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The Stratigraphy of the Othris Mountains, Eastern Central Greece: a Deformed Mesozoic Continental Margin Sequence

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ABSTRACT

The stratigraphy of the Othris Mountains is formally defined. Sixteen formations are proposed, fifteen of which are classed into three Groups. The Othris Group contains continental margin deposits and overlies a metamorphic basement, the Pteleon Formation. The Mirna Group, an ophiolite complex, was thrust over the Othris Group in uppermost Jurassic or Lower Cretaceous time. Unconformably overlying both Groups is the Dinai Group, of Upper Cretaceous conglomerate, sandstone, limestone and lower Tertiary "flysch". The area includes the best-known and best-exposed examples of Lower Cretaceous orogenic structures in the Hellenides.

Introduction

The Othris Mountains of eastern central Greece (Fig. 1) have been mapped by the Greek Geological Survey (the Institute of Geology and Subsurface Research) on a scale of 1:50,000. Eastern and central Othris were mapped under the direction of G. Marinos, and western Othris was partly mapped by KOCH & NICOLAUS (1969). The northwestern edge of Othris was mapped by AUBOUIN (1959) on a scale of 1:200,000. These studies established the gross stratigraphic succession in Othris. Subsequent detailed mapping on a scale of 1:10,000–1:20,000 has established a detailed stratigraphic succession which is here formally defined. The scheme proposed is based on the work of a group at Cambridge University: A.G.S. (1966–1974); A.J.H. (1969–1971); M.M. (1972–1974); E.G.N. (1970–1972); I.P. (1972–1974) and M.J.P.W. (1969–

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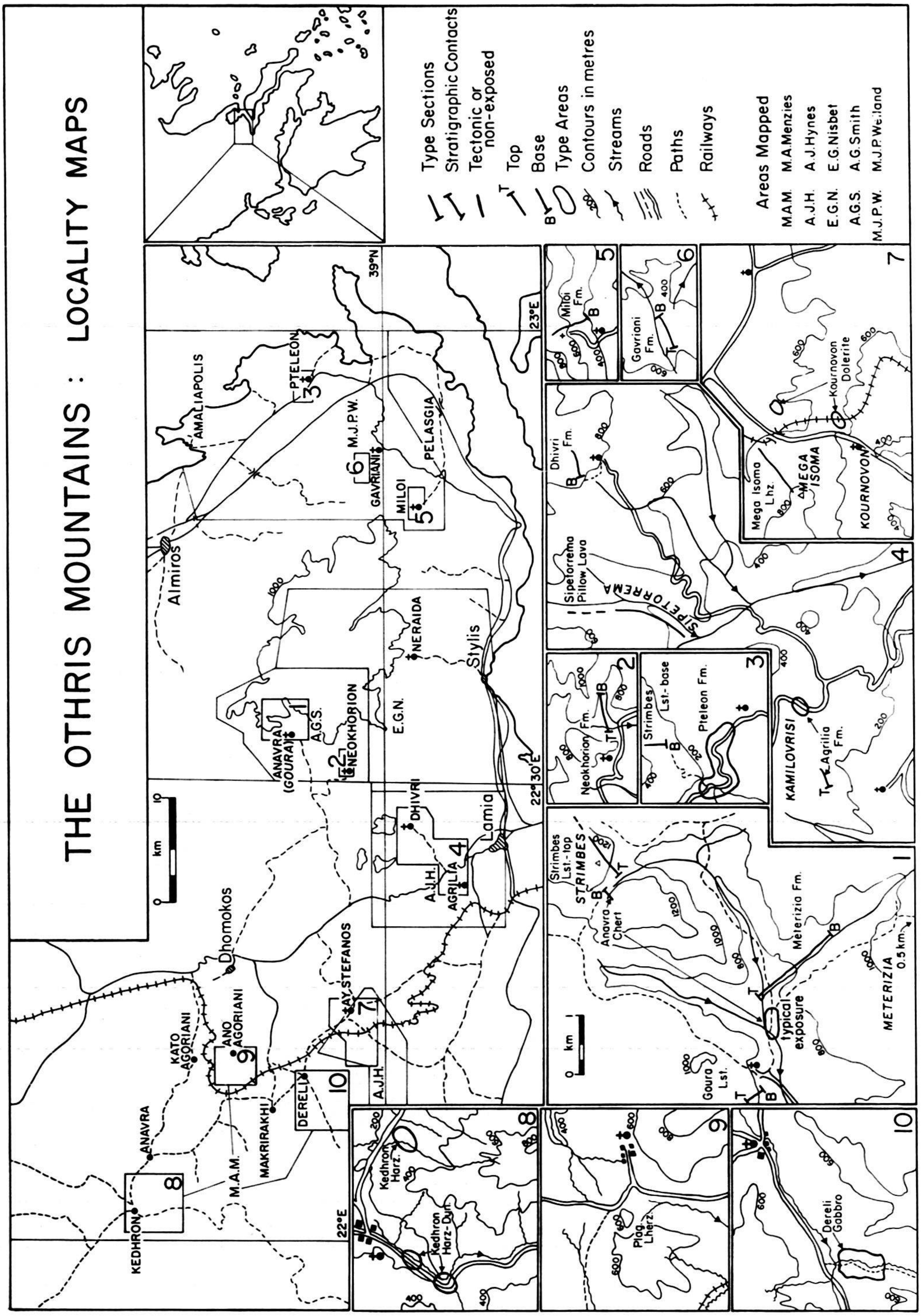
THE OTHRIS MOUNTAINS : LOCALITY MAPS
km
0
10
Type Sections
Stratigraphic Contacts
Tectonic or non-exposed
Top
Base
Type Areas
Contours in metres
Streams
Roads
Paths
Railways
Areas Mapped
M.A.M. M.A.Menzies
A.J.H. A.J.Hynes
E.G.N. E.G.Nisbet
A.G.S. A.G.Smith
M.J.P.W. M.J.P.Weiland
Almiros
AMALIAPOLIS
PTELEON
GAVRIANI
M.J.P.W.
MILOI
PELASGIA
NERAIDA
Stylis
E.G.N.
ANAVRA (GOURA)
NEOKHORION
A.G.S.
DHIVRI
AGRILIA
A.J.H.
Lamia
Dhomokos
AY. STEFANOS
KATO AGORIANI
ANO AGORIANI
DERELI
A.J.H.
MAKRIRAKHI
M.A.M.
ANAVRA
KEDHRON
39°N
23°E
22°30'E
22°E
Miloi Fm.
Gavriani Fm.
Dhivri Fm.
Sipetorrema Pillow Lava
SIPETORREMA
Mega Isoma Lhz.
MEGA ISOMA
KOURNOVON
Kournovon Dolerite
Neokhorion Fm.
Strimbes Lst.-base
Pteleon Fm.
KAMILOVRISI
Agrilia Fm.
Strimbes Lst.-top
STRIMBES
Anavra Chert
Meterizia Fm.
METERIZIA
0.5 km
typical exposure
Goura Lst.
Kedhron Harz.
Kedhron Harz-Dun
Plag. Lherz.
Dereli Gabbro

1971); supplemented by the paleontological work of J.F., of the University of Lille (1969–1974)[8]. As far as practicable the rock stratigraphic units have been defined according to the principles laid down in the summary to an International Guide to Stratigraphic Classification, Terminology and Usage (HEDBERG 1972). A brief description of each formally defined unit is given. Type localities are given on Figure 1. The table (p. 466) summarizes the proposed stratigraphical scheme; Figure 2 gives a provisional geological map of Othris; Figure 3 shows the general lithostratigraphic sequence. Rock colours have been obtained from the Rock-color Chart of the Geological Society of America (1963).

Three Groups have been defined: the Othris, Mirna and Dinai Groups. The Othris Group consists of a variety of Mesozoic carbonates and cherts underlain by Mesozoic pillow lavas and dolerite, and by Paleozoic carbonates. Locally the Othris Group overlies unconformably a metamorphic basement: the Paleozoic or older Pteleon Formation. The Mirna Group, consisting of harzburgites, lherzolites, gabbros, mafic dykes and Mesozoic pillow lavas, has been thrust over the Othris Group. The Mirna Group is an ophiolite complex, as defined by the Geological Society of America Penrose Conference on Ophiolites (Anon. 1972). Unconformably overlying both the Othris Group and the Mirna Group is the Dinai Group: Upper Cretaceous conglomerate, limestone and Lower Tertiary "flysch".

The area displays one example of the kinds of rocks formed on an evolving continental margin. Undeformed examples of such margins have been partially sampled during the JOIDES drilling program. Deformed examples are well-known in the Apennines and western Greece (BERNOULLI 1972). The Othris region provides yet another example of such rocks. In addition, rocks transitional to the ocean-floor, and the ocean-floor itself are exposed. The area is readily accessible by car from Athens. Essential features can be seen in two days of driving and traversing along paths in the mountains.

Formal stratigraphy

Pteleon Formation

Name and type area: The formation is named after the town of Pteleon on the old road to Volos in eastern Othris (Fig. 1). Because of intense deformation, and the absence of good marker horizons, it is not possible to define a type section (stratotype) for the formation. Typical exposures occur on the west of the road northwest of Pteleon.

Fig. 1. Positions of the type localities and typical exposures of the stratigraphic units defined in the text. The inset maps show areas in detail. The numbers on them correspond to those on the large-scale map. Villages (shown by church symbols) named on the large-scale map are indicated only by symbols on the insets. Areas of detailed mapping are shown. Intervening areas have been mapped on a reconnaissance scale (more than 1:20,000). J.F. and I.P. have been engaged on regional projects.

[8]) The tectonic reconstruction of Othris envisaged by J. F. differs somewhat from that proposed here. The alternative is set out in FERRIÈRE (1974).

Proposed stratigraphic classification of the Othris area. The lateral extent of the units and their relationships to the isopic zones of the Hellenides is indicated.

West — OTHRIS (= SUB-PELAGONIAN) ZONE — PELAGONIAN ZONE — East

DINAI GROUP
- Dhivri Formation (sandstone & shale - 'flysch')
- Goura Limestone (shallow-water limestone)

Miloi Formation (conglomerate, sandstone, shale derived from erosion of Othris and Mirna Groups)

——— angular unconformity ———

MIRNA GROUP (ocean-floor thrust over Tzudi sequence)	OTHRIS GROUP (continental margin sequences): Tzudi seq. (thrust over Poulia)	Poulia seq. (thrust over Karolina)	Karolina seq. (autochthonous)
Agoriani Plagioclase Lherzolite		Anavra Chert (abrupt change in sedimentation)	
thrust	Neokhorion Formation (shales and cherts in upper part; pelagic limestones in lower).		
Kedhron Harzburgite		Meterizia Limestone (fragmental carbonates, turbiditic)	Strimbes Limestone (shallow-water platform carbonates)
thrust			
Mega Isoma Lherzolite	(transitional change in sedimentation)		
thrust	Agrilia Formation: Neraida Chert Member; lower member (volcanic rocks transitional chemically to ocean-floor)		
Dereli Gabbro			
thrust			
Kournovon Dolerite	thrust	Gavriani Formation (shallow-water limestones, sandstones, conglomerates, shales)	
thrust		thrust	—— angular unconformity
Sipetorrema Pillow Lava			* Pteleon Fm. (basement)
thrust			

(*Note: The Pteleon Fm. is excluded from the Othris Group)

Lithology and variation: The Pteleon Formation consists of quartzites, metamorphosed arkosic sandstones, schists, phyllites and some marbles. Grain size is variable, as is the colour. The rocks contain abundant metamorphic muscovite and albite and belong to the lower greenschist facies. Finer-grained rocks have a well-developed metamorphic foliation. Deformation varies, but isoclinal and chevron folds are common.

Upper and lower boundaries: The stratigraphic base of the Pteleon Formation is not exposed. It is overlain unconformably by the much less deformed Gavriani Formation (see below).

Thickness and regional extent: The exposed thickness is probably greater than 1,000 m and it outcrops only in eastern Othris (Fig. 2).

Gavriani Formation

Name and type area: The Gavriani Formation is named after the village of Gavriani (or Plakis), on the old Pelasgia to Volos road (Fig. 1). The type section is at the site of the former village of Gavriani, 2 km to the northwest.

Lithology and variation: The formation consists mainly of quartz-pebble conglomerates, conglomeratic sandstones, and shales that weather yellow to grey or green (5Y 7/4–5BG 3/2). Grains are mainly quartz and feldspar, with some detrital muscovite and schistose lithic fragments. The grains are angular and poorly sorted. Some well-graded units are present, as are carbonate horizons. These latter are very variable, but include massive, grey-white recrystallized limestones, orange and pinkish veined limestones (5 YR6/4–10YR 6/4), and compact thin-bedded black or dark grey fossiliferous limestones. They are common towards the top of the formation, particularly in central Othris. In eastern Othris the rocks are in lower greenschist facies. In central Othris the rocks are unmetamorphosed but have been extensively sheared so that reconstruction of the original stratigraphic section is difficult.

Upper and lower boundaries: In eastern Othris the Gavriani Formation unconformably overlies the Pteleon Formation and is tectonically overlain by the Strimbes Limestone (see below) at the type section. Elsewhere in eastern and in central Othris the base is not exposed. In central Othris the upper boundary is taken at the horizon where rocks of the Gavriani Formation (here sandstones, shales, limestones or limestone conglomerates) pass upward into the igneous rocks or cherts of the overlying Agrilia Formation (see below). In other parts of eastern Othris the transition to the Strimbes Limestone is apparently conformable.

Thickness and regional extent: The thickness of the Gavriani Formation is very variable. The minimum thickness at the type locality is 400 m, but in central Othris the exposed thickness varies from 20 to 300 m. A few outcrops are known in western Othris.

Strimbes Limestone Formation

Name and type locality: The formation is named after a peak on a high plateau of carbonates about 5 km northeast of Anavra (= Goura). The type section for the base is in eastern Othris on the slopes of Mount Khlomon. The type section for the top is the exposure below the contact with the overlying Anavra Chert, southwest of

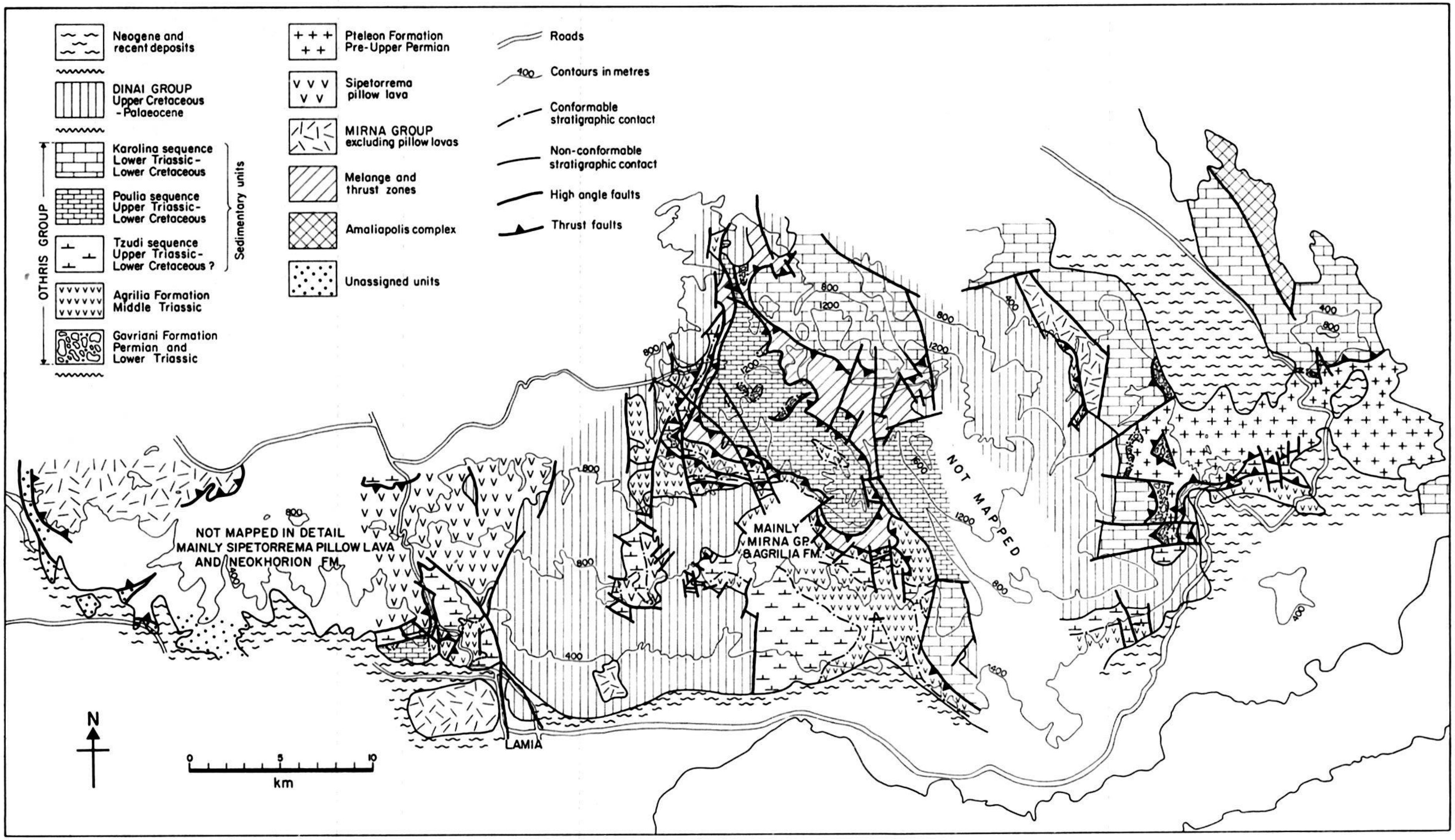

Fig. 2. Simplified geological map of Othris, based mostly on small-scale maps (1:20,000 or smaller) included in the Ph. D. theses of A.J.H., E.G.N., M.J.P.W., together with unpublished maps of A.G.S. Structural complexities and poor exposure are responsible for the unshaded ("not mapped") central portion. The teeth on the thrusts are on the upper plate.

Strimbes (Fig. 1). No continuous section is known through the formation. Lithologically similar rocks in north central Othris yield fossil ages intermediate between those of the limestones at the base and those at the top at the type localities. It is assumed that the entire formation consists of carbonates.

Lithology and variation: The formation is very homogeneous, consisting mostly of massive carbonates, with minor laminated, oolitic, algal-banded or loferitic horizons (c.f. FISCHER 1964). Locally, coarse limestone breccias, possibly of syntectonic origin, occur. Dolomitic limestone is particularly abundant near the base of the unit.

Upper and lower boundaries: The probable base is exposed 2 km northwest of Pteleon, where dark (N3–N1) limestone of the Gavriani Formation is overlain, apparently conformably, by 10 m of white (N9) coarsely crystalline dolostone, followed by 5 m of dark grey (N5–N4) impure limestone, which in turn is capped by massive carbonates typical of the Strimbes Limestone as a whole. The top of the formation is defined as the abrupt and apparently conformable change to the siliceous siltstones at the base of the Anavra Chert. Very locally there are thin ferruginous crusts at this contact, which may reflect a paleokarst or hard ground.

Thickness and regional extent: The exposed thickness of the lower part of the formation is at least 700 m, that of the upper part is at least 900 m. Total thickness is not known, owing to incomplete exposure and absence of marker horizons. The formation is exposed in central, northern and eastern Othris. One of us (J.F.) believes the total thickness may be less, and that the Strimbes Limestone as defined here is divisible into two distinct units (I and III of FERRIÈRE 1974).

Agrilia Formation

Name and type locality: The formation is named after Agrilia village, 10 km northwest of Lamia. The type section is 0.5 km north of Agrilia (Fig. 1). Pillow lavas, not present in the type section, are exposed at the Kamilovrisi spring, 5 km north-northwest of Lamia, on the road to Dhomokos.

Lithology and variation: The Agrilia Formation consists of picrites, dark green (10GY 4/2) dolerites, light coloured siliceous sediments and tuffs, red, brown-green and purple pillow lavas, pillow breccias, dark red siltstones (10R 3/4) and cherts, and red (10R 4/6) dolostones. Picrites and dolerites lie at the base, overlain by light coloured siliceous rocks and occasionally by pillow lavas. Dark red (10R 3/4) siltstones and red cherts occur as intercalations at the top of the succession, where they form a mappable unit that has been named the Neraida Chert Member of the Agrilia Formation (see below).

Upper and lower boundaries: The lower boundary of the formation is placed at the top of the Gavriani Formation (see above). This contact is commonly sheared, but may originally have been conformable. The upper boundary is conformable, and commonly transitional to the overlying Meterizia Limestone or the Neokhorion Formation via the Neraida Chert Member of the Agrilia Formation (see below).

Thickness and regional extent: The Agrilia Formation varies from as little as 5 m, where it underlies the Meterizia Limestone, to as much as 200 m where it underlies the Neokhorion Formation. It is exposed throughout the Othris Mountains, from Pelasgia in the east to Kournovon in the west.

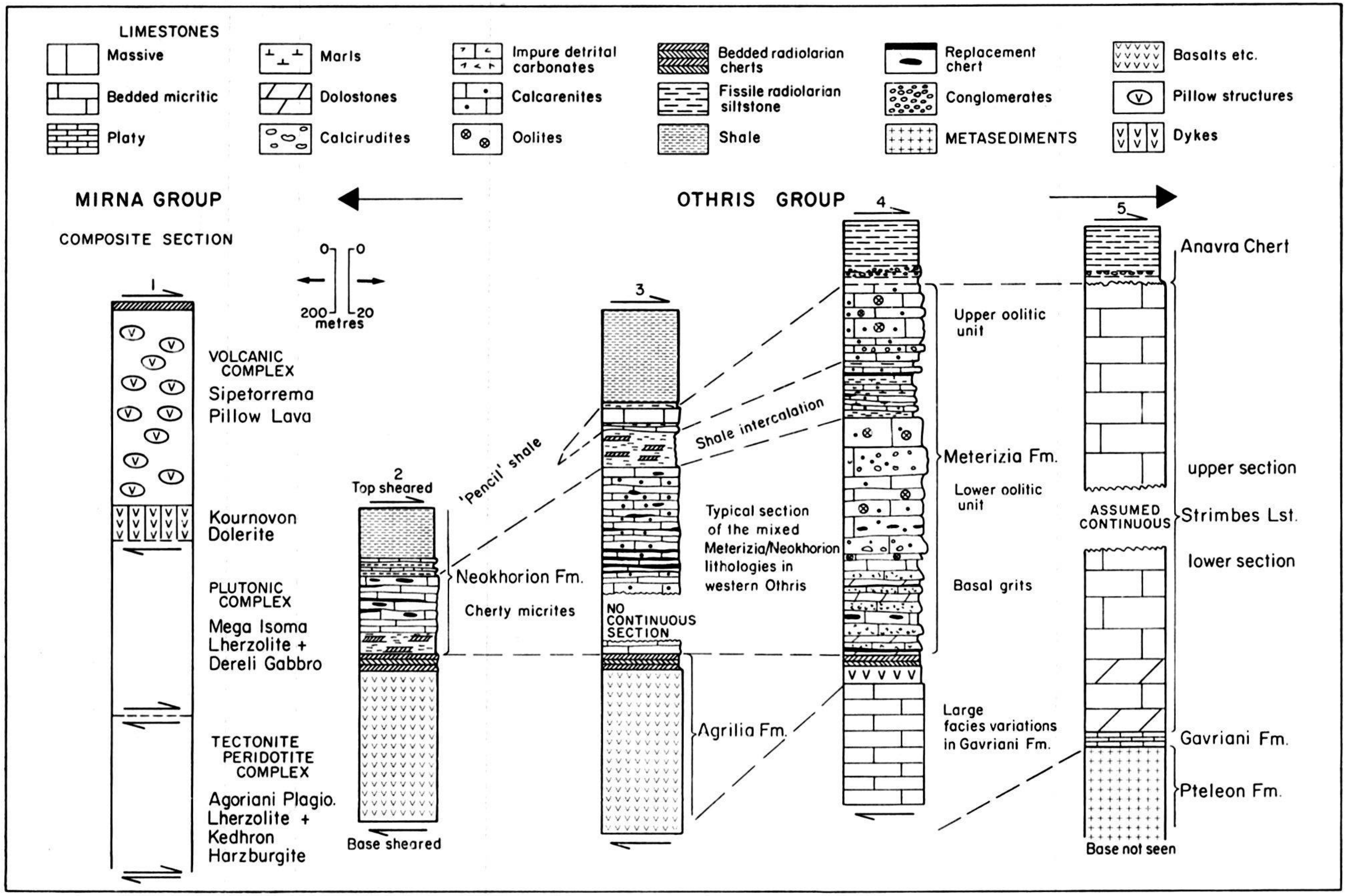

Fig. 3. Lithological sections in Othris. Sections 2, 4 and 5 are based on type sections. Section 3 represents the transitional facies between the Meterizia and Neokhorion Formations. The Gavriani Formation is mostly calcareous in sections 4 and 5, and clastic parts of the Formation are thin or absent.

Neraida Chert Member of the Agrilia Formation

Name and type locality: This member is named after Neraida village, north of Stilis in central Othris. The type section is a roadside quarry 1 km south of Neraida (Fig. 1).

Lithology and variation: The Neraida Chert Member consists of thin, rhythmically bedded radiolarian cherts with common shaley partings. Beds vary from 1 to 7 cm in thickness, with partings up to 0.5 cm in thickness. Both chert and partings are dark red in colour. Minor red and grey shales, weathering to angular fragments are also present.

Upper and lower boundaries: The lower boundary of the member is not exposed because the contact is tectonic. North of Agrilia and also 3 km east of Anavra, the chert lies conformably on lavas of the Agrilia Formation. The chert is conformably overlain by the Neokhorion Formation and the Meterizia Limestone Formation. This contact can be sharp, especially below the Neokhorion Formation. Transitional contacts are usually marked by interbedded red chert and red dolomitic carbonate. In such cases, the predominance of limestones and dolostones over chert marks the top of the member.

Thickness and regional extent: The Neraida Chert Member is between 4 and 15 m thick. It is exposed over most of Othris.

Meterizia Limestone Formation

Name and type locality: The formation is named after the high ridge about 4 km southeast of Anavra (Fig. 1). The type section is in a gorge about 2 km east of Anavra.

Lithology and variation: The formation consists mainly of highly variable carbonates. At the base are graded, fine-grained calcirudites; locally with beds up to 2 m thick, containing clasts of previously deposited carbonates, together with fragments of chert and igneous rock. Grey (N7–N6) and red (10R 4/6) calcilutites are interbedded with the graded carbonates. The red calcilutites are dolomitized. This lower facies passes upward into generally thicker bedded, purer, commonly oolitic carbonates. Thick calcirudite beds occur in this facies. About two-thirds of the total thickness above the base are greyish red (10R 4/2) and greenish brown (5YR 6/4) shales, interbedded with red cherts and impure clastic carbonates like those at the base. Chert nodules, lenses and stringers are common.

Upper and lower boundaries: The base is defined as the top of the Agrilia Formation (i.e. the top of the Neraida Chert Member). The top is taken where the massive limestones of the upper part of the formation pass abruptly, but apparently conformably, into the overlying siltstones of the Anavra Chert Formation.

Thickness and regional extent: The thickness at the type locality is about 200 m, but in western Othris the formation is thinner and the carbonates are finer grained. The Meterizia Limestone is exposed in central, northern and western Othris. Western sections resemble thick sections of the Neokhorion Formation, but contain less chert and more calcarenite (Fig. 3).

Anavra Chert Formation

Name and type locality: This unit is named after the village of Anavra in northern Othris. The type section is in a col, about 500 m west-northwest of Strimbes (Fig. 1).

Typical, but tectonically thickened exposures exist on the ridge about 1.5 km east of Anavra.

Lithology and variation: The formation consists of purplish, commonly manganiferous siltstones at the base, passing up into cherts and siliceous mudstones, and then reverting to siltstones. The rocks are generally more brown (10R 3/4) and more fissile than those in the Agrilia Formation, with which they may be readily confused. In eastern Othris the formation consists of reddish (5R 2/2), purple (5P 2/2) and yellow (approx. 10YR 6/6) phyllites. At the base of the formation in northern Othris there are some coarse lithic sandstones, pebbly mudstones, fine-grained tuffs and possibly some vesicular volcanic rocks. These rocks occur immediately above both the Strimbes Limestone and the Meterizia Limestone.

Upper and lower boundaries: The base of the Anavra Chert is an abrupt transition (see above) from the Strimbes or the Meterizia Limestone. The top is always a tectonic contact or an unconformity at the base of the Goura Limestone (see below).

Thickness and regional extent: The type section is about 50 m thick, but may be tectonically thickened. The typical exposures east of Anavra are tectonically thickened to at least 300 m. The formation is exposed mostly in central and northern Othris.

Neokhorion Formation

Name and type locality: The formation is named after the village of Neokhorion in northern Othris. The type section is exposed in a valley about 1.5 km east of the village (Fig. 1).

Lithology and variation: The formation consists of two members that are only informally defined: a lower member of medium- to thin-bedded limestone with interbedded chert, and an upper member of mudstone, shale and interbedded silicified calcarenites. The limestone is grey green (5YR 5/2 to 5G 2/2) or dark red (5R 4/2) and micritic. Beds are 5–10 cm thick. The chert is commonly green or greenish black (10G 4/2 to 5G 3/2), but may be red, particularly near the base of the formation. It occurs as beds 2–4 cm thick, or as nodules. Bedded brown cherts (approx. 5YR 3/4) occur in the limestones in western Othris. The mudstone is generally purplish in colour, with minor green intervals. It may be calcareous. It weathers into characteristic, small, lozenge-shaped fragments forming a "pencil shale". The silicified calcarenites are generally grey and weather out to form resistant ribs within the mudstone. Manganiferous concretions occur in the mudstone.

Upper and lower boundaries: The lower boundary is defined as the top of the Agrilia Formation (see above). The upper boundary is generally tectonic.

Thickness and regional extent: The lower member is probably about 30 m thick in its type area, and the upper member is probably thicker. The formation occurs throughout most of Othris. In western Othris the upper member is less well exposed and the lower member attains a thickness of at least 80 m.

Agoriani Plagioclase Lherzolite

Name and type locality: The Agoriani Plagioclase Lherzolite is named after the village of Ano Agoriani, which lies 8 km west of Dhomokos. Typical exposures exist on the slopes and summit of a hill 2.5 km west of the village. Gabbroic schlieren within the Lherzolite are best exposed in stream sections terminating at the Ayios Stefanos to Dereli road.

Lithology and variation: The Lherzolite consists of a metamorphic plagioclase lherzolite, lherzolite and gabbroic schlieren. Serpentinization is variable. The schlieren are rodingitized. Segregations of anorthositic gabbro may contain large pyroxene crystals and glomeroporphyritic olivine.

Upper and lower contacts: The Agoriani Lherzolite is bounded by tectonic contacts in all localities, except possibly west of Ano Agoriani, adjacent to the Kedhron Harzburgite (see below). Northwest of Ayios Stefanos the plagioclase lherzolite tectonically overlies the Mega Isoma Lherzolite (see below).

Thickness and regional extent: The thickness near Ano Agoriani is not known. Near Ayios Stefanos the thickness of a thrust sheet is at least 400 m.

Kedhron Harzburgite

Name and type locality: The Kedhron Harzburgite is named after the village of Kedhron, at the mouth of the river Sofadhitikos, located approximately 50 km northwest of Lamia. Typical exposures occur along the road to the south paralleling the river toward Smokovou. Harzburgite is exposed in many other parts of the western Othris Mountains.

Lithology and variation: Fluctuations in modal pyroxene cause intimate interfoliation of harzburgite with dunite. Enstatite up to 15 mm in grain size occurs, locally concentrated into bands. Chromite grains tend to be concentrated into small clusters within the dunite, parallel to the harzburgite contact. Flinty peridotite, locally developed, results from mylonitization. Serpentinized areas weather readily.

Upper and lower boundaries: The unit tectonically overlies the Kournovon Dolerite (see below), pillow lavas and sediment. The contact is exposed near Ayios Stefanos on the road from Xinias to Dereli (see below).

Thickness and regional extent: The unit occurs as a thrust sheet at least 80 m thick, covering an area 3 km^2 south of Ayios Stefanos. Similar ultramafic rocks occur immediately west of Lamia, and possibly east and northeast of Vrinaina in eastern Othris.

Mega Isoma Lherzolite

Name and type locality: The Lherzolite is named after the hill Mega Isoma 2 km northwest of Kournovon in western Othris. The type section is from the summit of this hill to a point 2 km north-northeast, reached from the highest point of the Ayios Stefanos to Grammeni road.

Lithology and variation: The Lherzolite consists of magmatic plagioclase lherzolite (2-pyroxene peridotite with accessory plagioclase) with subordinate wehrlite (peridotite with clinopyroxene and little or no orthopyroxene), and some gabbro. The ultramafic rocks are usually serpentinized and commonly deeply weathered. In fresh outcrop, small (0.5 mm) interstitial plagioclase grains are clearly visible in the Lherzolite. Large (2–3 mm) pyroxene grains are commonly visible. Vertical sheet-like bodies of banded anorthositic gabbro, about 5 mm thick, and irregular masses of more homogeneous gabbro occur in the serpentinized lherzolite. In the wehrlite, plagioclase or clinopyroxene occurs in large (0.5–1 mm) triangular patches, irregularly distributed throughout the rock.

Upper and lower boundaries: The Mega Isoma Lherzolite is bounded by tectonic contacts. Above it lies serpentinized ultramafic rocks, below it lies the Kournovon Dolerite (see below).

Thickness and regional extent: The Lherzolite is a thrust sheet in which the probable original horizontal direction in the rocks is now dipping vertically. The unit is over 400 m thick and is exposed over a large part of western Othris. Similar rocks are exposed 1 km west of Lamia, and the ultramafic rocks near Vrinaina in eastern Othris may belong to the unit.

Dereli Gabbro

Name and type locality: The unit is named after the village of Dereli, which lies between Ayios Stefanos and Makrirakhi. Typical exposures of the layered troctolite, olivine gabbro and minor anorthositic gabbro outcrop 3 km southwest of Dereli on the south side of the valley. Typical pyroxene gabbro, anorthositic gabbro, pegmatitic gabbro and minor olivine gabbro occurs in a stream section between the villages of Kato Agoriani and Ano Agoriani.

Lithology and variation: The gabbros tend to be homogeneous. Sporadic patches of pegmatitic gabbro exist, as do thin pegmatitic veins pyroxenes up to 2.5 cm in size. In other outcrops fine-grained gabbro cuts the coarser, more typical gabbro. Bleaching of the gabbro, due to alteration, is common. Olivine gabbros are fresher and display cumulus layering of olivine and plagioclase. Poikilitic augite is observable in hand specimen, even in weathered specimens.

Upper and lower boundaries: The pyroxene gabbros are tectonically overlain by the Kournovon Dolerite (see below) and overlie serpentinized Agoriani Lherzolite. Olivine gabbro occurs as tectonic fragments in serpentinized ultramafics or is tectonically bounded by ultramafic rocks. Infrequent dioritic masses occur in a similar manner.

Thickness and regional extent: Thickness is not known. Total outcrop area is less than 2 per cent of the total mafic-ultramafic exposures in western Othris.

Kournovon Dolerite

Name and type locality: The unit is named after the village of Kournovon in western Othris. Typical exposures occur in the railway cutting 0.5 km northwest of Kournovon, and in the river valley 2 km southwest of Ayios Stefanos.

Lithology and variation: The Dolerite consists of fine-grained, vertical dolerite dykes; gabbroic cumulates; pillow lavas; flow basalts and occasional siliceous igneous rocks. Exposures vary considerably. Most show dolerite dykes which may cut gabbro; others show brecciated basic lava flows cut by occasional dolerite dykes. Some, however, are 100 per cent dolerite dykes or contain rhyolite flows and pillow lavas. The poor exposure, the faulting and folding all preclude determining the stratigraphical relationships among the various rock types.

Upper and lower boundaries: The Kournovon Dolerite is tectonically overlain by rocks of the Mega Isoma Lherzolite (see above) and the Ayios Stefanos Harzburgite. It tectonically overlies pillow lavas and sediments.

Thickness and regional extent: The Dolerite occurs as a thrust sheet 150 m thick. It outcrops over a 10 km arc, concave to the northwest, centred on Kournovon. It has not been recognized elsewhere in Othris.

Sipetorrema Pillow Lava

Name and type locality: The Lava is named after the Sipetorrema River which flows south into Xarias River, 6 km north of Lamia. The type section is the bed of the Sipetorrema River. More accessible exposures exist at the top of the pass on the road from Lamia to Dhomokos (Fig. 1).

Lithology and variation: The unit consists of monotonous pillow lavas, rare lava flows and a few thin beds of red siltstone and chert. In weathered outcrop the pillows are brown (10R 4/6 to 5YR 4/4); in fresh outcrop they are dark green or black. Amygdales are not common, and when present are small (0.2 mm). Individual mineral grains are not easily discernible in hand specimen. In one location in western Othris there are flows of olivine and pyroxene cumulates in the pillow lava. The flows are 1–10 m thick and contain phenocrysts of olivine and pyroxene 2–3 mm in size. Occasional pale green, fissile material occurs interstitial to the pillows. Red (5R 3/4 to 10R 3/4) siltstones and cherts occur as thin (2–5 cm) isolated beds, or as 5–10 m thick horizons of thin-bedded sediment in various places in the Pillow Lava.

Upper and lower boundaries: The Lava tectonically overlies rocks of the Neokhorion Formation and the Anavra Chert. It is unconformably overlain by the Goura Limestone (see below).

Thickness and regional extent: The thickness of the thrust mass is at least 700 m. It outcrops over a large part of western Othris and of south central Othris.

Miloi Formation

Name and type locality: The Formation is named after the village of Miloi in eastern Othris (Fig. 1). The best exposed sections occur around Miloi, on the slopes of Mount Taratsa. The type section for the upper part of the unit is on a track immediately west of Miloi, the type section for the lower part is in a stream section to the east.

Lithology and variation: The formation consists of red and brown weathering polymictic conglomerates at the base; well-bedded, graded, lithic sandstones, siltstones and shales in the higher parts. The detritus consists of basic volcanic rock, chert, limestone and biogenic fragments. Quartz grains are rare. The formation is usually calcareous, with some horizons of silty or platy limestones and massive, rudist-bearing limestone.

Upper and lower boundaries: The base of the formation is distinguishable by a massive conglomerate, resting unconformably on the Agrilia or Neokhorion Formations, or on the Meterizia Limestone. At its top it grades conformably into the Goura Limestone (see below).

Thickness and regional extent: In eastern Othris the thickness is at least 150 m, and the overlying Goura Limestone has been eroded. It wedges out to the west, and is essentially absent from western Othris. Thick exposures exist in northern Othris on the tractor trail to Almiros 5 km north of Anavra.

Goura Limestone Formation

Name and type locality: The formation is named after the village of Anavra, whose former name was Goura, in northern Othris (Fig. 1). The type section is on the cliffs northwest of Anavra.

Lithology and variation: The formation consists almost entirely of massive or thick-bedded carbonates. Rudists and their debris are common near the base of the formation, and also occur at some higher horizons.

Upper and lower boundaries: The lower boundary is taken in the middle of the transition from the rocks of the Miloi Formation upward into the massive or very thick-bedded carbonates of the Goura Limestone. Where this is absent the boundary is the unconformity of the Goura Limestone on underlying rocks. The upper boundary is taken as the base of the Dhivri Formation (see below).

Thickness and regional extent: The thickness of the formation is variable, from about 100 m to more than 400 m. It occurs throughout Othris.

Dhivri Formation

Name and type locality: The formation is named after the village of Dhivri, 8 km north-northeast of Lamia. The type section is 2.5 km north of Dhivri, just east of the track running from Dhivri to Ayios Athanasios (Fig. 1).

Lithology and variation: The Dhivri Formation is flysch-like, but lacks the bottom markings common in typical flysch deposits. It consists of pale blue and red argillaceous limestones in 10 cm beds; blue-grey, fissile, bedded quartzose sandstone and some calcarenite. It becomes increasingly siliceous and coarser-grained towards the top.

Upper and lower boundaries: The base of the unit is defined as the horizon where the massive grey limestone of the underlying Goura Limestone passes upward into the predominantly blue and red thin-bedded argillaceous limestones of the Dhivri Formation. The boundary is conformable. The top of the Dhivri Formation is not preserved.

Thickness and regional extent: The unit is over 120 m thick, and is exposed throughout Othris.

Groups

Othris Group: The Othris Group is defined as consisting of the following formations: Gavriani, Strimbes Limestone, Agrilia, Meterizia Limestone, Anavra Chert and Neokhorion. This Group is informally divided into three sequences (table, p. 466): the Tzudi sequence (Agrilia and Neokhorion Formations); the Poulia sequence (Gavriani, Agrilia, Meterizia and Anavra Chert Formations); the Karolina sequence (Gavriani, Strimbes and Anavra Chert Formations). The Pteleon Formation is excluded from the Othris Group.

Mirna Group: The Mirna Group is defined as consisting of the Kedhron Harzburgite, the Agoriani Plagioclase Lherzolite, the Mega Isoma Lherzolite, the Kournovon Dolerite, the Dereli Gabbro and the Sipetorrema Pillow Lava. Some features in this group have been described in detail by MENZIES (1973).

Dinai Group: The Dinai Group consists of the Miloi, Goura Limestone and Dhivri Formations.

Other stratigraphic units

Amaliapolis Complex: This informal name is given to a complex of metamorphic rocks and limestones exposed near the village of Amaliapolis in eastern Othris (Fig. 2). Apart from the limestones, which are probably correlative with the Goura Limestone (see below), correlation of the metamorphic rocks with the Othris Group or Pteleon Formation is not yet possible. High angle faults separate the complex from the Strimbes Limestone. The metamorphic rocks consist of pelites, marbles and basic igneous rocks of greenschist facies.

Paleontological data

The stratigraphical scheme described above was established by lithological mapping. Correlation from one Othris Group sequence to another was made by using the Gavriani, Agrilia and Anavra Chert Formations as markers. Presently available paleontological data are still somewhat limited and are summarized below.

Permian. RENZ (1955) identified fusulines in the type area of the Gavriani Formation. Upper Permian faunas occur in this unit north of Pteleon (J.F. in AUBOUIN et al. 1970) and in central Othris (MARINOS & REICHEL 1958; J. L. Cutbill and A.G.S., unpublished data). These are the oldest fossils known from Othris. The underlying Pteleon Formation must be older still.

Triassic (upper Gavriani, lower Strimbes, lower Meterizia, lower Neokhorion and Agrilia Formations). East of Anavra the upper Gavriani limestones contain Lower Triassic (Werfenian to Anisian) ammonites, lamellibranchs, poorly preserved gasteropods and foraminifera (FERRIÈRE 1974). *Meandrospira iulia* and *M. dinarica* indicate the same age range for the lowest parts of the (Strimbes ?) Limestone south and east of Pelasgia (FERRIÈRE 1974). *Halobia* sp. occurs in the Neraida Chert Member of the Agrilia Formation and in the transitional carbonates at the top of the member (I.P. and A.G.S.). Conodonts of Upper Triassic age (Carnian to Norian) occur in the base of the Meterizia Limestone and of the Neokhorion Formation (FERRIÈRE 1974). In the western exposures of the Strimbes Limestone the oldest faunas known are of Upper Triassic age, consisting of megalodonts and *Triasina hantkeni*. Upper Triassic or Lower Jurassic megalodonts occur in the Strimbes Limestone of eastern Othris.

Jurassic (upper Strimbes, upper Meterizia, upper part limestones in Neokhorion, lower Anavra Chert[?]). Youngest fossils in the carbonate units in the Othris Group are all Jurassic in age. In its type area the upper Strimbes Limestone ranges into the Liassic with *Involutina liassica* (FERRIÈRE 1974). To the east, near Mt. Flambouri, *Protopeneroplis striata* and *Conicospirillina basiliensis* occur, the latter indicating an Upper Jurassic (Kimmeridgian) age (FERRIÈRE 1974). The top of the Meterizia Limestone south and east of Anavra contains *Trocholina* sp., *Pseudocyclammina* sp., and *P. striata*, suggesting a Middle or Upper Jurassic age. *Posidonia* sp. in the middle of the limestones of the Meterizia and Neokhorion Formations suggest a Middle Jurassic age (I.P., unpublished data). Radiolaria in the lower Anavra Chert suggest a lowest Cretaceous (Berriasian or Valanginian) age, because the assemblage is indicative of the lower *Sphaerostylus lanceola* Zone (W. R. Riedel, personal communic.). An upper Tithonian or, more probably, Berriasian age was suggested for the same unit by E. A. Pessagno (personal communic.).

Cretaceous (Anavra Chert, Miloi, Goura and part of Amaliapolis complex). See above for Anavra Chert data. Cenomanian nerineids occur at the base of the Miloi Formation north of Paleokerasia. Near Gavriani the nerineids are of lower Aptian age, but may be redeposited (CLEMENT & FERRIÈRE 1973). *Globotruncana* dates the middle Miloi as Turonian to lower Senonian (J.F. and J.J. Fleury, personal communic.). The base of the Goura Limestone may range from Cenomanian to Santonian (HYNES et al. 1972; FERRIÈRE 1974). The uppermost limestone is always of Maestrichtian age with *Orbitoides media* and *Siderolites calcitrapoides* (FERRIÈRE 1974). Turonian and Maestrichtian fossils (*Globotruncana, O. media* and *S. calcitrapoides*) occur in the limestones within the Amaliapolis complex (FERRIÈRE 1974).

Tertiary (Dhivri Formation). The Dhivri Formation ranges from Maestrichtian or Paleocene at the base to middle or upper Paleocene, or higher (BECK 1972).

Isotopic data

The fossil data clearly show that the K–Ar ages given by HYNES et al. (1972) are minimum ages. For example, two igneous specimens from the Middle(?) or Upper(?) Triassic Agrilia Formation gave apparent ages of 156 and 181 m.y. Apparent K–Ar ages of 125 and 127 m.y. were obtained from two samples of the Mirna Group, indicating a Lower Cretaceous age, though the real age may be Jurassic. Five new K–Ar ages are reported here for the first time, all analysed by D. C. Rex of the University of Leeds. They consist of two amphibolites believed to be contemporaneous with the emplacement of the Mirna Group ophiolites and yield apparent ages of 162 ± 10 m.y. and 152 ± 15 m.y., or Upper Jurassic ages. These apparent ages may be close to the true ages because amphiboles retain argon much better than do the minerals in the basaltic rocks dated previously. Three muscovites from the Pteleon Formation confirm the importance of a period of recrystallization in Upper Cretaceous time: 94 ± 4, 82 ± 3, 74 ± 3 m.y.

Interpretation

The Pteleon Formation is a pre-upper Permian continental basement on which the formations of eastern Othris were deposited. Shallow water facies of the Gavriani Formation in central Othris suggest that the Poulia sequence accumulated on continental crust. In middle(?) or upper(?) Triassic time a profound change began to take place in the Othris region: eastern Othris continued to be the site of shallow-water carbonate deposition, whereas central Othris was the site of the minor vulcanism in the Poulia sequence (the Agrilia Formation). The vulcanism in the tectonically higher Tzudi sequence was more intense (Fig. 4). Trace element studies (E.G.N.), electron microprobe analysis of pyroxenes (A.J.H. and E.G.N.), and major element analysis (A.J.H. and E.G.N.) suggest that the Agrilia igneous rocks are transitional between calcalkaline and oceanic rocks. They have been interpreted as rocks forming during a period of continental splitting (HYNES et al. 1972; HYNES 1974*a*). E.G.N. believes that the above data suggest that the splitting may have been caused by the initiation of a marginal ocean basin and a nearby downgoing slab. Other authors consider that an origin by the breaking apart of a once continuous continent, as for the present Red Sea, cannot be excluded. The sedimentary structures and composition of the Neraida Chert Member of the Agrilia Formation may also reflect deposition from low-density turbidity currents flowing from a developing ocean ridge (NISBET & PRICE 1974).

Three broadly contemporaneous carbonate facies were deposited in the Jurassic: shallow-water platform carbonates in eastern and central Othris (Strimbes Limestone); clastic carbonates with reworked neritic debris and material deposited by density flows from erosion of the platform and underlying rocks (Meterizia Limestone of central and western Othris); pelagic carbonates and hemipelagic distal fraction of turbidity flows (carbonates in lower Neokhorion Formation). In western and northwestern Othris ocean-floor may have been formed contemporaneously with the carbonates, and given rise to the Mirna Group ophiolites. The precise spreading age of the Mirna Group ophiolites is not yet known, but it is transitional chemically with the presumably older Agrilia Formation (HYNES 1974 *a*/*b*).

Tectonic emplacement of the ophiolites onto the platform probably occurred in uppermost Jurassic to Lower Cretaceous time. An ordered tectonic stack was created, with undisputed continental material at the base of the stack and progressively more pelagic carbonates and finally ophiolites at the top of the stack. During middle Cretaceous time its surface developed an uneven topography, partly by subaerial erosion, and partly, perhaps, by high angle faulting. The thicker parts of the Miloi Formation accumulated in the valleys, deriving their detritus from the erosion of the underlying Othris and Mirna Groups. The Goura Limestone then blanketed the area. In latest Cretaceous time carbonate sedimentation ceased abruptly and "flysch" deposition began. Following the "flysch" deposition some folding and thrusting took place in middle Tertiary time, particularly in northeast Othris. The final tectonic phase was the development of high angle faulting, probably in late Tertiary time. Some of these faults may still be active. The major fault blocks largely control the present topography.

As noted above, the main stratigraphic interest in the area lies in the well-exposed, telescoped Othris and Mirna Group sequences. These reveal a lateral transition from a continental to an oceanic basement, with corresponding facies variations in the overlying sediments. Here too are the clearest and best-known examples of Lower Cretaceous orogenic structures in the Hellenides. Precisely how these structures developed and how they should be reconstructed palinspastically are not yet known. These problems are currently being investigated.

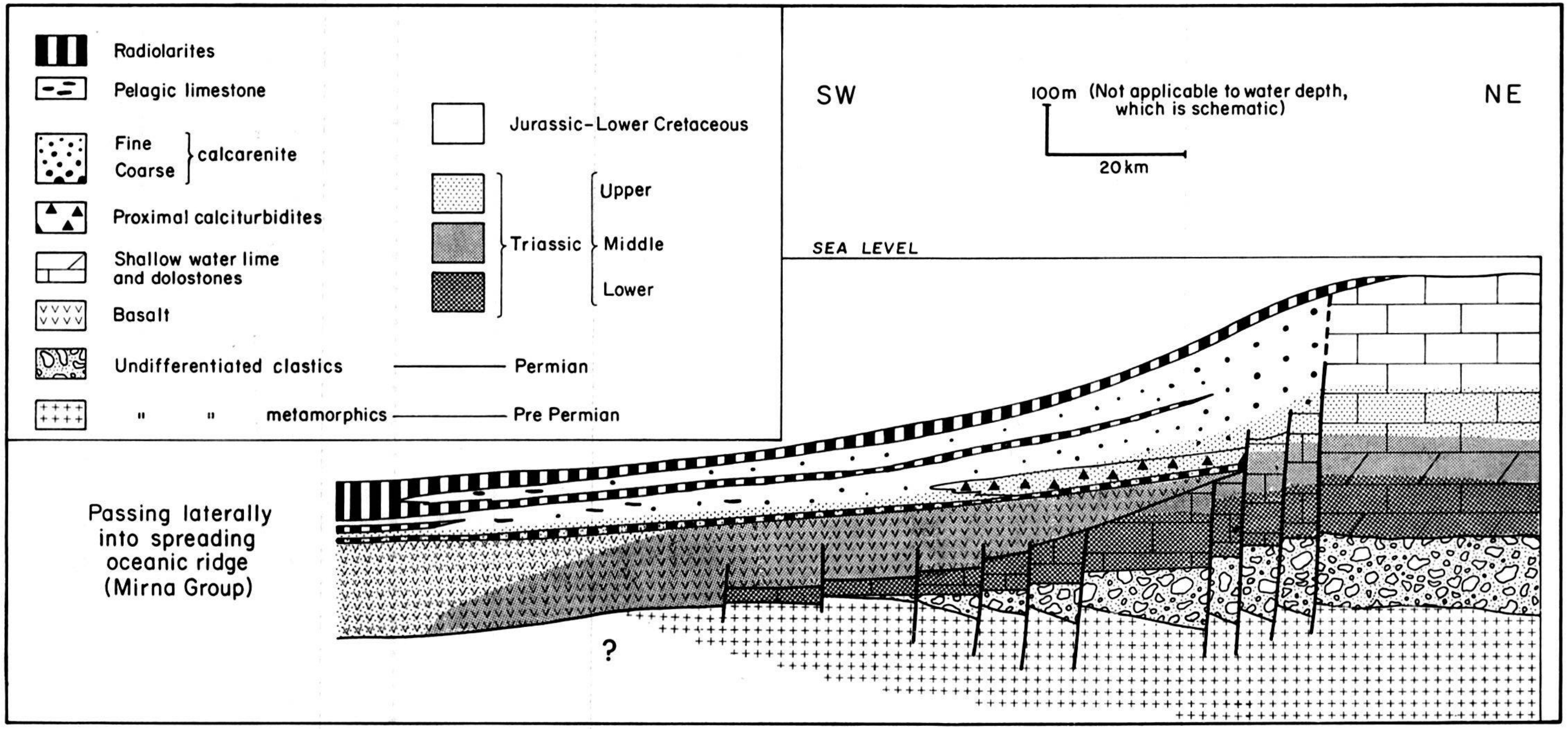

Fig. 4. Schematic reconstruction of the Othris Group, showing approximate facies and time relationships. The orientation of the section is perpendicular to the inferred continental margin. The trend of the margin and the position of the adjacent ocean floor (Mirna Group) is based on unpublished structural and paleocurrent evidence.

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