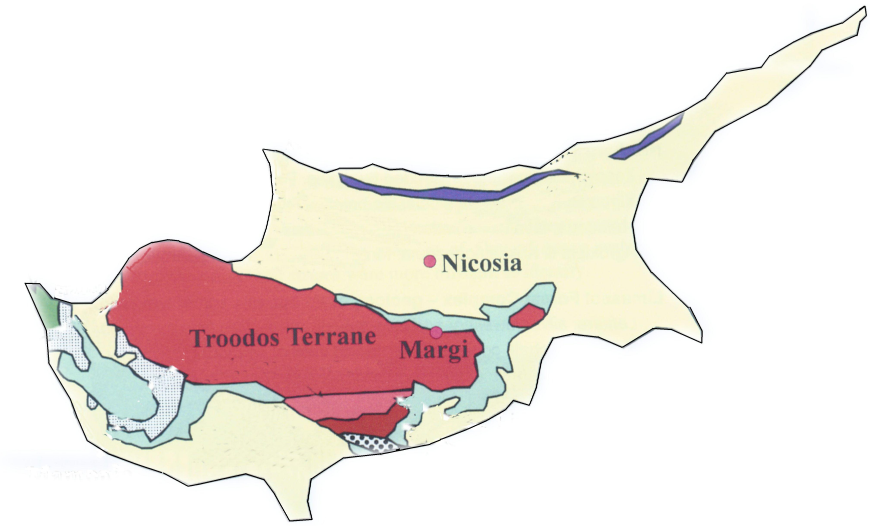
Special Proceedings of the Reading Geological Society

Field Trip to the Cyprus
7th - 14th October 2006



Contents

Introduction

This was the sixth of a series of overseas trips undertaken by the RGS at two yearly intervals. These originated from our celebration of twenty years of the RGS in 1996.

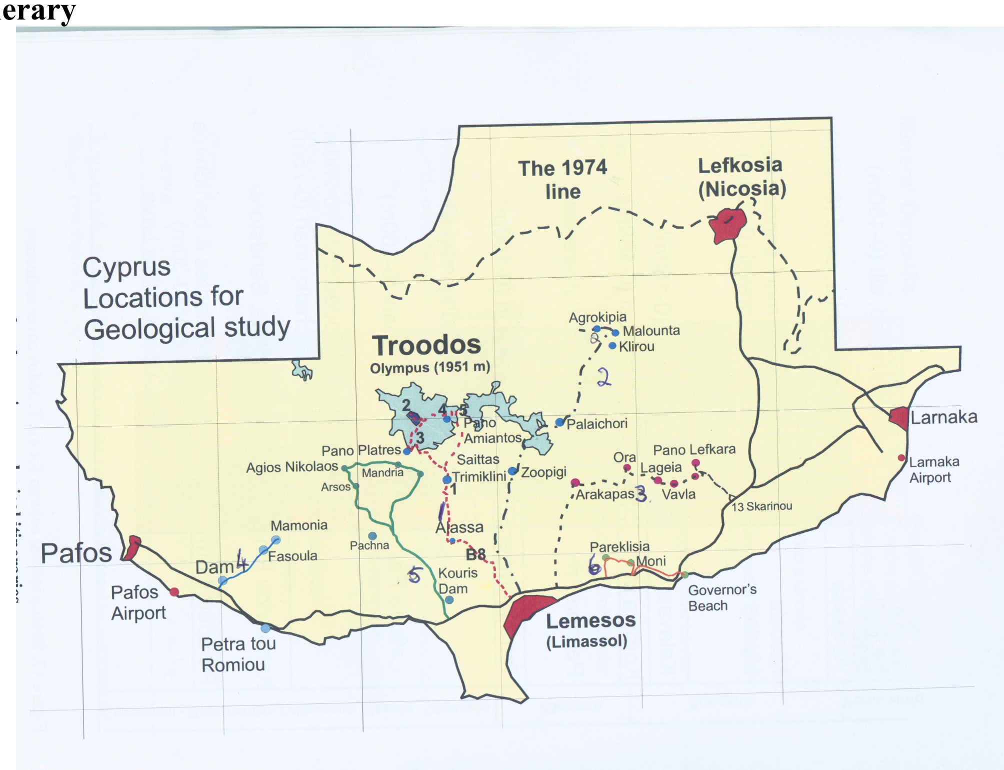
David Ward, our field secretary, was very fortunate in securing Professor Rory Mortimore of ChalkRock Ltd and the University of Brighton, as leader. Although Rory produced a detailed handout for the trip, the party were expected to work at measuring, drawing and, most important, thinking about the geology.

On Saturday 7th October 2006 in the cold light of dawn, the party of 19 set out via Gatwick, to Paphos Airport, Cyprus. Then by coach to the Pefkos Hotel, Limassol (a perfect hotel for a group of geologists. A friendly family hotel, out of the tourist area, with a bar and swimming pool). There followed six days of geology, archaeology, wonderful evening meals and good companionship. We returned on Saturday 14th October, on the reverse route to that taken on the way out.

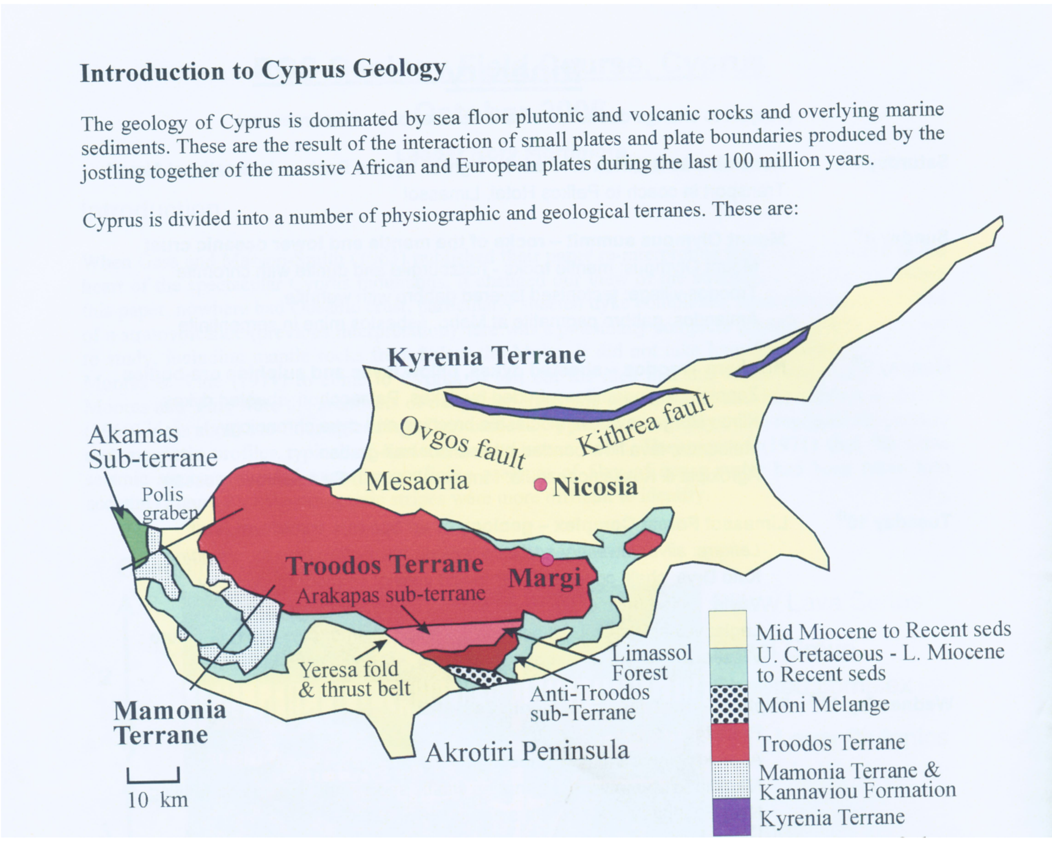
These proceedings are a chronicle of the member's reports on the excursions, both geological and otherwise. It is presented as half-day reports – mornings and afternoons.
Those contributing were: Jane and Alan Lane, Christine and Roger Moore, David Riley and Chris Eden, Ed Shirley, David Ward, Jill and Roger York, June and David England, Clare and Chris Fone, Christine Hooper, and Caroline Hubbard. Also with the party were: Louise Knight and Carol Gregory.

Christine Hooper
Editor.

Itinerary



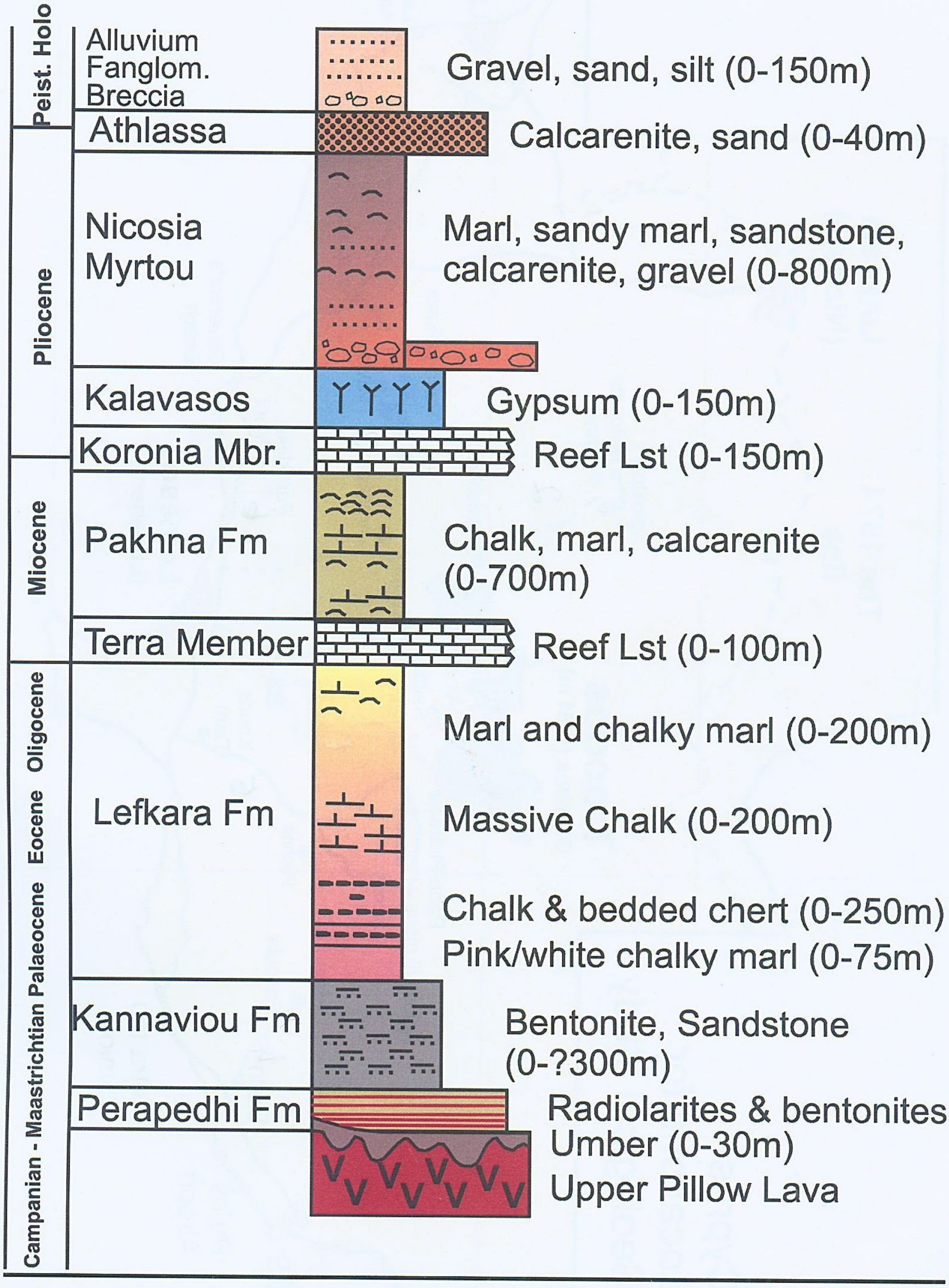
Introduction to Cyprus Geology



Introduction to Cyprus Geology

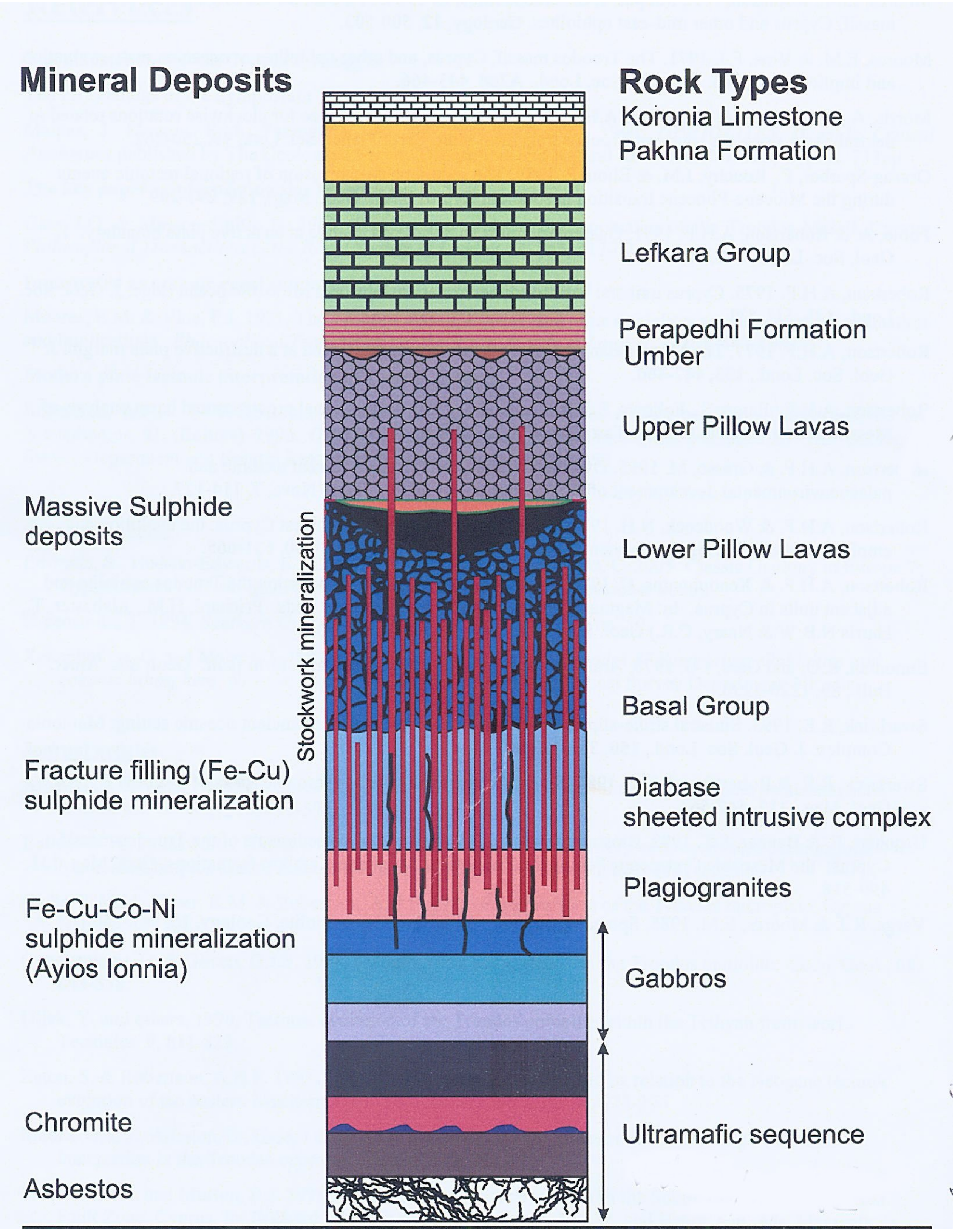
The geology of Cyprus is dominated by sea floor plutonic and volcanic rocks and overlying marine sediments. These are the result of the interaction of small plates and plate boundaries produced by the jostling together of the massive African and European plates during the last 100 million years.

Cyprus is divided into a number of physiographic and geological terranes. These are:



Stratigraphical column for the Troodos cover sediments

Prof. R Mortimore


Mineral Deposits
Rock Types
Koronia Limestone
Pakhna Formation
Lefkara Group
Perapedhi Formation
Umber
Upper Pillow Lavas
Massive Sulphide deposits
Stockwork mineralization
Lower Pillow Lavas
Basal Group
Fracture filling (Fe-Cu) sulphide mineralization
Diabase sheeted intrusive complex
Plagiogranites
Fe-Cu-Co-Ni sulphide mineralization (Ayios Ionnia)
Gabbros
Chromite
Ultramafic sequence
Asbestos

Day 1 Sunday 8th - The Troodos

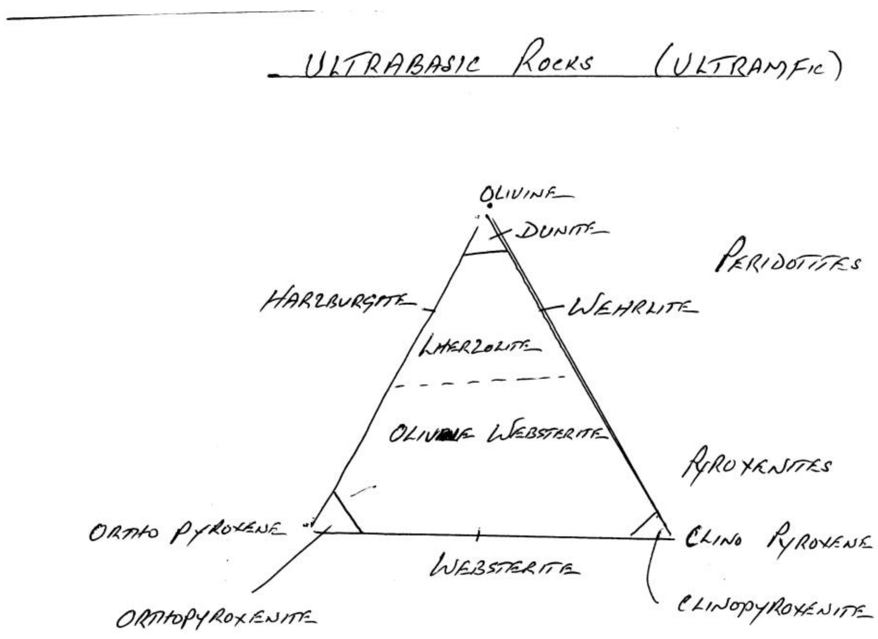
Morning
Itinerary 1

The party departed from the Pefkos Hotel, Limasol on a beautiful warm, sunny morning and we reached our first location **Trimiklini** in about 30 minutes.

From this viewpoint wonderful views were obtained over the **circum-Troodos** chalks and other sedimentary rocks to the dark volcanic rocks of the Troodos range of mountains with their deeply incised river valleys and, in the centre, Mt. Olympus (1952m) with its white radar dome. On the right side of the road, a good section of the bedded chalks were exposed; much more of these interesting chalks were to be seen later in the field excursion.

After leaving **Trimiklini** the road climbed up into the mountains where **umbers** (a naturally-occurring brown pigment composed to iron and manganese oxides formed by the weathering of the rock) were observed, followed by **bentonites** and **plagiogranites**. A brief stop was made just before the village of Troodos to photograph the magnificent view over the mountains and one of the many Byzantine monasteries to be found in this area.

Our next stop was at the Troodos ski-lift car park, just below the summit of Mt. Olympus, which lies at the centre of the Late Cretaceous (Campanian) **ophiolite complex**. The ophiolite has a central core of plutonic rocks 11-20kms thick made up of medium to coarse-grained basic and ultrabasic rocks, many of which have been intruded from multiple magma chambers, distributed at varying depths along several fault- bordered spreading axis.



Olivine General formula M_2SiO_4

Dunite Ultramafic rock, 90% Olivine, often of mantle origin.

Hartzburgite Ultramafic/ultrabasic 40% Olivine, 60% Orthopyroxene

Peridotites Ultramafic rock 40-90% Olivine and Pyroxene including Harzburgite, Wehrlite and Iherzolite.

Wehrlite Peridotite > 95% Clinopyroxene and Olivine 4 – 5% minor.

Iherzolite A phaneritic rock, similar to Peridotite containing 40-90% Olivine, 5% Orthopyroxene and 5% Clinopyroxene.

Webersterite Pyroxene 95% Orthopyroxene and Clinopyroxene.

The Troodos area forms an anticlinal dome with the oldest rocks, mostly ultrabasic and basic plutonic, in the centre flanked by younger **dolerites** (=Diabase) and basalt.

Peridotite and **gabbros** predominant at the centre are **techtonized** (deformed and during a late phase flowing) and serpentinized, **harzburgite** and **bronzite**. On the east side of Mt. Olympus the harzburgite is totally serpentinized with abundant **chrysotile** (asbestos).

All the rocks mentioned above were seen in the road sections between the car park and the summit.

On reaching the summit of Mt. Olympus we were disappointed that mist and low cloud kept us from seeing the Kyrenia range of mountains; however it was possible to see the southwest corner of the island.

Reported by Janet and Alan Lane

Afternoon

A walk through the phase changes at the crust and mantle boundary, the ultramafic or ultrabasic suite of igneous rocks.

Introduction:

The rocks at the crust and mantle boundary are subject to a range of temperature and pressure differences. We were looking to recognise the features left in the igneous rock. We were told that the temperature and pressures can be at their highest in the mantle. Mixing rocks at various stages of cooling produces a variety of effects. There are no gradual changes as the text book diagrams suggest; more fluid material and solidifying rocks are mixed together. On top of this the effects of weathering on the exposed faces can easily lead you astray.

In the morning we were looking at the mantle with harzburgite – site 2 at the top of Mount Olympus.

In the afternoon we were viewing in order of age, oldest and lowest originally first:
Site 4 – the oldest, weathered harzburgite at the asbestos mines
Site 5 – the Moho boundary between the mantle harzburgite and the crystal gabbros
Site 3 - the sections on the road to Pano Platres where the effects of temperatures of 1800*C and high pressures can be seen

We viewed the rocks as we descended from Olympus. It is challenging to understand that the oldest mantle rocks have driven up through the ocean crust leaving the younger rocks tilted and fractured on the slopes. As this area is still rising, the natural weathering of mountain streams, frequent storms, and melting snows have cut deep valleys into the Troodos range. There is a lot of pine forests, vegetation and building.

The asbestos mines

The harzburgite rocks have been serpentinised during weathering by water and can be recognised by the glossy, colourful appearance with streaks of red, green, purple and white. Chrysotile fibres have developed on the brecciated (coarse grained and angular) surfaces. The asbestos appears as slender veins with fibres up to 15mm long and make up less than 1% of the rock.

There has been exploitation since Roman times and intensive mining here for over 100 years, now ended, and there are still considerable deposits, 60 million tonnes, but the environmental impact is massive. The scale of the open cast mines is huge and can be seen for miles.

20 – 40000 tonnes of asbestos were extracted every year for 80 years and were an important export for Cyprus.

All attempts to terrace and introduce vegetation onto the slopes are failing. The village of Pano Amientos lies in the direct path of any subsidence and health problems in the village, the impact on water quality and farming are kept low profile by the government.

The Moho boundary

Finding it is a challenge. We parked on the road below the old bungalows built for the asbestos miners and passed a newer bungalow. A short walk led to an outcrop.

At first site there was little to distinguish the gabbros below with large crystals of pyroxine from the slightly darker harzburgite with large crystals of bronzite. The mantle crust boundary varies in height through this area.

The crystals in the outcrop above were larger than those on the Pano Platres road site as they formed more slowly at higher temperatures. The Pano Platres site is estimated to be 250 – 500 m above this site.

The larger crystals gave a better chance to appreciate the two cleavage planes of the pyroxine crystals

The hammer marks the boundary on the photograph overleaf

Site 3 The road cutting at Pano Platres below the Presidential summer bungalow

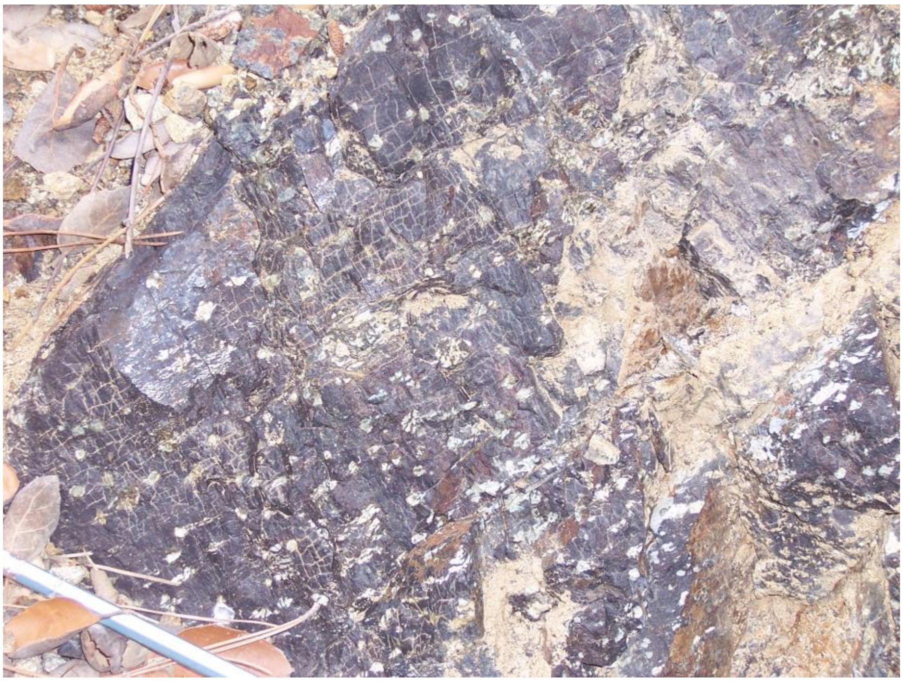
We viewed this site first after lunch although it is the ‘’highest above the mantle / youngest’’ in the rock sequence. To make this easier to follow for people who did not make the trip, I thought it made more sense to stay with the sequence of the rocks.

Here we were looking at the gabbros immediately above the mantle ¼ - ½ km. We were looking to see the subtle difference in these gabbros caused by cooling at high temperatures and pressures.

They are still ultramafic with low silica content and classed as ‘’dark’’ rocks.
We were challenged to draw a section of the rocks, a skill developed through the week. We saw unexpected sedimentary features in the rocks due to layering of semi-solid and more fluid materials.

There were some fine and some coarse grained rocks to distinguish, paler minerals to pick out, white veins of serpentinised material where hot water at high temperature and pressure had steamed through the rocks and had created chalcedony and dark lenses of wherlites

As we drew the section, it gave us a chance to consider that we were looking at a small slice though a massive three dimensional event and gave time to appreciate the chaotic nature of the mixing rocks, yet fitting the physics and chemistry of the current views on the which materials are typically formed at each temperature and pressure. The triangular diagrams express these relationships, figure 13 in the field guide.



The lenses often showed as areas of brittle fracturing, sheering on the planes of the crystal faces as the movements of new material caused rotation in the more solid material.

The wherlites were recognised by dark green pyroxine crystals

We were very fortunate in having benign weather on the mountain, cloudy and warm. Later in the week we viewed spectacular storms from Limmasol resulting in severe flooding and we could also have had snow. If anyone ventures into the Troodos range, it is best to be well-prepared.

Day 2 Monday 9th

Morning

Yesterday we studied the lower layers of the oceanic crust. Today we continued the journey up through the crust; the high level plutonics; sheeted dyke complex; series of pillow lavas; massive sulphide mineral deposits.

From Lemesos (Limassol) we drove north towards Zoopigi along a narrow valley. The sediments deposited in the valley indicated the extensive erosion of the Troodos Mountains. These sediments are a valuable aquifer for local water supplies.

The fresh cuttings on the road between Zoopigi and Agios Theodoros gave us a great opportunity to study the high level plutonics. We identified three distinct rock types (P1). Two of the rocks were clearly cut by basaltic dykes (weathered orange/brown) (P1 and P2). The relationship between the other two rocks was more difficult to unravel, but with considerable prompting from our leader we concluded the paler rock was a plageogranite (P1) and the slightly darker grey rock, a diorite (syenitic) (blue grey when fresh). The diorite appeared to have been intruded into the plagiogranite, but the boundary was sometimes diffuse and it is possible that two viscous magmas, from different sources, had been mixing in the magma chamber. The whole deposit had then been subject to low angle thrust faulting (P3).

We then drove on narrow mountain roads towards Palaichori (P4). The sheeted dyke complex was exposed in a large road cutting near Palaichori (P5). The rock was essentially 100% dykes, ranging in thickness from a few cm to 2m. These dykes were mainly basic doleritic bodies when emplaced but they were subsequently altered by hydrothermal metamorphic reaction with invasive sea water, into diabases. The dykes were emplaced by the infilling of tension cracks, rather than by forceful injection, during extension of the crust at a sea-floor spreading ridge. Our leader, Rory, taught us how to use a clinometer to measure the strike and dip angles. The strikes ranged from 8-52^0 and dips from 80-94^0. We closely examined the contacts between the dykes (P5) to try and work out the order of emplacement of the dykes. However, we could not identify any clear chill margins where fine grained glassy-looking zone would have been evidence of rapid cooling of a hot igneous body when it is intruded into and against a pre-existing colder rock.

We then drove NE to the Akaki River gorge Kilrou Bridge. Here we enjoyed a pleasant picnic while observing and sketching the wonderful exposure of pillow lavas and dykes (P6).

P1. Diorite (left), plagiogranite (centre) and basalt dyke (right) cross cutting the diorite and plagiogranite.

P2. Basalt dye cross cutting diorite and plagiogranite rock

P3. Low angle thrust fault

P4. Mountain scenery-between Zoopigi and Palaichori.

P5. Sheeted dyke complex near Palaichori.

D Riley

Afternoon
Akaki River Canyon

At Kilrou Bridge the Akaki River has cut a deep gorge exposing pillow lavas and basalt dykes, from the Lower Pillow Lava Unit of the Troodos Ophiolite.

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The gorge on the right bank is detailed in the picture below, which gives a general view of the pillow lavas; these have been cut through by basalt dykes (now weathered red-brown). To the right of the picture can be seen a later dyke (weathered grey-brown) intersecting at an angle.

The pillow lavas are of varying size, reflecting the differing rates and conditions in which they were formed**.**

The pillow lavas are often altered to volcanic glass at the contact with the basalt – by cooling too rapidly to allow crystallization to occur possibly as a result of a high water content. This is particularly clear in the smaller horizontal basalt dyke in the centre of the above picture, and in detail on the right. The surrounding pillow lavas have been turned to brecciated glass.

Closer inspection of the basalt shows amygdales (almond-shaped gas holes) resulting from the depressurisation of the basalt as it nears the surface; furthermore, the elongated shape indicates that the melt was moving. The holes have been filled with a variety of minerals: zeolites, celadonite and chalcedony.

Zeolites are formed as a result of the chemical reaction between volcanic glasses and saline water.

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Agrokipia Mine

At the top of the pillow lavas are found massive sulphide deposits, which are the remnants of “black smokers” found at mid-oceanic ridges. The mine at Agorakipia was the main source of silver and gold on Cyprus.

In the distance can be seen the upper pillow lavas which overlie the sulphides, and these are themselves covered by Lefkara chalks.

Reported by Ed Shirley

Day 3 Tuesday 10th - Anoirokoitia

Morning

This is a Neolithic village, visited by special request of the archaeologists present.
The site comes in two parts – the first, a reconstruction consisting of several circular houses, each 4 m diameter and 3 high, with flat roofs and small doorways and windows. Great emphasis was put on the presence of quorns for grinding corn- indicative of gatherers, if not hunter-gatherers – and burial underneath occupied buildings of dead relatives, in the foetal position.

Apparently, some of the houses were used as granaries, indicating a degree of organisation in the community. Higher up on the valley side were a series of 3 levels, each containing several of the original circular house bases, up to 1 m high and enclosed by a wall. The highest level – and apparently the youngest – had houses outside of the wall, indicating an expanding population. Descriptive material in Greek and, thankfully, English, explained the sites. There were two phases of occupation – 7000-5800 BC, then 5000-3900 BC.

Lefkara Pano Village (208508)

The Lefkara area is famed for lace making and silver working – argentiferous galena was worked locally up to the '50s and supported a thriving silver working industry.
The village still clings to its reputation and there are many shops with the regulation lady sitting on the pavement with needle and thread. We found one man tapping away at a piece of silver. Another local item seems to be carved wooden ornaments consisting of "objects within objects"including parrots in cages etc. The mayor has a shop and Rory introduced us to him – he had spent 20 years working in Sheffield and was delighted to show us his stock. Amazingly, on the wall outside a sign said "Branch in Ragstone Road, Slough" – Ragstone Road was Joyce Ward's Secondary School!

Kato Drys (208506) about 3Km from Lefkara

A viewpoint to the W showed a long, wide valley, which Rory explained was along the line of a transform fault. Transforms are active between the offset parts of MORs and the valley here shows evidence for this. While this valley and the transform fault lies approx E-W, the major faults in Troodos were at 90 deg, indicating that Cyprus has revolved 90 deg since the transform fault (and presumably the MOR) were formed.

In the valley, we could see brown rocks, interpreted (at a distance) as pillow lavas, capped with chestnut coloured umbers and khaki coloured bentonites and pale brown radiolarian cherts. Above all this was the Chalk. Topographically, we could see that there were mounds of pillows with the higher sediments draped over the pillow surfaces, neatly sectioned by road cuttings to our advantage. The pillows are of picrite rather than the basalt seen else ware, because the lava has come directly from the mantle without any differentiation. The form of transform faults is of deep –Km- trenches in the ocean floor, interestingly with Pull Apart structures just like the Sticklepath in Devon.

Road Cutting at Kato Drys (very near to above view point)

This cutting showed very weathered pillow lavas (about 1 m) at the base, which were fractured, red, pink and green, with washed down materials from above in the spaces between fragments. These were overlaid by bentonites and umbers, grey- brown and orange-brown red respectively and about 1 m thick. Above these were 2m of chalk, then a thin soil. The contacts between each rock were very irregular, so the bens and umbers filled depressions in heaps of pillows. Across the valley to the NW, we could see much bigger piles of pillows and thick coverings of umbers, indicating that the deposits were very varied, as would be expected of deposits on an irregular sea floor. Rory explained that MOR and transform fault systems link to major structures on the continents -
For instance the Cyprus MOR can be shown to link with the Hercynian Front.

The Lesser Antilles and Scotia Arc areas are zones of accelerated faulting, brought about by the oblate shape of the Earth and with transforms running through them.

Valva (250 506)

This area has a very erratic topography – many small, pointed hills and deep, closed valleys between them. The topography is totally controlled by the pillow lava piles, over which everything else is draped.

A short walk into a valley brought the party to an exposure of pink, very thinly bedded rock, showing very tight, but unbroken folds.

A covering of scrubby herbage was disrupted by areas of grey bentonite, where apparently, plants could not establish themselves because of the continual movement of the clay as it shrank and expanded.

Rory explained that the Si rich waters round the MOR vents allowed Radiolarians to flourish, ultimately becoming radiolarian cherts. The cherts here are in 1 -2 cm beds, distinctly pink coloured and interbedded with powdery umbers and bens. In hand specimen, the radiolarian chert appears very much like a sandstone, but with some perseverance and a hand lens, 1mm round masses of individual rads. could be distinguished.

The folds are wrapped round in irregular 5m dia circles and are explained as the result of soft sediment deformation, possibly triggered by movements on the transform. This would have caused slumping of semi-solidified cherts over the pillow lava mounds.

There were probably other animals in this environment, but they did not have the potential for preservation of the radiolarians.

Reported by D Ward

Afternoon - Lagia

The third site of the day was the road cutting just west of Lageia. This is described in Itinerary 14 (Layia) in the GA Guide No. 50 – Southern Cyprus.

We first had lunch sitting at the top of the cutting and had plenty of time to study the section on the north side of the road from a distance (which gave me plenty of time to come to some erroneous conclusions) - the section appeared to have straightforward bedding dipping to the east and be made up of a rubble, a finer bedded sediment, more rubble then red beds and, finally, a thick brown weathered bed.

After lunch, we made our way down to the roadside to study the site more closely.

Moving along the section to right (or eastwards) the material is seen to be a breccia made up of volcanic clasts and occasional pillows with the finer bedded sediment actually a slab of sediment which is upside down (evidenced by the fining *downwards* seen in the beds) and contained within the breccia. The red beds seen above the breccia, are continuous and fine upwards and are baked on the top by the pillow lavas which make up the brown weathered bed. The fining upwards and the baking on top indicate that for this section the younger rocks are above and to the right (east).

The slab formed in a turbidite depositional sequence which later became involved in another slump movement. The lower beds (breccia and slab) are the deposits from that slump with the upper (red, finer) beds being later deposits from the same or an even later slump.

The next stop was 2 km further west along the road towards Ora. This exposure beside the road showed small (30-40 cm across) pillows of lava and faulted dykes. The pillows had glassy surfaces and are said to be limburgite, high in aluminium and extruded straight from the mantle. Part of the exposure shows devitrified lava - sheared and broken and with a spotted appearance. The sheared surfaces show serpentinite.

This was the end of the planned itinerary for the day but, on the way back - west to Arakapas then south to Limasol, we found time for stops at three further sites. These are sites (or similar to sites) described in Itinerary 15 (Limassol Forest) in the GA Guide No. 50 – Southern Cyprus.

The first was about 4 km south of Dierona where the diorite was cut by vertical basalt dykes. A very narrow dyke (3-4 cm) had a white deposit in the middle possibly due to faster cooling by the country diorite.

The next was a new roadside cutting about 2 km further along where a serpentine body, extruded from the harzburgite, contained lots of chrysotile. The body was also cut across by a basalt dyke (similar to the dykes at the previous site), showing that the serpentine was emplaced before the dykes.

The third site was another cutting further along the road where basalt dykes criss-crossed through wehrlite (an ultrabasic igneous rock composed of olivines, pyroxenes, hornblende and iron ores). There were lots of brown holes – probably where olivine crystals had weathered out.

Reported by Roger York

Day 4 Wednesday 11th   Paphos -The Mamonia Complex

Morning.

Locality 1
River terraces – Pissouri road, 1km east of Petra tou Romiou

Our journey west to Petra tou Romiou, on another beautiful day, took us through a landscape of Pakhna chalk capped with Koronia reef limestone. The numerous new motorway cuttings showed well defined sedimentary deposits with folding and superb slide deposits. Having passed below the earthquake village of Pissouri, perched high up on an active fault, we stopped at the side of the road and looked back at a small valley. There was a sequence of steep-sided terraces on the side of the valley where the river had cut down deeply into the bedrock of the Pakhna chalk and marls in a series of pulsed incisions as the Troodos mountains were uplifted. These river terraces are an excellent example of Quaternary uplift.

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Quaternary terraces near Pissouri

Locality 2 Panoramic view over Petra tou Romiou

`Our next stop standing on the 80metre high cliff of Lefkara and Pakhna chalks, gave us an overview of the geology of our next site, which demonstrates the volcanic stacks and coral reefs of the Mamonia complex. It is one of the loveliest coastal views in Cyprus and probably the most famous. This is the legendary place where, according to Greek mythology, Aphrodite arose from the waves and a small stack is named after her. Against the azure blue sky and deep blue sea, white Triassic limestone stacks (knockers) and the dark pillow lavas, on which they stand, were clearly visible, as were patches of dark umbers above the beach and chalks which overlay some areas. There was evidence of recent landslips on the beach due to the marly nature of the beach rock.

Locality 3 Petra tou Romiou

We donned yellow jackets and hard hats before venturing onto the roadside exposure, above the beach, where fast cars and coaches whizzed past us on a sharp bend. Undeterred, we examined the marine sediments of the Ayios Photios Group and the pillow lavas beneath both of Triassic age.   On the right hand side was a well-weathered olistolith of brown lavas, with pillows above, which have a different composition from those of the Troodos. Immediately above lay a Triassic, coral-bearing reef limestone, which suggests a shallow sea with volcanic seamounts flanked by coral reefs. The limestone consisted mainly of shattered fragments, the cavities of which were filled with fossil fragments and minerals. We were delighted to find a 10cm bivalve shell in situ, (not previously seen by Rory) as well as evidence of limestone alteration to marble. There were lumps of pillow lava cemented within the reef matrix suggesting it may all be may be reef rubble which fanned out over the edge of the reef over time.

Bivalve shell in situ

To the west of this exposure we found very hard, red, deepwater Triassic radiolarian chert layers interbedded with pink pelagic limestone. We could see that these cherts were laid down onto the edge of the limestone with the younger beds overlapping the older ones and curving up against the limestone. This suggests that the area was subjected to subduction and sinking and then the cherts and muds covered the atoll. There is an unconformity between the chert layers and the overlying metre thick layer of rounded pebbles and gravelly deposits of late Pleistocene age. These raised beach deposits are further evidence of Quaternary uplift. Earthquake activity occurred to the southwest of Cyprus in 1995 and 1996 proving that the island is unstable to the present day.

As we scrambled down onto the pebbly beach we walked over chestnut coloured umbers to reach the major stacks. The largest consisted of a hard, well-jointed, brecciated reef limestone containing many fragments of shell fossils and crystals. On the western side there were two large areas of highly polished slickenslide surface probably caused as these large, sheer fault faces sank into the deeper ocean during tectonic activity and were later obducted. The pillow lavas at the base of the stack were clearly visible. There was time for the group to swim or paddle in the sea (no incriminating photos) followed by cold drinks and ice-creams in the shade of the café to cool down.

Limestone stack on the beach

Locality 4 Asprokremmos Dam

We drove along the coastal marine terraces through fertile, highly productive, horticultural land with citrus and olive groves full of fruit and turned inland up the Xeros river valley. The dam, built in 1981, serves Paphos and the local agricultural demand. It is a rock-fill dam, a cheap and quick method of construction, particularly suited to high-risk earthquake areas as the rock attenuates the earth tremors. It has a self-sealing, well-compacted puddle clay core, a necessity as the site sits on Quaternary terraces of gravels, silts and sands. Adjacent rivers feed the lake from the Troodos range together with wells sunk into the gravel aquifers. The water level was low due to several years of drought. Lack of rain is a major concern in Cyprus where 78%of water use is for irrigation of fruit and vegetable crops.

Locality 5 Road section near Fasoula

Our last site of the morning was an exposure in the Dhiarizos Valley situated opposite the abandoned Turkish village of Souskiou. A large, rocky crag of the Vlambouros Formation, within the Agios Photios Group, is a sedimentary structure, which slumped down onto the seabed in late Cretaceous time. The exposure, about 25m high and 80m long consists of two types of bedding. On the right hand side is a large block of greenish, fractured, calcareous gritstone containing a number of large boulders while the left hand side consists of finely bedded red sandstones, siltstones, limestones and bioturbated mudstones. The different colour is due to the oxidation/reduction effect at different depths. The division between the two is just discernible on the weathered surface, where it is delineated down the centre by a series of five folds. The hard gritstone has large open folds with some areas around the hinges deeply fractured, which contrasts with the numerous fine, multiple curves of the mixed beds on the left hand side where the softer material has buckled more under pressure and is a good example of differential movement of hard and soft rock. This folding was probably tectonic as the fold axes are roughly pointing in the same direction. On close inspection of the rock face, numerous calcite crystals were visible in both rock types. The group enthusiastically combed the site for sole structures and trace fossils. We were well rewarded with a wide range of linear trails, branching trails of varying width and length as well as depressions and grooves on the upper surfaces, which indicate that the beds have been inverted since the sequence was deposited. When we had admired our many finds we chose our spot overlooking the valley to eat our lunch. We feasted contentedly on pies, pizzas and rolls from our local bakery followed by the new season’s grapes, figs and pomegranates while gently lulled by the sound of the goats’ bells on the other side of the valley.

Reported by June and David England

Afternoon
Chris & Clare Fone

Roadside stop near Fasoula

This stop was to look at the line of uncomformity between the Mamonia complex and the early chalk of the Lefkara formation on the western side of the road. In this case the Mamonia complex rocks were large, red blocks of Umber from the late Triassic period. Their highly disturbed appearance is perhaps a result of the collision between the Mamonia terrane and the Troodos Terrane during the Maastrichtian (end of the Cretaceous).

The chalk, from early Tertiary period, was of a marly texture and at this stop overlies the Umber on a line of conformity at about 30^{o} to the horizontal (see Fig 1). Interestingly the chalk at the line of contact was lumpy, hard and had significant and yet beautiful manganese dendrites within it (see Fig 2).

Fig 1 Roadside stop, unconformity between Mamonia Umber and Lefkara chalk

Fig 2 Manganese Dendrites in Chalk

The road journey from Fasoula to Agios Georgios was through the Photoios group of the Mamonia complex consisting of Turbidites, Halobia Limestone and pillow lavas. The limestone occurred in some places as massive, isolated lumps, referred to as ‘Knockers’ but looked nothing like the item screwed to my front door!

Roadside stop at Taverna, Agios Georgios, north of the village of Mamonia.

There were mixed emotions at this roadside stop. Firstly heavy black clouds were looming around us and thunder and lightening were crashing to warn us of an impending storm. The relief however was that the section was opposite a lovely traditional Taverna (see Fig 3)!

Fig 3 Taverna at Agios Georgios

The road section consisted of an impressive, contorted and buckled sandstone with other layers of grits, cherts and shales (see Fig 4).

Fig 4 Roadside stop at Agios Georgios

The primary sandstone was lain down in the upper Maastrichtian (74 MY BP) and presumably had been distorted during the final stages of the ‘docking’ of the Mamonia to the Troodos Terrane with subduction and obduction. The sandstone was seen to consist of a wide range of grains, including quartz, limestone, serpentine, epidote, chert and chlorite. Some layers were very course grained and others quite fine suggesting an episodic type deposition. In some of the very tight folds the sandstone had fractured and white calcite was detected within it. Chert layers, presumed to have originated from silica radiolarian fossils also existed within the depositional sequence.

We all attempted to sketch the section with one eye on the weather, which threatened all around. Fig 5 is Rory’s sketch, which the author decided was slightly superior to his own efforts.

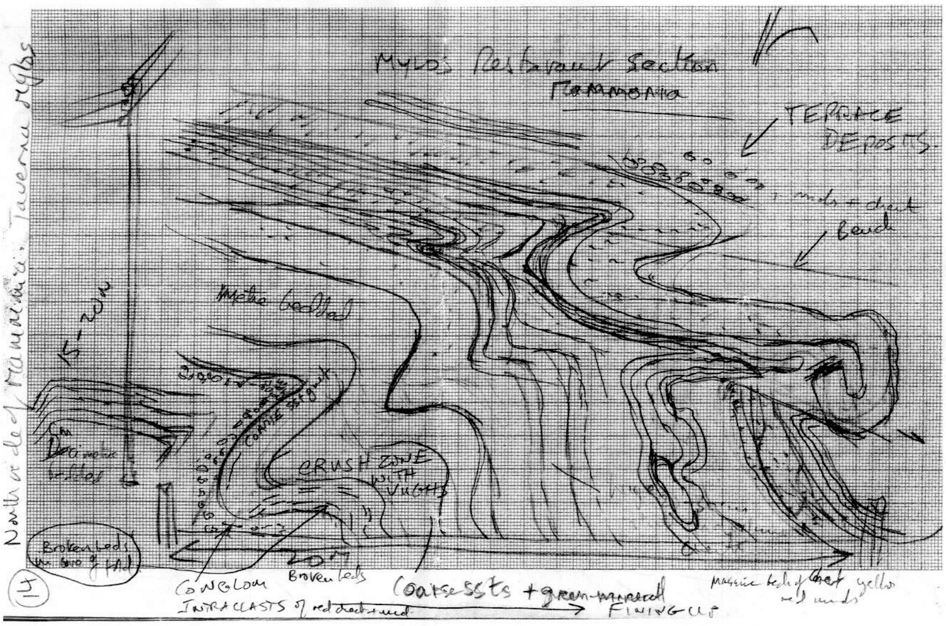


Fig 5 Geological sketch of section at Agios Georgios by Rory Mortimore

In the end the weather broke and we all rushed into the Taverna for a well-earned coffee/tea or stronger! While we all relaxed Rory gave us a short lecture on 'Rock Folding', explaining that although rocks are structurally very stiff they can strain without fractures when the movement is over a very long period and at a significant temperature. Rory estimated that the sandstone rocks in the cutting were probably between 200ºC and 300ºC when the folding occurred (between 5 and 10 km depth). The folds in the sandstone of North Devon are very similar in their origin. A discussion ensued concerning the tectonic setting and how the Troodos Terrane rotated through 90º in the collision with Mamonia partly caused by the 60º rotation of the adjacent African plate.

Serpentenite Intrusion near village of Fasoula.

Turning off the road at the village of Fasoula we then followed a track up to a ridge on the west of the village. Near the top of the ridge a small quarry had been created to extract Serpentenite from an outcrop (see Fig 6). The Serpentenite outcrop is one of a number in the area that appear to have been emplaced along thrust faults, which follow the linear ridges which run NE/SW in direction.

Fig 6 Collecting at the Fasoula Serpentenite quarry

The reason and origin of the Serpentenite is very controversial. It is known that when the Harzburgite is metamorphosed to Serpentenite there is a significant volumetric expansion so it has been theorised that there had been some conversion and mobilisation of the Troodos Harzburgite underneath the Mamonia Terrane during the tectonic collision. Still during the Maastrichtian but post-dating the main collision, sheets of Serpentenite were then squeezed and punched their way to the surface. This occurred through the tectonic thrust planes, which were closely adjacent to the areas of subduction/obduction. The debate rages as to whether the intrusion was hot or cold. Apparently there is evidence of cooled contacts in other locations but Rory felt that because there are indications of considerable sheer in the rock it is most likely the rock was relatively cool during the intrusion. We debated whether the intrusions ever reached the deep sea floor that existed at the time.

A period of collecting was enthusiastically adopted by everyone. Regions of Harzburgite were discovered within the Serpentinite, confirming its origin, with quite large crystals of bronzite observed within it. Some members discovered veins of crysotile in the Serpentenite and a zeolite, Natrolite, was discovered in a crack in the Harzburgite (see Fig 7).

Fig 7 Natrolite in Harzburgite from Fasoula (2000nm scale)

Roadside Cave near Nikoklia
On the return back to the Hotel there was an impromptu stop to look at a small cave on the side of the road (see Fig 7). The cave followed a natural anticline fold in the surrounding sandstone with evidence of calcite veins local to the edges of the cave. It was presumably of significant age as there was cemented rubble on the roof of the cave. It was only a few metres open-depth, being in filled with soil but as can be seen, even after a long day there was still two boys wanting to play at cavemen!

Fig 7 Roadside cavemen singing for their supper!

Reported by Chris & Clare Fone

Day 5 Thursday 12th - Mandria, Lefkara Chalks

Morning

On the road to Mandria, Stop 1

The first stop was made where a long road cutting exposed the Lefkara Chalks and underlying rocks, but the immediate interest was the view up into the Troodos Mountains – these are not very high (1951m) but have a very pleasant covering of coniferous forests with just sufficient rock exposure to keep geologists happy and are very attractive.

The party worked along the cutting examining the rocks and to no one’s surprise, found pillow lavas, under bentonites and umbers, covered with chalk.

The pillows were about 0.5 m dia. and have crusts of white and brown secondary minerals and also veins of similar materials cutting through them. The pillows were in the, now to be expected, conical pile which extended along the road for 30m. Banked up against them were the bentonites and umbers – khaki and chestnut colours again – with little in the way of structure, probably lost during slumping. A not very accurate assessment of the thickness of the bentonites and umbers would be about 30m.

The contact of these rocks with the chalk was distinct, with fragments of the chalk caught up in the lower rocks and slickenslide on the chalk faces. The strike of the contact is 80 deg E, while the dip is 90 deg.
A few metres beyond the contact, the dip in the chalk was estimated and found to be about 30 deg, while 100 m further on, the dip was reduced to a few degrees – indicative of the chalk being draped over the underlying rocks.
Rory explained that the chalk here is the Lefkara Chalk, that low in the sequence it has a pinkish hue – possibly due to Fe – while less than 10 m above its base, it becomes very white with bands of black and brown chert. High up in the cutting – perhaps 40m up – we could see what appeared to be a fossil, the form of which was an annulus, with the body 20 cm dia. and the whole structure 1.5 m diameter. Rory had tried to climb up to it on a previous occasion and assured us it was not possible to get there, but that it would be a contribution to science if we could collect it!

At road level in the chalk were found burrows about 1.5mm dia., with pale brown fills. These burrows were straight for distances of 20 mm, then branched in one plane to give further straight parts. The genus is Trichnos and several other fossils were seen – a 4mm sharks tooth, a spine 1mm dia by 4 long and Forams, discovered after considerable searching with 10x and 20x lenses on slabs of chert. Rory interpreted this collection of fossils as being representative of harsh conditions with deep water and hence the deposition of the thin beds seen at this exposure. Another indicator of deep water was the large number of spherical holes where Forams have dissolved out – attributed to the water depth being greater than the Carbonate Compensation Depth, below which carbonates dissolve. The CCD here, Rory estimated, could have been 1500 metres.
So the Forams we observed were probably preserved in silica.

Stop 2, 1 km nearer to Agios Nikolos

Rory explained that here, the rocks had suffered more uplift than at stop 1 and the result was an increased amount of chert, some clay horizons and thin grits, probably derived from the Troodos. Two joint patterns were seen in the chert and chalk – one running at 120 deg, the second at 0 deg . The faces of the joints on 0 deg were mineralised with calcite while the others were bare chert. This was some indication that the mineralised faults were open and submerged in a sea rich in Ca, while the second set were clearly closed when submerged.

Site 3 another Km nearer to Agios Nikolos

This site was higher in the succession – estimated to be under 1000m of water. The chalk here was massive, with no chert or clay. The great excitement here was the plentiful supply of Zoophycos – a trace fossil, consisting of a vertical tube several mm dia. with at the lower end an area up to100 mm dia where there were radial marks. There is a serious lack of understanding of the form and function of this animal and Rory was unable to help us on this occasion.

A different trace fossil from site 1 was observed – this one had tubes 2-3 mm dia. and a 3D branching habit and with some “limbs” up to 60mm long. It was suggested that this bigger trace fossil indicated that conditions were less harsh than at site 1.
Sites 1 to 3 are actually continuous sections in a vertical direction, and are of the lowest age in the Palaeogene, being Danian age – as found also in Denmark.
A very short drive brought the party back to the taverna at Agios Nicholos, where a very pleasant lunch was taken – salads for those already overwhelmed by Cypriot fare, chicken for the carnivores.

Reported by D Ward

Afternoon - Kouris Dam – Pakhna Formation

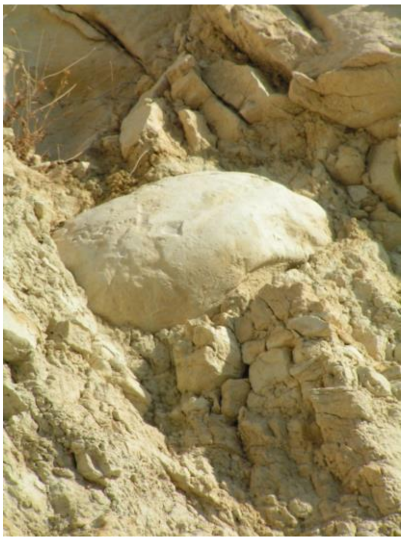
Leaving the Taverna at Agios Nikolaos- the storm had passed - a long drive through Mandria gave us time to appreciate the scenery as we made our way down to our next locality.

The Kouris Dam and reservoir is cut into the Pakhna Formation chalks, marls and limestones. A new road cut for access round the reservoir gives clean exposures of the rocks. At the time of our visit the rainy season had not begun and the water level was very low as there has been a ten-year water shortage on Cyprus.

Slumped bedding at roadside.

Stop 1

The first stop on the dam gave a fine example of the Pakhna Formation. At first sight the white bedding planes, dipping 5^0 to the south (the Troodos lie to the North), seemed straightforward but closer inspection showed a multi-layer sandwich of normally bedded sediments (full of trace fossils) and slumped debris flows – some 2m in depth. This is thought to show episodic periods of uplift of the Troodos and erosion of the earlier formed chalks that took place during the Miocene. The uplift causing deformed sediments to slide down from the Troodos area infilling channels with massive boulders of Lefkara chalk. The periods of comparative calm allowed deep sediments to form, the diversity and abundance of bivalves, gastropods and trace fossils – mainly worm burrows - showed that this was a shallow water sediment (<50m), as opposed to the earlier deep water chalk sediments we had seen previously. In one bed a large fossil bivalve? (about 1m) could be seen, unfortunately it was too dangerous to climb for a closer inspection.



Large bivalve?

Trace Fossils

Approximately 250m up the road, in a southerly direction, walking with the dip (but uphill), in effect walking up through the sequence to younger sediments at the next locality.

This locality showed angular blocks of a rock avalanche reworking other material, similar to those seen in alpine valleys; but taking place under water. A large boulder of coral bearing limestone showed that the re-worked rocks came from various ages.

Sediments draping over the boulders showed periods of relative calm following the upheaval, which caused the rock avalanche. The water depth became shallower as we moved up the sequence.

Corals in limestone

Another 500m on, another submarine channel showed disturbed environments; layers of unsorted pebble size material from the Tertiary to Quaternary, topped with massive sandstones. Would the seas be sufficiently shallow for this to be a tidal environment? This problem remained unresolved.

Channel on right

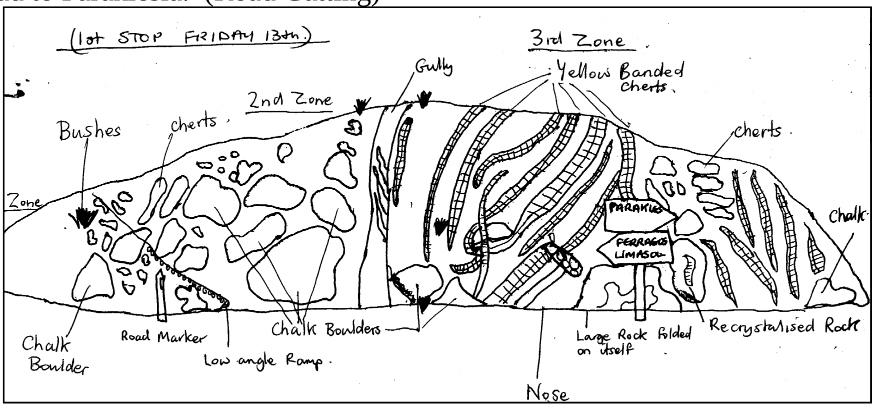
The last stop, a farther 1km up the hill, brought the final stop for the day. A channel scouring down in a high-energy environment (the very fast flows giving thin laminations), interspersed with quieter periods, a pulsation caused by the still rising Troodos Mountains. The seas were now very shallow during the Mio-Pliocene period as the old Tethys Ocean slowly disappeared as the mini-plates closed.

Reported by Christine Hooper

Day 5 Friday 13th - Mona Melange

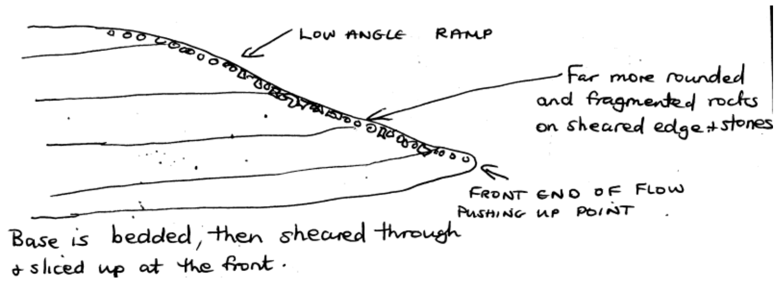
Morning

Stop1 On the road to Paraklesia. (Road Cutting)



This turned out to be very interesting, if very noisy, due to the large volume of lorries and wolf whistles that some RGS members received, (all dressed in Hi-Viz, shorts and hard hats) the cutting was a mixture of chalk boulders, yellow banded cherts and marls, and could be divided into 3 events.

The 1st event (on the left side looking at pictures) mostly was bedded chalks, marls and cherts, though there was a distinct low angled ramp, that had been sheared by the force of the (2nd event)



The rocks on the top edge of the ramp were sliced, fractured, shattered and stretched quite a lot. The end is forced up and rocks rolled around (cherts and chalks) plus a tiny zone of fragmented stones. There was a lot of movement in the mass and some fluidity, as some bent round shapes formed from still plastic rocks showed.

The 2nd section

This 2nd central section was made up of cherts, some moulded, boulders of chalk and disrupted marls (clays). These had collided with the 1st section, having moved very rapidly down the slope, then squashing and slumping the mass. Hitting the better bedded 1st section, the contact surface is very irregular and shoved forwards. Thrusts are at a very low angle, no drape structures and just half metre of uniform material with rounded cherts in it, (cherts fairly plastically disturbed) This could have been caused by obstruction, or loss of fluidity, in contact with the clay/marls. Or as a result of pressure from rocks behind expelling the fluids (very plastic rock or wet sediment needs water to remain fluid/plastic, when contact with the clay/marls rocks affect the water content, fluidity slows or stops). When fluidity stops or becomes drier more fracturing and shearing occurs. The initiating and sliding, together with the fluidity and traction carpet effect, meant that giant blocks were transported down slopes as oceanic avalanche (probably when the Mamonia and Troodos collided) this thrust up rocks in the air and large flows were created.

This whole cutting is a very energetic formation, probably made up in minutes and hours, rather than weeks or months.

Gully

On the down slope side is fractured chalks, on the topside chalk/cherts.

3rd Last Zone.

This nose was layered, and then disrupted by next slump fold. The cherts are in some places instead of hard and stiff, were soft when this happened, as they are folded and draped over boulders and hardened later in these shapes. The boulders included chalks, cherts, and marls. Other cherts were sufficiently brittle to be cracked, then re-crystallized. Thick and thin drop stone have been squeezed and stretched again indicating some plasticity. A time dependent process changed chalcedony and cherts, silica to alpha and beta quartz (see photo). One large block folded back on itself.

Stop2

After the 1st stop, we travelled again by coach, into the hills. Rory was pointing out geological features, of the huge variety and sizes of apparent outcrops and boulder, and the Coronia Limestone, which was now visible of the tops of the hills. All the other rocks were jumbled up and dumped in completely random fashion. This was the Mona Melange.

The Moni Melange was formed, by huge under sea avalanches, being deposited on the lowest part of the sea floor. When the sea floor was later pushed up and became land, it was left as it had been. Blocks, boulders, rocks, pebbles and sediments were all mixed together. In these avalanches, blocks, several kilometres long and wide, were moved, both by gravity and fluidity, the water aiding flow and traction down slopes. In fact some of these blocks had buildings/towns built on top of them. Precariously, depending on the type of rock chosen.
The avalanches would have been extremely quick, minutes and hours, only to form. So extremes of energy affect the rocks, both solid and semi-solid or plastic rocks. Shown by extremes of folding and shearing and fracturing.
At a cutting of one of these huge blocks, we stopped, to see lots of reddish materials, Bentonites and Pillow lavas, in this block. The Pillow lavas were surrounded glass and de-vitrified glass changing to crystal. The lavas were ultra basic, with more silica and sodium rich plagioclase. Pillow lavas you would expect to be brittle but aren't.

Next we visited a site higher up the road. To get to this site we passed fields of tomatoes being tending by workers and recently planted peppers (Oct?), which looked very healthy. Alan was interested in finding fossils (corals in limestone), which he did quite quickly. The rest of us studied the variety of rocks, Limestones, Bentonites, Sandstones, Blocks of Pillow lavas. On the skyline high hills were capped with Coronia Limestone, with bentonites steep, sloping sides beneath. On the lower slopes, large boulders and blocks lay all over the place, again randomly.
Roy explained groups of students would come out on field trips and in two's and three's would map and note their positions and type and size. We also investigated a large platform of rock, which turned out to be Serpentanized, which had been brought down and dumped in a trough. We also found a small piece of Red Chert, which David Ward brought back to the UK.
This led to the group visiting Paraklesia village in search to an area with lots of Red Cherts/stones. However, after driving precariously through narrower and narrower lanes in the coach, Louise found this area had been developed since her last visit. Chris the coach driver, however, amazed us by steering us back

out, without hitting anyone's house. We carried on then to the last stop for the morning – The Governors Beach.

Stop 3
Governors Beach

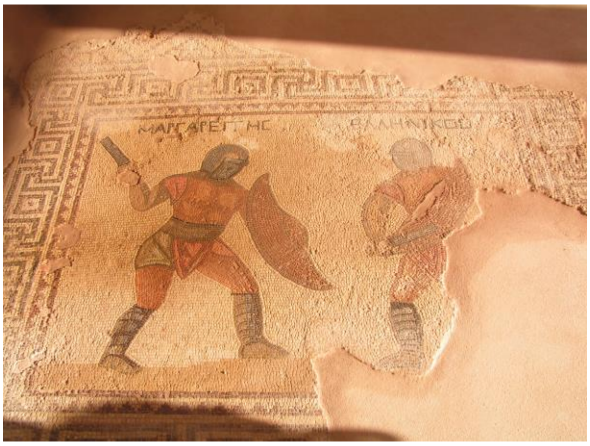
From the coach we were greeted by blue skies and blue sea. We walked down onto the beach; this was fine sand turning to dark gritty material. We walked a short distance to a protrusion of rock (Lefkara bedrock lying on pillow lavas underneath. On top were chert beds and chalk with cherts). Here RGS members divested clothes, to walk knee deep along the edge of these cliffs, to a small cove for geology and lunch. These cliffs were wave cut and smooth. Around the corner we found massive chalks, these with different cherts than before, now modular and isolated and lots of tectonics happening here. (Writer is now thigh deep in the Mediterranean, so writing blurs in notebook). There are new areas of slumping, also small scale slumping. The rocks show lots of faulting and fracturing. The clean polished surfaces in this cove, showed trace fossils and bioturbation. Also visible were burrows, in both the green rock and chalk, where other colour material had been pulled into the other, showing that both had been soft on the ocean floor before being pushed up and hardened. There were clay cherts and marls here, some offset as were the burrows by little faults. Syn sedimentary faulting and fracture orientation was also evident. At this point most of the RGS, well above half went swimming, though David W. and Chris F and Rory went to investigate the wave cut cave with its amazing faults and features.

Reported by Caroline Hubbard

Afternoon - Kourion

A non-geological trip by popular demand, Friday afternoon saw the party at the ancient city of Kourion, one of the most important archaeological sites of Cyprus.
The city was founded (according to Herdotus) by the Argives; inhabitants of ancient Argos.
The earliest remains are late Classical and Hellenistic (325-50BC) but most of the visible remains are Roman (50BC –395AD) and late Roman (330 – 7th Cent. AD).
Unfortunately the area is an active earthquake zone, major reported earthquakes in 15, 75, 332, 342, 360 and 364 AD, the last causing the city to be deserted.

The House of Eustolios. (late 4thC to mid 7thC) has the most beautiful, detailed mosaics, the area being protected from the weather by a large dome-like construction. First constructed 2ndC BC and remodelled 1st AD it was badly damaged by earthquake in AD77. The final phase built in Trajans reign (AD98-117)



1 2

Mosiacs,

1 - In the Frigidarium. The bust of KTICIC – symbolizing the Founding Spirit of Creation.

2 - The Gladiators House, a fine mosaic of gladiatorial combat.

The Forum.

The hub of any Roman city, whilst most of the buildings were of local stone the Forum was the finest workmanship and used imported stone; especially in the columns. One of the columns had been raised to its position giving an idea of the size and grandeur of the original building.

Detail of the large upright column

Perhaps the most poignant, the ruins of an ordinary Roman citizens house, destroyed the 4th century, perhaps the 365AD 'quake. The bodies of the family and their donkey were found in the recent excavations.

The Forum showing the large upright column.

Storm clouds were forming over the Troodos as we left Kourion. During the evening's celebratory dinner we were treated to a great light show from the storms over the mountains.

Party hats had been produced by our Field Secretary, each with a different type of rock printed on it – enabling the group to stand in line to produce a stratiographic column. The end-of-trip cake, produced and iced by a local bakery, was jointly cut by Rory M and David W., leading to much amusement and speculation by the waiters.

Reported by Christine Hooper