Central Crete Field trip 2018

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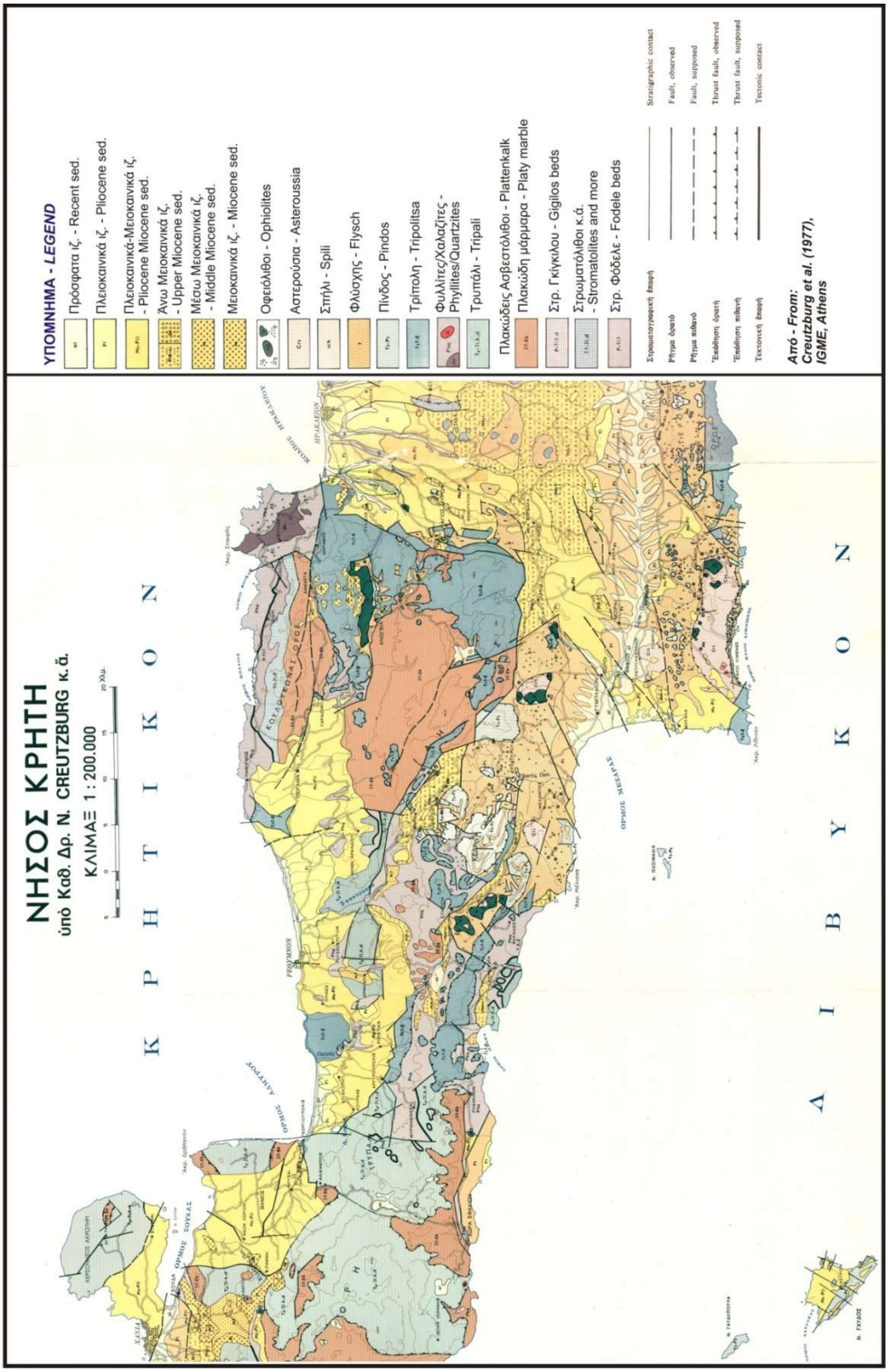


General Geological Map of Crete scale 1:500.000 IGME (1970)

The Geology of Crete

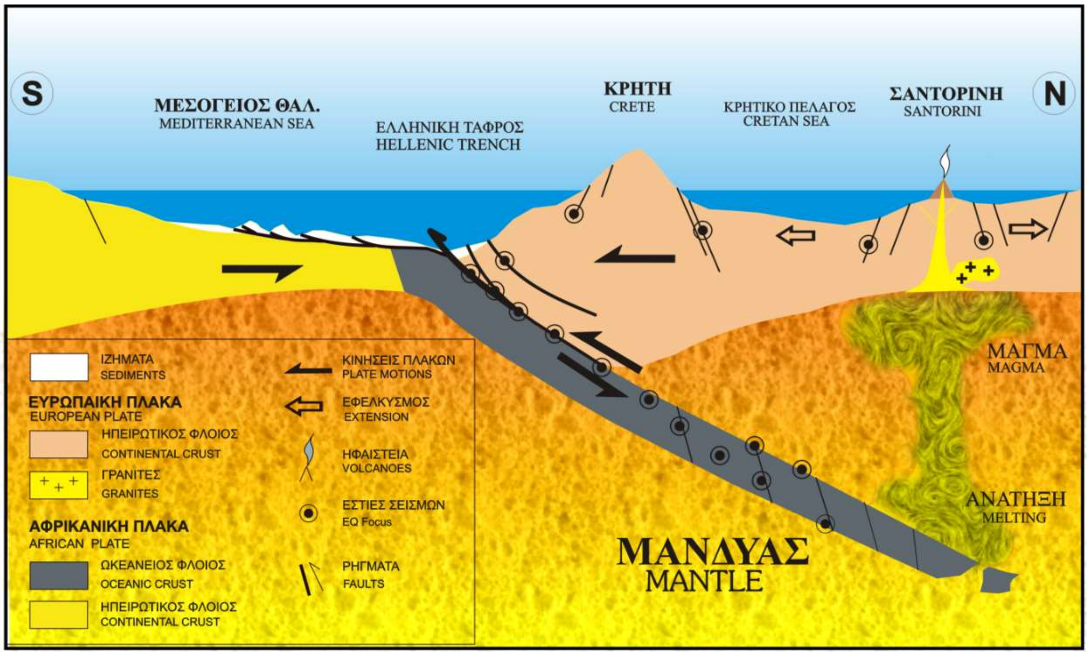
The western Alpine Mountain Chain

Crete is a mosaic of characteristic features which make it unique and special throughout the Mediterranean. It is very well known for its antiquities, its civilization and its biodiversity; it also has however a hidden treasure, its outstanding geological wealth.

It was formed as a part of the Hellenic mountains, the southern continuation of the Alpine chain system. Tectonostratigraphically, Greece is subdivided into several zones that are merged into two groups the internal and external ones. The internal are arranged around the Rhodope massif occurring at the northeastern Greece and Bulgaria , and from east to west are the Perirhodopic rocks, the Servo-Macedonian rocks, the Vardar-Axios Opiolitic belt and Pelagonian massif. Pindos Oceanic basin created the first rocks of the external units, then appear westwards the Tripolitsa rocks, the Phyllite-quartzite rocks (or Arna Unit), the Ionian and Plattenkalk rocks and the pre-Apulia zone cropping out at the Ionian islands to the west. Generally, the external units are the result of the most recent, late Tertiary orogenesis that formed the Pindos mountain chain and its southern continuation in Peloponnese, Crete and Dodecanese islands.

A polymorphic relief has thus been formed on Crete as a result of the physical processes which have been bringing Europe and Africa closer together for millions of years. Natural processes, often violent and extreme such as the catastrophic earthquakes, have created the mountains and the seas, shaping the land of the Aegean and of Crete. Crete, just like all the Greek mountain ranges, is just one link in of a great chain of mountains which were created millions of years ago along with the Alpine orogenesis, the process which built the mountains from the Pyrenees until the Himalayas.

The geological structure of Crete is characterized by the existence of rocks formed before, during and after the Alpine orogenesis. Most of these are the remains of the sediments which fell into the Tethys Ocean, an ancient sea existed between Africa and Eurasia which is now limited to the present day Mediterranean. Some others were islands in the ocean or submarine volcanoes, which were frozen at the great depths.



The present Hellenic subduction zone (From Fassoulas 2000)

The closure and the catastrophe of Tethys, which in the eastern Mediterranean began about 100 million years ago, forged the sediments into hard rocks, it smashed them and cracked them to such an extent that one began to go up and to climb on top of the other. Great groups of rocks, where each one is also a piece of the old Tethys Ocean, were found to cover each over like successive blankets. The nappes, as geologists call them, created the mountain ranges which came up from the sea, about 23 million years ago in the area of Crete and which made the first dry land. A land dry and never ending, which covered all the Aegean, joining with Europe and Asia, and which was called Aegais.

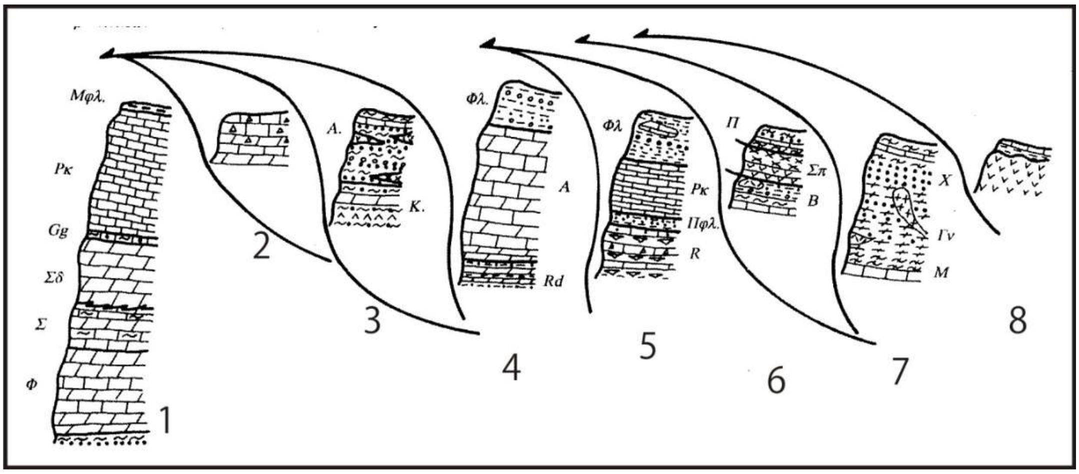
The rocks of Crete

The marine sediments are usually rich in calcium carbonate, and for that reason the rocks of Crete are about 60-70% carbonate in their composition. That is, they are constituted of limestone, dolomite and marbles which are found in nearly all the groups – nappes which form the island.

The spine of Crete is built from rocks called "**Plattenkalk**". This group is constituted mainly by marbles of different ages which form an almost continuous range of rocks age-wise. The oldest ones are approximately 300 million years in age (Permian period), while the younger ones go back until 30 million years before present. Thus at the base we meet schist, where have been found fossils which are scientifically very impressive, such as trilobites and graptolites, white marble and grey dolomite with very well preserved corals and other marine fossils. There follow the multi-colored rocks of stromatolitic dolomite with the reddish lines of the oxidization of iron. They are in reality the same fossilized rocks with those which primitive organisms began to shape on the earth billions of years ago freeing up oxygen into the atmosphere as they also do today in an area of Australia. Above the stromatolitic dolomite follow dolomites, typical white marbles, yellow schist rocks which get their name from mount Gigilos of West Crete and finally the great mass of conventional platy marble (Plattenkalk). In this grey marble, alterations of white and reddish silica materials form thinner or thicker plates which are the characteristic structural material of all the mountain ranges of Crete. These rocks began to be created approximately 140 million years ago and continued until 30 million years ago, when they began to be converted into a thin carbonate metaflysch.

Above the different rocks of the "Plattenkalk" group we will meet all the remaining rocks of Crete. Marbles with characteristic holes and spaces on their interiors which are called "**Trypali**" rocks are found only in western Crete directly above the "Plattenkalk".

In most areas of Crete however the rocks which cover the “Plattenkalk” are the rocks of the group “**Phyllites-quartzites**”. They are rocks which just like the “Plattenkalk” were metamorphosed at a great depth and at great pressure in the interior of the earth during late Oligocene/ early Miocene times. They contain a great variety of rocks, such as typical schist, phyllites, quartzites, marbles and gypsums which were once sediments on the Tethys Ocean. Likewise however, we also meet older volcanic rocks such as andesites and rhyolites which have now also been changed into green schist. But the most interesting rocks of this group however, and the oldest in age which goes back until 380 million years, are the schist of the Siteia area, inside of which there are also interesting minerals such as crystals of garnets.



The Cretan nappes: 1. Plattenkalk series (Φ. Fodele, Σ. Sisses, Σδ. Stromatolithic dolomite, Gg. Gigilos, Pk platy marble, Μφλ. Metaflysch); 2. Trypali unit; 3. Phyllites-quartzite nappe; 4. Tripolitsa nappe (Rd. Ravdoucha beds, A. Carbonates, Φλ. Flysch); 5. Pindos nappe (R. Radiolirites, Πφλ. First flysch, Pk. Platy limestone, Φλ. Flysch); 6. Tektonic mélange (Π. Preveli, Σπ. Spili and B. Vatos groups); 7. Asteroussia nappe (M. Marble, Γν. Gneiss, X. Quartzite); 8. Ophiolites (from Fassoulas et al 1994)

The other rocks which we meet above the “Phyllites-quartzites” in nearly all of Crete are also of carbonate composition, mainly limestone and dolomite of the “**Tripolitsa**” group. Indeed in many areas of the island these rocks immediately cover the “Plattenkalk” without the interference of the “Phyllites-quartzites”. The older rocks of the “Tripolitsa” group are the Ravdoucha schist and black dolomite approximately 250 million years in age, in which fossils of ammonites have been found in the area of Plakias. While the younger ones are flysch rocks which we find in many of the mountain ranges of the island, such as the Asteroussia mountais, which go back as far as 40 million years before present.

The remaining groups (- nappes) of the rocks of Crete are much smaller in extent and spread out around the great mountain masses of mainly central and eastern Crete. They are rocks of the “**Pindos**” group which includes clastic sediments, pelagic limestone, red cherts, radiolarites and large outcrops from flysch rocks. The ages of these rocks are comparable with those of the “Tripolitsa” group, that is, they begin from 250 million years and last until about 35 million years before present.

Above the “Pindos” group in central and south Crete different smaller groups of rocks are found with more characteristics of the “**Arvi**” group with lavas approximately 70 million years in age (Upper Cretaceous), “**Vatos** ” and “**Preveli**” schists, the group of the “**Asteroussia**” from the mountain range of the same name, which are constituted by rocks of intensely metamorphosed schist, gneisses, marbles and also granites with an age of approximately 65 million years. Finally the uppermost group of rocks found in Crete, the “**Ophiolites**”, was formed from submarine volcanic eruptions which took place at the depths of the Tethys Ocean some 140 million years ago.

These groups of rocks, placed one on top of the other, built up the first landmass in the area of **Crete 23 million years ago,** as part of an extended land covering the whole Aegean. The area of Psiloritis is unique throughout the island for playing host to all the rock groups of Crete and to nearly all types of rocks on the island.

Various younger sediments were deposited in the Neogene and more recent basins that were formed due to neotectonic activity. The majority compise of Miocene and Pliocene marine sediments.

The development of its relief

The pile of the rocks (wedge) which the mountain building process (orogenesis), and the convergence of the two plates, created in the area of Crete was not destined to last for long. The more the mountain range at Crete rose up the more unstable it became. The rocks of the "Plattenkalk" and of "Phyllite-quartzite" groups which were covered by all the other nappes reached a depth of greater than 40 km in the Earth, based on the HP paragenesis. Their small density however did not allow them to remain at that depth for long and just like a ball in the sea they bounced up towards the surface, and thus these too, approximately 19 million years ago, began their upwards path towards the surface, reaching surface conditions at about 15 ma.

The unified dry land at the south of Aegais began to break up into smaller pieces at about 12 ma, forming the eastern Aegean and Cretan Sea. Great normal faults began to move up and across the surface rocks, making space for the deepest rocks of the "Plattenkalk" and "Phyllites-quartzites" to reach the surface .

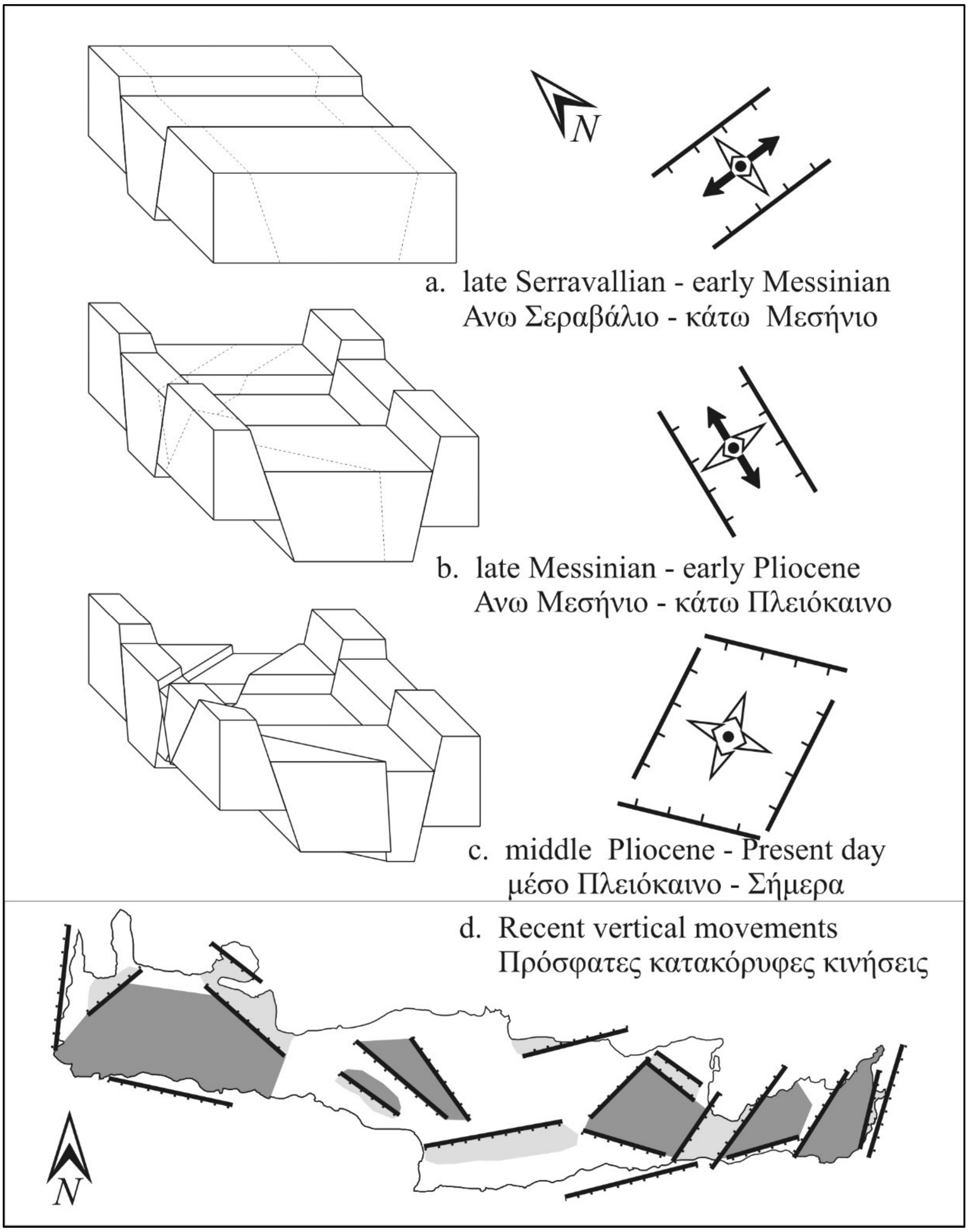
Today, these faults mark out the limits of the mountain ranges and basins in Crete. Due to faulting, the continuous landmass in the area of Crete became after middle Miocene, a mass of small and large islands which continually varied in extent and height for about 10 million years. The sea covered great areas of present day Crete and new, soft sediments were laid out at the depths. Those are the fertile rocks which we meet in the neogene basins of the island and are constituted by marls, sandstone and hard yellow-white limestone, all with an abundance of fossils.

Only for the last two million of years has all of Crete been whole, raised up, and Crete attained the shape which it roughly has today. The studies of the recent sediments of the island have shown that the high mountains of Crete, such as Psiloritis and Lefka Ori, began to be raised, most rapidly just over the last 2 million years at rates of about 1mm/year. This rock uplift process is the reason for the formation in the carbonate rocks of the abundant gorges and the 6000 caves of the island. Some, like in Lefka Ori mountains, exceed 1200m in depth.

Crete however is a place which is always on the move and continually changing. Many of the faults which shattered its rocks in the past are today still active resulting in sometimes moving parts of the dry land upwards and downwards. In many coastal areas of south Crete are to be seen the traces of the movements of the earth with old coast lines having been raised several meters in relation to the present sea level.

The most impressive phenomenon, however, is related with its continuous "journey" towards the south. Present day technology allows us, by using satellites, to measure the slightest movements of every area on the surface of our planet. It has subsequently been found that Crete, just like the whole of the south Aegean, is moving approximately 3 centimeters every year towards the south and likewise is distancing itself from north Greece and Europe. Africa on the other side is coming further north by about one centimeter a year with the result that the two areas, Crete and Africa are coming closer together by about 4 centimeters every year

All of these movements are happening on the faults which appear because of the relative movement of the African plate below the European one with all that it entails. These movements are often accompanied by strong earthquakes which are not infrequent for the island.



The development of Cretan basins (From Fassoulas 2001)

Itinerary

March 27, 2018 Arrival to Crete

16:00 Visit at Natural History Museum of Crete

Dinner at Heraklion

March 28, 2018, Alpine tectonics-Psiloritis UNESCO Global Geopark

<u>08:30 Departure form Hotel</u>

<u>09:00 Stop 1. The Cretan detachment fault</u>

Under the highway bridge an exposure of the fault gouge and shear zones related to the Cretan detachment fault is well demonstrated. Furthermore, the fault is also seen on the mountain slope with Tripolitsa nappe on top of PQ.

<u>09:45 Stop 2. The Almyros Spring</u>

Almyros is a Karstic spring existing on the intersection of Cretan detachment and a normal fault. Has huge capacity and is connected with nearby mountains as well as with Psiloritis Mts

<u>10:15 Stop 3. Short Stop at Voulismeno Aloni Pothole</u>

It is a spectacular circular pothole related with Almyros Karstic system.

<u>11:00 Stop 4. Vossakos folds</u>

Along a 1 km road section, spectacular folds crop out at the Platy marbles of Plattenkalk Unit. Rocks are successively folds in any kind of fold type and also faulted by reverse faults. Folding is related to the early Oligocene subduction process.

<u>12:15 Stop 5. Sfentoni cave at Zoniana (Optional, extra fee of 5 euros))</u>

An impressive and well decorated cave developed in the Tripolitsa Unit just on top ot the Cretan detachment fault.

<u>13:00 Lunch break at Anogia</u>

<u>15:15 Stop 6. Agios Fanourios Detachment fault</u>

At Agios Fanourios the Cretan detachment fault is exposed again, but this time Tripolitsa lies on top of PlattenKalk metaflysh without the existence of PQ unit. Nice shear indicators can be seen on the fault gouge.

<u>16:00 Stop 7. Nida Plateau</u>

View point on the Nida Plateau, the Idaion Andro Cave and Psiloritis mountain. The Plateau has been developed due to a normal fault cutting the slope of Psiloritis and along the Cretan detachment fault.

<u>17:00 Stop 8. Gonies Section</u>

Over the village of Gonies and along a section of about 2 kms the upper nappes of Crete are exposed. From the upper most Ophiolites, a road drives to the lower Pindos, and Tripolitsa nappes.

<u>19:00 Arrival at Heraklion</u>

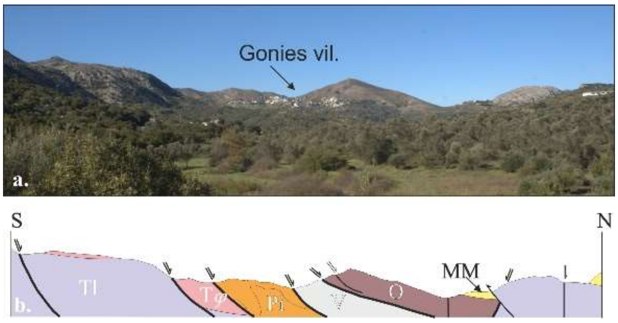
Stoop 1. The fault gouge at Cretan Detachment

Stop 3 The Voulismeno Aloni pothole

Stop 4 Vossakos folding in platy marble

Stop 6 Agios Fanourios Cretan Detachment

Stop 7 Nida Plateau



Stop 8The Gonies section

March 29, 2018 Neotectonics and recent uplift – S. Rethymno area

<u>08:30 Departure form Hotel</u>

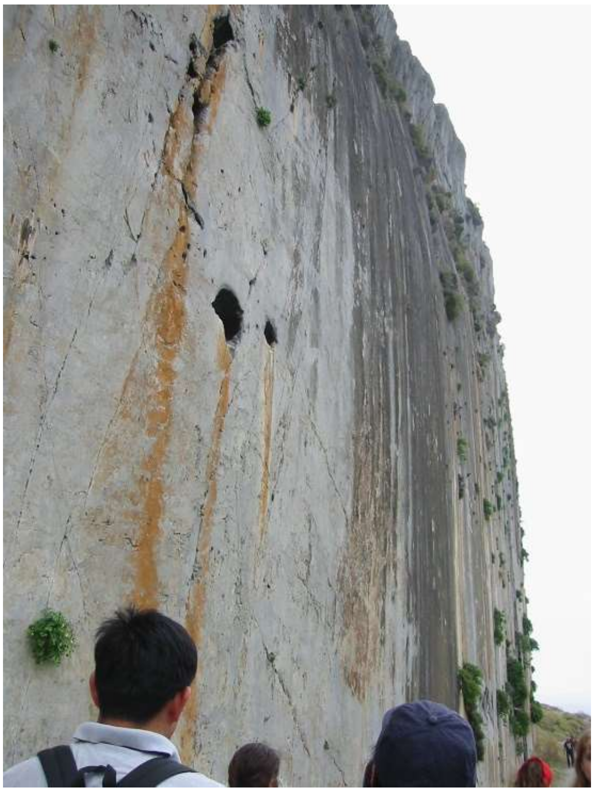
<u>09:00 Stop 9. The PQ Unit at Pantanassa area</u>

Along the highway (needs attention) will see the prevailing deformation of PQ at central Crete (foliation, extensional ductile and semi ductile structures and boudinages) just 100 – 200 meters below Cretan detachment fault.

Stop 9 Boudinage in PQ unit

Stop 10 Fodele Permian fossils

Stop 12 Kourtaliotis gorge and Agios Nickolaos springs



Stop 13 The Plakias fault

Stop 14 Present day and pre-365 AD notches at the Amoudi bay

Stop 15 The impressive, active Spili fault scarp

10:00 Stop 10. Fodele fossils

Along the highway (needs attention), very well preserved Upper Permian fossils can be seen at the base of the Plattenkalk unit. Rocks appear there in an inverted series.

11:15 Stop 11. Lignite section at Spili Basin

Along the regional road appear Upper Miocene sediments of the Spili Basin containing lignite deposits as well as Upper Miocene fossils. Similar rocks can be found further lower on topography in the Plakias basin

12:00 Stop 12. Kourtaliotis gorge and Spring

Kourtaliotis is an impressive gorge developed in the Tripolitsa rocks due to the neotectonic activity at the Plakias basin. Cliffs are very steep and karstic erosion very intense. Gorge continuous at lower topographies forming the Preveli gorge and lagoon at the coast. A big Karstic spring occurs at the riverbed of Kourtaliotis.

13:30 Lunch break at Plakias

15:00 Stop 13. Plakias fault Scarp

The southern edge of Plakias bay is bounded by a big normal fault zones that continues into the sea with impressive fault scarps.

16:00 Stop 14. Amoudi raised beaches

At nearby bay of Amoudi, a sea notch related with the 365 AD 8,2R can be observed over the sea level as well as older marine terraces related with the recent tectonic uplift of the island.

17:00 Stop 15. Spili active fault

Spili is considered one of the most active fault located on the island of Crete. Impressive fault scarps occur near to Spili village, with abundant shear sense indicators. Recent studies have identified at least five successive large ruptures in the last 16500 years.

19:00 Arrival at Heraklion

March 30, 2018 Heraklion Basin development-Cultural visits.

08:30 Departure form Hotel

09:00 Stop 16. Visit at Archaeological Museum of Heraklion (optional, but suggested to hire a tourist guide there)

The Archaeological museum of Heraklion is a magnificent place to see the vast majority of the Minoan Period treasures of Crete, and not only. It has been recently renovated.

11:00 Stop 17. Visit at Knossos Palace (optional, but suggested to hire a tourist guide there)

13:30 Lunch at Archanes village

15:00 Stop 18. Archanes fault and Giouchtas graben

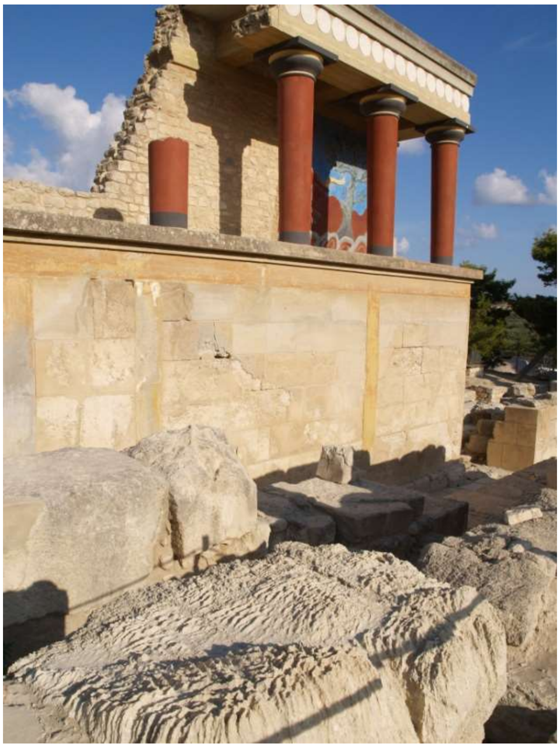
Archanes fault is the east bounding fault of the Giouchtas horst existing within the Heraklion Basin. Horst is intersected by younger northeast-southwest trending normal faults that create the newest depressions.

16:30 Stop 19. Amnissos Santorini tsunami remnants

Near Amnisos exist the minoan “Villa with the lilies”, where Prof Marinatos claimed for first time on the effects of Santorini tsunami in Minoan civilization. Pumice remnants and also possible tsunami deposits can be found on the beach.

18:00 Return at Heraklion


Stop 16 Archaeological Museum of Heraklion


Stop 17 Knossos Palace


Stop 18 Giouchtas horst seen from the west


Stop 19 Amnisos bay

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