**Zeitschrift:** Eclogae Geologicae Helvetiae

**Herausgeber:** Schweizerische Geologische Gesellschaft

**Band:** 67 (1974)

**Heft:** 1

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

**Autor:** Bernoulli, Daniel / Graciansky, Pierre Charles de / Monod, Olivier

**Kapitel:** 3: The Mesozoic sequences of the Lycian Nappes

**DOI:** https://doi.org/10.5169/seals-164280

**Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Mehr erfahren

**Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. En savoir plus

**Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. Find out more

**Download PDF:** 27.12.2025

**ETH-Bibliothek Zürich, E-Periodica, https://www.e-periodica.ch**

*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.

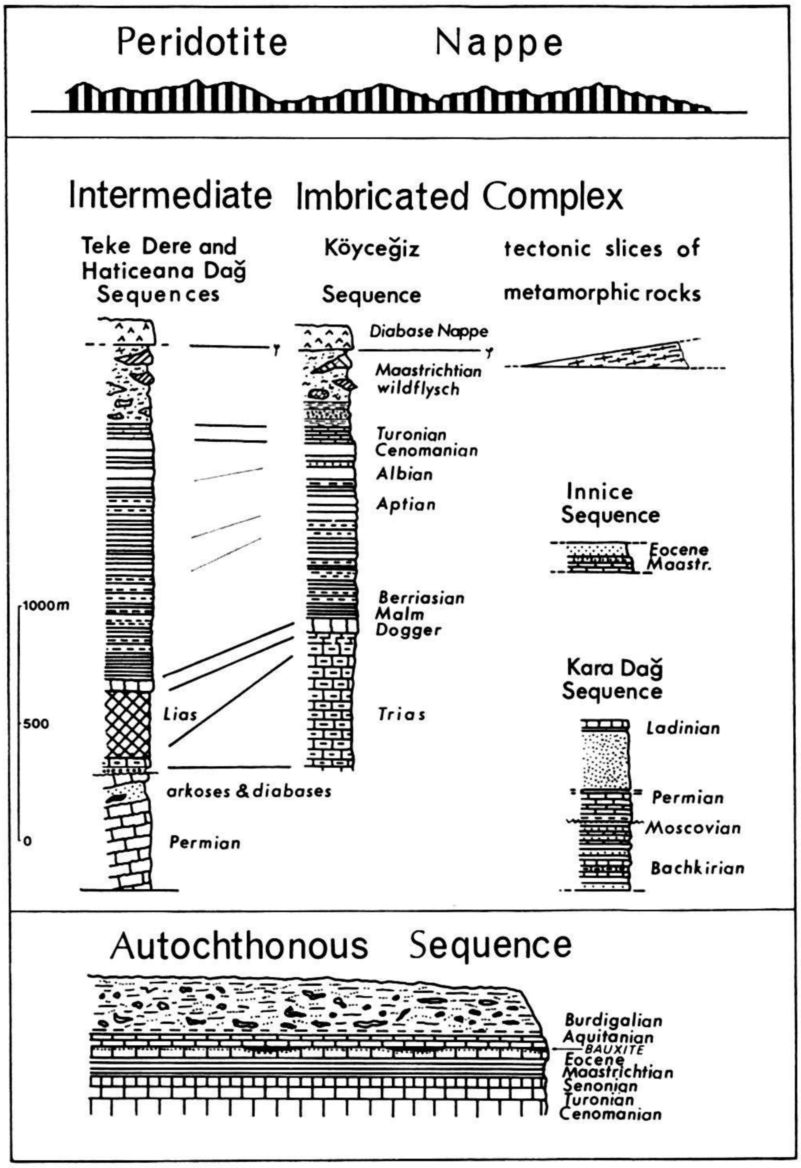


Fig. 5. Simplified stratigraphic sequences of the Lycian Nappes (from GRACIANSKY 1968, modified).

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

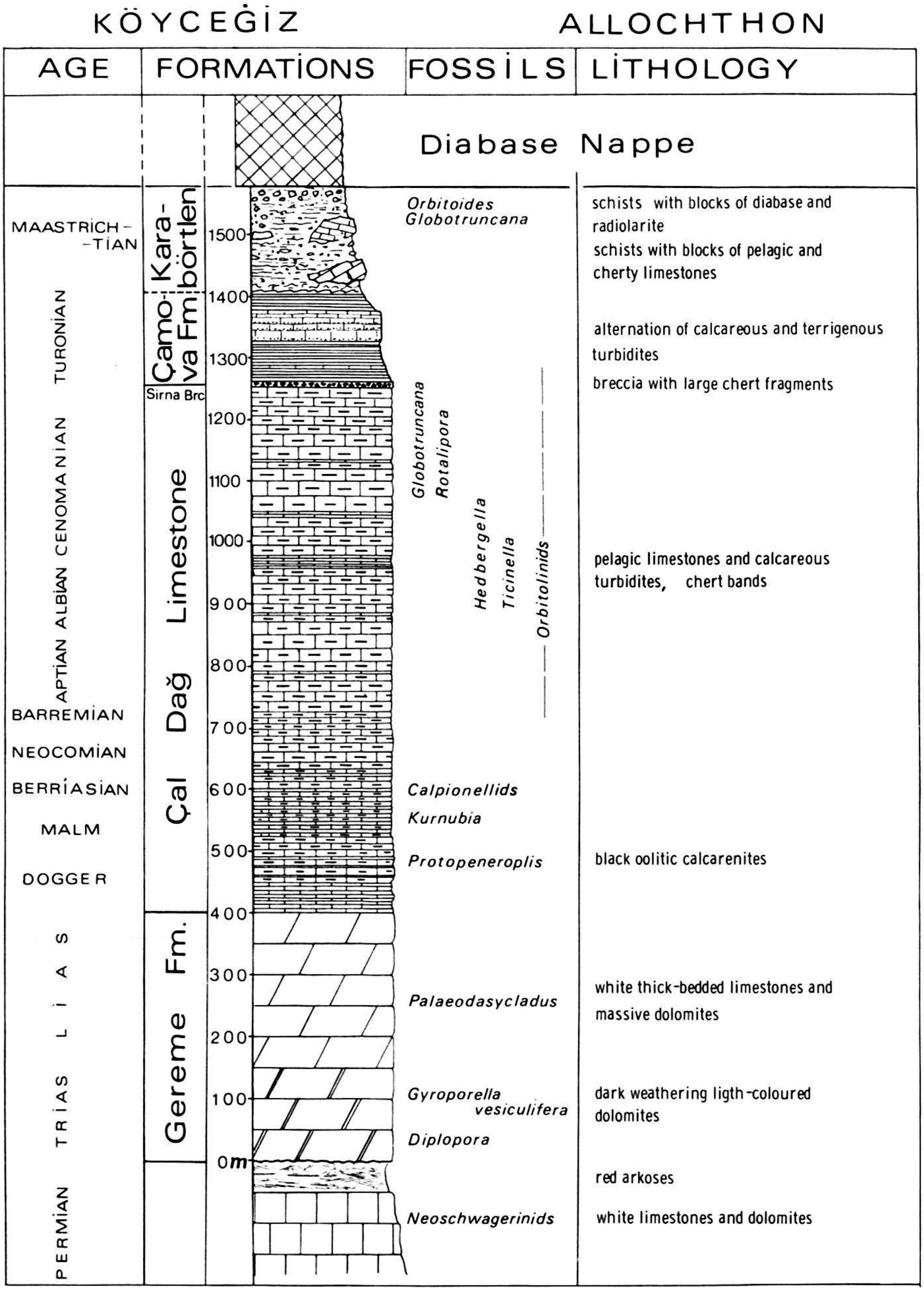


Fig. 6. Stratigraphic sequence of the Köyceğiz series in the type-area.

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.

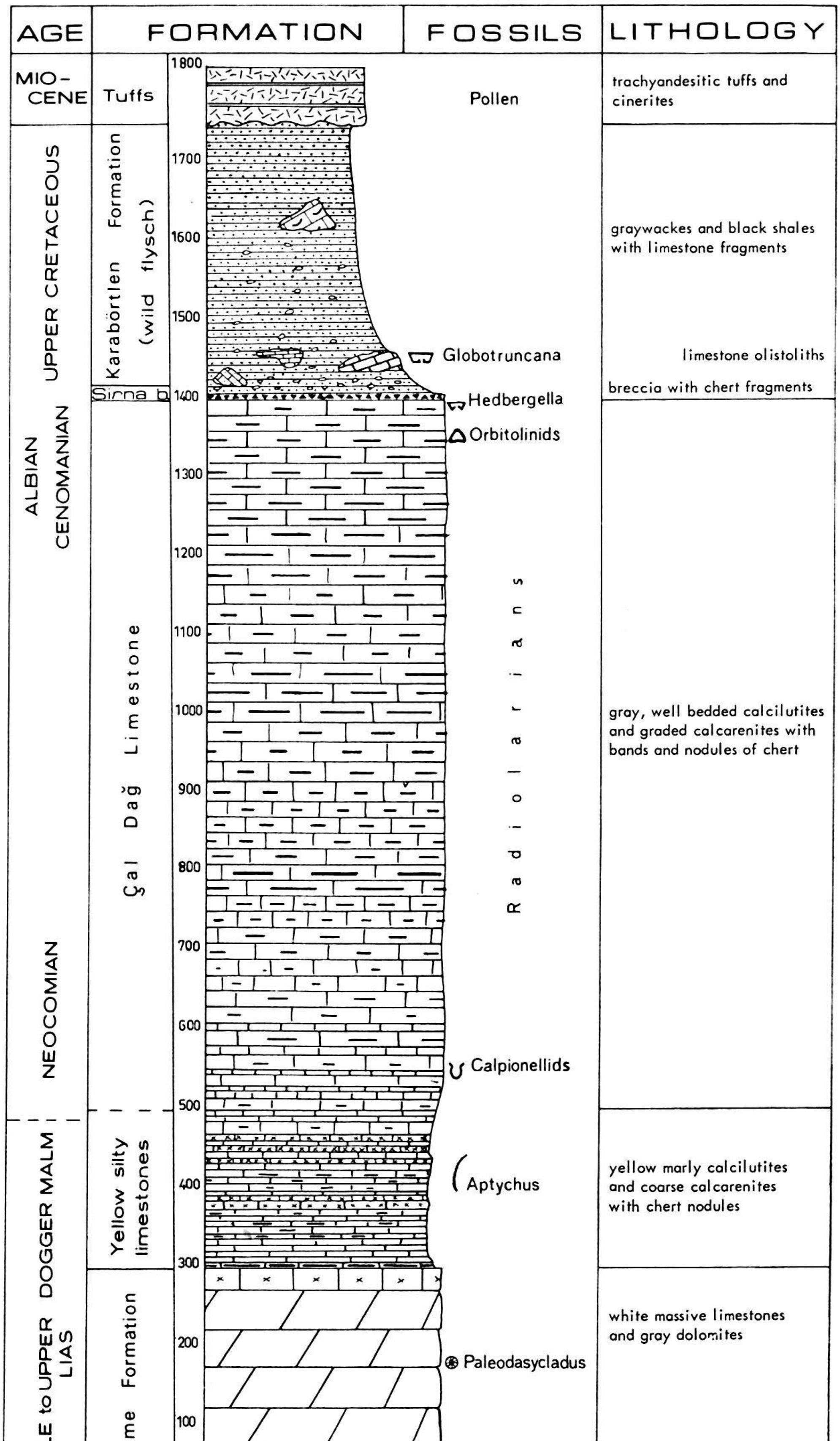


Fig. 7. Stratigraphic sequence of the Köyceğiz series at Bodrum.

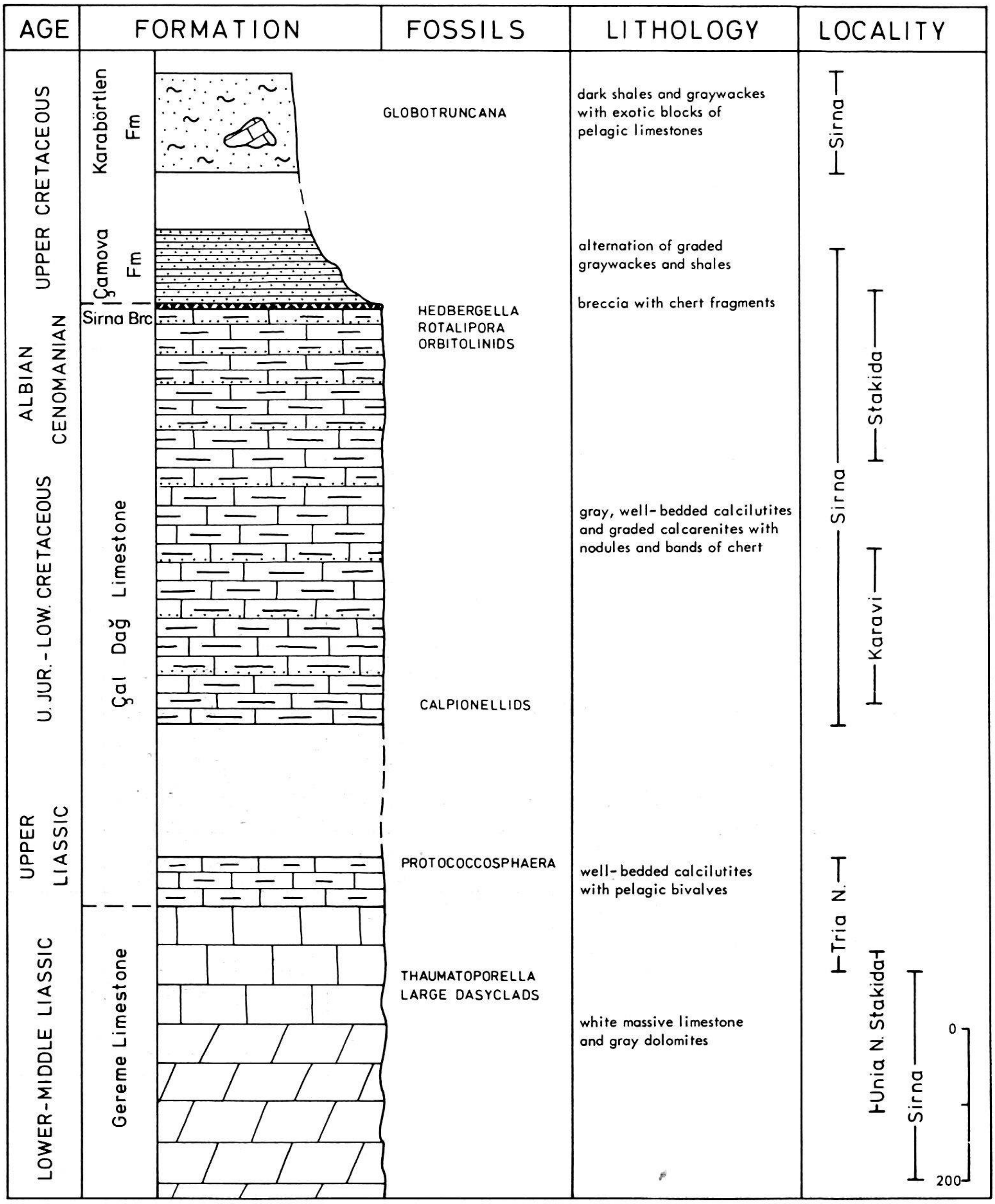


Fig. 8. Composite stratigraphic section of the Intermediate Complex in the small islands between Crete, Karpathos and Astypalia.

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),

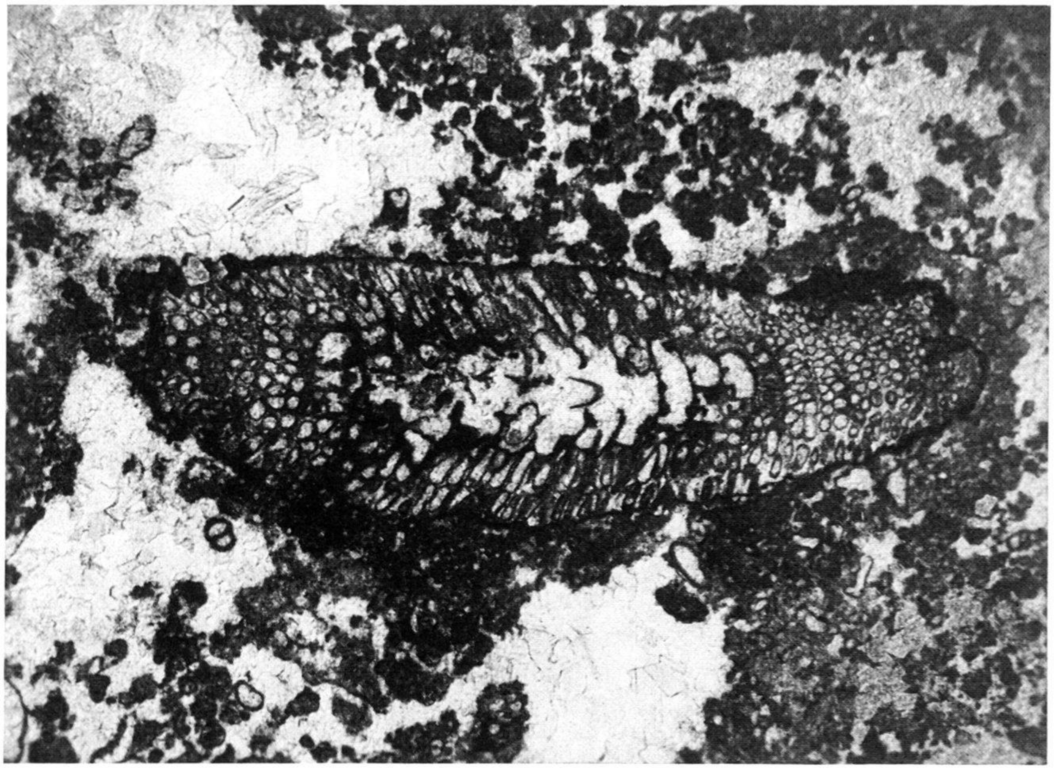

Fig. 9. Pelletoidal lime grainstones with *Palaeodasycladus mediterraneus* Pia, large calcite-cemented voids due to leaching, large late-diagenetic dolomite rhombs. Gereme Limestone, Lower Jurassic, Karaçal Tepe, at the foot of Çal Dağ, NW of Nif. Lycian Taurus. F. 1303. Thin section. ×10.

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;

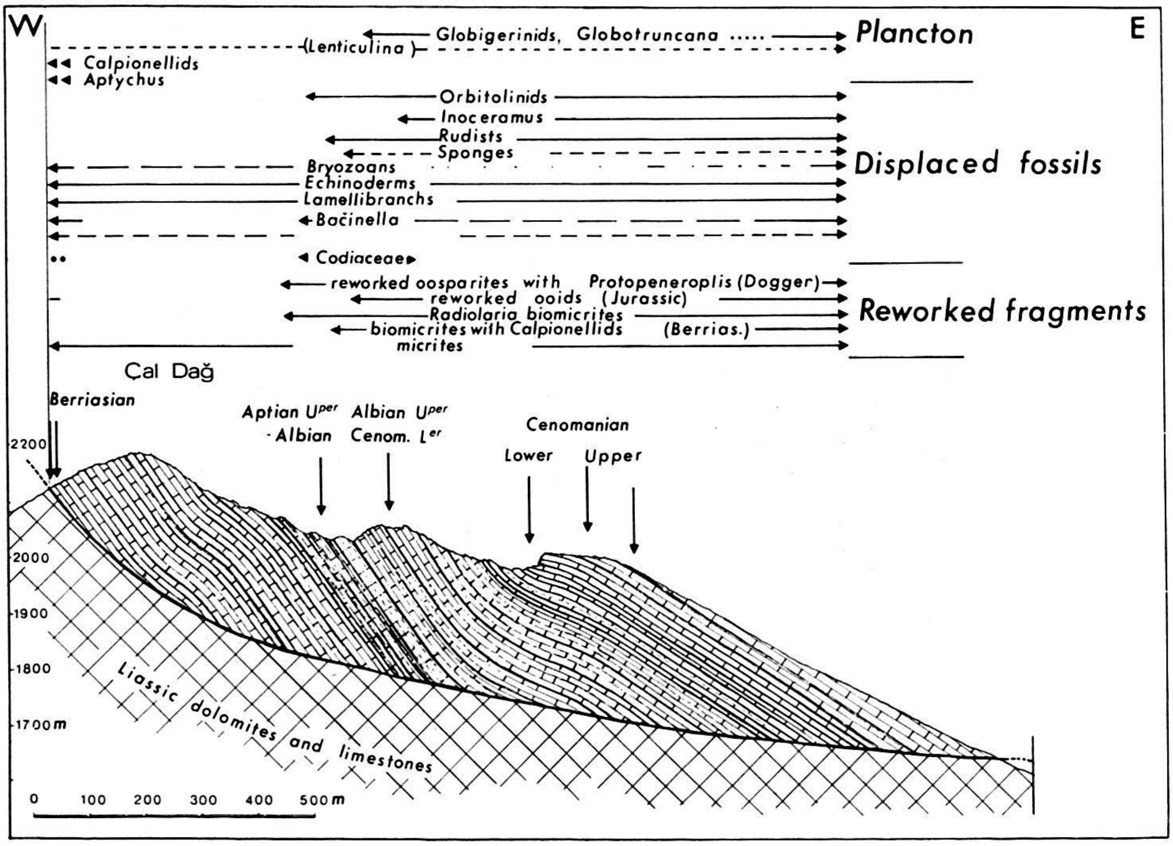


Fig. 11. Stratigraphic section of the Çal Dağ Limestone at the crest line of Çal Dağ, 5 km of NW of Nif, Lycian Taurus.

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.

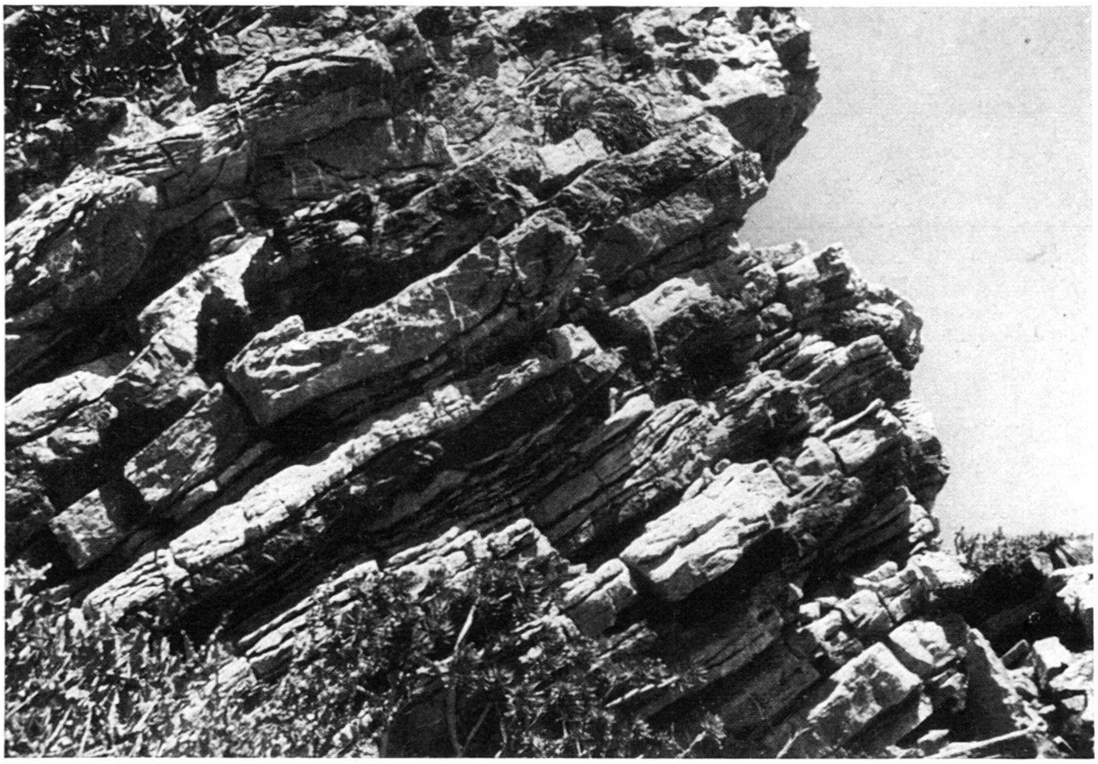

Fig. 15. Pelagic calcilutites, interbedded with graded calcarenites; nodules and bands of replacement chert. Çal Dağ Limestone, Lower Cretaceous, Island of Karavi.

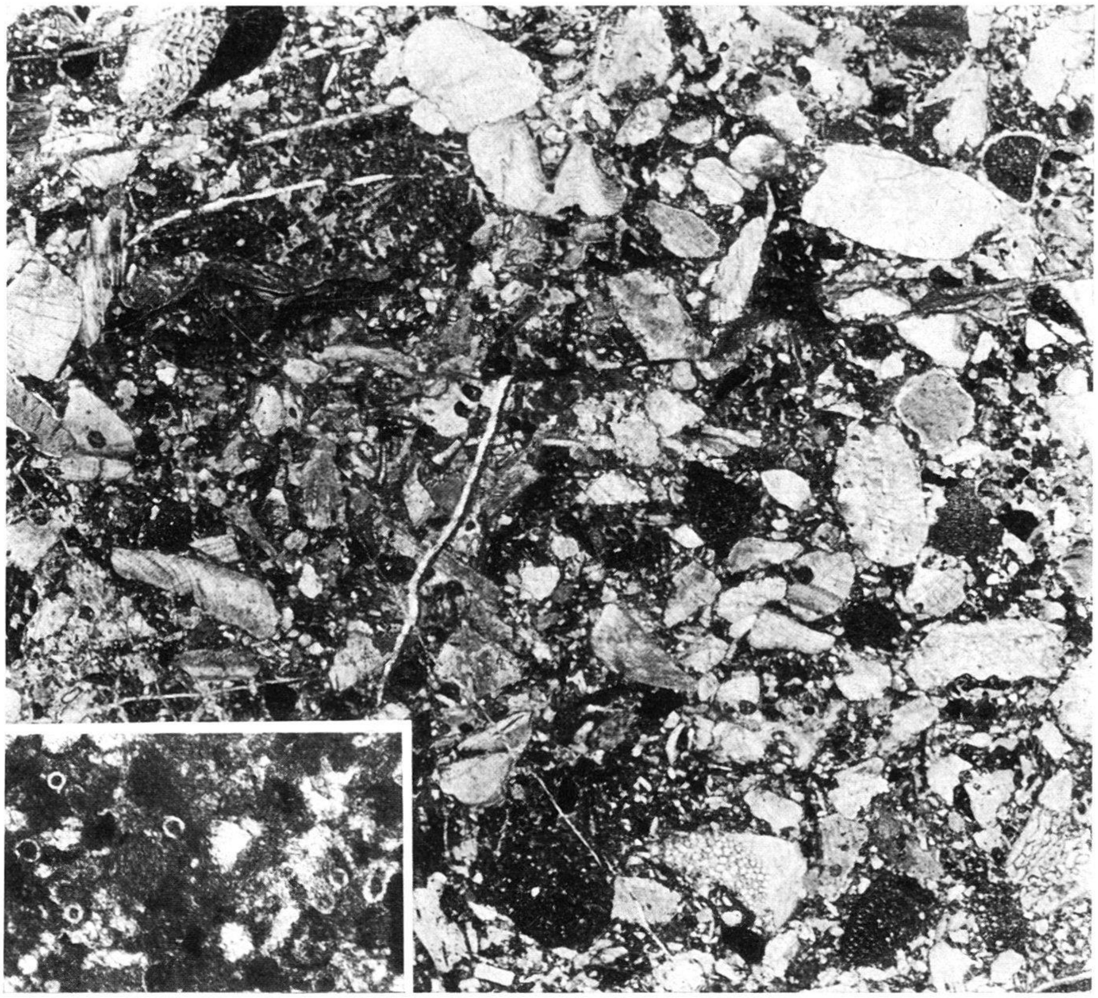

Fig. 16. Redeposited fine calcirudite to calcarenite containing closely packed skeletal debris including rudist fragments, inocerams, hydrozoans, *Orbitolina* and lithic fragments of pre-existing formations (*Calpionella* limestones).
Çal Dağ Limestone, Upper Albian to Lower Cenomanian, Çal Dağ, Lycian 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:

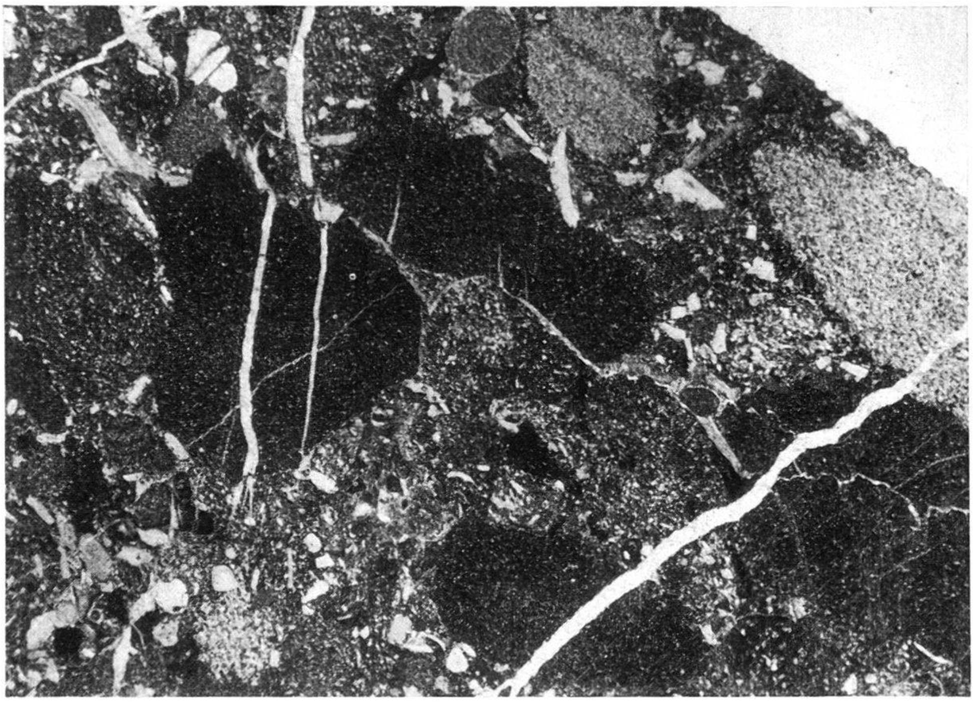

Fig. 17. Lithoclast-bioclast lime packstone, containing closely packed, solution-welded displaced skeletal fragments (rudist, echinoderm fragments, orbitolinids) and pelagic wackestone pebbles containing fine biogenic material (*Pithonella*, small globigerinids, spicules and occasional larger planktonic 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

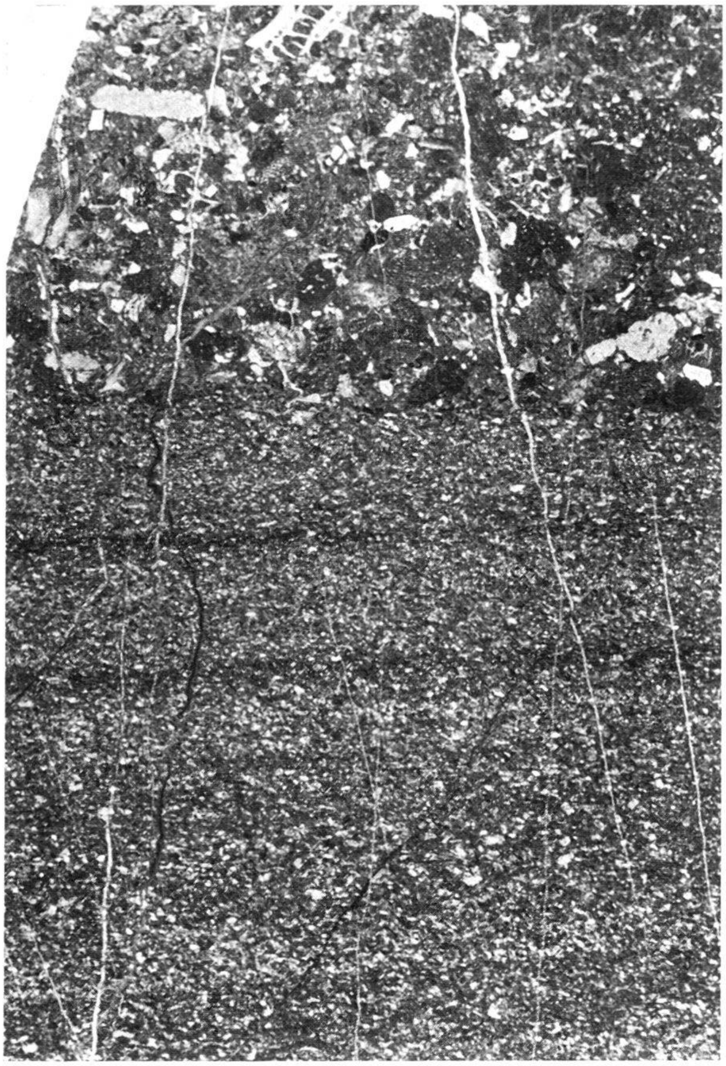

Fig. 18. Redeposited, graded and laminated fine calcarenite to calcisiltite, overlain by coarse graded calcarenite. The lower, finer grained lithology contains mainly closely packed skeletal fragments including obviously displaced crinoid, mollusc and brachiopod remains with intermixed planktonic foraminifera (*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)

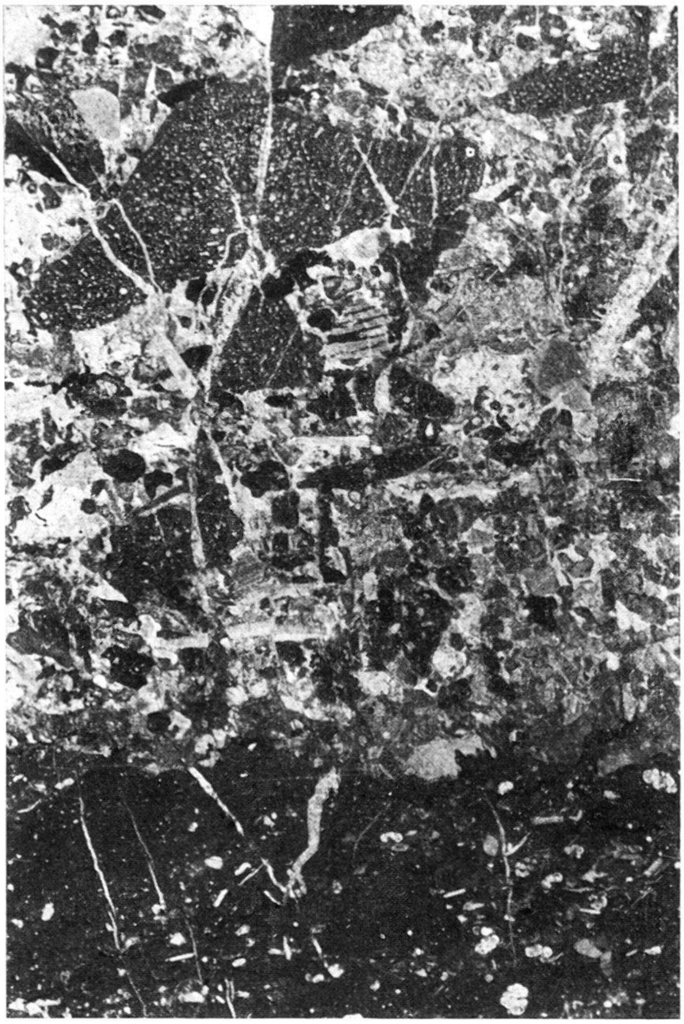

Fig. 19. Redeposited bioclastic to lithoclastic calcarenite overlying a pelagic foraminiferal lime wackestone. The calcarenite contains mainly closely packed skeletal fragments of echinoderms, rudists and *Orbitolina* and various lithoclasts. In the pelagic limestone a.o. *Ticinella* ex. gr. *roberti* (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

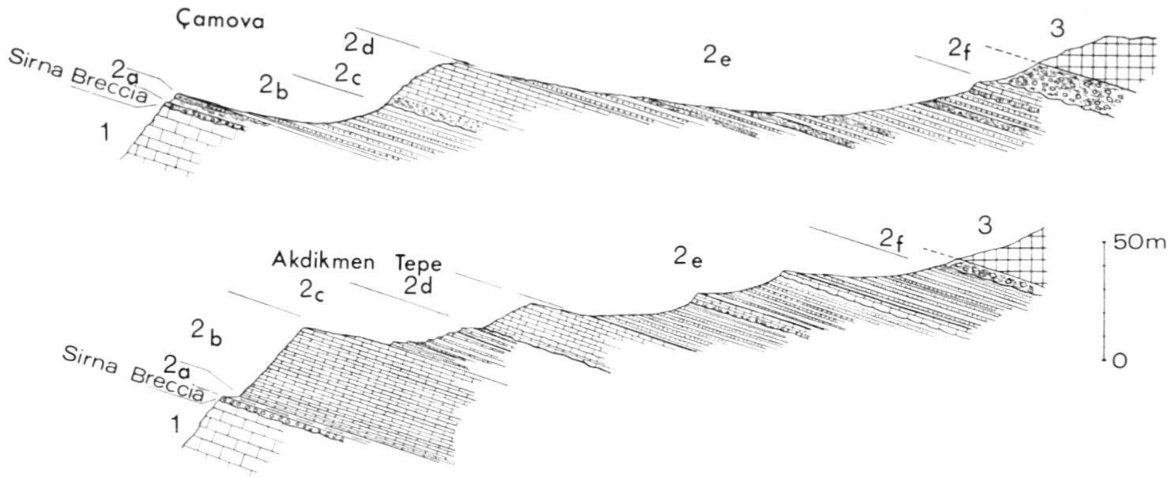


Fig. 22. Stratigraphic sections in the Çamova Formation in the Köyceğiz allochthon, Lycian Taurus. *3* Diabase Nappe. *2f* Karabörtlen Formation (wildflysch), reduced to only a few meters. *2e* Graded feldspatic sandstones with subordinate graded skeletal calcarenites*). *2d* Graded skeletal calcarenites*).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

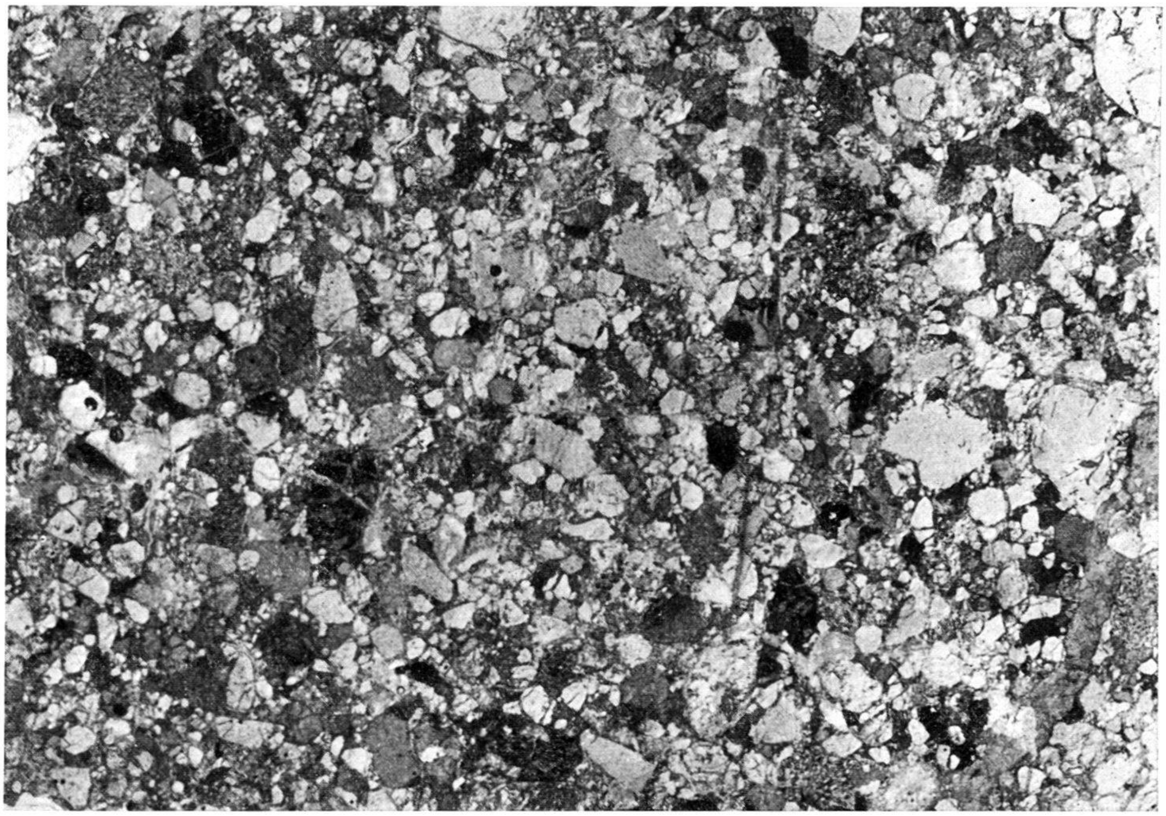

Fig. 23. Typical greywacke of Çamova Formation containing lithic particles of sedimentary rocks (quartzites, radiolarites, pelagic limestones), volcanics (diabase, fragments of pillows?), quartz, more or less altered mafic minerals, picotite and plagioclase. Upper Cretaceous. DB 1657, Island of Sirna,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

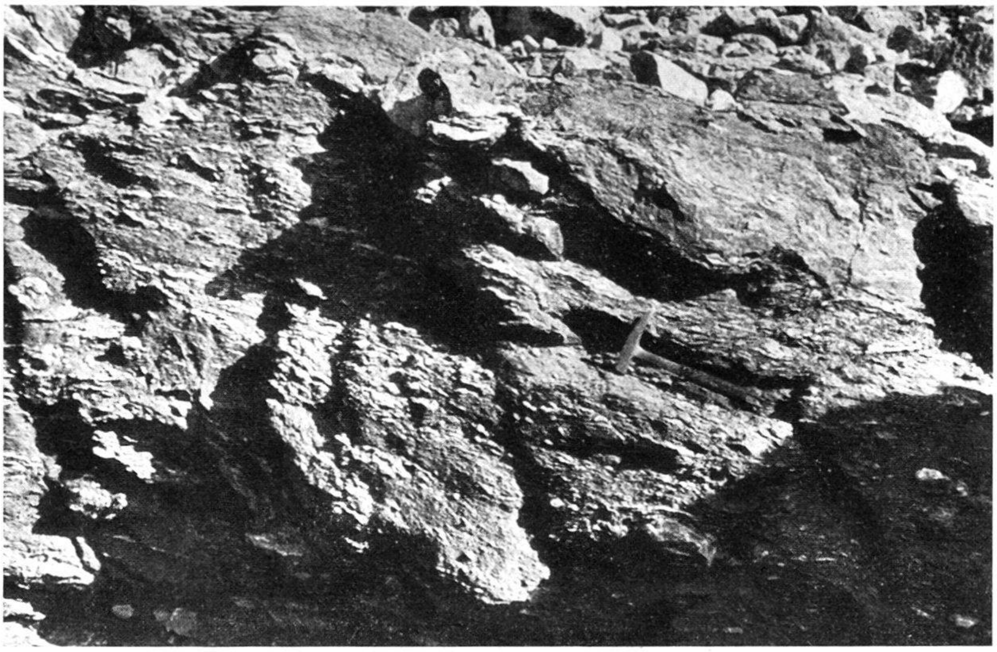

Fig. 27. Karabörtlen Formation (wildflysch): Lenses and nodules of limestone in a dark gray shaly to sandy matrix. Upper Cretaceous–? Lower Tertiary. DB 1693, north-coast of the Island of Sirna.

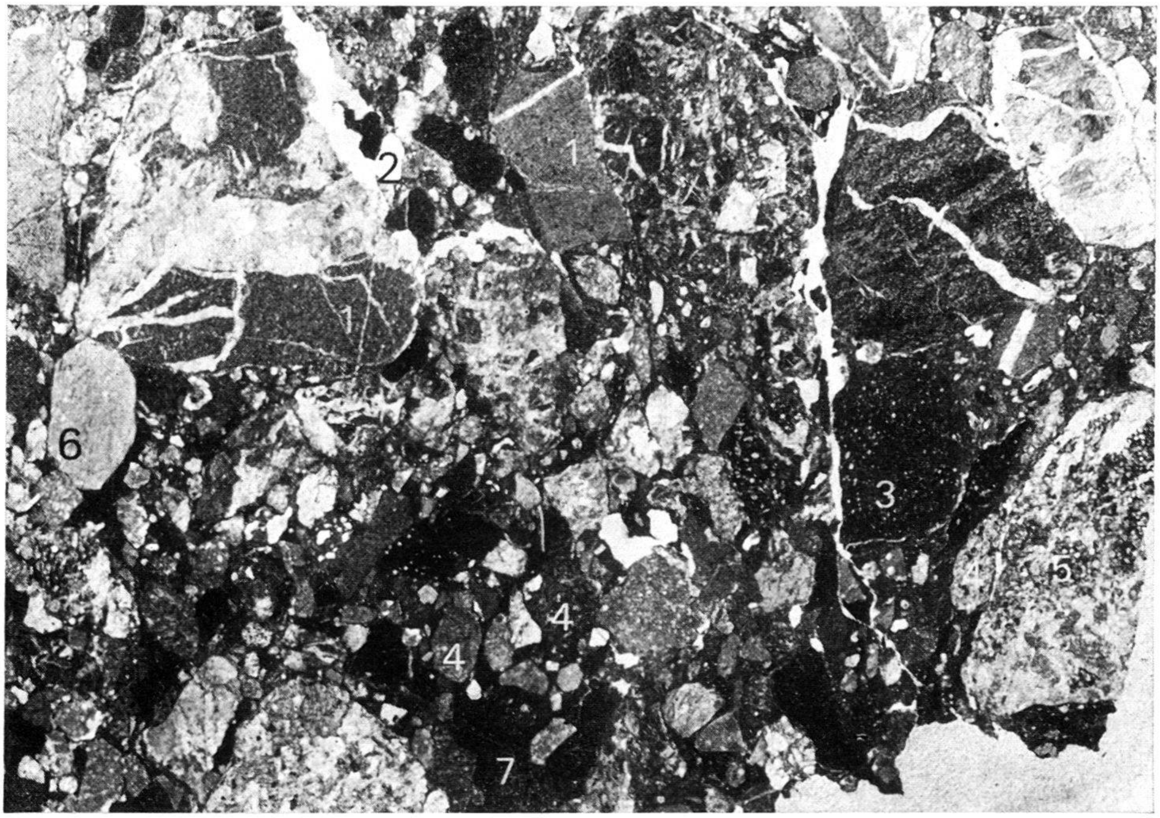


Fig. 28. Sandy matrix of Karabörtlen Formation mainly composed of lithic fragments including fine-grained limestones (1), quartzites (2), radiolarites (3), diabase (4), fragments of pillowlavas (5) and volcanic glass (6), all set in a silty matrix (7) containing some larger grains of detrital feldspar,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

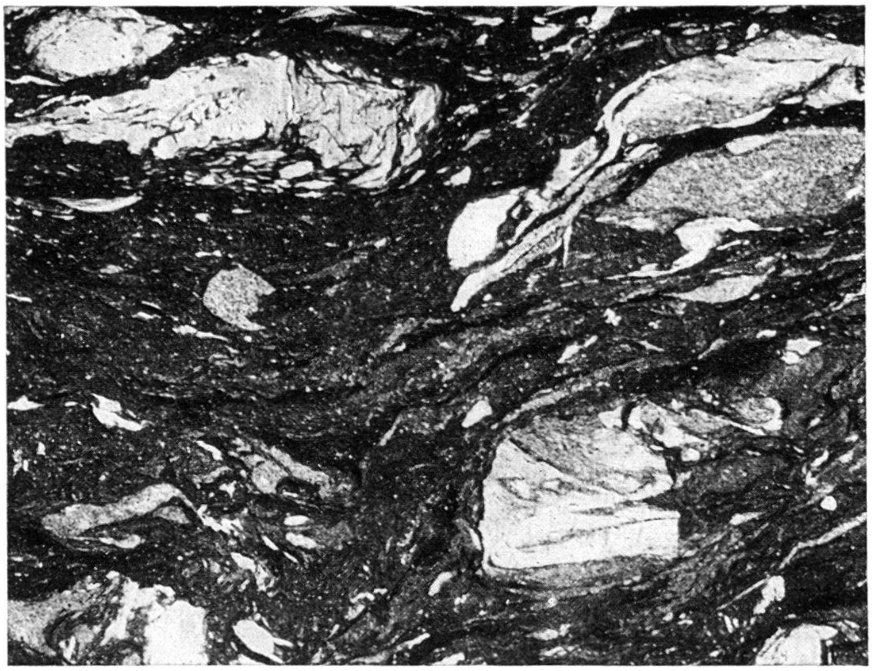

Fig. 29. Shaly matrix of Karabörtlen Formation: strongly recrystallized calcite fragments in a contorted shaly matrix. Upper Cretaceous–? Lower Tertiary. Southern slopes of Sandras Dağ, Elmatasi, Lycian Taurus. S 86, thin-section, ×4.8.

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