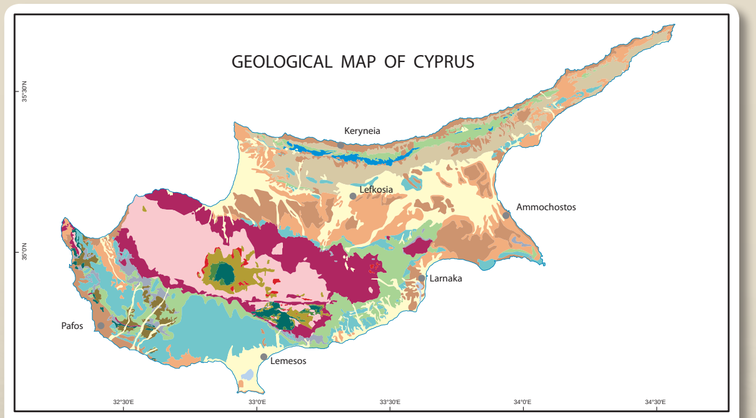
CYPRUS GEOLOGICAL SURVEY

Ministry of Agriculture,
Rural Development and Environment

GEOLOGY OF CYPRUS



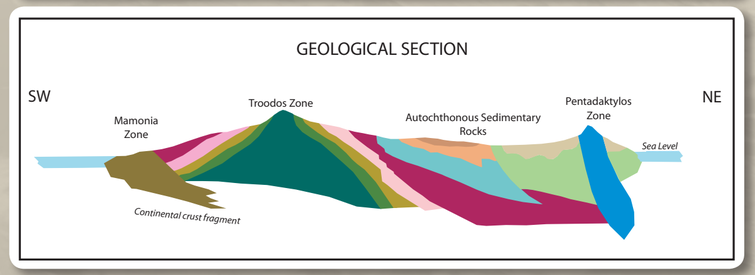
LEGEND

SEDIMENTARY FORMATIONS

Alluvium - Colluvium	*HOLOCENE*
Terrace Deposits, Fanglomerate	*PLEISTOCENE*
Apalos and Nicosia Formations	*PLIO-PLEISTOCENE*
Kalavasos and Pakhna Formations	*MIDDLE-UPPER MIOCENE*
Kythrea Formation	*MIDDLE - UPPER MIOCENE*
Lefkara, Kalogrea-Ardana and Lapithos Formations	*MAASTRICHTIAN - LOWER MIOCENE*
Kathikas, Moni, Kannaviou and Perapedhi Formations	*CAMPANIAN - MAASTRICHTIAN*
Hilarion, Sykhari, Dhikomo and Kantara Formations	*PERMO-CARBONIFEROUS TO LOWER CRETACEOUS*
Mamonia Complex	*TRIASSIC - LOWER CRETACEOUS*

TROODOS OPHIOLITE (Upper Cretaceous)

Upper and Lower Pillow Lavas and Basal Group	*VOLCANIC SEQUENCE*	
Sheeted Dyke Complex (Diabase)	*INTRUSIVE SEQUENCE*	
Plagiogranite	*CUMULATE SEQUENCE*	*PLUTONICS*
Gabbro		
Dunite, Wehrlite and Pyroxenite		
Harzburgite and Serpentinite	*MANTLE SEQUENCE*	



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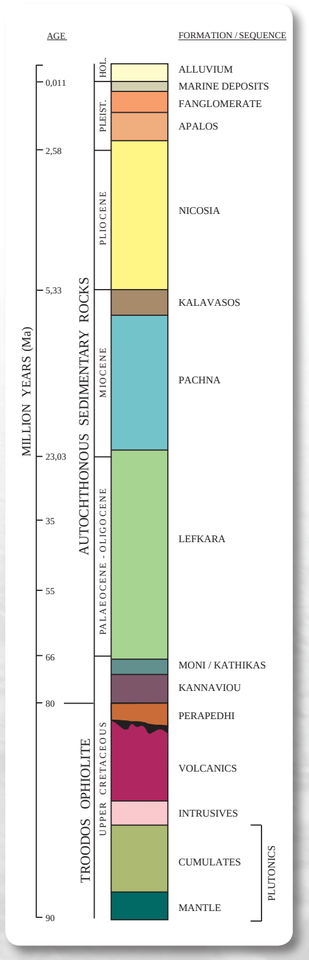

The geological structure of Cyprus

Cyprus is divided into four geological zones: (a) the Pentadaktylos (Keryneia) Zone, (b) the Troodos Zone or Troodos Ophiolite, (c) the Mamonia Zone or Complex and (d) the Zone of the autochthonous sedimentary rocks.

The **Pentadaktylos (Keryneia)** Zone is the northern-most geological zone of Cyprus and is considered to be the southern-most portion of the Tauro-Diranide Alpine Zone. It has an arciform disposition with an east-west direction and is characterised by southward thrusting. The base of the Zone is mostly composed of a series of allochthonous massive and recrystallised limestones, dolomites and marbles of Permian-Carboniferous to Lower Cretaceous age (350-135 Ma). These are stratigraphically followed by younger autochthonous sedimentary rocks of Upper Cretaceous to Middle Miocene age (67-15 Ma), on which the older allochthonous formations have been thrust southward.

The **Troodos Zone or the Troodos Ophiolite** dominates the central part of the island, constitutes the geological core of Cyprus, appears in two regions (main mass of the Troodos mountain range and in the Limassol and Akapnou Forests south of the range) and has a characteristic elongated dome structure. It was formed in the Upper Cretaceous (90 Ma) on the Neotethys sea floor, which then extended from the Pyrenees through the Alps to the Himalayas. **It is regarded as the most complete and studied ophiolite in the world.** It is a fragment of a fully developed oceanic crust, consisting of plutonic, intrusive and volcanic rocks and chemical sediments. The stratigraphic completeness of the ophiolite makes it unique. It was created during the complex process of oceanic spreading and formation of oceanic crust and was emerged and placed in its present position through complicated tectonic processes relating to the collision of the Eurasian plate to the north and the African plate to the south. The stratigraphy of the ophiolite shows a topographic inversion, with the lower suites of rocks outcropping on the highest points of the range, while the stratigraphically higher rocks appear on the flanks of the Troodos massif. This apparent inversion is related to the way the ophiolite was uplifted (diapirically) and then differentially eroded. The diapiric uplift of its core took place in many episodes with more intense uplift taking place in the Pleistocene (2.6 Ma).

The **Mamonia Zone or Complex** appears in the Pafos district in the southwestern part of the island. It constitutes a series of igneous, sedimentary and metamorphic rocks, ranging in age from Middle Triassic to Upper Cretaceous (230-75 Ma). These rocks, which are regarded as allochthonous in relation to the overlying autochthonous carbonate successions and the Troodos ophiolite rocks, were placed over and adjacent to the Troodos ophiolite during the Maastrichtian.

The **Zone of the autochthonous sedimentary rocks**, ranging in age from the Upper Cretaceous through the Pleistocene (67 Ma to recent years), covers the area between the Pentadaktylos and Troodos Zones (Mesaoria) as well as the southern part of the island. It consists of bentonitic clays, volcaniclastics, marls, chalks, cherts, limestones, calcarenites, evaporites and clastic sediments.

GEOLOGY OF CYPRUS

The Troodos Ophiolite

The Troodos Ophiolite consists of the following stratigraphic units, in ascending order: **Plutonics** (mantle sequence and cumulates), **Intrusives, Volcanics and Chemical sediments**.

The **mantle sequence** is thus termed because the rocks that form this suite are considered to be the residuals after the partial melting of the upper mantle and the formation of basaltic magma, from which the remaining rocks of the ophiolite have been derived. It is mainly composed of harzburgite and dunite with 50-80% of the original minerals altered to serpentine, and serpentinite (with or with-out concentrations of asbestos) where the alteration is almost complete.

The **cumulate rock**s are the products of crystallisation and concentration of the crystals at the floor of the magma chamber, beneath the zones of sea floor spreading. The main cumulate rocks include dunite with or without chromite concentrations, wehrlite, pyroxenite, gabbro and plagiogranites, which are observed in small discontinued occurrences.

The **Intrusive rocks** (Sheeted Dyke Complex - Diabase) have a basaltic to doleritic composition and were formed by the solidification of the magma in the channels, through which it intruded from the magma chambers at the bottom of the oceanic crust, feeding at the same time the submarine extrusion of lava on the sea floor. The Sheeted Dyke Complex is followed by a suite of **volcanic rocks** that consist of two series of pillow lavas and lava flows, mainly of basaltic composition. The pillow lavas have a characteristic spherical to ellipsoidal pillow shape, 30-70 cm in diameter, which were formed as a result of submarine volcanic activity. Between the intrusive rocks and the pillow lavas a transitional zone known as the Basal Group occurs. Dykes dominate the Basal Group while pillows are less common.

The **Pera Pedhi Formation** is composed of umber (chemical sediment), radiolarites and radiolaritic shales. These were the first sediments to be deposited over the ophiolite rocks as a result of hydrothermal activity (hot solutions rich in Fe and Mn) and sedimentation on the sea floor.

Contact between gabbro (oceanic crust, close view) and harzburgite (mantle, distant view)

Pillow lavas with the characteristic spherical to ellipsoidal pillow shape

The Autochthonous Sedimentary Rocks

The sedimentation in the geological history of Cyprus started 80 Ma in a deep sea which becomes gradually shallower. The sedimentation begins with the deposition of the **Kannaviou Formation** (bentonitic clays, volcaniclastics), followed by the deposition of the **Moni and Kathikas Formations**. Carbonate sedimentation begins 65 Ma with the deposition of the **Lefkara Formation**, which includes pelagic marls and chalks with characteristic white colour, with or without cherts. The Lefkara Formation is followed by the **Pakhna Formation** 22 Ma, which consists mainly of yellowish marls and chalks. The colour of the rocks, the presence of calcarenitic layers and the occasional development of conglomerates are characteristics that differentiate the Pakhna from the Lefkara Formation. Sedimentation of the Pakhna Formation began and terminated in shallow-water environment with the development of reefal limestones (Terra Member at the base and Koronia Member at the top of the Formation).

The deposition of the evaporites of the **Kalavasos Formation** (6 Ma), was the result of the isolation of the Mediterranean Sea from the Atlantic Ocean and the subsequent evaporation of its waters. The Formation is composed of gypsum and gypsiferous marls that cover extensive areas.

Upon the reopening of the Gibraltar Strait and the reconnection of the Mediterranean Sea with the Atlantic Ocean, a new cycle of sedimentation began (5 - 2 Ma). The **Nicosia Formation** was deposited first and contains grey and yellow siltstones and layers of calcarenites and marls. Upwards it consists of calcarenites interlayered with sandy marls **(Athalassa Member)**. They follow the **Apalos and Fanglomerate Formations**, which consist of clastic river deposits (gravels, sand and silt).

Lefkara Formation

Gypsum outcrop

Nicosia Formation calcarenite

The Mamonia Zone

The Mamonia Zone is named after the village of Mamonia in Pafos, where classic outcrops of the Zone occur. It consists of a series of allochthonous volcanic, sedimentary and in smaller proportion metamorphic rocks that were formed 230-75 Ma and it includes the following:

I. Volcanic (lavas) and sedimentary rocks (recrystallised limestones) of the Diarizos Group.
II. Pelagic sedimentary rocks (limestones, mudstones and quartzitic sandstones) of the Agios Photios Group.
III. Metamorphic rocks (schists and marbles) of the Agia Varvara Formation. These rocks were derived from the metamorphism of the Diarizos Group.

The rocks of the Mamonia Zone have been intensely deformed and mixed with large fragments of the Troodos ophiolite rocks foming extensive zones of melange.

The Pentadaktylos Zone

The three main geological formations aged between 250 and 135 Ma are the **Dhikomo, Sykhari and Hilarion Formations**, which form the main carbonate masses of the Kyrenia Range. The Dhikomo Formation consists of deformed thinly bedded limestones with layers of grey and green phyllites. The Sykhari Formation is composed of massive to thickly bedded dolomitic limestones. The Hilarion Formation consists of medium-bedded to massive limestones, which were subjected to a very low degree of metamorphism. These formations were placed southward over the younger autochthonous marine sediments, which are known as the Lapithos, Kalogrea-Ardana (Belapais) and Kythrea Formations. Impressive and continuous outcrops of limestones occur in the central part of the range, whereas in the eastern part they occur in the form of olistholiths over the younger sediments. These limestones (olistholiths) are referred to as the **Kantara Formation** aged between 350 and 250 Ma.

The Mineral and Groundwater Resources

Directly associated with the Troodos ophiolite are the massive **sulphide, chromite and asbestos mineral deposit**s. These ore deposits were formed in different stratigraphic units of the ophiolite (lavas, dunite and harzburgite, respectively) and came to the surface as a result of its uplift. The exposure of the ore bodies to the surface, and especially that of massive sulphides, resulted in the discovery and exploitation of copper since the ancient times.

Cyprus has also significant **industrial mineral deposits**. The main industrial minerals include gypsum (used in the cement production), brick clays, umber, ochre and terra verte (natural pigments), marls, chalks and reef limestone (cement production), bentonitic clays (various industrial uses), building and decorative stone, celestite and magnesite.

The construction and building industry require use of aggregates (gravel and sand) and armourstones for marine works. Today, the production of aggregates is derived from the crushing of diabase, reefal limestone and calcarenite and for armourstone from carbonate rocks.

The **groundwater resources** of Cyprus depend mainly on rainfall and the ability of the aquifers to store and transmit water. The main aquifers develop in areas of clastic deposition and chiefly in broad valleys and river deltas. Such aquifers are those of western and eastern Mesaoria, Akrotiri and Pafos. Aquifers also develop in porous rocks such as calcarenites, in limestones and gypsum and in fractured rocks of the Troodos ophiolite, especially in the gabbros.

Folded strata of the Mamonia Zone. Folds are quite common in the Zone due to the high degree of deformation

The Pentadaktylos mountain crest

Hilarion Formation limestones

The Phoenix copper mine

Diabase quarry

The geological evolution of Cyprus

The genesis of Cyprus took place through a series of complex tectonic processes in the broader context of the subduction of the African plate under the Eurasian plate. Thus, about 90 Ma, a new oceanic crust was created, part of which was cut off and later formed the Troodos ophiolite. About 75 Ma, older rocks (230 to 75 Ma) of the African plate have been thrusted onto the ophiolite and are currently found mainly in the southwestern part of the island. Then a period of relative tectonic inactivity followed that lasted up to 10 Ma, resulting to the deposition of a sequence of carbonate sediments, in progressively uplifted area.

About 6 Ma, a series of allochthonous limestones, aged between 350 to 135 Ma were thrusted over the northernmost flanks of the Troodos Ophiolite, forming the Pentadaktylos range. At the same time, the Mediterranean Sea was isolated from the Atlantic Ocean resulting to intense evaporation, drastic sea level drop and salinity increase resulting in gypsum and salt deposition throughout the Mediterranean region, with thickness of up to 3 km. These rocks form today the impermeable layer (trap), beneath of which the hydrocarbon reserves of the eastern Mediterranean are found.

The reopening of the Gibraltar Strait, reconnected the Mediterranean Sea with the Atlantic Ocean, 5,3 Ma, and caused its flooding and the quick rise of the sea level, thus resulting in the deposition of marls and calcarenites. During the last 2,6 Ma, there was an abrupt uplift of the Cyprus area where in this period the Troodos and Pentadaktylos ranges were gradually uplifted to their current position. The abrupt uplift, combined with intense rainfall, resulted in extensive erosion of the ranges, particularly that of Troodos, and the transportation of large quantities of clastic sediments that were deposited in river valleys developing the most important aquifers of Cyprus.