Higgins MD, Higgins R (1996) A Geological companion to Greece and the Aegean.
Cornell University Press / Duckworth Publishers, Ithaca, NY / London

# 15

# The Cyclades

The islands of the Cyclades were so called by the ancient Greeks, who saw them as a wheel, or cycle, placed round the sacred isle of Delos (Fig. 15.1). On the map they look more like stepping-stones between Europe and Asia, and that has been their role many times in history. They number about 30 islands, large and small; some twelve are important. They are for the most part dry, rocky and picturesque, dotted with dazzling white buildings. They are mountainous and largely barren, but many have useful minerals, and all inhabited islands have at least one good harbour. The larger islands produce olives, vines, and a little barley, but the main industry of most is now tourism.

They were first properly settled about 3000 BC by prospectors for metals and other minerals, who brought with them the Bronze Age culture of their home in western Turkey. They quickly grew rich from metal-working and trading. Their great days were the Early Bronze Age, 3000-2000 BC, during which they produced those exquisite marble figurines known as Cycladic idols and superb silver jewellery. About 2000 BC Minoans from Crete took over the islands and to a large extent transformed their culture. This mixed culture was further diluted around 1600 BC, when the influence of Mycenaean Greece was increasingly felt. This is especially noticeable in the destruction layers on Thera, which will be considered below. The curtain falls on the Cyclades about 1100 BC and (as elsewhere in the Greek world) a Dark Age of some three centuries ensued. It would, however, appear that around 1000 BC Mainland Greeks, fleeing from troubles in their homeland, settled in these islands. The Ionians occupied most of the islands, but it was the Dorians who chose Milos and Thera.

The fortunes of the individual islands will be considered below. Suffice it to say here that the Cyclades were very prosperous in the seventh and sixth centuries BC, but then their luck turned. Overrun by the Persians in 490 BC, they voluntarily entered into the Delian League, which eventually developed into the Athenian Empire. In due course they passed to the Romans and then the Byzantines, who abandoned them to the raids of Goths, Saracens and Slavs. After the fourth Crusade in AD 1204 the islands were given to various Venetian adventurers, who held them until the fall of Constantinople to the Turks in 1453.

The Cyclades are part of a band of dominantly metamorphic rocks, the Attic-Cycladic metamorphic belt, which continues north to Attica and southern Euboea. To the east it abuts similar metamorphic rocks of the Menderes massif exposed on the northern Dodecanese islands and the Turkish mainland (Fig. 15.1). The oldest rocks are part of the Hercynian belt, a chain of mountains formed during the Late Proterozoic by collision of continents (like the Alps and Himalayas), but soon eroded down to their roots. This chain extended to southern Britain. Sedimentary and volcanic rocks were deposited on this basement during the Mesozoic period. Compressions associated with the Alpine orogeny reached this area during the Eocene and parts of the ocean floor descended a subduction zone beneath the Pindos basin (zone). When this ocean had been completely consumed the edge of the Pelagonian micro-continent was dragged down the subduction zone to a depth of about 50 km, before subduction ceased. The rocks were metamorphosed at high pressures and rela-

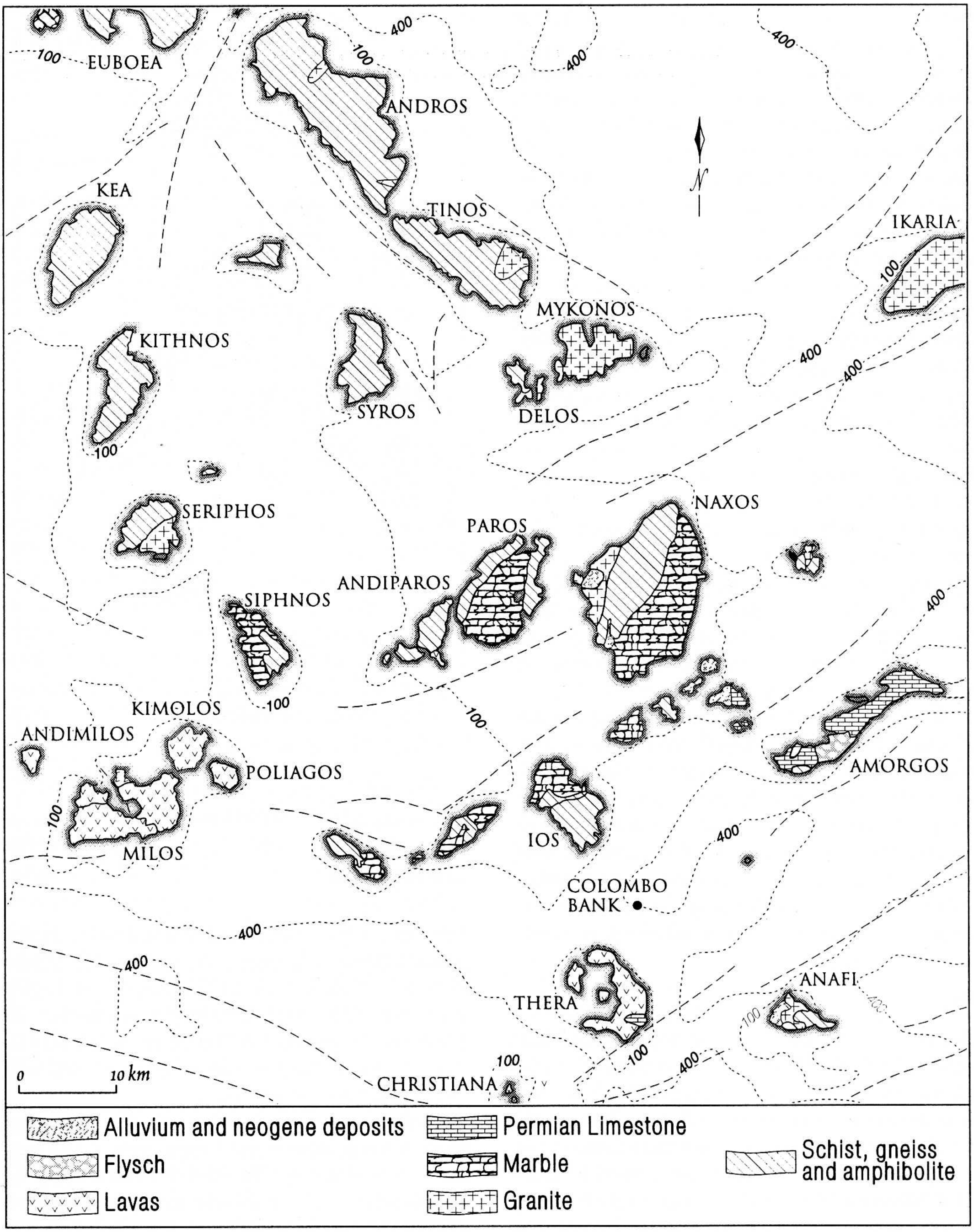



Fig. 15.1. The Cyclades.

tively low temperatures to become blueschists and related rocks.[241]

By Oligocene or Miocene times the overall tectonic force had turned from compression to tension. Movement along shallow normal faults (unlike the steep graben faults that followed in the Neogene) resulted in the rapid uplift of the blueschist rocks, and their juxtaposition against rocks that had never descended very far into the earth.[19, 163] Metamorphism at lower pressure produced greenschists and other rocks. Hot crustal rocks were brought towards the surface by these faults where they melted to form the widespread granite plutons that were emplaced after the faulting ceased. The final result of the extension was that the crust was rather thinner than normal, and hence 'floated' rather lower on the mantle.

Finally, subduction of the eastern Mediterranean sea-floor beneath the Aegean began to produce volcanism about 5 million years ago along the South Aegean volcanic arc from Corinthia to the Dodecanese. In the Cyclades volcanism started on Andiparos and continues now on Milos and Thera.

The Cyclades now lie on a broad underwater plateau, generally less than 200 m deep. This plateau is mostly underwater as the crust is somewhat thinner here than elsewhere in the Aegean region. The widespread Neogene stretching of the crust probably occurred here also, but has not been so significant as elsewhere. Hence the Neogene grabens that are so fertile on the mainland are here underwater.

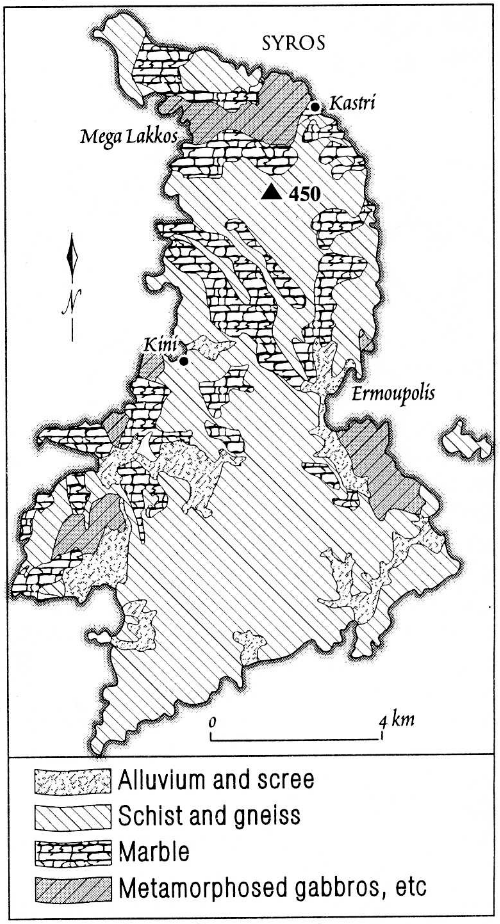



Fig. 15.2. Syros.

## Syros

Syros was inhabited in the Bronze Age, but otherwise little is known of the history of this rocky island. However, it may have been the source of jade in antiquity (see below). It is now an industrial island with an active port.

The bedrock of Syros is dominated by marbles, schists and quartzites (Fig. 15.2).[168] These rocks were originally deposited during the Mesozoic period as limestones, shales and sandstones. Basalts, peridotites and granites, probably parts of an ophiolite, were then thrust on these sedimentary rocks. The whole package was metamorphosed at great depths, in the blueschist metamorphic facies, about 45 million years ago, and subsequently at lower pressures. The high pressure metamorphism produced a number of interesting minerals, including the blue amphibole glaucophane and the green pyroxene jadeite.

Jadeite is the main mineral of one form of jade, a hard, dense and tough rock much valued in antiquity for the manufacture of axe-heads and other objects. Although the mineral jadeite is fairly common, it is rare to find it comprising the bulk of a rock. However, such material occurs as blocks in a band of serpentinite between Kastri and Mega Lakkos in the northern part of the island.[64] It is not known if jade was exploited here in antiquity, but jade axes have been found in Greece and elsewhere, and the provenance of the stone is not known.[238]

## Mykonos

Although the island of Mykonos is now a major holiday resort, in antiquity it was unimportant: Strabo notes only that baldness was prevalent here. In recent times the island has produced a little manganese and baryte, as well as wine and tomatoes.

Mykonos is almost completely made up of a single mass of hornblende-biotite granite which was emplaced into the metamorphic rocks of the Attic-Cycladic metamorphic belt about 11 million years ago (Fig. 15.1).[111] The granite is well exposed around Mykonos town and consists of orthoclase phenocrysts up to 5 cm long, set in a matrix of quartz, orthoclase and biotite. Sedimentary and metamorphic rocks exposed around Panormos bay and on the north-eastern coast were emplaced tectonically on the granite, possibly during the last stages of solidification. Indeed, the granite may have risen up this fault from greater depths during regional stretching of the crust.[163]

Pliocene volcanic ashes, now well lithified, crop out in a small area in the north-east, near Mavro Vourno and Profitis Elias, and on the adjacent island of Tragonissi. Fluids probably associated with this volcanism crystallised in north-west-directed faults as 1-3 m wide veins of baryte, with minor amounts of lead, silver, zinc and iron sulphides, now strongly oxidised to depths of up to 200 m. Iron, lead and silver were mined in the nineteenth century, but recently only baryte has been produced.[18, 158]

## Delos

Although in its day the most significant of the Cyclades, the barren island of Delos is one of the smallest. It owed its importance in antiquity to its being regarded as the birthplace of the god Apollo and his twin sister Artemis, born to Leto under a palm tree near the Sacred Lake. There was a flourishing Mycenaean presence between 1600 and 1150 BC and Delos may actually have been a sanctuary at that early date. About 700 BC the historical sanctuary of Apollo was founded by the Naxians and Delos became the religious centre for all Ionian Greeks. The sanctuary was beautified with statues made by Naxian artists of their marble, among them a colossal statue of Apollo and an avenue of lions. About 550 BC the Athenians replaced the Naxians and from 314 BC Delos became increasingly a commercial rather than a religious centre, a process which was accelerated when in 166 BC the Romans turned the city into a free port. The houses and public buildings which we see belong chiefly to this era, which came to an end in 88 BC when Delos was destroyed.

The island of Delos is dominated by schist and granite (Fig. 15.3). The oldest rocks are mica schists, transitional to gneiss, with minor blocks and layers of marble.[38] These rocks are especially common on the northern part of the island and on the adjacent island of Rheneia. A granite intrusion was emplaced into these rocks about 11 million years ago.[111] This intrusion dominates the southern parts of the island, and is an extension of a larger granite body on Mykonos. In places the granite flowed during crystallisation and orthoclase crystals up to 3 cm long were aligned. The large size of these crystals serves to distinguish this rock from the schist.

Although marble is very sparse on the island it was quarried in antiquity at a number of locations for local use. Layers of white marble about 1 m thick above the theatre were exploited, but numerous other occurrences in the ravine of the Inopos were too small. Both white and grey marble were extracted from small quarries on the hill of Ghlastropi, south-east of the theatre. The grey was used on the Patico of Philip.[269] The largest mass of marble is situated on the coast south-east of Mt Kynthos. This unusual white marble contains very large, branching crystals of calcite, up to 25 cm long. It was used from the Archaic period onwards, and can be seen in the steps of the Great Temple of Apollo.

Most of the ancient city is underlain by granite, with outcrops of schist principally

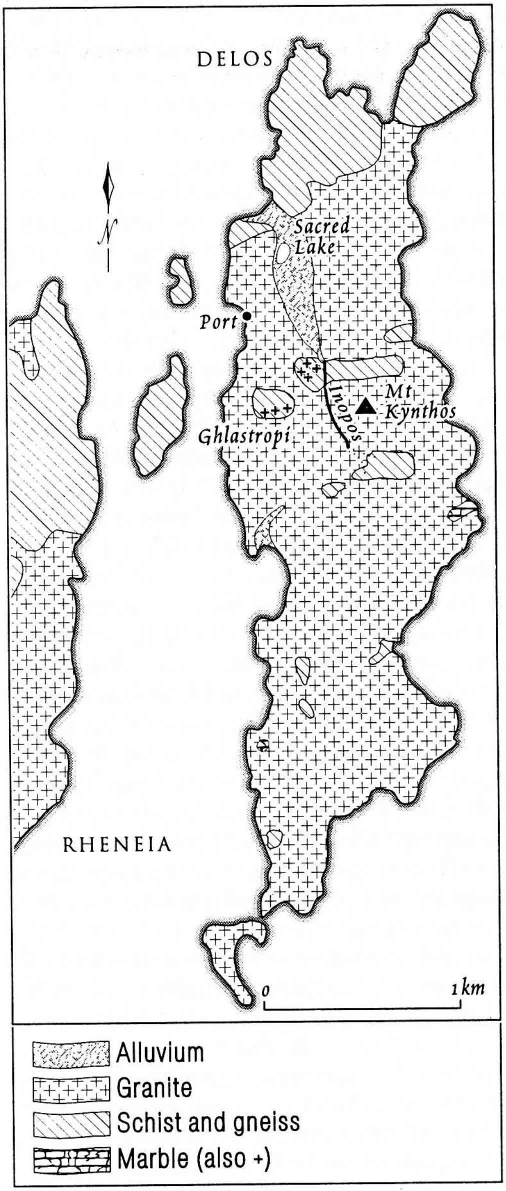



Fig. 15.3. Delos (after 38).

around the Sanctuaries of Foreign Gods. Mt Kynthos (113 m) is dominated by granite, massive in its upper parts but with well-aligned orthoclase crystals at the base of the steps. The streets and squares were paved with local schist, which was also the most important construction material for the houses. Public buildings had foundations of granite or schist, but commonly with superstructures of marble, generally from Naxos or Delos itself.

The island has no streams, except in winter when the small Inopos torrent drains into the bay of Skardhana. The ancient Sacred Lake in the centre of Delos was formed by artificial enlargement of swamps in the lower part of the torrent. Water supply for the ancient town was from countless wells, and many houses had their own rainwater cisterns.

## Seriphos

Seriphos was an important source of iron in antiquity. Iron replaced bronze very slowly partly because of the higher temperatures necessary for smelting. It came into general use at about 1000 BC. Despite the importance to the ancient world of the iron of Seriphos, the island home of the evil King Polydekes of the Perseus legend was only mentioned with contempt in antiquity because of its poverty.

The northern part of Seriphos is made up of blueschists similar to those elsewhere in the Cyclades (Fig. 15.4). There are layers of calcite and dolomite marble within these schists, especially in the central part of the island.[239] A granite pluton was emplaced about 9 million years ago into the southern part of the island.[111]

Hot, watery solutions were released during the crystallisation of the granite and circulated into the adjacent rocks. These solutions contained iron and other elements, which were precipitated during cooling and reaction with calcite or dolomite in the marble, forming a rock called skarn. Skarns formed near the contact, in the central part of the island, were deposited at high temperatures (500-600°C) and are rich in magnetite. These deposits were mined at Playa between AD 1850 and 1930. The limonite iron deposits of Mega Livadi were formed at lower temperatures away from the granite.[64] Reaction with the host marbles also produced many large, fine crystals of green quartz, hedenburgite amphibole, andradite garnet and the unusual calcium and iron silicate mineral ilvaite.[100] A total of about 7 million tonnes of iron have been produced on Seriphos

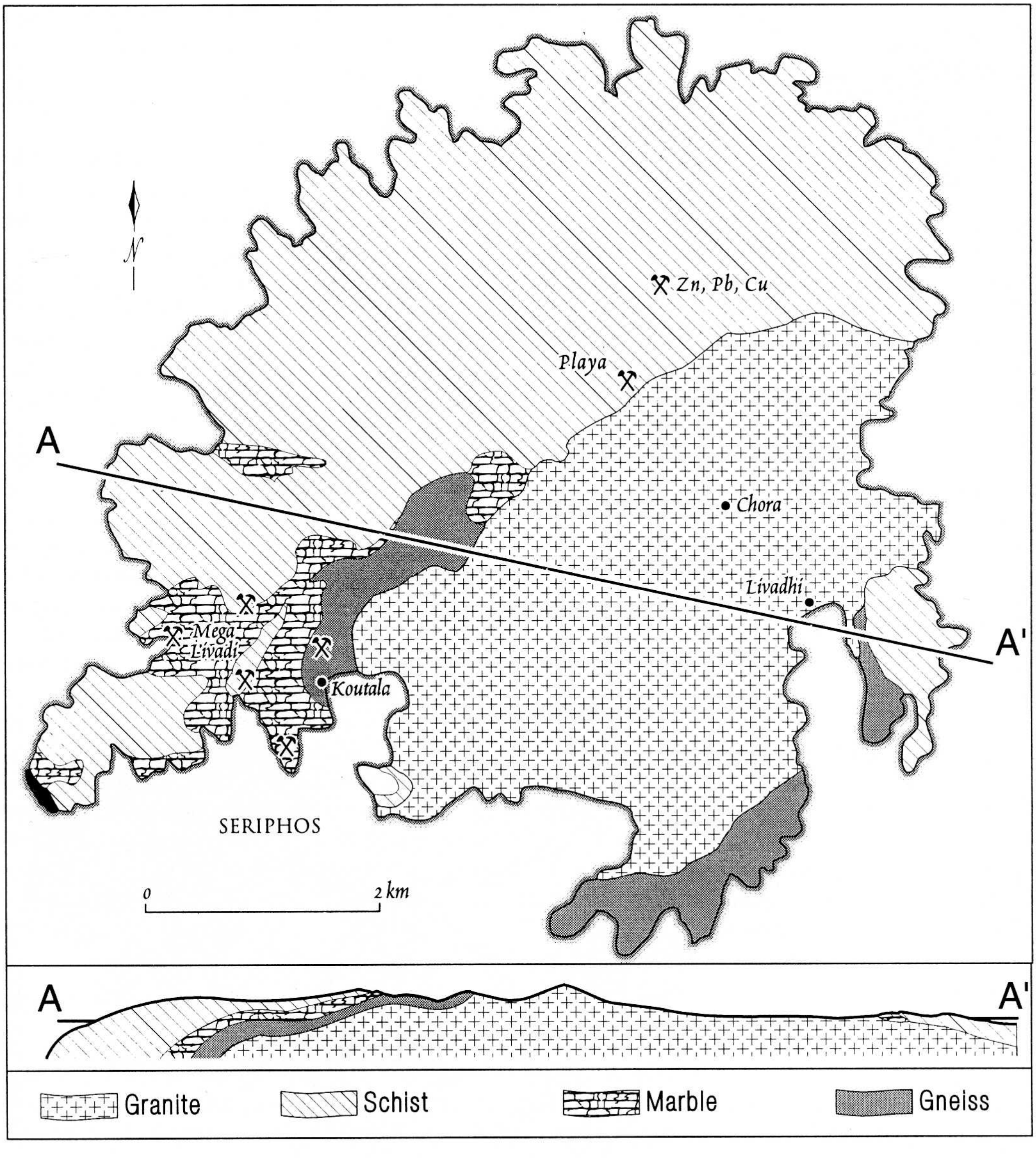



Fig. 15.4. Seriphos (after 239 and other sources).

since antiquity.

A cave opens off one of the iron mines near the bay of Koutala.[216] It is a typical karstic cave, developed in the marble host-rock long after the mineralisation. It was a sanctuary in antiquity as ancient objects were discovered cemented into stalagmites.

## Siphnos

Siphnos is a fertile, well-watered island with a mountainous interior. Until recently it lived by fruit-growing, grazing, and the production of excellent pottery, but in antiquity things were a little different: Herodotus writes that, thanks to their gold and silver, the Siphnians

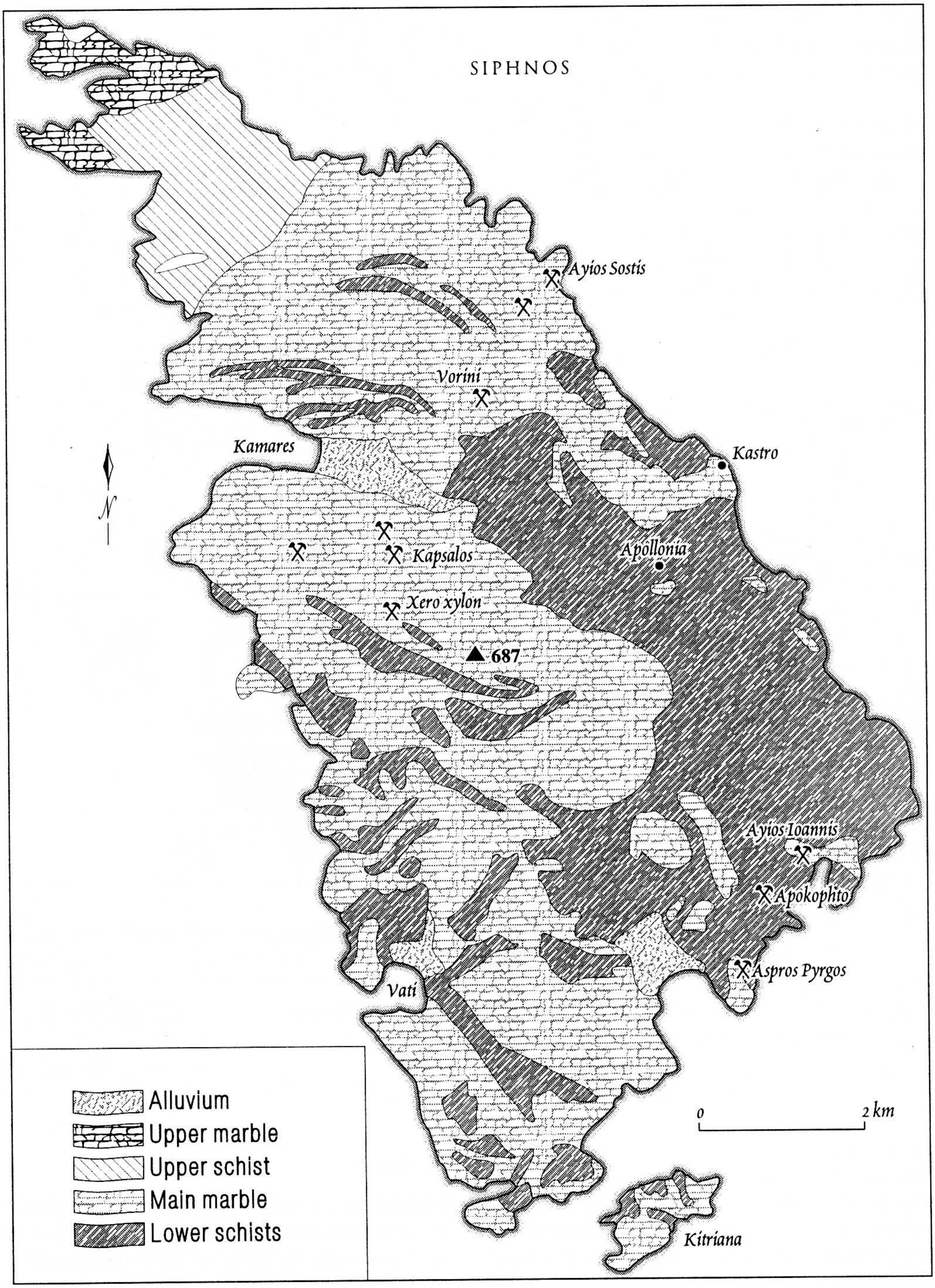



Fig. 15.5. Siphnos.

were the richest of the islanders, and this is borne out by the opulence of their Treasury at Delphi, which they built about 530 BC of Siphnian, Naxian and Parian marble. But 600 years later Pausanias mentions that their gold mines were flooded out, perhaps in the fifth century BC, because they denied to Apollo at Delphi the promised tithe of their wealth.

Much silver jewellery and plate and many lead objects belonging to the Early Bronze Age (3000-2000 BC) have been found in the Cyclades. The principal sources of these metals were the island of Siphnos and Lavrion in Attica.[95] Gold appears not to have been produced at that time. During the sixth and fifth centuries BC silver, lead and gold were produced in large quantities, but the mines were soon exhausted, and from then on Siphnos was poor and unimportant. In the late nineteenth century many of the ancient mines were reopened for iron and zinc.

The geology of Siphnos resembles that of many of the other Cycladic islands and consists of a series of layers of schists and marbles about 2,500 m thick (Fig. 15.5). The lower schist was metamorphosed in the greenschist facies and is mostly exposed in the east. This is overlain by the main marble unit, about 800 m thick, that covers much of the island. The highest units crop out in the north, and comprise an upper schist 400 m thick made of blueschist, and an upper marble unit.

### *Ancient mines*

The ore deposits of the island cluster in the middle and south-eastern parts of the island, mostly within the main marble unit (Fig. 15.5). The five main deposits in the centre line along a rough line, oriented north-east, perhaps reflecting a deeper major fault. All these deposits contain lead and silver, as well as iron minerals. The deposits in the south-east also contain gold.[283]

The deposits were formed from fluids associated with the metamorphism, or with a granitic pluton not exposed on the surface, in the same way as those in Siphnos. The lead deposits, which contain silver and gold as byproducts, formed at lower temperatures, probably from fluids that had already precipitated iron elsewhere.

Most of the ancient mines on Siphnos were worked for silver and lead, but antimony is also present in the ore, though not exploited in antiquity. The workings at Ayios Sostis on the east coast mostly date from the Early Bronze Age and the Late Archaic period (520-480 BC). Other ancient workings at Ayios Silvestros, Vorini, Kapsalos, and Xero Xylon are mostly Late Archaic. All the mines seem to have ceased working about the fifth century BC. Only Ayios Sostis is sufficiently low-lying to have been possibly flooded out; perhaps the others were exhausted by the fifth century BC.

There are three localities on the south coast that are believed to be ancient gold mines, probably dating from the sixth or fifth centuries BC. The ore at Apokophto is a quartz-pyrite vein, that at Aspros Pyrgos is rich in copper and the third mine is at Ayios Ioannis.[283]

## Naxos

Naxos is the largest of the Cyclades, the greenest and, some say, the most beautiful. It is traversed from north to south by a mountain range, culminating in Mt Zas (Zeus) at 1,004 m. Fruit, olive oil, cheese, corn and wine are produced, and the honey is particularly good. The island is also famous for its white marble. Here, according to legend, the God Dionysus found and loved the Cretan Princess Ariadne, abandoned by Theseus on his return from Knossos after killing the Minotaur.

The prehistory of Naxos is that of all the Cyclades: a brilliant Early Bronze Age (3000-2000 BC), with particularly fine 'idols' and vessels of the local marble, followed by an equally brilliant period of first Minoan, then Mycenaean influence. This world ended about 1100 BC, but a century later Naxos was resettled by Ionian Greeks, who rapidly became leaders of all the Ionians and protectors of the Sanctuary of Delos. Thanks to their plentiful supplies of excellent marble, regarded as second only to Parian, and emery, the Naxians founded a school of sculptors second to none in Greece. In 490 BC Naxos was sacked by the

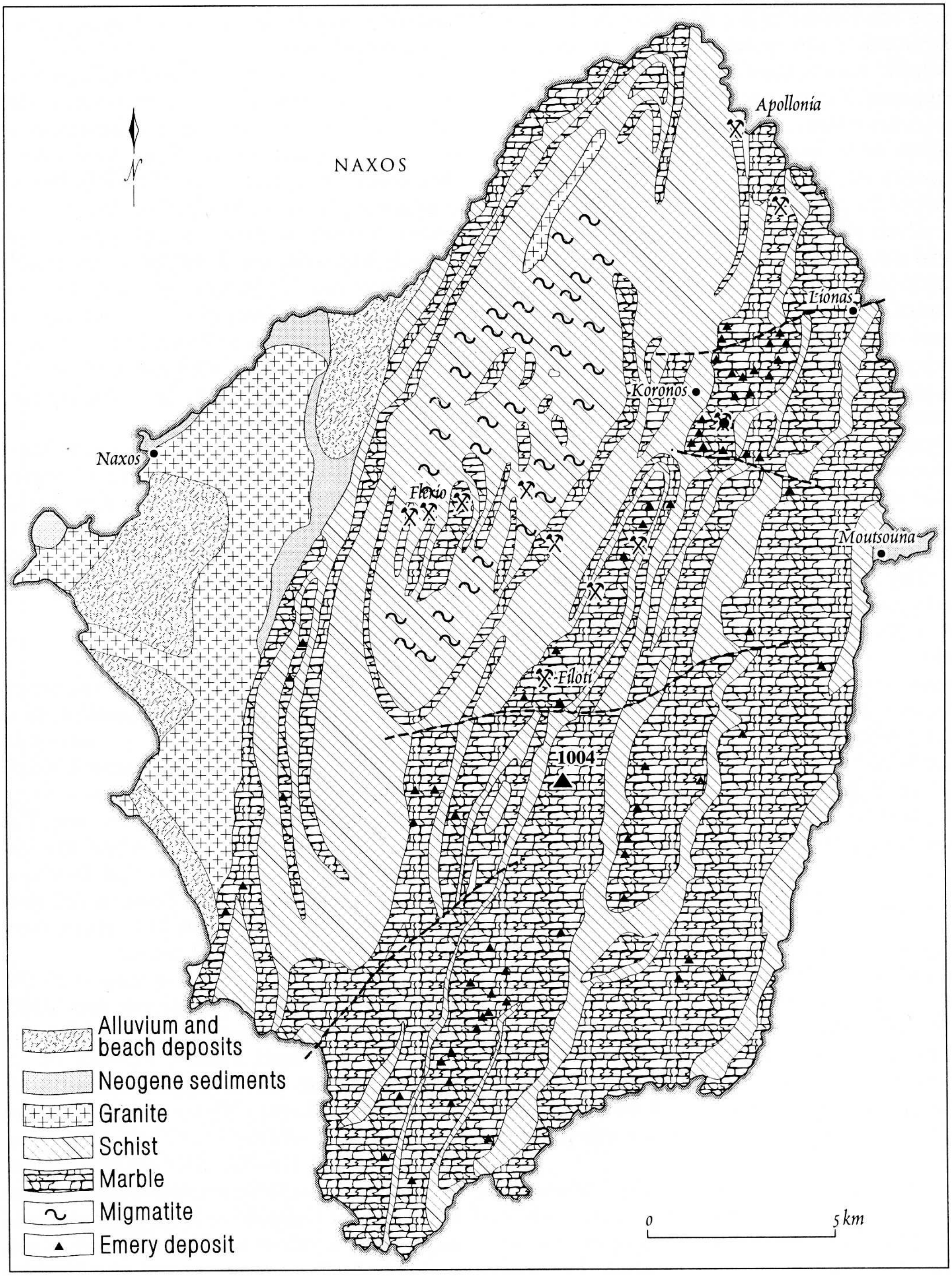



Fig. 15.6. Naxos (after 128 and other sources).

Persians. This was the end of her prosperity until the Venetian occupation in the thirteenth century, which has left many castles and mansions in the Naxian towns and villages.

Much of Naxos is dominated by metamorphic rocks – in the east, marble and dolomite with layers of schist, and in the centre, schist with layers of marble (Fig. 15.6).[128] These rocks were originally limestones and shales, deposited on the Hercynian basement, and were metamorphosed several times, notably 45 and 25 million years ago at depths of 25 to 15 km and temperatures of 400 to 700°C. The temperature of the metamorphism was highest in the centre of the island, where parts of the schists melted. Most of this magma was retained in the original rock, which is called migmatite, but some escaped to form a small granite intrusion.

The original limestones contained layers of bauxite, similar to that found today in central Greece. When the limestone was metamorphosed into marble the bauxite layers were transformed into emery, a rock containing the hard mineral corundum together with magnetite, haematite and margarite mica.[200] In some deposits these minerals have recrystallised to form fissures lined with well-formed crystals of margarite, platy green diaspore, tourmaline, magnetite, rutile and chlorite.

Much of the western part of the island is underlain by a granite which was emplaced about 12 million years ago, long after the end of the metamorphism.[111] This granite contains pale phenocrysts of orthoclase up to 8 cm long, set in a matrix of finer-grained orthoclase, quartz and biotite.

Finally, sedimentary rocks were deposited on parts of both the granite and metamorphic rocks during the Tertiary period. Late, low-angle normal faulting moved these sediments onto the granite.

*Naxos town*

The town of Naxos is built on the edge of an area of low hills and plains (Fig. 15.7). This whole area is underlain by granite, which easily breaks down in this climate initially to produce a fine gravel and finally a fertile soil.

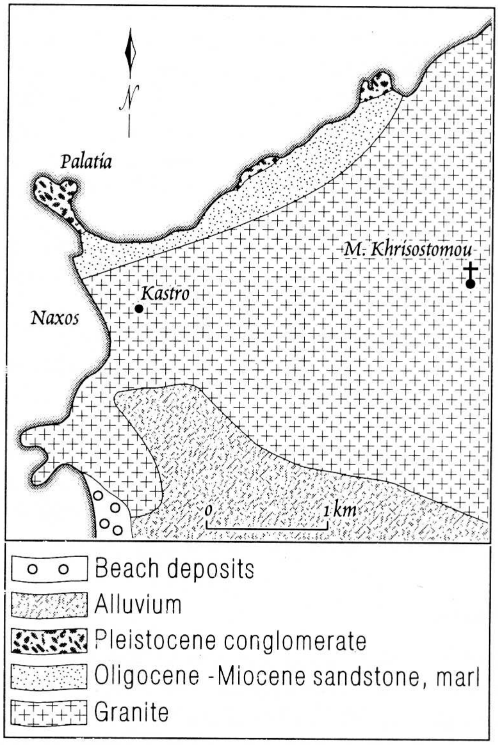



Fig. 15.7. Naxos town and environs.

Weathering of the granite also releases large amounts of quartz, which is reworked by the sea to produce the 'white' sand beaches south of Naxos town.

The Islet of Palatia contrasts with Naxos as it is made of well-cemented Pleistocene conglomerates. Evidence for recent submergence of this area can be seen in a small Roman fish-tank, on the peninsula just north of the isthmus, whose lip now lies about 50 cm below sea-level. The site of the Mycenaean city a few hundred metres north is also partly submerged.

*Marble and emery quarries*

The white, coarse-grained marble, widespread on the island, is excellent for sculpture and architecture. It was quarried in antiquity from many parts of the island, especially towards the centre, where whiter material was available (Fig. 15.6). This is probably related more to the lower stratigraphic level exposed there, which was purer than higher strata, rather than the higher temperature of metamorphism. Unfinished statues of the sixth century BC survive in the ancient quarries at Flerio (Melanes) and Apollonia – the statue in the latter quarry would have been 10.5 m in height (Plate 14A).

Emery was very important in antiquity as an abrasive to shape marble and other stone. Although it occurs at several other places in the Aegean, rarely does the quality match that of Naxos. In ancient times emery was extracted from a large number of shallow quarries, principally in the eastern part of the island between the villages of Lionas, Koronos and Moutsouna.[200] More recently it was extracted from underground mines and transported by aerial tramways to the coast.

## Paros

Paros is the second largest of the Cyclades after Naxos. The interior is almost entirely occupied by Mt Profitis Elias (771 m), which is dominated by the white marble for which Paros was renowned in antiquity. It slopes down to a maritime plain which completely rings the island. Paros is fertile by Cycladic standards, if not as fertile or as well wooded as Naxos.

The earliest settlement was on Saliagos, an islet between Paros and Andiparos, which was settled in Late Neolithic times (5000-4500 BC), a very rare occurrence in the Cyclades. The brilliant Bronze Age civilisation echoes that of Naxos, particularly in the production of 'idols' and vessels in the translucent Parian marble. Around 1000 BC the Ionians arrived, and Paros grew rich. The superb statuary marble of Paros came into its own about 700 BC and for a thousand years there was a famous school of sculptors here.

Like most of the Cycladic islands Paros is dominated by marble and schist (Fig. 15.8). The central, high part of the island is underlain by marble, which better resists erosion, with layers of schist and amphibolite.[198] The lower relief to the east and west reflects the abundance of more readily eroded schist. The original limestones and shales were probably of Permian to Cretaceous age. Three small granite bodies were emplaced into metamorphic rocks around, and possibly beneath, the alluvial plain to the west of Naoussa.

Weakly metamorphosed serpentinite, probably the remains of an ophiolite, and conglomerates of Cretaceous to Miocene age crop out in the north-east and south-east parts of the island. They have been emplaced by low-angle normal faults over the strongly metamorphosed rocks. Finally, these rocks have been partly overlain by Pliocene limestone.

The island was sliced up by faults during the Neogene and a graben, now partly filled with alluvium, stretches almost all the way from Paroikia to Naoussa. The lowlands near the north-east coast were probably formed by erosion of the soft serpentinites, limestones and conglomerates. The relative fertility of Paros is due to the presence of these plains.

### *Ancient marble quarries*

Parian marble was famous throughout the Greek world. Some of the ancient quarries still exist, in the form of tunnels running deep into the mountainside, following the best veins; that is why Parian marble was known as Lychnites, because it was quarried by the light of a lamp (*lychnos*).

Marble was mined in several different areas in antiquity, but the most important was the Lychnites mine near Marathi (Fig. 15.8). This mine exploited a seam of medium-grained, pure white marble 3-4 metres thick. The purity and crystallinity are such that it is translucent. This marble could be extracted in large blocks as it has few joints, cracks or karstic voids.

The mine extends underground at an angle of 35° for about 200 metres. The chisel marks of the ancient workers can be clearly seen on the ceiling and walls. Stalagmites and stalactites have started to develop in the mine, some since it was reopened in the nineteenth century.

Above and below this seam the marble is not so pure and is coloured grey by the presence of graphite. The banding of the marble is related to original layering in the limestone, but the

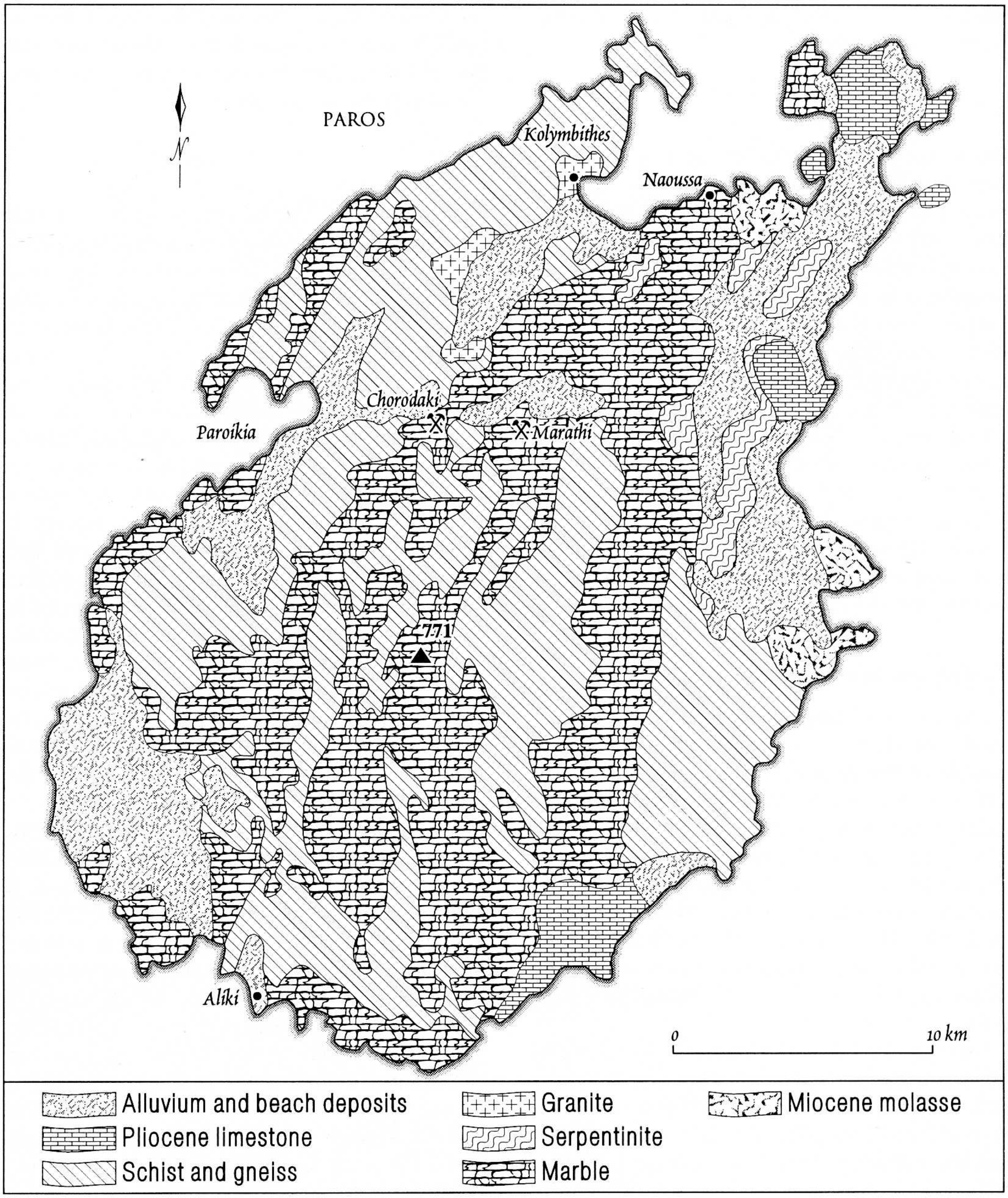



Fig. 15.8. Paros (after 198 and other sources).

orientation has been changed by deformation during metamorphism.

*Naoussa*

The beach at Kolymbithes, just across the bay from Naoussa, is well-known for the strange shapes of the rocks (Fig. 15.8). The bedrock here, and on the hills behind the beach, is a grey granite, which is slightly foliated and is comprised of quartz, feldspar and muscovite. Distant from the beach the rock erodes along joints to produce a blocky, barren landscape, but at low elevations the erosional style is quite different. Here, erosion by the sea has produced dimples, basins and lace work. The process starts with the adsorption of seawater into the rock surface. Crystallisation of the salts on drying expands the rock and small amounts flake off. Once the process has started it continues in the same place, like rust, and hollows out the rock beneath the surface.

## Andiparos and adjacent islands

Andiparos and the two islands to the south-west are dominated by gneiss, schist and marble of the Attic-Cycladic belt (Fig. 15.1).[8] The earliest volcanism of the South Aegean volcanic belt started about 5 million years ago with the eruption of a series of lava domes in the southern part of Andiparos and the two smaller islands to the south.[123] Magmas formed at depth within or above the subduction zone reached the surface via a major zone of faulting which stretches from Ikaria to Milos (see Chapter 2).

All the volcanic rocks here are rhyolites and most are glassy. However, this obsidian was little used in ancient times as it was not available in large enough blocks. Instead the better quality material from the adjacent island of Milos was used.

Andiparos is well-known for the cave on the side of Mt Ayios Ioannis where the Marquis de Nointel celebrated Christmas in 1673. This is a large cave developed in fine-grained marble, following joint planes that dip at about 35° into the side of the hill. The cave probably formed when the topography was very different from its present form. The well-developed formations in the cave date from a time when the climate was much moister as little new material is now being deposited.

## Milos

Milos is one of the two dominantly volcanic islands of the Cyclades. It is almost bisected by an enormous bay with an entrance on the north (Fig. 15.9). The east side of the island is largely low-lying, while the west side is dominated by Mt Profitis Elias (751 m). Apart from some warm springs, Milos lacks surface water and produces little agriculturally but olives and vines. However, it is rich in economic minerals and rocks, used both now and in antiquity.

The natural volcanic glass obsidian was a rare and important commodity in antiquity: it was used for the manufacture of tools and weapons as it gave a much better edge than chert (flint). Melian obsidian has been found in the lower excavated levels of the Franchthi Cave (Peloponnese), and so must have been taken from Milos before 8000 BC, perhaps as early as 11,000 BC. However, there were no settlements on Milos anything like as early as that, and it would appear that for long the obsidian was collected by visiting sailors.

Milos was first settled about 3000 BC at Phylakopi on the north-east coast, presumably with the object of exploiting the obsidian. A royal palace built about 2300 BC lasted till 1100 BC, when the town was deserted. A century later Dorian Greeks from Laconia established a new settlement near Plaka, which has been the capital of the island ever since. Again Milos grew rich, thanks to the thermal springs and the economic minerals. But in 416 BC tragedy struck: the Melians wanted to remain neutral but the Athenians invaded the island, slaughtered the men and enslaved the women and children. Milos never recovered.

Although most of Milos is covered with volcanic rocks, the basement of the island is exposed in a small area in the south-east (Fig. 15.9). It consists of greenschists, minor marbles and relicts of blueschists similar to other parts of the Attic-Cycladic metamorphic belt.[142, 247] About 100 metres of yellow conglom-

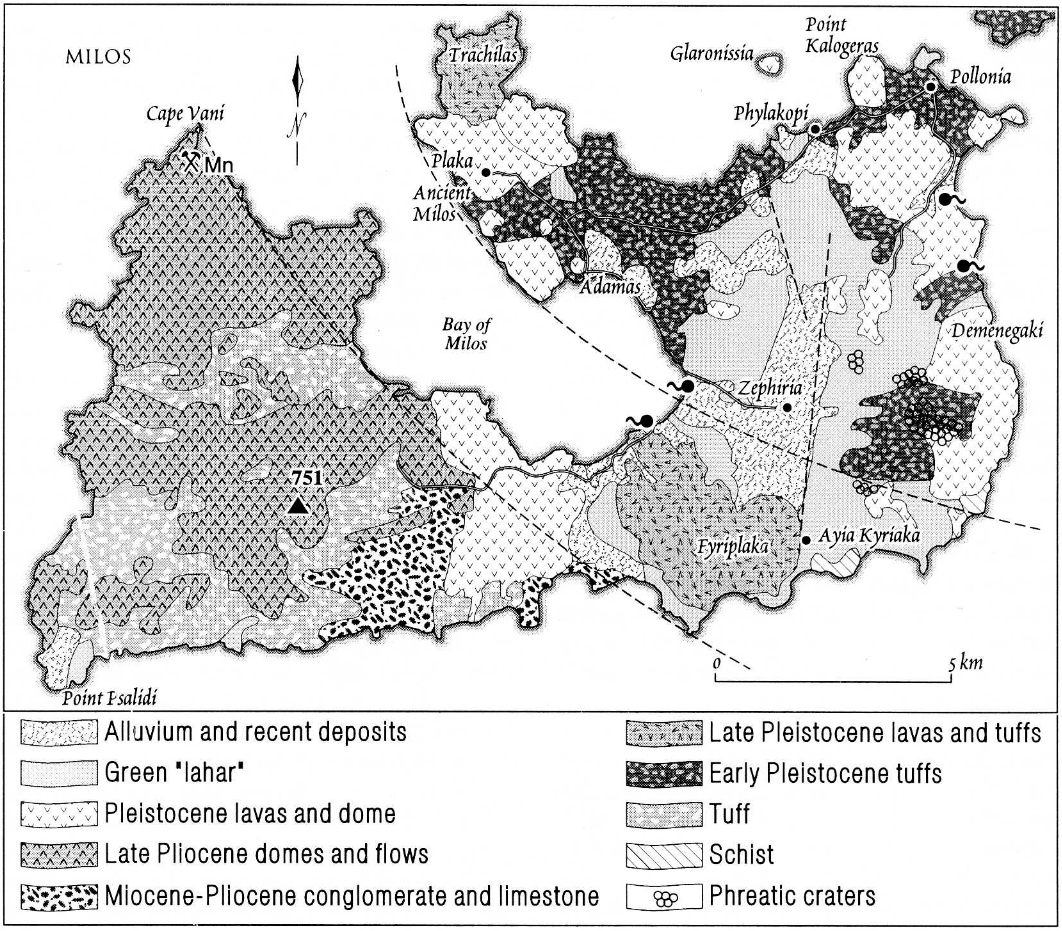



Fig. 15.9. Milos (after 93 and other sources).

erate and limestone were deposited on these metamorphic rocks during the Upper Miocene and Lower Pliocene. Their original extent is unknown, but they now crop out in the south-central part of the island.

Volcanism started on Milos about 3.5 million years ago with the eruption of a series of volcanic ashes in the south-west.[93] Milos must have been submerged at this time as these rocks were erupted underwater. This series of rocks finished with the eruption of andesite pillow-lavas. The next phase of volcanic activity occurred about 2.5 million years ago. It was sub-aerial and was confined to the western part of the island. Andesite and dacite domes and flows, together with the volcanic ashes produced during the eruptions, almost completely covered the earlier volcanic rocks. Volcanic activity then switched to the east, with the eruption of rhyolite domes and submarine andesite lavas and pyroclastic rocks around 1.7 million years ago. These rocks are commonly highly altered and brecciated and may be the source of bentonite and kaolin (see below). This phase of activity finished with the eruption of rhyolitic domes and flows in the central part of the island one million years ago. Activity resumed about 400,000 years ago at Trachilas, north of Plaka. This eruption started with explosive production of pyroclastic rocks, which formed a broad tuff-ring. The violence of the eruption decreased with time until finally lavas were erupted that flowed towards the north. A similar eruption occurred further south at Fyriplaka 140,000 to 90,000 years ago (or possibly more recently, see below). Explosive eruptions of ashes produced a small cone and finally gave way to lavas. This was followed by extensive phreatic eruptions, which deposited rocks made up of pulverised metamorphic basement, the 'Green Lahar'. Following a pause sufficiently long for the development of a soil, volcanism restarted with explosive eruptions and the production of a tuff-ring 1,500 m in diameter. Smaller cones were formed within the larger cone, and lavas flowed from these cones north-eastward to the Bay of Milos.

More recently Milos has again been affected by strong phreatic activity: craters from these explosions are widespread in the easternmost parts of the island. In one area repeated explosions have reworked earlier debris, to give a mass of interlocking craters.

Debris from a phreatic explosion on the south coast, south of Ayia Kyriaka, has buried ancient walls, staircases and unbroken amphorae, indicating that the explosion destroyed an ancient town. This event has been dated at between AD 80 and AD 205, making it the most recent activity on Milos. The volcanic ashes of the Fyriplaka tuff-ring lie under the debris of the explosion, with little sign of erosion, suggesting that the Fyriplaka eruption may have been much more recent than initially estimated.[263]

The two grabens that cross Milos have had an important effect on the geology and topography. The largest comprises most of Milos bay, and continues to the south-east under the Fyriplaka volcanic field (Fig. 15.9).[199] This graben is still very active, as testified by the hot-springs and a significant earthquake in 1992. Most of the damage was restricted to the graben. Another graben runs north-south around the village of Zephiria. The graben fault is well defined on the eastern side by a steep scarp, indicating that it is still active, but the west side may be a hinge.

The heavily indented coastline of Milos and the absence of raised sea-level stands (see Chapter 2), except for a small area around Point Psalidi, shows that the island is subsiding. Other evidence includes drowned beach-rock and ancient structures. Initial work suggests subsidence of up to 7 m since antiquity. This subsidence may be related to the cessation of major volcanism on Milos about 90,000 years ago – since then the crust has cooled and contracted. Or it may reflect crustal tension in this region, as the non-volcanic Naxos is also subsiding.

The earliest settlements in Milos were in the areas with the richest soils. Most of Milos is covered with volcanic ash or scree. This material is transported before there is sufficient time for weathering (chemical breakdown) of the igneous minerals into the clays and other minerals of soils. However, there are parts of the island where streams, and their sediments, have no outlet or restricted access to the sea. In these areas there is sufficient time for weathering and fertile soils can form. One such area is the plain around Zephiria, which is a graben formed by tension in the crust during recent times.

There is no evidence that volcanism has completely ceased on Milos. It is only 90,000 years or less since the last eruption, and pauses of this duration are common. Significant thermal sources at shallow depth (see below) suggest that magma is present beneath the island. However, resumption of volcanic activity would undoubted be preceded by increased hydrothermal activity, such as fumaroles.

### *Plaka and ancient Milos*

The village of Plaka is built on a series of andesite and dacite domes and short, thick flows about 1 million years old (Fig. 15.10). The Kastro hill is the youngest of these domes and towers above the rest. The end of another flow underlies the small hill of Profitis Elias and has been isolated from the main flow under Plaka by faulting. Material from these flows was used to construct the ancient city of Milos. The steep, straight coastline here follows one of the graben faults.

The Christian catacombs were cut into pale-

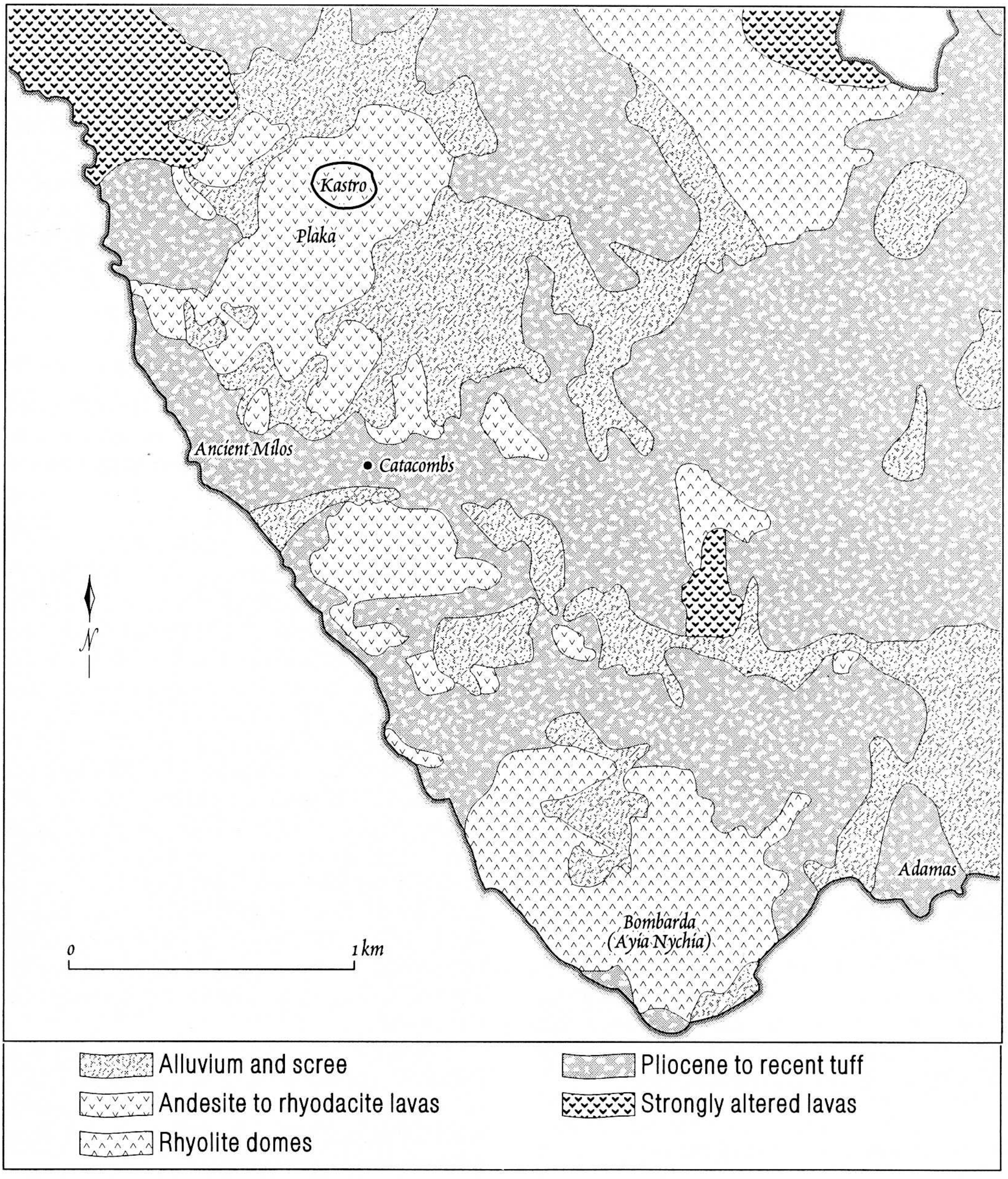



Fig. 15.10. Plaka and Ancient Milos.

grey volcanic tuffs of Late Pliocene-Pleistocene age.[11] This rock is easily excavated as it is light, being mostly made of pumice fragments, and loosely-cemented. It is very porous, so that accumulation of water is not a problem.

### *Obsidian quarries*

Obsidian was extensively exploited in Palaeolithic to Neolithic times, but was not completely displaced by the arrival of bronze in

3000 BC, as it was cheaper and gave sharper blades. Only the coming of iron in about 1000 BC finally supplanted obsidian for blades, but its use continued for ornaments and mirrors.

Obsidian was extracted at two different locations in antiquity.[230] The most important was in the east at Demenegaki where it occurs in the external parts of a 1.8 million-year-old rhyolite dome (Fig. 15.9). Obsidian was also extracted from similar rocks in the Bombarda dome (Ayia Nychia) west of Adamas (Fig. 15.10). In both areas obsidian occurs near the external parts of the domes, where cooling was most rapid. Obsidian is not stable once erupted and eventually crystallises to fine-grained, pale-coloured rhyolite. Layers with bubbles devitrify first and then the crystallisation proceeds along cracks into the bubble-free layers. The result is layers of rounded blobs of fresh obsidian set in fine-grained rhyolite (Plate 15A).

*The Glaronissia islands and Point Kalogeros*

Thick andesite flows near Cape Kalogeros and on the Glaronissia islands have well developed columnar joints (Fig. 15.9, Plate 14B). These joints form after solidification of the lava during cooling and contraction. They propagate inwards from the outer surfaces of the flow, even when they are fan-like. The joints in the lavas at Cape Kalogeros converge towards the centre, showing the original convex shape of the flow. Hexagonal prismatic blocks of andesite from these flows were used in construction at the ancient site of Phylakopi. Caves along the south-west coast have been excavated relatively recently by the sea into old tuffs of the earliest volcanic cycle.

*Hot springs and geothermal energy*

The largest hot spring on the island bubbles up into the Bay of Milos, a few metres offshore near Kanava. A small fumarole issues from a cave beneath caliche adjacent to the salt pans. There is also a small fumarole at Atmoloutra in the lavas of Fyriplaka volcano that has been converted into a Turkish bath but its thermal output is variable, depending on the direction of the wind. Geothermal wells drilled near Zephiria, on the eastern fault of the graben, have located interesting thermal anomalies, although currently there is no thermal activity on the surface. The exploitation of this resource has been prevented for technical and political reasons. The heat source on Milos is probably a cooling body of magma at a depth of several kilometres. Surface water heated by these rocks circulates towards the surface along the graben faults.

*Bentonite, kaolin and other products*

The volcanic products of both Trachilas and Fyriplaka volcanos are rhyolites with unusually high water contents. After extraction the rock is heated, which boils the internal water, and the expanded material, 'perlite', is used as a lightweight aggregate and insulator.

Bentonite and kaolin are rocks rich in clay formed by the alteration of volcanic rocks by circulating hot water.[61] The initial rocks were rhyolite pumice and submarine andesite lavas and breccias. Long after the eruption of these rocks the heat from renewed volcanism circulated water at temperatures of 160 to 230°C. The rhyolite was converted to kaolin and the andesite to bentonite (a rock rich in montmorillonite). These rocks now occur as veins, pipes and irregular masses, and have frequently been eroded and redeposited in depressions. Both are white when pure, but may be coloured red by iron oxides, green by chlorite or yellow by sulphur. Both bentonite and kaolin are extracted from many quarries in the north-east of the island.

The 'alumen' of antiquity was probably bentonite. It had many uses: as a deodorant, as a salve when mixed with honey and as an emetic with copper salts. It was also used in dyeing, soldering and cloth finishing.

Circulating hot waters not only altered the rocks, but also deposited the yellow mineral sulphur, which was mined here in Hellenistic and Roman times. Sulphur was burnt as a disinfectant and for religious purification. It was also applied externally as a medicament and used to whiten and soften wool.

Baryte occurs on Milos as veins and irregular masses associated with the volcanic rocks.[288] It was deposited from circulating hot waters and generally contains other hydrothermal minerals such as sulphides. Some of the veins on Milos are associated with important amounts of silver which was also mined in antiquity.

Extensive deposits of the manganese minerals pyrolusite and cryptomelane occur in the north-west part of the island, near Vani. These minerals have a curious botryoidal form and were probably deposited from large mineral springs during the last few 100,000 years. These deposits have been heavily exploited during the last 150 years.[288]

### Andimilos, Kimolos and Poliagos

The islands of Andimilos, Kimolos and Poliagos are covered with volcanic rocks that are roughly contemporary, and similar in composition to those of Milos (Fig. 15.1). Andimilos is the top of a complex volcano dominated by lavas. Activity ceased here about 320,000 years ago.

The island of Kimolos is dominated by pyroclastic rocks.[89] The Kastro ignimbrite was erupted from a vent west of Kimolos about 3 million years ago and originally covered the whole Milos group, but is today mostly exposed in the north-western half of the island. A complex series of younger pyroclastic rocks, with some lavas, covers the south-eastern side of the island. A number of hot springs debouche near the coast, especially in the north-west. Early fumarolic activity altered the pyroclastic rocks to give important deposits of the clay bentonite. Bentonite is mined on Kimolos and minor deposits of lead and silver have been exploited.

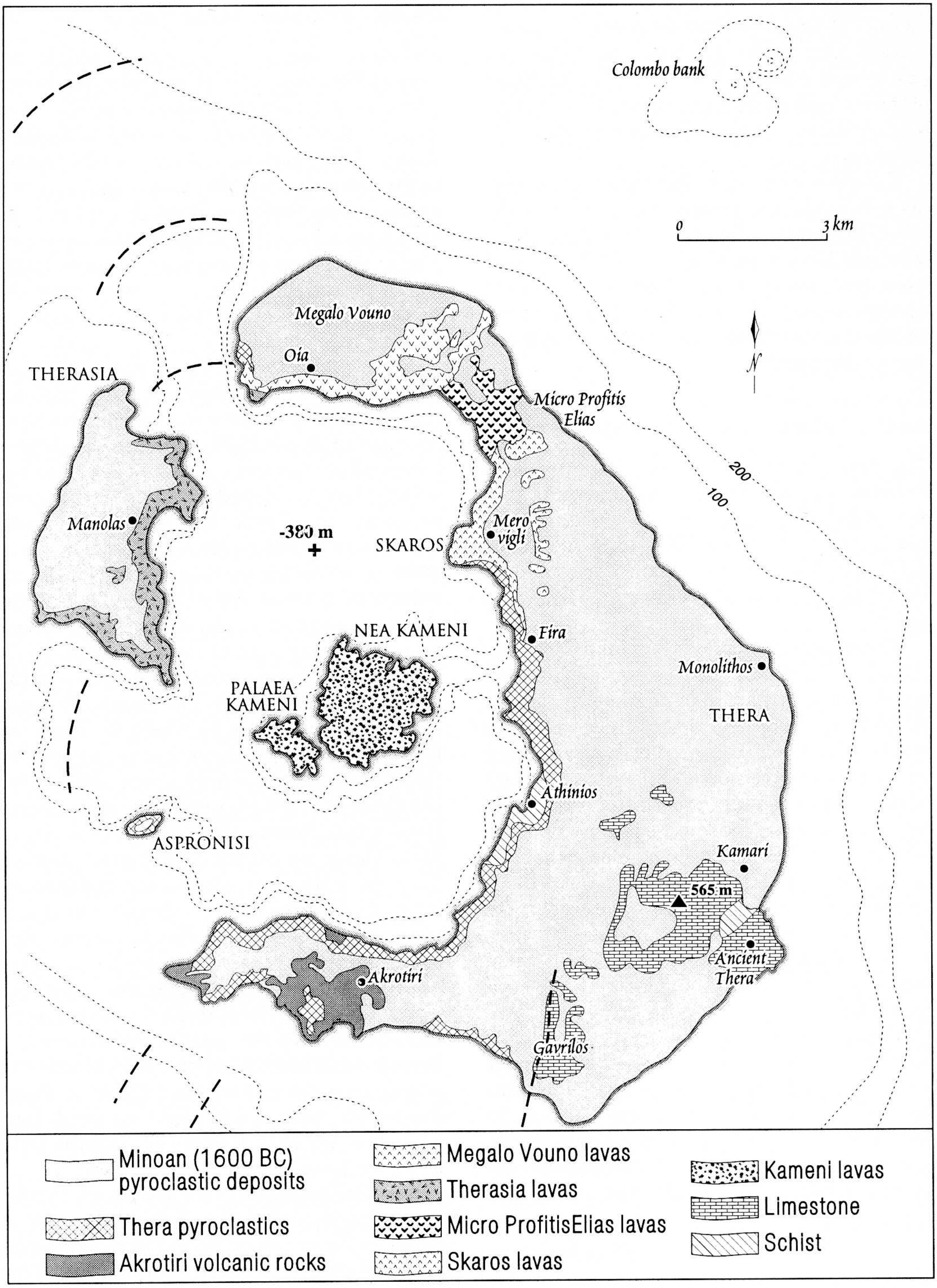
Poliagos is also dominated by pyroclastic rocks.[89] It was covered with tuff by a major eruption about 2 million years ago, which also covered much of the Milos group. These rocks are exposed in the north-west part of the island, but have been buried by more recent lava domes and flows in the south-east.

### Thera (Santorini) island group

Sailing into the 10 km diameter multiple caldera at Thera (Santorini), one experiences one of the most impressive geological sights in the Aegean. Three hundred metre high cliffs show a magnificent section of the geological history of the island and the 700 m deep caldera gives an idea of the explosive force required to excavate such a hole. The eruption that produced part of the present caldera, probably the largest in recent times, buried a town near the modern village of Akrotiri, and created a Bronze Age Pompeii.

The early history of Thera, from Late Neolithic (about 4000 BC) down to about 1600 BC, runs parallel to other Cycladic islands. Then between 1600 and 1500 BC (to use the chronology preferred by most archaeologists, but see below) there flourished a brilliant civilisation, excavated at Akrotiri and elsewhere, which was closely linked to Minoan Crete. In about 1500 BC a terrible earthquake forced the inhabitants to leave the island. In due course they returned and set about repairing the damage, but were soon interrupted by a cataclysmic volcanic eruption that changed the landscape dramatically. For about 150 years afterwards Thera was uninhabited. There followed a limited re-occupation by Mycenaean Greeks at Monolithos until about 1100 BC. We next hear of Thera about 800 BC, when Dorian Greeks from Sparta established a new city at Mesa Vouno, on the south-east coast. Ancient Thera (as it is known today) prospered from the start, and continued into Roman and Early Byzantine times. When the Venetians took control in the thirteenth century they created a new capital on the west coast called Santorini (today Fira) after Saint Irene. The next important event was the partial rediscovery of Bronze Age buildings in the 1860s in ash and pumice quarries on Thera and Therasia. These discoveries were not followed up until 1967 when the fabulous remains at Akrotiri were unearthed (see below).

One last point – is there any foundation for the suggestion that the story of Atlantis is based on the events at Thera? Most archaeologists feel that there is not: many aspects of the


Colombo bank
0
3 km
N
Megalo Vouno
Oia
THERASIA
Micro Profitis Elias
200
100
Manolas
-380 m
SKAROS
Mero vigli
NEA KAMENI
Fira
Monolithos
PALAEA KAMENI
THERA
Athinios
ASPRONISI
Kamari
565 m
Ancient Thera
Akrotiri
Gavrilos
Minoan (1600 BC) pyroclastic deposits
Thera pyroclastics
Akrotiri volcanic rocks
Megalo Vouno lavas
Therasia lavas
Micro ProfitisElias lavas
Skaros lavas
Kameni lavas
Limestone
Schist

story just do not fit with what happened at Thera and most scholars would agree that the Atlantis story was no legend, but the invention of Plato in the fourth century BC in his books *Timaeus* and *Critias*. As his famous pupil Aristotle said: 'The man who dreamed it up made it vanish.'

Although Thera and the adjacent islands are now mostly covered with volcanic rocks, the volcano was built on a base of non-volcanic rocks (Fig. 15.11). The highest hills of the main island, Mt Profitis Elias (565 m), Mesa Vouno (Ancient Thera) and Gavrilos, are dominated by Triassic crystalline limestone transitional to marble. The underlying rocks are also exposed in the lower parts of the caldera walls near the port of Athinios. Here a series of schists and other metamorphic rocks are cut by minor granite intrusions. Fluids associated with the granite reacted with the host rocks to produce a small deposit of lead and silver.

Volcanism started about 1.5 million years ago in this region, and was related to subduction of the African plate beneath the Aegean plate. Volcanic features on the island of Nea Kameni and in the northern part of Thera are oriented north-east/south-west, a direction reflected in the location of the Colombo Bank underwater volcano 10 km to the north-east (Fig. 15.11; see below) and the volcanic Christiana islands 18 km to the south-west (Fig. 15.1).[227] The prevalence of this direction suggests that magmas probably rose up steep north-east/south-west faults, produced during Neogene regional tension in the crust.

The volcanic history of Thera is complex and about seven different volcanic centres (more or less independent volcanos) have been active. The earliest volcanic rocks are exposed on the Akrotiri peninsula: small amounts of andesite and dacite lavas and ashes were erupted intermittently from 1.5 to 0.6 million years ago.

Volcanism restarted about 200,000 years ago and has continued to the present day.[70] The most active volcanic centre was situated near the town of Fira, in the presently flooded calderas, or beneath the recent Kameni islands. There have been at least twelve major eruptions from this centre, particularly 100, 79, 54, 37, 18 and 3.5 thousand years ago. Many eruptions started with a fall of pumice and culminated in pyroclastic flows. In several eruptions the magma chamber was partly emptied and the roof fell in to produce a caldera. The last major eruption, the Minoan, 3,500 years ago, resembled many of the previous eruptions (see below). The volcanic centres in the north of the island, Therasia, Megalo Vouno, Micro Profitis Elias and Skaros, were also active during this period. They produced lava as well as pyroclastic rocks.

Fig. 15.11. The Thera island group and the Colombo bank (after 218 and other sources).

There has been much research on the exact geography of the islands just before the Minoan eruption because of the archaeological implications.[69] The Thera caldera is the product of at least four major eruptions during the last 100,000 years. Just before the Minoan eruption the caldera formed 21,000 years ago had become shallow, but was still flooded by the sea (Fig. 15.12). The coast followed a line close to that of the present caldera, except that Thera, Therasia and Aspronisi were all jointed together to form a single horse-shaped island with a gap to the south-east. At the centre of the bay was a volcano, rather similar to the Kameni islands today, except larger. The bay would have provided an excellent harbour, sheltered from the prevailing winds.

### *The Minoan eruption*

The Minoan eruption was one of the largest in recent times, producing about 36 cubic kilometres of rhyodacite pumice and ash over a period of a few days, and its effects were felt around the world. The eruption occurred between 1650 and 1500 BC, but there is still considerable debate on the exact date (see below). Strangely enough there are no written records of the eruption, although various biblical episodes have been attributed to it. The description given below is based on the study of the rocks produced by the eruption.

The eruption began from a north-east/south-west fissure on an island in the bay

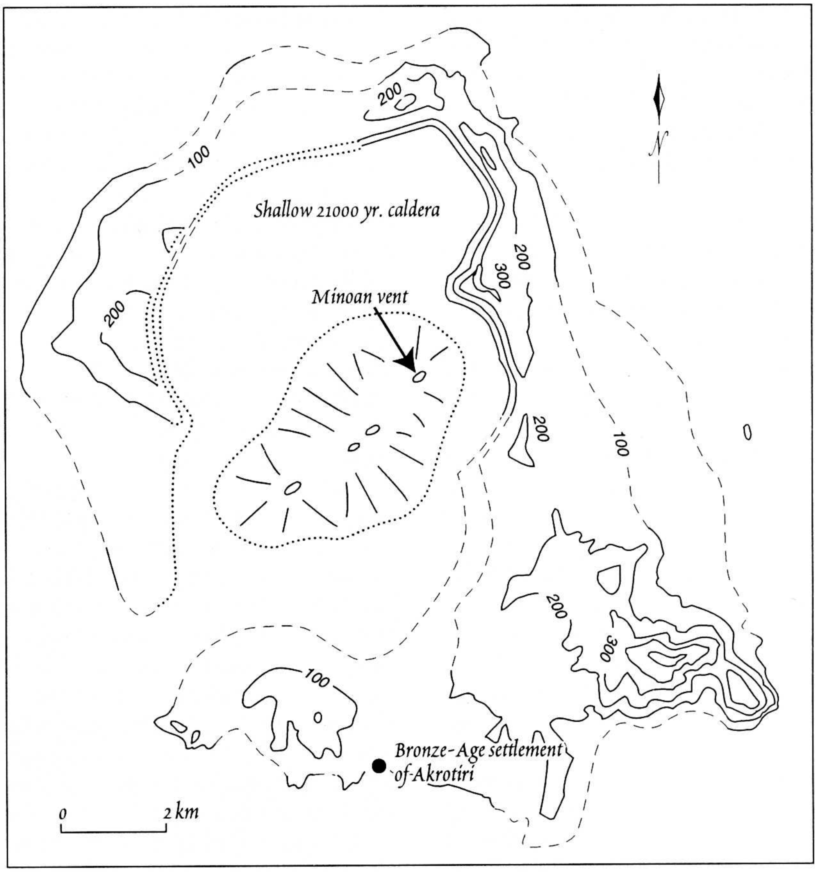



Fig. 15.12. Pre-Minoan eruption geography (after 69). The solid lines indicate the most well-defined coastline; the broken lines show where it is less certain; and the dotted lines are conjectural.

about 1 km south-west of Fira town and was initially of the 'Plinian' type.[110] The magma erupted as a fast-moving jet of hot gas and pumice blocks some of which rose to a height of 36 km in the atmosphere. During the next phase the fissure grew towards the south-east, into the shallow bay. Interaction of the magma with seawater produced steam (phreatomagmatic) explosions which widened the vent and increased the rate of eruption. Some of the fine ash simply fell from the cloud, but most was deposited from surges of dust and gas that moved at great speed horizontally from above the fissure, commonly producing great dunes. The next stage of the eruption is enigmatic: The pumice and rock blocks of this phase may have been produced by pyroclastic flows, mudflows, or by very large phreatomagmatic explosions, or perhaps a combination. The final phase of the eruption produced thick ash flows that were sometimes sufficiently hot to weld themselves together to produce a hard, dense rock called ignimbrite. Fig. 15.13 is a schematic section through the products of this eruption.

Most of the pumice and ash fell close to the volcano, covering much of Thera and the surrounding sea-bed to a depth of several metres. However, substantial quantities of ash also fell on the islands of the western Aegean and on

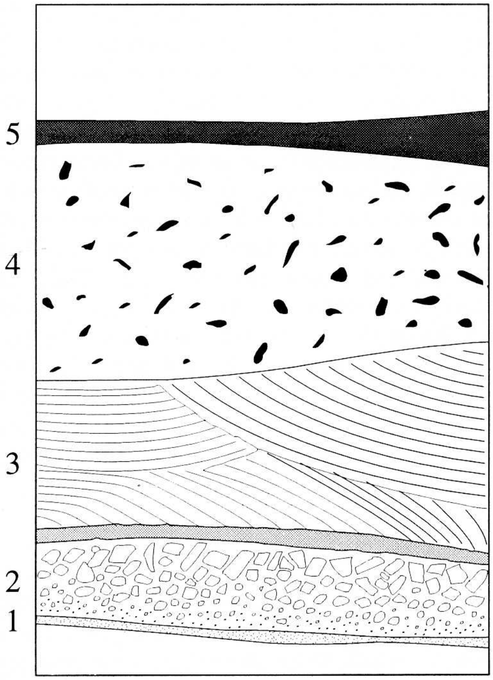



Fig. 15.13. Generalised stratigraphy of the Minoan deposits (after 110). 1 = Ash of precursor? eruption, 1-4 cm thick. 2 = Ash of Plinian phase, 10-600 cm thick. 3 = Phreatomagmatic, base-surge deposits, 10-1200 cm thick. 4 = Ash-flow deposits 1-55 m thick. 5 = Ignimbrite 0-40 m thick.

western Turkey. Thin layers have also been found 800 km away in the Nile delta,[255] lending credence to the descriptions of the veiling of the sun in Egyptian papyrus records and the book of Exodus in the Bible: 'There may be darkness over the land of Egypt, even darkness which may be felt.'

Draining of magma from the chamber beneath the island during the eruption created an unsupported roof, which collapsed to produce much of the caldera that we see today. This started in the west, along what is now the eastern shore of Therasia, and unzipped towards the east along a circular fracture. The original vent area and fissure were destroyed and the new caldera had a floor about 400 m below sea-level or about 700 m below the summits of the shield volcanos. The sides of this hole were unstable and huge blocks 1-2 km wide slipped into the caldera. These areas now form the channels north and south of Therasia.

The Minoan eruption was almost certainly accompanied by a major tsunami, either produced by the eruption itself, or by associated landslides and earthquakes.[14, 203] Wave-borne pumice has been found in Israel at a height of 7 m, and on the nearby island of Anafi at a maximum height of 40 m. These heights can be extrapolated to give a maximum wave height at Thera of about 50 m and about 12 m on the north coast of Crete. Such waves would have been extremely destructive, though it is debatable whether they caused the final destruction of the Minoan palaces.

The exact age of this eruption has been much debated, with many archaeologists favouring 1500 BC and much geological evidence supporting 1650 BC.[107, 169] Archaeological evidence is based largely on the styles of pottery and other artifacts found at Akrotiri, and this assumes that the town was abandoned immediately before the eruption. This chronology was calibrated by reference to Egyptian king lists and an astronomical fix. The most direct geological evidence of the date of the eruption comes from carbon-14 dating of vegetation killed shortly before or by the eruption. Most recent analyses give ages in the range 1700-1600 BC.

Major eruptions can also be dated indirectly by their global effects, although the identification of the volcano responsible is not always clear. One such effect was produced by injection of sulphuric acid into the upper atmosphere during the eruption. Layers of ice deposited in Greenland at about 1645 BC were especially rich in sulphuric acid, but there is no significant anomaly at 1500 BC. Injection of ash into the upper atmosphere produced climatic effects: widths of tree-rings in Californian bristlecone pines indicate that there was extensive frost damage in the winters of 1628 to 1626 BC, which could be ascribed to a large volcanic eruption. Chinese records indicate that at the end of the reign of King Chieh (about 1600 BC) the sun was dimmed and there was a yellow fog. Floods followed by severe drought led to massive crop failures. We cannot be sure that all these effects were not caused by an eruption of another volcano in the northern hemisphere of similar magnitude, slightly earlier than the eruption of Thera, but there is no evidence for this.

If the geologically established age is shown to be correct, the archaeological chronology must be adjusted. A possible source of error in the archaeological chronology may be in the Egyptian king lists used for calibration.

*The caldera wall*

A wonderful 250-metre section of the caldera wall can be seen from the cable car and the zig-zag steps up to Fira (Fig. 15.14). Almost all the rocks seen are tuffs (hardened volcanic ashes) of variable composition, in contrast with the predominance of lavas on the Kameni islands with a limited range of composition (see below). The lowest part of the section is probably about 100,000 years old and is made up of tuffs formed during the large eruption that produced the southern part of the present caldera. This was followed by a 35,000-year-old sequence of tuffs. Finally at the top there are silica-rich lava flows and domes, and a thick section of tuff produced during the Minoan eruption on which the town is built (Plate 15B).

The colour of the rocks in the caldera wall reflects both variations in original composition as well as oxidation and alteration of the rocks since their crystallisation. The steepness of the cliff is related to the hardness of the rock. Ashes that were still at high temperatures when they were deposited welded themselves together as they settled to give a very durable rock (ignimbrite). Those ashes that were cool when they fell gave a weaker rock (tuff) that can be crumbled in the hand. Some of the vertical wall-like structures seen in the rock-face are dykes, cracks that have been filled with magma. Some of these dykes may have been the 'plumbing' system, up which magma flowed to produce lavas or ashes. These dykes tend to be harder than the surrounding rocks and hence stand out after erosion. Some of the vertical structures lack a core of solidified magma and hence are not dykes. They too started as cracks, but only hot watery fluids passed up them to form fumaroles on the surface. Crystallisation of minerals from these hot fluids in the walls of the crack made these rocks slightly harder than those surrounding them, and hence they have better resisted erosion and now stand out.

*Palaea Kameni and Nea Kameni islands*

The names of these islands, Palaea Kameni, 'Old burnt island' and Nea Kameni, 'New burnt island', reflect their present, inhospitable appearance. Although now almost uninhabited, the islands, such as they were, supported a small fishing community during the Middle Ages.

The Kameni islands are the summits of a volcano that rises 400 m from the floor of the caldera (Fig. 15.15). Volcanic activity may have restarted soon after the Minoan eruption, but nothing broke the surface until 197 BC when a new island called Lera was formed. It was located near the old Minoan fissure but was rapidly eroded to below sea-level. The oldest rocks now seen date from AD 46 and make up most of the island of Palaea Kameni.[23] A further eruption occurred near the same spot in

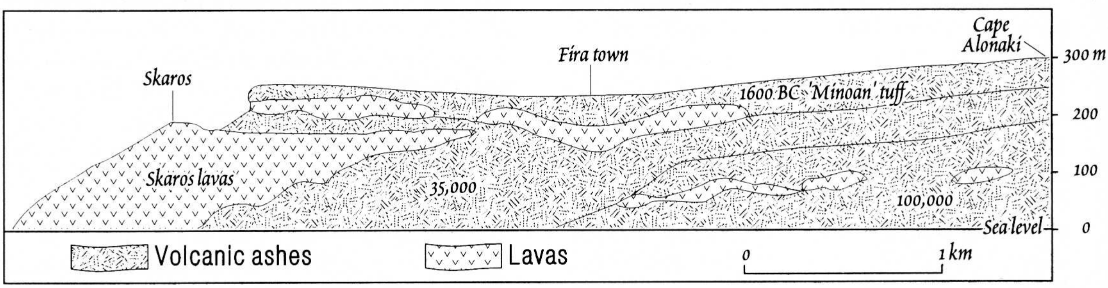



Fig. 15.14. The caldera wall near Fira town (after 118).

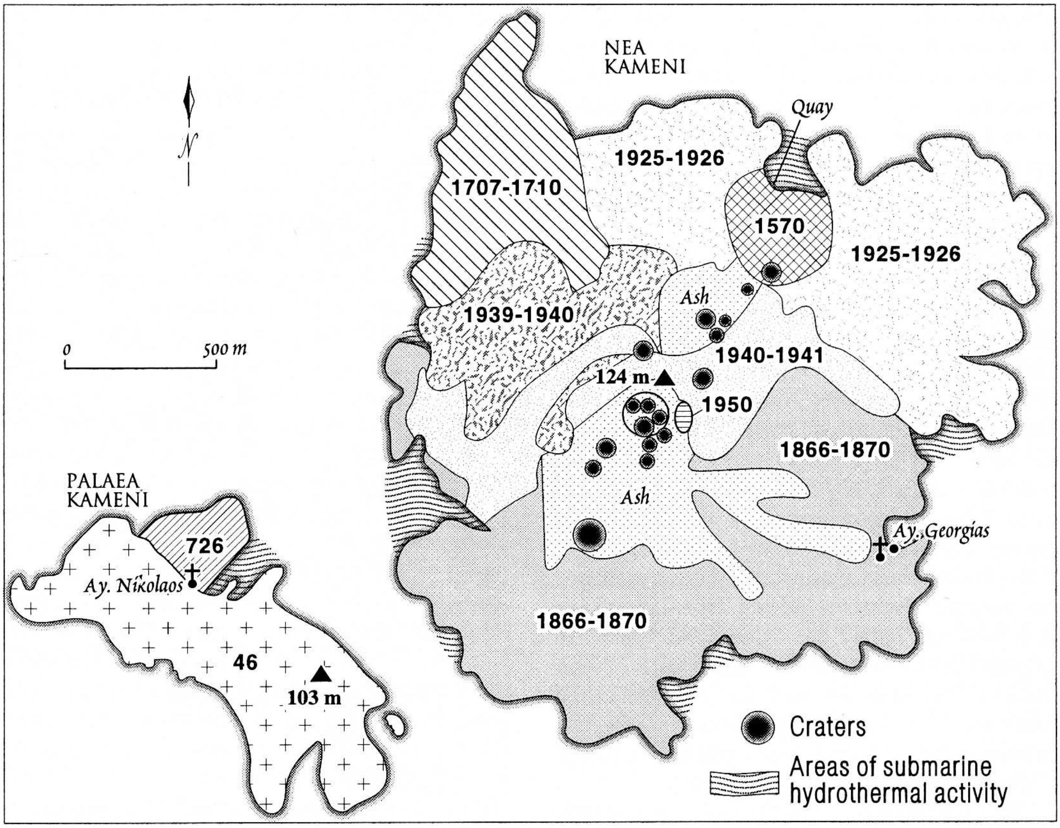



Fig. 15.15. Kameni islands (after 23, 280 and other sources). The age of each series of flows is indicated. The ash comes from many different eruptions.

AD 726, but since then activity has shifted to the north-east to form Nea Kameni. The last eruption was in AD 1950. Most of the eruptions have been relatively quiet, except those of 197 BC and AD 726. The latter was sufficiently spectacular, and produced so much floating pumice, that it was noted by the Emperor Leo III in Constantinople. He interpreted it as a sign of divine displeasure, and imposed the Iconoclasm.

In contrast to the preponderance of ash on the main islands, both Kameni islands are dominated by lava. The composition of the rocks erupted on these islands has not changed substantially since AD 46 and is a dacite, with phenocrysts of pale plagioclase and minor green olivine.

The boat from Thera passes the lava flows of the AD 1925-6 eruption before docking in a small cove between two lobes of these lavas. Here the AD 1570 lavas and ashes are exposed. These are more strongly weathered than the recent flows and hence provide a better landing point. From here a path follows a line of ash cones produced from AD 1570 to 1950. The line is approximately north-east/south-west, and is probably the expression of a deep fault that taps the magma chamber 2-4 km below. About halfway up we see the lavas of the AD 1940-1 eruptions.[101] In general the amount of vegetation is related to the age of the lava flow or ash.

At the summit (148 m) there are many intersecting cones and craters. The youngest was formed in 1950 and is about 100 m south-east of the triangulation point. The eruption which formed this crater started on 10 January 1950 with an explosion. The frequency of the explosions reached a maximum on 17 January and then decreased until 2 February, when the eruption ceased.[102] Eruption of lava started around 17 January and produced a small dome, about 10 m thick and 40 m in diameter. This eruption was much less important than the eruption of 1939-41.

There are many fumaroles in the walls of the craters near the summit, and their activity changes from year to year. These are vents where gases, largely water vapour, escape from the earth. These gases alter the surrounding rocks to produce clays, silica and red iron oxides. Small amounts of hydrogen sulphide in the gases are oxidised by the air to sulphur which crystallises as yellow needles around the vents. These gases originated as seawater from the bay which seeped into the rocks at the base of the islands and was warmed by heat from the magma chamber below. This hot water then rose up below the island, all the time interacting with rocks on the walls of the cracks and dissolving sulphur, iron and other elements. Therefore, although the water in the fumaroles comes from the sea, the heat and the sulphur come from the volcanic rocks.

Much of the water that circulates at depth does not emerge in the fumaroles, but as hot springs in the bays around the islands. Iron dissolved in these waters is precipitated as they interact with the cool seawater. The fine particles of iron hydroxide colour the waters brown and green, and form a brown deposit on the surrounding rocks and the floors of the bays. One such spring is on Palaea Kameni, beneath the chapel of Ayios Nikolaos.[272]

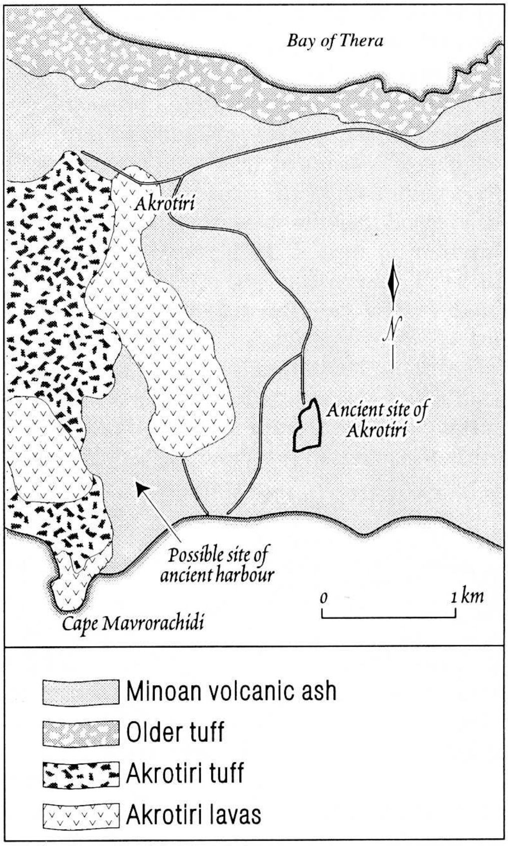



Fig. 15.16. Ancient and modern Akrotiri (after 218).

*Ancient Akrotiri*

South-east of the modern village of Akrotiri lies a Bronze Age town buried by the Minoan eruption (Figs. 15.11, 15.16). The remains were discovered after ancient walls were exposed in a gully cut into the Minoan tuff deposits. The town (now also known as Akrotiri) will be described below, but what of the geological environment at the time of the eruption? To the west of the town lay low hills of much older dacite lavas and andesite ash cones, such as at Cape Mavrorachidi.[218] These rocks were partly covered by tuff from eruptions 100,000, 35,000, and 13,000 years ago. Weathered tuff from the last eruption formed an ancient soil on which the town was constructed.[225] There may have been a harbour to the west, beneath the hills (Fig. 15.16).

And now for the human situation, as revealed by the recent excavations. The community at Akrotiri inhabited a prosperous city with cobbled streets and small squares. The houses, of stone and clay with timber reinforcements, had up to four storeys; staircases were usually of stone, doors and windows of wood. The best houses were decorated with lively frescoes on the walls, many like those of the Minoan palaces, but often with a strong local flavour. There were domestic toilets connected with sewers which ran beneath the streets.

Walls in the ancient town were commonly constructed of black to brown tuff, with occasional glassy lenses, derived from eruptions about 35,000 years ago.[73] A lava with the same composition (which can be distinguished from the tuff by the presence of gas bubbles) is harder and was used for cornerstones, stairs, etc. Harder blocks were carved into vases. Another construction material was a fine-grained white to greenish rock, formed from one-million-year-old andesitic tuffs by the action of hot water. The colour is due to clays and quartz. This rock is exposed about 100 m west of the site.

The Minoan eruption was probably preceded by a major earthquake that severely damaged the town. The inhabitants had started to clear the debris and begin reconstruction when the main eruption occurred. The lack of human skeletons and valuables suggests that the inhabitants had warning of the eruption, either by a minor precursor eruption, represented here by a 1 to 4 cm thick layer of fine-grained, light grey to orange ash (Fig. 15.13), or by a continuous shaking of the ground, called harmonic tremor, which commonly precedes major eruptions.

The first phase of the main eruption produced a rain of white pumice blocks about one metre thick. Subsequent phases produced bedded and massive ash deposits, each also about one metre thick. The eruption finished with an ignimbrite. All these layers can be seen in the Akrotiri region but each section is not necessarily complete.[225] Since 1600 BC the only geological process in the area has been erosion, which has occurred very rapidly in these soft volcanic sediments.

### *Ancient Thera*

The acropolis of the city of Ancient Thera was built on a fault-bounded block of the non-volcanic roots of the island which towers 300 m above the surrounding plains (Fig. 15.11). The saddle and valleys to the west are underlain by metamorphosed sandstones and conglomerates, which are softer than the grey crystalline limestones under the city and hence have been eroded away. Mt Profitis Elias (565 m), to the west, is made of similar, resistant grey limestone.

### *The Colombo Bank volcano*

There is a recently active volcano 10 km north-east of Thera, the Colombo Bank volcano, but it is little known as it lies underwater (Fig. 15.11). This small volcano rises up from the sea-floor at a depth of 280 m to a height of about 20 m below sea-level.[88] It started to erupt on 29 September AD 1650 and continued for three months. Calm extrusion of lava, punctuated by periodic explosions, built a island several metres above sea-level. The volcano also emitted large quantities of sulphur dioxide gas, which killed many people and animals on Thera. The eruption was also accompanied by a tsunami. After the end of the eruption the volcano was rapidly eroded to below sea-level.