase. The sedimentary style corresponds, in general, to a half-graben geometry. Prismatic syn-sedimentary wedges of the syn-rift formations in the small palaeogeographic units (in most cases the units did not exceed 5 km across) vary in thickness east-west. Thus, unconformities are located on top of tilted blocks and complete Toarcian to Tithonian successions with Ammonitico Rosso or Lower Posidonia beds at their base are located in the deeper parts of the half grabens.

The post-rift sequence

The post-rift period was defined by an Early Berriasian break-up that is marked by an unconformity at the base of the Vigla Limestones. Sedimentation during the post-rift period was synchronous in the whole Ionian basin. The post-rift sequence (Vigla Limestones and overlying formations) largely obscures the syn-rift structures, and in some cases, directly overlies the Pantokrator Limestones pre-rift sequence. The deposits of Vigla Limestones do not correspond to a eustatic sea level rise, but to a general sinking of the entire basin (Karakitisos, 1995).

The post-rift formations, following the Vigla Limestones, consist of the Upper Senonian, which comprises microbreccious horizons with limestone and rudist fragments within a calcareous cementing material containing pelagic fauna. Thus the Upper Senonian corresponds to basin sedimentation, which reflects the clear distinction of the Ionian basin into a central topographically higher area, with reduced sedimentation taking place, and two surrounding Lower taluses, with increased sedimentation. The adjacent to this area, two neritic platforms (the Gavrovo to the east and the Apulia to the west), provide clastic material to the Ionian basin.

The Paleocene and Eocene sediments appear in continuity after the Cretaceous, without significant facies changes. During the Paleocene, the erosion of the Cretaceous beds of the Gavrovo and Apulian platforms continues to provide the Ionian basin with microbreccious or breccious elements. However during the Eocene, the supply of clastic material diminishes significantly, and the main facies, are platy sublithographic limestones with Globigerinidae and siliceous nodules. The greatest thickness of the Eocene formations can be found in the marginal parts of the Ionian zone, where also the microbreccious beds are more frequent.

The flysch sedimentation commences at the Eocene – Oligocene boundary interval, in stratigraphic continuity with the underlying Upper Eocene limestones, through marly limestone transitional beds.

The Paxi zone

The Paxi zone is considered as the transition zone between the Apulia platform and the Ionian basin. It is characterised by a thick sedimentary section which was deposited continuously from Late Triassic until Late Miocene time (Fig. 3). Upper Triassic to Middle Jurassic sediments include thick anhydrite/carbonate sequence deposited in a restricted environment. Evaporitic sedimentation closed with the onset of Ionian rifting and pelagic sedimentation occurred represented by limestones interbedded with cherts and marls. From Late Cretaceous to Oligocene times sedimentation occurred in shallow platform and slope environment. The Miocene is represented by marlstone, sand and shale. Flysch deposits are unknown in the Paxi zone. After a period of uplift and erosion, Pliocene beds were deposited and rest upon older rocks of all ages. Both marine and fresh water facies are present.

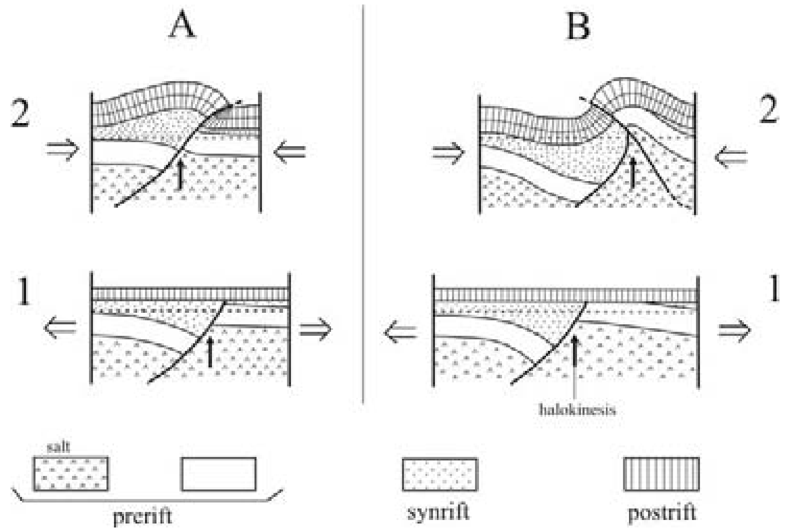
Tectonism

The main orogenic movements took place at the end of the Burdigalian (IGRS-IFP, 1966). The extensional Jurassic faults reactivated as thrust faults by the compressional movement and large scale westerly directed thrusts developed. The resulting NNW-SSE trending structures are cut by transverse tear faults (Fig. 4).

During Early Pliocene the front of the deformation migrated westwards and emplacement of the Ionian thrust sheet to the Paxi zone took place. The Paxi zone faulted and folded. The deformation of the more external elements occurred during Early Quaternary (Kamberis E. et al., 1996).

The Triassic evaporites are the principal level along which there has been the detachment of the overlying sedimentary succession. Secondary detachment levels corresponding to incompetent levels in the carbonate sequence and in the clastic (flysch) section are also present. The mechanical behaviour of the pelagic succession is different than the thick bedded Lower Lias limestone which represents the competent rock interval. The presence of chevron folds in the pelagic formation (Vigla limestone) witnesses the structural disharmony in relation to the underlying Pantokrator limestone. Structural disharmony also exists within flysch formation.

The Ionian basin evolution constitutes an example of inversion tectonics of a basin sequence with evaporitic base (Karakitsios, 1995). The double divergence of the basin (westwards in the central and western part and eastwards in the eastern part) is attributed to structures inherited from the Jurassic extensional phase, which were reactivated during the compressional phase as westwards and eastwards displacements respectively. In general, extensional faults were entirely transformed into either reverse or transcurrent faults and/or thrusts, which is consistent with the classical inversion tectonic scheme. Although, in some cases during the compressional phase, extensional faults did not reactivate as thrusts in the way described above, but the most elevated footwalls were thrusted over the pre-existing hanging walls due to evaporitic base halokinesis. This phenomenon was facilitated by diapiric movements of the evaporitic base's salt layer.



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Examples of inversion tectonics affecting a half-graben system with evaporitic basement (Ionian zone, northwest Greece). (A) Classical inversion tectonics. (B) Particular case of inversion tectonics observed at locations where the evaporitic substratum halokinesis was more expressed and consequently the footwalls of the extensional phase were above average. Therefore, during the compressional phase these most elevated footwalls have been thrust over the pre-existing hanging walls. (A1) and (B1) correspond to the beginning of the post-rift period; (A2) and (B2) correspond to the end of post-rift deposition and show the subsequent inversion geometries (Karakitsios V., 1995)

Petroleum Potential

Exploration history of Epirus Region (NW Greece)

Numerous oil seeps in Epirus and mainly the Dragopsa seep drew the attention of many scientists from the beginning of the century. Exploration activities in the Dragopsa area began in 1919 in order to exploit asphalt from the bituminous Neogene shales. 9 shallow holes and galleries have been opened. During the Second World War, in the same area the Italians drilled 7 shallow wells, the deepest of which was approximately 700m, without any success.

A cooperative program between the Greek State and I.F.P involved regional geologic mapping and systematic exploration activities in the greater area of Epirus from 1960 to 1966. Seven exploratory wells have been drilled to test:

- Neogene sediments in the south
- The top of the carbonate sequence
- The evaporitic formation and its possible basement to the NW.

During 1979-1990, Public Petroleum Co. of Greece (now Hellenic Petroleum) conducted regional geological and geochemical studies in NW Greece. Detailed geological maps were produced in selected areas having complex structure, to better understand the geological model. 2000 km seismic lines were acquired and 8 exploratory wells drilled in an effort to evaluate the HC potential of the area. The emphasis was on structures located in swallow depths, which appeared to be relatively uncomplicated. Most of the wells encountered oil shows but never reached an oil field. One of the reasons was that the structures were not delineated properly due to the bad quality of the seismic data. A second attempt was made in order to identify deeper structures and to calibrate the structural models. At the same time gravity and magnetic programs covered the greater part of the Epirus area.

From 1997 to 2002 Enterprise Oil as the operator of the concession ‘‘Ioannina’’ (the northern part of Epirus Region) conducted the oil exploration activities and drilled 1 well. The well reached the Triassic evaporites but failed to penetrate them through due to technical problems.

Petroleum system

Prospects in Western Greece are associated with folded and faulted anticlines which provide good structural traps, sourced by Mesozoic source rocks. Deep compressive structures are expected beneath the major thrust sheets, forming the main objective of sub-thrust exploration.

Hanging wall anticlines formed by high-angle faults are present beneath the flysch cover in the broad syncline located in the West of Pindos overthrust and in the Botsaras syncline. Traps may also exist in the Lias shallow water carbonates sealed by the Posidonia shales and the pelagic thin bedded Lower Cretaceous limestones

Traps beneath the main detachment level of the Triassic evaporites have not yet been explored. Such an attempt is considered to be very promising and it is one of the main targets of the future exploration activities.

Reservoir Rocks (Fig. 5, 6)

Potential reservoir rocks are found in the Late Mesozoic – Tertiary limestones where primary porosities and permeabilities may be improved by tectonically induced fracturing. The Upper Cretaceous/Eocene formations, generally low matrix porosity reservoirs, include massive detrital limestones which in some levels have good porosities up to 8%. Reservoir quality may be enhanced by fracturing. Offshore Katakolon oilfield contains significant quantities of hydrocarbons in this Eocene/Cretaceous reservoir.

High prospectivity has been observed in a thick sequence of the Upper Cretaceous chalk deposits in the Paxi Island, where high values of porosity have been encountered.

Terrigenous sediments of the post orogenic successions (Upper Miocene) could contain suitable sandstone reservoirs. All levels of the Mesozoic carbonate sequence are considered to be good reservoirs in the areas where the carbonates are eroded and karstified during the Miocene uplift (e.g. Ionian Sea areas).

Seal

The Oligocene flysch acts as a seal to hydrocarbon accumulations in the carbonate section. Shales of Upper Miocene or Pliocene age are another seal in the offshore area. The West Katakolon structure located in the South Ionian Sea is sealed by Late Pliocene shales. The Triassic evaporites are the best cap rocks for the traps existing beneath the thrusted units.

Source Rocks (Fig. 5, 6)

1. Very good source rocks (1%-12% TOC) occur in the Lower Cretaceous of internal Ionian Zone, with a Type I to Type II organic matter.
2. The best source rock in central and external Ionian Zone is the Lower Jurassic shales (Posidonia beds), with a TOC of 2 to 18% and a Type I to II organic matter.
3. Very good source rocks occur in the Triassic horizons of central Ionian zone, with TOC up to 16% and a Type I to II to organic matter.
4. Good source rocks have been identified in Upper Jurassic of Paxi Zone, with a TOC 1%-4.5% and a Type II organic matter.
5. Source rock horizons have also been identified in the Miocene shales of external Ionian and Paxi Zone, with a TOC up to 6% and a Type II and III organic matter.

Kouklioi, Posidonia beds.

Maturation and Oil Generation

1. The calculated oil window for each subbasin is the following:

- Internal Ionian Zone: 3450m-5600 m
- Central Ionian Zone: 3750m-5800 m
- External Ionian Zone: 5200m-7700 m
- Paxi Zone: 5600m-7250m

2. The main oil generation on central, external Ionian and Paxi Zone occur after the main phase of orogeny.

3. In internal Ionian Zone, oil generation started during Late Oligocene time and 30% of oil was generated prior to the main orogenic phase.

Oil Shows

A lot of oil shows are known in Western Greece. Most of them appear as impregnations of porous rocks or faults, but there are some oil seeps as well.

1. Most oil shows are located in central Ionian Zone, mainly at the edges of Botsaras Basin. Oil shows have also been identified in several wells. These oils have been generated from the Lower Jurassic Posidonia beds.
2. Some oil in central Ionian, different than the others, is believed, in combination with their geological setting, to have been generated from Triassic sources.
3. A few oil shows are known in internal and external Ionian zones.

- A lot of oil shows are known in Paxi Zone, especially in Paxi and Zante Islands. Their origin is believed to be Triassic and Lower & Upper Jurassic sources for Paxi Island and Miocene for Zante oils.

Dragopsa oil shows

West Katakolon Oil Field.

The relatively limited hydrocarbon exploration that has taken place onshore and offshore in Western Greece resulted in the discovery of the offshore West Katakolon Field.

Two wells drilled in the Mesozoic limestone reservoir tested oil at flow rates of up to 1500 bbl/day from two separate zones and gas with calculated flow rates of up to 20 MMSCFD from two zones as well.

Although this reservoir lies at a sea depth of 250m-300m, its short distance from the shore makes it a candidate for exploitation by extended reach drilling.

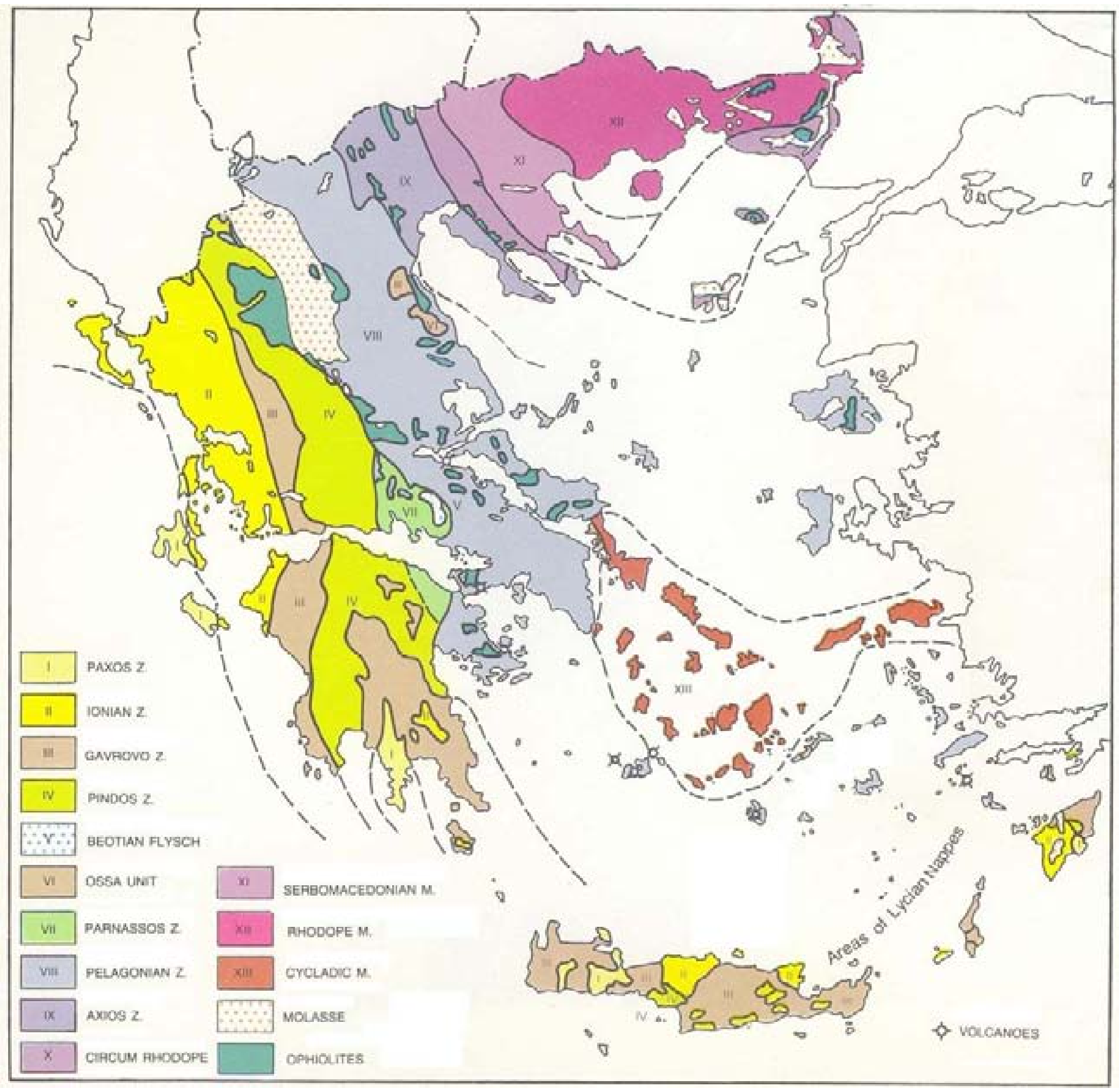


Fig. 1 Map of the geotectonic zones of Greece

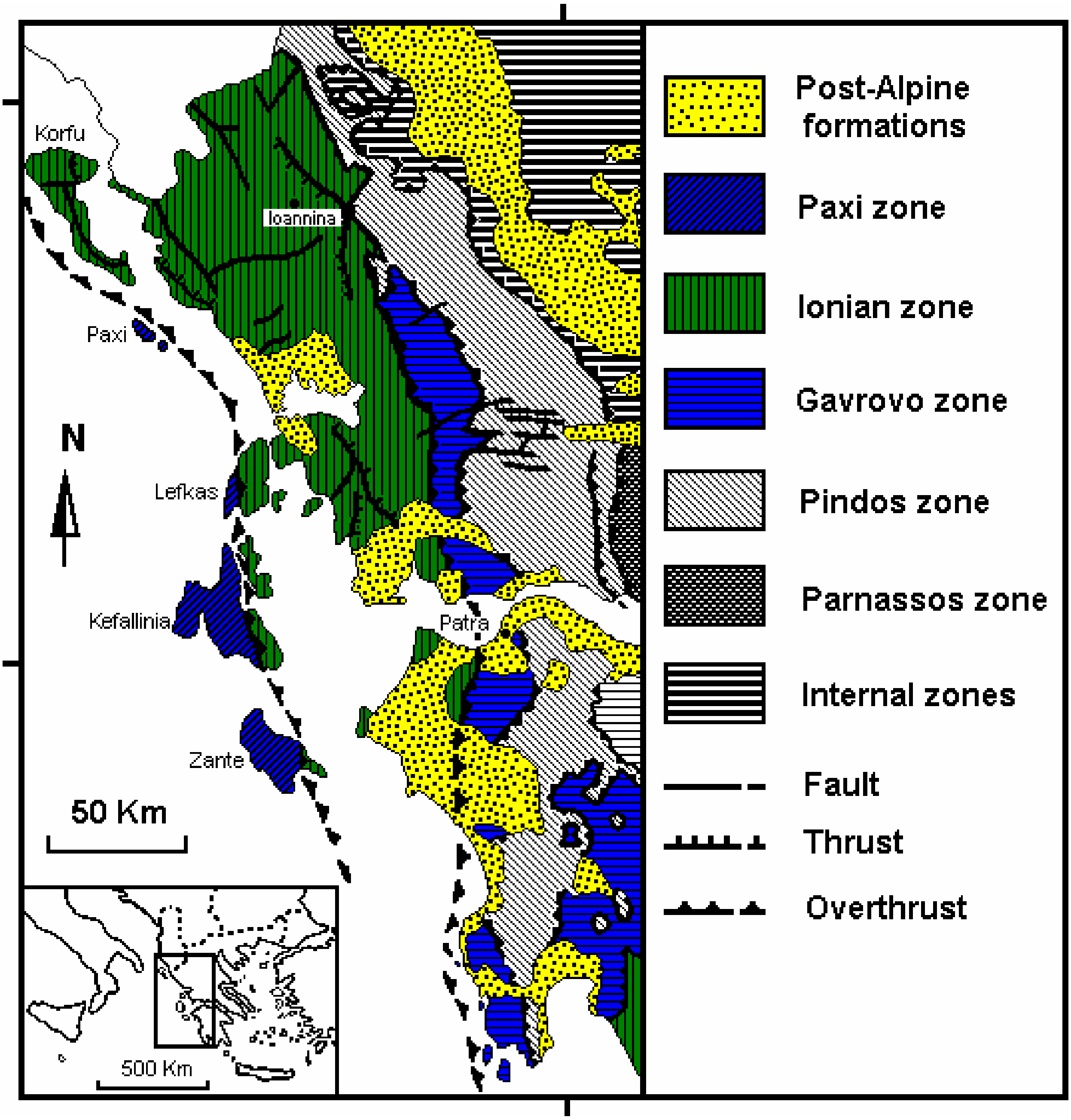


Fig. 2 The geotectonic units of the Western Greece

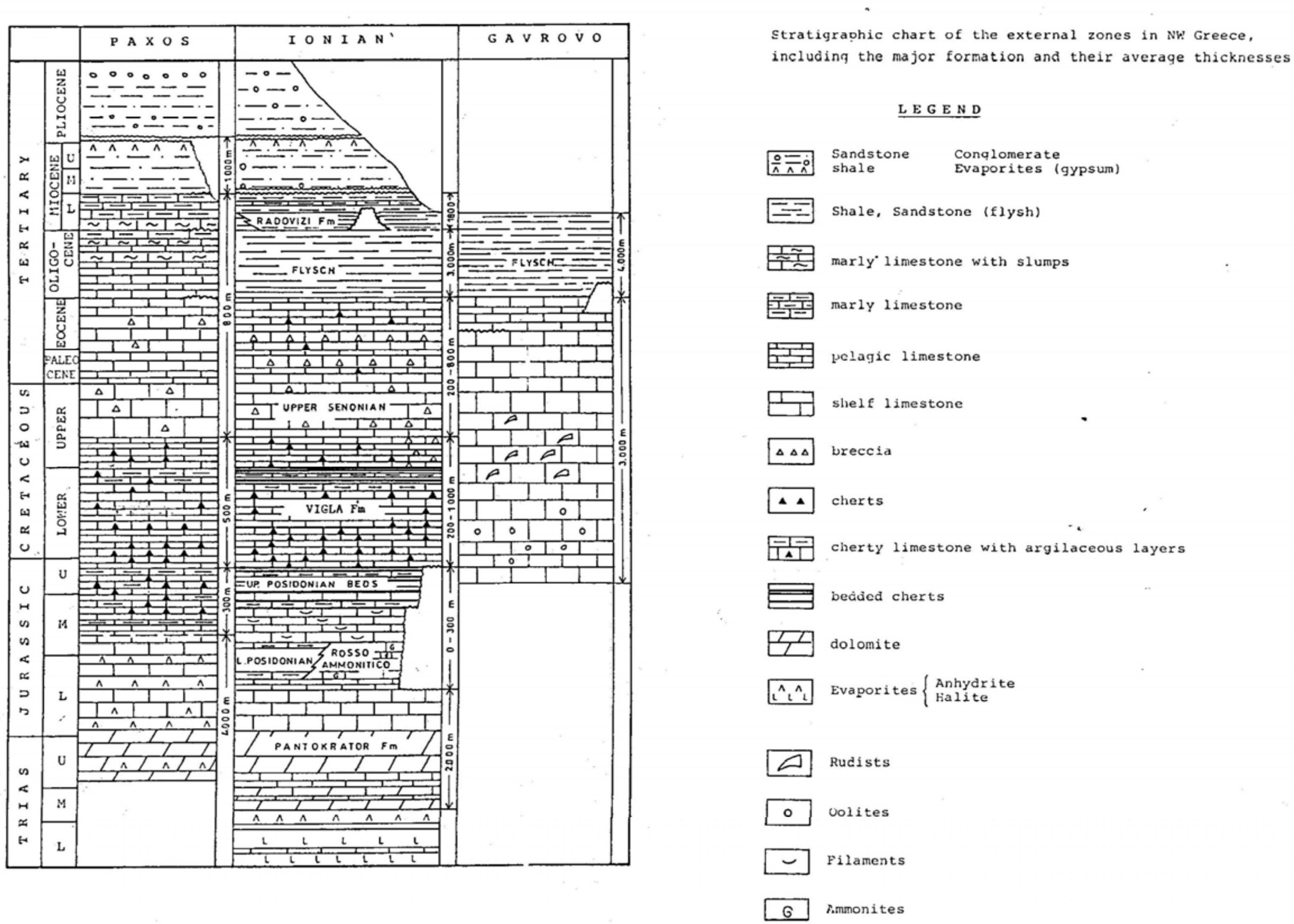


Fig.3 Stratigraphic chart of the Gacrovo, Ionia and Paxi zones.

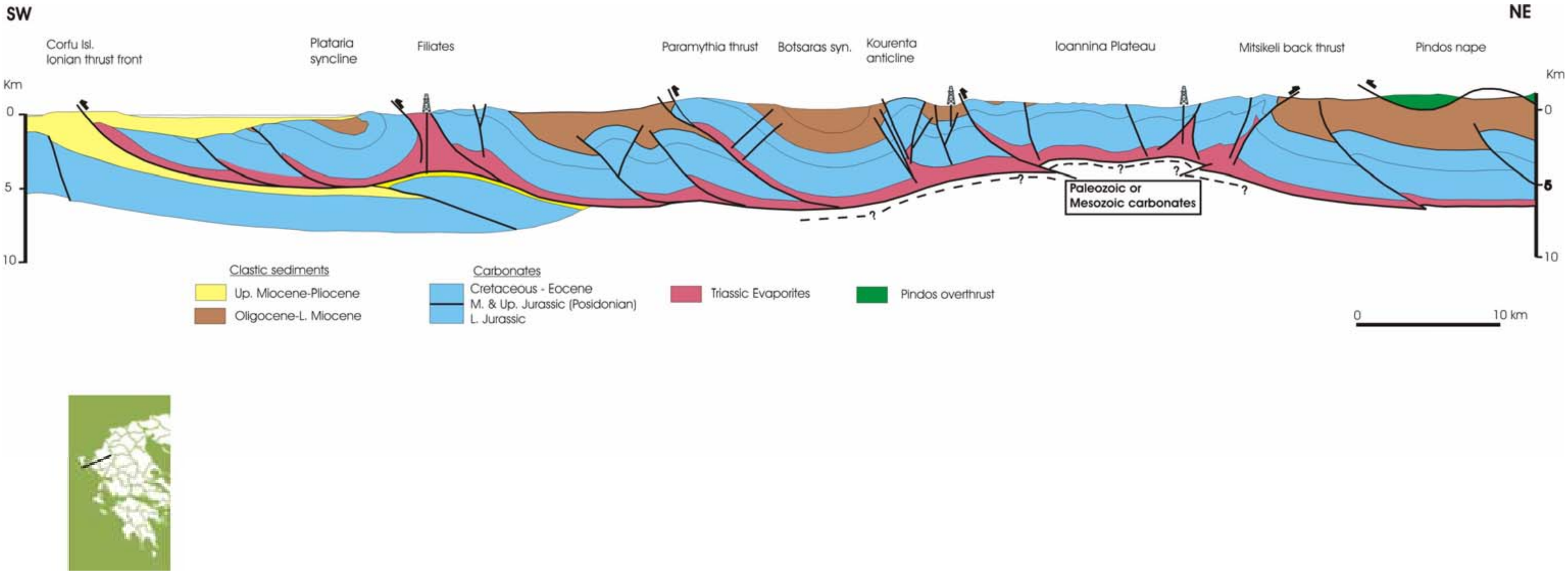


Fig. 4 Structural section from Corfu Island. to Metsovo

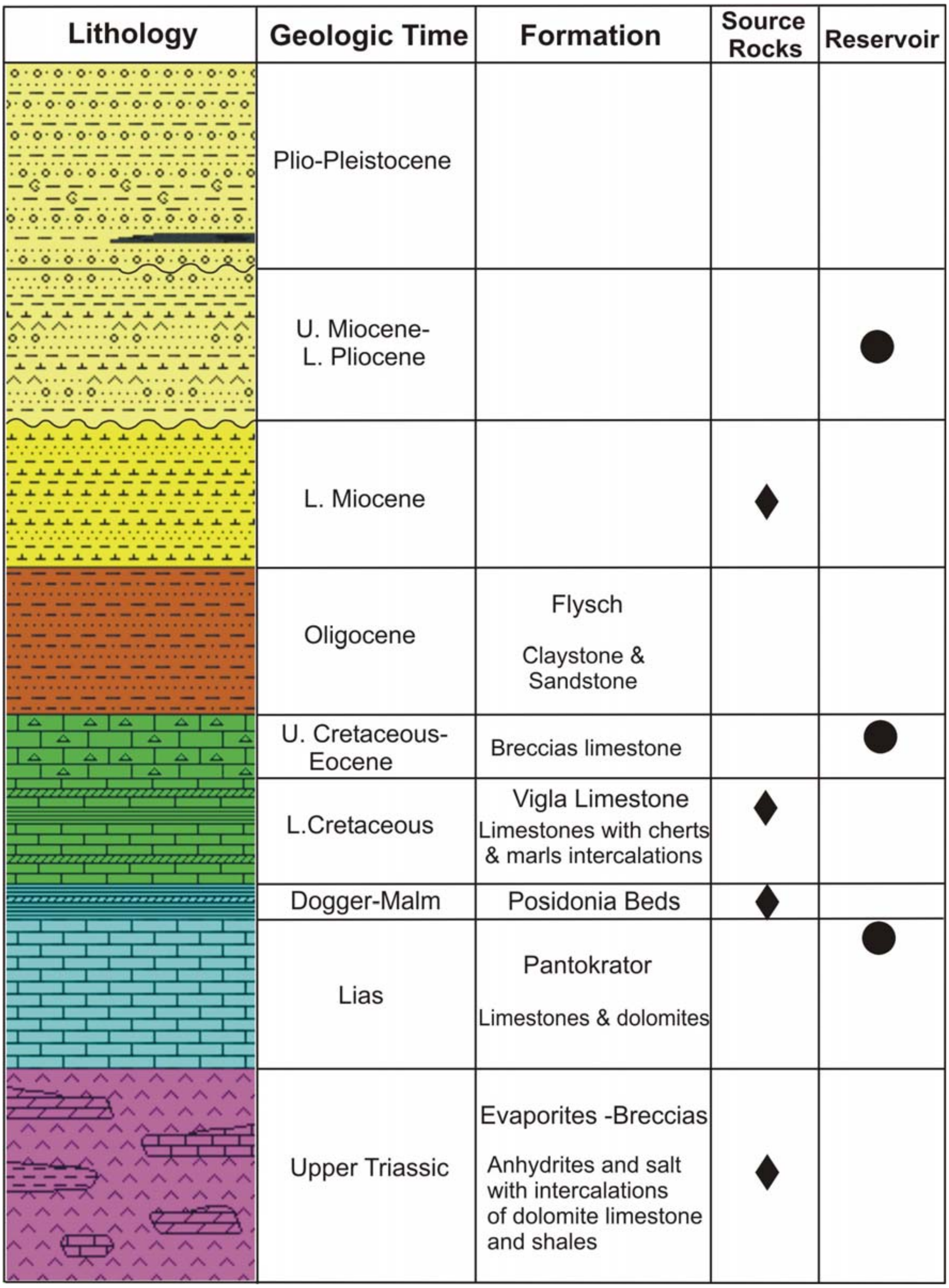


Fig. 5 Lithostratigraphic column of the Ionian zone

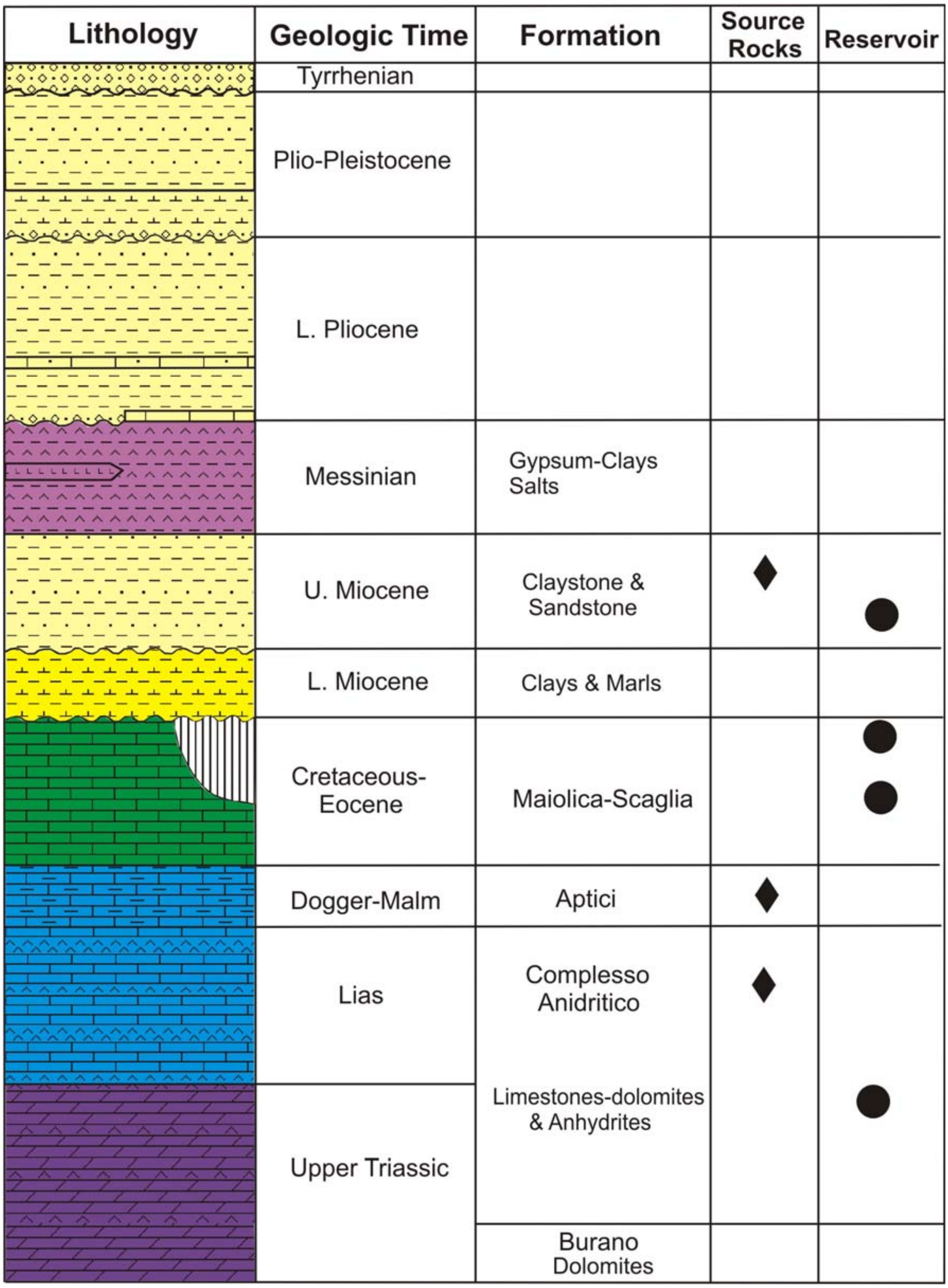
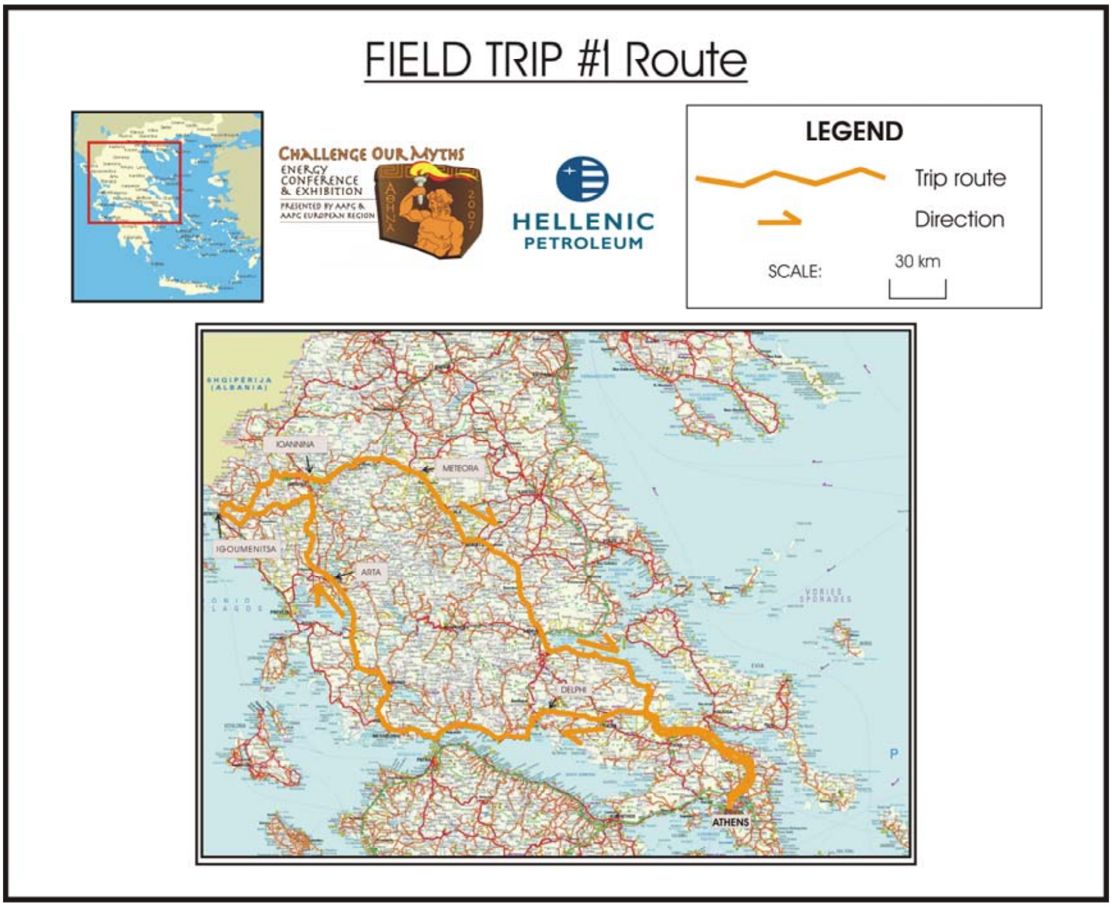


Fig. 6 Lithostratigraphic column of the Paxi zone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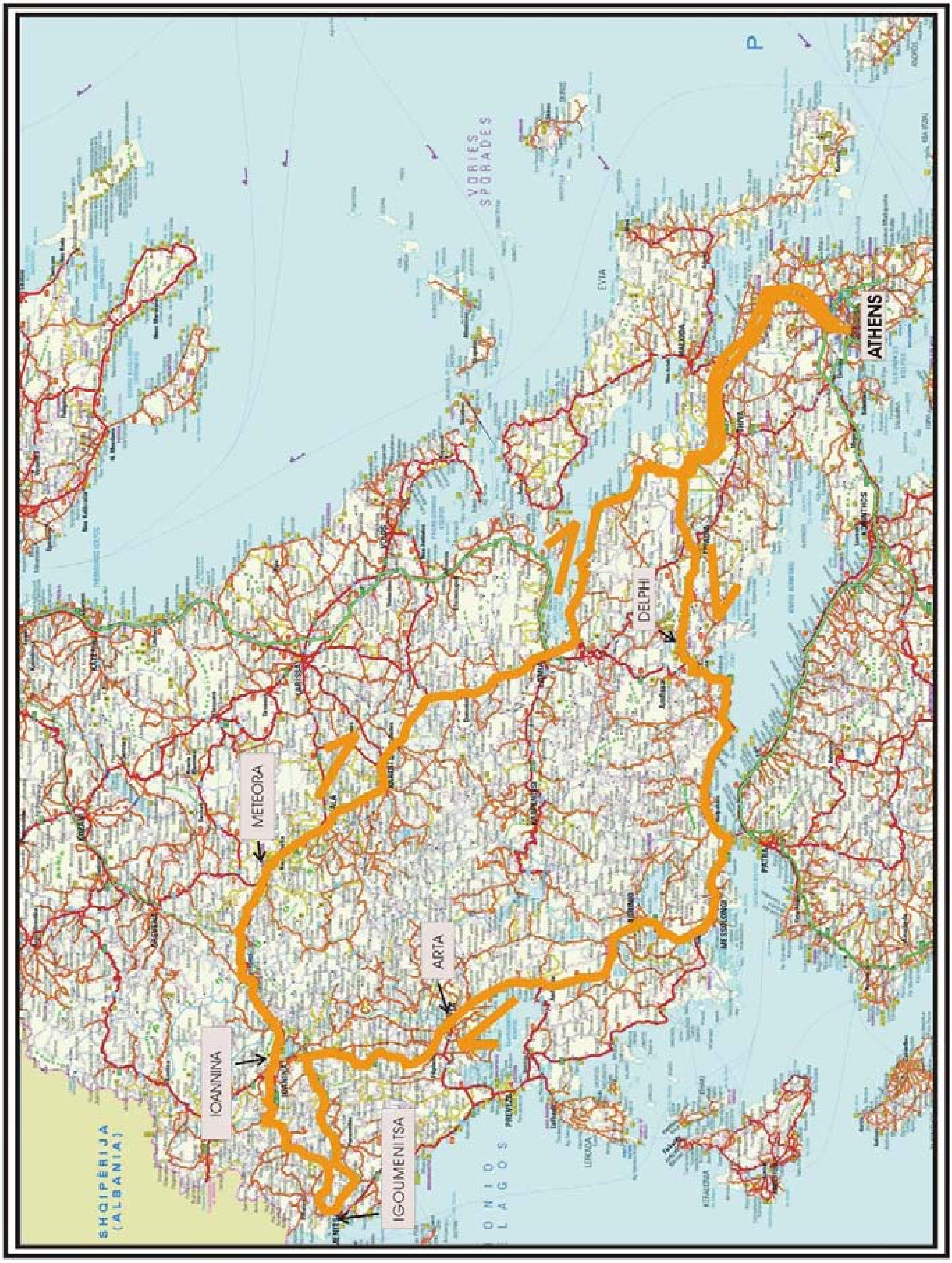
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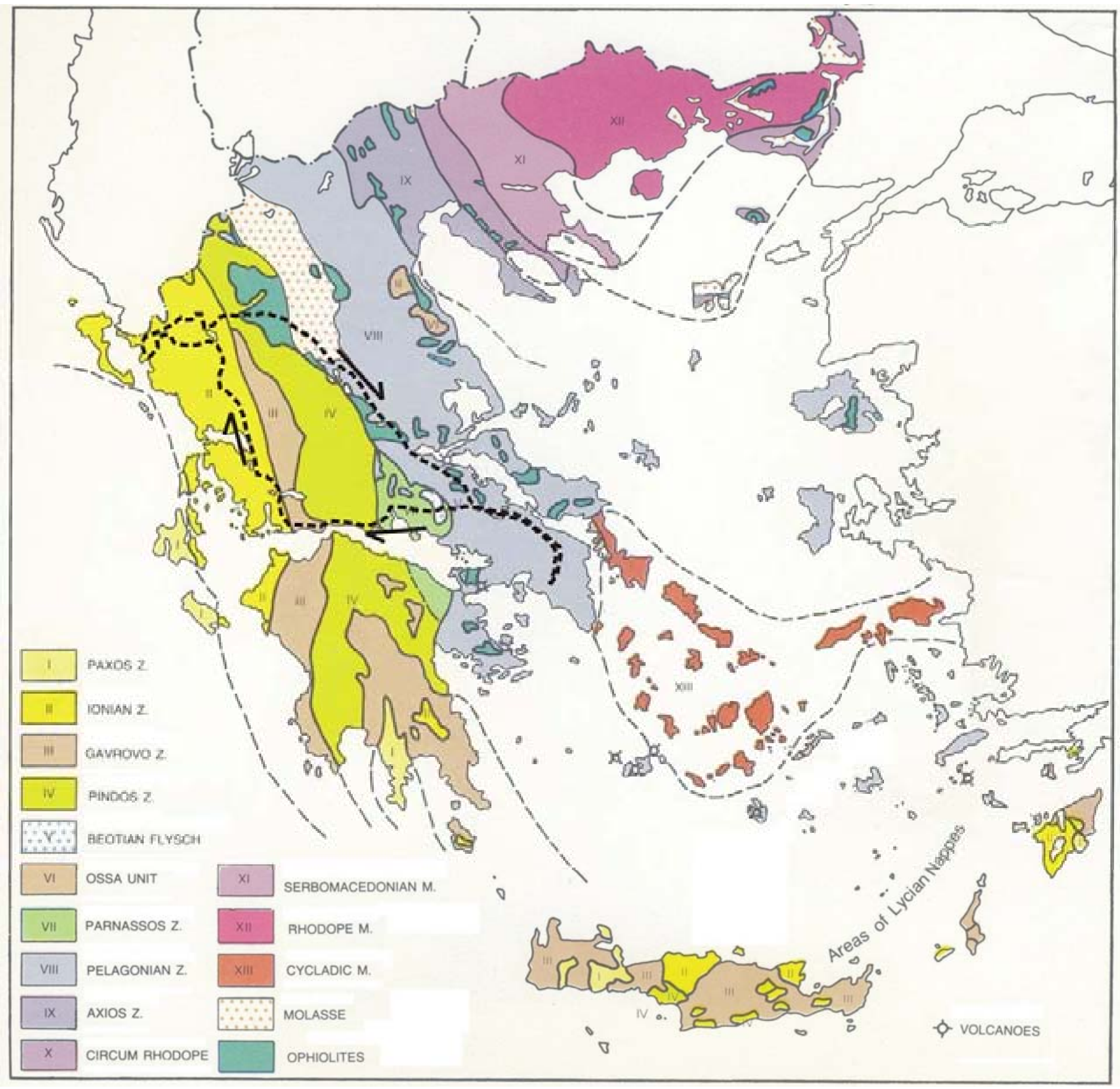


Fig. 8 The itinerary through the geotectonic zones of Greece

DAY 1

Travel from Athens to Delphi. We will arrive in Delphi at 11.00 to visit the archaeological site and the museum (1 hour conducted tour).

On the way from Delphi to Nafpaktos along the north cost of the Corinth's gulf, we will cross several tectonic units of the Hellenides (Fig.7, 8, 9). We are planning 3 stops to observe, from East to West, the successive thrust emplacements (Fig. 9):

- Parnassos zone (a small platform with neritic carbonates of Upper Triassic to Late Cretaceous age and several bauxite intercalations) is thrusted on to the Pindos zone.
- Pindos zone (a deep basin with pelagic limestones and radiolarites) is thrusted on to the Gavrovo zone.
- Gavrovo zone (a platform with neritic carbonates of Upper Triassic to Eocene age) is thrusted on to the flysch of the Ionian zone.

We will also see representative sections of the folded radiolarites and Cretaceous limestone of the Pindos zone.

Arrival in Arta at 19.00.

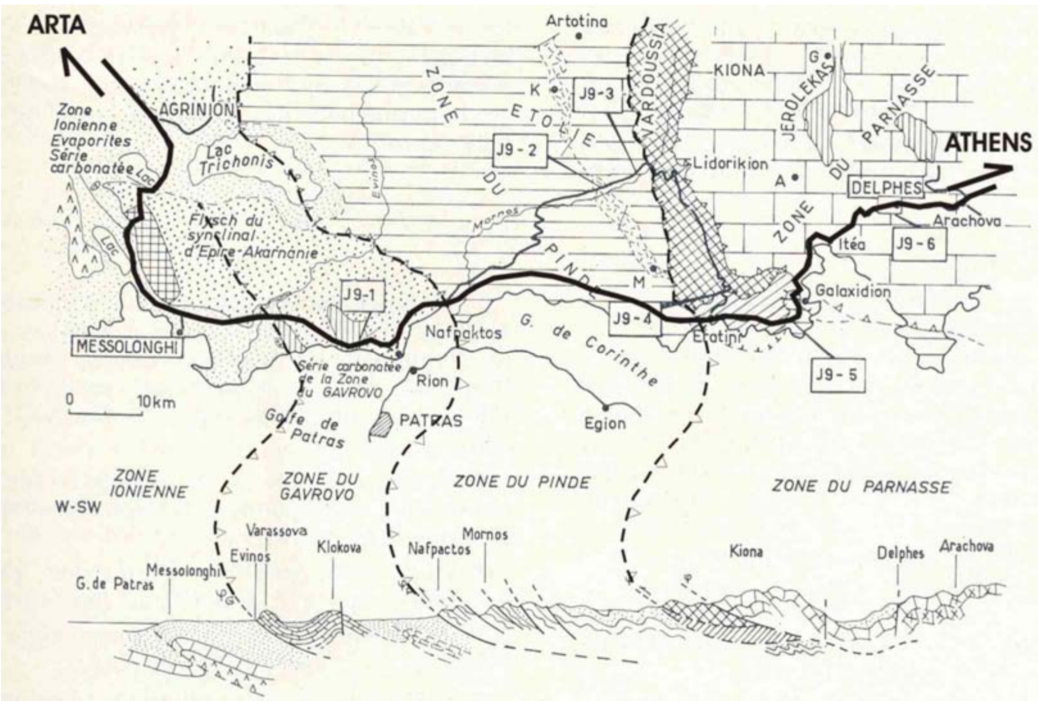


Fig. 9 Geological cross section from Delphi to Nafpaktos (Celet P., 1976).

DAY 2

Fig. 10 Map of Epirus Region

DAY 2: Stops 1 to 8
DAY 3: Stops 9 to 15
DAY 4: Stop 16

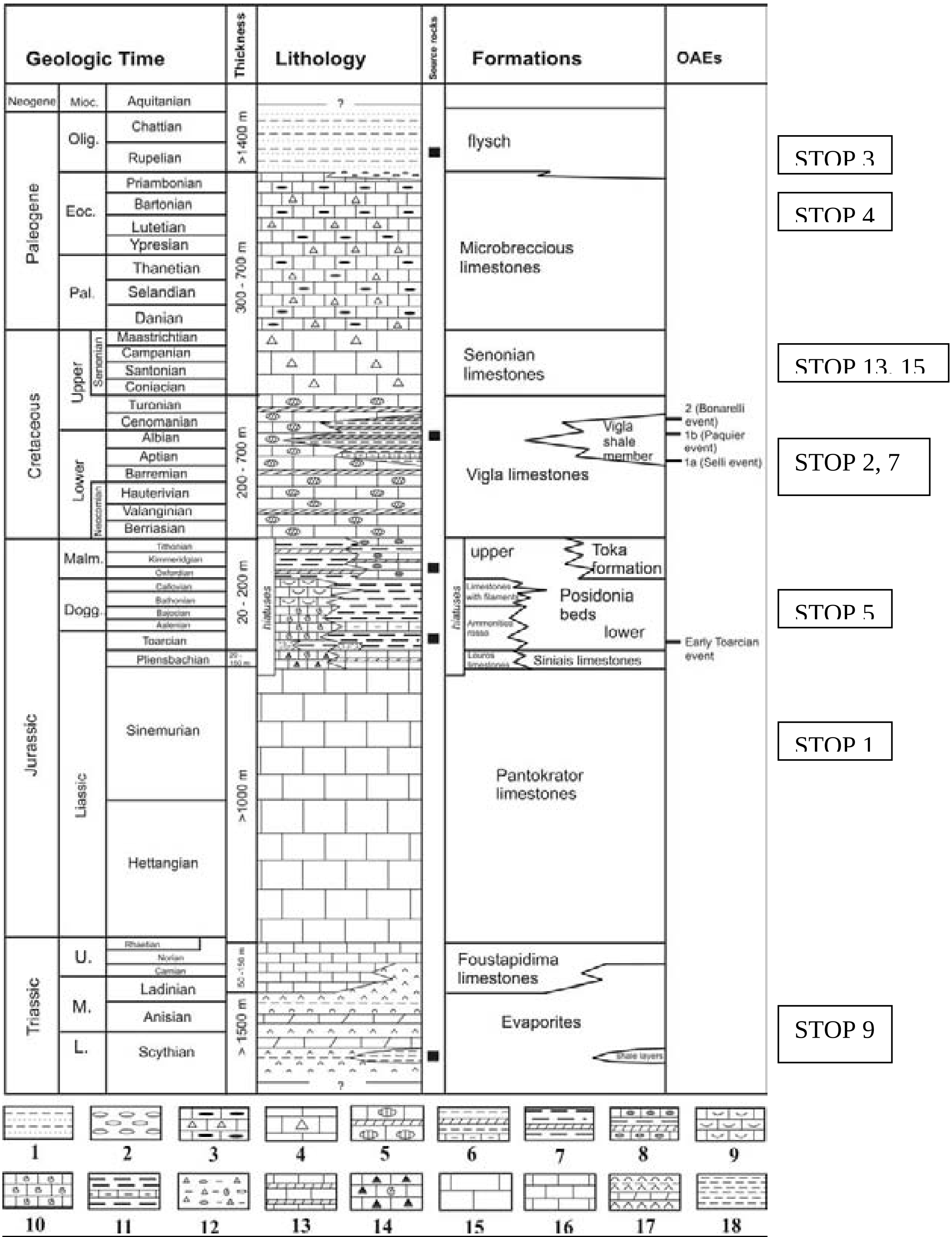


Fig.11 Synthetic lithostratigraphic column of the Ionian zone (after Karakitsios 1995, modified).
1: pelites and sandstones, 2: conglomerate, 3: limestones with rare cherty intercalations, occasionally microbreccious, 4: pelagic limestones with clastic calcareous intercalations, 5: pelagic limestones with cherts, 6: cherty beds with shale and marl intercalations, 7: alternating cherty and shale bends, 8: pelagic limestones with cherty nodules and marls, 9: pelagic limestones with Lamellibranches, 10: pelagic, nodular, red limestones with Ammonites, 11: marly limestones and laminated marls, 12: conglomerates-breccias and marls with Ammonites, 13: pelagic limestones with rare cherty intercalations, 14: external platform limestones with Brachiopods, and small Ammonites in the upper part, 15: platform limestones, 16: thin-bedded black limestones, 17: evaporites, 18: shale horizons.

DAY 2

STOP 1. Lias limestone (Pantokrator limestone, fig.11, 13)

The Pantokrator limestones consist of Algae (*Palaeodasycladus mediterraneus, Thaumatoporella parvovesiculifera, Porostromata*), onkolites, pellets and algal stromatolites with bird eyes indicating a very shallow sedimentary environment (intertidal environment). These limestones constituted part of the vast carbonate platform extended, during the Early Lias, over the whole of western Greece. The thickness of the sequence exceeds the 1.500m (data from boreholes).

STOP 2. Early Cretaceous limestone (Vigla formation, Fig.11, 13)

In this stop a section of the Vigla limestone will be studied (fig. 12). A pelagic sequence of thinly bedded limestones (Berriasian - Turonian) of about 250m thickness is observed, which towards the stratigraphic top, contains the Vigla shale member. The base of the Vigla limestones sequence overlies with unconformity the Pliensbachian Louros limestones. A significant stratigraphic gap exists between the two formations, encompassing most of the Jurassic (Toarcian to Tithonian). At the base of the Vigla limestones Calpionelids and Aptychus are observed. In terms of paleoenvironment, the Panagia Cretaceous sequence is interpreted as pelagic accumulation on a Jurassic seamount which could temporary emerged during Toarcian to Tithonian.

The 5m of Vigla limestones underling the Vigla shale member are thinly bedded (10 to 30 cm thick). Chert layers and nodules are relatively abundant and it is striking that many limestone beds display, in their middle part, a 2-8 cm thick, irregular bedded chert layers. Some shale layers of 2 cm thickness are also present. The Vigla shale Member is represented by 35-40m sediments, consisting in the first 3-4 meters by a cyclic alternations of radiolarian chert beds of 4-10 cm thickness and thin shale interlayers of 0,5 to 4 cm thick. They are followed by about 20m of alternating thinly bedded limestones and chert beds, containing marcassite nodules. The Member ends by about 9m of an alternation (reddish to greenish-yellowish in color) of radiolarian cherts and thin shaly interlayers. This member contains in other localities of Epirus the Cretaceous OAEs (Selli, Paquier and Bonarelli events). The anoxia is manifested here by the presence of marcassite nodules.

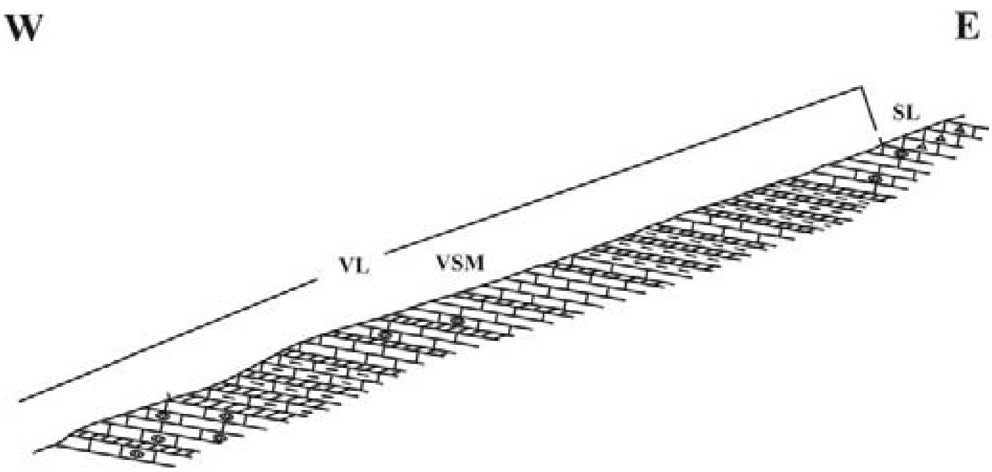


Fig. 12 SL: Senonian Limestones, VL: Vigla Limestones, VSM: Vigla Shale Member.

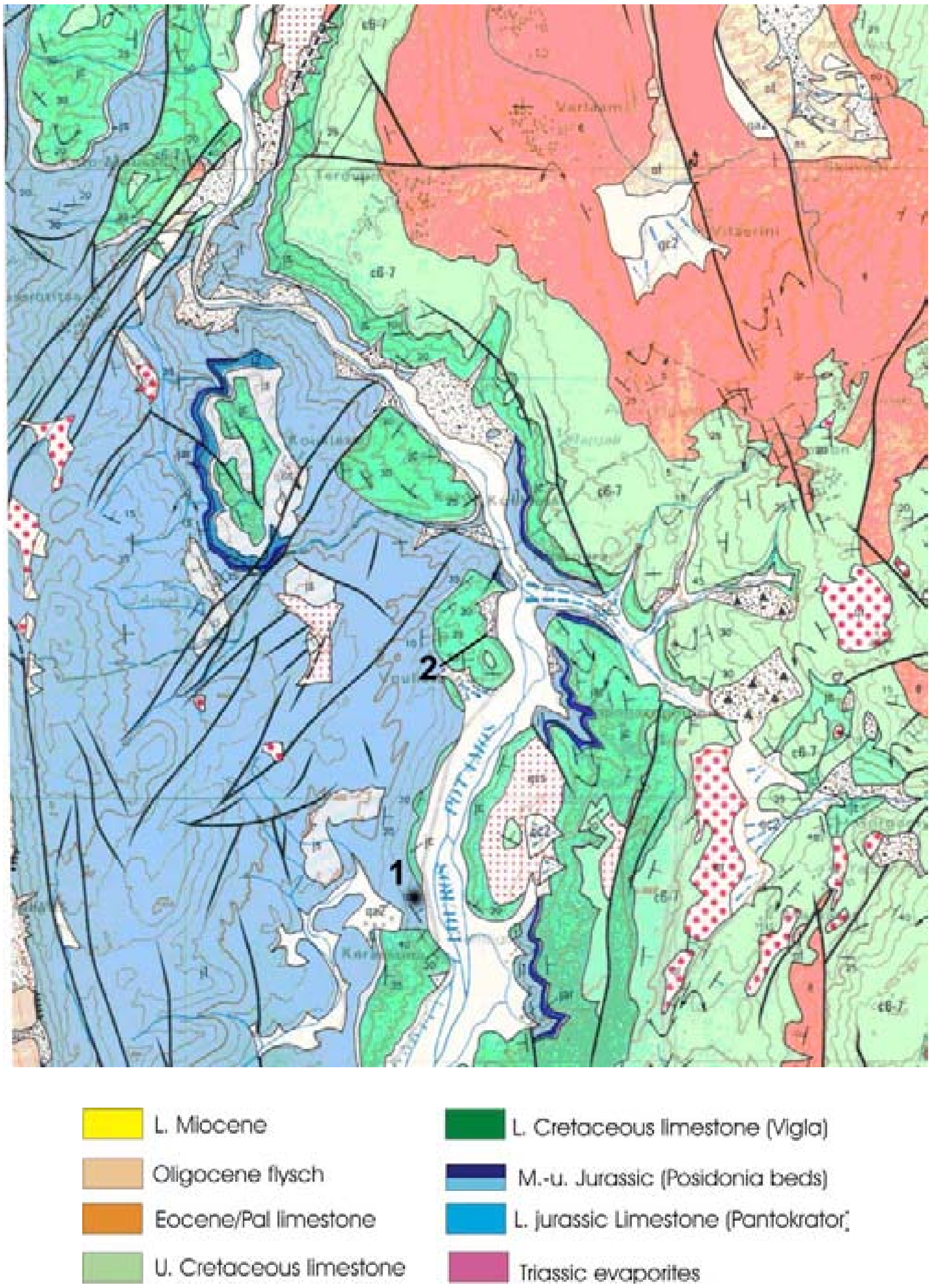


Fig. 13 Geological map. Stops 1, 2

STOP 3: Transition zone from carbonates to clastics sediments (Dodoni section Fig. 11, 14)

The carbonate sedimentation has been progressively replaced by clastic sedimentation in Late Eocene. The transition zone between Eocene limestone and Late Eocene to Oligocene flysch comprises thin bedded limestones alternating with marls of reddish or greenish colour (Fig.15). The thickness varies from a few meters to 30 m maximum. The flysch consists of siltstones, clays-shales and sandstones deposited by turbiditic currents in a deep water environment. Along the road to the next stop, many outcrops of flysch can be observed.

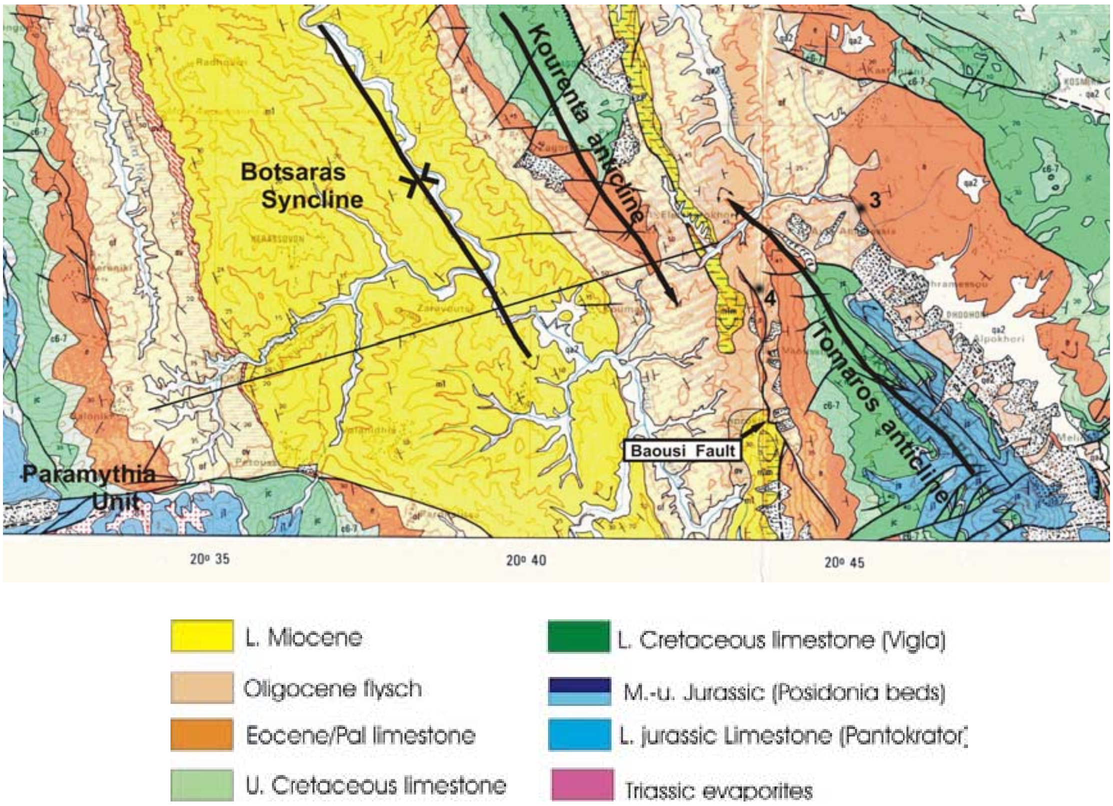


Fig. 14 Stops 3, 4 and location of the seismic line.

Fig. 15 Transition zone between carbonates and flysch

STOP 4: Baoussii oil seeps (Fig. 11,14)

In this stop a good example of an outcrop of fractured pelagic limestone of Eocene age, impregnated with oil will be observed (fig.16).

The structure is situated in the western limb of the Tomaros anticline and it is formed by a minor back-thrust (Baousi fault, Fig. 14). The Eocene limestone locally crops out and the fault continues to the south within the flysch and finally reaches the Eocene limestone of the anticline. The oil migrated along the fault plane, from the deeper part of the Botsaras syncline, sourced by the Posidonia beds.

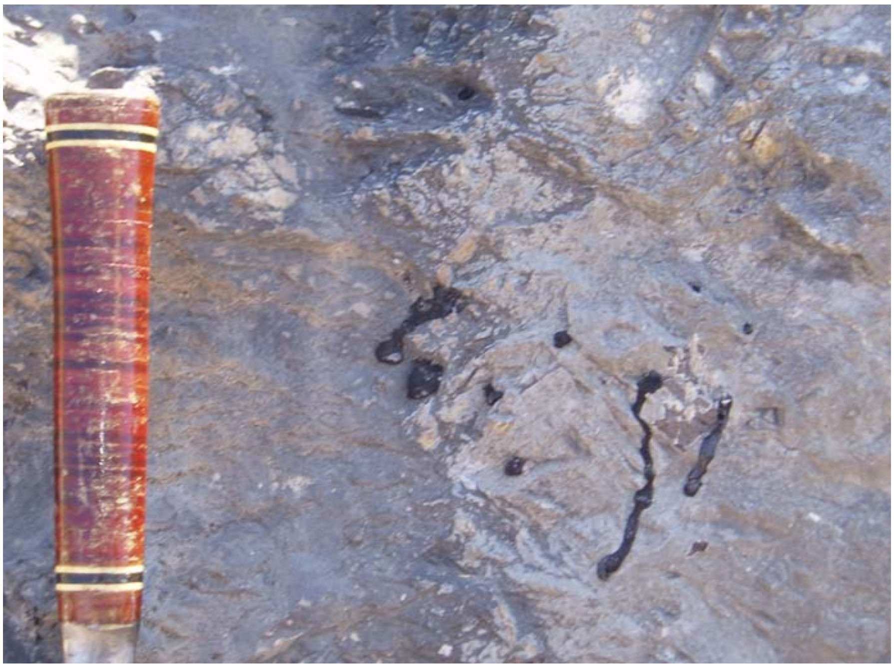
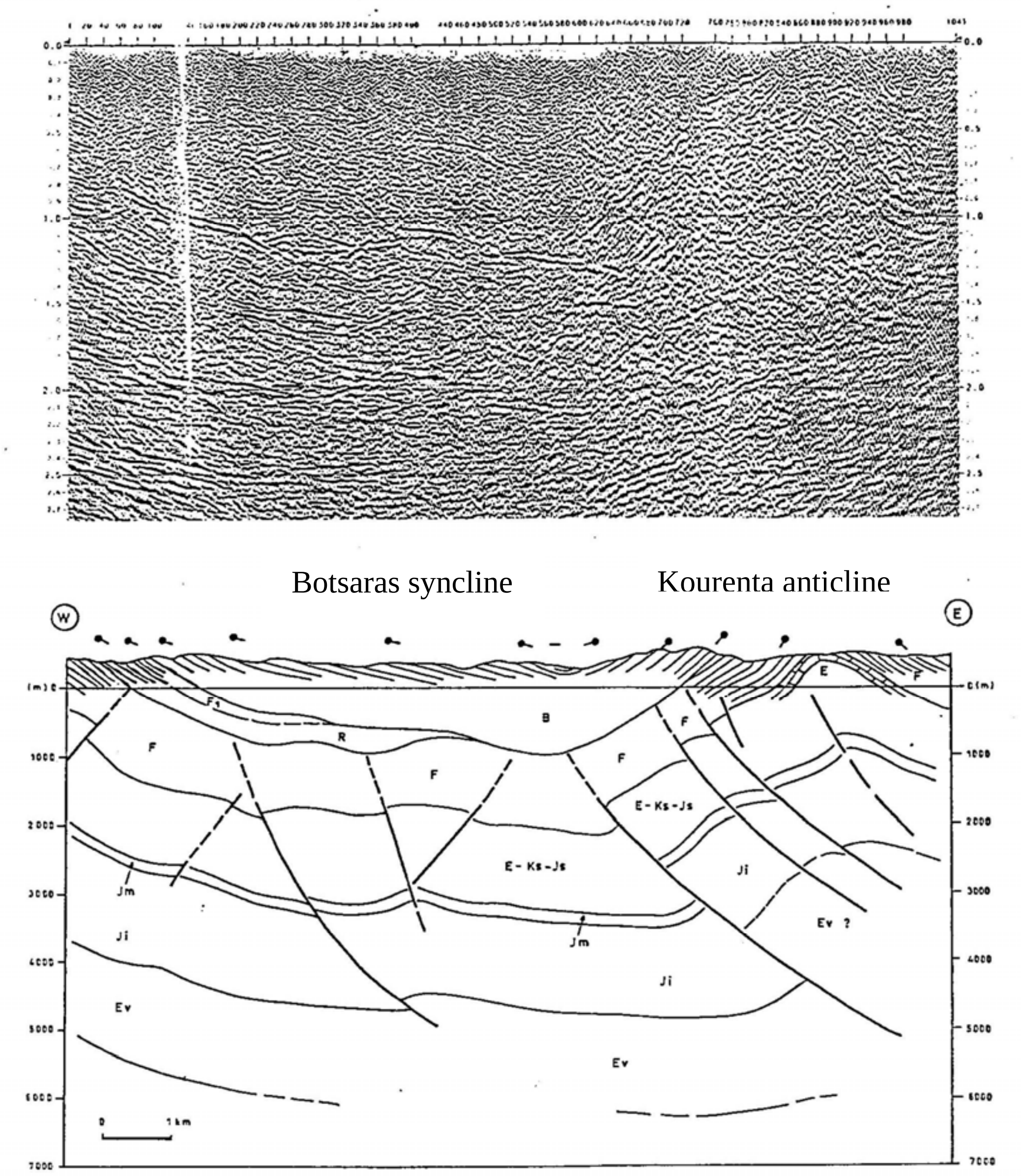


Fig. 16 Eocene limestone impregnated with oil

STOP 4a: Botsaras Syncline (Fig. 14)

This stop provides also a panoramic view of the Botsaras Syncline where exploration activities took place from 1976 to 1987.

The Botsaras Syncline is located between the eastern east-dipping monocline of the Paramythia unit to the west and the Kourenta anticline to the east. This anticline is interpreted as a pop-up structure. On the eastern flank of the Botsaras syncline the Burdigalian terrigenous sediments rest unconformably above the Oligocene flysch. Anticlinal folds involving limestone have been mapped from seismic interpretation at reasonable depths (2-3 km) beneath the flysch cover. The traps could be sourced by the Posidonia shales that entered the oil window after the Middle Miocene compressional event (Fig. 17). Expected reservoirs are the Eocene/Cretaceous limestones sealed by the flysch.



B : Burdigalian
R : Aquitanian
F : Oligocene - Flysch
E-Ks-Js : Eocene to up. Jurassic
Jm : middle Jurassic
Ji : Lias
Ev : Triassic - Evaporites

Location in Fig. 14

Fig. 17 Geological section based on seismic data.

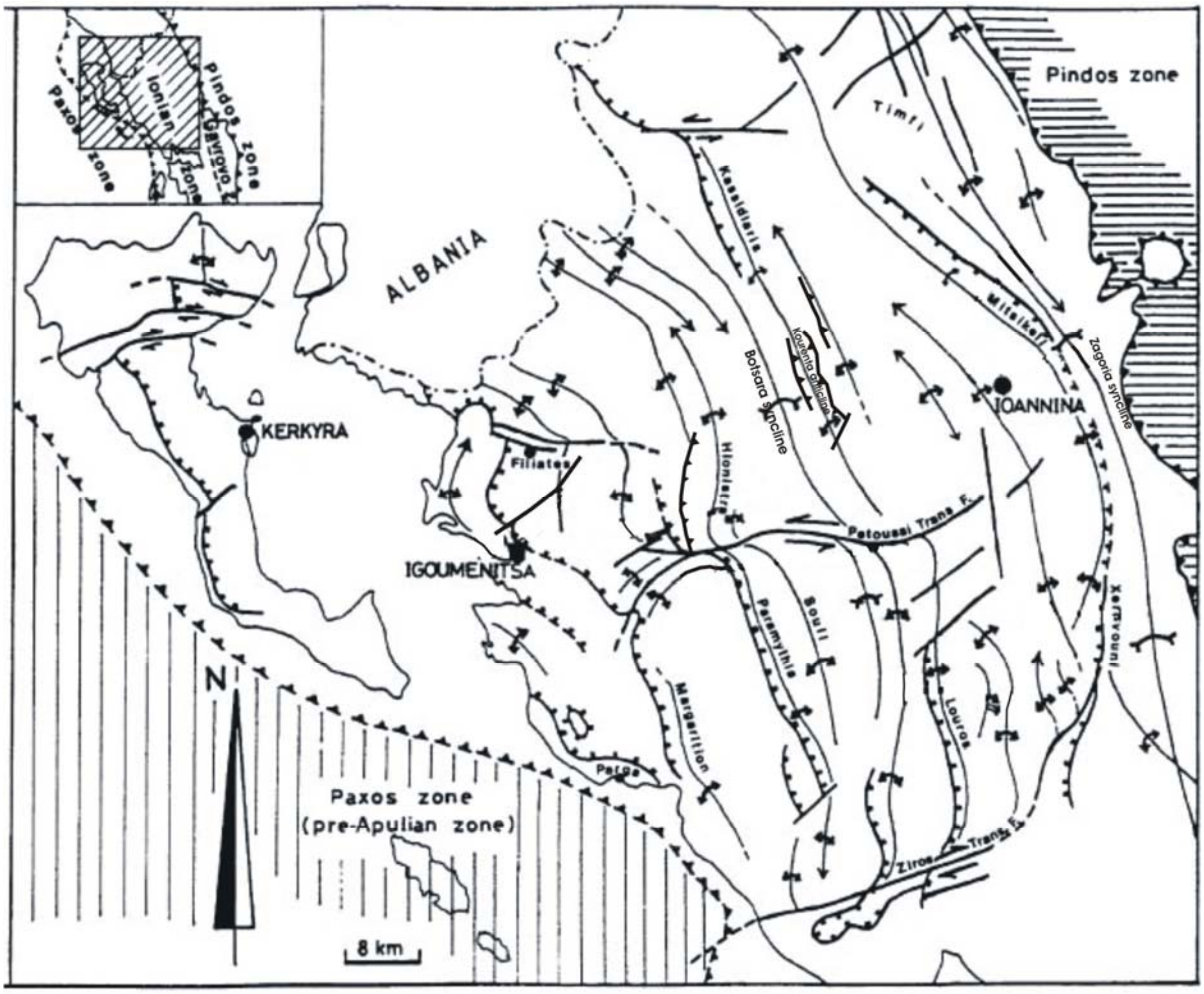


Fig. 18 Structural map of the Epirus region. (after Karakitsios 1995, modified)

STOP 5: Petoussi Fault and Posidonia Beds (Fig. 18, 19)

A section of Posidonia beds, the principal source rock of the Ionian zone, will be studied (Fig. 11, 20). Both horizons, Upper Posidonia of Upper Jurassic age and Lower Posidonia of Toarcian age are well exposed. Its thickness is about 30m., probably shortened by the Petoussj fault. The organic carbon content ranges from 0,9% to 2,3% average 1,5%. Oil shows originated from the Posidonia shales are observed in the limestone bank inside the shales. This formation could reach the oil window at a depth ranges between 3,75 and 5,8 Km.

From this stop we will observe an important transcurrent fault, the Petoussi fault.

This fault is a Neogene regional wide E-W trending left-lateral strike slip system. Although it has been inferred that the fault is active since Liassic times, its major activity was during the Middle Miocene deformation. The fault affects Lias to Eocene carbonates, Oligocene flysch and Lower Miocene clastic formations. Along some segments of the fault, young geomorphic features have been recognised showing a recent tectonic activity.

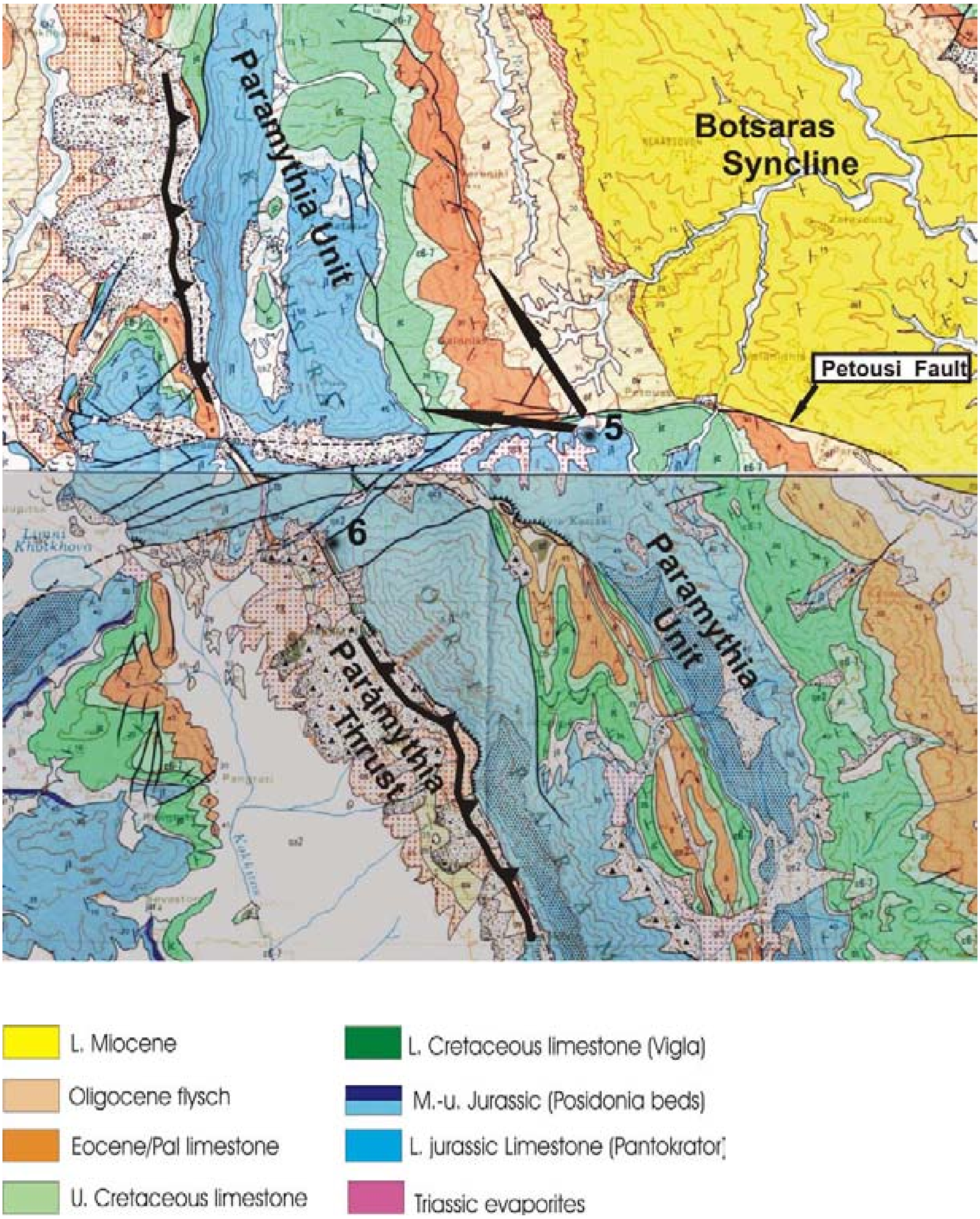


Fig 19 Geological map. Stops 5, 6

Fig. 20 Petoussi section: Posidonia beds.

STOP 5a Section of Paramythia unit (Fig.19)

This stop provides also, a panoramic view of the Paramythia unit (Fig. 21). The eastern side of the Paramythia Mountain shows in stratigraphic continuity all the stratigraphic sequences from the Lower Jurassic Pantokrator limestones to the top of the mountain, up to the flysch formation, to the east

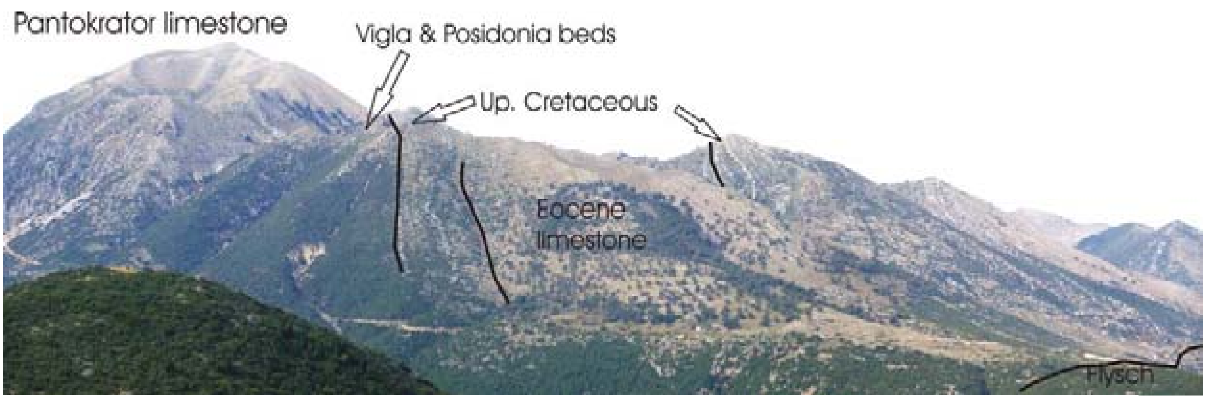


Fig. 21 Panorama of the Paramythia unit.

STOP 6: Paramythia Thrust front (Fig. 18, 19)

In this stop we will observe the major NNW-SSE trending Paramythia thrust which is cut by the Petoussi fault. The Liassic carbonates (Pantokrator limestones) overlie the Oligocene flysch. On the footwall, the strata of the flysch are folded and overturned close to the fault plane. Between the flysch and the Pantokrator limestone several wedges of Cretaceous and Eocene limestones outcrop. Those originate from the footwall and move upwards along the fault plane.

Along the thrust contact, thin layers of Triassic evaporites (gypsum) and shales are preserved (Fig. 22).

To the west, we can observe the east dipping ramp of the Margariti thrust sheet which is the next major structural unit of the Ionian zone.

Fig. 22 Thin layers of Triassic evaporites (gypsum) and shales along thrust

STOP 7: Folding and faults of Vigla limestones (Perdika section)

In this section, we will observe folded thinly bedded limestones and chert layers .In a small scale, we see low angle "thrust faults" and disharmonic tectonics (Fig. 23, 23a).

Fig. 23

Fig. 23a

STOP 8: The overturned Plataria syncline (Fig. 25, 26)

The panoramic view of the Plataria bay, offer an impressive example of an overturnd syncline.

From the top to the bottom, we observe:

- Thick massive beds of Late Cretaceous dipping to the east
- Thin well bedded Eocene limestone dipping to the east.

This section represents the overturned flank of the Plataria syncline. As it is shown in the cross section of the Fig.24, the syncline has been deformed by the diapiric movement of the Triassic evaporites.

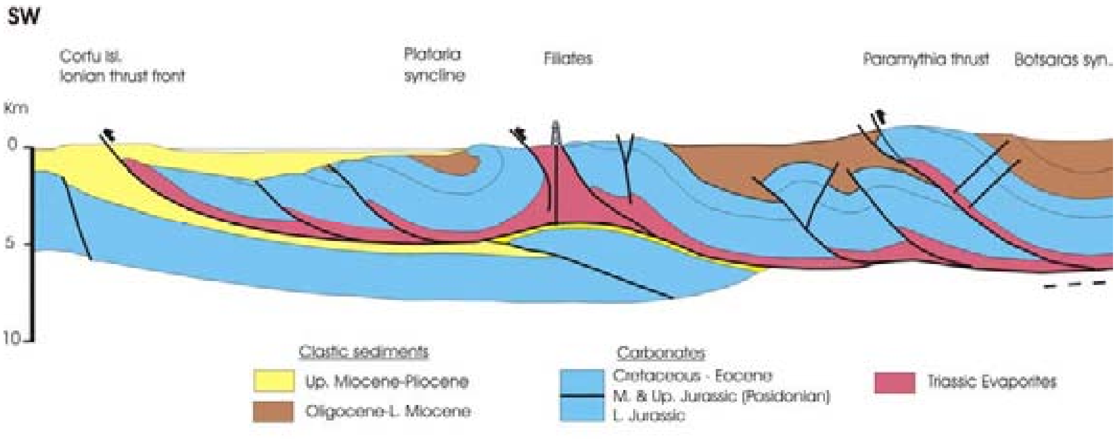


Fig. 24 Cross section across the Plataria bay.

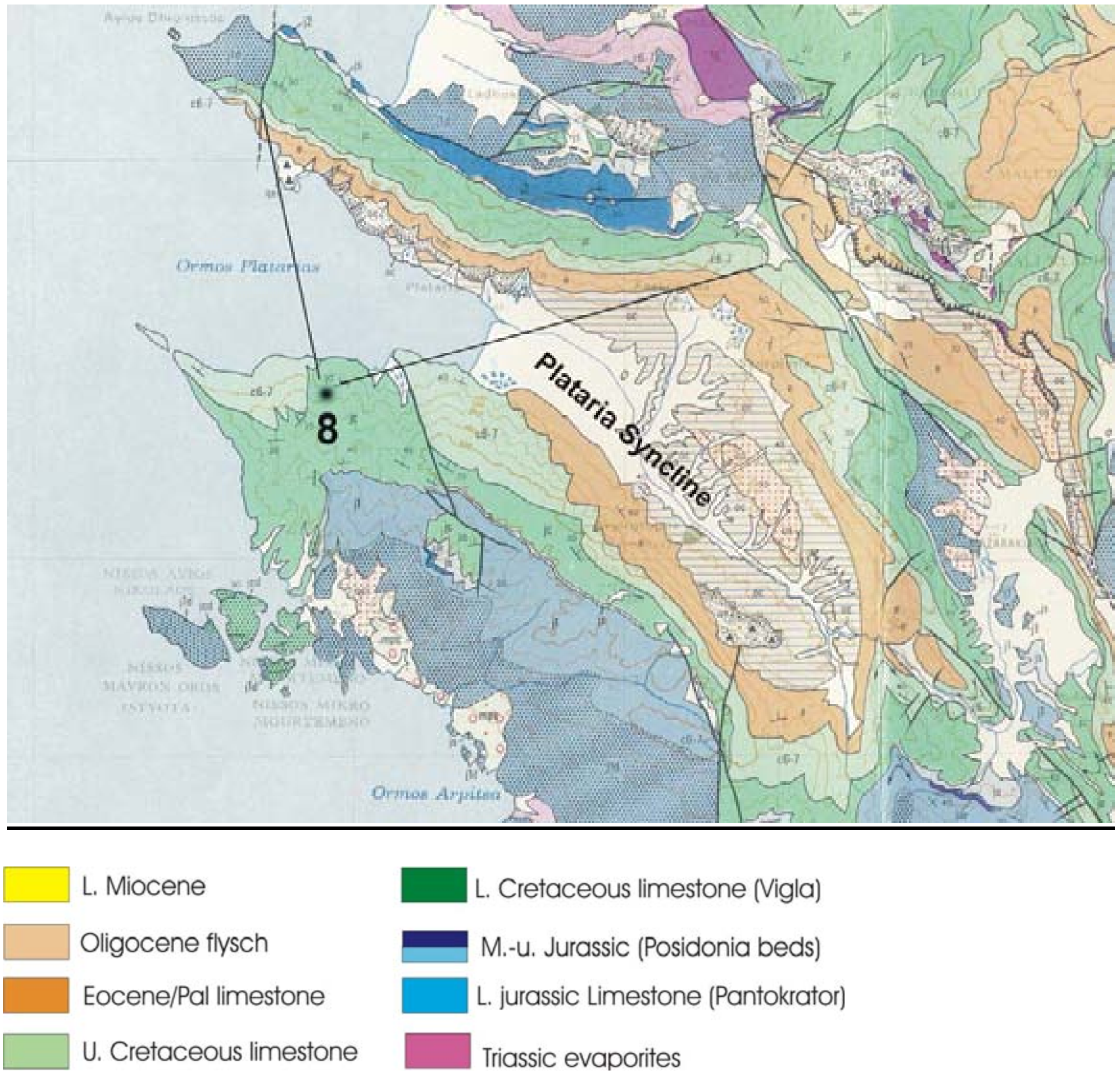


Fig 25 The Plataria syncline.

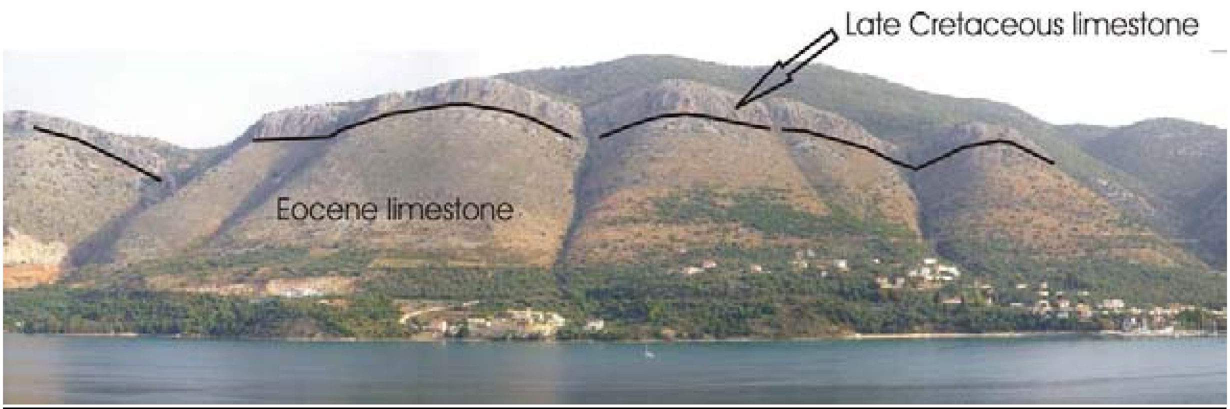


Fig. 26 Panoramic view of the Plataria bay

DAY 3

STOP 9: Filiates Diapir (Fig. 28)

The structural situation of the Filiates area is complicated and characterised by large scale diapirism evidenced by the Filiates#1 well. This well encountered Eocene and Serravalian marls under the Triassic evaporite at a depth of 3.800m, proving the post-Middle Miocene age of the thrust emplacement. The Mesozoic carbonate sequence occurs both in the complete and condensed form, around the Triassic evaporite outcrops. The clastic sequence developed on the eastern side of the structure.

In this section we can observe the Triassic gypsum and the associated breccias formation. They are typically unbedded rocks consisting of re-cemented angular fragments of limestones and dolomites – fetid, grey-brown to black and vuggy. The gypsum crops out under microcrystalline or flake form, white to grey in color, with rotated black or red traces, in confused masses into the breccias. Two main lithological types are distinguished: the massive gypsum and the stratified gypsum, with rare dolomite. The Triassic Breccias are essentially evaporite solution-collapse breccias. In fact, the microscopic observation shows the presence of former evaporites indicated by pseudo-morphs after evaporites. This transformation resulted from the aerial exposure of the injected subsurface evaporites, due to progressive dissolution of evaporites, by infiltration of meteoric fluids and by soil-forming processes (Karakitsios & Pomoni – Papaioannou, 1998). The only remnant of these evaporites is the rare gypsum bodies (subsurface anhydrite) found within the breccias.

In some areas shale fragments have been found incorporated inside the breccias. These fragments appear residual organic matter in some outcrops. In one well drilled near Ioannina city the shale fragments contain up to 16% organic carbon and they are considered as very prosperous source rock (Rigakis & Karakitsios, 1998).

Fig. 27 Triassic gypsum

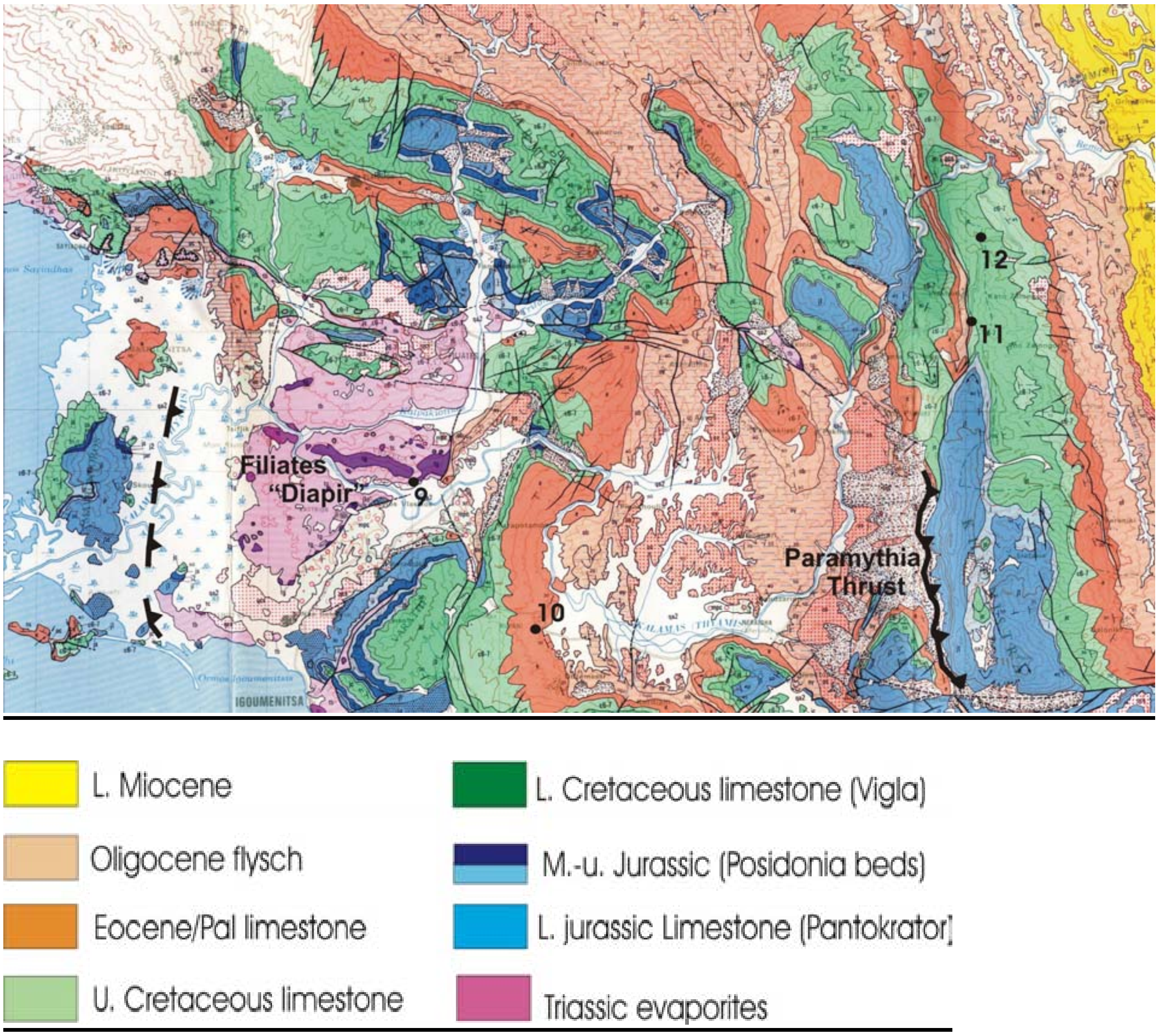


Fig. 28 Map of Filiates area

STOPS 10, 11 & 12: Folds and deformation of the sedimentary sequences (Fig. 28)

On the way to Ioannina we will cross again the main structural units of the area and we will observe the deformation style of the Cretaceous and Eocene limestones and the Oligocene flysch.

We will also observe how the fractures can enhance the porosity of the low matrix porosity Eocene limestone, looking at an outcrop of folded Eocene limestone (Fig.29).

Finally we’ll see one more oil show inside flysch formation.

Fig. 29 Fold in Eocene limestone

STOP 13: Upper Cretaceous limestone (Fig. 11)

The Upper Cretaceous limestone is expected to be the primary reservoir rock in Western Greece. The profile represents the development in a distal zone of carbonate turbidites. The detrital material (Fig. 30) derived from the adjacent Gavrovo platform.

Fig. 30 Upper Cretaceous limestone

STOP 14: Exploration of the deep subevaporites targets (Fig. 32)

In this stop we will go through the results of the well Demetra-1 which was drilled in 2001-2002. In 1997 this area was granted for exploration to a consortium comprising Enterprise Oil, Texas Union, Hellenic Petroleum and MOL, with Enterprise Oil as operator.

The evaluation of the geological and geophysical data carried out by the consortium, led to the determination of the Demetra prospect, a structural high that is lying below the Triassic evaporites (Fig. 31, et 33). The target of the well Dem-1 was to penetrate the evaporites and to evaluate the H/C potential of the underlying formations. Two models have been proposed for the structural evolution of the area.

In the first case (thin skin model) the sedimentary sequence was affected by compressional deformation which caused a "tectonic doubling" of the thickness, with a decollement surface within Triassic evaporites. In the geological cross section which is presented in the Fig. 4, the Oligocene flysch, the mesozoic to Paleogene carbonates and the underling Triassic evaporite, detached along an intra Triassic detachment from their substratum and transported further west, forming an extensive thrust sheet, overriding the same sequences (autochthonous lower unit). The front of this thrust sheet is located west of the island of Corfu and coincides with the thrust front of the Ionian zone mapped by seismic data. In this case the target of the well is the Cretaceous - Eocene limestones sealed by the evaporites (and probably by flysch or neogene sediments of the autochthonous lower unit).

In the second case, the basement is involved in the deformation. The post- hercynian, Permian paleogeography is ambiguous and difficult to determine. Based on the limited geological data existed in Greece and adjacent areas, we believe that during Permian period a shallow epicontinetal sea was developed in the area of Greece, where carbonate sedimentation occurred. In this hypothesis, shallow water carbonates of Permian age, are the primary targets.

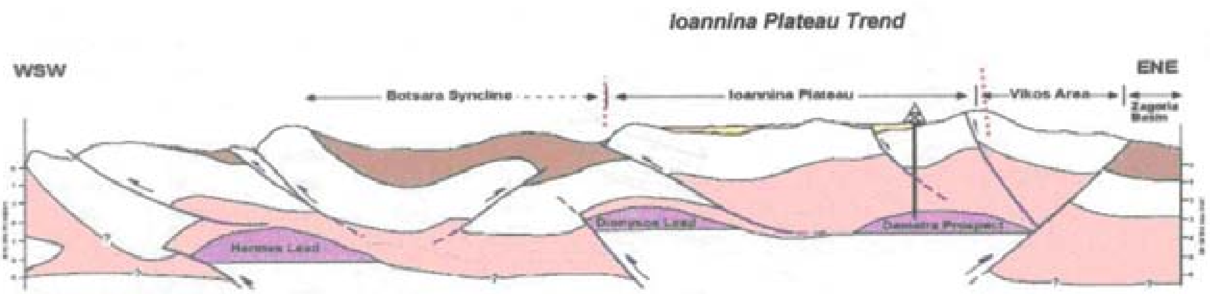


Fig. 31 Sub-evaporites leads and the location of the well Dem-1. (Brown colour: Oligocene flysch, White colour: carbonates-Jurassic to Eocene, pink colour: Triassic evaporites)

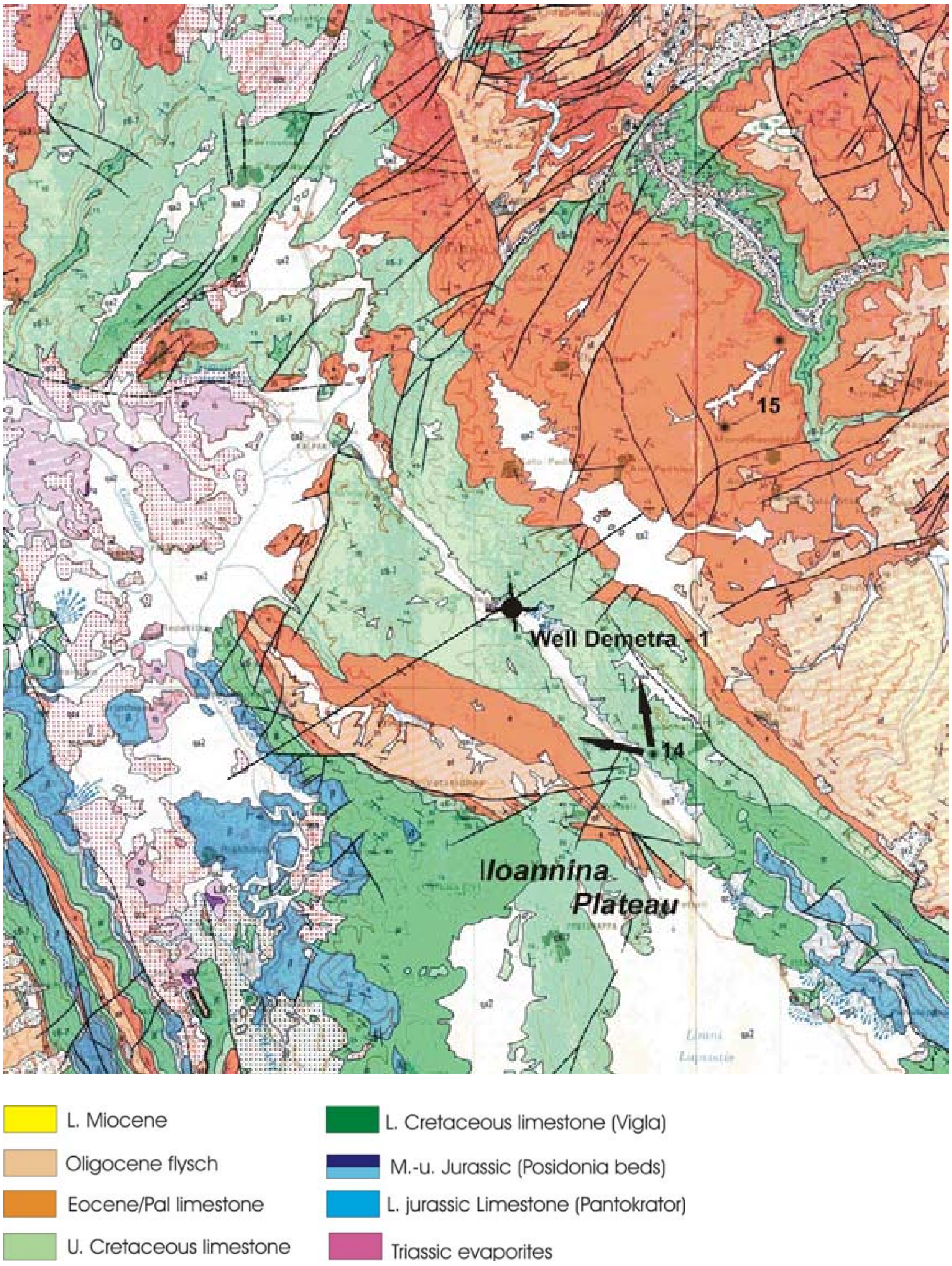


Fig. 32 Geological map of Ioannina area

The well drilled 1897m of Mesozoic carbonates and 2100 m, evaporites (Fig. 34). At the 3966m the well encountered unexpectedly high pressures and after many attempts was suspended, after 5 months of drilling. Consequently, the target to penetrate the evaporitic section and to evaluate the hydrocarbon potential of the deeper plate did not succeed and the prospect remains untested.

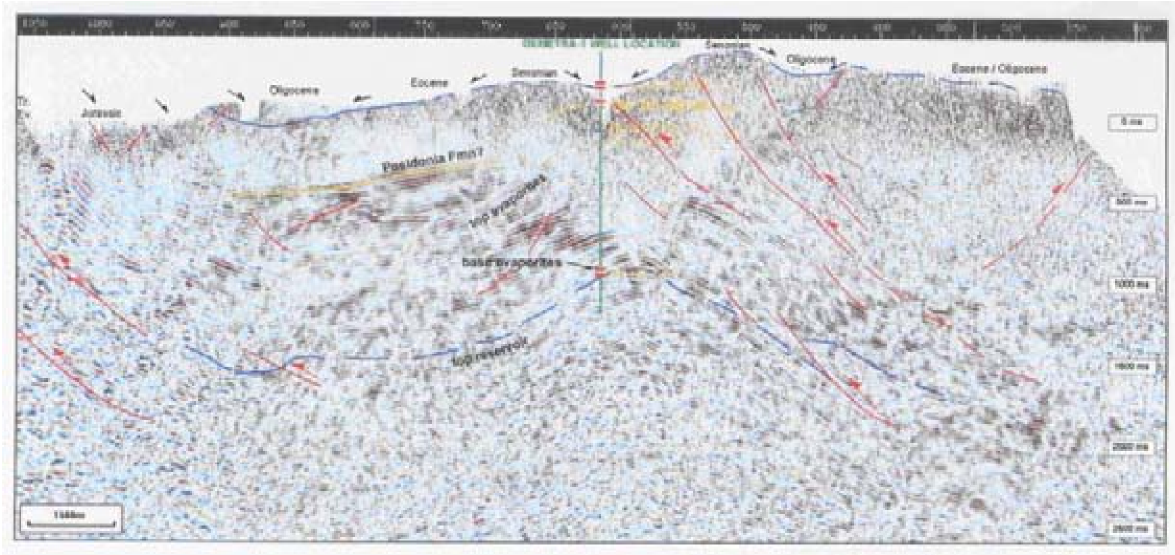


Fig. 33 Interpreted E-W directed seismic line (location in Fig. 32).

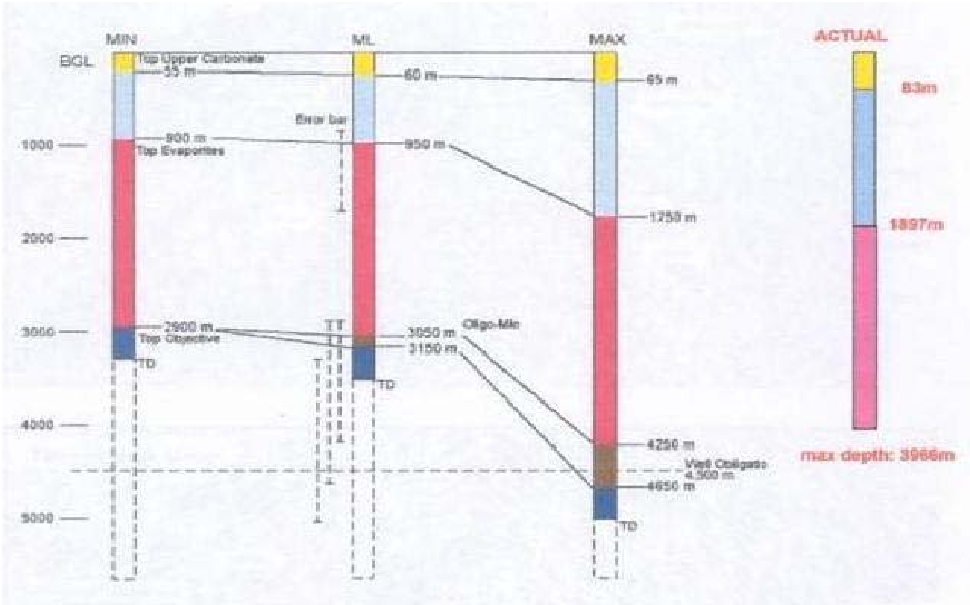


Fig. 34 Well Demetra-1**:** Pre-drill prognosis vs. actual drilled section

<u>STOP 15: Vikos gorge (Fig. 32)</u>

In this stop we will visit Vikos gorge, one of the deepest canyon in the world, in proportion to its width (900 meters deep and 1100 meters wide from rim to rim, Fig. 35).

The sub horizontal Eocene and Upper Cretaceous beds of limestone were eroded by the Voidomatis River and the gorge was formed. Nummulitic limestone and slumps can be observed. To the south, the Eocene limestone is plunged beneath the flysch with dips less than 10° to the south.

Stone houses and monasteries and picturesque stone bridges in the area, fitted to the natural environment.

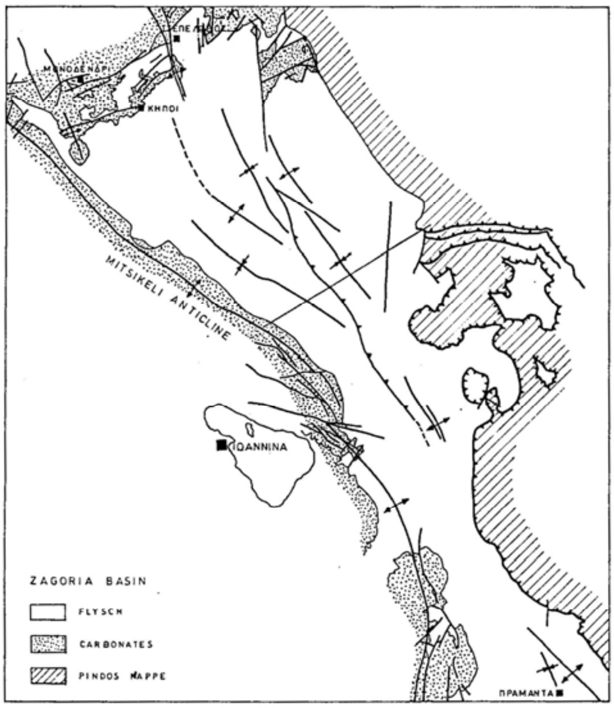
Fig 35 Paleocene – Eocene Limestones in the Vikos gorge.

DAY 4

STOP 16: The Mitsikeli back-thrust and the syncline of Zagoria

The synclinorium of Zagoria includes flysch sediments of Late Eocene to Aquitanian age, which is over 3,000 m thick in the area. The flysch sequence is conformable with the underlying Eocene limestone at the south-eastern edge of the Mitsikeli Mountain. Further to the east, the flysch is thrusted by the Pindos zone. To the west, the Eocene limestone and the flysch are overturned, dipping to the west. This zone of strong deformation is associated with an east-vergent thrust fault (Mitsikeli back-thrust).

A major thrust fault which is followed in the flysch exposures is mapped and forms at depth in the top of the limestone a well defined anticline (Fig. 36).



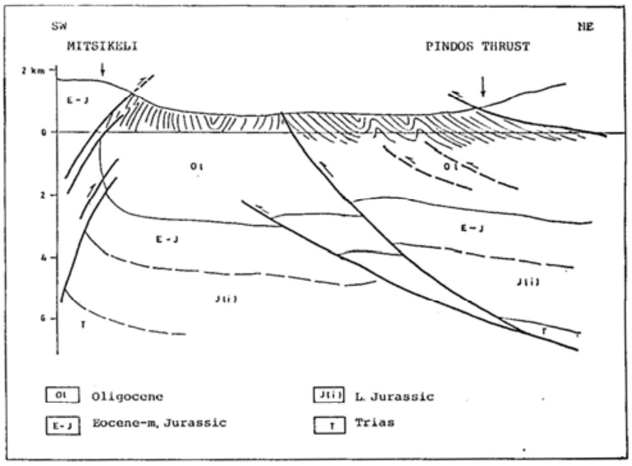


Fig. 36 Geological section across the Zagoria syncline

Fig. 37 Zagoria basin, folds in flysch formation

Fig. 38 The Mitsikeli back-thrust

The Pindos nape

The Pindos nape consists of a stack of thrust sheets with a NW-SE direction. The thrust sheets curved towards west and acquire an E-W direction. The deformational event responsible for the uplift, folding and thrusting of the Pindos Zone took place during Oligocene time Fig.39 (Zouros et al., 1991).

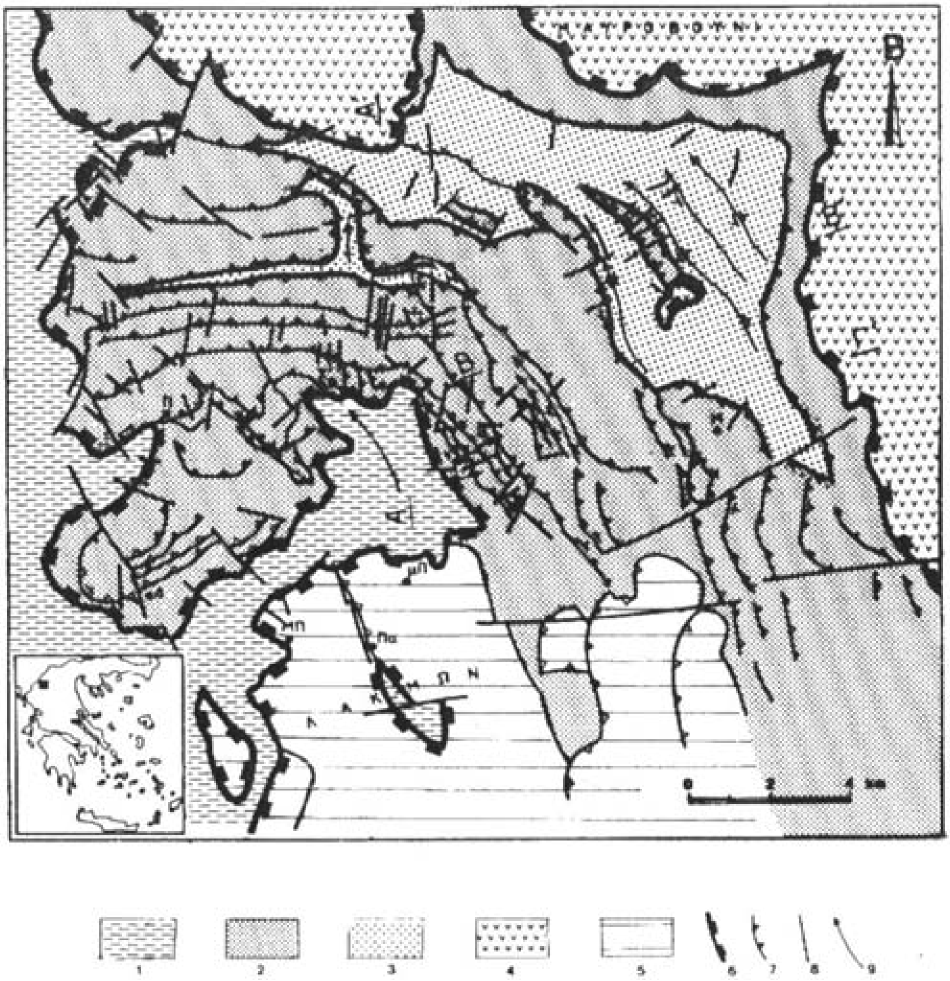


Fig. 39 Geological map of Metsovo area. 1: Flysch of Zagoria, 2: Pindos Flysch, 3: Flysch of Poltses group, 4: Ophiolites, 5: Mesozoic carbonates (Pindos zone), 6: Pindos thrust, 7: imbricated thrusts, 8: faults, 9: axis of anticlines. (Zouros 1991)

<u>***A transverse section from Ioannina to Meteora.***</u>

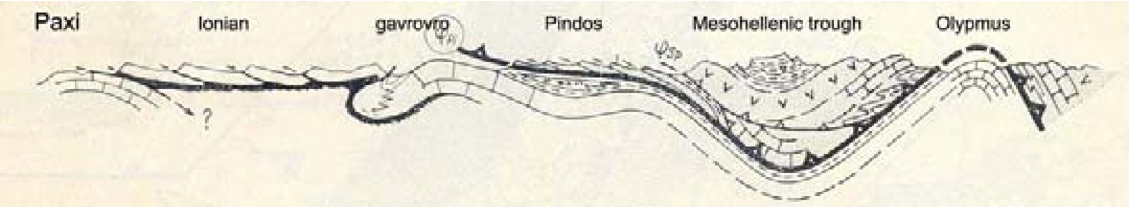


Fig. 40 Schematic cross section through the Hellenides of north continental Greece (Auboin J., 1973).

METEORA

Fig. 41 Panoramic view of the Meteora conglomerates

Meteora conglomerates

The Meteora conglomerates (Aquitanian – Bourdigalian, Fig.41) are exposed at the border of the Thessali plain, at the southern tip of the Mesohellenic basin (Fig.8, 40). Two main kinds of sedimentary bodies are recognised in the Meteora conglomerates: a) wedge shaped bodies which are consistent with an interpretation as a Gilbert – type delta model (Fig. 42) and b) channelled bodies which are perpendicular to the progradation axis of the delta. Tectonics, erosion due to water flow and eolian erosion are considered the responsible mechanisms for the formation of the present geomorphes of Meteora conglomerates. (Dermitzakis et al., 1995)

Fig. 42 Example of a section of Gilbert-type delta

Several monasteries were built on top of the huge, vertical rocks. A short visit to monastery Varlaam, built on 14th centure is scheduled.

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