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THE PRE-TERTIARY ROCKS OF SW CYPRUS

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ABSTRACT

The pre-Tertiary rocks of SW Cyprus consist of an autochthonous unit, composed of Campanian sediments, and an allochthonous assemblage containing igneous and sedimentary rocks of Triassic to Lower Cretaceous age, and some undated metamorphic rocks. The complex rests on a basement of Cenomanian to Campanian basic pillow lavas, which form the youngest unit of the Troodos Igneous Complex.

The basal autochthonous sediments (Perapedhi Formation) consist of thin (less than 10 m) iron-rich shales (umbers), locally associated with cherts and manganese nodules. The overlying autochthonous sediments (Kannaviou Formation) comprise 500 m or more of abyssal mudstones and marls intercalated with tuffaceous sandstones containing also lithoclasts similar in lithology to the large allochthonous rock units that are now referred to as "Mamonia Allochthonous Complex" The volcanic elements in the Kannaviou Formation have been derived from an andesitic-dacitic source, extraneous to Troodos, and probably reflect the crustal instability that culminated in the emplacement of the Mamonia Allochthonous Complex. During this time the Troodos Massif was probably a submarine high, undergoing submarine weathering and local brecciation.

The Mamonia Allochthonous Complex comprises Triassic alkali lavas associated with reef and pelagic limestones, metamorphic schists, serpentinites, peridotites, gabbros, Triassic turbiditic sandstones and packstones intercalated with shales, Jurassic cherts, shales and packstones, and Lower Cretaceous quartz sandstones intercalated in shales. The total sedimentary thickness is not more than a few hundred metres. The association is interpreted to be of deep-marine origin in general, but including also shallower, probably continental-margin-related elements at its base and yop. The allochthonous units were probably emplaced on southern Cyprus as olistolithic blocks or small-scale sheets, and as debris in Campanian-pre-Upper Maastrichtian times. Their regional distribution in Cyprus makes a proveance north of Troodos unlikely.

I. INTRODUCTION

The pre-Tertiary rocks of SW Cyprus consist of autochthonous and allochthonous igneous and sedimentary rocks that range from Triassic to Upper Cretaceous in age and of some undated allochthonous metamorphic rocks. The purpose of this paper is to discuss the nature, sedimentology and statigraphy of these rocks. This paper forms part of a regional study of Cyprus, undertaken by the writers in October-November 1971 (Cleintuar, Knox & Ealey, 1974).

II. REGIONAL SETTING

1. Cyprus

The centre of Cyprus is dominated by the Troodos igneous massif, which forms the structural and morphological backbone of the island (Fig. 1). This igneous massif consists of an ultramafic plutonic core, surrounded by basic dykes and sheet intrusives, which themselves are overlain by basaltic pillow lavas. It forms the basement for SW Cyprus and much of the remainder of the island. The upper part of the pillow lavas, known in the literature as the 'Upper Pillow Lavas', is considered on the basis of radiolaria and the single occurence of certain arenaceous foraminifera to have been extruded some time between the Cenomanian and Campanian (Mantis, 1971).

The Troodos Igneous Massif is flanked to the north and south by a little-disturbed autochthonous sedimentary cover ranging in age from Upper Maastrichtian to Recent. In the north these sediments are bounded by a belt of steeply northward dipping thrust slices of Tertiary flyschlike deposits which culminate in the Kyrenia Range with a core of pre-Tertiary allochthonous rocks.

South of Troodos, this sequence is separated from the igneous basement by a wedge of volcanoclastics of Campanian age (Mantis 1970), on which exotic blocks and sheets of older igneous, metamorphic and sedimentary rocks have slid in, probably during early Maastrichtian time. This pre-Upper Maastrichtian assemblage, often referred to as the "Mamonia Complex" because of its broken-up and sometimes chaotic appearance in the field, is poorly exposed and thin, except for SW Cyprus where large masses of these composite autochthonous/allochthonous rocks can be studied in two interconnected belts where the Upper Maastrichtian and Tertiary sediments have been removed by erosion. North of Troodos, Campanian sediments are also present, but as bentonitic clays.

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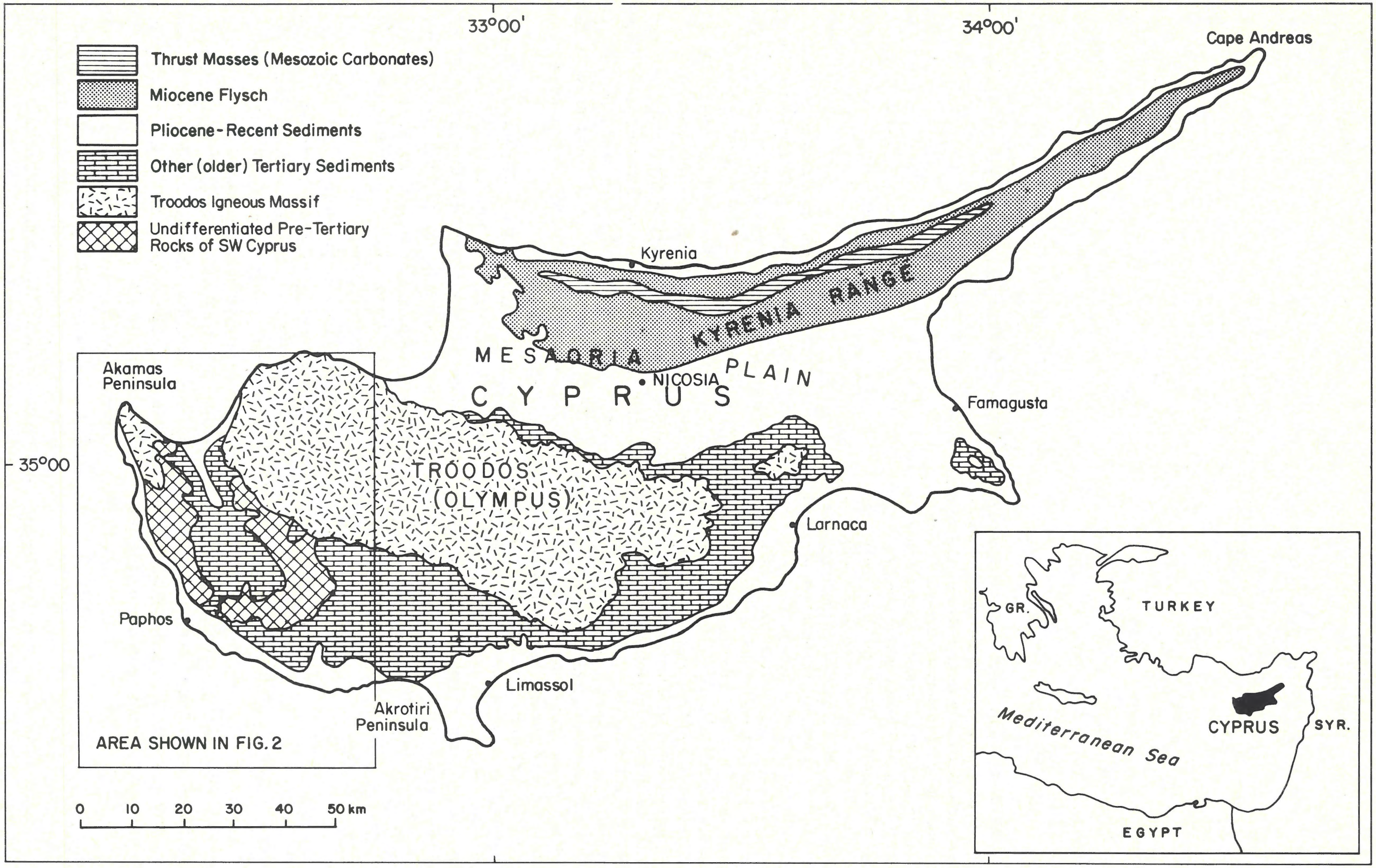

Fig. 1
Outline geology of Cyprus

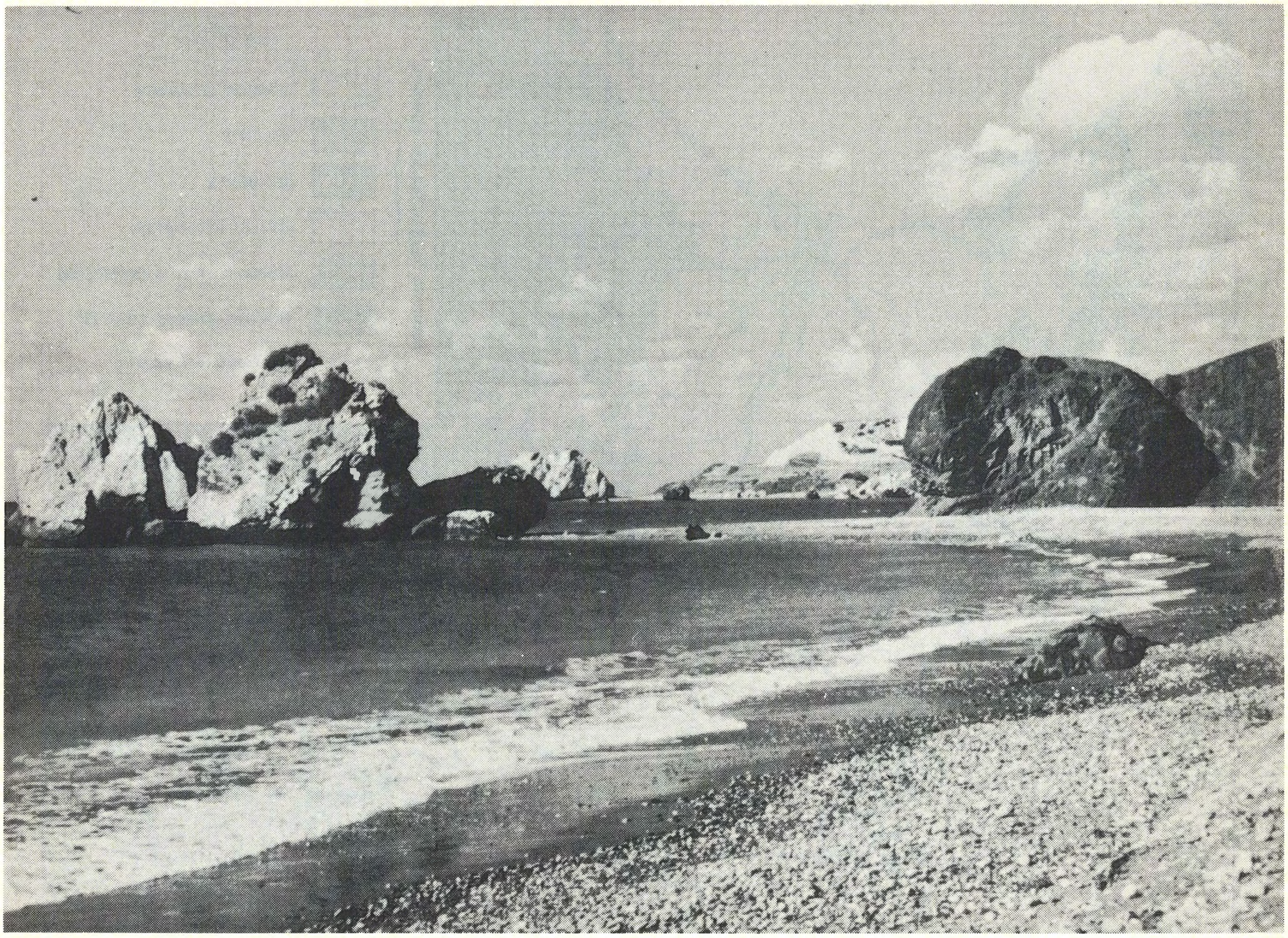

Plate A
Isolated blocks of pillow lava (right) and Triassic reef limestone (Mamonia Allochthonous Complex) outcropping on the shore at Petra tou Romiou, SW Cyprus.

2. SW Cyprus

The geology of SW Cyprus (Fig. 2) consists of Upper Maastrichtian-Recent carbonate sediments which are relatively undisturbed. Within these sediments the pre-Upper Maastrichtian rocks outcrop as windows.

Recent work (Kluyver, 1969; Lapierre, 1968-a and 1972) in SW Cyprus has shown that these rocks can be divided into an allochthonous component, ranging in age from Triassic to Lower Cretaceous, and an autochthonous component of Campanian age on which the former is emplaced (Fig. 3). The allochthonous rock units, even though their crude stratigraphy can now be determined, form a little-organised assemblage to which the term "Complex" would apply. In this paper the name "Mamonia Allochthonous Complex" is introduced, using the prefix "Allochthonous" to distinguish the assemblage from the former undifferentiated allochthonous/autochthonous grouping (see stratigraphic scheme, Fig. 3).

The autochthonous Campanian sediments comprise two formations, the Perapedhi Formation and the Kannaviou Formation. The Perapedhi Formation is essentially a thin (10 m or less), basal argillaceous and cherty sequence lying on top of the Troodos Upper Pillow Lavas and comprising (by volume) a negligible portion of the autochthonous sediments.

The Mamonia Allochthonous Complex presents a chaotic appearance in the field, which can be readily broken down into two principal groups:

- Igneous and metamorphic rocks with associated reef and pelagic limestones of Triassic age (Plate A)
- A sedimentary group that ranges in age from Triassic to Lower Cretaceous

The sedimentary group is very broken up, and nowhere are complete sections available. Locally, however, the more competent, thicker-bedded units outcrop as isolated sections seldom more than 100 m in thickness and usually less, in the

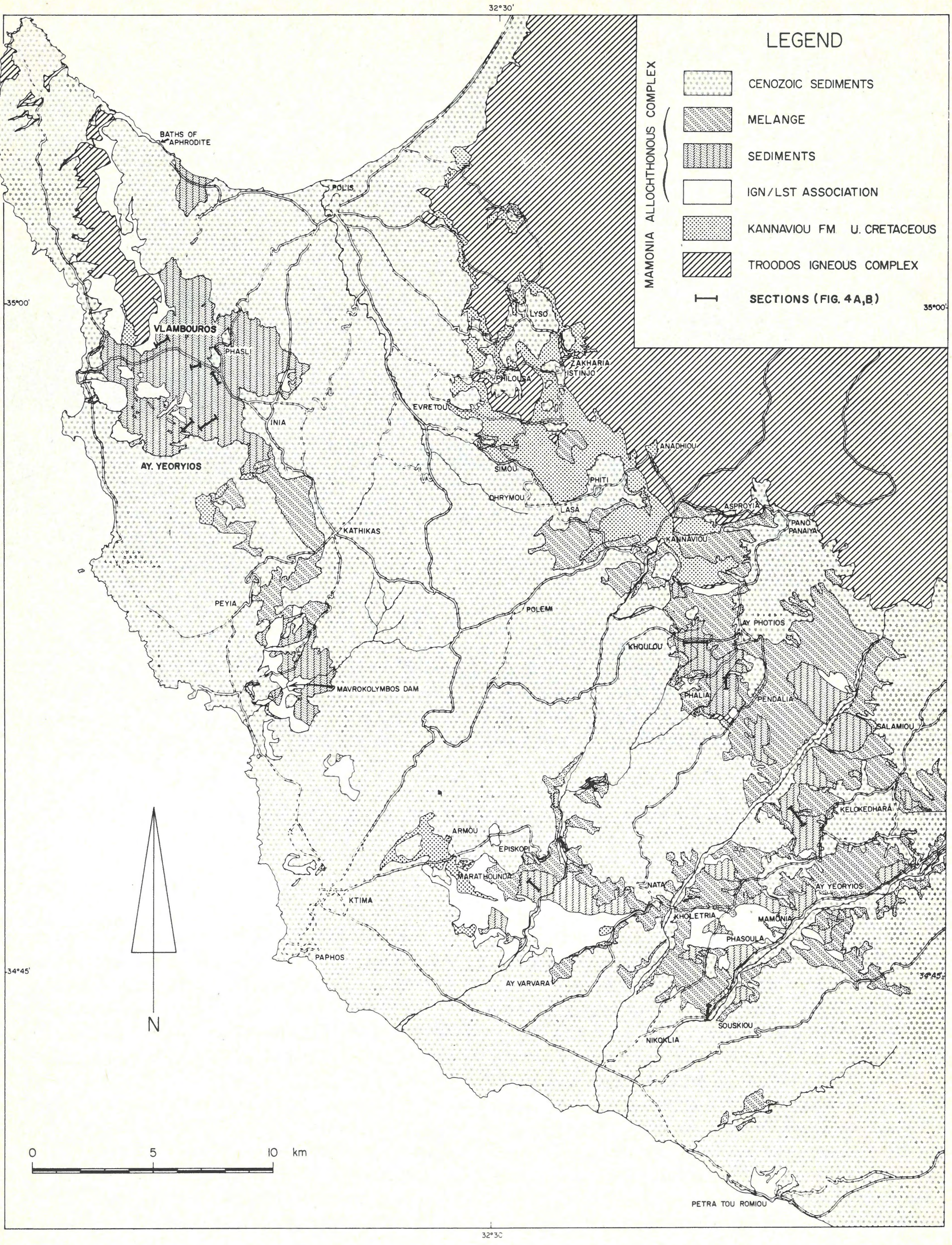

Fig. 2
Simplified geological map of Southwest Cyprus

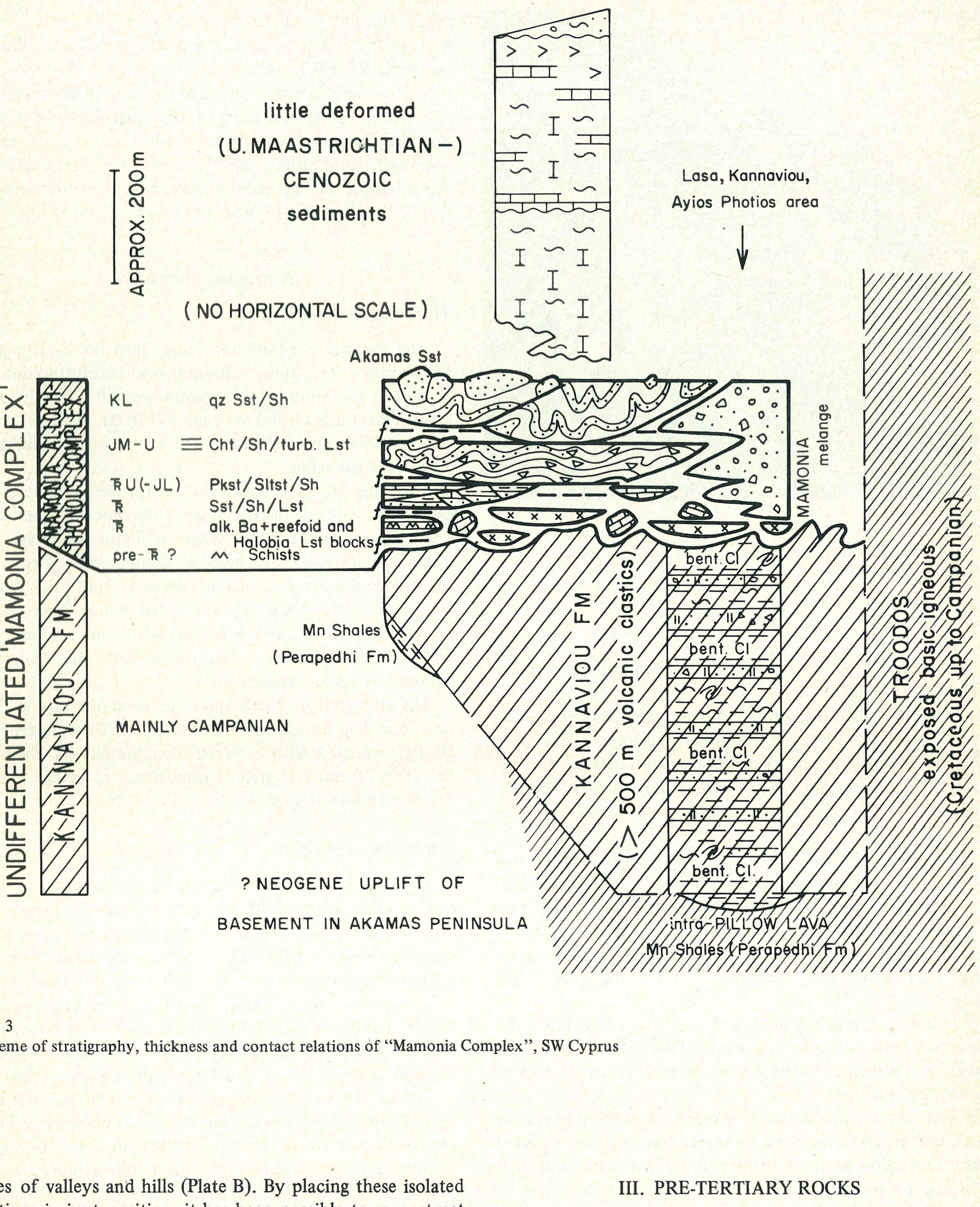

Fig. 3
Scheme of stratigraphy, thickness and contact relations of "Mamonia Complex", SW Cyprus

sides of valleys and hills (Plate B). By placing these isolated sections in juxtaposition, it has been possible to reconstruct the stratigraphy of the sedimentary group and establish some thickness data. The upper stratigraphic units are more argillaceous and incompetent and have been intensely deformed. Their thickness can therefore only be estimated very approximately.

III. PRE-TERTIARY ROCKS

1. Autochthonous sediments

Basal relations – Perapedhi Formation

The Perapedhi Formation, at least in the sense used in this paper, represents the earliest sedimentation after cessation of

Plate B
Valley wall, west of Ayios Yeoryios. Cherts, packstones and shales of Mamonia Allochthonous Complex.

the extrusion of the Upper Pillow Lavas of the Troodos Igneous Complex.

Lithologically, the formation comprises dark-brown iron-rich shales (umbers) and reddish mudstones, with interbedded cherts in places. Manganese nodules occur in the type area of the Perapedhi (east of Perapedhi), and were found to be comprised exclusively of manganese oxides (manganite, pyrolusite).

Sediments similar to those found in the Perapedhi Formation, as well as tuffaceous conglomerates and limestones, occur within and at the base of the Upper Pillow Lavas of the Troodos Igneous Complex. These sediments are sometimes also referred to as "Perapedhi Formation". This wider use of the formation name "Perapedhi" is not followed in this paper.

Outcrops are very patchy and usually occur within topographic depressions on the Upper Pillow Lava surface. As such, the formation rarely exceeds a thickness of 10 m and is generally much less.

The origin of the Perapedhi Formation, with its characteristic umbers and associated sediments, has long been debated. The restriction of these Perapedhi sediments to basal topographic depressions in the underlying pillow lavas has led some workers to suggest a lagoonal environment (Bear, 1963). Pantazis (1967), on the other hand, has argued for an open-marine environment of deposition, on account of the radiolarian fauna. Recent workers (Desprairies & Lapierre, 1972; Constantinou & Govett, 1972) have concentrated more on the chemical composition of the sediments and come to the conclusion that they are the submarine weathering products of the underlying pillow lavas, while Robertson and Hudson (1973) believe that they were derived from late-stage hydrothermal emanations. Paleontological examination of our own samples indicates that the fauna is almost identical with that of the overlying Kannaviou Formation, and therefore the environment of deposition of the Perapedhi Formation will be discussed with that of the Kannaviou Formation below.

Kannaviou Formation

Thickness and lithology

The Perapedhi Formation passes into the overlying yellowish green mudstones, tuff-sandstones and tuffaceous greywackes of the Kannaviou Formation, which probably attains a total thickness of 500 m or more (Fig. 3), of which at least 300 – 400 m are exposed in the vicinity of the villages of Lasa and Kannaviou.

Lithologically, the Kannaviou Formation consists principally of mudstones, marls and sandstone intercalations. Chert and lime mudstone bands occur as minor subsidiary components. Poorly exposed breccias, composed of igneous fragments, which were probably derived from the Troodos Igneous Massif occur in the Paleomylon River section between Kannaviou and Asproyia, where the northern contact of the Kannaviou Formation with the underlying Troodos basement can be seen.

The sandstones of the Kannaviou Formation vary in thickness from 1 m or less to more than 20 m. They are generally poorly cemented with carbonate and are friable. They vary texturally from fine-grained sandstone to grits, and are poorly to moderately sorted.

Petrography and origin

Petrographically, the sandstones of the Kannaviou Formation contain phenoclasts of such minerals as paramorphs after β-quartz, plagioclase feldspar, hornblende, ortho-and clino-pyroxenes and biotite. Volcanic glass (pumice) is also an important constituent. The mineralogy of this volcanic mineral assemblage strongly suggests an andesitic magmatic source, belonging to the calc-alkali suite. The presence of pumice, β-quartz and zoned plagioclase crystals indicates a hypabyssal chamber associated with subaerial vulcanism.

In addition to the volcanic mineral assemblage, the Kannaviou sandstones contain subrounded lithoclasts of chert, muscovite-quartzite, marble, metabasalt, basaltic glass, trachyte and serpentinite, indicating a detrital source in addition to an active volcanic source (Plate C). The absence of massive quartz-rich sediments and metamorphic rocks, on or north of Troodos in the basement or its sedimentary cover argues against this being the source of such fragments. The lithoclasts are more similar in nature to rocks found in the Mamonia Allochthonous Complex than to those in the Troodos Igneous Massif. The proportion of volcanic minerals

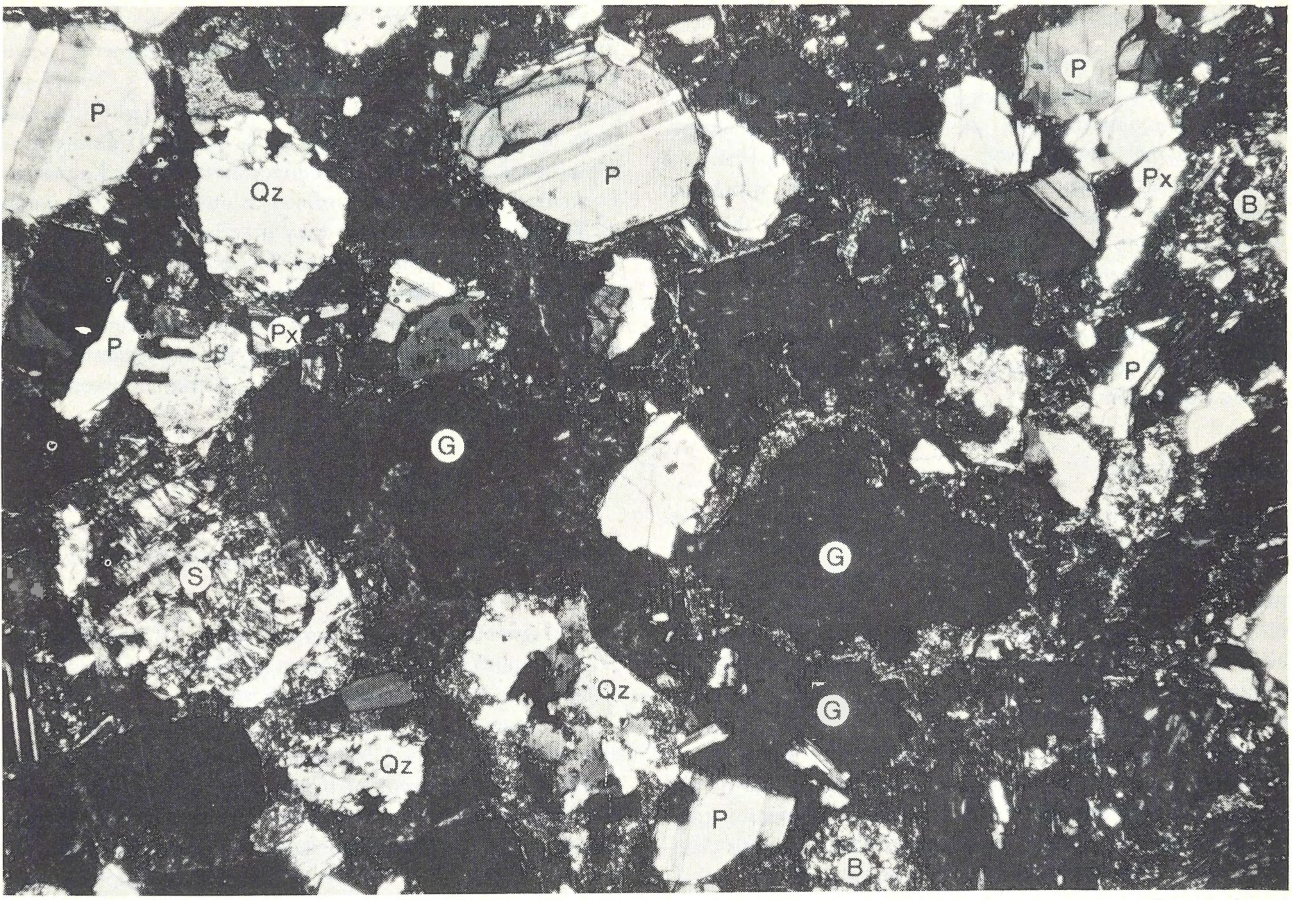

Plate C
Vitric tuff showing plagioclase (P), pyroxene (Px), quartzite (Qz), basalt (B), serpentinite (S), dark areas are isotropic pumiceous glass (G); (viewed under X-nicols).

and lithoclasts varies in the sandstones, so that they range in composition from tuffs to tuffaceous greywackes.

Recent X-ray work (Desprairies and Lapierre, 1972) indicates that the argillaceous sediments of the Kannaviou Formation are also derived from a volcanic source. There are two possible eruptive source areas for the Kannaviou volcanoclastics which are petrographically of calc-alkaline intermediate type.

a. Troodos
b. An area not now visible

The Troodos igneous massif is calc-alkaline in type and is believed to represent a remnant of Cretaceous ocean crust generated at some time about a spreading ocean ridge (Moores and Vine, 1971; Greenbaum. 1972). As the Kannaviou volcanic sanstones lie stratigraphically on the southern flank of Troodos and include possible pebbles derived from Troodos, the main structure of Troodos was consolidated and the magmatism that produced it was dead in the area of Troodos itself. However, some later magmatic event may have taken place in the area of Troodos. If such was the case, the following should be considered: the physical evidence of an eruptive centre, the likely nature of the volcanics, and their likely disposition and distribution.

The volcanic sandstones are likely to have been erupted from an explosive andesitic source. This type of vulcanism is widespread in island arcs and would leave behind strong evidence of its former presence, either as a dissected volcano or at deeper levels as the basal wreck of such a structure such as calderas or hypabyssal intrusions. Such structures may be of the order of several kilometres in diameter. *On Troodos no such structures have been recognised.*

Finally the Kannaviou volcanoclastic sandstones are confined solely to the southern flank of Troodos. There are no clear reasons why this should be if an eruptive centre existed on Troodos. One argument is that erosion has removed the Kannaviou volcanic equivalents from the northern flank, but such an erosion would not have left the uppermost pillow lavas intact.

Taking all the above into account, it is considered that Troodos was not the source for the Kannaviou volcanic sandstones. These are considered to be derived from a source extraneous to the island of Cyprus which is not now visible.

Sedimentary structures

Sedimentary structures within the Kannaviou sandstones include graded bedding, small-scale cross-bedding (less than 10 cm), laminations, and convolutions. Synsedimentary slump structures are relatively common. The slumps take the form of balls, elongate masses and slump folds, which can locally attain a height of 1 m or more. At one locality, mudstone slump balls were found that had evidently rolled into the site of sandstone deposition.

These sedimentary structures and poor sorting suggest that mass movement of partly turbiditic nature was the main mechanism of transportation for the sandstones of the Kannaviou Formation.

Palaeontology/age

The marls and mudstone samples of the Kannaviou Formation and Perapedhi Formation contain an identical radiolarian and agglutinated foraminiferal fauna. A few poorly preserved Globotruncana also occur, of which some, according to H. Lapierre (pers comm), range up into the early Maastrichtian. The radiolarian fauna has been correlated with similar faunas found in Puerto Rico and Northern Germany and assigned a Campanian age (M a n t i s, 1970). This age has been largely confirmed by the finding of a rich microplankton fauna of Santonian-Campanian age in one of our samples. The deposition of the Kannaviou Formation (and emplacement of the overlying Mamonia Allochthonous Complex) must have been complete before, or probably within, Lower Maastrichtian times because the oldest sediments of the post-Mamonia carbonate cover (Lefkara Formation) are Upper Maastrichtian in this area (M a n t i s, 1970).

Environment of deposition

The environment of deposition of the Kannaviou Formation (and its basal part, the Perapedhi Formation) is important since it was into this environment that the overlying Mamonia Allochthonous Complex was introduced.

The nature and distribution of the basal Perapedhi sediments suggest that, following the extrusion of the uppermost pillow lavas of the Troodos Igneous Massif, there was a period of submarine weathering and/or hydrothermal emanations, the products of which accumulated in depressions on the surface of the pillow lavas, partly and locally as manganese nodules. The association of radiolarian and agglutinated foraminifera and the absence of calcareous tests within residual (Perapedhi) sediments suggest that they accumulated in an abyssal environment.

The tuffaceous deposits of the overlying Kannaviou Formation were subsequently introduced by mass movement into the same abyssal environment, because they contain a radiolarian and agglutinated foraminiferal fauna identical with that of the basal sediments, although in addition some calcareous plankton (Globotruncana) were present.

The Kannaviou depositional basin was probably bounded to the north by elevated relief (? submarine proto-Troodos). Breccias composed of Troodos-derived fragments occur within the Upper Pillow Lavas (L u n d b e r g, 1969) and probably within the Kannaviou Formation, indicating that parts of Troodos had relief (? fault-controlled) during their formation and deposition. The breccias within the Kannaviou Formation appear to be confined to outcrops on the flanks of Troodos, suggesting that they may be slope breccias that wedge out away from Troodos. Secondly, although Campanian (radiolarian datings) deposits are widespread on the northern and southern flanks of Troodos, the sandy detrital facies is confined to the southern flanks, suggesting that there may have been a topographic barrier between north and south in these times.

2. Mamonia Allochthonous Complex

Igneous and metamorphic rocks and associated sediments

Igneous and metamorphic rocks

The igneous and metamorphic rocks of the Mamonia Allochthonous Complex are most extensively exposed in the southern pre-Maastrichtian outcrop belt.

The igneous and metamorphic rocks generally lie at the base of the Mamonia Allochthonous Complex, a relationship that is clearly apparent in the vicinity of Ayia Varvara and the Akamas Peninsula. This igneous and metamorphic association comprises three principal rock types, (a) serpentinites, (b) lavas and (c) schists of the epidote-amphibolite-m etamorphic facies. The schists are volumetrically the least important. The contacts between these rock types are always tectonic. Peridotites, porphyrites and gabbros are also present.

In many places the serpentinites occur on the soles of thrust planes; their dips are often toward the northeast, but northward and low-angle westward dips occur also. In the outcrop of igneous and metamorphic Mamonia rocks north of Ayia Varvara, it is clear that the serpentinites are alteration products of peridotites.

The bulk of the Mamonia lavas consist of alkali basalts (L a p i e r r e, 1972). Trachytes also occur as isolated blocks. The alkali basalts are generally badly altered, but at Petra tou Romiou and Marathounda freshlooking pillow lavas are exposed. Radiometric age dating of lavas at Petra tou Romiou gave 215 ± 10 MY, indicating a Triassic age (L a p i e r r e and R o c c i, 1969). Similar Triassic age dates, as well as one Permian data, have been obtained from other Mamonia lavas elsewhere (Lapierre; personal communication). Paleontological-age determinations from limestones, associated with the Mamonia lavas and discussed below support a Triassic age for the bulk of the Mamonia lavas.

The metamorphic Mamonia rocks consist principally of greenish epidote-amphibolite schists or garnet amphibolites which have intercalated bands of quartzite, marble and meta-pelites ranging in thickness from about 5 cm to 1 m, and mylonitised amphibolite gneisses. Rare pods of pyroxene

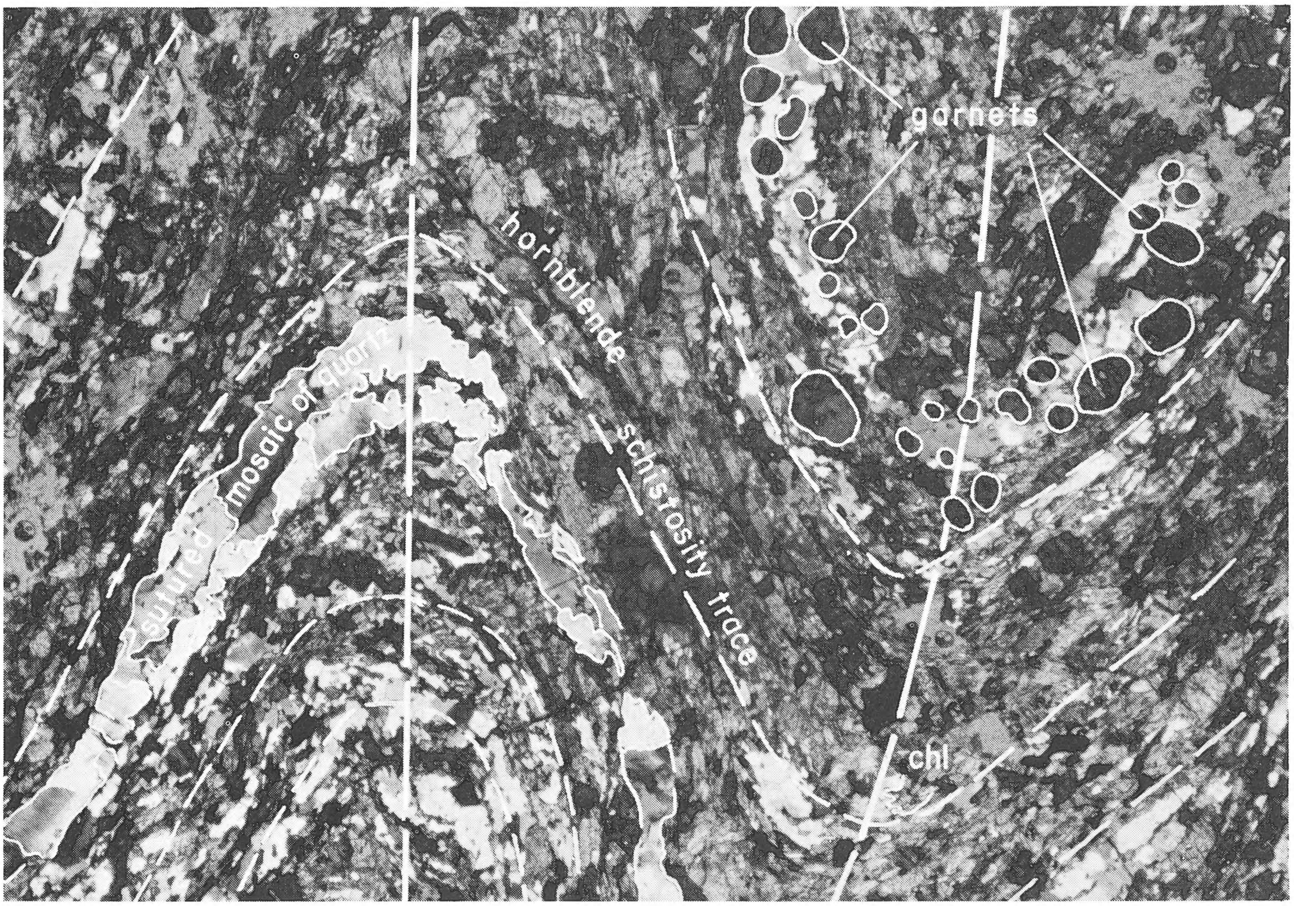

Plate D
Garnet-hornblende schist from Ayia Varvara. Hornblende dominant mineral plus bands of mosaic quartz, within the schistosity. Concentrations of garnet may be prominent. Locally hornblende has regressed to chlorite (Chl). The schistosity is folded about axial traces of a later deformation. (partial x-nicols, 30x).

garnet amphibolites may occur locally. The metamorphic facies present in the Mamonia metamorphics represent moderate to high pressure-temperature conditions possibly of the upper part of the greenschist facies (see W i n k l e r, 1967).

These metamorphosed rocks show evidence of refolding (Plate D) of schistosity. This structural observation, taken with the metamorphic mineral associations suggests that the autochthonous area from which the schists were derived, had been subjected to intense, and probably orogenic, deformation and therefore was outside Cyprus. The mineralogy of the schists suggests that they are the metamorphic equivalents of basic to intermediate volcanic rocks with intercalated sandstones, pelites and limestones. The mylonitised amphibolite gneisses probably result from emplacement because the earlier amphibolite texture is largely destroyed by crushing and mylonitisation. Other schists also exhibit this dynamic destruction at low temperatures, which postdates their earlier dynamo thermal metamorphism.

Sediments associated with igneous rocks

In many places in SW Cyprus enormous blocks (locally 25 – 50 m high) of limestone are exposed (Plate A), which are not randomly distributed throughout the Mamonia outcrop area, but are almost always associated with the igneous rocks of the Mamonia Allochthonous Complex. Most of the limestones appear crystalline in the field, but in thin section they can be seen to be algal or reef boundstones.

In addition to these blocks of massive reef limestone, other thinner bedded limestones are associated with lavas. In places they apparently overlie the lavas; elsewhere they occur as intercalations within the lavas and are often interbedded with cherts. At some localities they are recrystallised lime mudstones. In several outcrops, the limestones and associated lavas present a very brecciated appearance. In outcrops north of Ayia Varvara, this brecciation can be seen to decrease in intensity away from the faulted contact between the lavas

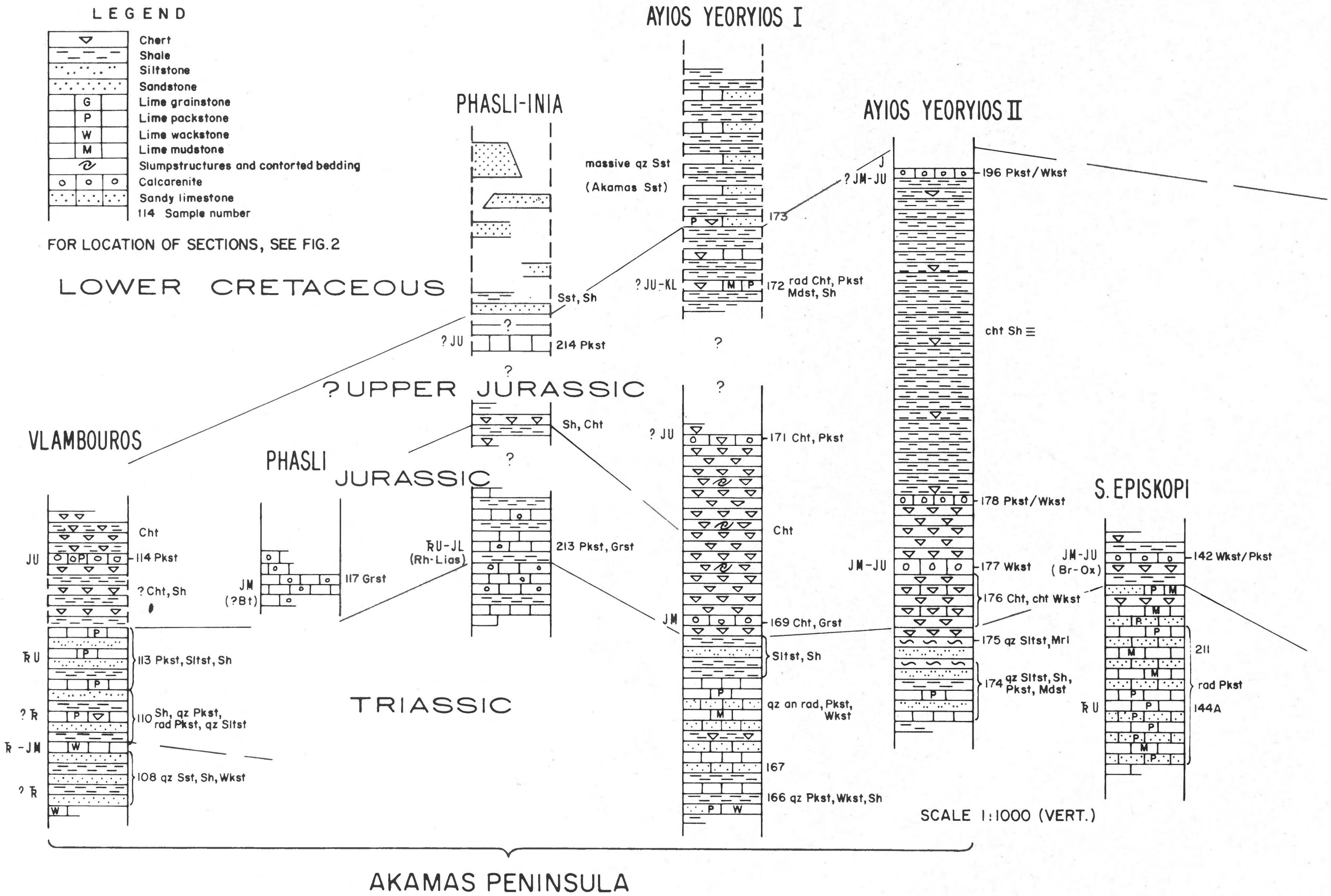

Fig. 4a
Sedimentary sections of the Mamonia Allochthonous Complex

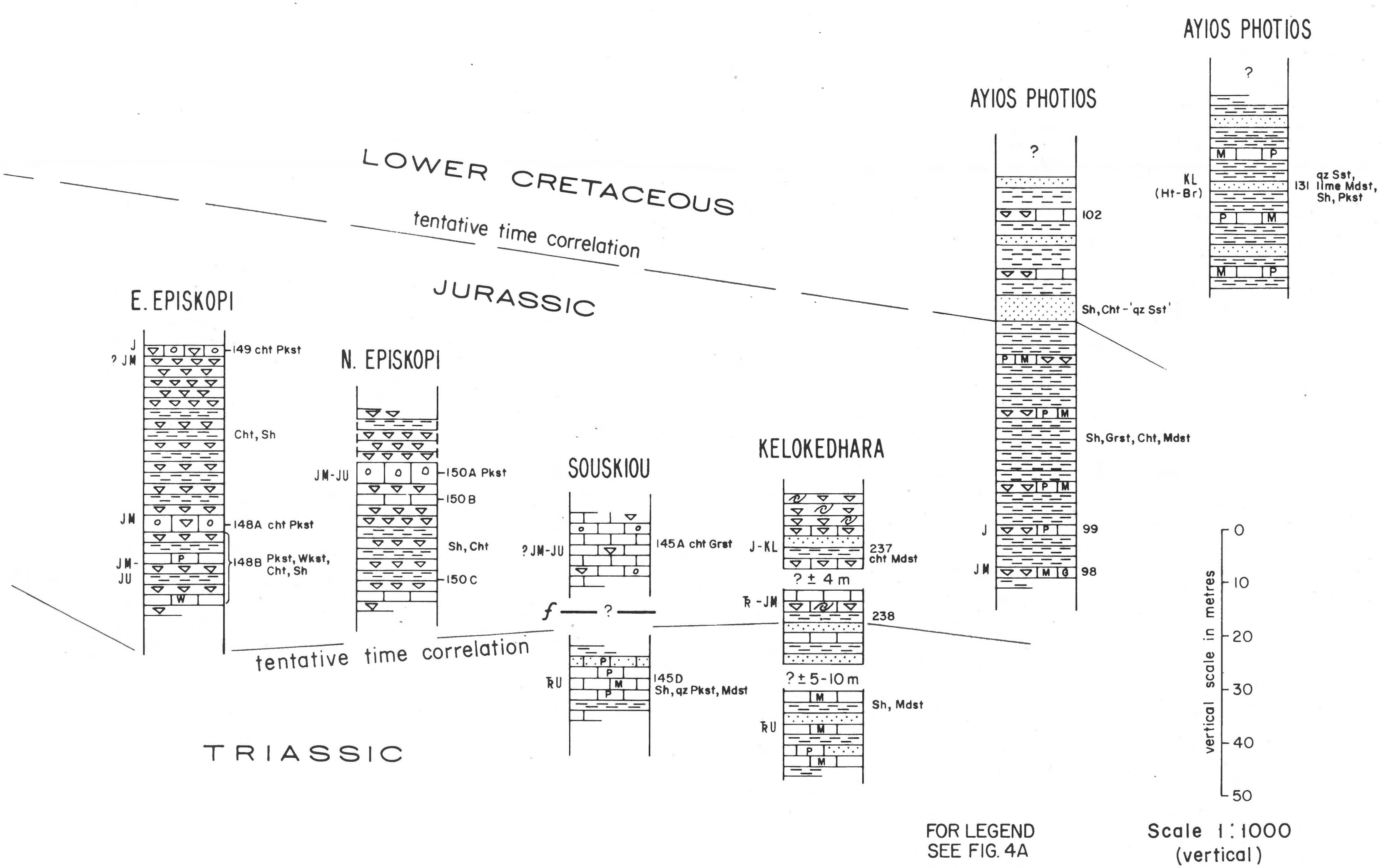

Fig. 4b
Sedimentary sections of the Mamonia Allochthonous Complex

with interbedded limestones and metamorphic schists, suggesting that the brecciation is tectonic and probably related to the emplacement of these allochthonous components.

Several samples from widely scattered outcrops of reef limestone contain an Upper Triassic microfauna (see Fig. 4 sample locations and Appendix). Corals of possible Upper Triassic age (Wellnhofer, pers. comm), were also found at one locality 1 km north of Souskiou. It has not been possible to date the thin-bedded limestones associated with the allochthonous Mamonia lavas with much precision. At two localities, north of the Mavrokolymbos dam and on the Akamas Peninsula, a Triassic-Middle Jurassic age is suggested by the presence of pelagic lamellibranchs. North of Limassol, P a n t a z i s (1967) found, on the basis of ammonoids and nautiloids, an Upper Triassic age for pelagic limestones which are locally associated with lavas. It would seem that the bulk of the reef, and probably the pelagic limestones associated with the allochthonous Mamonia lavas, and the lavas themselves are of Triassic age, a fact that seems to corroborate their intimate relationship in the field.

It is not possible to detail the environment represented by the allochthonous Mamonia lavas and related sediments outcrop by outcrop. However, the whole association of lavas, fragmented reef limestones and deeper-water limestone is suggestive of volcanic build-ups crowned with carbonate reefs and flanked by deeper-water limestones and slumped reef blocks; alternatively, the assemblage could represent the rim of carbonate platform from which blocks and fragments have slid into a deeper-marine sedimentary basin with lime muds and lavas.

Sediments of Triassic – Lower Cretaceous age

Quartz sandstone, shale and lime wackestone/mudstone formation – Triassic

The basal sediments of the Mamonia allochthonous sedimentary group consist of light green sandstone beds range from 20 cm to 1 m in thickness, with

Individual sandstone beds range from 20 cm to 1 m in thickness, with sand/shale ratios of 50% or more. They are composed of medium-to fine-grained quartz clasts and often show finely disseminated carbonaceous matter on their bedding planes. Sedimentary structures include graded bedding, cross-bedding, convolutions, laminations and occasional flutes, suggesting that the sandstones were deposited by turbidity currents. The lime mudstone/wackestones associated with these sandstones contain radiolaria and pelagic lamellibranchs.

The maximum observed thickness of these basal sediments is of the order of 10 – 15 m. However, isolated blocks of thin-bedded sandstones of similar nature occur in many parts of SW Cyprus; in places these sandstones can be seen interbedded with shales in highly disturbed outcrops, suggesting that these basal sediments could be thicker. Direct evidence of the age of these basal sandstones is poor. A determination based on very poor microflora found in associated shales suggested a Mesozoic age, which could possibly be Triassic. Pelagic lamellibranchs in a lime wackestone sample indicated a Triassic-Middle Jurassic age. The stratigraphical position of these basal sandstones beneath lime packstones dated as Upper Triassic (see Fig. 4 and Appendix) indicates, however, that these sandstones are Triassic.

Lime packstone, quartz siltstone, lime mudstone/wackestone and shale formation Upper Triassic (to? Lower Jurassic)

The basal sandstones are overlain by lime packstones and quartz siltstones, interbedded with radiolarian lime mudstones/wackestones and reddish shales (Fig. 4). The packstones vary from radiolarian micropackstones to quartz packstones with occasional coarse lithoclastic packstones. Slump balls, cross-bedding, laminations, clay pebbles, graded bedding and small-scale channelling are observed within these beds. Bed thickness vary from 20 cm to 1 m, and shales generally form less than 50% of outcrops. At Kelokedhara, very thin turbiditic sandstones and lime packstones interbedded with shales and lime mudstones were found suggesting a more distal facies. It has not been possible within the paleontological framework of study to establish whether this more shaly development is the equivalent of the thicker packstones described in this section, and/or the basal quartz sandstones.

The maximum observed thickness of the packstones and siltstones overlying the basal quartz sandstones is of the order of 20 – 30 m. An Upper Triassic age is assigned to the lower part of this unit on the basis of the fossil content of the skeletal fragments within the packstones (see Fig. 4 and Appendix). It is possible, that the upper beds are Jurassic in age, since Upper Jurassic or Middle Jurassic beds occur only 10 – 20 m above. Alternatively, there may be a disconformity or hiatus between the Upper Triassic and the Middle-Upper Jurassic.

Bedded chert, and shales with intercalated lime grainstone, packstone wackestone and mudstone formation Middle to Upper Jurassic

The Triassic (? Lower Jurassic) sandstones and packstones are overlain by bedded cherts and red shales with intercalations of lime packstones, wackestones and grainstones. The benthonic fauna within these carbonate clastic beds have been identified as Jurassic forms (see Fig. 4 and Appendix)

The bedded cherts are particularly well developed in the Vlambouros and Ayios Yeoryios sections, attaining a thickness of at least 20 – 40 m. Even greater thickness (50 – 75 m) of bedded chert occur at Kelokedhara and Cape Zevgari. The thickness of individual chert beds range from 5 to 50 cm and the cherts vary in colour, being red, green, brown or white. Sedimentary structures within the chert are rare, but in the Ayios Yeoryios I section synsedimentary slumps are present (Plate E), and it is possible that the highly disturbed cherts observed elsewhere may also represent slumping. In some sections (Ayios Photios and Episkopi), shales

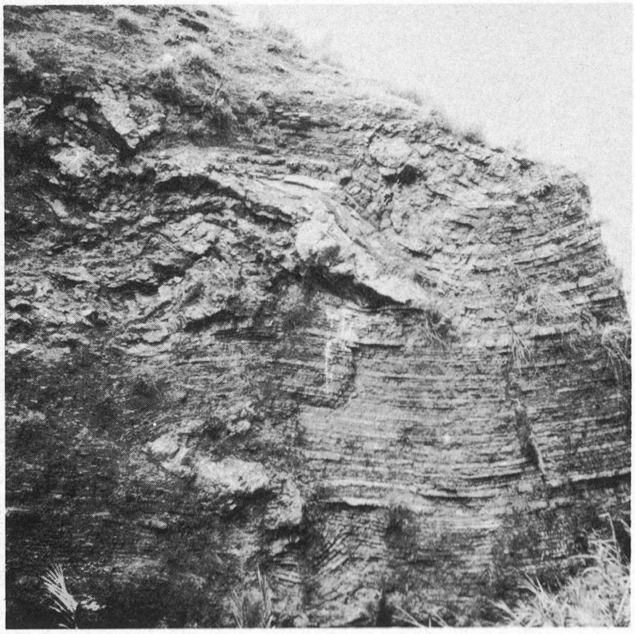

Plate E
West of Ayios Yeoryios. Slump structures within bedded chert sequence (Mamonia Allochthonous Complex).

are more extensively developed at the expense of the cherts. Within the paleontological framework, it would appear that there are lateral facies changes between well- developed bedded cherts and shales with intercalated chert beds (Fig. 4).

Interbedded within these cherts and shales are lime packstones and grainstones ranging in thickness from 5 to 50 cm and containing oolites, skeletal fragments and lithoclasts. In places, these beds exhibit grading and poorly developed flute marks, suggesting a turbiditic origin. At Souskiou and between Phasli and Vlambouros, massive-bedded grainstones with similar clasts were observed with a thickness of 10 – 15 m. Whether these beds, dated as Middle Jurassic or Middle-Upper Jurassic, represent slump blocks from shallow-water equivalents of the turbiditic packstones interbedded elsewhere with shales, or an extremely massive turbiditic development, is not clear. East of Peyia, a block of massive saccharoidal dolomite was also found overlain by cherts.

At many localities massive reddish or greenish limestones with a thickness of 1 to 4 m and a characteristic nodular appearance, suggestive of slump balls, are associated with the cherts and shales. Texturally, these limestones range from lime wackestones to packstones, and contain oolites, lithoclasts and skeletal fragments within a red radiolarian clay matrix. In places, angular pebbles and blocks of chert, as well as slump folds, are present. Often silicified, these beds are occasionally graded. They are interpreted as products derived from the slumping of interbedded lime packstones, cherts and/or shales. Near Kelokedhara, breccias composed of angular chert fragments and mudstones within a red radiolarian clay matrix were observed, again suggesting a process of submarine erosion and resedimentation.

Quartz sandstone and shale formation-Lower Cretaceous

The uppermost part of the Mamonia allochthonous sedimentary group comprises shales interbedded with rounded quartz sanstones and minor lime mudstones. It is difficult to establish the exact thickness of these intensely folded beds, but the combined thickness of the underlying Jurassic shales and cherts and the sediments is probably not more than a few hundred metres.

Individual sandstone beds range from 20 cm to 5 m or more in thickness. Grain size varies from fine to very coarse, with rounded quartz pebbles up to ½ cm or more in diameter. The sandstones are locally quartzitic. They are generally massive and structureless, although layering is observed in places. Clay pebbles are present in some beds, and at some localities the beds have a contorted appearance suggestive of slumping. On the Akamas Peninsula, sandstones of similar nature are embedded in the hillside or occur as massive isolated blocks dominating the landscape. The complex, known as the Akamas Sandstone, could be several tens of metres thick. There appears to be a lateral gradation, best exposed at Ayios Yeoryios between the villages of Inia and Phasli, between these blocks and massive sandstones interbedded with shales. The age of these sandstones in the upper part of the Mamonia sedimentary series has hitherto been a matter of conjecture. A sample of shales collected at Ayios Photios and associated with sandstones, contained a rich microflora and microplankton fauna of Lower Cretaceous age (Hauterivian to Barremian) (see Fig. 4 and Appendix, sample number 131), and in the Ayios Yeoryios I section, benthonic fauna in packstones about 10 m below the first sandstones indicated a probable Late Jurassic, possibly earliest Cretaceous (see Appendix, sample number 172), age. Both the interbedded sanstones and massive Akamas sandstone blocks are therefore probably Lower Cretaceous.

Environment of deposition of the sediments belonging to the Mamonia Allochthonous Complex

The cumulative evidence, such as the presence of radiolarian cherts, turbidites, redeposited turbidites, radiolarian clays, pelagic lamellibranchs and radiolaria, suggests that the bulk of the sediments were deposited in a deeper-marine environment as opposed to a shallow-marine environment proposed by Turner (1973) and Lapierre (1968-b).

The allochthonous Mamonia sediments represent a variety of interrelated facies types. They have been deposited in a basin that during Triassic times received siliciclastic, partly proximal, turbidites. Within this basin (alkali) basic vulcanism occurred, while local reefs or carbonate platforms may have contributed, in addition to large olistolithic blocks, lithoclastic and skeletal debris, to the basin. The association of turbiditic deeper-marine sediments and basic vulcanism is suggestive of that found in modern ocean basins, in particular along the continental margin. Whether the allochthonous metamorphic rocks represent pieces of pre-Triassic metamorphic basement or Mesozoic (Mamonia equivalent) involved in orogenic movements is not clear. All that can be reasonably suggested is that metamorphism took place prior to the emplacement of the rocks in SW Cyprus owing to the regional metamorphic nature of these schists.

The source of the siliciclastics was replaced in Jurassic times by a shallow-marine area which contributed oolites and other carbonate fragments to the basin, which was then deep enough for radiolarian cherts to accumulate. In Lower Cretaceous time, siliciclastics once again became prominent, suggesting a rising relief in the hinterland.

Mode of emplacement of the Mamonia Allochthonous Comple the Mamonia "Melange"

That the Triassic-Lower Cretaceous rock units are allochthonous on the Campanian Kannaviou Formation or Cretaceous pillow lavas of the Troodos Igneous Complex is clear.

It is also clear from the jumble of lithologies and the difficulties of reconstructing their stratigraphy that the Mamonia Allochthonous Complex was not emplaced as one large nappe sheet, but rather as small-scale thrust sheets with dimensions of the order of one or two kilometres at the most and a composite thickness of some 250 m or less. The style of deformation in the underlying autochthonous sediments of the Kannaviou formation also suggests that small-scale sheets or isolated blocks glided into the Kannaviou basin. The Kannaviou sediments show gentle to moderate dips (10 – 30°) on average, but locally the beds dip very steeply and are tightly folded. Immediately south of the village of Kannaviou, this locally severe deformation is directly related to a block or small-scale thrust sheet of brecciated serpentinite, and the autochthonous sediments become rapidly less disturbed away from the serpentinite. The style of deformation is consistent with a picture of more rigid allochthonous blocks or sheets gliding over the autochthonous beds, with their fronts pushing up the underlying sediments.

Associated with the Mamonia Allochthonous Complex is a clayey deposit, known in SW Cyprus as the "Melange", full of angular boulders (several metres in size) and smaller fragments. This "Melange" is widespread attains a thickness of up to 100 m (Turner, 1973), and rests directly on top of the Kannaviou Formation, where units of the Allochthonous Complex are absent. Its stratigraphical position and the lithological similarity of most of the fragments within it to rocks of the Mamonia Allochthonous Complex indicate that the "Melange" was for a large part emplaced at the same time as the latter, and that it is almost certainly the debris formed as a result of the mylonitisation and tectonic fragmentation which accompanied the emplacement of the allochthonous complex.

IV. CONCLUSIONS

The overall picture that emerges from the Late Cretaceous geology of SW Cyprus is one of a period of tectonic instability during which allochthonous units glided into a marine basin as olistolithic blocks, small-scale sheets, and debris from either a tectonically oversteepened slope or the disintegrating nose of a massive nappe complex.

The facies changes (proximal and distal turbidites, bedded chert sequence, massive oolitic limestones) within the Jurassic and Triassic sediments of the Mamonia Allochthonous Complex suggest that the basin in which they accumulated was sufficiently large for these facies changes to develop, and conversely that rocks from different parts of this basin were subsequently emplaced in SW Cyprus.

Conclusions regarding the provenance of the Mamonia Allochthonous Complex are made on general grounds. The restriction of coarse volcanoclastics within the Upper Cretaceous sediments to the southwest flank of Troodos, and the absence of quartz-rich allochthonous masses on its north flank suggest that the main source of the Mamonia rocks was not (at the time of their emplacement) located north of Troodos, but rather to the west, south or southwest of this oceanic basement complex.

The (calc-alkaline) andesitic-dacitic nature of the Kannaviou tuffaceous sandstones indicates relative proximity, at the time of their deposition, to an intermediate volcanic source which was probably not located on the site of present-day Troodos. The source of the lithoclastic components within the Kannaviou sandstones must also have been located beyond the borders of present-day Cyprus, presumably on the advancing Mamonia front. Whether the volcanic and detrital sources were related in space is not clear.

The explosive (pyroclastic) volcanic nature of the bulk of the Kannaviou Formation in SW Cyprus is best thought of as heralding the tectonic conditions that led up to emplacement of the Mamonia Allochthonous Complex. The Perapedhi sediments are transitional between the final stages of Troodos pillow lava extrusion and the onset of pyroclastic andesitic-dacitic vulcanism, represented by the Kannaviou Formation.

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APPENDIX

Age determinations of selected surface samples (see Fig. 4 for locations of samples).

Sample No		*Observations*	*Age*
98	1.	Radiolaria cf. *Haurania* cf. *Lucasella* *Nautiloculina circularis* *Tubiphytes morroniensis* *Pseudocyclammina* sp. *Trocholina polastiniensis*	Middle Jurassic Probably lower part
	2.	Radiolaria	
99		Radiolaria *Tubiphytes morroniensis* *Trocholina* Calcisponge debris cf. Endothyrid form cf. *Baccinella*	Jurassic (? late Jurassic) with Triassic debris
102		Radiolaria indeterminate	
110		Glomospirids	??? Triassic
113		*Cheilosporites* aff. C. sp (Oman) *Permodiscus* pelagic lamellibranch debris	Late Triassic
114		Radiolaria *Protopeneroplis striatus* *Pseudocyclammina ukrainica* dasyclad algae ? *Pianella* cf. *Everticyclammina* *Trocholina* aff. *Cheilosporites* debris	Late Jurassic with Triassic debris
117		*Pfenderina* spp *Kurnubia* (simple) *Lucasella* (?) *Nautiloculina* *Meyendorffina* cf. *Cheilosporites* debris	Mid Jurassic Probably Bathonian with Triassic debris
142		*Kurnubia* C. *Meyendorffina* *Nautiloculina* *Pfenderina* Pianella sellii Protopeneroplis	Middle – Late Jurassic Bathonian – Oxfordian
144A	(1)	Radiolaria	
	(2)	*Permodiscus* *Cheilosporites* aff. C. sp (Oman)	Late Triassic
145A		Dasyclad fragments ? *Protopeneroplis*	probably Middle – Late Jurassic

145D	Calcisponge debris *Cheilosporites* aff. C. sp (Oman) *Permodiscus* *Microtubus* Radiolaria	Late Triassic
148A	*Trocholina* *Kurnubia* *Protopeneroplis* cf. *Lucasella*	Middle Jurassic
148B	(1) Radiolaria (2) Radiolaria *Protopeneroplis*	 Middle – Late Jurassic
149	*Pseudocyclammina* cf. *ukrainica*	Jurassic probably Middle Jurassic (Triassic lithoclasts)
149ct	Trocholina *Nautiloculina*	
150A	*Protopeneroplis* *Trocholina*	Middle – Late Jurassic
150B	*Protopeneroplis* *Trocholina* ? *Kurnubia* *Cheilosporites* debris	Middle – Late Jurassic (late-Triassic lithoclasts)
150C	Radiolaria	
169	*Pfenderina* cf. *Lucasella* *Pseudocyclammina* cf. *ukrainica* Radiolaria	Middle Jurassic
171	v. small forams	possibly Late Jurassic
172	*Trocholina* *Pseudochrysalidina* *Pseudocyclammina lituus* cf. *Everticyclammina* *Lithocodium* *Tubiphytes* cf. *morroniesis* *Calpionella*	probably Late Jurassic possibly Earliest Cretaceous
172	Radiolaria	
173	Radiolaria	
174	Radiolaria	
176	Radiolaria	
178	? *Zonotrichites* debris Cheilosporites debris	? (Triassic lithoclasts)
196	*Pseudocyclamina* cf. *ukrainica*	Jurassic (probably Middle-Late Jurassic)

211	indeterminate small forams cf. *Nautiloculina*	Rhaetian – Early Liassic
213	*Involutina turgida/ liassica* Tufted algae (unusual) cf. *Uragiella*	
214	Radiolaria *Trocholina* *Kurnubia* cf. *Lithocodium* cf. *Everticyclammina*	poor faunas probably latest Jurassic
237	Indet. Radiolaria Burrow cf. *Chondrites*	
238	Pelagic lamellibranchs	Triassic – Middle Jurassic
108	Very poor microflora	Mesozoic, possibly Triassic
210	Poor microflora	Late Triassic
237	Poor microflora	Jurassic to (Early) Cretaceous
103	Practically no pollen Rich in microplankton *Odontochitina costata* *Cyclonephelium distinctum* *Trichodinium castaneum* *Pseudoceratium ceratioides* *Codoniella campanulata* *Dinogymnium denticulatum* *Dinogymnium albertii* *Palaeohystrichophora infusorioides*	Santonian to Campanian
131	Rich in sporomorphs and microplankton *Ephedripites spiralis* *Ephedripites sp.* *Spheripollenites scabratus* *Circulina parva* *Eucommiidites troedsonii* *Perinopollenites elatoides* *Cicatricosisporites* sp. *Cicatricosisporites* cf. *cooksonii* *Cicatricosisporites dorogensis* *Perotriletes rugulatus* *Peromonolites reticulatus* and some microplankton such as *Ascodinium* spp. *Cyclonephelium distinctum*	Hauterivian to Barremian, possibly only Barremian