The extension of the Lycian Nappes (SW Turkey) into the Southeastern Aegean Islands

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The Extension of the Lycian Nappes (SW Turkey) into the Southeastern Aegean Islands

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ABSTRACT

Independent geological investigations on the Mesozoic sequences of the Lycian Taurus (regions of Köyceğiz and Bodrum) and in the small Aegean islands between Crete, Karpathos and Astypalia have revealed striking resemblances in the facies development of the Mesozoic series. In southwestern Turkey three different tectonic assemblages can be distinguished:

1. To the south an apparently autochthonous sequence outcropping in the windows of Göcek and in the Bey Dağlari.
2. Above the autochthonous and sandwiched between the latter and the uppermost unit of the nappe pile, there is an Intermediate Complex of imbricated wedges and small thrust sheets. These imbrics are made up for the most part by the Köyceğiz series and the Diabase Nappe.
3. The Peridotite Nappe.

The autochthonous sequence of Göcek is composed of shallow-water and pelagic limestones of Cenomanian to Lower Burdigalian age with an intercalated laterite horizon indicating emersion from the Middle Eocene to the Lower Miocene. Emplacement of the overlying tectonic units is preceeded by Upper Burdigalian clastics.

The small islands of Chamili, Saforà and Di Adelphi are composed of shallow-water carbonates ranging from Upper Cretaceous to Lower-Middle Eocene and of Middle Eocene flysch. These sequences compare very well with continental margin sequences of Gavrovo-type and a more external origin with respect to the Intermediate Complex has been assumed; contrary to the sequence of the Bey Dağlari these sequences have been involved in the general nappe structure.

In the Intermediate Complex of Lycia, the series of Köyceğiz is the most widespread extending from Fethiye to Bodrum. Its exact equivalents have been found on the islands of Sirna, Tria Nisia, Karavi, Avgò and Unia Nisia. The stratigraphic sequence comprises: 1. Middle Triassic to Middle Liassic shallow-water limestones and dolomites (Gereme Limestone), 2. pelagic and turbiditic limestones with chert, ranging from the Upper Liassic to the Cenomanian (Çal Dağ Limestone) overlain by 3. a thick breccia with chert fragments (Sirna Breccia), 4. regularly stratified flysch sediments (Çamova Formation) leading to a typical wildflysch with exotic blocks not younger than Maastrichtian in age (Karabörtlen Formation). The Diabase Nappe which has been emplaced on the Karabörtlen Formation during the Late Cretaceous or the Early Tertiary, and the Peridotite Nappe are not known in the small Aegean islands. Similar Mesozoic sequences, however, occur on the Datça

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Peninsula, on the islands of Tilos, Symi, Chalki and probably also on Rhodes and possibly as far as the Argolis Peninsula. Major discrepancies within the Lycian sequences concern the inset of flysch sedimentation.

Although detailed correlation of palaeogeographic and palaeotectonic units between the Hellenides and the Taurides could still not be established, the presence of typical Lycian units has clearly been established in the southeastern Aegean Sea. However, emplacement of the different nappe structures in Greece and Turkey could not be correlated and it therefore seems that tectonic boundaries could be discordant in space and time.

RÉSUMÉ

Les recherches menées simultanément sur les séries mésozoïques affleurant dans le Taurus lycien (région de Köyceğiz et de Bodrum) et dans les petites îles égéennes au nord de la Crète ont révélé l'existence d'analogies frappantes dans la stratigraphie des différentes unités mésozoïques.

En Turquie, trois ensembles superposés peuvent être distingués:

- En position inférieure, un autochtone relatif affleure à la faveur des fenêtres de Göcek et dans l'avant pays des Bey Dağlari.
- Au dessus, un «Complexe Intermédiaire» d'écailles imbriquées parmi lesquelles la série sédimentaire de Köyceğiz et la nappe des diabases jouent un rôle important. Elles sont comprises en sandwich entre l'autochtone et
- la nappe des péridotites, qui est la plus élevée des unités charriées de Lycie occidentale.

La série autochtone de Göcek comporte des calcaires pélagiques et d'eau peu profonde, échelonnés du Cénomanien au Burdigalien inférieur, puis des dépôts clastiques au Burdigalien supérieur. Un épisode d'émersion, marqué par des latérites entre Eocène terminal et Aquitanien transgressif, interrompt la série.

Les îles de Saforà, Di Adelphi et de Chamili montrent une succession analogue de calcaires de plateforme jusqu'à l'Eocène inférieur; le passage au flysch, d'âge éocène, peut évoquer une série de type Gavrovo: une position structurale inférieure en a été déduite.

Parmi les unités allochtones de Lycie, *la série de Köyceğiz* a été trouvée sur de vastes étendues, de Fethiye à Bodrum. Elle a été retrouvé dans les îles de Sirna, Tria Nisia, Stakida, Unia Nisia, Karavi et Avgò.

La série Köyceğiz est caractérisée par le passage, au Lias supérieur, de la sédimentation carbonatée de plateforme (*Formation de Gereme:* calcaires et dolomies à dasycladacées du Trias et du Lias) à la sédimentation pélagique et turbiditique (Calcaires du *Çal Dağ:* Lias supérieur–Cénomanien). Au sommet, *la Brèche de Sirna* forme un bon niveau repère. A partir du Turonien basal, les apports détritiques terrigènes apparaissent, d'abord régulièrement stratifiés *(Flysch de Çamova)*, suivis par un wildflysch typique (*Formation de Karabörtlen*), dont les blocs exotiques les plus récents datent du Maastrichtien.

La nappe des Diabases qui a été charriée au dessus du wildflysch à la fin du Crétacé ou au début du Tertiaire, et *la nappe des Péridotites*, ne sont pas connues dans les petites îles égéennes.

Des séries comparables à celle de Köyceğiz existent dans la péninsule de Cnide, dans les îles de Tilos et de Symi, de Chalki, probablement à Rhodes et peut-être en Argolide. Des variations interviennent, notamment sur l'âge de l'apparition du flysch.

Si les étapes de l'orogenèse dans les Hellenides et dans le SW de la Turquie sont marquées par une succession de phases ayant eu un rôle comparable, celles-ci ont intervenu à des époques différentes; l'indépendance des lignes structurales vis à vis des anciennes zones paléogéographiques s'en déduit nécessairement, à la fois dans le temps et dans l'espace.

Bien que la nature des relations entre les unités lyciennes et les zones des Hellénides soient encore mal définies, la présence d'unités lyciennes typiques en Mer Egée est en tous cas clairement établie au nord de la Crête.

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1. Introduction

1.1 *Generalities*

During the last few years, our knowledge of the structure of the Hellenides of the Greek mainland and of the Tauride mountain chains of Anatolia has increased considerably and several attempts to reconstruct their sedimentary and structural evolution have been undertaken. Evidently, both mountain systems are composed of a pile of basement and sedimentary cover nappes with a general southwestern to southeastern vergence (cf. AUBOUIN et al. 1963 for Greece; and BRUNN et al. 1970, for southwestern Turkey), though antinappist views are still maintained by several authors (e.g. MARINOS 1957; BRINKMANN 1967). As the youngest structural trends of both mountain systems can be followed from the Peloponnesus through the islands of Crete, Karpathos and Rhodes to southwestern Turkey, the two mountain systems obviously are somehow connected. However, even a rapid comparison between the well-documented picture of Greece, as it results from the recent work of AUBOUIN, BRUNN, and their co-workers in Greece (AUBOUIN 1959; AUBOUIN et al. 1963, 1970; BRUNN 1956, 1959; CELET 1962; DERCOURT 1964; GODFRIAUX 1968; MERCIER 1966), and the synthetic outline of the western Taurides depicted by the Laboratoire de Géologie Historique at Orsay (BRUNN et al. 1970, 1971) clearly shows that there are definite limitations for purely cylindristic reconstructions and that considerable changes along the strike of the orogen must take place. More specifically, the correlation of the Mesozoic and Lower Tertiary sequences and the reconstructions of paleotectonic trends across the Aegean Sea are still ambiguous, though some major features such as the basement complexes of the Pelagonian and Menderes "massifs" and the Ophiolite Nappe may be well compared.

In this paper we attempt a comparison of some Mesozoic sequences of southwestern Turkey with corresponding sequences in the Aegean islands, in order to evaluate their possible place in a paleogeographic and paleotectonic frame. Of particular interest are the sequences of the so-called "Intermediate Complex", a pile of nappes and imbrics, intercalated between the Ophiolite Nappe and the "autochthonous" sequence in southwestern Turkey. The Mesozoic sequence of the main tectonic unit of this complex could be clearly followed into the small Aegean islands situated between Astypalia, Crete and Karpathos and we believe that somewhat comparable sequences may occur as far to the northwest as the Argolis Peninsula in the eastern Peloponnesus.

The present study is based on extensive field work carried out by Graciansky in the Lycian Taurus (GRACIANSKY 1972), on an unpublished study undertaken by Monod in 1967 in the region of Bodrum and on a geological reconnaissance by Bernoulli on the small islands between Astypalia, Crete and Karpathos in 1967 (Plate I). Comparisons with continental Greece are based on literature studies and personal observations by the authors.

1.2 *Extension of the Hellenide tectonic units in the southern Aegean Islands*

The tectonic units of continental Greece have been established and discussed by many workers and the reader is referred to the work of AUBOUIN et al. (1970), BRUNN (1956) and others. In this context the interpretation of the ophiolites is of primary importance; earlier concepts by AUBOUIN (1959, 1965) and BRUNN (1956) included their emplacement by a giant extrusion during the Jurassic along the Pelagonian margins (BRUNN 1956, AUBOUIN 1959, 1965) but a *tectonic* emplacement during the latest Jurassic (AUBOUIN 1973a–c) or Early Cretaceous (BERNOULLI and LAUBSCHER 1972; HYNES et al. 1972) seems now generally accepted. This interpretation implies Tertiary deformation of a pre-existing nappe edifice and the existence of composite thrust-sheets. The different tectonic units of the Hellenides are, in fact, not all of the same order (cf. BERNOULLI and LAUBSCHER 1972), and Alpine tectonic boundaries may run obliquely or even at right angles to the older paleogeographic units and paleotectonic trends. As a consequence a straight-forward correlation of Greek and Anatolian Mesozoic paleogeography seems hardly possible.

The extension of the different tectonic units of the Greek mainland in the Aegean islands still presents major difficulties, as most of the Alpine nappe edifice has been affected by post-orogenic block-faulting and was drowned during the Pleistocene. As a consequence the attribution of an isolated island to one or another facies zone or tectonic unit is often conjectural and in some cases may never be established with certainty. However, the following trends can be recognized (cf. Plate I):

The sequences of the Tripolitza Zone of the southeastern Peloponnesus and the underlying metamorphic units can be followed to Crete and (?) Kasos, where they are involved in a complicated, Alpine nappe structure. In the southeastern Peloponnesus (H. LAUBSCHER, personal communication 1973) and in Crete (EPTING et al. 1972a, 1972b) it appears that the Tripolitza Zone is detached from its basement and overthrusted on a metamorphic Upper Paleozoic to *Mesozoic* ("Plattenkalke", etc.) and *Early Tertiary* (O. RENZ 1932; FYTROLAKIS 1972; cf. FLORIDIA 1932, for Kasos) sequence which possibly corresponds to the Ionian Zone. Further east, possible equivalents of the Ionian and Gavrovo Zones occur on Rhodes (MUTTI et al. 1970).

The Pindos Nappe, characterized by Upper Triassic *Halobia* limestones and Cenomanian-Turonian flysch, has been recognized on Crete (CAYEUX 1903a, b; BONNEAU 1970; SEIDEL 1968, 1971), Gavdos (CREUTZBURG 1928; VICENTE 1970), Karpathos and Rhodes (OROMBELLI and POZZI 1967), but internally of the outer arc of the

Aegean islands no remnants of this nappe have been recognized with certainty. The uppermost unit of the nappe pile in Crete is represented by remnants of the Ophiolite Nappe (mainly ultramafics) with slivers of metamorphics along its base (VICENTE 1970, BONNEAU 1972a, 1972b).

In Crete, the nappe movements have been dated as pre-Tortonian by postorogenic sediments (MEULENKAMP 1969); on Rhodes the nappe edifice is, according to MUTTI et al. (1970), older than the onset of sedimentation of the Middle to Late Oligocene neoautochthonous or mesoautochthonous Vati Group.

The continuation of the Parnasse Zone south of the Gulf of Korinth has been discussed by various authors. On the Argolis Peninsula the Pindos Zone is bordered internally by a zone characterized by alternation and interfingering of carbonate platform and pelagic facies. DERCOURT (1962, 1964) has interpreted this as an expression of a paleogeographic termination of the Parnasse platform. In general, the Mesozoic sequence of the eastern Argolis is very similar to that underlying the Cretaceous ophiolite nappe in central Greece. The sequence is characterized by the sinking of the former shallow water sites during the Liassic (Ammonitico Rosso), a thick sequence of radiolarites, volcanic sandstones and basic extrusives (Diabas-Hornstein Formation, "série détritique infra-ophiolitique", AUBOUIN et al. 1970), Upper Cretaceous pelagic limestones and Lower Tertiary flysch. In the Argolis, the main mass of ophiolites with its overlying Cretaceous shallow-water limestones seems to have been emplaced during the Early Tertiary (personal observation by D. BERNOULLI and H. LAUBSCHER 1973), the paleotectonic situation of the Argolis is thus somewhat comparable to the Paleogene front of the Ophiolite Nappe in the northern Pindos ranges.

Equivalents of the Pelagonian basement and its cover are found in Attica, on Euboea and several of the Cycladic islands. In Attica the situation is obscured by Alpine nappe structure and metamorphism (ARGYRIADIS 1967). Non-metamorphic Permian and Triassic overlying granites and metamorphics are reported from Mykonos (PAPASTAMATIOU 1963 and references therein) and Naxos (MARKS and SCHUILING 1965, cf. C. RENZ 1955). Small remnants of the Cretaceous ophiolite nappe, overlain by Barremian skeletal limestones are found on the island of Paros (PAPAGEORGAKIS 1969a). Lower Tertiary "flysch" sediments are reported from Naxos (NEGRIS 1915) and remnants of the postorogenic "Sillon Mésohellénique" could be present on the island of Paros (PAPAGEORGAKIS 1969b).

The paleographic and tectonic position of many of the islands of the southeastern Aegean Sea is still enigmatic. According to S. DÜRR (personal communication) Amorgos presents many analogies to the Parnasse zone, e.g. the absence of a Cretaceous ophiolite nappe, and the presence of Cretaceous bauxites and Lower Tertiary flysch.

The stratigraphy of the smaller islands of the southeastern Aegean Sea is only poorly known. Most of them are composed of metamorphics (Samos, Leros, Kalymnos) or of Upper Cretaceous-Lower Tertiary shallow-water carbonates and flysch. Some of these sequences seem to overlie unconformably the old basement complexes (Kalymnos, Pserimos, DESIO 1931) while others may belong to a more external zone (?Astypalia). The paleotectonic position of Kos is still uncertain. The sequences corresponding to the Intermediate Complex in southwestern Turkey will be discussed in section 5.

1.3 *The tectonic units of the Lycian Taurus*

The Lycian Taurus constitutes the eastern end of the arc that connects the Dinarides through the Hellenides, Crete and Rhodes with southwestern Turkey.

In the Lycian Taurus the following tectonic units, appearing on the map as NE–SW-trending belts, can be distinguished (Pl. I and Fig. 1–3):

1. An "autochthonous", external sequence, occurring along the Mediterranean coast and culminating in the calcareous massif of the Bey Dağlari (BRUNN et al. 1970). This sequence also occurs in a number of tectonic windows below the pile of the Lycian nappes to the north of the small town of Göcek. There the sequence is composed of Cenomanian to Lower Burdigalian carbonate rocks, and Upper Burdigalian and possibly somewhat younger clastics.
2. The western Lycian Nappes (BRUNN et al. 1971), composed of a lower series of complex thrust-sheets and imbrics (Intermediate Complex) that comprise essentially four different stratigraphic sequences, each derived from a different paleogeographic realm, and a large nappe of peridotites representing the uppermost unit of the nappe pile. Within the Intermediate Complex, the Köyceğiz series and its equivalents are of particular interest as they appear to be the most extensive series.
3. The belt of the Lycian Nappes is bordered to the northwest by the Menderes "massif", an old basement complex. The core of this massif is composed of "Augengneiss", enveloped by different layers of micaschists and marbles with emery. Most probably the Augengneiss represent an old deformed and granitized core, overlain by detrital and, later, by carbonate sediments with emery deposits (GRACIANSKY 1966). Based on scanty fossils, these marbles were considered young Paleozoic in age, but recently typical sections of *Hippurites* have been discovered by S. DÜRR (personal communication, 1972) in crystalline limestones overlying the emery near Milas. This, of course, implies an Alpine remobilization of the core of the Menderes "massif" and an Alpine metamorphism of its Late Paleozoic to Cretaceous cover (cf. Pelagonian basement, GODFRIAUX 1964, 1968).

Wherever the contact between the Menderes "massif" and the Lycian Nappes has been investigated thoroughly, the Menderes "massif" and its metamorphic cover dip below the pile of the Lycian nappes (GRACIANSKY 1972), which therefore rest tectonically on two apparently different sequences along their internal and external margins. Over large distances the tectonic contact between the Menderes "massif" and the Lycian Nappes is unconformably overlain by the Oligo-Miocene clastics of the Kale-Tavas basin. This basin therefore occupies a position similar to that of the "Sillon Mésohéllenique" as stated by BRUNN (1960). The structural situation here may be compared to the one in continental Greece where the Ophiolite Nappe and its underlying mélange rest internally on the Pelagonian "massif" and externally on the flysch of a more external zone (Pindos zone). Similarly the Menderes "massif" might represent a sort of "paleoautochthon" for the Lycian Nappes, which has later been thrust together with its Lycian cover as a composite nappe on the "autochthonous" foreland (cf. BERNOULLI and LAUBSCHER 1972, Fig. 3, for the Pelagonian composite nappe).

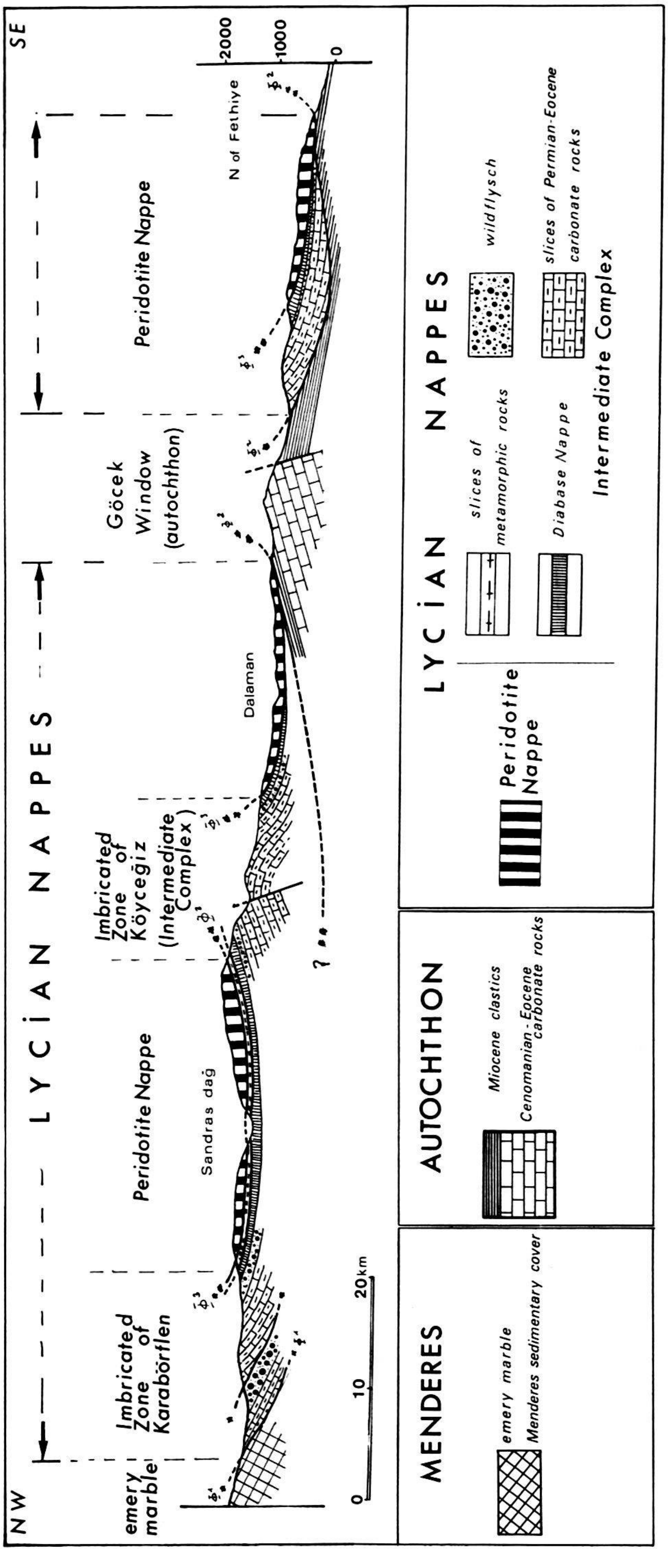

Fig. 1. Tectonic cross-section of the Lycian nappe system in southwestern Turkey by P. CH. DE GRACIANSKY.

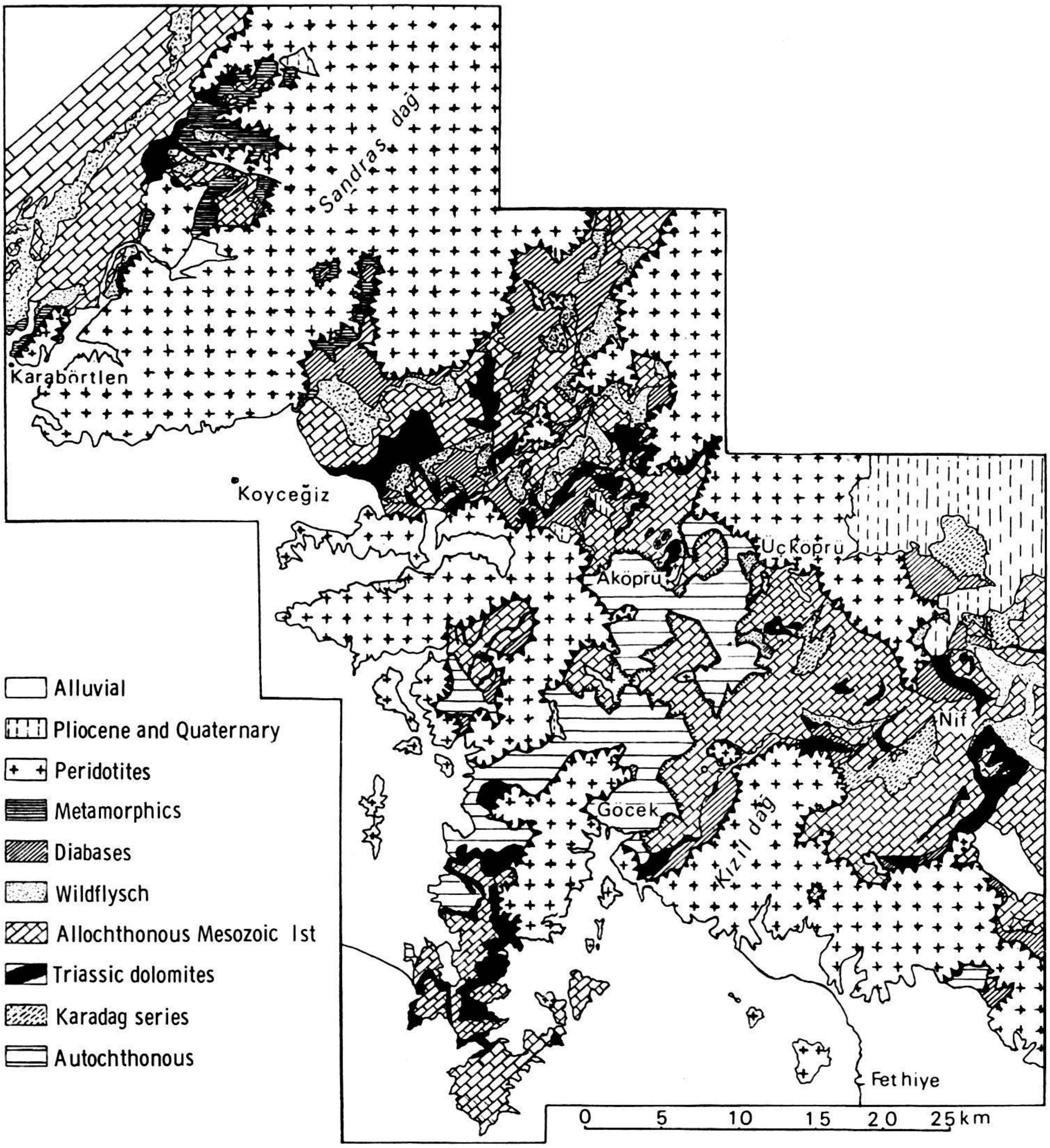

Fig. 2. Geologic map of the region between Fethiye and Karabörtlen by P. Ch. de Graciansky.

2. Stratigraphy of the lower tectonic units

2.1 *Southwestern Turkey*

In southwestern Turkey, the complex nappe pile of the Lycian Nappes is underlain by a probably autochthonous, originally more external sequence which comprises Middle Jurassic to Eocene limestones (Bey Dağlari, A. Poisson, personal communication) which in turn are disconformably overlain by Lower Miocene limestones and Lower to Middle Miocene clastics. Older sediments and the basement of this sequence are not known. The westernmost outcrops of this sequence occur in a

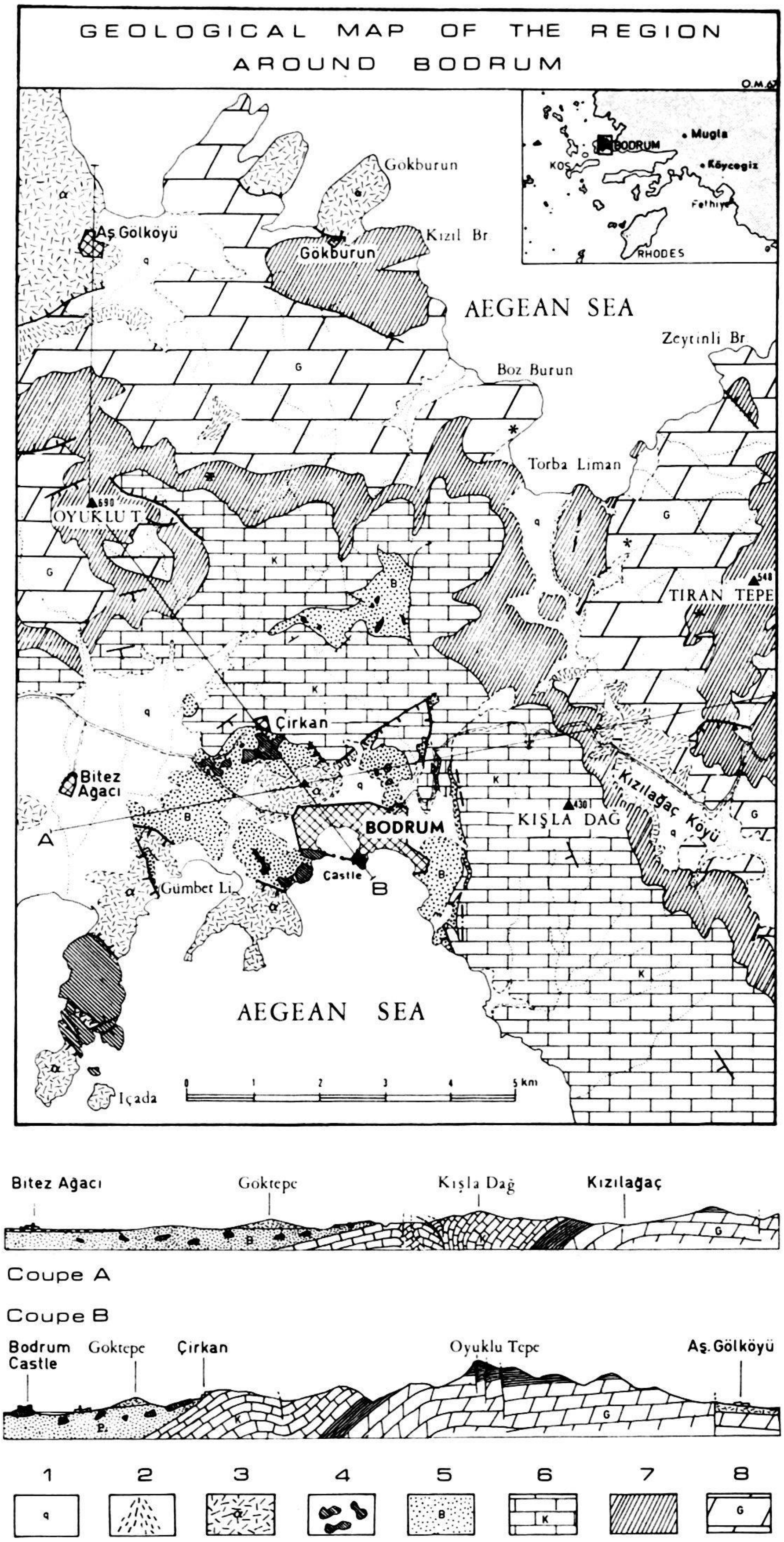

Fig. 3. Geologic map of the region of Bodrum by O. Monod. *1* Alluvial deposits. *2* Scree. *3* Trachyandesites and tuffs, Miocene. *4* Exotic blocks in Karabörtlen Formation (Ages of the blocks vary from Upper Triassic to Upper Cretaceous). *5* Karabörtlen Formation (Bodrum Shales): black shales with exotic blocks, post-Cenomanian, probably Upper Cretaceous to ? lowermost Tertiary. *6.–7.* Çal Dağ Limestone, yellow silty limestones (*7.*): ? Upper Liassic to Cenomanian. *8* Gereme Formation, Upper Triassic to Middle Liassic.

number of tectonic windows situated to the north of the small town of Göcek (Pl. I and Fig. 2). Here the sequence comprises from bottom to top (Fig. 4, BRUNN et al. 1970; GRACIANSKY et al. 1970; GRACIANSKY 1972):

1. 200 meters of thick-bedded, mainly skeletal limestones of shallow-marine origin. At the base they contain rudists and larger foraminifera of Cenomanian age.
2. 80 to 90 meters of mainly pelagic limestones with planktonic foraminifera ranging from Upper Campanian to Lower Eocene. The limestones are relatively thick-bedded in the Upper Cretaceous and lowermost Paleocene. In the Paleocene to Lower Eocene fragments of larger foraminifera (*Discocyclina*, *Nummulites*) are found.

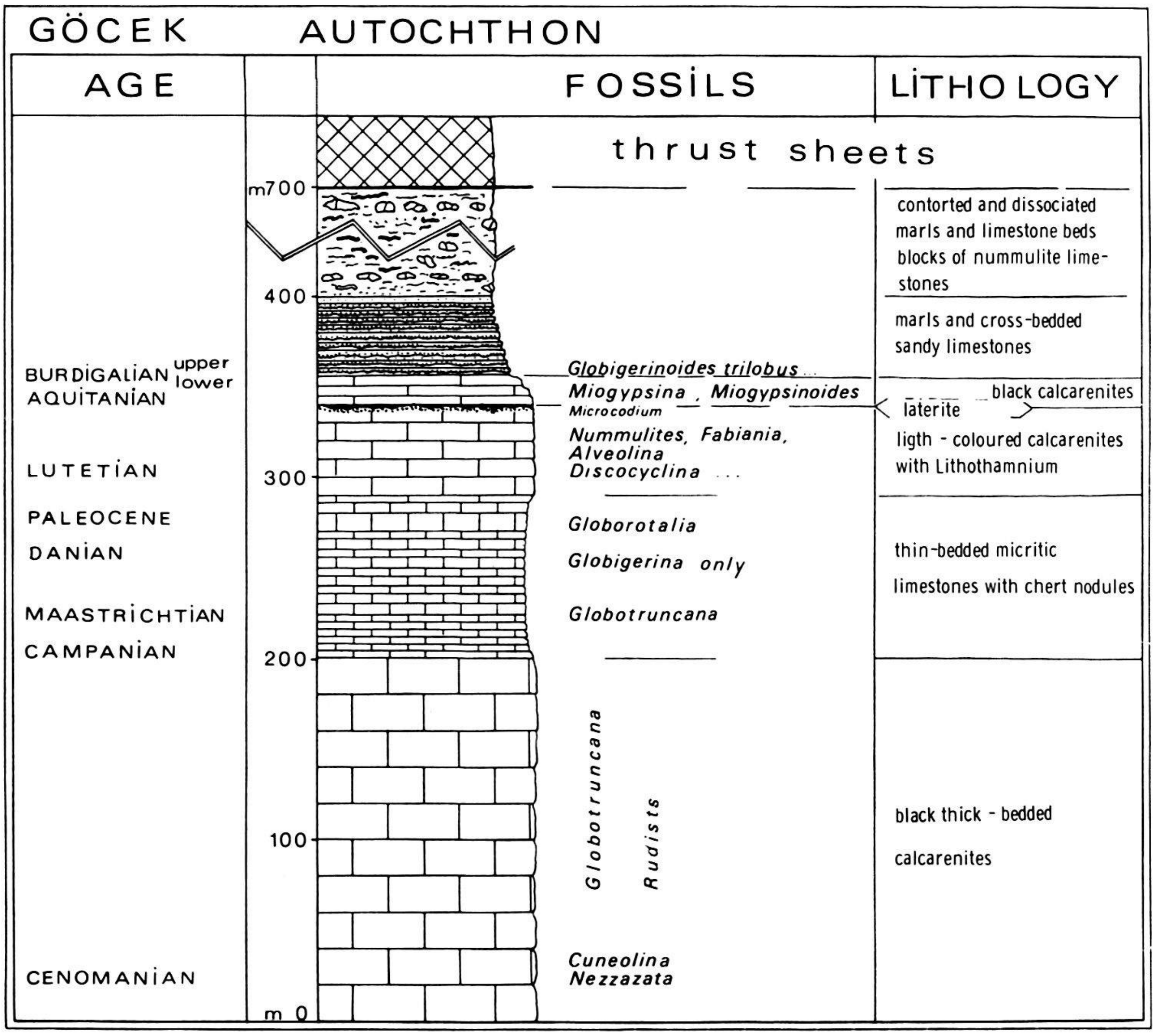

Fig. 4. Stratigraphic sequence of the "Autochthonous" at Göcek.

3. 50 meters of bioclastic limestones with larger foraminifera of Middle to possibly Late Eocene age. The upper part of this formation contains intercalations of coral and *Lithothamnium* limestone with a Late Lutetian or Early Priabonian fauna. At the top of the Eocene sequence the limestones are encrusted with *Microcodium* (RICHARD 1967a), and at its upper surface, pockets filled with lateritic material

indicate prolonged emersion during most of Late Eocene and Oligocene times (AYRTON et al. 1966).

4. 15–20 meters of uppermost Oligocene or lowermost Miocene to Lower Burdigalian shallow marine limestones that, aside reworked Eocene fossils, contain calcareous algae, bryozoa and corals and higher up some planktonic foraminifera. In the Göcek windows, rich associations of larger foraminifera at the base indicate a marine transgression prograding from south to north during the latest Oligocene to the Early Aquitanian (GRACIANSKY et al. 1970).
5. 200–300 meters of sandy limestones, marls and conglomerates. The lower 50 meters consist of a regular alternation of cross-bedded sandstones and marls that contain Lower Miocene faunas and, more specifically, Upper Burdigalian planktonic foraminifera (GRACIANSKY et al. 1970). The conglomerates are derived from the underlying Eocene and Miocene sequences and from the Lycian Nappes. The upper part of the sequence is composed of marls and argillaceous or calcareous sandstones with locally preserved small-scale current-laminations. The stratification of this part of the formation is highly disturbed; there are numerous large-scale slump complexes and olistostromes that contain large olistoliths of graded nummulite limestones of Middle to Late Eocene age emplaced during sedimentation of the formation.

A similar lithological succession which belongs to the same paleogeographic and tectonic unit (region of Kaş, PISONI 1967; POISSON 1967) is found in the southern Bey Dağlari; however, thicknesses are somewhat greater (BRUNN et al. 1970). The *Microcodium* limestone and the lateritic horizon are missing and the skeletal limestones of the Middle Eocene are overlain with a regional unconformity by the Lower Miocene clastics.

The main characteristics of the autochthonous sequence, underlying the Lycian nappe pile in southwestern Turkey, may be summarized as follows: The Middle Jurassic to Middle/Upper Eocene sequence is mainly composed of shallow water limestones with one major intercalation of pelagic, though not deep-water limestones from Upper Campanian to Lower Eocene. Part of the Upper Eocene and nearly all the Oligocene are missing and beginning first in the uppermost Oligocene to Lower Miocene the sea transgressed from the south, leading to the deposition of limestones and terrigenous clastics derived from the underlying sequence and the Intermediate Complex. On the eastern flanc of the Bey Dağlari, however, flysch deposits of Paleocene-Early Eocene age are intercalated in the sequence. They are closely associated with the emplacement of the Antalya Nappes and are not present in western Lycia (BRUNN et al. 1970).

2.2 *Aegean Islands*

Stratigraphic sequences which are most probably external and in a lower tectonic position to the Intermediate Complex of the Lycian Nappes are found in some of the small islands between Astypalia, Crete and Karpathos. Some of the sequences (island of Chamili) are very similar to those described from the Gavrovo Zone of continental Greece, whereas others show close affinity to the sequence observed on Astypalia, the tectonic position of which could not be established with certainty until now.

Chamili: On Chamili, a strongly faulted anticline is observed with a more complete sequence in the WSW. In the core of the anticline, skeletal limestones with rudists in growth position are present. Finer-grained skeletal lime grainstones contain rudist fragments and larger foraminifera including *Orbitoides media* (D'ARCHIAC), *Omphalocyclus macroporus* (LAMARCK) and *Siderolites calcitrapoides* LAMARCK (det. L. HOTTINGER). These forms indicate a Maastrichtian age. At places, the rudist limestones are heavily brecciated and it appears that dolomitization is following zones of brecciation and thus is, at least in part, of late diagenetic origin. The rudist limestones are overlain by some hundred meters of dolomites with occasional intercalations of rudist limestones. The dolomites are mostly fine-grained and at places they are finely laminated recalling stromatolitic laminations.

At one single place, the Cretaceous sequence of Chamili is overlain with a sharp discontinuity, accentuated by later stylolitization, by a small relict of Tertiary limestone. This rock is composed of skeletons of *Melobesieae* and closely packed, pressure-solved skeletal fragments, mainly larger foraminifera. L. HOTTINGER determined the following forms: *Nummulites* sp., *Assilina* sp., *Operculina* gr. *parva* DOUVILLÉ, *Pararotalia* sp., *Discocyclina* sp. and *Gypsina* sp. This association indicates an Early to Middle Eocene age.

Saforà: The main island of the small group of Saforà (Megalo Sofrano) is built up by a faulted sequence of Cretaceous limestones and some flysch sediments of probably Early Tertiary age. The oldest limestones, occurring in a fault block in the southern part of the island and along a fault in the central part, are light grey lime wackestones of Aptian to Albian age, with small primitive *Hedbergella* and some dasyclad algae (*Munieria baconica* HANTKEN and *Actinoporella* sp., det. E. FLÜGEL). On the eastern shore, there are skeletal lime wacke- to packstones with rudists (cf. DESIO 1931, p. 323–324) and a faunal/floral association of Senonian age including large specimens of *Thaumatoporella* sp., *Cuneolina* sp., *Dicyclina* sp. and *Accordiella conica* FARINACCI. These rudist limestones are overlain by well-bedded lime wackestones containing planktonic foraminifera and obviously redeposited shallow water fossils. The association includes double-keeled *Globotruncana* of the *G. linnei* group (det. H. LUTERBACHER) and some larger foraminifera (*Pseudosiderolites vidali* (DOUVILLÉ), *Navarella joaquini* CIRY and RAT, *Gavelinella* sp., det. L. HOTTINGER), indicating a Late Senonian age. In the Maastrichtian, skeletal limestones with rudist and inoceram fragments and larger foraminifera (*Orbitoides* sp., *Siderolites calcitrapoides* LAMARCK, det. L. HOTTINGER) occur. They are overlain by partly laminated dolostones with guttulinids, miliolids and thin-shelled ostracods. This facies corresponds closely to the so-called "Liburnian" facies of the uppermost Cretaceous, it is widespread in the Gavrovo Zone of the Hellenids and in the Dalmatian Zone of Yugoslavia (cf. FLEURY 1970).

The flysch is separated from the limestones by high angle-faults. It consists of graded lithic sandstones with interbedded shales and has not yielded any fossils, however, a Early Tertiary age is most likely. As a whole the sequence could be compared with sequences described by DERCOURT (1964) from internal parts of the Gavrovo Zone in the eastern Peloponnesus; however, in detail several rock types are identical with specimens from Astypalia (see below).

Di Adelphi: The larger (southeastern) of the two islands is composed of vertical rudist limestone and an overturned syncline in the Tertiary flysch. The island is not easily accessible, but a few relevant observations could be made. The Cretaceous limestone has been largely recrystallized but the rudist shells are still recognizable. The uppermost part of this sequence could not be observed and the contact towards the flysch syncline appears to be somewhat tectonized, however, the basal part of the flysch is well exposed in the southwestern part of the island. The flysch consists of an alternation of thick-bedded Nummulite breccias and shales that are followed by an alternation of shales and dirty sandstones. The core of the syncline is made up by coarse conglomerates with sub-ordinate intercalations of sandstones. In the Nummulite breccias the following fossils, indicating an Early to Middle Eocene age, have been found: *Nummulites* sp., *Operculina* sp., *Asterocyclina* sp., *Discocyclina* sp. (det. L. HOTTINGER). The conglomerate contains chiefly limestone pebbles that match very well with the facies of the Intermediate Complex. They include pelleted and skeletal lime grainstones with indeterminable dasyclad and codiacean algae that could be derived from the Gereme Limestone, lime wackestones with pelagic lamellibranchs and calcitized radiolaria of possible Upper Liassic to Middle Jurassic age and other lithologies rich in radiolaria (cf. Çal Dağ Limestone). In the arenites, quartz, plagioclase, biotite, glauconite and lithic fragments of diabase, radiolarite and limestone have been found.

The smaller, northwestern island of Di Adelphi is composed of strongly tectonized limestones. The following association, determined by L. HOTTINGER, indicates a Paleocene age: *Archaeolithothamnium* sp., *Miscellanea* sp., ? *Alveolina primaeva* REICHEL. This age is in good agreement with the Early to Middle Eocene age of the base of the flysch on the larger island of Di Adelphi.

The sequences of the islands described above compare very well with the sequence of an external zone of the Greek Hellenides, characterized by regular subsidence and mainly by carbonate platform deposits throughout the Cretaceous. The island of Chamili shows a development similar to the external Gavrovo Zone in western Greece, whereas the sequence of Saforà could be compared to the internal Gavrovo Zone in the Peloponnesus where pelagic intercalations also occur (DERCOURT 1964). Finally, the lithologic types of the sequence of Di Adelphi are comparable to the sedimentary sequence of the nearby island of Astypalia (cf. DESIO 1931; N. CREUTZBURG, personal communication, 1969).

In Astypalia, the Upper Cretaceous-Tertiary carbonate platform sequence is followed by flysch that apparently starts in the Middle to Upper Eocene. According to S. DÜRR (personal communication, 1970), the series of Astypalia is comparable to the one of Amorgos, that in turn is considered by DÜRR to be an equivalent of the Parnasse Zone; however, a more external position of Astypalia and Di Adelphi as similarly postulated for the Olympus window by some authors (AUBOUIN in GODFRIAUX 1964; BERNOULLI and LAUBSCHER 1972), cannot be excluded on paleogeographic grounds.

3. The Mesozoic sequences of the Lycian Nappes

In southwestern Turkey the Intermediate Complex includes several stratigraphic sequences that have been imbricated tectonically below the Peridotite Nappe and that often are characterized by a chaotic style of deformation.

The following units have been distinguished (GRACIANSKY 1968; see Fig. 5) (from bottom to top):

1. The series of Haticeana Dağ and Köyceğiz, ranging stratigraphically from Permian or Triassic to Upper Cretaceous or possibly lowermost Tertiary and corresponding to lateral variations within the same broad paleogeographic unit. We also allocate the sequence of Bodrum to this association for stratigraphical reasons.

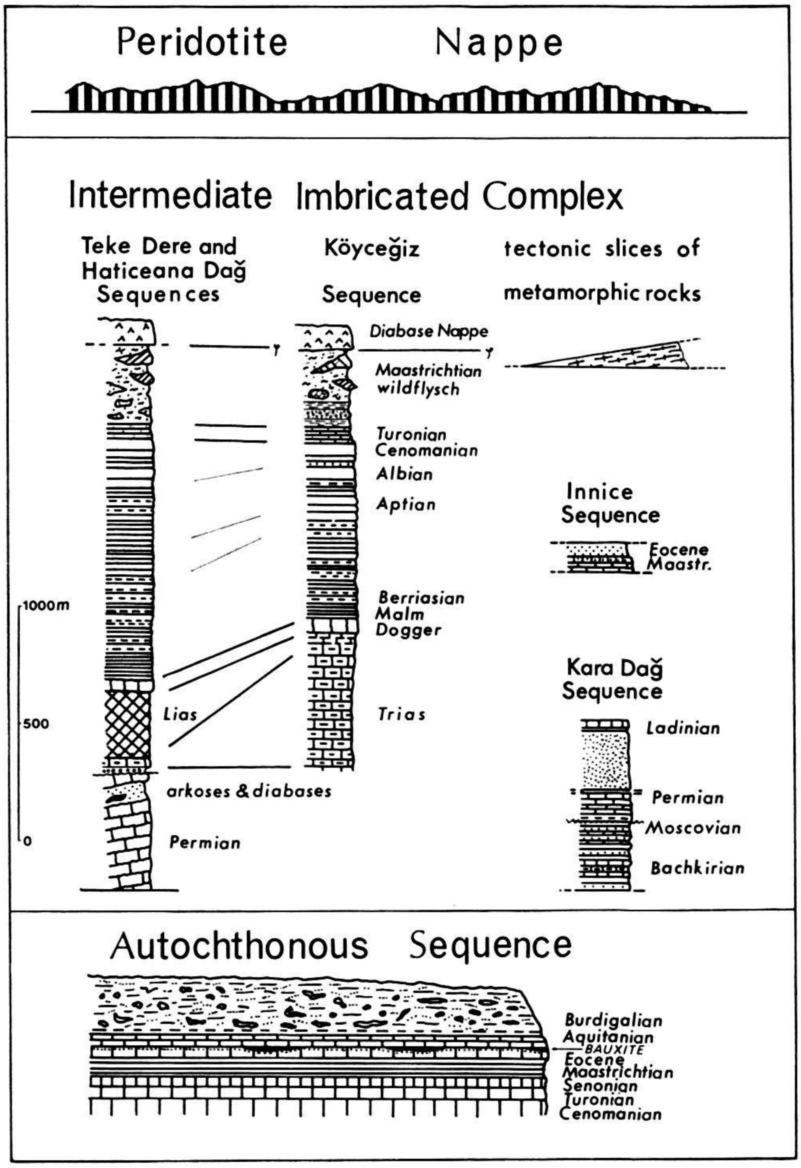

Fig. 5. Simplified stratigraphic sequences of the Lycian Nappes (from GRACIANSKY 1968, modified).

2. Kara Dağ Series: Permian-Carboniferous carbonate rocks, Lower Triassic quartzites and Middle Triassic carbonates.
3. Innice Series: Maastrichtian limestones and Eocene clastics.
4. Diabase Nappe: an association of diabases, radiolarites and pelagic limestones of various ages, ranging up to the Upper Cretaceous.

5. A number of tectonic slices of metasediments in epidote-amphibolite facies that occur at the base of the Peridotite Nappe. At places, the pillow lavas and pelagic sediments of the Diabase Nappe are tectonically mixed with the metamorphic slivers and with serpentinites and doleritic dykes derived from the Peridotite Nappe to form a "coloured mélange" (GRACIANSKY 1972, 1973).

Of these tectonic units, two groups are of particular interest as they occur not only in southwestern Turkey but extend far into the Aegean Islands. Equivalents of the *Haticeana Dağ, Köyceğiz* and *Bodrum Series* have been found on different small islands in the Dodekanes and their analogs may be found as far as eastern continental Greece (Argolis) as is suggested by the facies resemblances discussed below. However, in Turkey these units have their largest extension and are most conspicuous. Orographically they constitute most of the high reliefs and steep cliffs that characterize the morphology of the coast between Fethiye and the parallel of Milas, whereas the other elements of the Intermediate Complex are of minor importance.

The *Diabase Nappe* appears to be closely associated with the Haticeana Dağ and Köyceğiz Series. It has been emplaced during a Late Cretaceous or Early Tertiary phase in the sedimentary basin of the Köyceğiz Series towards the end of the sedimentation of the wildflysch. This unit is characterized by the presence of diabases (pillow-lavas) and contains blocks of red cherty limestones with *Globotruncana*, that are of the same facies as coeval formations which are widespread in the region of Marmaris (TATAR 1968). Equivalents of the *Diabase nappe* have not been found on the small islands between Crete, Karpathos and Astypalia, such equivalents occur, however, in an analogous position in the island of Crete (BONNEAU 1972b, 1973).

3.1 *The Mesozoic sequences of the Köyceğiz series and its equivalents*

Between Fethiye (Haticeana Dağ) and Köyceğiz the Mesozoic sequence conformably overlies a characteristic formation of red arkoses that in turn lies with a slight unconformity on Upper Permian limestones with neoschwagerinids. From Triassic to early Upper Cretaceous, carbonate rocks were deposited which were followed by clastic sediments in the Upper Cretaceous and possibly in the lowermost Tertiary (Fig. 6). In the region of Bodrum (Fig. 7), outcrops of the pre-Lower Jurassic sequence are lacking, but from the neighbouring area to the east the Mesozoic sequence is reported to rest unconformably on the shales and sandstones of Karaova the age of which is not known.

In the Aegean realm, equivalents of the Köyceğiz Series that comprise Upper Triassic or Lower Jurassic to Upper Cretaceous sediments have been found on the islands of Karavi, Avgò, Unia Nisia, Stakida, Tria Nisia and Sirna (Fig. 8) and apparently occur on the islands of Symi (CHRISTODOULOU 1969; personal communication by N. CREUTZBURG 1970); Tilos (personal communication by N. CREUTZBURG 1971; CHRISTODOULOU and TATARIS 1972) and Rhodes (Salakos Zone, OROMBELLI and POZZI 1967).

3.11 *Gereme Limestone*

Definition: With this name PHILIPPSON (1914, V, p. 56) designates a thick dolomitic limestone of dark colour, containing dasyclad algae of Triassic age, which is well

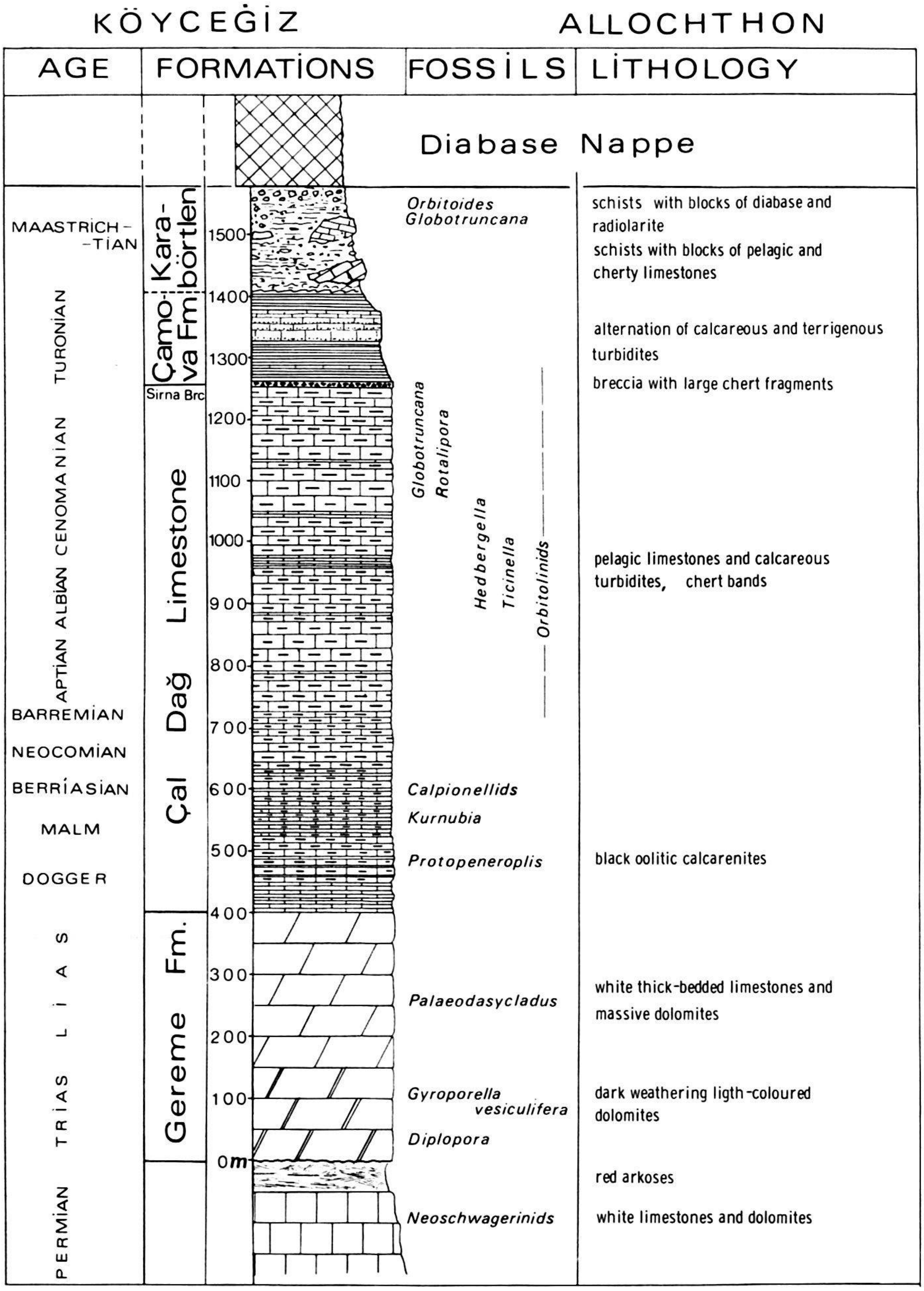

Fig. 6. Stratigraphic sequence of the Köyceğiz series in the type-area.

exposed near the village of Gereme, along the southern coast of Bodrum peninsula. This unit grades into massive white limestones that are also found near Bodrum. We will use here the name given by PHILIPPSON and extend its range to include the overlying Liassic platform limestones.

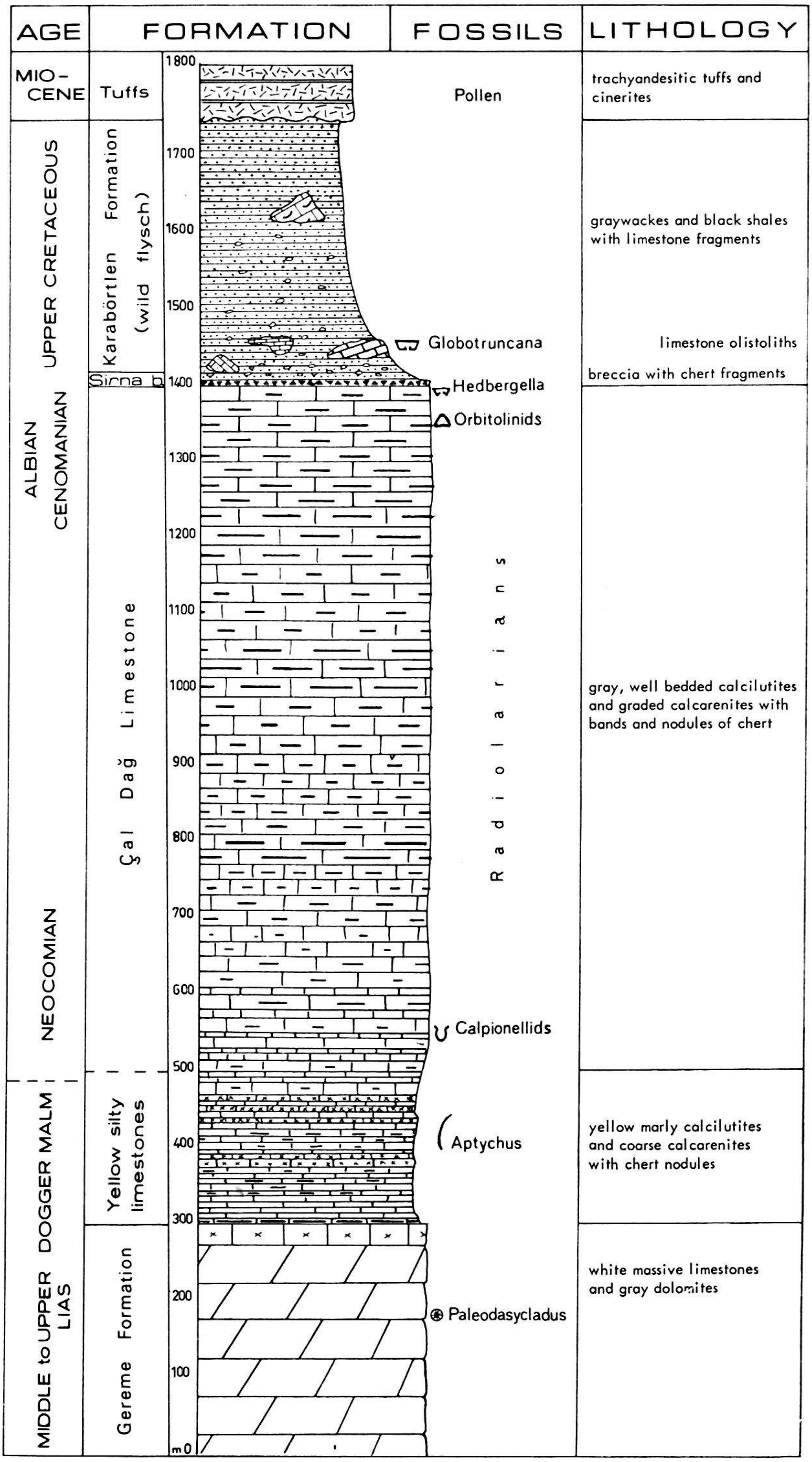

Fig. 7. Stratigraphic sequence of the Köyceğiz series at Bodrum.

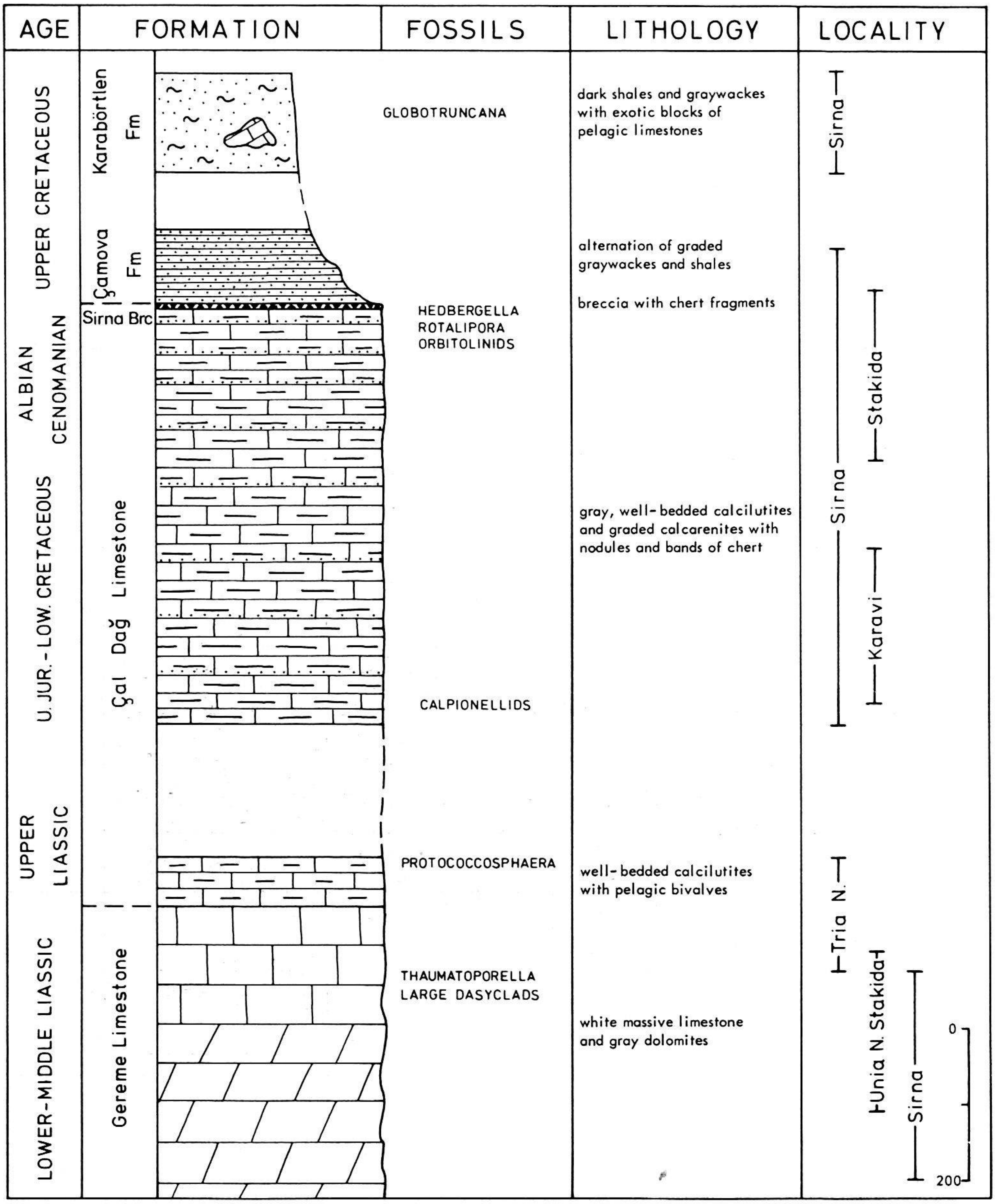

Fig. 8. Composite stratigraphic section of the Intermediate Complex in the small islands between Crete, Karpathos and Astypalia.

In the region of Fethiye and Köyceğiz, the red arkoses that are of Late Permian or Early Triassic age are overlain by limestones and dolomites with dasyclad algae indicating a Triassic to Middle Liassic age of the formation.

Lithology: The lithologies of the Gereme Limestone include mainly pelletal, intraclastic and skeletal grainstones. They are similar in the Haticeana Dağ and Köyceğiz Series at Bodrum and in the Aegean Islands; but at Bodrum and in the Aegean Islands the fabric of the rocks has been altered by late diagenetic recrystallization and dolomitization to a much greater extent. Due to the chaotic style of deformation in the Intermediate Complex the thickness of the formation is difficult to evaluate, however, it may be on the order of a few hundred meters. The thickness of the lower, Triassic, part of the formation is quite variable: it amounts to 300 to 400 m in the internal regions (Karabörtlen, Köyceğiz); towards the south-east it gets continuously smaller and is reduced to a few meters in the region of Fethiye. In the Haticeana Dağ Series, the depositional texture and structure is often very well preserved. There are mainly skeletal limestones with gastropods (*Nerinea*), onkoidal packstones and algal to pelletal limestones that contain large dasyclad algae (*Palaeodasycladus*, Fig. 9),

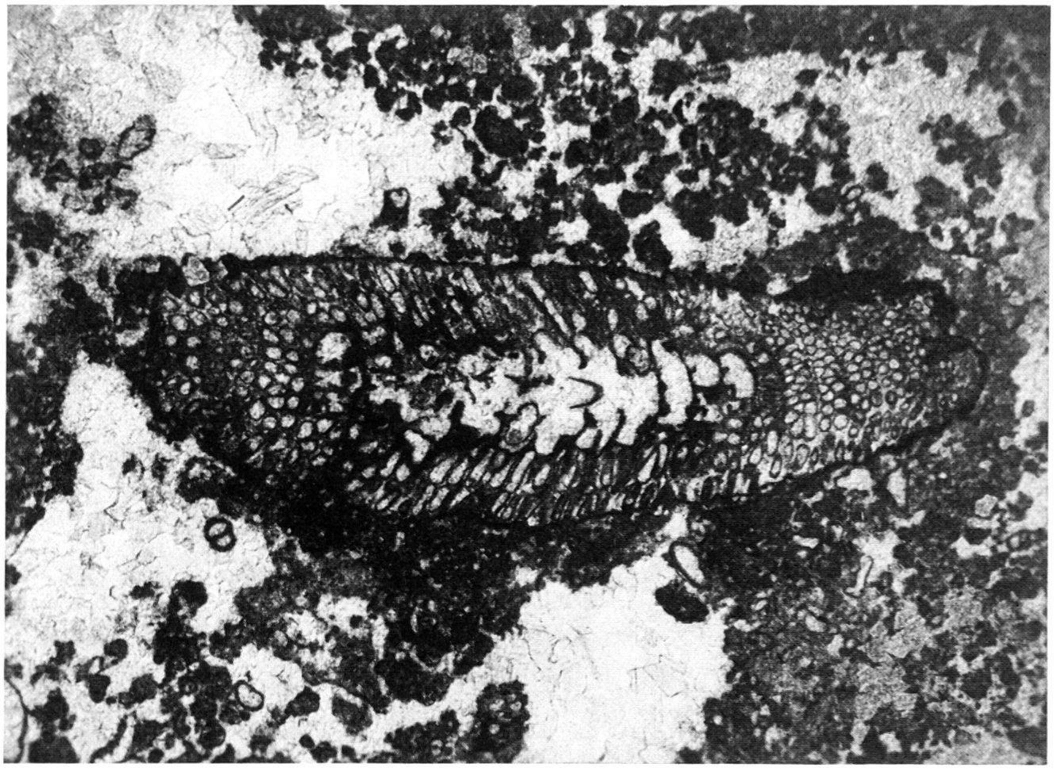

Fig. 9. Pelletoidal lime grainstones with *Palaeodasycladus mediterraneus* PIA, large calcite-cemented voids due to leaching, large late-diagenetic dolomite rhombs. Gereme Limestone, Lower Jurassic, Karaçal Tepe, at the foot of Çal Dağ, NW of Nif. Lycian Taurus. F. 1303. Thin section. ×10.

codiacean algae (*Cayeuxia*), smaller benthic foraminifera and recrystallized or dissolved/calcite-filled mollusc shells; the skeletal fragments of which are often enveloped by onkoidal coatings. The grainstones often show large birds-eye structures that apparently have been enlarged by leaching processes.

At Bodrum the Gereme Limestone consists of about 300 m of massive white limestones and dolomites which, most often, are largely recrystallized and poorly stratified. However, some better preserved limestone beds show skeletal fragments associated with calcareous algae. All the facies are grainstones with abundant intraclasts, pelletoids, occasional onkoids and large fragments of dasyclad algae indicating relatively high energy environments.

On Unia Nisia and Tria Nisia skeletal limestones with large indeterminable dasyclad algae occur. The fabric of these rocks, which closely resembles that of the Lower Jurassic Salakos Limestone of Rhodes (cf. Fig. 10, and OROMBELLI and POZZI 1967, plate 41), has been largely altered by different phases of recrystallization, but intermediate stages between the latter and the well preserved algal limestones of southwestern Turkey occur frequently.

Fig. 10. Strongly "recrystallized" skeletal limestone with large dasyclad algae, *Thaumatoporella*. Gereme Limestone, Lower Jurassic, Unia Nisia, DB 1612. Thin-section. ×4.5.

At Avgò mainly finer grained pelletal grainstones with *Thaumatoporella*, *Favreina* and smaller foraminifera are found. Similar rock types occur in southwestern Turkey and on the island of Tilos (CREUTZBURG, personal communication 1971).

Dolomitization is frequent in the Lower Jurassic limestones. Often there are mm-sized rhombohedra that cut across grains and sparry calcite cement and therefore are of late diagenetic origin. In places (Mikro Sofrano), these dolomite rhombs appear to be connected with joints and to follow zones of tectonic weakness. Very frequently dolomite rhombs have been dedolomitized and rhombs filled by a fine equigranular calcite mosaic or rhombohedral pores are found (EVAMY 1967). Locally the limestones have been fully dolomitized and show a fabric of coarse grained, subhedral dolomite crystals.

Age: A Triassic age of the Gereme Limestone was originally postulated by PHILIPPSON, on the occurrence of dasyclad algae a few kilometers west of the village of Gereme. Near Köyceğiz the lower part of the Gereme Limestone contains a few dasyclad algae of Triassic age. M. LEMOINE determined *Diplopora subtilis* PIA, a form of the Anisian and *Gyroporella vesiculifera* GÜMBEL which indicates a Norian age. A Late Triassic, Carnian to Norian, assemblage including *Uragiella supratriassica* BYSTRICKY and different species of *Involutina* has been found by N. CREUTZBURG (personal communication 1971, det. by E. OTT) in the Salakos Limestone at the Prophit Ilias Archangeliotikos (Rhodes).

The upper part of the Gereme Limestone is well dated as Lower Jurassic by algal assemblages including *Palaeodasycladus mediterraneus* (PIA), *Palaeodasycladus gracilis* CROS and LEMOINE and *Fanesella* sp. CROS and LEMOINE (det. M. LEMOINE). At places *Orbitopsella praecursor* GÜMBEL has been found indicating that the formation ranges at least into the Middle Liassic. At Bodrum *Palaeodasycladus* cf. *mediterraneus* has been found as well and the same form has been reported from the island of Symi (CHRISTODOULOU 1969), from Tilos (CHRISTODOULOU and TATARIS 1972), from the Salakos Limestone of Rhodes (OROMBELLI and POZZI 1967), and from the Yelimlik Limestone of the Datça Peninsula (OROMBELLI et al. 1967).

Environment of deposition: The sedimentary association of the Gereme Limestone resembles in many respects coeval carbonate platform deposits widespread in the Mediterranean Lower Jurassic (Pantokrator Limestone of the Ionian Zone, AUBOUIN 1959; in the Argolis, SÜSSKOCH 1967; Calcare Massiccio, central Apennines, COLACICCHI et al. 1970; BERNOULLI and WAGNER 1971; Lower to Middle Jurassic platform limestones of western Sicily, JENKYNS 1970). The lithological associations and the faunal and floral content of these formations all indicate a carbonate platform environment, oscillating from shallow subtidal to supratidal (cf. FISCHER 1964). Temporary exposure is suggested by indications of subaerial diagenesis and the presence of reworked vadose pisoids (DUNHAM 1969; cf. BERNOULLI and WAGNER 1971).

3.12 *Çal Dağ Limestone*

Definition: The Gereme Limestone is overlain by a thick complex of pelagic and turbiditic limestones that range from Upper Liassic to Cenomanian and for which we introduce the name of Çal Dağ Limestone. The type locality is situated along the crest line of Çal Dağ, about 5 km northwest of Nif Köyü (Fig. 11).

Lithology: The sedimentary association consists essentially of an alternation of well-bedded pelagic calcilutites and of graded calcirudites and calcarenites that chiefly contain particles of shallow-water origin and neritic organisms (Fig. 12–19). Both rock types contain lenses and bands of replacement chert (GRACIANSKY 1968: «calcaires à zones siliceuses»). Thin intercalations of marls occur as well.

The calcilutites are rich in pelagic organisms, mainly calcitized radiolaria, set in a micritic or microsparitic groundmass (Fig. 19). In the lower part pelagic bivalves, *Globochaete*, small broken ammonite shells and some benthic foraminifera occur. In the Lower Cretaceous, calpionellids are frequently found and from the Aptian-Albian onwards, planktonic foraminifera occur. Under the stereoscan electron microscope the groundmass appears to be composed of badly preserved coccoliths in a neomorphically formed calcite mosaic. Displaced shallow-water particles in the graded calcirudites to calcarenites include skeletal and lithoclastic material in various proportions. Skeletal components of these beds are chiefly crinoid ossicles, echinoid fragments and spines, fragments of molluscs, brachiopods, bryozoa, sponges, corals, hydrozoa, algae (*Codiaceae*, *Lithocodium*, *Bačinella*, *Macroporella*), benthic foraminifera and from the Barremian onwards *Orbitolina*, rudists and inocerams. Slump structures and turbiditic features such as graded bedding, pseudonodules etc. occur frequently;

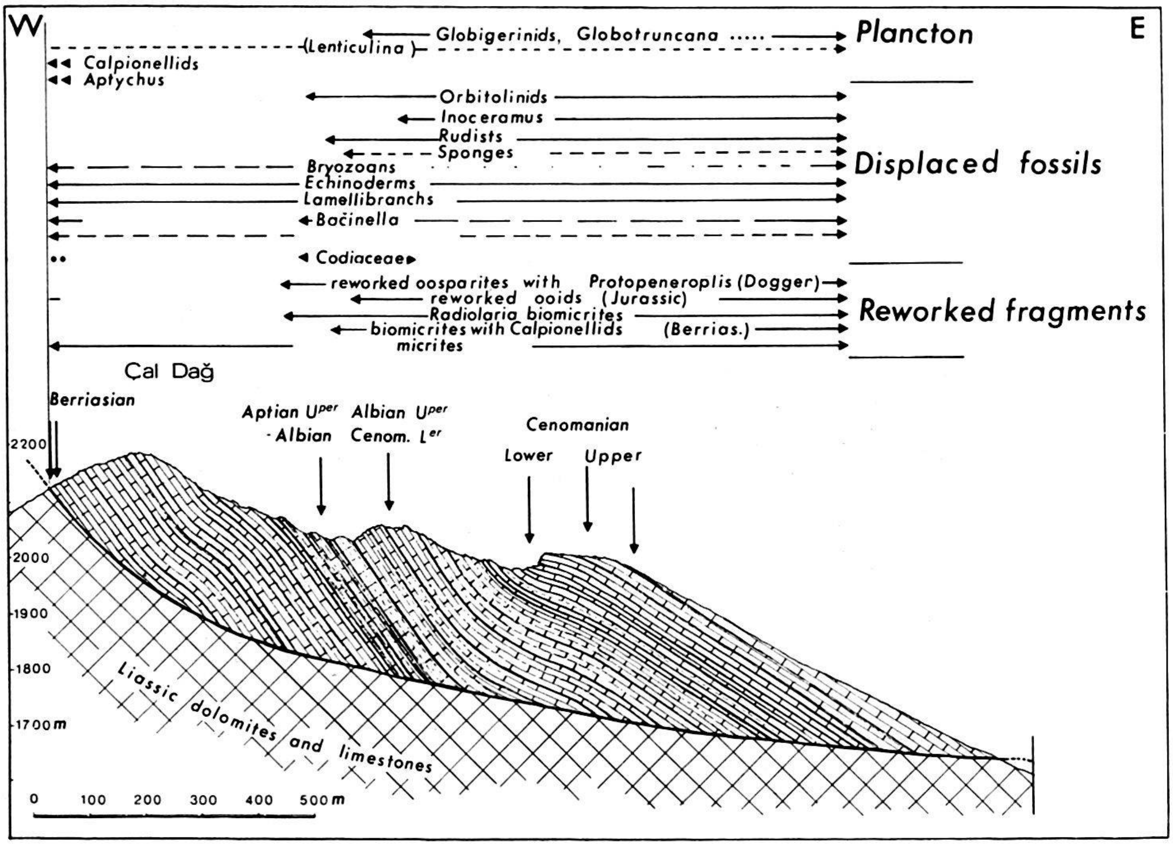

Fig. 11. Stratigraphic section of the Çal Dağ Limestone at the crest line of Çal Dağ, 5 km of NW of Nif, Lycian Taurus.

sole marks (flute casts, drag marks etc.) are less obvious as the redeposited limestones are mostly welded (often with a stylolitic contact, Fig. 19) to the underlying limestone beds, but scouring by the turbidity currents is suggested by reworked pelagic mud pebbles and planktonic fossils (Fig. 13, 17). From the Aptian onwards components of older rocks (Middle Jurassic-Lower Cretaceous) appear. Nodules and bands of chert are clearly of early diagenetic replacement origin, as they cut across sedimentary structures (laminations) and substitute carbonate grains.

In the mountains surrounding Bodrum in the north and in the east (Kisla Dağ) the Çal Dağ Limestone is generally very similar to the formation in the type-area. However, some differences occur in the basal part of the formation: the uppermost massive layers of the Gereme Limestone are discontinuously overlain by a few meters of bedded yellow cherts which gradually pass into thinly-bedded yellow to pink siltitic limestones with intercalated calcarenites and thin chert layers. Some hundred meters higher up, the terrigenous material disappears and the formation shows the typical aspect of radiolarian lime mudstones and calcarenites with chert bands.

In the Aptian to Cenomanian sequence of the island of Stakida graded and laminated fine calcarenites and calcisiltites occur that are entirely composed of pelagic organisms including small globigerinids and *Pithonella*.

The thickness of the Çal Dağ Limestone varies from up to 900 meters in the region of Bodrum and Fethiye (Haticeana Dağ) to 200 meters in the region of Köyceğiz. From the Datça Peninsula some 370 m are reported from the partly equivalent

Fig. 12. Light gray calcilutites with dark gray redeposited calcarenites. The complex pattern of the calcarenites intermixed with the lime mud apparently is due to the combined effect of penecontemporaneous slumping or flow of the calcarenites and differential loading (cf. PRENTICE 1956). Fine graded calcarenites to calcisiltites appear as dark streaks within the calcilutites. Bands and nodules of replacement chert. Çal Dağ Limestone, Albian, Bördelik-Armutalani, N of Akköprü, Lycian Taurus.

Fig. 13. Dark gray redeposited calcarenite intermixed with reworked light gray pelagic calcilutite; the calcarenites grade upwards into calcarenite to fine calcisiltite. Irregular nodules of replacement chert. Çal Dağ Limestone, Albian, Bördelik-Armutalani, N of Akköprü, Lycian Taurus.

Fig. 14. Pseudonodule of dark gray calcarenite in light gray pelagic calcilutite. The pseudonodule is still connected with the overlying redeposited calcarenite, most probably it originated from syndepositional sinking of the calcarenite down into its substratum of calcilutite (cf. DZULYNSKI and WALTON 1967). Selective chertification at the boundary between calcarenite and calcilutite. Çal Dağ Limestone, Upper Albian to Lower Cenomanian, Bördelik-Armutalani, N of Akköprü, Lycian Taurus.

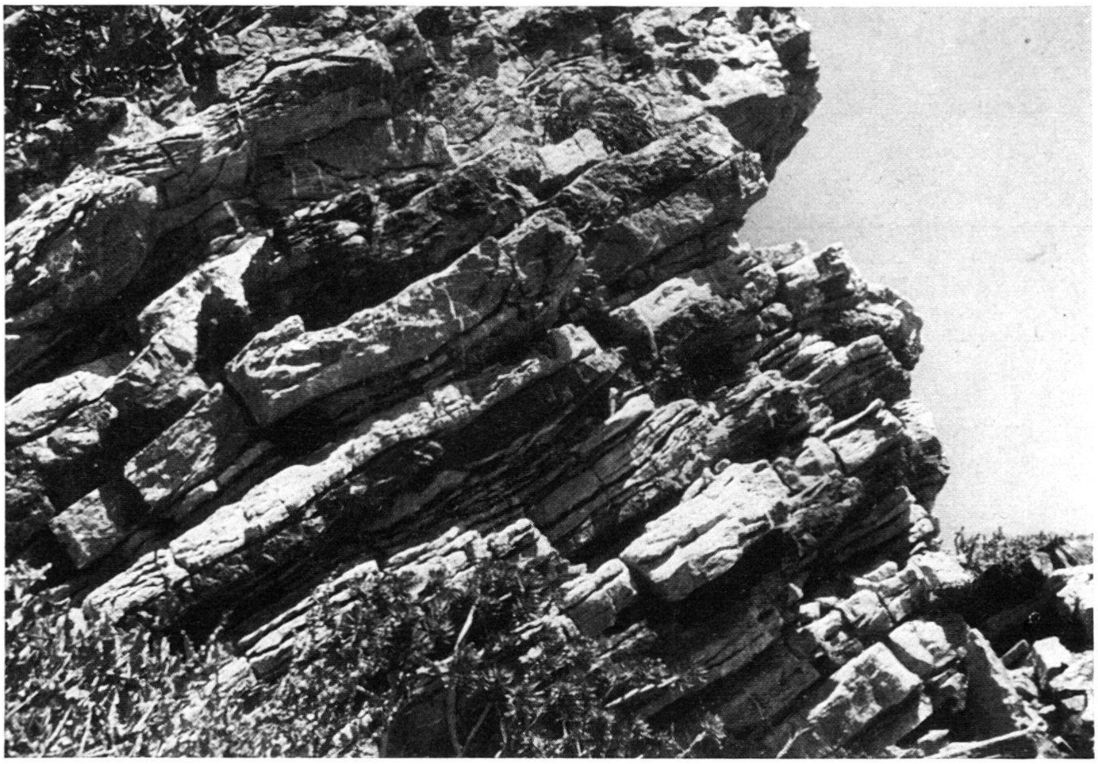

Fig. 15. Pelagic calcilutites, interbedded with graded calcarenites; nodules and bands of replacement chert. Çal Dağ Limestone, Lower Cretaceous, Island of Karavi.

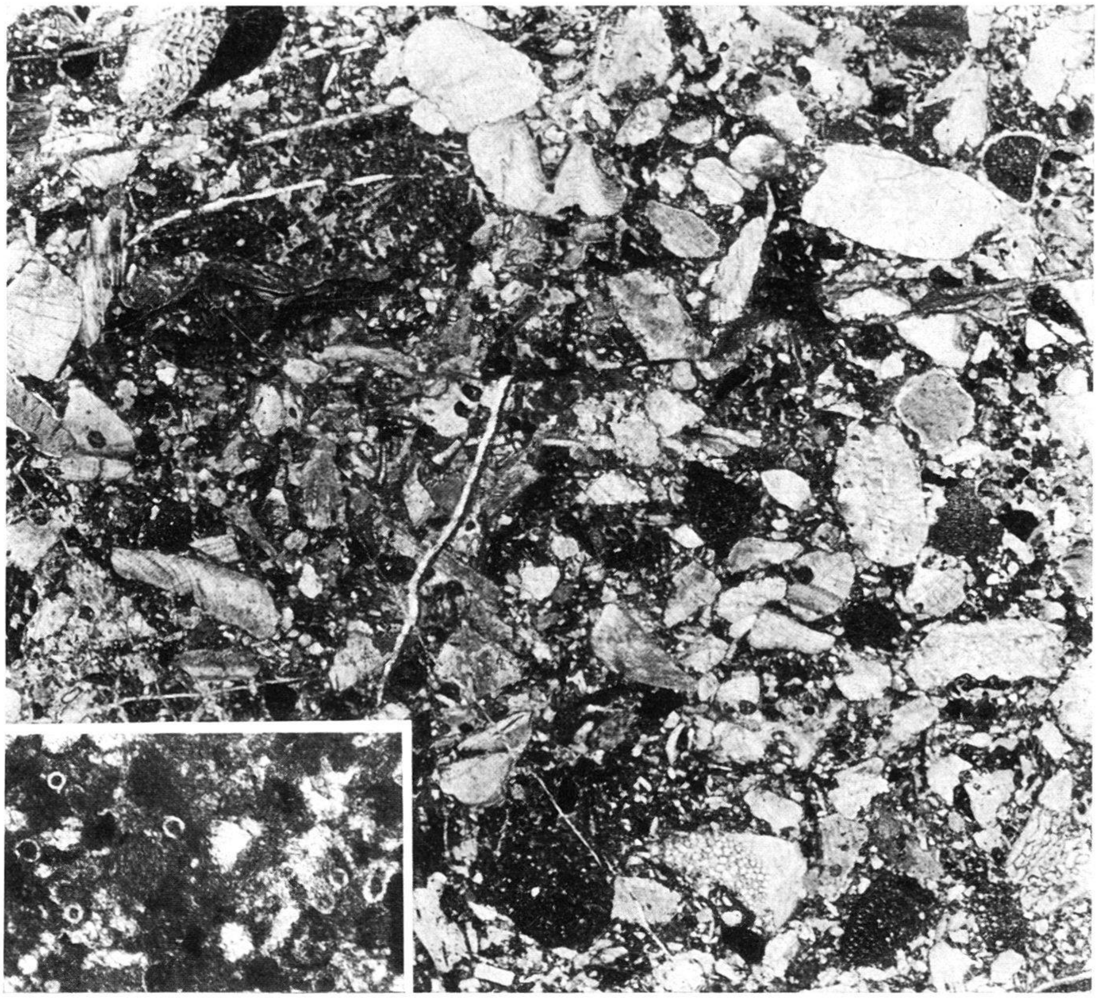

Fig. 16. Redeposited fine calcirudite to calcarenite containing closely packed skeletal debris including rudist fragments, inocerams, hydrozoans, *Orbitolina* and lithic fragments of pre-existing formations (*Calpionella* limestones).
Çal Dağ Limestone, Upper Albian to Lower Cenomanian, Çal Dağ, Lycian Taurus, F 611, thin-section, × 5.5; inset of reworked *Calpionella* limestone: × 30.

Mandalya Cherty Limestone by OROMBELLI et al. (1967). On the Aegean Islands thicknesses are difficult to estimate, but are in the order of several hundred meters (at least 120 meters for the Berriasian to Barremian on the islands of Karavi and some 500 m or more on Sirna).

Age: Upper Liassic to Barremian: Up to the Barremian the pelagic limestones predominate. To the north of Göcek, the Gereme Limestone is overlain by about 50 meters of pelagic limestones and some graded calcarenites. This part of the formation contains no age diagnostic fossils, however, the microfacies compares rather well with that of Upper Liassic to Middle Jurassic sequences in other parts of the Tethys. Such an age is in agreement with the age of the overlying strata that contain fossils of Late Dogger to Early Malm age. This latter interval measures about 50 meters thickness; no age diagnostic forms were found in the calcilutites, but the redeposited beds contain a number of benthic foraminifera including:

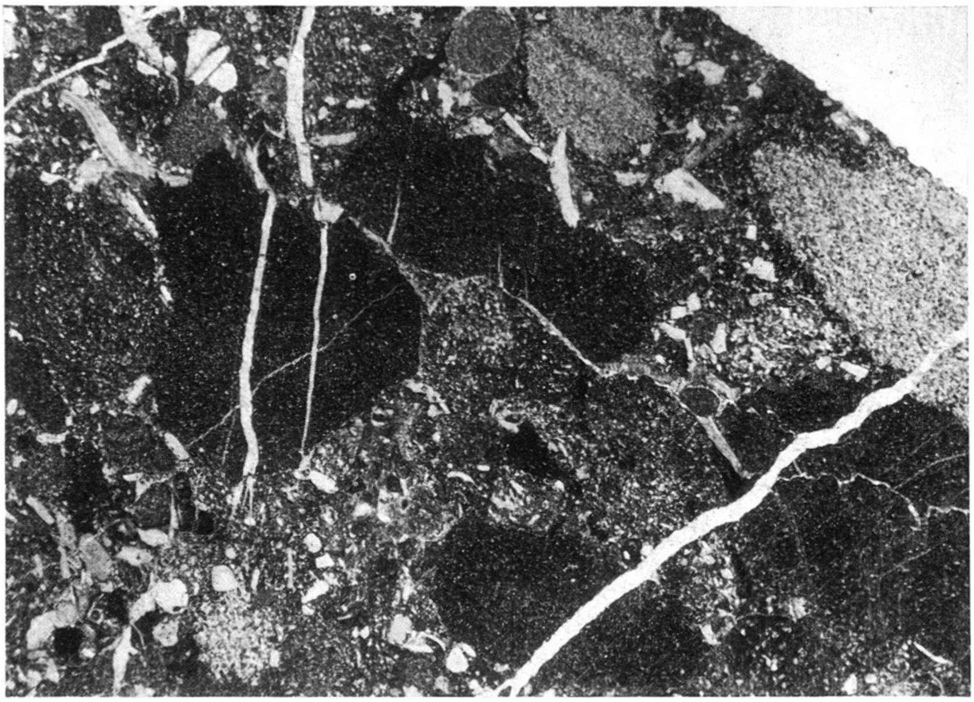

Fig. 17. Lithoclast-bioclast lime packstone, containing closely packed, solution-welded displaced skeletal fragments (rudist, echinoderm fragments, orbitolinids) and pelagic wackestone pebbles containing fine biogenic material (*Pithonella*, small globigerinids, spicules and occasional larger planktonic foraminifera: *Hedbergella* spp., *Rotalipora* sp.). Çal Dağ Limestone, Upper Albian-Cenomanian. Island of Stakida, DB 1645, thin-section, ×4.

Pseudocyclammina cf. *maynci* HOTTINGER
Trocholina sp.
Labyrinthina mirabilis (WEYNSCHENK)
Protopeneroplis striata (WEYNSCHENK), determinations by L. HOTTINGER and J. SIGAL

Of these forms, only *Protopeneroplis striata* has a relatively short range indicating a Late Middle Jurassic to Early Malm age.

In the Haticeana Dağ–Köyceğiz Sequence the interval with *Protopeneroplis striata* is overlain by pelagic limestones that contain chiefly calcitized radiolaria and occasional planktonic crinoids (*Saccocoma*). In the Berriasian different characteristic associations of calpionellids occur (determined by M. DURAND DELGA), which are characteristic for the Lower and Middle Berriasian according to the zonation of this author.

In the Lower Berriasian:

Calpionella alpina LORENZ
Calpionella elliptica CADISCH
Lorenziella gr. *hungarica* KNAUER
Stomiosphaera minutissima COLOM

In the Middle Berriasian:

Remaniella cadischiana (COLOM)
Lorenziella transdanubica KNAUER and NAGY
Calpionellites dadayi KNAUER
Tintinnopsella gr. *longa* (COLOM)
Calpionella cf. *undeloides* COLOM
Lorenziella sp.
Crassicollaria sp.
Stomiosphaera minutissima COLOM
Stomiosphaera misolensis KOSLER
Calpionella gr. *alpina* LORENZ, probably reworked

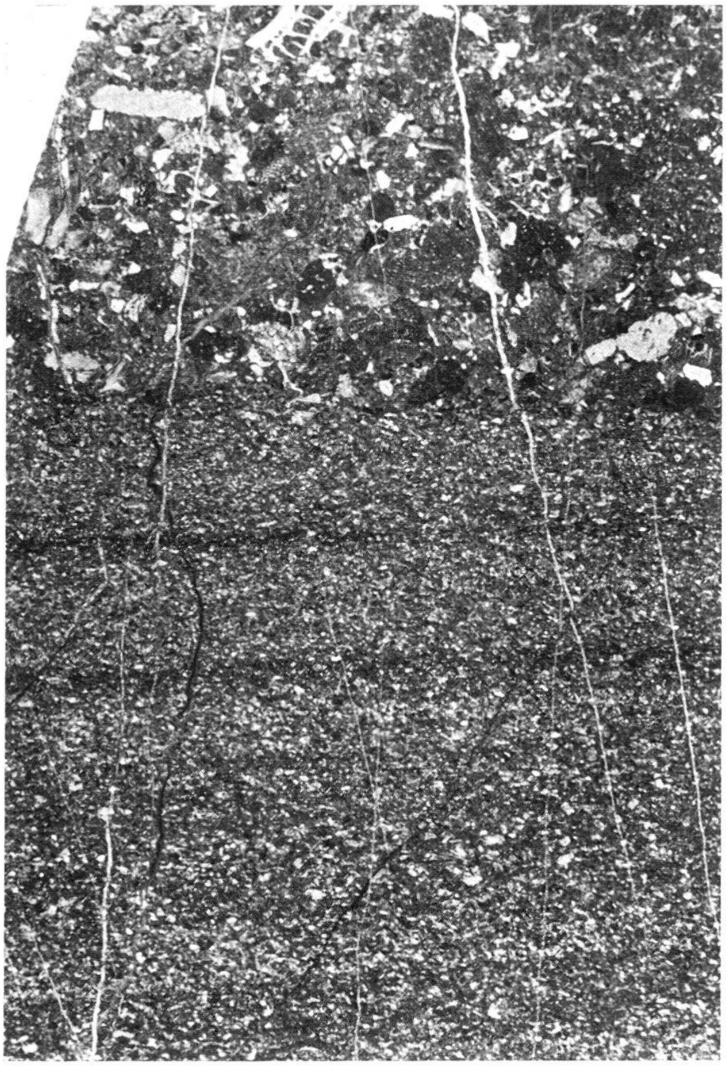

Fig. 18. Redeposited, graded and laminated fine calcarenite to calcisiltite, overlain by coarse graded calcarenite. The lower, finer grained lithology contains mainly closely packed skeletal fragments including obviously displaced crinoid, mollusc and brachiopod remains with intermixed planktonic foraminifera (*Hedbergella* sp., *Rotalipora* sp.). The upper coarse calcarenite contains penecontemporaneously displaced carbonate platform material (rudist and echinoderm fragments, orbitolinids, algae, *Hydrozoa*) and reworked lithoclasts, ooids and distinctly older fossils (*Protopeneroplis*, Dogger to Lower Malm). Some scouring could be indicated by the slightly oblique boundary between the two lithologies, however, the contact is accentuated by post-depositional stylolitization. Çal Dağ Limestone, Upper Albian-Lower Cenomanian, Çal Dağ, Lycian Taurus. FC 34, thin-section, × 3.75.

From the associated carbonate turbidites of this part of the formation, L. Hottinger and M. Lemoine determined some benthic foraminifera and calcareous algae that indicate a Late Jurassic to Early Cretaceous age:

Macroporella gigantea Carozzi
Thaumatoporella sp.
Bačinella irregularis Radoičić
Pseudocyclammina lituus Yokoyama
Pseudocyclammina sp.
Kurnubia sp.
Trocholina sp.
Nautiloculina sp.
Lituosepta sp. (= *Urgonina forojulensis* Cuvillier, Foury and Pignatti Morano)

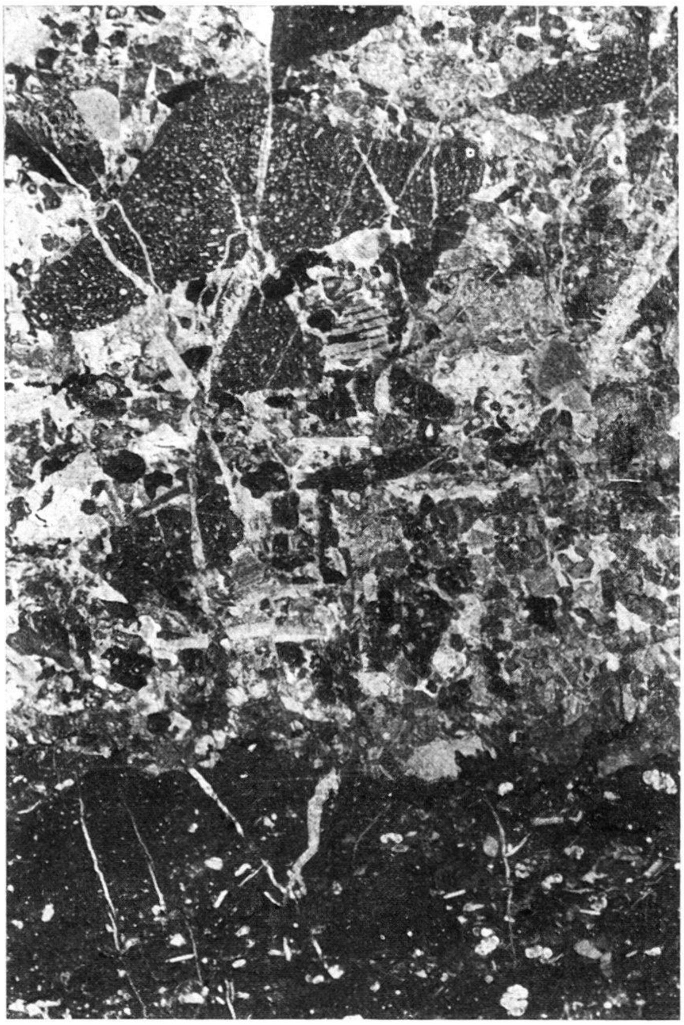

Fig. 19. Redeposited bioclastic to lithoclastic calcarenite overlying a pelagic foraminiferal lime wackestone. The calcarenite contains mainly closely packed skeletal fragments of echinoderms, rudists and *Orbitolina* and various lithoclasts. In the pelagic limestone a.o. *Ticinella* ex. gr. *roberti* (GANDOLFI) and *Hedbergella* ex. gr. *trochoidea* (GANDOLFI) have been determined. The boundary between the two lithologies is a post-depositional stylolite. Çal Dağ Limestone. Middle to Upper Albian. Island of Sirna, DB 1668, thin-section, × 7.

At Bodrum, the upper half of the yellow siltitic limestones which form the lowermost part of the Çal Dağ Limestone contain some poorly preserved aptychi of Late Jurassic age. M. DURAND DELGA determined the following species:

Lamellaptychus gr. *beyrichi* (OPPEL)
Lamellaptychus cf. gr. *lamellosus* s.l.
Laevaptychus sp.
associated with *Stomiosphaera* gr. *minutissima* COLOM

On the Aegean Islands, a stratigraphic contact at the top of the Gereme Limestone has not been observed, but the occurrence of limestones rich in pelagic bivalves on Tria Nisia suggests the presence of Upper Liassic to Middle Jurassic pelagic limestones. Such an age is confirmed by the occurrence of a calcareous nannofossil, that has been allocated to *Schizosphaerella* by NOËL (1965) and to *Protococcosphaera* by MONTANARI (1972). The interval containing *Protopeneroplis striata* has not been observed, but Upper Jurassic to Lower Cretaceous associations are frequent. On the island of Sirna, there are carbonate turbidites that contain some forms that give a Late Jurassic to Early Cretaceous age:

Favreina sp.
? *Kurnubia* sp.
Pseudocyclammina cylindrica REDMOND
Nautiloculina sp.
Robulus sp. det. L. HOTTINGER
Actinostromaria tokadiense YABE and SUGIYAMA
Milleporidium sp. det. E. FLÜGEL

An Late Berriasian to Early Valanginian age is given by calpionellids that occur in pelagic limestones at other parts of this sequence; F. ALLEMANN determined the following species:

Calpionella alpina LORENZ (reworked)
Tintinnopsella carpathica (MURGEANU and FILIPESCU)
Transitional form *T. carp.* – *T. longa* (COLOM)
Calpionellopsis oblonga (CADISCH)
Oblique sections of *Calpionellites dadayi* KNAUER or *C. darderi* (COLOM)

On the smaller of the two islands of Karavi rich associations of calpionellids and calcareous nannofossils have been found, that comprise the following forms (determinations by F. ALLEMANN):

Calpionella alpina LORENZ
Calpionella cf. *elliptica* CADISCH
Calpionella aff. *simplex* COLOM
Tintinnopsella carpathica (MURGEANU and FILIPESCU)
Tintinnopsella aff. *longa* (COLOM)
Calpionellites neocomiensis COLOM
Calpionellites darderi (COLOM)
Calpionellites dadayi KNAUER
Calpionellopsis oblonga (CADISCH)
Cadosina lapidosa VOGLER
Nannoconus cf. *steinmanni* KAMPTNER
Nannoconus sp.

This association infers a Valanginian or younger age, however, as the calpionellids mostly occur in pelagic limestone pebbles in turbidites, the fauna could be partly or even entirely reworked. Unfortunately there are no other age-diagnostic fossils in the turbidites in which the calpionellids occur.

On the larger island of Karavi the pelagic limestones contain only calcitized radiolaria, but the association of displaced orbitolinids of Lower Cretaceous aspect together with *Trocholina* sp., *Neotrocholina* sp. and *Bačinella* suggests an Early Cretaceous, but slightly younger age for this locality.

Berriasian calpionellid associations have also been recorded from the Mandalya Cherty Limestone of the Datça Peninsula (OROMBELLI et al. 1967).

Aptian–Cenomanian:

From Aptian times onwards, there is a considerable increase in carbonate turbidites that contain not only penecontemporaneously displaced particles but also fragments of pre-existing formations. These include fragments of pelagic limestones with calpionellids and of ooidal grainstones, most probably fragments of lime turbidites, with *Protopeneroplis* (Middle Jurassic). The pelagic limestones, that are associated with the turbidites are well dated by planktonic foraminifera and penecontemporaneously displaced benthonic forms.

In the Haticeana Dağ-Köyceğiz Series the stages from Aptian to lowermost Turonian are documented by faunas of planktonic foraminifera. For complete faunal lists see GRACIANSKY et al. (1967) and GRACIANSKY (1972).

In the region of Bodrum the upper part of the formation may be dated as Lower Albian to Lower Cenomanian by *Hedbergella* cf. *trochoidea* (GANDOLFI) in the pelagic limestones and by displaced orbitolinids in the associated turbidites.

On the small islands between Astypalia, Karpathos and Crete, the uppermost part of the Çal Dağ Limestone contains well preserved faunas of Aptian to Cenomanian age (determinations by L. HOTTINGER, H. LUTERBACHER and M. REICHEL).

On Stakida an association of small globigerinids without *Hedbergella* is probably of Hauterivian to Early Aptian age. In the Aptian-Albian, an association comprising small globigerinids, *Hedbergella trochoidea* (GANDOLFI) and displaced *Bačinella* sp. and *Orbitolina* sp. occurs. *Hedbergella* spp. coexisting with *Rotalipora* sp. indicates a Late Albian to Early Cenomanian age.

Sirna: In the Aptian-Albian small *Hedbergella* and displaced *Orbitolina* are very frequent. Middle to Upper Albian is proved by the association of *Hedbergella* cf. *washitensis* CARSEY, *Ticinella* gr. *roberti* (GANDOLFI) and *Rotalipora appenninica* (RENZ).

Similar faunas of essentially Aptian-Albian age, composed of planktonic foraminifera and displaced orbitolinids, are reported from Symi (CHRISTODOULOU 1969; N. CREUTZBURG, personal communication 1970), from the Mandalya Cherty Limestone of the Datça Peninsula (OROMBELLI et al. 1967) and from the Salakos Limestone of Rhodes (OROMBELLI and POZZI 1967; MUTTI et al. 1970).

Environment of deposition: The sharp lithological change at the top of the Gereme Limestone marks an abrupt change in depositional environment. Similar to what observed over large parts of the southern continental margin of the Tethys, the former carbonate platform was submerged during Pliensbachian times probably as a consequence of synsedimentary blockfaulting, and a pelagic regime installed over wide areas (cf. BERNOULLI 1971); persistence of carbonate platforms in neighbouring areas is, however, indicated by carbonate turbidites with displaced shallow marine particles and fossils. Conditions of pelagic and turbiditic carbonate sedimentation persisted from Late Liassic to Cenomanian times, but from the Aptian onwards fragments of older rocks appear which indicate considerable rejuvenation of the submarine topography most probably due to tectonic movements. The rock fragments are all derived from the underlying pelagic and turbiditic sequence and no pre-Upper Liassic fragments were identified. Considering the thickness of the Upper Dogger to Middle Cretaceous sequence, differences in relief along fault scarps would amount to 500 m or more.

3.13 *Sirna Breccia*

Definition: In most places the Çal Dağ Limestone is overlain by a breccia composed of fragments of the underlying formation and of large angular fragments of chert. This horizon proved to be an excellent marker bed and can be followed over a considerable distance from Nif (Fethiye) in the southeast to Bodrum and the islands of Sirna and Stakida in the west. The breccia is particularly well developed in the southern part of the island of Sirna where the type locality has been chosen and where it reaches a thickness of up to ten meters and occasionally even more. In southwestern Turkey the thickness never exceeds five meters and at places the breccia is not present at all. Locally two brecciated horizons occur that are separated by a few decimeters of limestones with chert.

Fig. 20. Sirna Breccia: ill-sorted breccia with closely packed, angular components of limestone and chert. Upper Cretaceous (? Cenomanian-Turonian). Island of Sirna.

Lithology: On Sirna the breccia contains closely packed limestone fragments (Fig. 20) that include Upper Jurassic skeletal limestones and Cretaceous lithologies containing numerous rudist fragments but no terrigenous clastics or volcanics are present. On the island of Stakida, the breccia contains sparse angular chert fragments in a fluidally textured fine-grained matrix.

In southwestern Turkey, the Sirna Breccia has a similar aspect, especially on weathered surfaces as the chert fragments are more resistant to chemical solution (Fig. 21). In most places, about equal proportions of chert and limestone fragments are present, but locally, near Nif Köyü, tiny clasts of diabase and a few detrital quartz grains and mica flakes have been found in the matrix. At Bodrum mainly closely packed chert fragments occur (good exposures near the village of Çirkan).

Age: The Sirna Breccia has not been directly dated, however, a Cenomanian to Turonian age can be assumed from its position between the Çal Dağ Limestone and the Upper Cretaceous flysch.

Environment of deposition: The Sirna Breccia is discontinuously followed by a cyclic alternation of graded conglomerates and sandstones of the flysch (Çamova Formation), obviously marking a pronounced break in the sedimentary evolution of the Intermediate Complex. Most probably the breccia has been deposited by sub-

Fig. 21. Sirna Breccia: massive breccia with closely packed angular components of limestone and chert. In the background limestone olistoliths in the Karabörtlen Formation: the Çamova Formation is here reduced to a few metres only. Upper Cretaceous (? Cenomanian-Turonian). Western slopes of Eyrilice Tepe, southern part of Kara Dağ (Nif). Lycian Taurus.

marine mud-flows that may have been triggered by tectonic movements preceeding initiation of flysch sedimentation.

3.14 *Çamova Formation*

Definition: The Çal Dağ Limestone and the Sirna Breccia are overlain by a thick sequence of clastic sediments that in the lower part show the characteristics of a typical flysch sequence (Çamova Formation); it is overlain by a typical wildflysch (Karabörtlen Formation, see below).

The type-locality for the regularly bedded flysch sequence has been chosen near the locality of Çamova, 10 km NE of Köyceğiz, where the greatest thicknesses (100–150 m) are exposed (Fig. 22). At other places (Karabörtlen, Fethiye: Haticeana Dağ) the Çamova Formation is reduced to a few meters; however, on the island of Sirna a thickness of 50 meters or more is present. At Bodrum the formation is missing (Fig. 7). The formation has also been recognized by N. CREUTZBURG (personal communication 1970) on the island of Symi.

Lithology: Lithologically the Çamova Formation consists of a cyclic alternation of graded conglomerates, subfeldspatic and sublithic sandstones and siltstones (Fig. 23). Most of the formation is regularly stratified, but at some places intercalated slumped beds occur (Fig. 22). The conglomerates and sandstones contain various proportions of continental detritus, volcanic fragments, carbonate rocks and bioclastic material. Terrigenous components include mainly fragments of micaschists

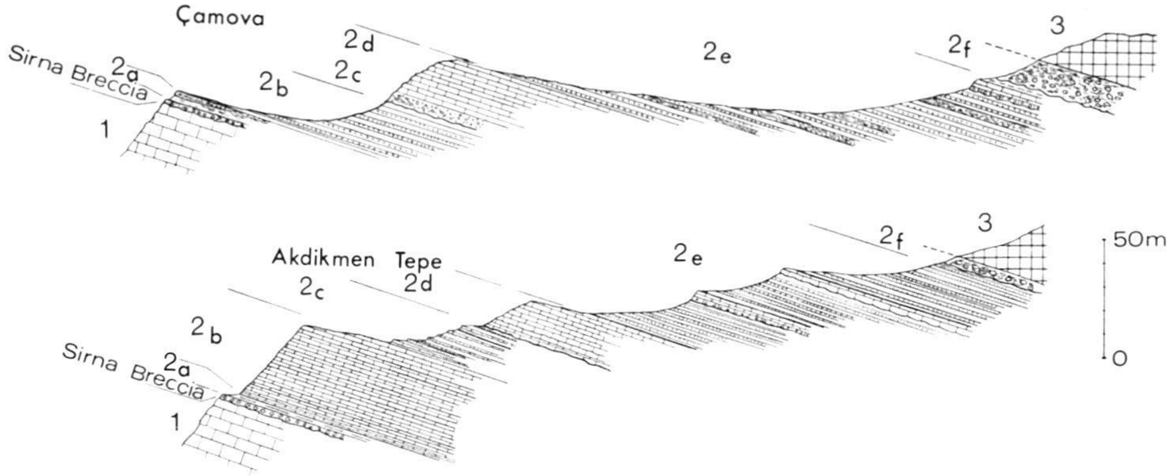

Fig. 22. Stratigraphic sections in the Çamova Formation in the Köyceğiz allochthon, Lycian Taurus. *3* Diabase Nappe. *2f* Karabörtlen Formation (wildflysch), reduced to only a few meters. *2e* Graded feldspatic sandstones with subordinate graded skeletal calcarenites*). *2d* Graded skeletal calcarenites*). *2c* Graded feldspatic sandstones*). *2b* Graded skeletal calcarenites*). *2a* Sirna Breccia. *1* Çal Dağ Limestone. – *) Çamova Formation.

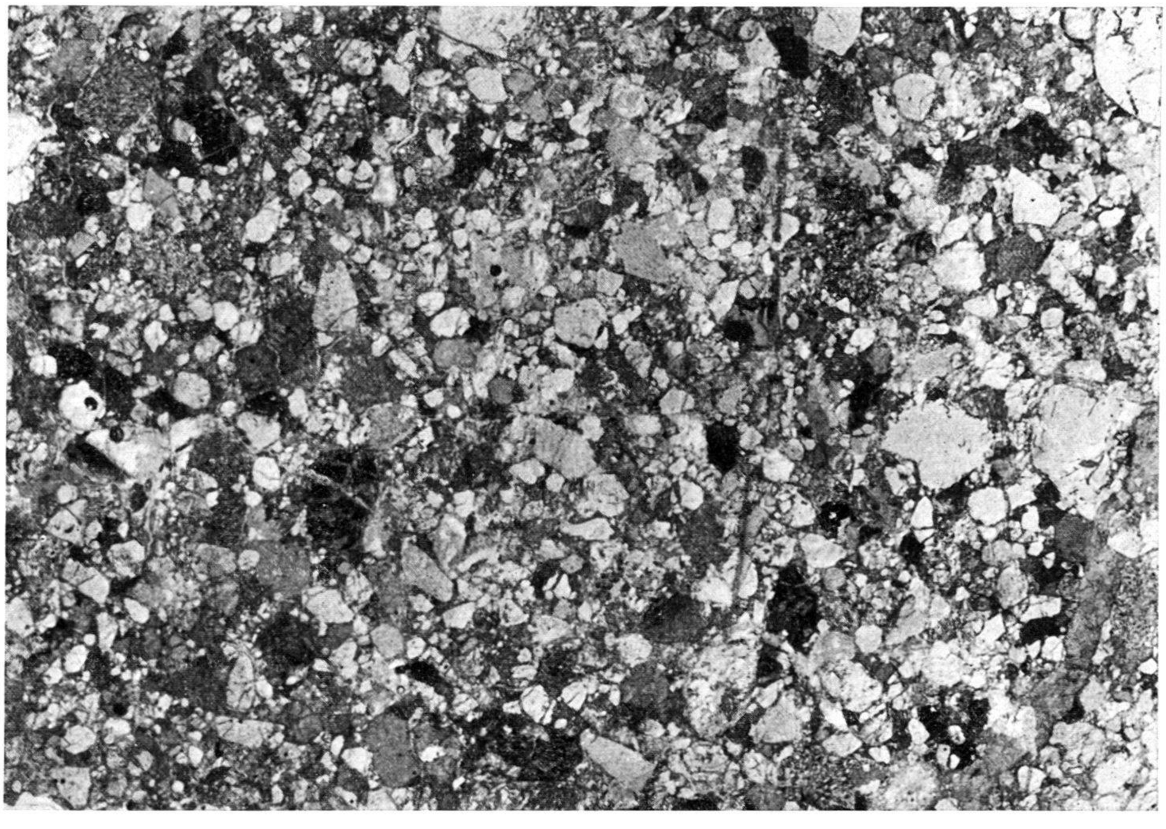

Fig. 23. Typical greywacke of Çamova Formation containing lithic particles of sedimentary rocks (quartzites, radiolarites, pelagic limestones), volcanics (diabase, fragments of pillows?), quartz, more or less altered mafic minerals, picotite and plagioclase. Upper Cretaceous. DB 1657, Island of Sirna, thin-section, ×7.5.

and quartzites, quartz, micas, chlorite and feldspars; volcanic fragments are mainly diabases, dolerites and fragments of pillow-lavas whereas the bioclastic fraction is composed of rudist and echinoderm fragments, reworked *Orbitolina* and planktonic foraminifera. At Çamova, the carbonate particles are not distributed at random but are concentrated in calcirudites and calcarenites that contain only minor fractions of terrigenous or volcanic components.

On the island of Sirna the Sirna Breccia is followed by an up to 50 m thick cyclic alternation of graded conglomerates, sandstones and siltstones; shales are virtually absent. The conglomerates mainly contain rounded pebbles of the underlying limestones, including pelagic limestones with *Hedbergella* or *Rotalipora*, fragments of lime turbidites with *Orbitolina* and lithoclasts with Upper Jurassic Hydrozoa (*Actinostromaria*) in a sub-feldspatic to sub-lithic sandstone matrix.

On the island of Stakida graded and current-laminated sandstones occur that are tectonically isolated from the associated formations.

Age: The Çamova Formation contains hardly any age-diagnostic fossils; however, possibly reworked planktonic foraminifera in the lowermost part of the formation suggest an Late Turonian to Early Senonian or slightly younger age (*Globotruncana* cf. *convexa* (SANDIDGE), *Globotruncana* cf. *renzi* THALMANN and GANDOLFI, *Globotruncana* cf. *sigali* REICHEL, *Globotruncana linnei* (D'ORBIGNY) (det. J. SIGAL)). This age attribution matches well with the age of the uppermost pelagic limestones in the Çal Dağ Limestone. The upper boundary has not been dated, but a Late Cretaceous to possibly Early Tertiary age is suggested for the wildflysch, as no faunas younger than Maastrichtian have been found in the latter.

Interpretation: The various types of clasts suggest different source areas: an exposed continental crust, a source of volcanic fragments of basic composition and a source area in the depositional realm of the pelagic limestones with cherts (Çal Dağ Limestone).

3.15 *Karabörtlen Formation* (wildflysch)

Definition: wildflysch terranes outcrop widely in the western Lycian Taurus and particularly in the surroundings of Karabörtlen where in accordance with KAADEN and METZ (1954) the type locality has been chosen. The thickness of this formation is on the order of about 100 to 200 meters. Near Karabörtlen and Köyceğiz it does not exceed 200 meters; in southwestern Lycia, around Fethiye, only about 100 meters or somewhat less are present and only at Bodrum, where the formation lies directly on the Sirna Breccia, some 300 meters may be estimated. On the Aegean islands, the wildflysch has been found only in a very small area along the northern coast of Sirna, separated by a young normal fault from the Triassic-Lower Jurassic carbonates to the south. According to N. CREUTZBURG (personal communication 1970) the same formation is found on the island of Symi. In Lycia the upper boundary of the formation is given by the overlying Diabase Nappe which is thought to have been emplaced by the end of sedimentation of the wildflysch. At Bodrum and on the Aegean Islands the top of the formation is not known.

Lithology: The wildflysch consists of an association of dark shales, siltstones and sandstones with numerous blocks of different size and lithology (Figs. 24, 25). The composition of the sandstones and siltstones is essentially the same as in the under-

Fig. 24. Karabörtlen Formation (wildflysch): Large limestone olistoliths in shaly to sandy matrix. The high summit in the back-ground (Koruçali) is composed of Çal Dağ Limestone. Upper Cretaceous – ? Lower Tertiary. Southern slopes of Kara Dağ (Nif). Lycian Taurus.

Fig. 25. Karabörtlen Formation (wildflysch): lenses and blocks of limestone in a chaotically deformed shaly to sandy matrix. The white limestones cliff in the back-ground is formed by Gereme Limestone brought up by a steeply north-dipping young (subrecent) fault. Upper Cretaceous–? Lower Tertiary. North-coast of the island of Sirna.

Fig. 26. Karabörtlen Formation (wildflysch): limestone and shale fragments in a shaly/sandy matrix ("Schistes à blocs"). Upper Cretaceous–? Lower Tertiary. Köyceğiz (Ağla). Lycean Taurus.

lying flysch (Çamova Formation), but their stratification is highly disturbed and they merely form a chaotic matrix for the generally sparse exotic blocks (Figs. 24–26). Many features of this facies, such as the occurrence of dispersed volcanic and limestone blocks and of fragments of contorted sandstone beds in a shaly matrix, are comparable with those described from the "flysch dissocié" as defined by KERCKHOVE (1964) and the "flysch à lentilles" (CARON 1966) of the flyschs of the western Alps and the olistostromes occurring in different formations of the Ligurian Apennines (Basal complex of M. Caio Flysch, Breccias of Santa Maria di Taro, ELTER and RAGGI 1965a, 1965b; ABBATE et al. 1970).

The exotic blocks contained in the wildflysch range from pebble size to large olistoliths a few hundred meters across. They comprise large complexes of pelagic limestones with chert derived from the Çal Dağ Limestone and graded pelagic limestones with planktonic foraminifera of Late Cretaceous age. At Bodrum, large blocks of massive shallow marine limestone with thick-shelled molluscs (? Gereme Limestone) and coral debris are particularly abundant. Other blocks, mainly concentrated near the top of the formation, are of the same lithological composition as the overlying tectonic unit from which they most probably are derived (cf. Fig. 28): they include diabases, radiolarites, pink cherty limestones with *Globotruncana* and, near Karabörtlen, metamorphic rocks (gneisses, quartzites, amphibolites and glaucophane schists), but neither peridotites nor serpentinites are found.

Age: The Karabörtlen Formation contains very few diagnostic fossils, however, a few associations are found that set a minimum age for the formation. Near Köyceğiz

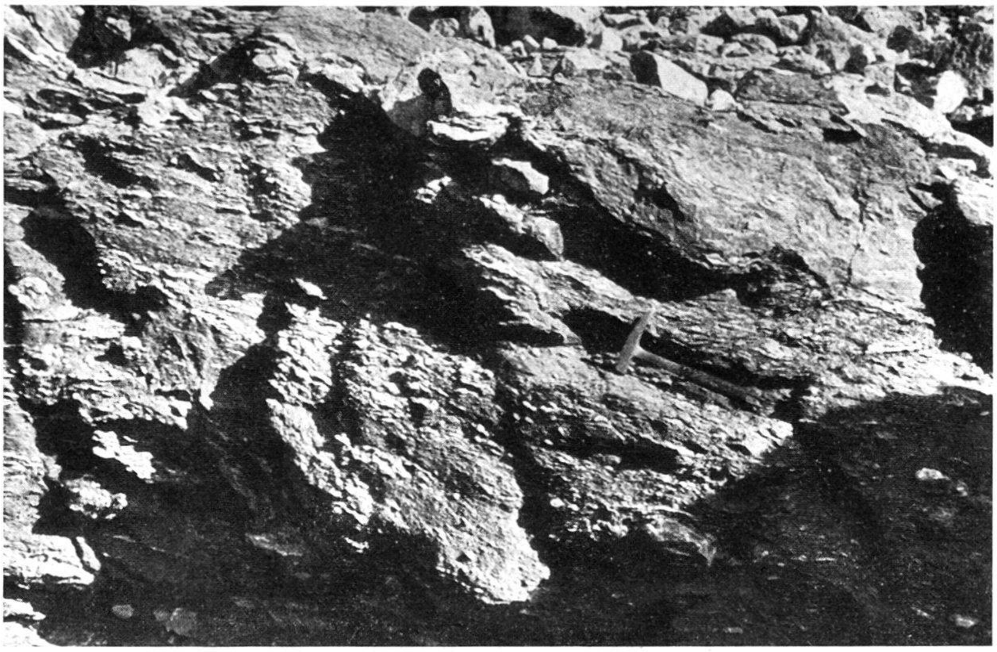

Fig. 27. Karabörtlen Formation (wildflysch): Lenses and nodules of limestone in a dark gray shaly to sandy matrix. Upper Cretaceous–? Lower Tertiary. DB 1693, north-coast of the Island of Sirna.

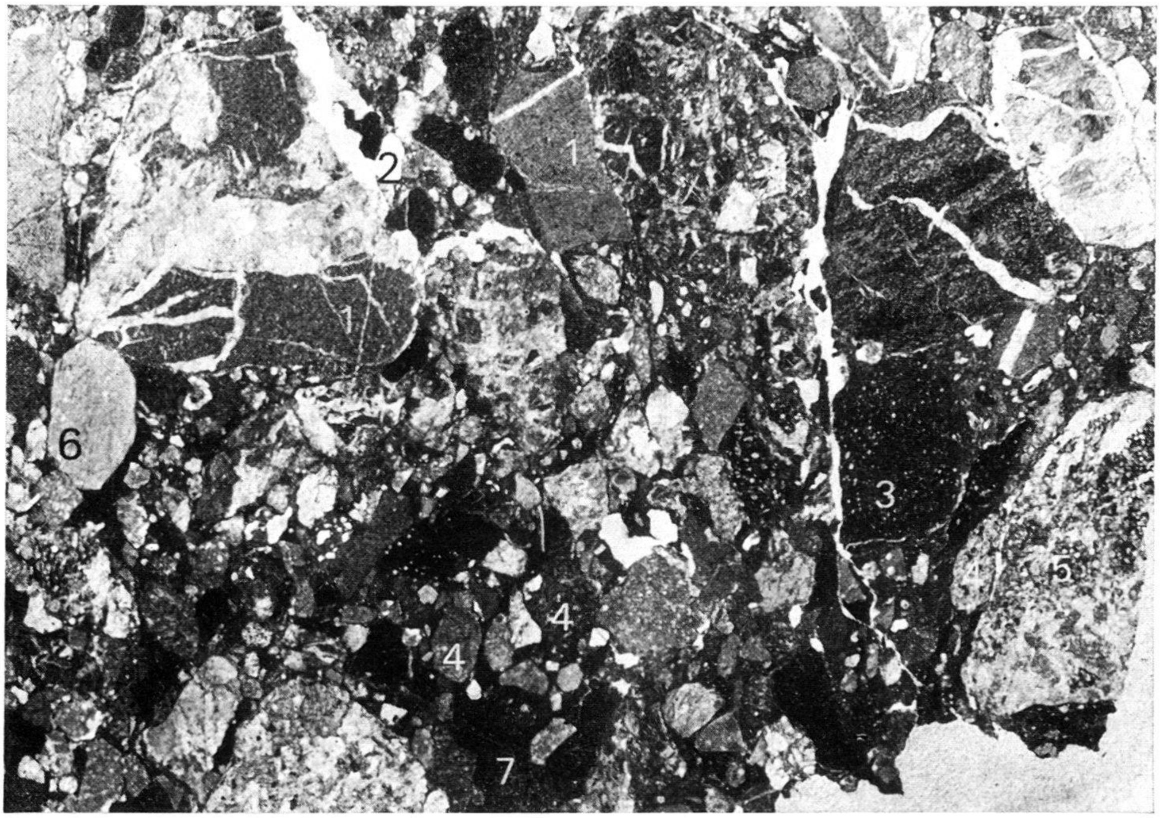

Fig. 28. Sandy matrix of Karabörtlen Formation mainly composed of lithic fragments including fine-grained limestones (1), quartzites (2), radiolarites (3), diabase (4), fragments of pillowlavas (5) and volcanic glass (6), all set in a silty matrix (7) containing some larger grains of detrital feldspar, quartz and chlorite. Upper Cretaceous–? Lower Tertiary. Southern slopes of Kara Dağ (Nif). Lycian Taurus (cf. Fig. 24). F 1429, thin-section, × 7.

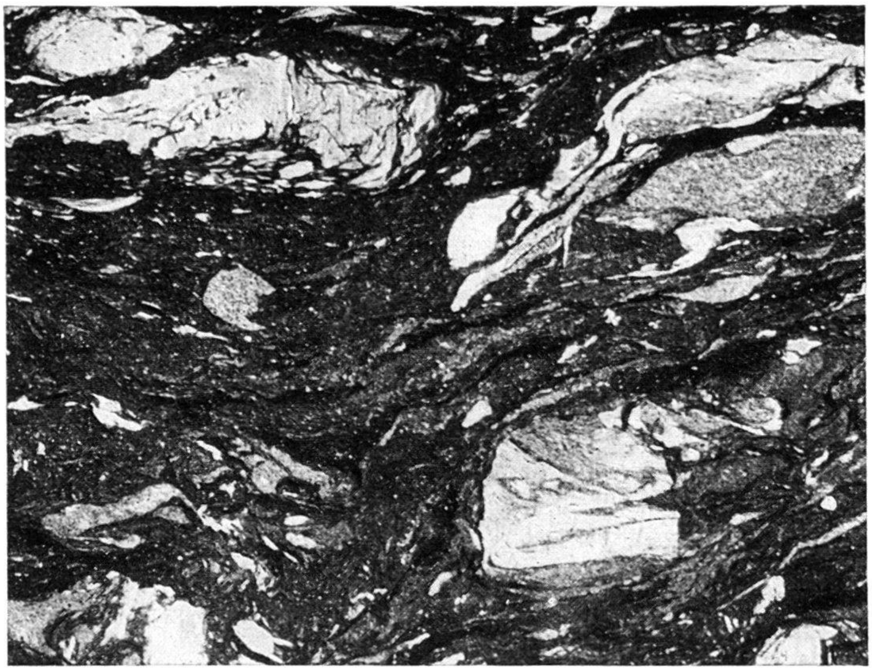

Fig. 29. Shaly matrix of Karabörtlen Formation: strongly recrystallized calcite fragments in a contorted shaly matrix. Upper Cretaceous–? Lower Tertiary. Southern slopes of Sandras Dağ, Elmatasi, Lycian Taurus. S 86, thin-section, ×4.8.

fragments of graded pelagic limestones embedded in a highly disturbed sandy to silty matrix occur. Both the limestone fragments and the matrix contain an association of Late Campanian to Early Maastrichtian age. J. SIGAL determined the following species: *Globotruncana stuarti* (DE LAPPARENT), *G. arca* (CUSHMAN), *G. elevata* (BROTZEN) and displaced fragments of *Siderolites* and *Orbitoides*. Associations of the same age have been found in red pelagic limestones contained in the wildflysch of the island of Sirna: H. P. LUTERBACHER and M. REICHEL determined the following forms characteristic for the Campanian-Maastrichtian:

Globotruncana gr. *arca* (CUSHMAN)
Globotruncana gr. *contusa* (CUSHMAN)
Globotruncana cf. *mayaroensis* BOLLI
costate Heterohelicidae

The youngest age-diagnostic fossils found so far in the wildflysch and in its exotic blocks are of Campanian-Maastrichtian age, it is, however, possible that these are partly reworked and the formation may thus extend into the Lower Tertiary.

Previously the Karabörtlen Formation has been regarded as Permian or Permo-Carboniferous (METZ and VAN DER KAADEN 1954) because the formation seemed to be slightly metamorphic (recrystallization of calcite, presence of amphibolites). However, the amphibolites present appear to be olistoliths and the clay minerals contain mixedlayered types excluding metamorphism.

3.2 *The Diabase Nappe and the Mélange*

In Lycia, the Karabörtlen Formation is overlain by the Diabase Nappe, an assemblage of basaltic pillow-lavas in primary association with red cherty Globotruncana limestones, radiolarites, white graded calcarenites and limestone breccias. Typically these rocks do not form continuous strata, but occur as blocks up to some kilometers across set in a matrix of volcanic sandstone or in places of calcarenite. Complex deformation seems to be a primary or penecontemporaneous feature of this association, however, the emplacement of the overlying Peridotite Nappe has largely altered the structural fabric. The thickness of the Diabase Nappe never exceeds 300 m.

The lower contact of the Diabase Nappe appears to be a normal and progressive sedimentary contact: within a few meters the sandy matrix of the wildflysch (Karabörtlen Formation) grades into a tuffitic matrix in which the exotic blocks are embedded. This, and the presence of olistoliths of diabase, radiolarite and pink pelagic limestones in the Karabörtlen Formation, suggests that the Diabase Nappe has been emplaced in the depositional basin of the wildflysch during the latest Cretaceous or the Early Tertiary. The upper contact with the Peridotite Nappe is clearly a nappe contact of first order. In the internal parts (region of Karabörtlen), this contact is characterized by slices of metamorphic rocks, amphibolites, quartzites, micaschists, gneisses and marbles of unknown provenience which are imbricated with or embedded in a matrix of serpentinite. Serpentinites and fragments of doleritic dikes are clearly derived from the Peridotite Nappe and are in turn imbricated and mixed with the rocks of the Diabase Nappe: the whole association forms a typical tectonic mélange (GRACIANSKY 1973) comparable to the "coloured mélange" described from other places in the Alpine-Himalayan chains (GANSSER 1959).

On the small Aegean islands, no remnants of the Diabase or the Peridotite Nappe have been found. Small relics of the latter, however, seem to occur on the island of Rhodes (MUTTI et al. 1970), and on Crete equivalents of both the Diabase Nappe and of the Peridotite Nappe (cf. CREUTZBURG and PAPASTAMATIOU 1969; BONNEAU 1970, 1972a, 1972b, 1973) can be recognized. Their former presence on the more internal islands can therefore safely be assumed.

4. The structural style of the Intermediate Complex

In southwestern Turkey the Intermediate Complex consists of a number of thrust-slices and imbrics between the underlying, apparently autochthonous sequence and the originally more internal Peridotite Nappe (Fig. 30). The size and structural relations of the single elements vary considerably; however, a number of common characteristics can be recognized: 1. folding occurs only occasionally and is usually absent and 2. the different elements are bound by even surfaces following decollement levels or cutting obliquely through the stratigraphic sequence. These basal shear planes ("troncatures basales", ELLENBERGER 1967) also cut across older thrusts.

The larger units of the Intermediate Complex are of the order of ten to fifteen kilometers across representing small nappes of a second order (TERMIER's "nappes du deuxième genre", TERMIER 1907–1922). The smaller units are sometimes in the order of only a few hundred meters: they are accumulated in a chaotic way between the larger units or between the latter and the autochthonous sequence or the Peridotite Nappe.

It appears to us that the chaotic style of deformation, characterizing the nappe system of the Intermediate Complex, is closely related to the interrelation of tectonic and erosional processes and this style seems, in fact, to be typical for a superficial structural level.

The structural relations between the wildflysch and the overlying Diabase Nappe suggest that the latter was emplaced in the depositional basin of the wildflysch at the end of the Cretaceous or in the Early Tertiary. As the youngest sediments in the underlying autochthonous sequence are of Miocene age, it becomes clear that the Mesozoic sequences of the Köyceğiz Series have been positioned together with their earlier emplaced cover of the Diabase Nappe ("fausse couverture") on the more external, autochthonous unit. This superposition of two different phases of nappe transport may, at least partly, explain the extreme structural complications observed in the Intermediate Complex of southwestern Turkey.

In the Aegean Islands, the sequences of the Intermediate Complex occur as isolated remnants and no contacts with underlying or overlying units are observed. Accordingly, there is no direct stratigraphic evidence for different phases of nappe transport. The existence of a complex nappe system, however, results from the general geological situation both in the internal and external Hellenides and Taurides. The underlying units, characterized by carbonate sedimentation throughout the Mesozoic and the earliest Tertiary, are exposed in the islands of Saforà, Chamili, and Di Adelphi; these units in turn make part of the composite nappe structure of the Hellenides if one accepts the nappe structure in the Gavrovo Zone and the so-called crystalline basement in Crete (see above, p. 42). Although the overlying units are not preserved, the former presence of the Ophiolite Nappe can be deduced from its remnants in Crete (Bonneau 1970; Vicente 1970) and Rhodes (Mutti et al. 1970).

The region of Bodrum shows a heavy tectonic style along two prominent, nearly orthogonal directions: an east-west trend is clearly apparent with a pinched syncline of wildflysch a few kilometers north of Bodrum and the general monoclinal style of the Oyuklu Tepe region. On the other hand, a north-south direction is indicated by the western edge of the Kişla Dağ limestones, which are somewhat thrusted against the wildflysch towards the West.

In the islands, the Intermediate Complex is characterized by internal imbrication and thrusting (e.g. Stakida, Fig. 31). In the Gereme Limestone no folding has been observed and the tectonic style seems very much to resemble the one in southwestern Turkey. In the Çal Dağ Limestone small-scale chevron-folds are most obvious on the island of Sirna, larger folds occur in the Çamova Formation (Sirna).

As everywhere in the Hellenid and Taurid nappe system, the nappe structures are deformed by later warping and faulting. Gentle folding during the Late Miocene following nappe transport has been recognized on the island of Rhodes (Mutti et al. 1970), but in the Lycian Taurus or in the more internal Aegean Islands this could not be proved as there are no postorogenic, Upper Miocene to Lower Pliocene sediments preserved. Later, during the Late Pliocene and the Quaternary the entire nappe pile was cut by normal faults that are responsable for the present-day morphology and coast-lines. In southwestern Turkey the fault pattern determines the distribution of the outcrops of the different tectonic units: in the depressions, remnants of the (upper) Peridotite Nappe are preserved, whereas in the uplifted blocks, the Intermediate Complex and the autochthonous sequence are exposed (Figs. 1 and 30). In the Aegean Sea the faults are associated with the breakdown of the Aegean realm

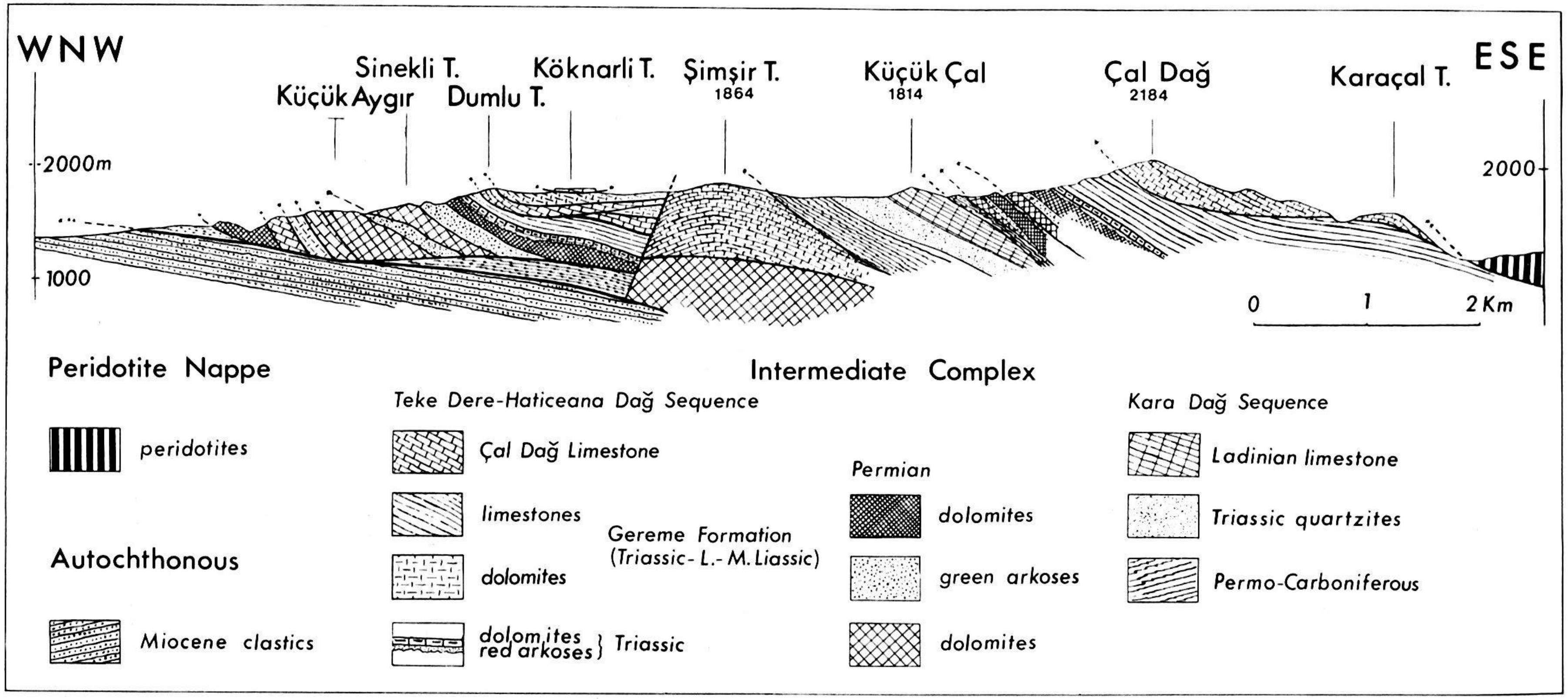

Fig. 30. Tectonic profile through the Intermediate Complex of the Lycian nappes. The profile shows the style of tectonic imbrication that brings into contact two sequences that are derived from different depositional realms: the Karadağ sequence comprising Permo-Carboniferous to Ladinian rocks and the Teke Dere sequence ranging from Permian to Upper Cretaceous (cf. Fig. 5). The Intermediate Complex is underlain by the Miocene clastics of the autochthonous sequence of Göcek and overlain by the Peridotite Nappe.

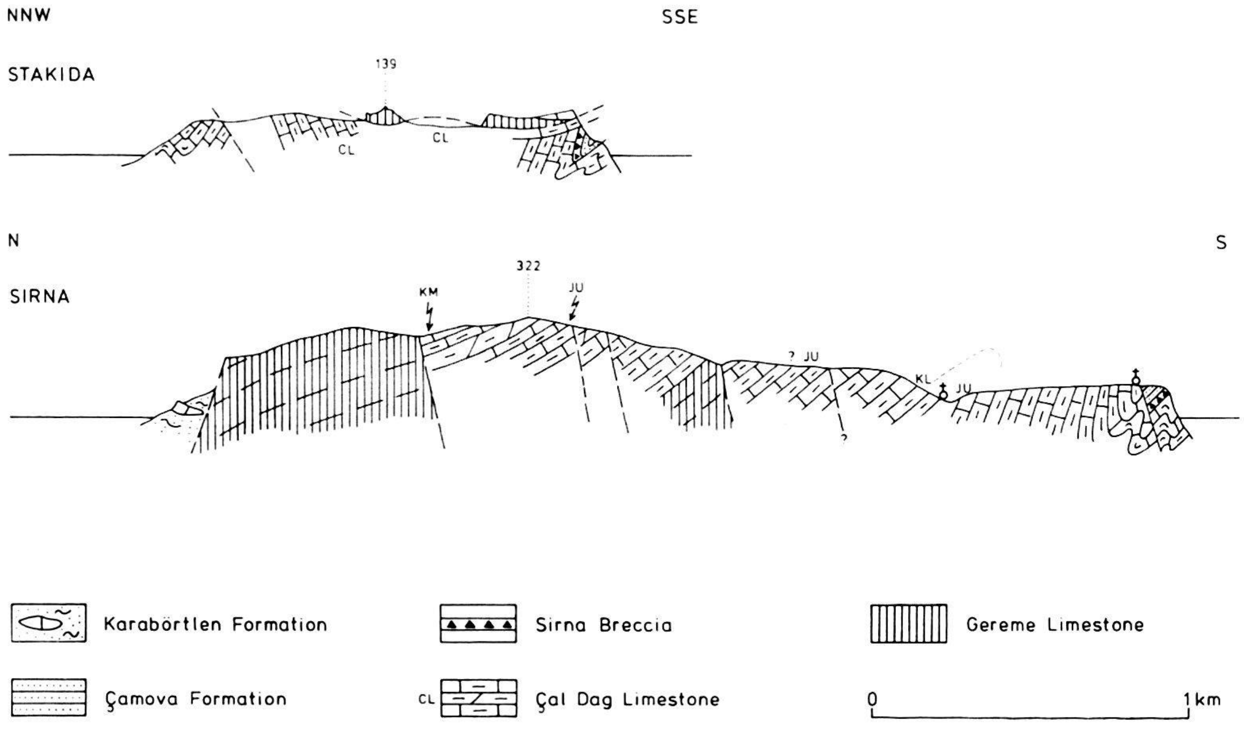

Fig. 31. Tectonic profiles through the islands of Sirna and Stakida.

and the Quaternary transgression. Still active faulting is suggested by young fault scarps hardly modified by erosion and by the general seismicity of the region.

5. The extension of the Lycian nappes in the Aegean region

The obvious region to investigate for the continuation of the Lycian nappes of southwestern Turkey is the area between the small Aegean islands, the Bodrum peninsula and the region of Fethiye-Köyceğiz. In this area stratigraphic sequences which closely ressemble the ones already described are found in the Datça Peninsula, on the islands of Symi and Tilos and possibly on the island of Rhodes.

Datça Peninsula

The sedimentary sequence of the Datça Peninsula has been described by OROMBELLI et al. (1967). The oldest stratigraphic unit, the Yelimlik Limestone, a massive, partly dolomitized limestone of Late Triassic to Liassic age, corresponds stratigraphically and lithologically to the Gereme Limestone. The uppermost part of this formation (as defined by OROMBELLI et al.) comprises thick-bedded cherty limestones with *Globochaete*, a planktonic form of unknown systematic position that indicates a definite pelagic influence and suggests a correlation with the lowermost Çal Dağ Limestone (? Upper Liassic). Above this, Middle to Upper Jurassic radiolarites (Sariabat Radiolarite) and marls and marly limestones with interbedded calcarenites (Kuru Dağ Marl) are found. Judging from OROMBELLI's descriptions, they could be compared with coeval rocks of the Bodrum peninsula (see p 60.). The overlying Cretaceous Mandalya Cherty Limestone is composed of pelagic limestones with bands and nodules of chert and closely ressembles the Cretaceous part of the Çal Dağ

Limestone: Both formation contain rich calpionellid faunas of Berriasian age and, from the Barremian onwards, lime turbidites with redeposited shallow-water material including displaced orbitolinids. According to OROMBELLI et al. (1967) the pelagic carbonate sedimentation persisted on the Datça Peninsula into the Lower Maastrichtian (cf. TATAR 1968). This of course would imply a major facies change within the depositional basin of the Köyceğiz series during the Late Cretaceous. An alternative interpretation would be a stratigraphic gap between the Sirna Breccia and the Çamova Formation with reworking of the scarce foraminiferal faunas in the latter.

The overlying Datça Flysch comprises, at the base, two members (Topanca and Kargi Members) that could be compared lithologically to the Çamova Formation; they are not dated by fossils. The Atolen Member is tectonically isolated from the rest of the sequence: it has been dated by larger foraminifera as Eocene. Locally blocks of pelagic limestones, radiolarites and pelagic lamellibranch limestones (Upper Triassic or Middle Jurassic?) are floating on top of the flysch, which, in the east, is overthrust by the Peridotite Nappe.

Symi

Data on the stratigraphic sequence of Symi are found in DESIO (1931), in CHRISTODOULOU (1969) and in OROMBELLI and POZZI (1967) who reexamined the material collected by DESIO. N. CREUTZBURG visited the island in 1970; he kindly allowed us to use his observations and put his samples and thin-sections at our disposal. From all these data it appears that the sequence of Symi is identical with the sequences described by us. It comprises the following formations:

1. Gereme Limestone: massive limestones with *Palaeodasycladus mediterraneus* (PIA). (CHRISTODOULOU 1969, N. CREUTZBURG, personal communication 1970.) OROMBELLI and POZZI (1967) compared this formation with the Salakos Limestone from Rhodes.
2. Çal Dağ Limestone: well-bedded limestones with bands and nodules of chert. They contain reworked pebbles of Berriasian limestones with calpionellids, displaced orbitolinids and planktonic foraminifera ranging from Aptian-Albian to Cenomanian.
3. The flysch is represented by well-bedded sequences of sandstones and shales and some outcrops of wildflysch (Karabörtlen Formation) containing blocks of red limestones and radiolarites.

Tilos (Piscopi)

According to DESIO (1931) the island of Tilos presents many analogies with the island of Symi. Judging from the unpublished observations by N. CREUTZBURG (personal communication 1971) lithologies of Lycian type are involved in a nappe edifice. This view seems to be confirmed by the data recently presented by CHRISTODOULOU and TATARIS (1972), we feel, however, that there are other possible interpretations of these data. CHRISTODOULOU and TATARIS (1972) recognize essentially two tectonic units, of which the upper would correspond to the Subpelagonian Zone and the lower to the Pindos Zone of continental Greece. According to CHRISTODOULOU and TATARIS (1972) the upper unit (series A) consists of neritic limestones containing Upper Triassic to Middle Liassic fossils. The lower tectonic unit (series B) comprises thin-bedded pelagic limestones ranging in age from the Late Liassic to the Late Cretaceous with the intercalation of a shale-chert-sandstone complex with spilitic extrusives in the Jurassic. The overlying flysch is of Maastrichtian age and may range into the Paleocene.

From our examination of the material collected by N. CREUTZBURG we conclude that the Triassic and Liassic platform limestones, stratigraphically and litholocally, correspond exactly to the Gereme Limestone (and to the Yelimlik Limestone of the Datça Peninsula, OROMBELLI et al. 1967).

The tectonically lower sequence is dated by CHRISTODOULOU and TATARIS (1972) only in the Upper Liassic and from the Cenomanian onwards. In general the observed lithologies compare rather well with the Çal Dağ Limestone. The lowermost part of the sequence includes pelagic lamellibranch pack- to wackestones with redeposited pelagic wackestone pebbles, crinoids, calcitized radiolaria and fragments of altered basaltic volcanics. This facies is found in the Upper Triassic and in the Lower to Middle Jurassic the Mediterranean Mesozoic; it has also been noticed by OROMBELLI and POZZI (1967) and compared to the Upper Triassic of the Pindos Zone of Rhodes. An Upper Liassic to Middle Jurassic age, however, seems more probable. The shale-chert-sandstone complex of CHRISTODOULOU and TATARIS (1972) then could correspond to the Sariabat Radiolarite of Datça (OROMBELLI et al. 1967). In the Upper Jurassic to Lower Cretaceous (material of N. CREUTZBURG) we found grey bioclastic wackestones with calcite-replaced radiolarians, and sponge spicules, crinoid and ophiuroid ossicles, foraminifera, occasional calpionellids and *Saccocoma*. This facies matches again well with the Çal Dağ Limestone. Particularly striking is the analogy between the Cretaceous lithologies of Tilos described by CHRISTODOULOU and TATARIS (1972), and the Çal Dağ Limestone; as on the Datça Peninsula flysch sedimentation starts only during the Maastrichtian.

From the above it appears that the entire sequence from the island of Tilos corresponds well with the sequences of the Intermediate Complex, particularly with the one of the Datça Peninsula. We therefore would interpret the tectonic structure of the island as characterized by internal thrusts in the Intermediate Complex as observed in southwestern Turkey (Fig. 1 and 30) and on the islands of Symi (CHRISTODOULOU 1969) and Stakida (Fig. 31).

Kos

The pre-Neogene geology of this island is only poorly known, however, from the descriptions by DESIO (1931) the presence of a wildflysch formation with large olistoliths, possibly of Çal Dağ Limestone, can be inferred. This wildflysch could correspond to the Karabörtlen Formation or to the Atolen Member of the Datça Peninsula (OROMBELLI et al. 1967).

Rhodes and Alimnia

On the island of Rhodes, several slivers of allochthonous sediments which are thrusted on the Lower Oligocene Katavia Flysch, have been grouped by OROMBELLI and POZZI (1967) and MUTTI et al. (1970) as Archangelos Group. They comprise partly dolomitized skeletal limestone and marls of Carnian age (Cumuli Formation); shallow water dolomites and limestones with *Palaeodasycladus mediterraneus* (PIA);

limestones with *Cladocoropsis*, skeletal limestones with chert (Alimnia Member) and skeletal limestones with nummulites of Paleocene to Eocene age. Although these different limestone types occur in isolated masses scattered all over the Oligocene Flysch, they have been grouped together into one single formation (Salakos Limestone, OROMBELLI and POZZI 1967; MUTTI et al. 1970) that was thought to represent one continuous formation of shallow-water limestones. This formation was tentatively attributed by C. RENZ (1929) and by MUTTI et al. (1970) to the Parnasse Zone; but OROMBELLI and POZZI (1967) allocated it to the Gavrovo Zone because it occurs structurally below the Pindos Nappe (Profitis Ilias Group of MUTTI et al.). However, as AUBOUIN and DERCOURT (1970) pointed out, the formations grouped in the Archangelos Group could be derived from different tectonic units and may just represent allochthonous slivers of different origin resting on the flysch.

Of the different lithologies, the shallow-marine Upper Triassic to Liassic limestones that yielded Norian (see p. 58) and Early Jurassic floras (OROMBELLI and POZZI 1967), compare rather well with the Gereme Limestone. On the island of Alimnia these limestones are overthrust on a sequence of cherty limestones with lime turbidites containing displaced *Orbitolina*; this formation in turn recalls the Çal Dağ Limestone. The Paleocene-Eocene nummulite limestones are, however, not represented in the Lycian sequences, except for the nummulite limestones associated with the Atolen Member of the Datça Flysch.

Similar sequences occur, according to OROMBELLI and POZZI (1967) on the island of *Chalki*.

Towards the north-west, the westernmost ascertained occurrences of the Lycian complex are found on the islands Unia Nisia, Avgò and Karavi. Further west no sequences are found that are strictly comparable with the Lycian sedimentary sequences; most analogies, however, present some formations in the southwestern Argolis peninsula. Of these, the facies of the shallow-water to supratidal carbonates of the Upper Triassic–Lower Liassic "Pantokrator Limestone" (SÜSSKOCH 1967) is identical with the one of the Gereme Limestone. Both regions are further characterized by block-faulting and sinking during the Middle to Upper Liassic. Major differences, however, are found from the Middle Jurassic onwards: pelagic and turbiditic carbonate sedimentation in most of the Lycian complexes contrast with sedimentation of radiolarites and volcanic sandstones and the extrusion of basic volcanics in the Argolis (BANNERT and BENDER 1968; AUBOUIN et al. 1970). Associated olistoliths of Jurassic limestones and of serpentinites possibly indicate local compressional movements as early as the latest Jurassic or the Early Cretaceous; such Jurassic compressional movements, however, are not known from the Eastern Aegean Sea until now.

6. Conclusions

Our geological investigations, which were carried out independently from each other, demonstrate the striking similarities between the Mesozoic sequences of three fairly distant areas in the Lycian Taurus and of several islands in the southeastern Aegean Sea (Plate I). In southwestern Turkey these sequences are comprised in a number of thrust-sheets intercalated between an apparently autochthonous sequence in the south and the uppermost unit of the nappe pile, the Peridotite Nappe. Internally the Lycian nappes are bordered by the Menderes "massif" and the "mesoautochthonous" Oligo-Miocene clastics of the Kale-Tavas Basin. In the Aegean islands the original position of the Lycian sediments cannot be deduced from present-day tectonic relationships but must be inferred from facies comparison with their Taurid or Hellenid equivalents.

The "autochthonous" carbonate platform sequence which appears in the tectonic windows near Göcek along the Turkish coast is nearly identical with the series of the southern Bey Dağlari. In the islands of Chamili, Saforà and Di Adelphi, similar types of Mesozoic to Lower Tertiary carbonate rocks have been found and both regions can be interpreted as relatively proximal parts of a carbonatic continental margin. In the Hellenides, such sequences are found in the carbonate platform deposits of the Zante, Gavrovo and Parnasse Zones, and in fact a correlation of the sequences of Chamili, Saforà and Di Adelphi with the Gavrovo and/or the Parnasse Zone seems possible. There exist, however, significant differences between the latter sequences and the autochthonous sequences at Göcek and in the Bey Dağlari, illustrating the obliquity of Mesozoic palaeogeography and Alpine tectonic boundaries: the sequences of Saforà and Di Adelphi are characterized by Eocene flysch sediments and are certainly involved in an Alpine nappe edifice similar to that observed for the Gavrovo Zone in Crete (EPTING et al. 1972a, 1972b).

Paleogeographic and sedimentary evolution characterize most of the sedimentary sequences of the Lycian Nappes as continental margin associations (BERNOULLI and JENKYNS 1974) and kinematic inversion clearly places them to the south of the oceanic ophiolite zone now represented by the Peridotite Nappe. Among the different Mesozoic sequences of the Lycian Nappes, the Köyceğiz sequence shows the largest regional extension. This sequence is characterized 1. by the sinking of a former carbonate platform during the Middle to Late Liassic, followed by the deposition of pelagic and turbiditic limestones up to the Cenomanian, and 2. by Turonian to Upper Cretaceous, possibly Lower Tertiary flysch and wildflysch and the sedimentary emplacement of the Diabase Nappe. The sequence of Köyceğiz correlates extremely well with the sequence at Bodrum and both sequences are evidently derived from the same palaeogeographic realm. In the southeastern Aegean Sea the reconstruction of the stratigraphic sequence is greatly hampered by the small and discontinuous outcrops, but the different associations observed fit surprisingly well into the Köyceğiz series. Comparison with available data in the literature demonstrates the extension of the same palaeogeographic unit on the Datça Peninsula, the islands of Symi, Tilos, Chalki and possibly on Kos and Rhodes. Within this broad palaeogeographic realm flysch sedimentation seems to start later during the Cretaceous towards the south (Datça, Tilos) and is possibly also ranging higher up into the Lower Tertiary towards the exterior of the zone.

In the context of continental Greece, part of the Lycian sediments could be compared with the sedimentary sequences bordering the Parnasse platform internally in the Argolis peninsula. The original relations between the Lycian Nappes and the Menderes "massif" (Pelagonian realm) are still ambiguous.

Although detailed correlation of palaeogeographic and tectonic units between the Hellenides and the Taurides are still not established, some of the major features appear to be very similar (BRUNN 1960). If the Vardar Zone finds its prolongation to the northeast of Izmir, then the Menderes "massif" is very likely to be homologous to the Pelagonian basement nappe. Externally, both metamorphic complexes dip below the tectonically emplaced ophiolites and the contact is sealed in both cases by the thick sequences of the postorogenic conglomerates of the "Sillon Méso-hellénique" and the Kale-Tavas Basin (BRUNN 1960). In both cases this implies the emplacement of composite nappes on the more external zones (BERNOULLI and LAUBSCHER 1972).

Despite this gross-correlation of megatectonic units, no uniform picture of the development of both segments of the orogen can be reconstructed: it appears that tectonic boundaries are discordant in space and time, and that younger tectonic zones cut discordantly through the foreland. Whereas in northern Greece a major tectonic phase with the emplacement of an ophiolite nappe during the Early Cretaceous seems to be well established, no direct proof of this phase has been discovered until now in the Lycian Taurus. On the other hand, the emplacement of the Diabase Nappe and the Peridotite Nappe on the Intermediate Complex during the latest Cretaceous to Early Tertiary seems to coincide with only a relatively minor phase in the Vardar Zone and along the internal margin of the Pelagonian Zone (MERCIER 1966). This phase can therefore only loosely be compared with the Paleogene orogeny in Greece with its emplacement of the composite Pelagonian Nappe. A possible equivalent of the latter, however, could be represented by the emplacement of the composite Lycian nappe edifice on the Eocene flysch unit of eastern Lycia (equivalent of Pindos flysch?). In fact, in both regions the Eocene emplacement of nappes is followed by differential vertical movements dissecting and deforming the nappe edifice and leading to the intramountanous basins of the "Sillon Mésohéllenique", the Salonica and Kale-Tavas Basins. Finally, the important post-Burdigalian phase with the emplacement of the composite Lycian nappe edifice on the "autochthonous" foreland, is represented in Greece only by the decollement nappes in the most external zones of western Greece (Ionian Zone, Gavrovo Zone).

The overall similarities between the general disposition of the Hellenides and the southwestern Taurides may result from a similar succession of analogous tectonic phases, although the time of occurrence of these phases differ widely. It is still uncertain whether major discrepancies in the evolution of the two segments of the arc reflect selective preservation of different documents or whether the kinematic evolution is highly discordant with time and space.

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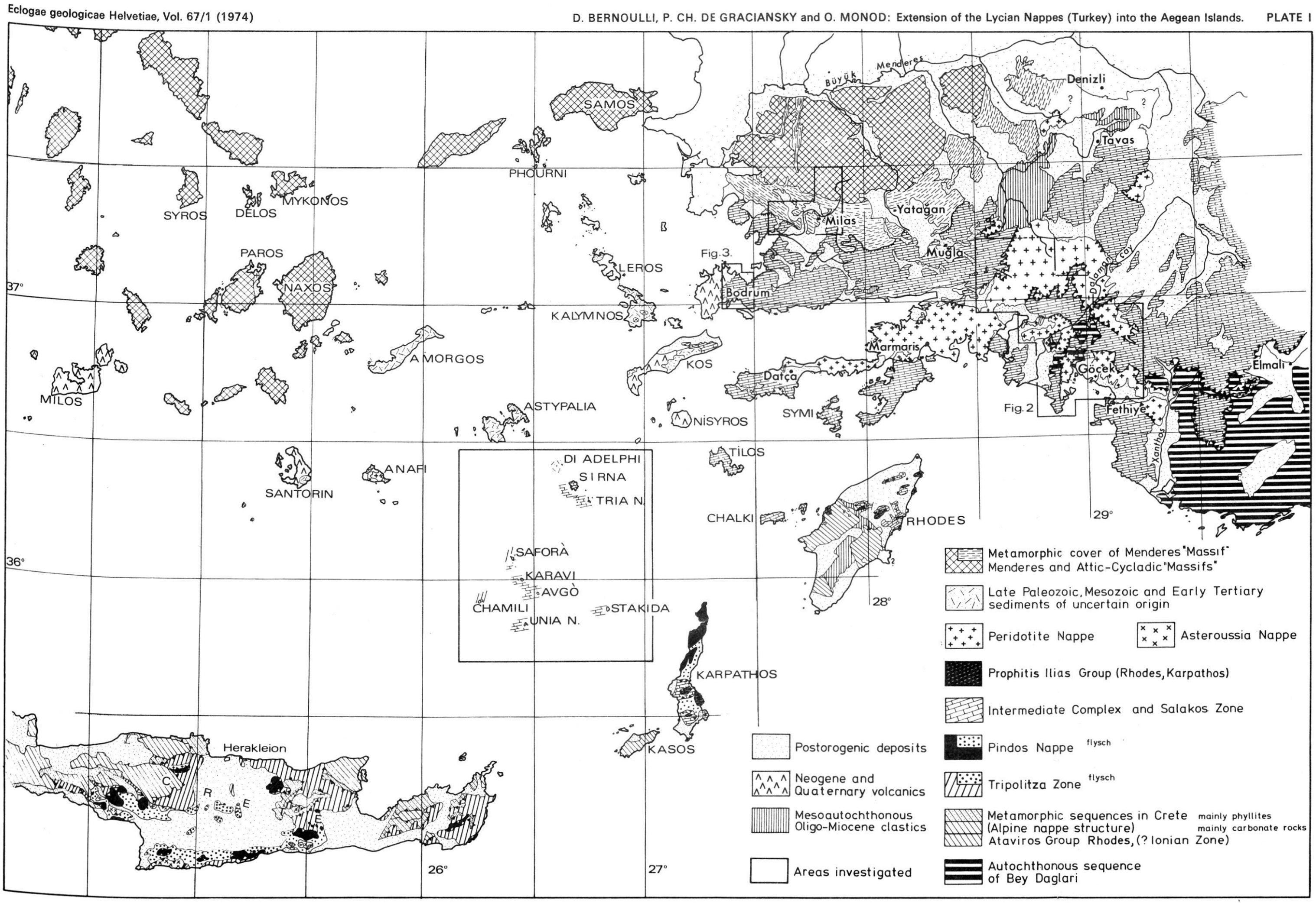
Plate 1

Tectonic map of the southeastern Aegean area, 1:2,000,000

Sources: Crete: M. BONNEAU (personal communications, 1973), N. CREUTZBURG (in preparation), EPTING et al. (1972b); Karpathos: J. DAVIDSON (personal communication, 1973); Rhodes: MUTTI et al., (1970); southwestern Turkey: BRUNN et al. (1970, 1971), OROMBELLI et al. (1967); Aegean Islands: N. CREUTZBURG (personal communications, 1969–1973), DESIO (1931), RENZ et al. (1954) and own observations.

Remarks: On Crete many of the metamorphic sequences cannot – at the actual state of knowledge – be safely allocated to the different tectonic units. Most of the carbonate rocks (Permian limestones of Talea Ori, "Streifendolomite", Plattenkalke) belong to the lowermost tectonic unit (EPTING et al. 1972) that possibly corresponds to the Ionian Zone. In part the phyllites represent the highest, Eocene, terms of this sequence (FYTROLAKIS 1972), in other cases the phyllites probably represent the Permian (PAPASTAMATIOU and REICHEL 1956) and Triassic (EPTING 1972b) substrate of the sheared-off Tripolitza sequence.

The Ethia series (Crete, Karpathos) has not been separated from the Pindos Nappe.


SAMOS
PHOURNI
SYROS
DELOS
MYKONOS
PAROS
NAXOS
LEROS
KALYMNOS
AMORGOS
MILOS
KOS
ASTYPALIA
NISYROS
SYMI
TILOS
SANTORIN
ANAFI
DI ADELPHI
SIRNA
TRIA N.
SAFORA
KARAVI
AVGÒ
CHAMILI
UNIA N.
STAKIDA
CHALKI
RHODES
KARPATHOS
KASOS
Herakleion
C
R
E
Büyük Menderes
Denizli
Tavas
Milas
Yatagan
Mugla
Fig. 3
Bodrum
Marmaris
Datça
Göcek
Fig. 2
Fethiye
Elmali
Xanthos
37°
36°
26°
27°
28°
29°
Metamorphic cover of Menderes "Massif"
Menderes and Attic-Cycladic "Massifs"
Late Paleozoic, Mesozoic and Early Tertiary sediments of uncertain origin
Peridotite Nappe
Asteroussia Nappe
Prophitis Ilias Group (Rhodes, Karpathos)
Intermediate Complex and Salakos Zone
Postorogenic deposits
Pindos Nappe flysch
Neogene and Quaternary volcanics
Tripolitza Zone flysch
Mesoautochthonous Oligo-Miocene clastics
Metamorphic sequences in Crete (Alpine nappe structure) mainly phyllites mainly carbonate rocks
Ataviros Group Rhodes, (? Ionian Zone)
Areas investigated
Autochthonous sequence of Bey Daglari