FGS trip to the Cyclades - May 2003

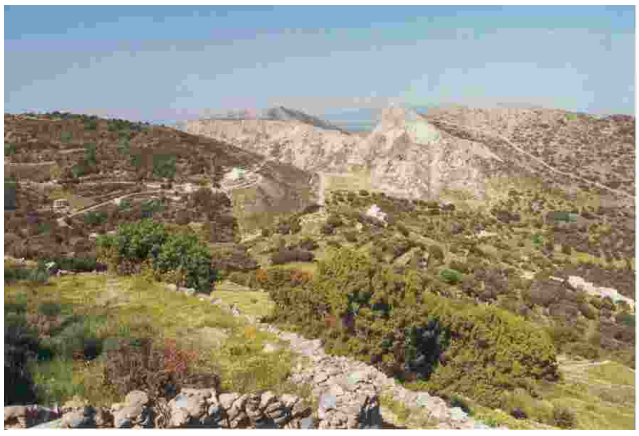
The purpose of the study tour, led by John Williams, was to compare the Cycladic islands formed from volcanic products (Milos and Santorini) with those that have been metamorphosed by the processes of tectonics (Naxos and Paros), and also to observe various effects of volcanism, view the products of an eruption and to see how they have weathered over time.

Sixteen members of Farnham Geological Society were thoroughly prepared for this Aegean trip by John's very comprehensive Study Tour Field Guide and the opportunity to attend a Day Course given by Alan Timms and John at the Natural History Museum. This explored the complex geology of the region and how it has dictated historical development and archaeology.

The first and last night were spent in Athens, four nights on Naxos with a day trip to Paros, six nights at Oia on Santorini then three nights at Adamas on Milos. Carole Hodge from Island Wandering was a very able right hand lady.

"One hundred and ninety million years ago the sun shone and the seas were warm, clear and blue. Surrounded on three sides by landmasses: Asia to the N.E., EuroAmerica to the N.W. and Africa to the S.W., life in the Tethys ocean was bliss. However, nothing lasts for ever. The supercontinent of Pangaea was breaking up and the Atlantic ocean far to the west was beginning to open. As a result, Africa rotated anticlockwise and was pushed northwards towards Eurasia.

At the Eurasian border the Tethys Ocean started to subduct ,pulling behind it a series of microcontinents, pieces of continental shelf that had once been attached to the African plate but had been separated from it by the formation of a new basin, the Mediterranean. The Tethys gradually shrank in size and by 60 Ma, when the most northerly of the microcontinents, Pelagonia, reached the subduction zone, the ocean closed. Pelagonia, being too buoyant to subduct, docked with the Eurasian continent folding and thickening because of being continually pushed from the SSW into the solid continent. One by one the other microcontinents docked behind it each adding to the pile-up and each increasing the deformation of the one in front. Eventually nappes formed with younger, unaltered folds thrust over earlier ones. The whole area became a mountain chain. The limestones and muds originating in the shelf seas metamorphosed with increasing pressures and temperatures to marbles and schists. Pelagonia where the most deformation took place became known as the Cyclades, and the mountain chain was the Hellinides, the Aegean portion of the Alpine orogeny."



The sun shone and the seas were clear and blue. We wore hats and carried bottles of water wherever we went. We travelled on coaches, local buses and taxis, took boat trips, walked, swam,

went shopping, visited museums and archaeological sites, dined wonderfully at the local tavernas and rested at the local watering holes. There were those among us who got lost, tired, forgetful, embarrassed and brown. We all got hot. In fact a typical field trip.

We were introduced to the metamorphic rocks of Naxos and Paros. 20 Ma of erosion had exposed the roots of the mountains. Marbles formed barren ridges and schists the fertile valleys. Crops and olives were growing in small fields (*see photo*) that had bamboo windbreaks and the occasional tethered cow. Many hillsides terraces were neglected as land had been divided up more and more between successive generations until the portions were too small and uneconomical to work so many had been abandoned.

Marble quarries punctured the landscape. We visited a marble mine at Marathi on Paros that descended 2000 ft into the mountain. We walked through the adit and down a slope (*see photo*) away from the bright sunlight to the gloom of the first gallery and peered into passages that led into the depths. The steeply dipping bed had last been mined by the French in the early 18th Century who brought up the beautiful highly metamorphosed marble with such large crystals that the rock was translucent up to 3½ cms. We all applied our torches for confirmation. Ancient Greek civilisations had appreciated its beauty, and Venus de Milo had started life as a piece of Paroan mountainside. Sites on Naxos and Paros had Kouroi statues, considered by some to be idols that had been partly carved from the bedrock in 7th century BC and then abandoned. They lay there still. We were convinced (I think,) that a hillside at Melanes, covered with marble boulders was an apprentice's practise ground where they could develop their marble-carving techniques. Emery (Moh's scale 9) was used for carving and we visited an emery dump to identify the black mineral. Emery is a metamorphosed laterite deposit rich in Fe and Al (corundum) and named after Cape Emeri on Naxos. Emery is no longer mined as there is a synthetic substitute. We visited George's marble works on Naxos. (There are, apparently, several islanders called George), and saw how huge white blocks, some streaked with grey, brought from the quarries that dotted the mountainsides were roughly cut to manageable sizes (ie.large) then sliced, polished, cut to size and then stacked ready for shipping. Only the 20 kg airline luggage limit prevented us from walking away with some tempting off-cuts.

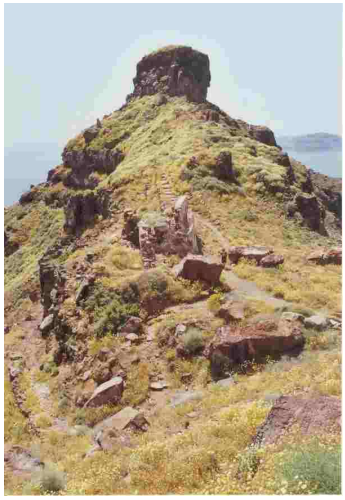
The intense high temperatures reached during nappe formation had in places further altered areas of schists to form augen gneisses and within these, further alteration had produced migmatites. The highest temperatures of all within the migmatites had actually melted the rocks to produce granites. We inspected

samples of granite domes and their aureoles in a roadside exposure in the Koronis area of Naxos. Nearby was a very neat and tidy marble quarry that was removing the top of one of the mountains. At Naoussa in the north of Naxos we saw how quartz in the highly metamorphosed schists at the centre of the nappes had been mobilised to form pegmatites in the highly deformed rocks. We followed the exposure across the bay.

Naxos with its windmills, its mountainous interior and its busy capital was a good introduction to the Cyclades. We looked eastwards through Apollos Gate at the old Venetian fortified Castro guarding Naxos town and the busy port, and then westwards through the Gate out to sea at the setting sun, real Greek holiday stuff.

"When the Hellenides mountain building could no longer accommodate the push from the SSW it became an active margin and a new subduction zone formed as the Mediterranean oceanic lithosphere subducted northwards beneath it. A calc-alkaline volcanic arc erupted through the mountains about 100km above the descending slab.

The opening of the Red Sea affected the absolute motion of the Aegean Plate. In the north, southwesterly movement was slowed to 2.5 cm. per year, while in the south nearest the trench it was 2.9 cm. per year. Clearly the middle of the Aegean plate was under tension and being stretched. Old faults and sutures were reactivated as the crust thinned. The result was uplift and erosion of Horst blocks and sinking of Grabens as the Hellinides sank beneath the sea with only the tops of the mountains remaining visible. Extension has given the Hellenic chain its present arcuate shape."



Santorini and Milos became our stamping ground for the rest of the two weeks. It was a good time to visit them, right at the beginning of the tourist season. Brilliant blue and white paint was being applied to all suitable surfaces and everywhere else was fresh and green and completely covered with wild flowers. They had even painted flowers on the road in Milos for the Easter processions. On Santorini we came to grips with the calc alkaline volcanoes. In fact a little party of 'intrepids', inspired by our leader did just that and scaled a promontory (*see photo*) on Skaros. We discovered that it had been previously inhabited because it was covered with the remains of dwellings dating from the Venetian occupancy of the island. They must have had a good head for heights in those days, and sure feet!

"There are few exposures of the metasediments on Santorini. For 1.5 Ma volcanic activity associated with the subduction zone has gradually shaped the island. At least five large volcanoes have formed since then, Megalo Vouno, Therasia, Skaros, MicroProfitis Ilias and Thera. Eruptions have been of basalt, basaltic-andesite, andesite, dacite, rhyodacite and rhyolite with the longer gaps between eruptions

producing the more acid magmas and pyroclastics. Some eruptions formed calderas.

The enormous eruption that shaped present day Santorini and formed the present caldera happened in 1600 BC. Known as the Minoan because it wiped out the Minoan civilisation it was also responsible for the legend of Atlantis.. The eruption was so violent that it emptied the magma chamber, and the sea rushing in enhanced the activity still further.20cu km of pumice and ashes that were ejected came from a magma chamber situated below the northern half of the present 16km wide caldera. Sections of the previous volcanoes are exposed in its impressive 300m high rim . This rim is broken in three places so Santorini comprises three islands. In the centre of the caldera volcanic activity since 197 BC has produce the Kameni islands and their eruptions of dacite lavas are gradually filling in the caldera. Volcanic activity is centred on a crustal fault that strikes NE/SW beneath Santorini."

If sailing into Santorini's caldera was breathtaking the drive away from the port up a road cut into the sheer walls of the caldera was even more so. We zigzagged up through the whole range of rocks that Santorini had to offer until on reaching the incredibly thick layer of ash and pumice we knew we were at the top (*see photo*). The best way to see Santorini's geological history was from our specially commissioned boat (owned by another George). We studied the rocks of the volcanic sections at close quarters and learnt to differentiate between the grey andesitic blocky lavas and lava flows, red pyroclastic scoria, pale dacitic ashfall and the creamy rhyodacite pumice. There were welded tuffs and unconsolidated pumice. The more resistant dark basic dykes stood proud of the weathered cliffs and were in places displaced by faults.

We landed on the Kameni islands and trekked across various lava fields to the crater (*see photo*) where current activity is progressing. Fumeroles were gently leaking hot sulphurous gases. We were in time to see their temperature being taken, a healthy 95°C-97°C just below the surface. The last eruption was in 1956. Sea temperatures and levels and Seismic monitoring also takes place regularly.

We were promised a swim at the islands, but nobody explained that the hot springs leached iron from the lavas, which combined with bacterial activity to form a thick red '*gunge'* that squelched through your toes when they landed on the seabed.

Back on land we examined hand specimens and looked at the products of the main Minoan event at Thera quarry. First the well-sorted pumice from the initial blast, followed by surge deposits, fine deposits that filled great channels scoured out by steam from when the magma chamber was breached by the sea. In the third stage a slurry of ash and pumice and blocks of volcano wall were incredibly violently ejected, followed lastly by the high temperature finer ignimbrite flow. The quarry was within a kilometre or so of the vent and here the various layers were thickest and the largest blocks had fallen. We included one in our group photo complete with its sag (*see photo*). The quarry was no longer being worked for pumice. It used to be tipped over the cliffs into the boats waiting to carry it away. The Suez canal had used hydraulic cement made from Thera pumice. The demands of tourism however required a pristine blue sea, and the fine dust was also a problem, so quarrying had to stop.

The third stage of the Minoan event dominates the island. It is easy to excavate and original dwellings in the cliff tops were man made caves. These have subsequently been improved and are very upmarket *des-res*. However their position on the caldera rim of an island often visited by earthquakes must make life exciting. 3,600 years of ash cover preserved the remains of the better situated fishing village of Acrotiri after the Minoan eruption. Archaeologists are still excavating the site and we had a glimpse of a life that basically differed little from our own.

Milos was our final port of call. It is far richer in minerals than Santorini because small high level magma chambers released gases and hydrothermal fluids through cracks and fissures into the overlying, mainly acid igneous rocks, altering and concentrating the minerals.

From the beginning this mineral wealth was traded. We visited the site near Filakopi where neolithic men worked and traded obsidian tools. The area was covered with obsidian flakes as well as pottery sherds.

The Romans exported sulphur, pumice, clay and alum from the old Dorian port of Klima as well as oil, wine and honey until the 6th century when it was abandoned after an earthquake.

At Paliochori on the south coast, groundwater moving up through the vent-agglomerates, ignimbrites and lahar deposits that formed the cliffs, leached out minerals such as copper, sulphur and iron and brought them to the surface. We saw where the rocks were coated with crusts of green chrysocholla, yellow sulphur and red oxides (*see photo*). There were hot springs bubbling through the sea here and steam rising through fissures in the rocks. The last sulphur mines on Milos closed in 1962.On the way to Plathiena we saw baryte crystals that had been brought to the surface by hydrothermal fluids rising through fissures in the rhyolite domes where the rocks were all stained red with iron or altered to white kaolin.

At Voudia we were in the industrial Milos and saw kaolin, formed from altered rhyolitic feldspars; perlite, a quickly cooled volcanic glass that contains water in its structure. (its density decreases as it expands on heating and it is used for thermal and acoustic insulation etc) and bentonite, an altered ash that increases its volume when water is added and is used as a sealant in landfill sites, as cat litter etc.

With trade came wealth, and we saw several archaeological sites including: the Bronze age site at Filakopi (where three ancient cities had stood), the Dorian site above Klima (~1000BC), and near Tripoti, the ancient Roman theatre and the Christian catacombs (2nd- 3rd century AD) which are the most extensive in Greece. Today Milos continues to trade and tourism is starting to be important.

There are no eruptions pending, the sun shines, the warm seas are clear and blue….I've heard that before!

Many thanks John for an excellent, friendly, well organised, field trip.

Beryl Jarvis