The Geological Heritage of Psiloritis

By Dr C. Fassoulas
Psiloritis Natural Park

INTRODUCTION TO THE GEOLOGY OF CRETE

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.

A polymorphic relief has been formed as a result of the physical processes which have been bringing Europe and Africa closer together for millions of years. These two lithosphere plates are like boats swimming in the molten lava of the interior of the earth which destroy everything in their passing. Natural processes, often violent and extreme such as the catastrophic earthquakes, have shaped 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, a most ancient sea 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 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 sunken 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 schists, 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 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 flysch.

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 mainly 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. They contain a great variety of rocks, such as typical schists, 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 following 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 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, 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 platy limestone, red 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 "**Spili**" group, with lavas approximately 70 million years in age (Upper Cretaceous), 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. 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.

The forming of its relief

The pile of the rocks 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 Earth's crust, as stable as it may seem (since it is made up of solid rocks), becomes so sensitive and changeable in the scale of geological time.
The more the mountain ranges of Crete went up the more unstable it became. In addition a special and rare phenomenon took place in the bowels of the Earth. The rocks of the "Plattenkalk" and of "Phyllite-quartzite" groups which were covered by all the other groups reached a depth of greater than 30 km in the Earth. 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 15 million years ago, began their upwards path towards the surface.
The unified dry land at the south of Aegais began to break up into smaller pieces, and great 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. Thus the continuous landmass in the area of Crete became 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 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 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, began to be raised, most rapidly just over the last 6-7 million years.
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 other times horizontally 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. 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.

Limestone and Water
As was mentioned, the rocks which are the main ones on Crete are mainly of carbonate composition (limestone, dolomite and marbles). These rocks have an even greater extent on Psiloritis and indeed cover more than 80% of the total mass of the rocks.

Even if in most of the areas the carbonate rocks are hard and compact, these behave in a special way in relation to the water. The surface water passes through the atmosphere and joins with the carbon dioxide and is converted into carbonate acid which while doing no harm to the vegetation does however dissolve the carbonate rocks like sugar.

Many forms in the relief of Crete and especially on Psiloritis are related with that special form of erosion of carbonate rocks known as karstic. A host of surface depressions which are continually being made larger from the continual erosion create the plateaus and the dolines which characterize the Cretan mountains. Sinkholes and potholes lead the water from the surface to the interior of the rocks continuing their dissolving activity underground, carving out caves and other underground cavities. At present on Crete more than 5000 underground cavities have been recorded, many of which are most impressive and unique. Some for the beauty of their decoration (such as Sfentoni at Zoniana), others for their unique species which they play host to (such as that of Agia Paraskevi at Skoteino), others for their depth (such as Gourgouthakas in the Lefka Ori mountains and Tafkoura on Psiloritis) and still others for their historical and archaeological worth (such as the Idaion Andro on Psiloritis and the Diktaion Andro on Dikti mountains, Gerontospilios at Melidoni and that of Kamares on Psiloritis).

The dominance of the carbonate rocks does not however allow the water to move on the surface since it is all lost in the interiors of the Earth and shapes subterranean rivers through the caves. Thus, and even if very few rivers are to be found on the surface of Crete, there are uncountable subterranean rivers which end up in the sea or which feed the springs at the base of the mountains. Indeed it has been found that the water that falls on the plateau of Nida of Psiloritis can, within 9 hours underground, reach the biggest but unfortunately brackish spring of Crete, the Almyros in Heraklion. In the same way all the interior of the carbonate mountains is turned into subterranean reservoirs where the water from the winter snow or from the rain is stored for the dry summer months.

In the creation of the relief of Crete, however, the interactive activity of the carbonate rocks with the continuous upraising of its mountains played a very important role. The water on the surface of the Earth always has the tendency to arrive quickly at the sea in order to neutralize its dynamic energy which it gets from its height. Thus it digs out the rocks even more deeply and the continuing rising of the mountains of Crete re-enforces this action of the water. As the mountains go up it digs continually deeper in order to approach the sea. In combination with the karstic erosion the water has created the deep gorges which cross the mountain ranges in order to end up in the plains and the valleys. Indeed in the same way it made the deep caves of Gourgouthakas (-1100 meters) and Tafkoura (-900 metres) on the Lefka Ori and on Psiloritis mountains.

Psiloritis Natural Park

Psiloritis Geopark

Geotopes are very special areas in respect to the rocks occurring there, the minerals or the fossils that can be found within them, the shapes of the rocks and the landscape, as well as the physical processes that affect them. These geotopes comprise the geological heritage of each territory. The number and variety of the geotopes characterize the geodiversity of the territory in the same way as the biodiversity.

The variety and value of Psiloritis geotopes is of great importance and was the main reason for the Psiloritis Natural Park to be included, in 2001, in the European

Geoparks Network and more recently in the list of the UNESCO Global Geoparks Network.
According to the European Geoparks' charter, geotopes and the geological heritage of an area are not only supposed to be protected and promoted, but are also valuable tools that can be used together with the rest of the natural wealth and human resources of the area in order to establish a sustainable development model in their territories
Psiloritis Natural Park, with the support of AKOMM "Psiloritis" S.A. and the scientific assistance of the Natural History Museum of Crete, systematically works to achieve these goals as a European geopark and this publication is one of these activities aiming to enhance its geological heritage. The park extends from the northern coast and the Kouloukonas (Talea Ori) mountains to the Messara and Amari basins in the south and west, covering the broad Psiloritis mountain chain.
The park includes all the unique elements of the natural environment of Psiloritis Mountain, the rich geological heritage, its wild nature and the unique culture and history of the area. A large part of the Park is participating in the European NATURA 2000 Network, whereas many other areas are characterized as Wild Life Reserves or Special Protection Areas for Birds. Additionally, many of the old settlements are designated as Traditional Villages.
Within the boundaries of the park are to be found many other interesting and important historical or cultural sites of Greece, such as the Idaion Andro cave, the Minoan settlement of Zominthos, the classical town of Eleytherna, the Arkadi monastery and many others of local importance.

Psiloritis' geodiversity
Psiloritis is an elongated mountain chain running along the central part of Crete, dominating approximately 2.5 kms over sea level. Huge cliffs rise up from lowlands at the southern and eastern parts, all formed by the activity of large faults which delimit the mountains from the plains. The northern extension of Psiloritis, the Kouloukonas Mountains seem to dip abruptly into the Cretan sea. Only the western part gradually comes down towards the Rethymno area.
Within the approximately 1100 square kilometers of Psiloritis Natural Park almost all the geological variety of Crete is to be found together. The majority of the nappes of Crete occur around the highest peaks, where the typical "Plattenkalk" group is exposed. In many place, such as in the vicinity of Gonies village, the large variety of all these rocks is concentrated in a very small area, which could indeed be regarded as a miniature of Crete itself.
Some very peculiar and rare rock types are also present in the area like the Ophiolites or the deepest rocks of the "Plattenkalk" group at Kouloukonas. However, it is the platy marble (plattenkalk in German) of Psiloritis that outline both the landscape and the human presence through the individual stone architecture in the mitata, the terraces and threshing floors.
Σχόλιο [ΔΠ1]: P3140122.jpg
Everywhere in the mountain karstic erosion has formed a unique landscape, which is rare for the rest of the world, and karstic structures such as the individual shapes of limestone rocks, the abundant plateaus, caves and gorges. In each of these structures life has adapted and developed special features, and some species that live only in these areas or which survive only there.
The presence on Psiloritis of the two main carbonate groups of Crete, i.e. the underlying "Plattenkalk" and the overlying "Tripolitsa" regulate the water cycle and the presence of life. In many areas at the eastern and southern parts of the Park (Livadia Kroussona, Petradolakia, Rouvas, Fourfouras etc.), a thin layer of the

argillaceous “Plattenkalk” metaflysch prevents water from escaping from the upper limestone to the lower “Plattenkalk” marbles. In such a way many small springs are created, of which very few are able to provide adequate quantities of water all year round, but which all create small oases in the limestone desert of the mountain.
The formation of the mountain and its landscape is a continuous and never ending process that even nowadays is reshaping the mountain. The tremendous forces of the Earth which created land in the past and raised up the mountains to their present altitude are depicted on the numerous faults and folds of the rocks. Life that at its very end was trapped as fossils in the rocks proves the statement of the ancient philosopher Heraclites: “…where today is sea, tomorrow might be land, and where mountains occur tomorrow might be ocean. Everything changes…”.
Fossils are found everywhere, from the rocky high mountain to the Neogene rocks in the surrounding basins. These comprise shells, fishes, Sea Urchins and the Sea Cows (Sirenia). The most impressive and rare, however, are the Fodele “high pressure” fossils (corals, brachiopods, and bivalves) that lived 300 million years ago, pressured by the tremendous forces and heat that was produced during the formation of the mountains 30 million years ago and which today occur within high pressure metamorphosed rocks.
All this wealth of the landscape and Earth which is concentrated on Mount Psiloritis, with its great variety in shapes and combinations, together with man who loved this place and adorned it with his creations and activities, constitute the geodiversity of the mountain. It is a heritage of the Earth itself and its processes that till recently only shepherds and rare travelers could admire.
Today, through the Psiloritis geopark, this natural heritage is under protection and enhancement and is used as another tool for the sustainable and responsible development of this area.

Wild life in the Park

Dozens of caves and potholes, numerous dolines and sinkholes, countless smaller and larger gorges and the great altitudinal variety of Psiloritis mountain, lead to a wide variety of biotopes, sometimes with special local climatic conditions. This diversity of life on Psiloritis combined with the isolation of the Cretan island forms an area of high biodiversity and endemism, which is unique for Greece. The biological importance of the area was the reason why many parts of the mountain were included within the NATURA 2000 network.
High altitude areas on Psiloritis are covered by phryganic vegetation, with a predominance of characteristic “pillow” shaped dwarf shrubs. Trees are scarce due to intensive grazing and high altitudes. Kermes Oak (*Quercus coccifera*) and Cretan Maple (*Acer sempervirens*) are the dominant trees. Oaks are very common as bushes, or “katsoprinia” (the overgrazed dwarf form), or even as bigger trees (when they have managed to escape grazing). Greek Spiny Spurges (*Euphorbia acanthothamnos*), Narrow-leaved milk-vetch *(Astragalus angustifolius),* Cretan milk-vetch (*Astracantha cretica),* are all cushion-like dwarf shrubs on the high altitude plateaus of Psiloritis, while Cretan Barberry (*Berberis cretica)* forms slightly taller bushes. In the lowlands Kermes Oak, Cretan Maple and Cypresses form small forests such as in the Rouvas or Arkadi area, while agricultural activities related to olive trees occur.
Many phryganic and annuals of Psiloritis are endemic to Crete, and indeed some are found only on Psiloritis (stenoendemic). *Horstrissea dolinicola* (one of the four endemic genera of Greece) grows only in small plateaus around Skinakas. *Tulipa doerfleri*, *Crocus oreocreticus* and *Polygonum idaeum*, are all Cretan endemics

common on the Nida plateau. In many places different orchid species occur, the most important of them, the Cretan Cephalanthera (*Cephalanthera cuculata*) which is a vulnerable species, occurring in the mountain areas of Gergeri and Kamares. The aromatic and pharmaceutical plants of the park are also well known, such as Cretan Dittany or "erontas" (*Origanum dictamnus*).
The fauna of the park is also of great importance. On Psiloritis, one of the last surviving populations of the Cretan Wild Cat (*Felis silvestris creticus*), a "phantom" animal for zoologists and researchers of the Cretan wild life, is to be found. Till the mid 90's, the animal was known only through vague hunter's and shepherd's tales. Recently, however, after an intense investigation by the Natural History Museum of Crete, the presence of the Cretan Wild Cat was scientifically confirmed at the southern steep cliffs of the mountain.
Many invertebrates and most amphibians and reptiles of Crete are living in the Park. All the Cretan mammals are also present here. Cretan Argus (*Kretania psylorita*, a small endemic butterfly) is quite common on the plateau of Nida, as well as the Cretan shrew (*Crocidura zimmermanni*), which is a "living fossil" and the only Greek endemic mammal! Furthermore, many birds are to be found inhabiting the area, such as the Bearded Vulture (*Gypaetus barbatus*) an endangered species in Europe. The Cretan population of the species is one of the few surviving in southern Europe and thus of great importance.

Man and Stone
On Psiloritis, man and his civilization were based on these special mountain features and its unique ecosystems in order to survive throughout the centuries. Cattle raising, agriculture, hunting, bee-keeping, craft, arts, and architecture are only some of the human activities that have blossomed since Minoan times.
The close relations between humans and the mountain are obvious in the "stone architecture" to be observed everywhere in the Park. The abundance of the square shaped stone marble has constituted the main element of construction throughout the ages all around Mount Psiloritis.
The unadorned usage of the stone which is observed both in the giant blocks of the walls of Zominthos, and in the stone terraces and shepherd's constructions, as well as those characterized as "traditional villages" occurring at the lowland of the mountain, is the dominant architectural feature.
The most outstanding examples of this architecture are the mitata, which are only to be found on Mount Psiloritis. These are circular in shape like the Minoan tombs, completely bioclimatic and dry, even without the presence of joining material and are well adapted to the landscape and environment, serving the needs both of the shepherds and also of the seasonal travelers.
A typical construction consists of two buildings, one without an entrance in order to mature the cheeses, and a yard in which to keep sheep and goats during milking. The circular ground plan and their simple appearance reflect both the communal way of life for the shepherds and the collective team spirit that characterizes the whole area of Mount Psiloritis.