SEDIMENTOLOGY OF THE KARAISALI LIMESTONE AND ASSOCIATED CLASTICS (MIOCENE) OF THE NORTH WEST FLANK OF THE ADANA BASIN, TURKEY.

By

Naci GORUR, B.Sc.; M.Sc.

Thesis submitted for the Doctor of Philosophy Degree of the University of London

Royal School of Mines,
Imperial College,
London, S.W.7.

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To my son Ahmet and my wife Ayten

ABSTRACT:

The rocks of the north west flank of the Adana Basin, Turkey, range in age from Palaeozoic to Kainozoic. The Kainozoic rocks form a transgressive sequence which has been divided into four formations: in ascending order these are: Gildirli, Karaisali, Guvenc and Cingoz Formations.

The Gildirli Formation lies unconformably on the pre-Miocene formations and consists of conglomerate, colcareous lithic arenite, and siltstone. It is red and unfossiliferous in the lower part (Cakmak Member) and is grey and fossiliferous in its upper part (Kabalak Tepe Member). The former is interpreted as fluviatile, the latter as marine.

The Karaisali Formation overlies and interfingers with the Gildirli Formation. It is a bioclastic limestone and shows the general characteristics of a bank (reef?) deposit. Six subfacies can be recognised:

(1) Coral-algal packstone and boundstone, (2) Small benthic foraminiferal-algal packstone, (3) Coral-algal wackestone and packstone, (4) Large benthic foraminiferal-algal packstone, (5) Globigerinid-algal packstone, (6) Globigerinid argillaceous wackestone. The first two subfacies were deposited on pre-Miocene topographical highs while the others occupied adjacent areas. Submarine diagenesis appears to have affected the Karaisali Limestone.

The Guvenc Formation has a contact which varies from gradational to onlap with the Karaisali Limestone and overlies the Gildirli Formation with a transitional contact. It is a silty, calcareous shale, which is occasionally carbonaceous, and contains a rich microfauna. Interbedding of calcareous lithic arenite and siltstone with the shale is common.

The Cingoz Formation overlies the Gildirli Formation and passes laterally and basinward into the Guvenc Shales. It appears to

be lateral equivalent ofthe higher parts of the Karaisali Limestone.It has two interfingering members:the Ayva Member,a cross-stratified pebbly calcareous feldspathic arenite and/or calcareous lithic arenite;the Topalli Member,which consists of alternating calcareous feldspathic arenite and/or calcareous lithic arenites and shales.

Thesetwo members are interpreted as being proximal and distal turbidites respectively.

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56 measured sections throughout the area

1 Key

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CHAPTER I INTRODUCTION

I.1. METHOD OF STUDY: The present thesis is concerned mainly with the Kainozoic history ofthe Karaisali area; it emphasizes the sedimentology of the Miocene rocks with particular stress on the limestones of the Karaisali Formation. The research had two phases. The first phase involved detailed geological mapping and the measurement of detailed stratigraphic sections in areas where the Miocene rocks are well exposed and show the complete stratigraphic succession. The second included laboratory examination of the samples, which were collected during the measuring of the stratigraphic sections.

During the summers of 1974-76, a total period of 7 months were spent in the field. An area of approximately 350 square kilometres was mapped and over 40 stratigraphic sections were measured with the help of Jacob's staff and Abney level and sampled with special emphasis being given to the Karaisali Limestone. Data collected in the field were plotted directly on 1/25.000 topographic maps. The sedimentological details of the stratigraphic sections were plotted using a modification of the method described by Selley (1968). In this method, the stratigraphic sections consist of columns showing rock type, grain size (in the case of terrigenous units), thickness, and sample number. Lithological and sedimentological properties of each unit are also recorded in columns, titled "description" and "environment of deposition".

Detailed laboratory study of samples was carried out during the winters of 1974-1977 using 365 thin sections, over 100 acetate-peels and 800 polished hand specimens. Laboratory work has consisted chiefly in making thin sections of selected samples in order to study the constituents and texture of the rocks. Most of these were cut at right angles to bedding with the stratigraphic top being carefully noted from field marks. Also with acetate-peel techniques large sections have been made from polished slabs, each orientated with respect to the planes of stratification. Some of the thin sections were treated with

alizarin red-S for differentiation of dolomite from calcite. Identification of minerals under the microscope was confirmed by X-ray analyses. Representative samples of various units of the area were selected and their carbonate contents were determined by using a calcimeter.

I.2. NOMENCLATURE:

2.1. Rock Colour: This has been determined by comparison with the "Munsell rock colour chart".

2.2. Size grades and shapes: For sedimentary particle size, Wenthworth's (1922) grade scale has been followed. The grain size of the sand grade particles were noted by comparing grains in hand specimen with a standard grain size chart. The shape of the clasts of conglomerates was determined by using the method described by Zingg (1935). In the description of carbonate rocks, the size and the shape of calcite crystals were described using the scheme proposed by Folk (1965) (Fig 1 2 and 3).

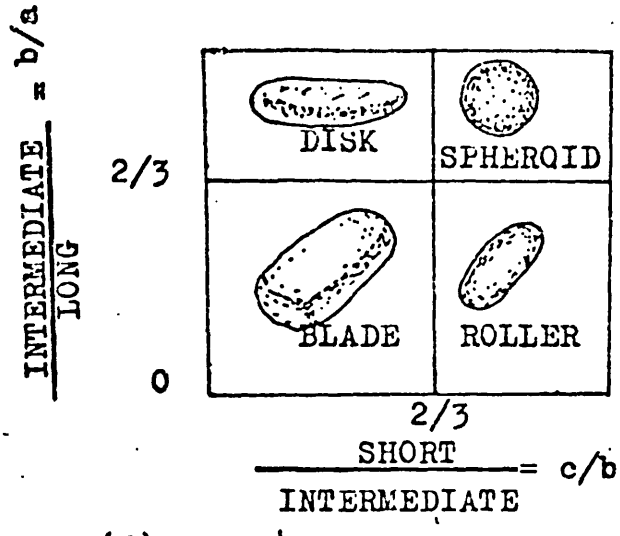
2.3. Textural components: The sedimentological terms which have been used for the microscopic descriptions of the carbonate rocks and the sandstones are defined below:

Skeletal grains: Grains which are formed of whole or part of original hard skeletons of organisms

Large benthic foraminifera: Include Heterostegina sp, Cycloclypeus sp ?, and Amhistegina sp.

Small benthic foraminifera: include miliolids, Alveolinellids with some peneroplids.

Corals: Paleoecological use of corals is verylimited in thin section studies since it is extremely difficult to differentiate similar species. For convenience, as suggested by Wells (1957 a), the term coral will be used here to include all hydrozoan, anthozoan and alcyonarian coelenterates which have calcareous skeletons.



Fig(1):Zingg's classification of pebble shapes,based on ratios of intercepts.(Zingg,1935)

SIZE(mm.)	NAME
	Extremly coarsely crystalline
4.0	
	Very coarsely crystalline
1.0	
	Coarsely crystalline
0.25	
	Medium crystalline
0.062	
	Finely crystalline
0.016	
	Very finely crystalline
0.004	
	Aphanocrystalline
0.001	

Fig(2):Crystal size scale(Folk,1965)

CRYSTAL SHAPE	LENGTH TO WIDTH RATIO
Equant	Less than $1_{1/2}$:1
Bladed	Between $1_{1/2}$:1 and 6:1
Fibrous	Greater than 6:1

Fig(3):Crystal shape(Folk,1965)

Non-skeletal grains: Consist of all inorganic particles, such as quartz, rock fragments, pellets, etc.

Matrix: Sedimentary particles which have been mechanically deposited between the framework grains.

Micrite: Carbonate mud with crystal diameters from 1 to 4 microns (Folk, 1965; Bathurst, 1971).

Microspar: Mosaic of calcite crystals with diameters from 4 to 40 microns (Folk, 1965).

Sparry calcite: Mosaic of calcite crystals larger than microspar.

2.4. Rock names: Carbonate rocks are named by using the simpler terminology of Dunham (1962) (Fig. 4). For the sandstones, the terminology of Gilbert et al (1954) was adopted.

2.5. Terminology for diagenetic features: The following terms have been used in the description of the diagenetic phenomena of the rocks studied.

Solution-cavity filling: refers to the process of deposition of cement in a mould which has been left by dissolution of an aragonitic grain (mollusc, etc.) (Folk, 1965).

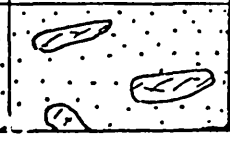
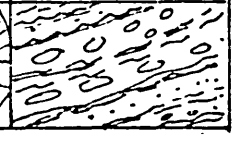
Inversion: Substitution of original aragonite by calcite without the intermediate formation of visible porosity (Folk, 1965; Bathurst, 1971).

Recrystallization: Alteration of original calcite to calcite of different grain size, morphology and orientation (Folk, 1965).

Neomorphism: Includes both inversion and recrystallization and is used when the original mineralogy of the altered grains can not be determined with certainty (Folk, 1965).

Replacement: The substitution of one mineral by another of a different composition (Folk, 1965).

Internal sedimentation: The secondary deposition of the matrix (micrite)

<table>
<tr><td colspan="3">ORIGINAL COMPONENTS NOT BOUND</td><td rowspan="2">LACKS MUD AND IS GRAIN SUPPORTED</td><td rowspan="3">ORIGINAL COMPONENTS BOUND TOGETHER DURING DEPOSITION</td></tr>
<tr><td colspan="2">CONTAINS MUD</td><td rowspan="2">GRAIN SUPPORTED</td></tr>
<tr><td>MUD SUPPORTED</td><td></td></tr>
<tr><td>Less than 10% grains</td><td>More than 10% grains</td><td></td><td></td><td></td></tr>
<tr><td>MUDSTONE</td><td>WACKESTONE</td><td>PACKSTONE</td><td>GRAINSTONE</td><td>BOUNDSTONE</td></tr>
<tr><td></td><td>  </td><td>  </td><td>  </td><td>  </td></tr>
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Fig(4):Dunham's classification(1962)

in inter and intraparticle voids during diagenesis.

2.6. Definition of term "bank": This is defined in this thesis as: a mound-like structure formed by "in situ" accumulation of skeletal debris which appears to have had some degree of resistance to wave actions. This usage agrees with the definition of "bank" by Davies (1970).

The term reef has been avoided because of considerable confusion in the use of this term in the geological literature (see discussion in L.F. Laporte, 1974). Furthermore nowhere could it be satisfactorily demonstrated in the rocks which have been studied that a true rigid skeletal framework was the major controlling feature during the development of the Karaisali Limestone, although patches of such framework existed locally. Hence, the term bank seemed more appropriate as the environment which has been envisaged was one in which coralline algae and corals grew and in which the former in particular were broken by biological and physical processes to produce a bank or mound. Both coralline algae and corals acted as baffles to help this build up and also coralline algae coated and in places bound together individual grains. The whole of the feature was however, probably a rather loosely bound mound of skeletal detritus rather than a hard rigid skeletal feature with merely infilled area of loose sediment. Of course, in spite of these reservations in the use of the term reef, the accumulation described can be referred to as a stratigraphical reef as defined by Dunham and others (Dunham, 1970; Wilson, 1975)or else it could be called a mixed buildup (Heckel, 1974) or organic bank (Wilson, 1975).

* The term replacement has been used in a general sense throughout the section on diagenesis.

I.3. PREVIOUS WORK: Geological studies in the Adana Basin began after the Second World War, mainly in connection with the Mineral Research and Exploration (M.T.A.) and the Turkish Petroleum Company (T.P.A.O.) exploration for oil and minerals.

Many foreign and Turkish geologists worked on the general geology of this basin and these have given particular attention to the Miocene formations and their oil possibilities. Unfortunately, the results of most of these studies have not been published and are mostly enclosed in confidential reports in the archieves of M.T.A., T.P.A.O., and Turkish Petroleum Administration. Some of these unpublished reports are of particular interest because of their detailed systematic stratigraphic descriptions and their lists of microfossils. Since it is not possible to give a complete list of research on this basin, the author is here going to summarize only the work which was carried out either in or around the area which is the subject of this thesis or any work which referred to the area which has been studied. Non of these studies have dealt with the detailed sedimentology of the Miocene rocks of the basin, and the present research is therefore the first report to cover this aspect in any detail.

In 1953 and 1957, Z. Ternek published the findings from his studies on the Lower Miocene formations exposed to the northwest of the Mersin-Tarsus region. He noted that these formations unconformably overlie the pre-Miocene rocks and consist of conglomerates, limestones, sandy limestones, marly limestones, and marls. The existence of lateral and vertical facies changes between these lithologies and the reefal character of the Karaisali Formation were recognised.

Following the work of Ternek, further research was carried out by M. Tasman (1957) and Erentoz-Erunal (1958) on the microfauna of the rocks of the Adana basin. Tasman correlated the sequence in four wells by means of quantitative analysis of foraminifera while Erunal-Erentoz made an attempt to compare the Adana Basin with other Miocene basins of southern Turkey, such as Karaman and Antalya.

In 1960, Stucker began a study of the stratigraphy in the northern part of the Adana Basin. He measured detailed stratigraphic sections from ten localities in this region in order to gain more information about the Lower Miocene deposition, particularly of the Burdigalian limestone (Karaisali Limestone). After a general description of these sections, Stucker concluded that the Burdigalian limestone should be considered a favourable objective for oil in the basin.

The first comprehensive stratigraphic nomenclature for the Adana Basin was published by G.C. Schmidt in 1961. In the same year, G.Sfondrini (1961) worked in the central part of the basin and but only described the general stratigraphy in his unpublished report.

More recently, Renz (1968 and 1971) and Loney and Cain (1971) described the geological setting of the Adana Basin. They noted that the Karaisali Limestone and its clastic equivalents are the earliest deposits in this basin and formed in an embayement of the Mediterranean Sea (Renz, 1971). They also suggested that this limestone developed as a reef on a pre-Miocene tectonic ridge which formed the western margin of the basin.

In 1972, H. Buchanan made an effort to gain a better understanding of the nature of the Karaisali Limestone. He examined 93 samples collected by the geologists of the Turkish Gulf Oil Company from the measured sections of the Karaisali Limestone. He differentiated 4 subfacies in this limestone, such as algal, benthic foraminiferal, planktonic foraminiferal, and mudstone subfacies. He then suggested that the Karaisali Limestone developed as a discontinuous barrier-reef along the Mersin-Tarsus-Bulgurdag trend.

The latest studies have been made by Ozer etal. (1974) and Bizon etal. (1974). Both groups carried out geological studies in the Neogene basins of Antalya, Mut, and Adana. Ozer etal (1974) made some broad micropaleontological and local geological studies in these basins; whereas Bizon etal. (1974) made some detailed micropaleontological and

biostratigraphical studies. These authors concluded that the Karaisali Limestone is Burdigalian and the Guvenc Shales are of Helvetian in age in the Karaisali area.

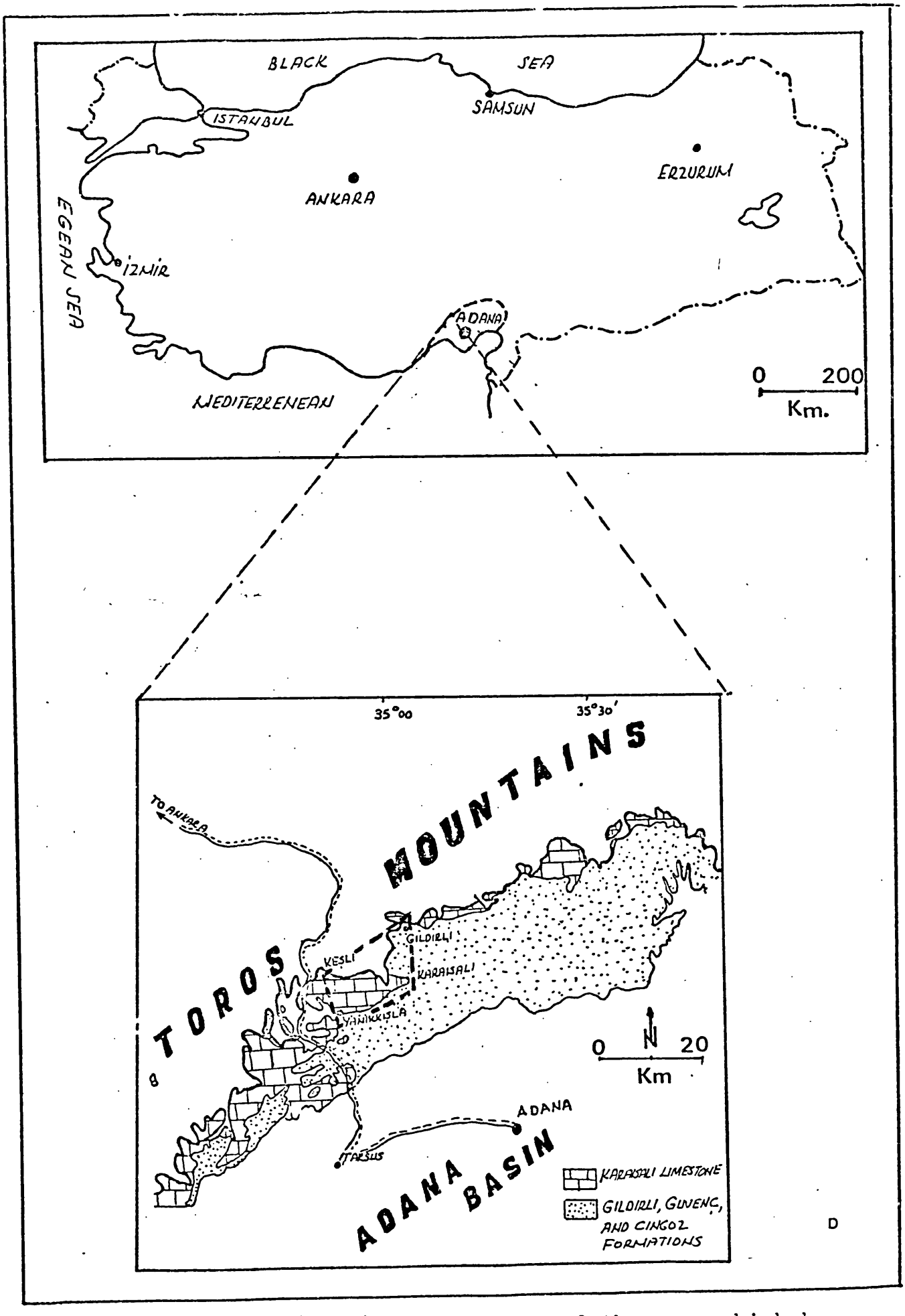
It is hoped that the present study has made a contribution to the understanding of the extremely interesting Miocene rocks of the area mainly by providing some detailed sedimentological and facies information. However, it is apparent that much work is needed to complete the understanding of these rocks and to be certain that their full potential as oil reservoirs has been exhausted.

I.4. GENERAL GEOLOGY OF THE AREA:

4.1. Geography:

(i) Location: The area which is generally known as the Karaisali embayment is located on the northwestern flank of the Miocene Adana basin. It covers about 350 square kilometres and is bounded to the north and northwest by the high Taurus Mountains, to the west by the village of Yanikkisla and Kesli, and to the east by the town of Karaisali and the village of Gildirli. The southern boundary of the area is formed by the relatively low-lying Adana plain which extends to the shores of the Mediterranean Sea (Fig. 5).

(ii) Topography: The area lies generally on the southern edge of the high Taurus Mountains, a zone of northeast-southwest trending ranges (Fig. 5). The Miocene Karaisali Limestone crops out over most of the area and it shows a complicated topography. This well indurated bioclastic limestone forms a series of continuous or discontinuous mound-like highlands throughout the area which in places in the north reach to over 1250 metres above sea level (see Cross sections D-D', F-F', G-G', K-K'). These hills are more or less continuous and connected with each other in the north and northeastern part of the area and occur as more isolated features in the southwest; here they are separated by relatively low ground where comparatively soft and argillaceous subfacies of the Karaisali Limestone or other lithologies crop out. The result is a karstic topography characterized by high carbonate uplands amongst which are areas of flat, low-lying ground (Map 1. Cross-sections B-B', C-C', D-D', E-E', F-F', G-G', K-K', L-L', Plate 1). The margins of the limestone mounds are in some places defined by abrupt and steep slopes and cliffs. A particularly sharp and continuous cliff borders the limestone plateaux in the south and forms the boundary of the carbonates of the Karaisali Formation with the Guvenc Shales (Plate 7). It commences near the town of Karaisali and extends southwestwards along the Guvenc Shale-Karaisali Limestone junction for about 15 kilometres to the



Fig(5):Location map of the area which has been studied

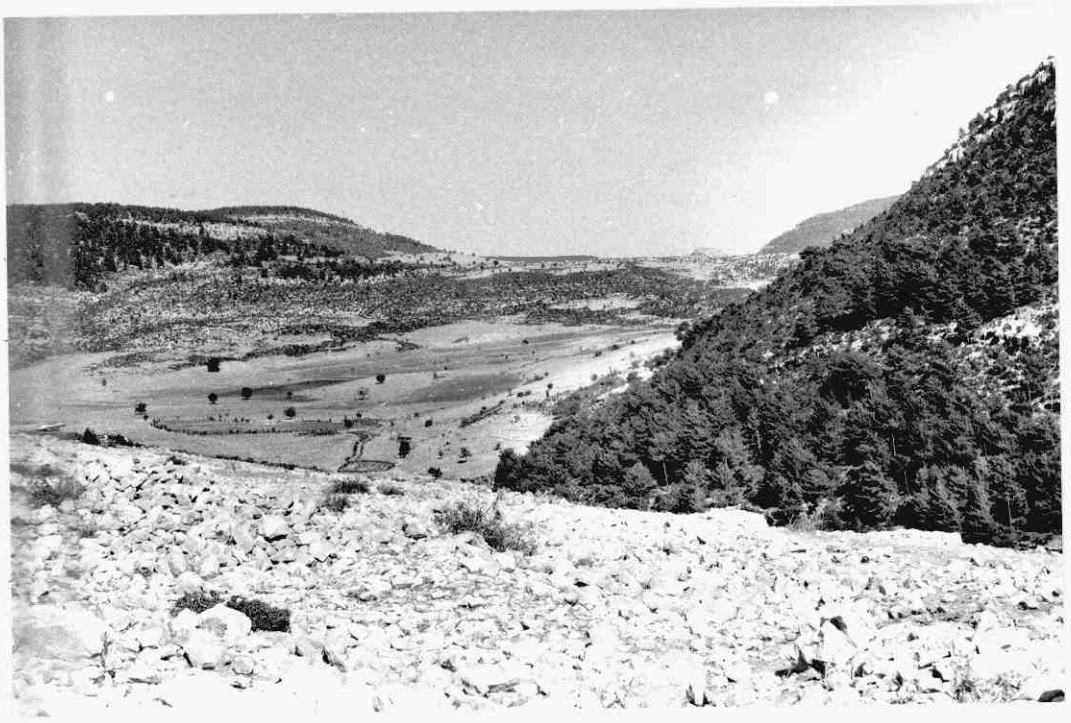


Plate (1) : Flat low-lying ground between high carbonate uplands, NE of Kuzoluk.

village of Bucak. It may rise to about 250 metres from the low shale covered ground. This impressive cliff and other similar features have caused a certain amount of confusion amongst the geologists who have worked in the region. They, perhaps understandably, were inclined to give a tectonic origin for the formation of the cliffs and the scarps. However, with more detailed observations, it can be seen that the tectonic causes are not always the best solution and in most cases the author has failed to produce any evidence of faults along these scarps. Instead it became increasingly clear that these features are merely related to a change from hard limestones to relatively softer argillaceous limestones and shales; the latter were easily eroded and left these scarps exposed. Of course, this observation does not deny the possibility of a tectonic origin for some of these steep slopes; one with such an origin was found by the author in the Kuzoluk area (Map 1, Cross-sections F-F', G-G', L-L', Plate 11).

The limestone highlands show an irregular, rough and pitted surface with some well developed sink holes. They are bare or only have a very thin cover of soil.

(iii) Drainage: The principal river of the area is the Cakit which flows in an approximately north-south direction. This river originates in the Taurus Mountains and cuts deep valleys and gorges as it descends from the mountains towards the Adana Plain (Plate 2). Elsewhere, there are only minor streams which flow only during the rainy seasons.

(iv) Climate: The area is generally characterized by the typical Mediterranean climate: hot summers and mild winters. The wettest seasons are usually winter and spring with a small amount of snow. Besides these general characteristics of the Mediterranean climate, the region shows slight variations in these conditions owing to a wide range in surface altitudes. The high mountains have cooler summer and colder winter temperatures and greater accumulations of snow and



Plate (2) : The gorge of the Cakit, near the village of Arapali.

greater rainfall compared with the areas of lower altitudes.

(v) Vegetation: Pine forests are common in the area. They are however, limited to its northern parts mostly above an altitude of 1000 metres. They become sparse below this altitude and are replaced by scrubby vegetation. The interesting point about this scrub is that its growth is favoured mostly on the rough surface of the coral-algal packstones and boundstones of the Karaisali Formation. This control may be very helpful for mapping purpose, particularly, for the differentiation of the relatively softer, argillaceous, and globigerinid bearing packstones and wackestones from those of the hard coral-algal packstones and boundstones.

(vi) Road conditions: The region is accessible by only one asphalt road from Adana. A main railway passes through the region from Adana to Ankara (Map 1). All other roads which connect the small villages and the towns of the region are generally earth roads and are often unusable in the rainy seasons.

4.2. Geological succession

(i) General: The rock formations of the area were formed during the Palaeozoic, Mesozoic and Kainozoic eras. The Kainozoic rocks, which are mostly Miocene in age, are characterized by conglomerates, sandstones, limestones and shales. They cover vast areas and include the main Miocene formations of the region. These formations are the subject of this thesis and will be described in detail with a particular stress on the limestones (Karaisali Formation). Very little work has been done by the author on the Palaeozoic and Mesozoic rocks and only a brief description of them will be given here.

For purposes of uniformity and continuity, the author has adopted the now widely accepted stratigraphical nomenclature of the Adana Basin which was presented by Schmidt(1961). In this nomenclature, the Miocene rocks have been divided into several distinct formations; those studied by the present author being the Gildirli, Karaisali, Güvenc, and the Cingoz Form-

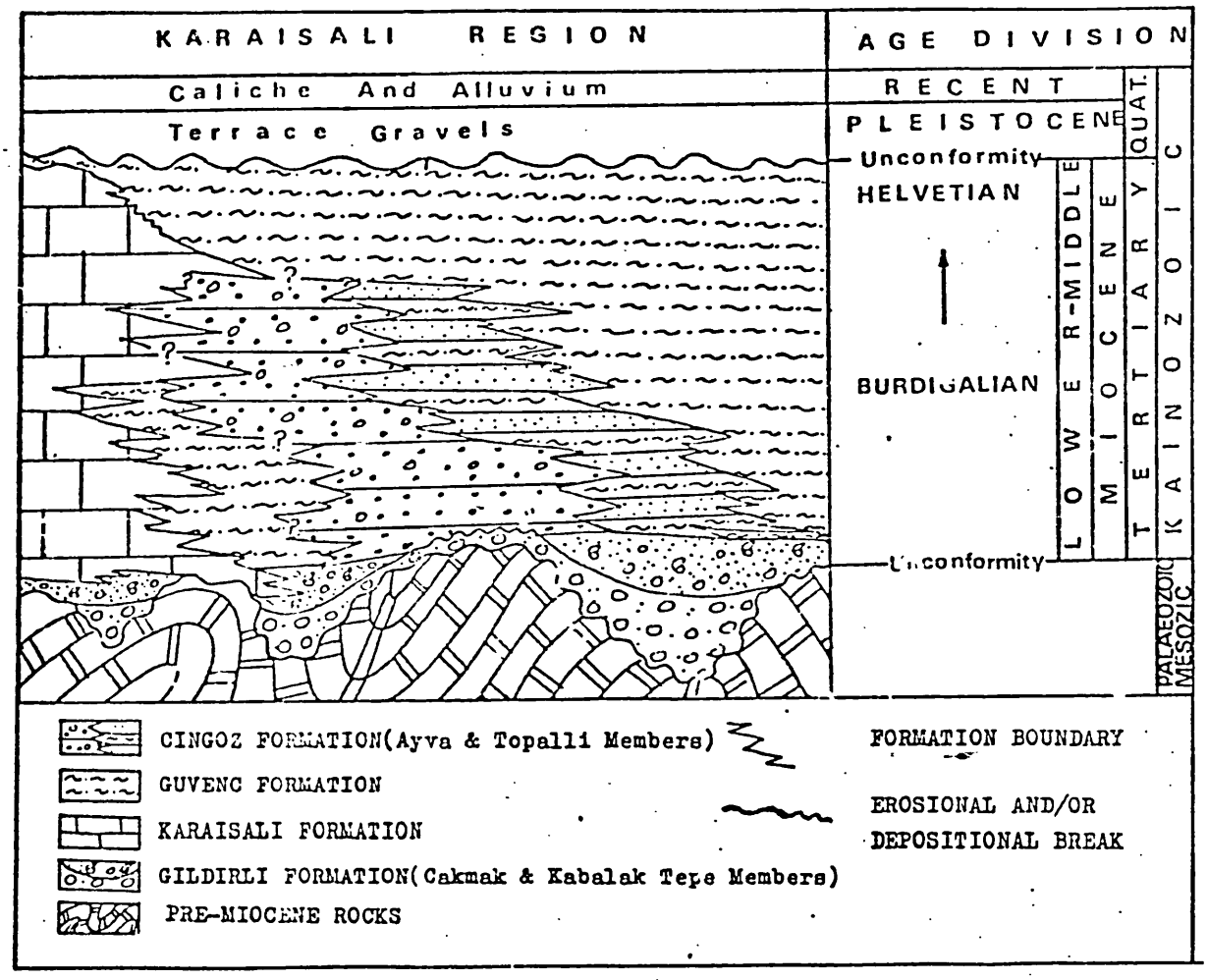
ations. However, in the present study, the Gildirli Formation has been subdivided further into two members: the Cakmak and the Kabalak Tepe.

The stratigraphical descriptions of this thesis are based entirely on the original fields observations and show some slight differences from those of Schmidt. Such differences are understandable, not only because of the scale of the area which has been studied, but also in view of the complex stratigraphic relations of the area. The distribution and the structure of the Gildirli, Karaisali, Guvenc, and the Cingoz Formations are shown on Map 1, and Cross-sections from A-A' to M-M'. Their relationships are shown diagrammatically in figure (6). These formations and their relationships to one another will be described in the following few pages from the base to top, unless otherwise indicated.

(ii) Pre-Miocene rocks: These rocks are largely limited to the northern part of the area but are also exposed in the Cakit Valley, elsewhere they are concealed beneath the Miocene rocks. They consist of sandstones, dolomites, and limestones of Palaeozoic and Cretaceous age. The outcrops of the Palaeozoic formations in the Cakit Valley, west of Karaisali are comprised of dark grey limestone, shaley limestone, grey to brown dolomite, dolomitic limestone, quartzitic sandstone and shales. In some places these shales are fossiliferous and contain fusulinids.

Rocks of the Cretaceous formations are the most widely exposed pre-Miocene rocks in the area. They form high mountains in the north and descend towards the south where they are covered by the Miocene rocks. However, some small scattered outcrops which protrude through the Miocene covers may be seen throughout the area. The Cretaceous formations usually comprise of white to pink, hard carbonate mudstone of very fine grained texture. They are massive to thick bedded and are variable in thickness. Globigerina sp and Globotruncana sp are the dominant fossils found in these limestones.

(iii) Miocene rocks: The Gildirli Formation represents the



Fig(6):Stratigraphic chart of the area studied

earliest Miocene rocks of the area. This formation fills the depressions and valleys of the pre-Miocene basement and lies with a distinctive angular unconformity on all the pre-Miocene rocks (Cross-sections H-H', I-I', Map 1). It consists mainly of conglomerate, sandstone and siltstone which are characteristically pale red (5 R 6/2) to moderate reddish brown (10 R 4/6) and is unfossiliferous in the lower part (Cakmak Member) and become yellowish grey (10 YR 8/2) and/or light olive grey (5 Y 6/1) and fossiliferous in its upper parts (Kabalak Tepe Member). The stratigraphic position, sedimentary structures, and the fauna of the Cakmak and the Kabalak Tepe Members indicate that the former was deposited under fluviatile conditions, and the latter under marine conditions. The Kabalak Tepe Member shows lateral and vertical tranistional contacts with the overlying Karaisali Limestone and the Guvenc Shales (Cross-sections C-C', D-D', I-I', etc.). The thickness of the Gildirli Formation, as a whole, varies considerably from place to place ranging from a few metres to more than 300 metres (Schmidt, 1961).

The Karaisali Formation usually overlies the Kabalak Tepe Member of the Gildirli Formation (Cross-sections D-D', Plate50), but sometimes is also found lying immediately on the pre-Miocene rocks where the Gildirli Formation is absent (Cross-sections D-D'). It exhibits the general characteristics of a bank deposit and is made up of mostly poorly or non-bedded tight coral-algal packstones and boundstones with well bedded varieties fringing the areas of the bank growth. Six rock types are recognised in the Karaisali Formation. These are: (1) coral-algal packstone and boundstone; (2) small benthic foraminiferal-algal packstone; (3) coral-algal wackestone and packstone; (4) large benthic foraminiferal-algal packstone; (5) globigerinid-algal packstone; (6) globigerinid argillaceous wackestone.

Each of these rock types represents a distinctive subfacies of the

Karaisali Formation and is characterized by diagnostic textures and fossil content. They all grade into one another over short distances in the field (See measured sections).

The thickness of the Karaisali Formation is extremely variable and ranges from less than 1 metre to about 350 metres in the Karaisali region. According to Schmidt (1961), the maximum thickness of this lithology may be as much as 500 metres to the south in the Adana Basin.

The Guvenc Formation shows lateral and vertical transitional contacts with the Karaisali Formation in some parts of the area, e.g.; in the vicinity of Bucak and Yanikkisla (Map 1; Cross-section E-E', K-K', L-L'; Measured section Bc, Bc_1, Yk_5, etc.) and elsewhere it onlaps the Karaisali Limestone (Cross-section: B-B', M-M'). It is an olive grey (5 Y 4/1), generally silty, locally carbonaceous, calcareous shale with a particularly rich microfauna. Interbedding of sandstone and siltstone with the shales is common in parts of this formation. The thickness of the Guvenc Shales is not known in the area which has been studied, however, it may range between a few metres to 2340 metres in the Adana Basin (Schmidt, 1961).

The Cingoz Formation, which is only exposed in the northeastern part of the area, can be seen in contact with all the formations of the area, except the Karaisali Formation. It overlies both the Cakmak and the Kabalak Tepe Members of the Gildirli Formation in the Valleys of Ucurge and Kocadere, near Nergizlik (Map 1, Cross-sections B-B', H-H'). Further to the south, around Camizli and Kelkoy, the Cingoz Formation passes laterally into the Guvenc Shales and eventually dies out in these shales as it is traced southward into the deeper part of the basin (Cross-section A-A'). The contact of the Cingoz Formation with the Karaisali Limestone has never been observed in the Karaisali area, except for some block-like, but apparent "in situ" remnants, of the Karaisali Limestone which were found sitting on top of the Cingoz Formation in the vicinity of Cakmak (Plate 3). However, the outcrops

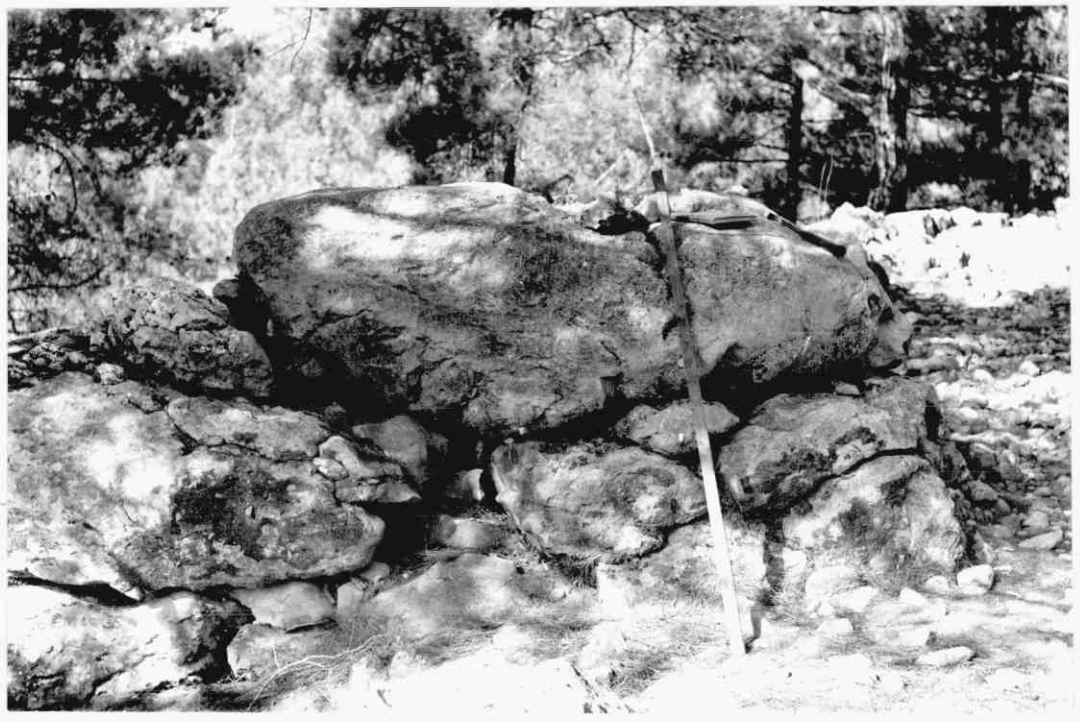


Plate (3) : In situ remnants or blocks of the Karaisali Limestone, sitting on top of the Cingoz Formation in the vicinity of the village of Cakmak.

of these very small blocks of the Karaisali Limestone indicates that the Karaisali Formation is either younger than the Cingoz Formation or more likely interfingers with it and is partly of the same age. The Cingoz Formation shows two distinct members, Ayva and Topalli (Schmidt, 1961). The Ayva Member is a yellowish grey (5 Y 7/2), granule to medium grained calcareous feldspathic arenite and/or calcareous lithic arenite with tabular crossbedding. Conglomerates and pebble bands are commonly found throughout this member.
The Topalli Member consists of alternating sandstones and shales. The sandstones are light olive grey (5 Y 6/1), coarse to very fine grained, and generally poorly sorted calcareous feldspathic arenites and/or calcareous lithic arenites. Internally, they display grading and often show erosional bases with some bottom structures (scoure and fill, groove casts, and a few flute casts). When traced southwards the Topalli Member passes into the basinal Guvenc Shales.
The Ayva and the Topalli Member are thought to be proximal and distal turbidites and follow one another in vertical sequence as well as interfingering with each other (Cross-section A-A').

(iv) Quaternary sediments: These sediments include modern alluvium in the valleys of the area and widespread caliche on the Guvenc Shales in the Karaisali region (Map 1).

The alluvium consists mainly of gravel, sand and silt. It is generally unconsolidated, but some older beds of alluvium along the river Cakit are well indurated. The gravel is sandy, poorly sorted, and ranges in colour from yellowish grey (10 YR 8/2) to moderate reddish brown (10 R 4/6). It is mainly massive or crudely bedded and sometimes shows cross-stratification. The larger clasts are of a variety of rocks that obviously represent widely different source areas. Downstream, these sediments are dominated by the sands and silts with subordinate gravels.

The caliche is found forming a capping layer with a thickness generally

of less than a metre on the Guvenc Shales of the area (Map 1). This surfical carbonate precipitate is formed by precipitation from the ground waters which ascend during the dry seasons.

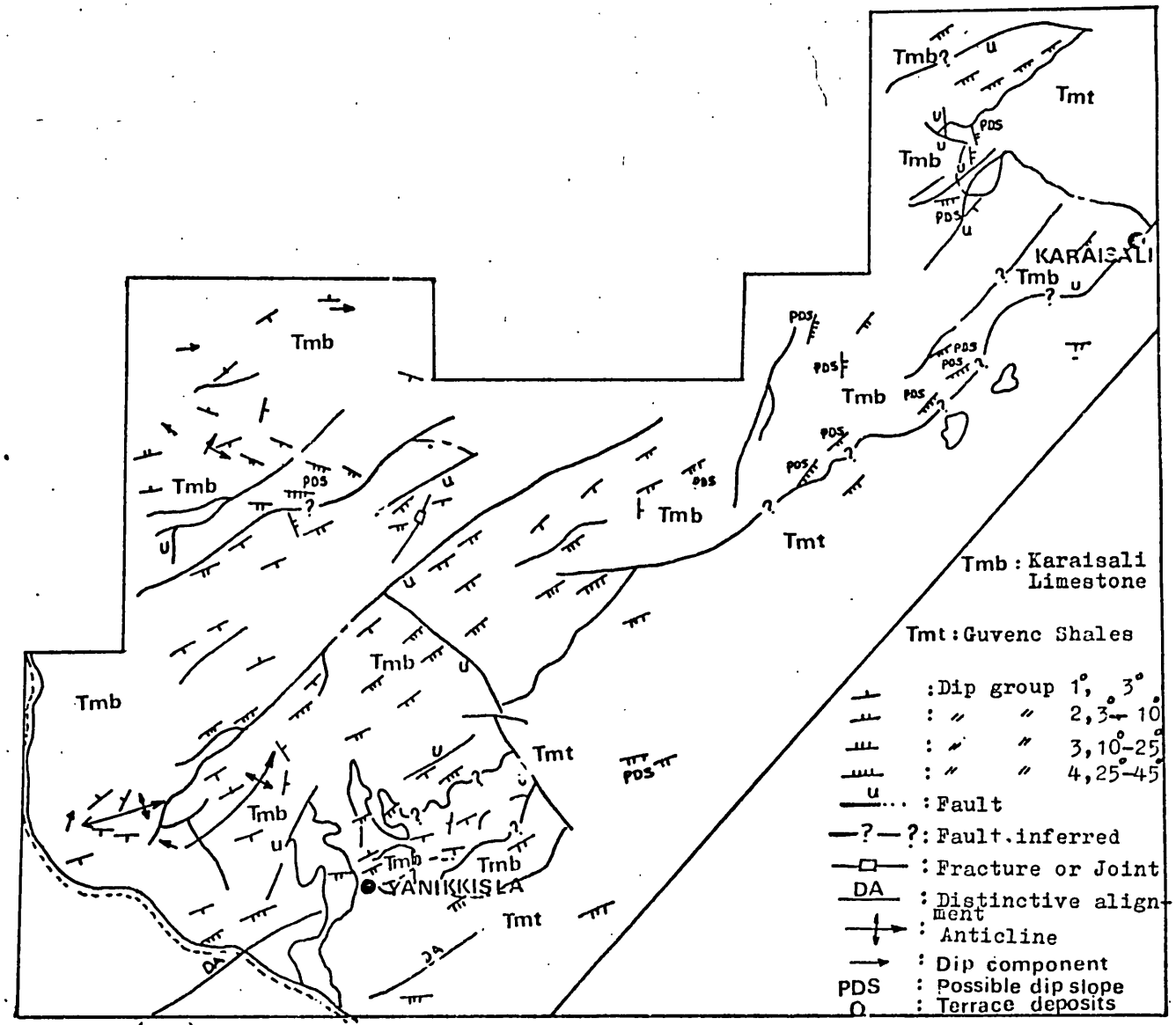
4.3. Structural geology:

(i) General: The structural pattern of the area, as a whole, is simple and although there is a gentle tectonically induced dip to the southeast, the majority of these dips and their pattern are primary depositional features and have not been produced by compressive forces. Despite the simplicity, the area has been described as a region of abundant faults and folds and considerable tectonic activities by some earlier geologists who worked in or around the area and made reference to it (Ternek, 1957; Stucker, 1960).

The photo-geological map of the area which was prepared by Geophoto Services in 1958 is also complicated by abundant faults and folds (Fig. 7). This false complexity of the geological structures of the area has been, in the view of the author, wrongly attributed to tectonic movements, although obviously a small part of it is due to such deformation. Some depositional features, such as initial dips, drape structures, compactional structures, scarps and collapse structures, and facies changes have been more important than tectonic activities in the construction of the geological structures of the area.

(ii) Primary structures:

A) Initially dipping deposits: The conglomerate and sandstone of the Gildirli Formation dip generally south and southeast between 5° and 32° and fill the bays and the valleys of the pre-Miocene land surfaces. The variation in thickness of these clastics and their occurence in the field suggest that the dips are mainly initial and are due to the deposition of the sediment in the depresions and on the slopes of the pre-Miocene topography. Thus the initial dips of the red conglomerates may be as much as 32° on the pre-Miocene slopes and may gradually become gentler towards the depres-



Fig(7):Areal geology and structural map of the area
(prepared by Geophoto Services,INC.,Denver,Colorado,1958)

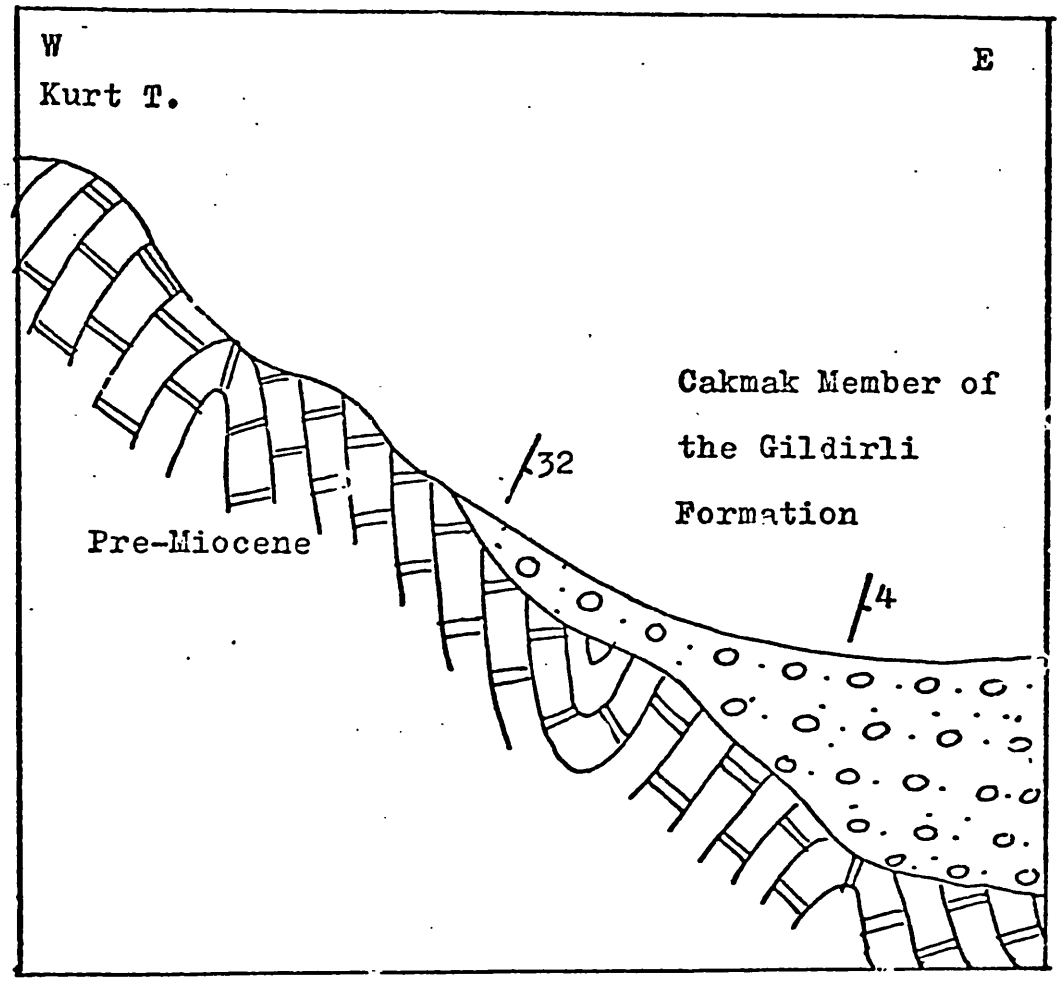
sions (Fig. 8, Map 1).

Other initial dips are found in the Coral-algal wackestone and packstone and in the Large benthic foraminiferal-algal packstone subfacies of the Karaisali Limestone Formation at different localities in the area, e.g., in the Camtepe, near the village of Kestepe (Plate 4). These two subfacies may show initial dips ranging from 10° to 40° and are associated with the non-bedded or poorly bedded and nearly horizontal Coral-algal packstone and boundstone subfacies of the Karaisali Limestone in these areas (Cross-sections I-I', Fig. 9). Steep primary dips in the Karaisali Limestone are likely to have been caused by the development of algal and coral growths on the pre-Miocene topographical highs.

From the above observations, it is obvious that the initial steep dips of the deposits and their variations in the formation and in the area may produce a complex structural pattern and caused confusion amongst the geologists who neither appreciated the nature of the surface on which the sediments were deposited nor the complex arrangement of lithologies.

B) Drape structures: Some apparent anticlines and synclines can be seen in the area; and these are seen particularly in the rocks of the Karaisali and the Gildirli Formations. They are, at most places, gentle undulatory structures and usually have primary rather than tectonic origins.

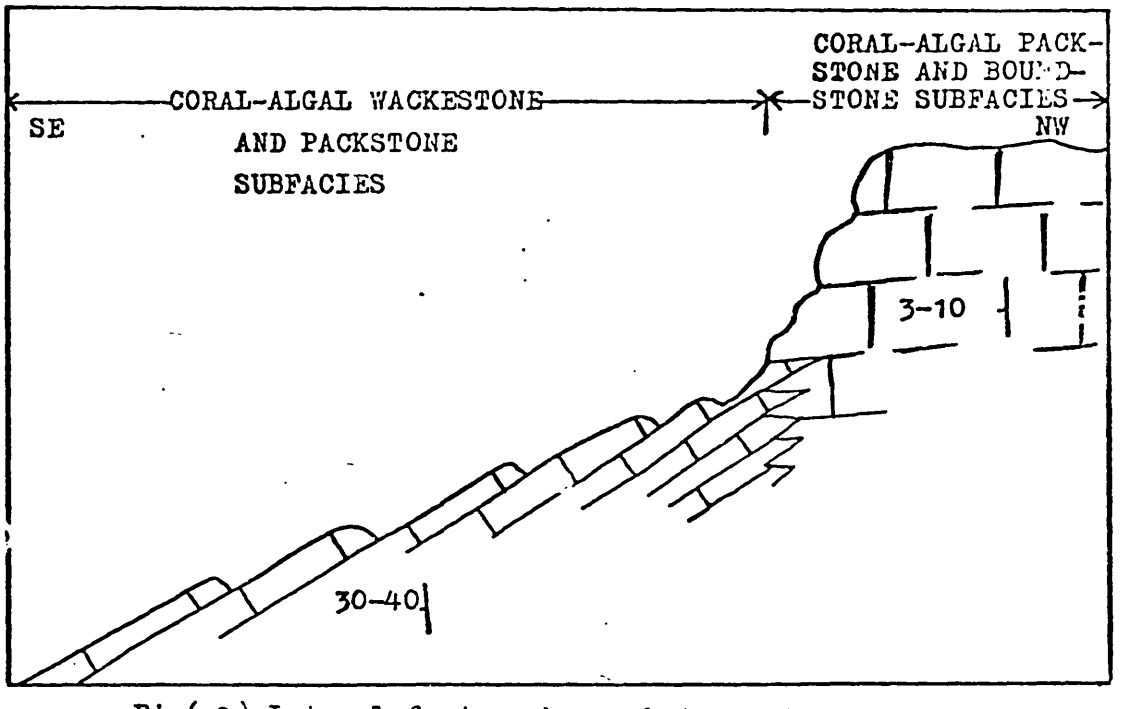
The formation of most of the pseudo-anticlines is not the result of any compressive movement but it is due to deposition of the sediments, limestone or conglomerate, on uneven pre-Miocene topographical highs. The layers of the sediments have been deposited with initial dips which conform to the topography of these highs, although they have probably been increased further by differential compaction, and broadly reflect their shapes. They are common and beautifully exposed to the north of Karaisali (Plate 5). The buried-hill structures attracted considerable interest in the oil companies in Turkey. These worked extensively in



Fig(8):Variations in the initial dips of the Cakmak Member on the pre-Miocene slopes of the Kurt Tepe,near Karakilic.



Plate (4) : Primary dips in the Coral-algal wackestone and packstone subfacies in the Cam tepe, near the Village of Kestepe (Dip is 30SE).



Fig(9):Lateral facies change between Coral-algal wackestone and packstone and Coral-algal packstone and boundstone subfacies in Camtepe ,Kestepe



Plates (5) : A buried-hill structure in the valley of Cakit (looking from E to W).



Plates (5) : A buried-hill structure in the valley of Cakit (looking from E to W).

the Adana Basin in an attempt to predict the locations of these buried hills, which have no surface expression, as they were thought to be the sites of possible stratigraphic traps. These structures were in the past and even now are sometimes confused with anticlines of tectonic origin. Ternek (1953) described an anticline in the vicinity of Yanikkisla which actually appears to be of depositional rather than of tectonic origin.

Some anticlinal-like undulations may also have been produced by growth of algae and corals on the irregular basement topography, simply because their development with non or poorly bedded cores and well bedded fringing parts generally gives a false impression of anticlines.

The majority of the "so-called synclines" of the area are also of a primary origin and have not been produced by tectonic activities. They are scattered throughout the area between the carbonate mounds of the Karaisali Formation (Map 1). These are actually nothing more than depressions of the pre-Miocene topography which are filled by the rocks of the Globigerinid-algal packstone and Globigerinid argillaceous wackestone subfacies of the Karaisali Formation. They were formed by deposition of these sediments in conformity with the uneven floor of the pre-existing depressions between the topographical highs on which the algae and corals were growing. The relationships of these sediments with the initially dipping parts of the algal-coral growths produced these false or "pseudo-synclines". It appears from the structural interpretation map and the work of Ternek (1953) that these have also been wrongly interpreted as of tectonic origin (Fig. 7). Plate 6 shows one such misinterpreted pseudo-syncline in the Karakutuk area (not shown on the Map 1).

C) Scarps and collapse structures: The topographic and aerial maps of the Karaisali region show high mountains composed of limestones which are surrounded by steep cliffs and scarps. Because of this appearance and sudden changes in topography, it was originally

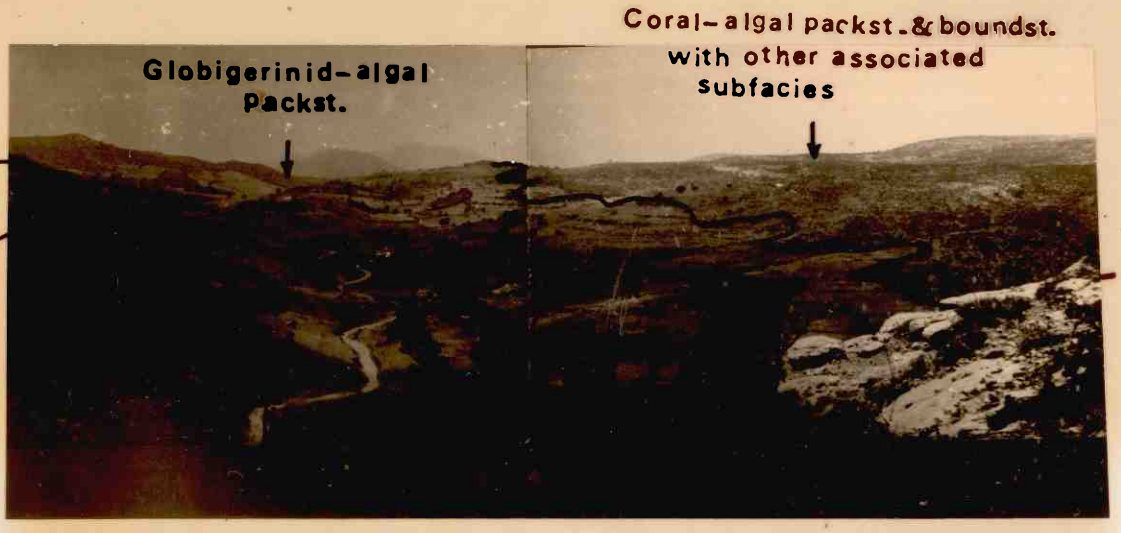


Plate (6) : "Pseudo-syncline" in Karakutuk (not shown on the map) in the NW of the village of Yanikkisla (looking from E to W).



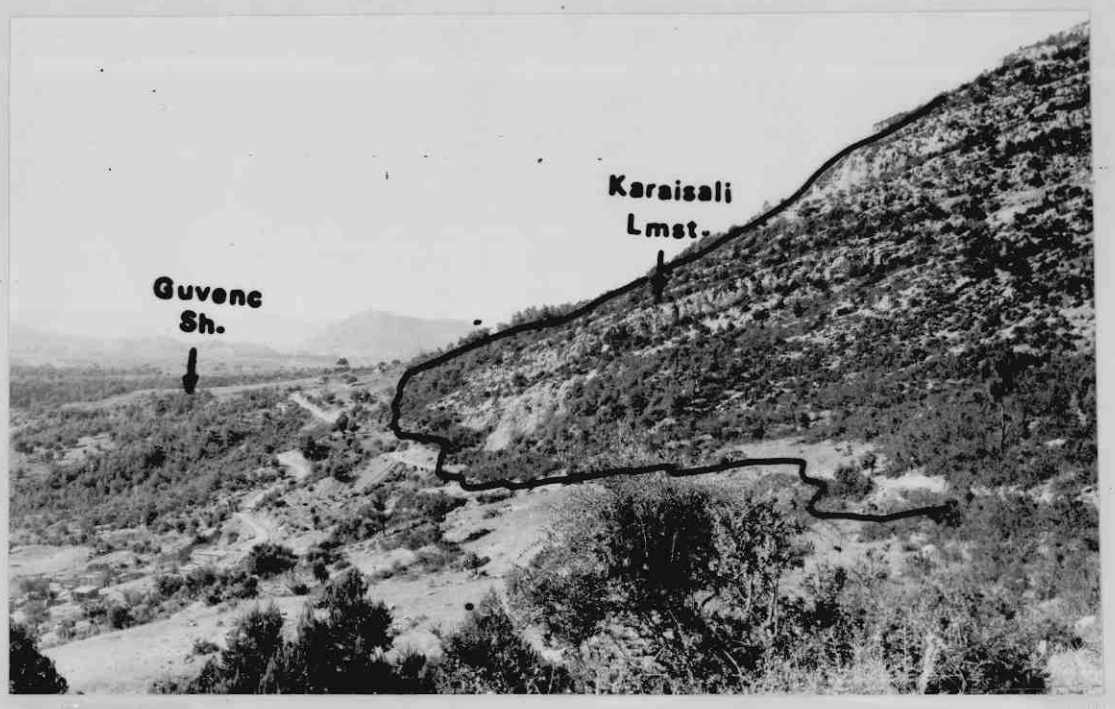
Plate (6) : "Pseudo-syncline" in Karakutuk (not shown on the map) in the NW of the village of Yanikkisla (looking from E to W).

mistakenly thought that the region was a tectonically active one during geological times. However, as has already been discussed, this was not so.

An unusually steep and persistent scarp forms a lithologic boundary between the hard Karaisali Limestone and the Guvenc Shales near Karaisali and extends for about 15 kilometres to Bucak (Plate 7). This scarp forms such a striking topographic boundary, between the high and rough karstic topography to the north and the plain to the south, which extends to the Mediterranean Sea (Map 1, Cross-sections B-B', C-C', D-D'), that it was originally and understandably interpreted as a fault scarp by early geologists. Stucker (1960) suggested a horst block origin for the Hasandagi in order to explain this unusual feature and to explain the stratigraphical relations of the Karaisali Limestone with the Guvenc Shales (Map 1, Cross-sections B-B'). In most places along the scarp, particularly, in the area between Karaisali and Arapali, these two formations show a sharp juxtaposition (Plate 7). The Karaisali Limestone is nearly horizontal or slightly inclined towards the shales and the Guvenc Shales themselves terminate against the limestone as if there is a fault or unconformity. However close examinations of this scarp between Karaisali and Arapali show that there is no evidence of faulting as suggested by Stucker (1960) and as shown on the structural map (Fig. 7), nor is there any evidence of an unconformity. The continuation of this scarp further to the southwest, for instance in Ebulhadi, appears to be a simple and normal dipslope despite its steepness (Plates 8 and 9). Here, the Karaisali Limestone may show bedding planes with dips of up to 20° which become horizontal upslope and represent another subfacies of the same formation. In this location, the well bedded and initially inclined portion of the Karaisali Limestone is overlain by the Guvenc Shales in a normal onlapping manner (Plate 9). As is seen from the same plate (9), once the initially dipping deposits of the Karaisali Limestone were covered by the Guvenc Shales, the non or poorly bedded



Plate (7) : Panoramic view of the sharp and continuous cliff surrounding the limestone plateaux in the south between the towns of Kuraisali and the village of Arapali.



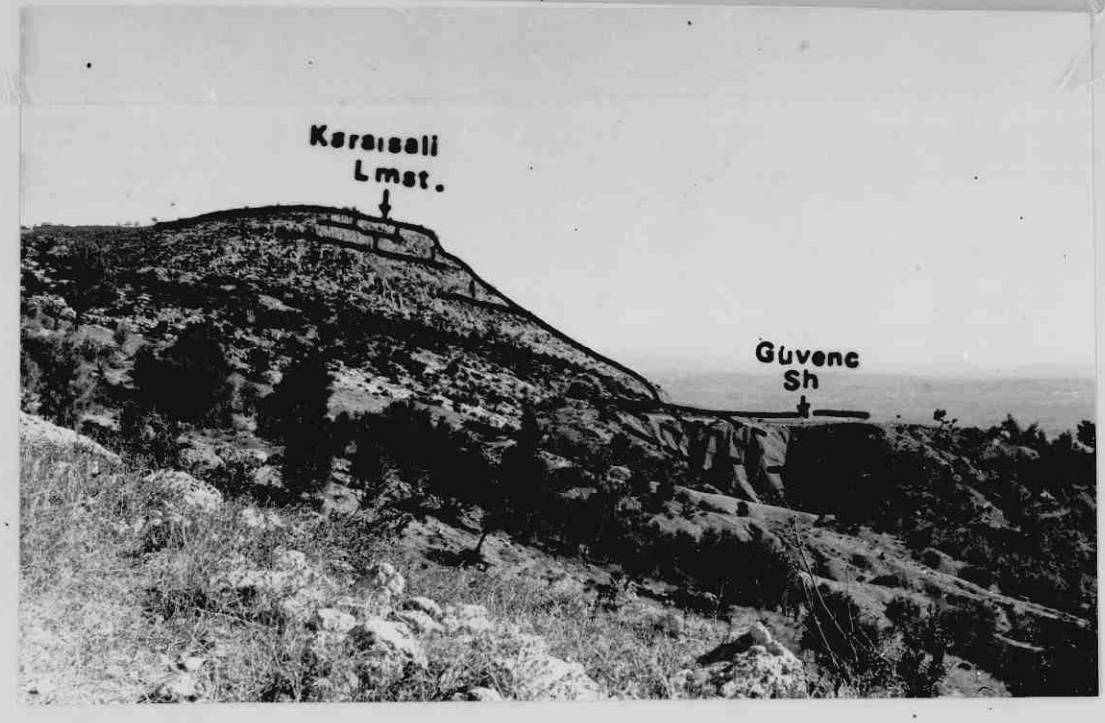


Plate (8) : A normal steep dipslope of the Karaisali Limestone in Ebulhadi.

Plate (9) : Initially inclined portion of the Karaisali Limestone is overlain by the onlapping Guvenc Shales in Ebulhadi.

facies of the former, which is usually almost horizontal, is in juxtaposition with the onlapping Guvenc Shales. Another interesting observation which gives a clue to the origin of the scarp was made in the huge gorge of the river Cakit. The Cakit cuts across the scarp and provides a good opportunity to study the geology in three dimension (Plate 10). The plate (10) shows quite clearly that the Karaisali Limestone sits on a pre-Miocene topographical high which was itself forming a scarp with the same orientation as that of the present one. This high and associated scarp obviously influenced the Miocene sedimentation.

From the above observations it becomes clear that the unusual boundary between the Karaisali Limestone and the Guvenc Shales (and may be the others) may not have always resulted from tectonic movements but may be depositional or primary in character since these primary features and the lateral passage of the Karaisali Limestone into the Guvenc Shales are observed at some localities along the scarp, such as in the vicinity of the village of Bucak, near the railway-bridge (Map 1, Measured section Bc). According to the evidence which has been observed in the field, a reasonable suggestion for the formation of the steep cliff and the stratigraphical abnormality in the Karaisali area may be as follows:

During the deposition of the Miocene sediments in the vicinity of Karaisali, a pre-Miocene topographical high was lying in a northeast-southwest direction. Algae and corals populated this high while the Guvenc Shales were being deposited to the south. The seaward edge of this algal-coral growth was a submarine cliff with talus deposits which interfingered with the shales (Fig. 10 stage 1). The sea level then rose so quickly that the algae and corals could not maintain their growth and were drowned. Consequently the interfingering of the shales and the initially dipping deposits of the Karaisali Limestone could not continue to develop whilst the shales and the others were continued to be deposited and covered the algal-coral growth (Fig. 10, stage 2). Of course, the

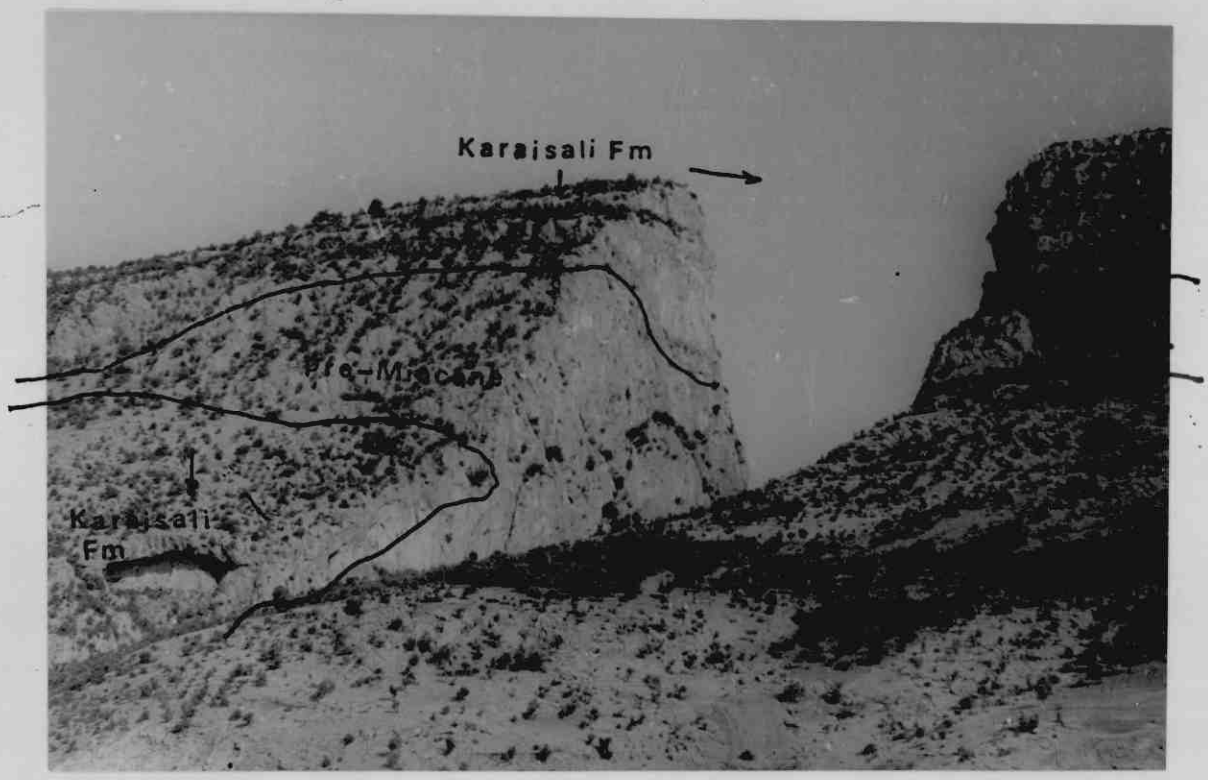


Plate (10) : The Karaisali Limestone sitting on a pre-Miocene topographical high, which was itself forming a scarp, between Karaisali and Arapali. Also note the collapse structure.

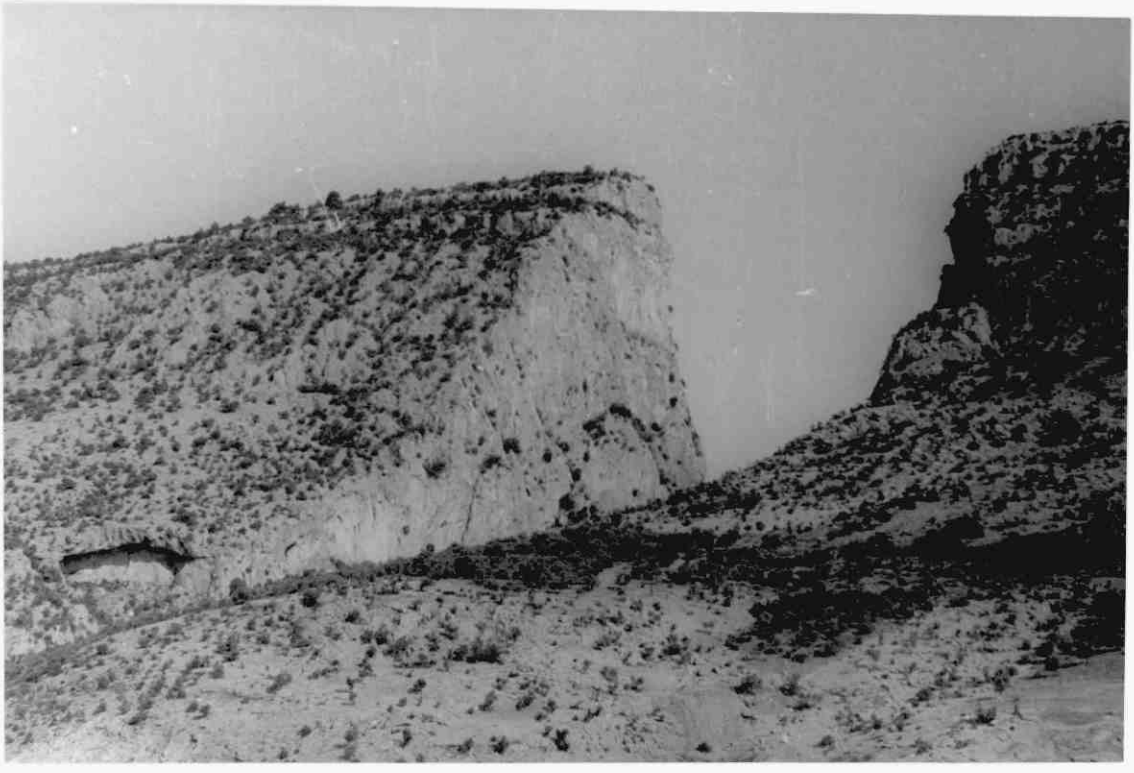
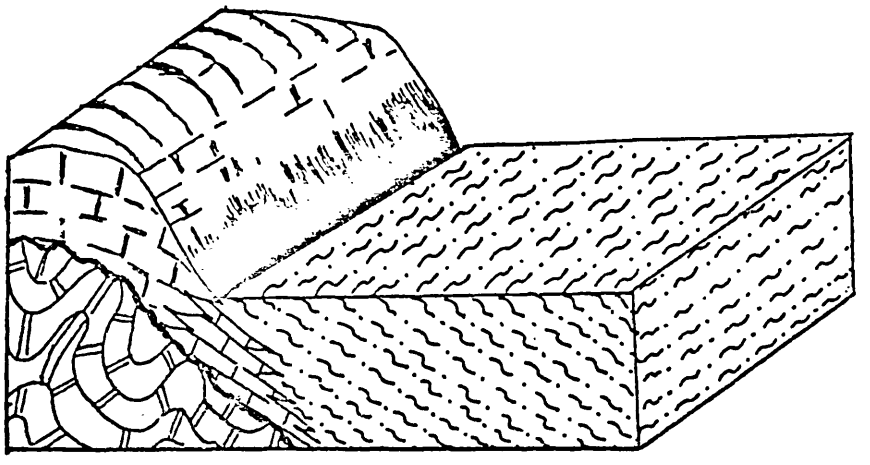
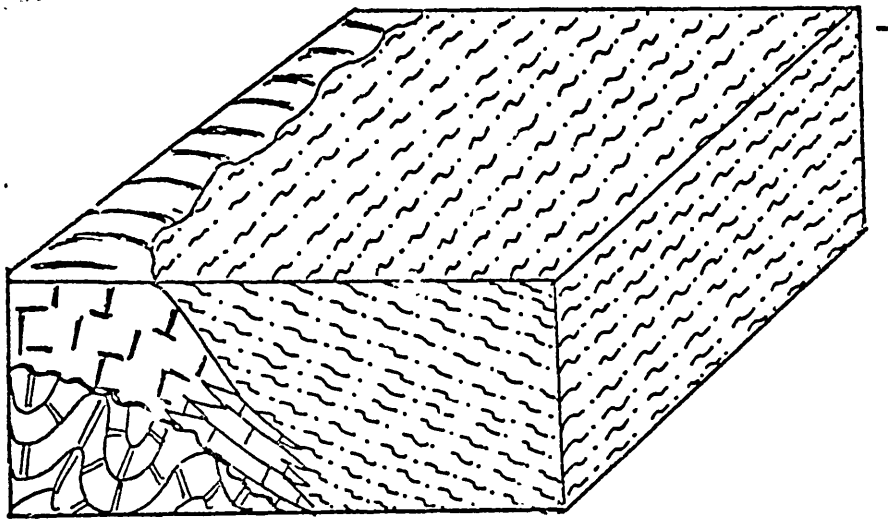


Plate (10) : The Karaisali Limestone sitting on a pre-Miocene topographical high, which was itself forming a scarp, between Karaisali and Arapali. Also note the collapse structure.



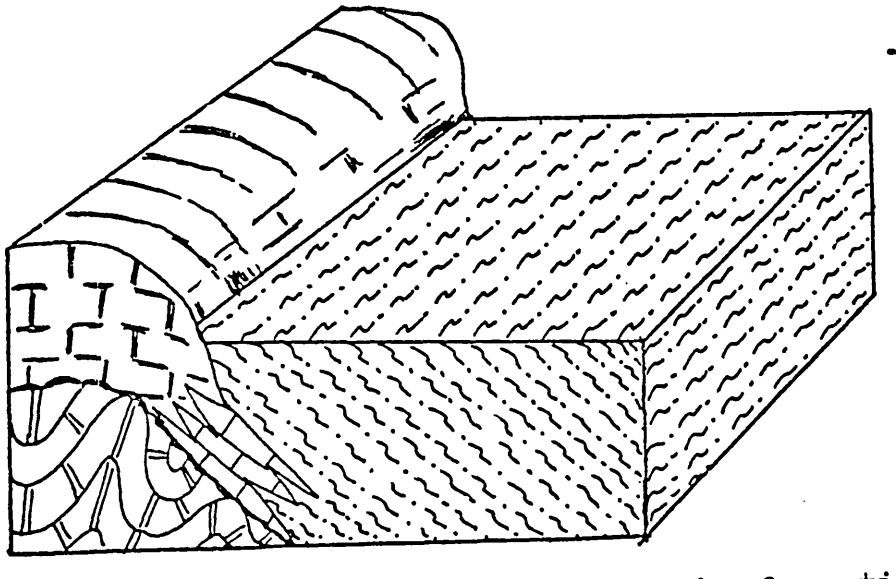
STAGE 1

The algal-coral growths were alive



STAGE 2

The algal-coral growths ceased due to the rise of the sea, but depcsition of the shale continued and probably the whole of the algal-coral limestone were covered



STAGE 3

Erosional phase and the formation of the scarp

Fig(IO): Diagram showing the formation of the steep scarps and cliffs between the Karaisali Limestone and the Guvenc Shales

shales ultimately covered the upper parts of the limestone disconformably.

It becomes clear from the above explanation that today's scenery is a result of erosion and the re-exhumation of the depositional form of the Karaisali Limestone which has variable bedding properties and dips (Fig. 10, stage 3). Evidently the nature of the boundary between the Karaisali Limestone and the Guvenc Shales is variable from place to place. Careful observations are necessary in order not to confuse a normal depositional relationship with the tectonic ones.

Collapse structures or slumps are not common in the area the only suspected one occurs near the Cakit gorge (Plate 10). The Coral-algal packstone and boundstone subfacies of the Kairaisali Limestone are separated from initially dipping adjacent subfacies of the same formation by the exposure of the pre-Miocene formations which should not have been normally exposed. Its exposure is not due to any kind of fault but may be due to slumping or collapse of the initially dipping sediments of the Karaisali Limestone during or after the deposition. Extreme variation of the dips ranging from 18° up to 25° or more and some chaotic bedding and tilting are features which support this interpretation (Plate 10).

(iii) Tectonic structures:

A) Faults: The main faults of the area which has been studied are usually high angle faults. They trend dominantly in a north-east-southwest direction, roughly parallel to the general trend of the Taurus Mountains (Map 1).

Some scattered minor faults which branch off from or intersect the principle faults obliquely or straight angles are found throughout the region (Map 1). Other minor faults which are too small to map tend mostly to be parallel with the principle faults. Although the actual surfaces of the main faults are not always exposed, where this does occur, most of them appear to dip southeast approximately at an average angle of 60° to 70° (Cross-sections B-B', C-C', D-D', F-F', G-G', L-L'). They are mostly normal and reverse faults and are downthrown on the north-

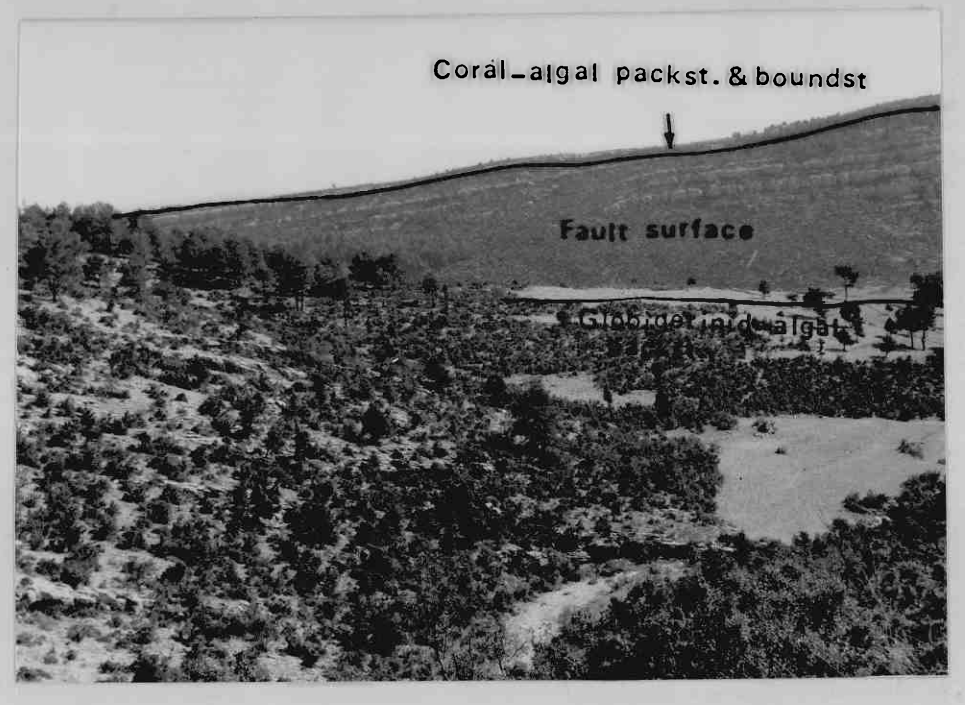
western and southern sides, with or no strike slip component to the movement. No strike-slip faults appear to be present in the area.

a) Normal faults: The most important and continuous fault of the area is the Kuzoluk fault (new name by the author) which lies between Kuzoluk and Karakutuk (Map 1, Cross-sections F-F', G-G', L-L'). It is about 12 kilometres long and is parallel to the strikes of the Miocene formations and the trend of the Taurus mountains. The surface of this fault may be observed at various localities along its course. The best exposure occurs in the Kuzoluk area where it appears to dip with a rather high angle (Plate 11, Cross-sections F-F', G-G', L-L'). The actual displacement is not known.

Besides the main Kuzoluk fault, other normal faults are scattered throughout the area (Map 1). Most of them are concentrated near the northwestern margin of the basin where they usually occur within the Miocene rocks. They are short and branching and are best seen in the vicinity of Eminlik and Kuscular (Map 1). A few small minor faults were also observed in the villages of Nergizlik and Yanikkisla (Map 1, Cross-sections B-B', Plate 12).

b) Reverse faults: Reverse faults are occasionally observed within the area, e.g., at Turel Tepe (north of Guluslu), in the vicinity of Nergizlik (Plate 13), and Kirilan. They also mark the contact locally between the Miocene and the pre-Miocene rocks near the northwestern margin of the basin (Map 1). The most striking one of these reverse faults is that which occurs at Turel Tepe (Map 1). It is about 3 kilometres long and trends in a northeast-southwest direction. The fault surface dips to the south at a high angle. Its actual vertical displacement is not known. However, it appears to be approximately 200 metres in the cross-sections (Cross-section C-C'). It forms a high cliff between the soft Guvenc Shales and the hard red conglomerates of the Gildirli Formation (Map 1).

B) Folds: Folds of truly tectonic origin have not been



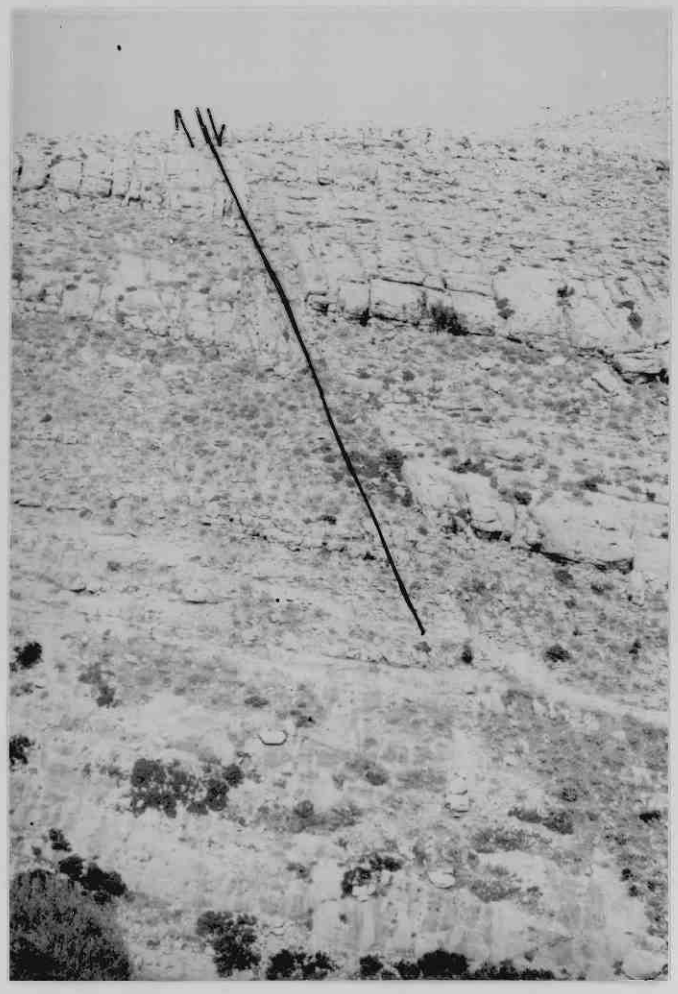


Plate (11) : The Kuzoluk fault in the vicinity of Kuzoluk, trending from NE to SW.

Plate (12) : A normal fault in Koytepe of Yanikkisla.

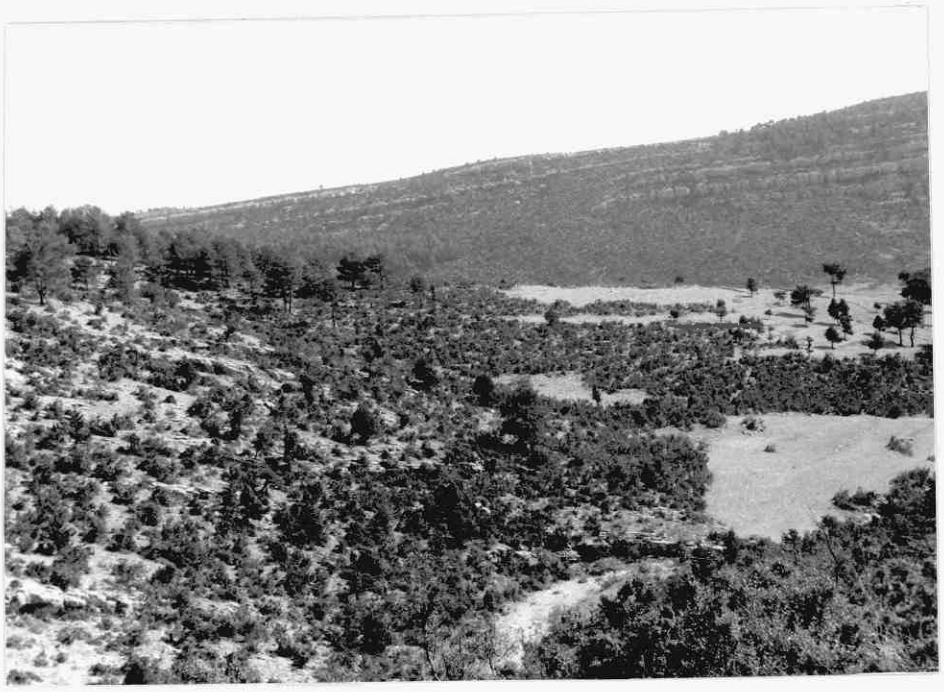




Plate (11) : The Kuzoluk fault in the vicinity of Kuzoluk, trending from NE to SW.

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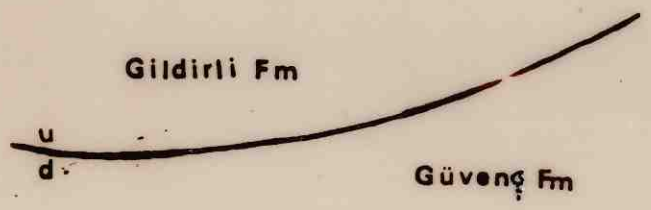

Gildirli Fm
u
d
Güvenç Fm



Plate (13) : A reverse fault between the Gildirli Formation and the Guvenc Shales in the village of Nergizlik, trending from NE to SW.



Plate (13) : A reverse fault between the Gildirli Formation and the Guvenc Shales in the village of Nergizlik, trending from NE to SW.

found within the Miocene rocks in the area by the author. All the broad and gentle undulations appear to have a depositional rather than a tectonic origin. The only true tectonic folds of the area are seen within the unstudied rocks of the pre-Miocene (Plate 14).

4.4. Economic geology: Limestones, gravels, and calcareous sands are the only economic resources of the area which has been studied. The calcareous sands and gravels which are Quaternary and Recent in age are widely used by the local people and authorities as concrete aggregate, fill for embankments, and as a base for roads. The river Cakit valley is the main place where these are worked. The limestones are usually very pure and can be exploited almost everywhere, particularly in the areas along the main roads and the railway. They are very hard and must be blasted. They are already used as aggregate and may be used for other pruposes, such as raw material for cement and building. They can not be used as decorative stones, because of difficulty of extracting large blocks.



Plate (14) : Folded pre-Miocene rocks in Yoruk Dere.

CHAPTER II - THE GILDIRLI FORMATION

II. 1. GENERAL: The Gildirli Formation consists of conglomerates, sandstones, and siltstones which are characteristically pale red (5 R 6/2) to moderate reddish brown (10 R 4/6) and unfossiliferous at the base and yellowish grey (10 YR 8/2) and/or light olive grey (5 Y 6/1) and fossiliferous at the top. For the purpose of discussion and simplicity, this formation was divided into two units and given member names.

The unfossiliferous, red lower part of the Gildirli Formation was named after a small village called Cakmak which is located on these red clastics (Map 1). The fossiliferous, grey upper part was named after a hill called Kabalak Tepe, west of Karakilic, where these sediments typically occur (Map 1). These divisions were made by the author in this study and have not been used by any previous workers. Each of these members have a distinct physical appearance and sedimentological properties and are easily distinguishable from each other. They are mappable units and are the result of different depositional histories.

II. 2. CAKMAK MEMBER: This is the most distinctive member of the Gildirli Formation and it consists mainly of pale red (5 R 6/2) to moderate reddish brown (10 R 4/6) conglomerate, sandstone, and siltstone; all of which pass laterally and vertically into one another over short distances (Plates 15 and 16).

2.1. Conglomerate:

(i) General description: The conglomerates make up the largest portion of this member and contain clasts which are composed entirely of pre-Miocene rocks of the area. Systematic description of the lithologies of pebbles which was made in the field and in the laboratory showed that white, grey or light brown, fine carbonate mudstone pebbles of the Cretaceous were found to be the most abundant rock type everywhere. These carbonate mudstones contain such fossils as Globigerina sp and Globotruncana sp and show tiny fractures filled by sparry calcite. Lesser quantities of clasts





Plate (15) and (16): Interfingering of conglomerate and sandstone in Ucurge Suyu, Nergizlik.

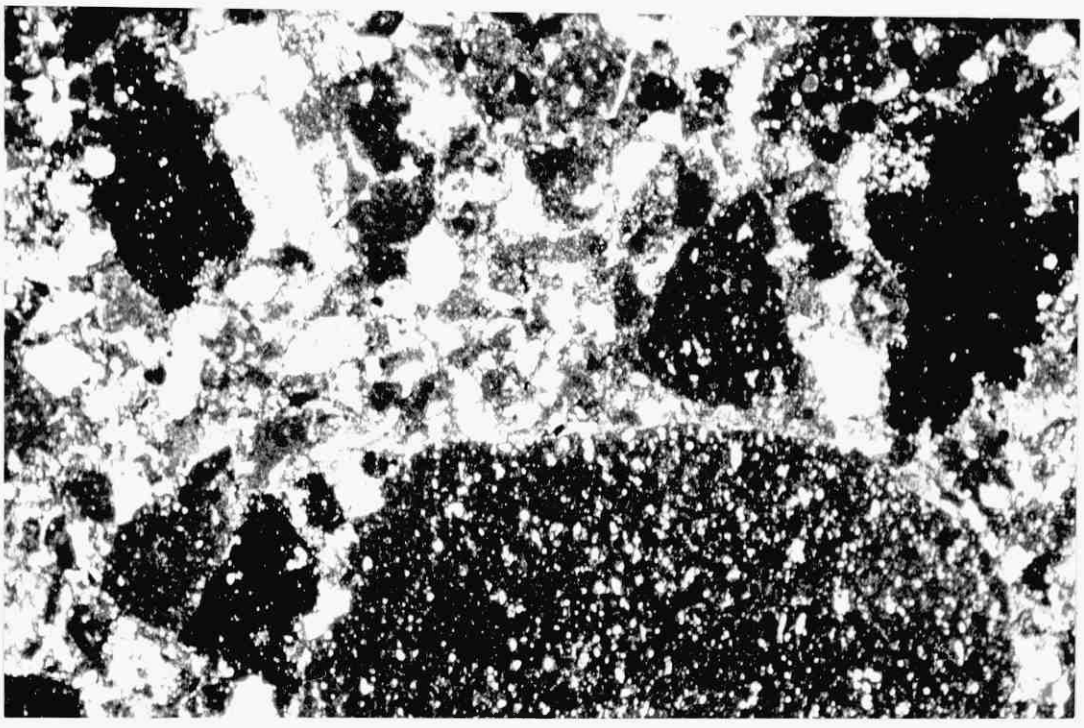
of black, grey, fine grained recrystallized fetid limestones of the Palaeozoic, chert, and various igneous rocks were found at most localities (Plates 15, 16, and 17). Igneous rocks sometimes include pebbles of various fine grained basic rocks, other volcanics, and serpentinites with some other green rocks derived from the Cretaceous ophiolite complex. Most of the pebbles in the conglomerates are 5 - 10 centimetres in length, although boulders 50 - 100 centimetres long are common (Plate 18). In Ucurge Suyu, near Nergizlik, the largest boulders were seen to commonly occur at the base of the sections studied. These large boulders and pebbles decrease in size from the base upwards and such a tendency is probably true for most of the sections studied in the field. The shapes of pebbles, which were determined approximately from some samples, are predominantly spheroidal with subordinate roller and blade types (Zingg, 1935). Their surface is generally rough, corroded and sometimes shows pressure solution pits.

The conglomerates are usually poorly sorted and contain surprisingly well rounded limestone pebbles. Packing of these rounded grains may be variable; in some beds, pebbles are packed tightly with little matrix; elsewhere they may be loosely packed within a red, granule to coarse grained lithic arenitic sandy or silty matrix (Plates 15, 16, and 18).

The conglomerates do not show many sedimentary structures other than some rare cross-stratification (Plate 19). They are generally crudely bedded with individual beds varying from 50 to 70 centimetres in thickness (Plate 19). Lenses of pale red (5 R 6/2) calcareous lithic arenites, that are sometimes interbedded with the conglomerate, may be commonly observed within this lithology. They are generally 30 to 100 centimetres in thickness and may be followed laterally for several metres (Measured sections Nz_3, Nz_4, and Nz_5, Map 1).

2.2. Sandstone:

(i) General description: Sandstones of this member are general-



X17

Plate (17): General texture of the conglomerate of the Cakmak Member (p = lithoclasts of Palaeozoic limestones; c = lithoclasts of Cretaceous carbonate mudstone and wackestones)



Plate (18): A boulder (100 centimetres in diameter) in conglomerates of the Cakmak Member, in Ucurge Suyu, Nergizlik.



Plate (19): Crudely bedded conglomerate showing cross-stratification in its upper part, in Ucurge Suyu, Nergizlik.

ly hard, well bedded (20 - 30 centimetres in thickness), rarely micro-cross laminated and are interbedded with carbonaceous siltstone (Plate 20). All gradations between sandstone and siltstone may be found, but sandstone beds predominate. The sandstone is generally fine to medium grained, commonly poorly sorted, and at some places contains minor quantities of coarse sand grains. The coarser grains are comparatively well rounded and are mostly disseminated throughout the sandstone, but locally they are found as lenticular or irregular lenses. The sand grains are generally angular to subrounded and are composed chiefly of carbonate fragments, chert, quartz, some scattered grains of igneous rocks, feldspar, mica, and opaque material (Plate 21). Calcite commonly cements the lithology.

(ii) Microscopic description:

A) Framework grains:

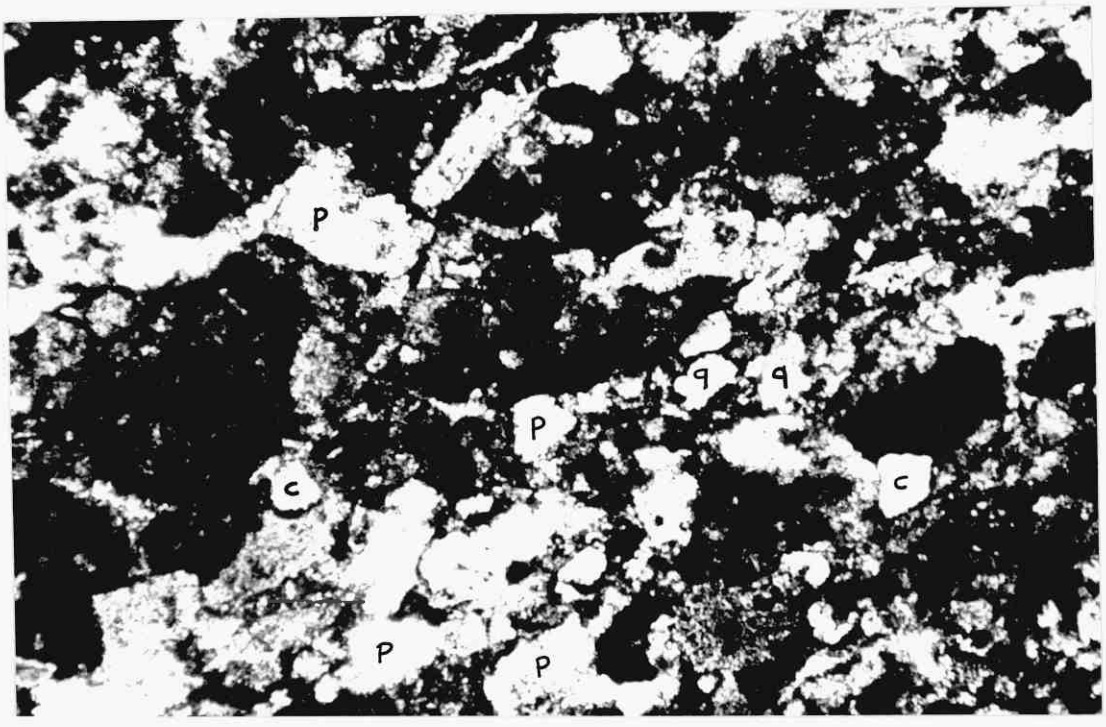
a) Carbonate lithoclasts: These are commonly angular to subrounded grains of recrystallized limestone. Their size ranges from less than 300 microns up to 1 millimetre. They usually show a fine, granular appearance with a light yellowish grey colour under plain light (Plate 21). However, some coarsely crystalline grains of this type are also seen. Besides these recrystallized limestone fragments, some comparatively well rounded carbonate mudstone grains are present. They display fine calcite filled fractures and some tiny spots which appear to be recrystallized micro fossils. This type of lithoclast is sometimes common in some thin sections together with the recrystallized ones.

b) Cherts: Second, in abundance, to the carbonate lithoclasts are chert grains which are generally subangular to angular in shape. Their size is extremely variable ranging from a few microns up to 1 or 2 millimetres. They are radiolarian cherts. These cherts show two distinct colours being either green or reddish brown.

c) Quartz: The third most common type of grain in



Plate (20): Well bedded sandstone in Ucurge Suyu, Nergizlik.



×24

Plate (21): General view of sandstone of the Cakmak Member (p = lithoclasts of the Palaeozoic recrystallized limestone, c = cherts, Q = quartz)

the sandstone is quartz. It occurs as detrital monomineralic grains. Most such single grains show unstrained extinction although many of them may also show strain extinction. Grains are angular to subrounded and are of various grain-size ranging from a few microns to 1 millimetre. There are no over-growths on these grains.

d) Igneous rock fragments: From the examination of the thin sections, these appear to include plutonic, hypabyssal, volcanic, and metamorphic rock fragments. The plutonic and hypabyssal rock fragments occur as grains in which anhedral and subhedral quartz, potash feldspar, plagioclase, and mica may be found. Some hypabyssal rocks which show phenocrystals of potash feldspar in a groundmass of finely crystalline quartz with a typical porphyritic texture are also recognizable. Volcanic rock fragments are easily distinguishable by their textural appearance. They generally contain feldspar or quartz within an aphanitic groundmass. Metamorphic rocks are not common and only a small amount of schists are present.

B) Accessory components: Feldspar, mica, fragments of serpentinite, and some opaque materials are also present as accessory components.

C) Fossils: Some rare derived fossil fragments, such as fragments of coralline algae, and echinoderms are seen in the sandstone.

D) Matrix: The groundmass of the sandstone is a brown, fine grained matrix consisting mostly of finely crystalline, sparry calcite which is intermixed with poorly defined opaque materials, microcrystalline quartz, and possibly some other unidentified minerals and clays.

E) Cement: The cement of the sandstone is again sparry calcite and occurs surrounding the individual grains. However, progressive growth of the calcite crystals from the host grains into pore spaces can only be observed on a few grains. Usually the grains instead show sharp boundaries with the calcite matrix with no intervening cement.

F) Porosity: The porosity is generally poor as the voids are usually filled by matrix and sparry calcite.

G) General texture (Plate 21): The sandstone is usually poorly sorted, fine to medium grained, consisting mainly of carbonate lithoclasts, chert, quartz, and igneous rock fragments which are all angular to subangular and are closely packed within a finely crystalline sparry calcite matrix. Cementation and pore-filling processes are due to precipitation of the sparry calcite.

H) Petrographic name: Calcareous lithic arenite. (Williams et al, 1954).

2.3. Siltstone:

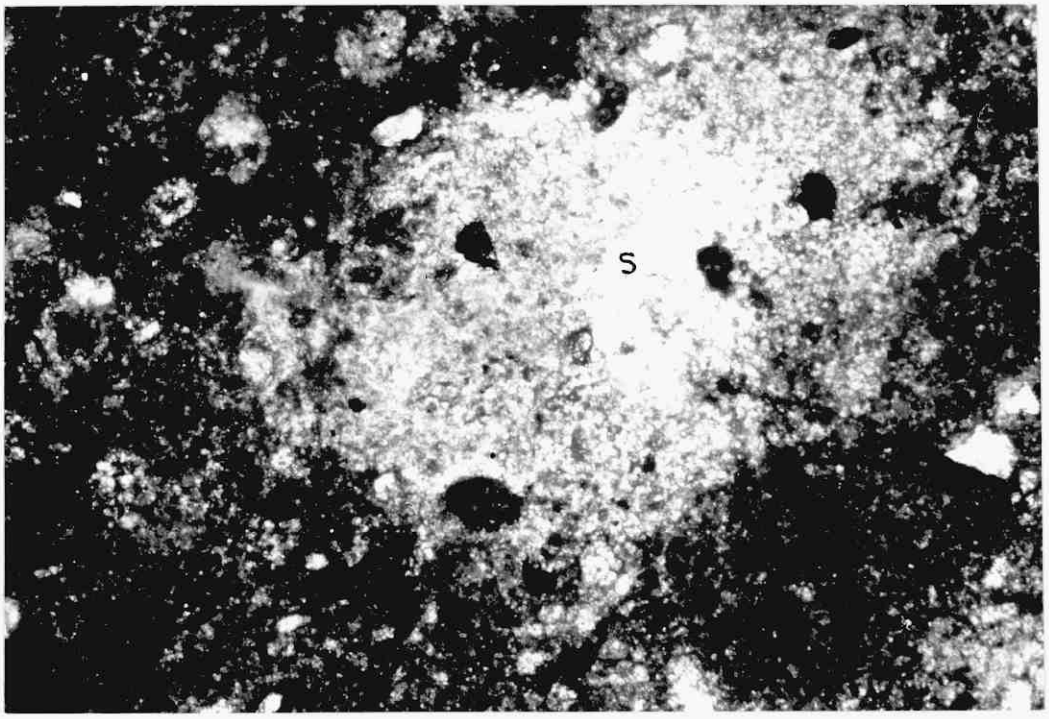
(i) General description: This is dominantly structureless, although it has a thinly bedded appearance in some localities. When it is interbedded with the sandstones of the member, the thickness of each bed ranges from 20 to 40 centimetres. Burrowing structures are quite common in these siltstones: such burrows are horizontal, vertical, and gently inclined and marked by infillings of caliche (Plate 22 and 23). Petrographic examination shows that this lithology contains some quartz, green and reddish - brown cherts, opaque materials, common patches of sparry calcite and carbonaceous material (Plate 24). These grains float in a reddish-brown silty matrix. The siltstone is generally soft, and easily erodable.

2.4. Distribution, thickness, and field relations of the Cakmak Member: The principal exposures of this member are in the northeastern margins of the area which has been studied. It crops out extensively in the valley of Ucurge Suyu (near Nergizlik), Cakmak, Gildirli, and in the area between Nergizlik and Karakilic (Map 1, Cross-sections A-A', B-B', C-C', H-H', I-I'). The unit may also be exposed as small inliers among the other Miocene rocks in various localities. They are the initial Miocene deposits and fill the valleys and depressions of the pre-Miocene topography (Plate 25). The angular unconform-





Plate (22) and (23): Vertical and gently inclined burrows, marked by infillings of caliche and sand or siltstone



×100

Plate (24): General texture of siltstone of the Cakmak Member (s = patchy sparry calcite).





Plate (25): A pre-Miocene depression in the north of Cakmak, filled by the rocks of the Cakmak Member of the Gildirli Formation.

Plate (26): An angular unconformity between the Gildirli and pre-Miocene formations, near Cakmak.



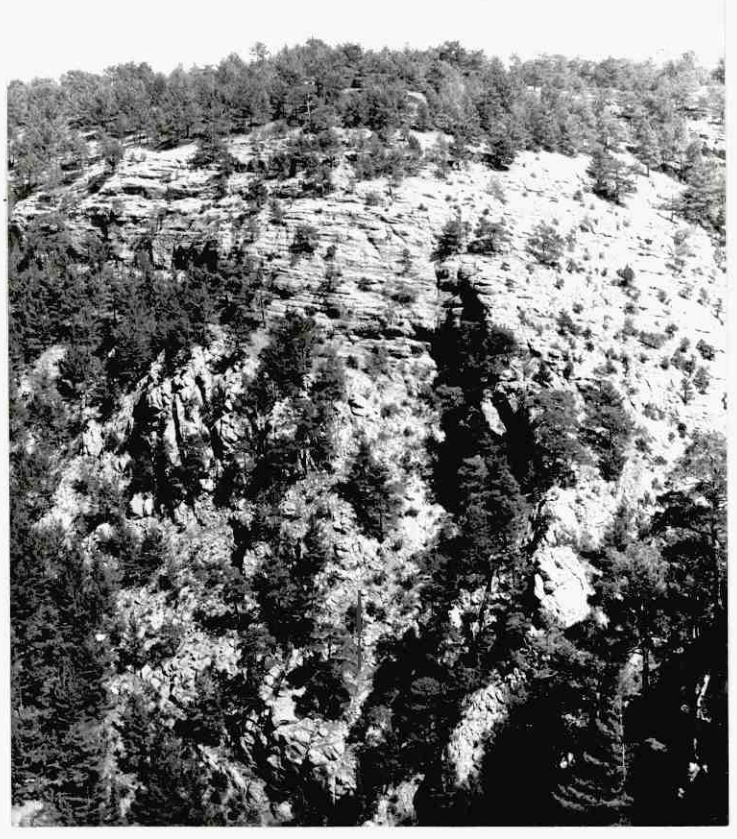


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ity separating these red clastics from the pre-Miocene formations can be examined at some localities, e.g., north of Karaisali and around Cakmak mahallesi. The unconformable surface is distinct, irregular and does not show any evidence of any palaeo-soil (Plates 26 and 27).

The geometry and thickness of the Cakmak Member are completely controlled by the pre-Miocene topography and they can be used for the reconstruction of the form of this irregular land surface. As a rule, the Cakmak Member reaches a maximum thickness in the pre-Miocene troughs and decrease in thickness on the topographical highs. Plate (28) shows this distribution very clearly. The pale red (5 R 6/2) conglomerate is about 100 metres thick on the pre-Miocene topographic high (Measured section Ck_2) and becomes much thicker southwards in the valley.

The complete thickness of this member is not known exactly but the thickness of the Gildirli Formation, as a whole, is more than 300 metres (Schmidt, 1961). The Cakmak Member gradually passes up with a general decrease in grain size into the Kabalak Tepe Member of the Gildirli Formation (Measured section Do, Map 1).

2.5. Source area and environment of deposition of the Cakmak Member:

The source of the conglomerate is obviously mainly the white, fine grained limestone of the Cretaceous in the study area.

Examination of the sandstone showed that the area which was the source of the conglomerates was contributing hardly any sand and silt size sediment to form this interfingering and interbedded finer grained lithology since the latter is dominated by dark coloured, fine grained, recrystallized limestone which is quite distinct from that of the clasts of the conglomerate. Evidently there appears to have been two different source areas contributing sediment at the same time to the depositional site of the Cakmak Member as it seems unlikely that limestones cropping out in the same locality would produce such very different sized detritus. Any other explanations, such as periodic changes in climate or tectonic



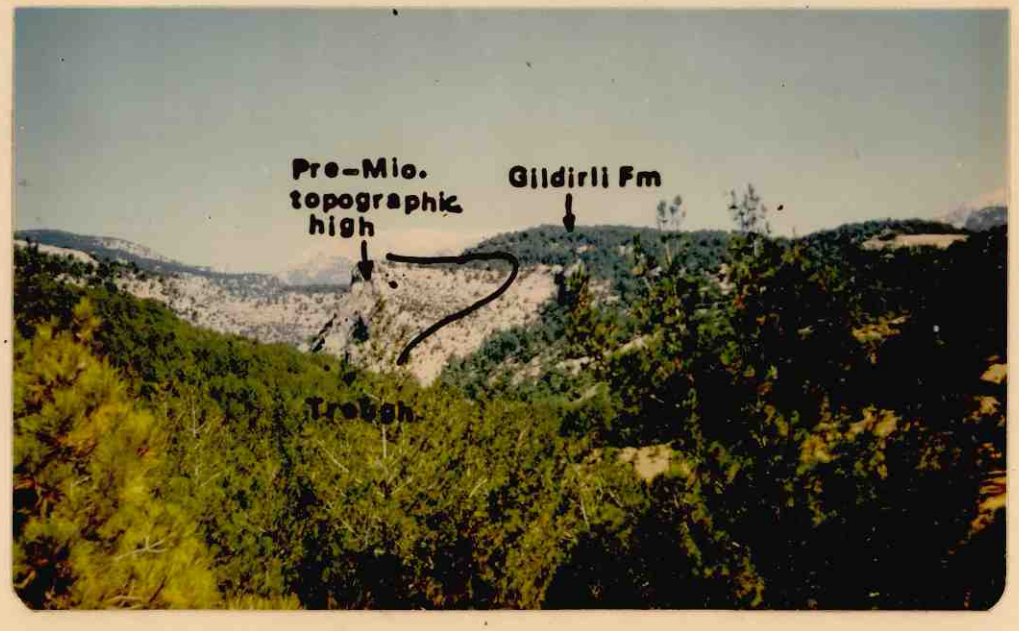


Plate (27): A distinct, irregular unconformable surface between the pre-Miocene and the Cakmak Member of the Gildirli Formation, without development of any soil, west of Cakmak.

Plate (28): The pattern of distribution of the Gildirli Formation: thin on the pre-Miocene topographical high and becoming thicker in the trough of the pre-Miocene topography.

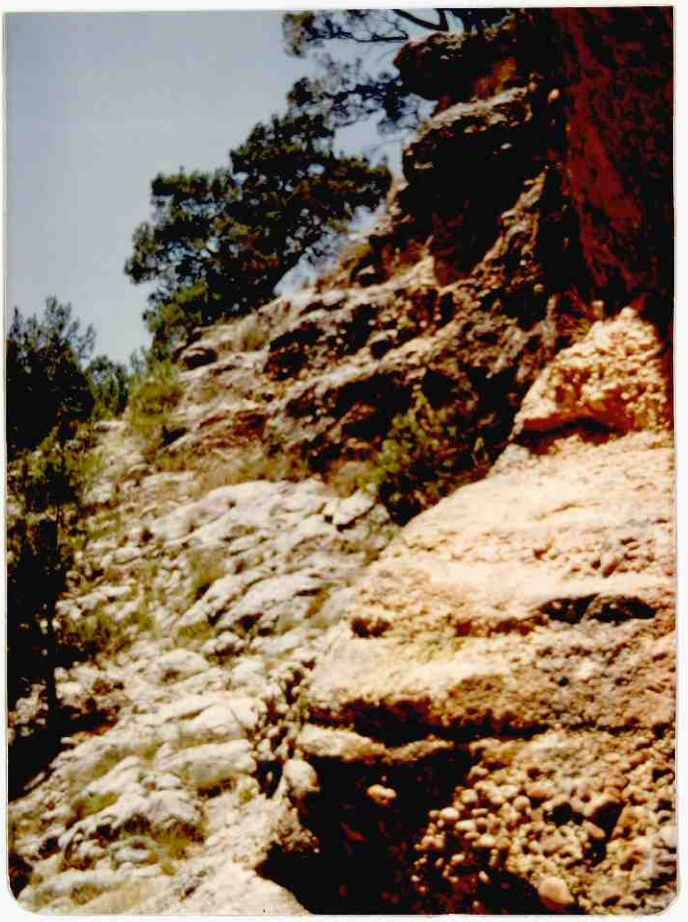




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conditions are difficult to accept simply because similar differences are also observed in the overlying Kabalak Tepe Member and in the Cingoz Formation.

The source areas were probably located in the northern part of the study area where the Taurus Mountains were forming a continuous belt during the deposition of these clastics. The source area of the conglomerate was most likely local and was lying immediately to the north of the basin. Most of the coarse materials were probably derived from this area where, perhaps, uplift was taking place.
The second source area which was supplying recrystallized limestone fragments to the sandstone may have been located in the northeast or northwest. These locations are generally indicated by the direction of sediment transport and by the distribution of these clastics in the field. Most ofthe cross-bedding which was observed in the Cakmak Member dips in a southerly direction. The source of the clasts of the recrystallized limestone may be the Cretaceous or the Palaeozoic limestones. However, they bear the greatest resemblance to the recrystallized limestone formations of the Palaeozoic which are exposed extensively in the Taurus Mountain belt.
A very similar modern analogue to this type of situation exists in southwest France where the valleys of the Dordogne and other rivers have sands derived fromthe Massif Central intermixed with conglomerate of a local origin, derived from the Jurassic - Cretaceous limestones bording the valleys (G. Evans personal communication, 1977).

The lithological and the sedimentological features of the Cakmak Member, together with the complete absence of fauna suggest a non-marine and fluviatile origin for these sediments. The conclusion that the Cakmak Member of the Gildirli Formation was deposited in a predominantly continental environment is supported by several lines of evidence:

1. - Typical pale red (5 R 6/2) colour
2. - Poor sorting

3. - Generally coarse grain size and its upward-fining character

4. - Crude bedding

5. - Cross-stratification and channeling

6. - Association of conglomerate, sandstone, and siltstone.

7. - Complete absence of fauna and presence of common carbonaceous materials in the red siltstone.

8. - The similarity of the Cakmak Member to alluvial sediment in modern streams of the mapped area (Plate 29) (Potter, 1967; Pettijohn, Potter, Siever, 1973).

Considering the Cakmak Member as a whole, an alluvial-fan model would probably best fit the environment of formation of these clastics. Their great thickness, coarse grain size, poor sorting, sedimentary structures, and the composition which is closely linked to the adjacent bedrock can be best explained by the alluvial-fan model. Sediments of alluvial-fan origin are reported from different areas to be coarse, poorly sorted, petrographically immature, and closely related to the adjacent bedrock with a considerable thickness (Blissenbach, 1954; Potter, 1955; Potter, 1967; Goldman, 1968; Pettijohn, Potter, Siever, 1973).

Besides these similarities of the Cakmak Member of the Gildirli Formation to the alluvial-fan deposits, its geographic setting is also consistent with an environment of deposition on alluvial-fans. As noted before these red clastics were deposited in the depressions of the pre-Miocene topography along the margins of the high Taurus Mountain chain. This type of geographic setting is generally accepted to be a characteristic of alluvial-fan deposits (Blissenbach, 1954; Selley, 1970; Bull, 1972; Pettijoh, Potter, Siever, 1973). A similar accumulation of alluvial-fan sediments can be seen in the Quaternary deposits between Mersin and Silifke, along the present Mediterrenean coast of Turkey (G. Evans, personal communication, 1977).

In summary, the Cakmak Member of the Gildirli Formation was deposited as



Plate (29): Modern alluvial sediments in the stream of Ucurge Suyu.

fans of coarse alluvial detritus in the troughs and the valleys of the pre-Miocene land surface along the southern margin of the Taurus mountain range. Coarse pebbles and boulders of the Cretaceous carbonate mudstone were shed from the northern part of the mapped area where probably uplift was taking place during the time of deposition of these clastics. The fine material of the sandstones and siltstones were perhaps supplied from somewhere in the northeastern or the northwestern margin of the Taurus Mountain, because the source rocks of these recrystallized limestone are not exposed to the immediate north of the region as are the white mudstone of the Cretaceous.

II. 3. KABALAK TEPE MEMBER: This member also consists predominantly of interstratified and interfingering layers of conglomerate, sandstone, and siltstone. Although the conditions of deposition of this member were different than those of the Cakmak Member, it has a similar lithology to this member.

3.1. Conglomerate:

(i) General description: The conglomerates are dominant and are commonly found at most localities. They form beds or units a few centimetres to decimetres thick that generally have erosional bases (Plate 30). The clasts in this lithology may be as large as boulders at a few places, but generally the largest are pebbles or small cobbles which are characteristically well rounded and poorly sorted throughout (Plate 31). The composition of the conglomerate varies considerably from place to place with an obvious pattern which is generally related to the lateral distance of the locations from the pre-Miocene topographical highs on-lapped by the Karaisali Formation. On the highs conglomerate are usually lithologically homogenous and are composed of clasts of white Cretaceous mudstone. Commonly amongst these pebbles, fossil fragments such as coralline algae, corals, small benthic foraminifera, echinoderms, and molluscs, all of which are characteristic of the Karaisali Formation, are found either forming a matrix or sometimes occuring as small pebbles. In some cases this skeletal matrix exceeds in amount the pebbles, particularly where lateral and vertical transitions of the conglomerate to the Karaisali Limestone occur. At such locations the conglomerate becomes a coarse, poorly sorted skeletal packstone with a few carbonate lithoclasts (Plate 32). The conglomerate also appears to have a fine grain size and its clasts are more angular when found on the topographical highs as compared with the coarser grained and better rounded type found in the low depressions and the valleys of the pre-Miocene. Where found in the depressions these sit on top of the red clastics of the Cakmak Member. In the extreme northwestern part of the





Plate (30): The erosional base of a bed in the conglomerate of the Kabalak Tepe Member.

Plate (31): A typical exposure of the conglomerate of the Kabalak Tepe Member in the depressions of the pre-Miocene topography in Nergizlik.



Plate (32): Typical appearance of the conglomerate where it becomes a coarse poorly sorted skeletal packstone with a few carbonate lithoclasts in the section of Eminlik (III) (Em_3). Here, lateral and vertical transitions of the conglomerate to the Karaisali Limestone occur.

area, this conglomerate passes into breccia along the junction of the Miocene basin with the high pre-Miocene mountain chains (Map 1). Other common lithologic types occurring as pebbles in this member are fragment of Palaeozoic limestones, and rocks of the Cretaceous ophiolite-complex. Because of the closely related occurrence of the conglomerate with the Karaisali Limestone on the pre-Miocene highs, detailed descriptions of the conglomerate from these areas are given below.

(ii) Size, shape, roundness, and surface markings of pebbles of the conglomerate: The long dimension of pebbles was measured systematically throughout the area where the stratigraphic sections of this lithology and of the Karaisali Limestone were measured. In the section of Usunlu (Us), the largest pebbles are as much as 26 centimetres in length; these are scattered among others which normally do not exceed 15 centimetres in length. In the section of Eminlik (I) (Em_1). large pebbles, as much as 16 centimetres in length, are abundant. In the other measured sections, such as Camtepe (II) (Ct_2), Eminlik (II) (Em_2), and Kessektepe (Kt) non of the pebbles of the conglomerate exceed 7 centimetres in length. Generally, pebbles of this conglomerate are smaller, in these areas, than those pebbles of the same lithology where it occurs in the depressions of the pre-Miocene topography.

Approximate three-dimensional measurements were made on some pebbles in the laboratory to determine their shape: it was found that they are mostly spheroidal with some roller and blade types (Zingg, 1935).

Pebbles of the conglomerate are generally well rounded with rough and corroded surfaces. Although these surfaces are mostly concealed by precipitated material they sometimes show pressure solution pits.

(iii) Lithology of pebbles of the conglomerate: In the section of Eminlik (III) (Em_3), the conglomerate appears to be almost

monomict and is characterized by the white, light brown, fine grained mudstone pebbles (sometimes with a brecciated appearance) derived from the Cretaceous (Plate 33 and 34). To the south, this monomict character changes and the conglomerate contains a few black and dark brown recrystallized limestone pebbles derived from the Palaeozoic, mixed with the predominant pebbles of the Cretaceous in the sections of Eminlik (I) (Em_1), Eminlik (II) (Em_2), and Usunlu (Us). Pebbles of volcanic rocks and of rocks of the ophiolite complex are virtually absent in the conglomerate in these places. It is of interest to note that the rock of the pre-Miocene basement in these areas are also white, light brown Cretaceous mudstone and packstone. In the section of Camtepe (II) (Ct_2), northwest of Karaisali, the marine conglomerate is composed solely of dark brown pebbles of recrystallized limestones derived from the Palaeozoic which appearently form the base of the section and the pre-Miocene topography in this area. Besides the pebbles of recrystallized Palaeozoic limestone, some small pebble size fragments of coralline algae, and a few pebbles of serpentinite are found in the conglomerate of this locality. The most polymictic type of conglomerate is observed in the section of Kessektepe (Kt) (Plate 35). Here, it contains common pebbles from the Cretaceous and the Palaeozoic formations; green pebbles of serpentinite, chert, and some volcanic rock fragments. The pre-Miocene at the base of this section is composed of white Cretaceous mudstone.

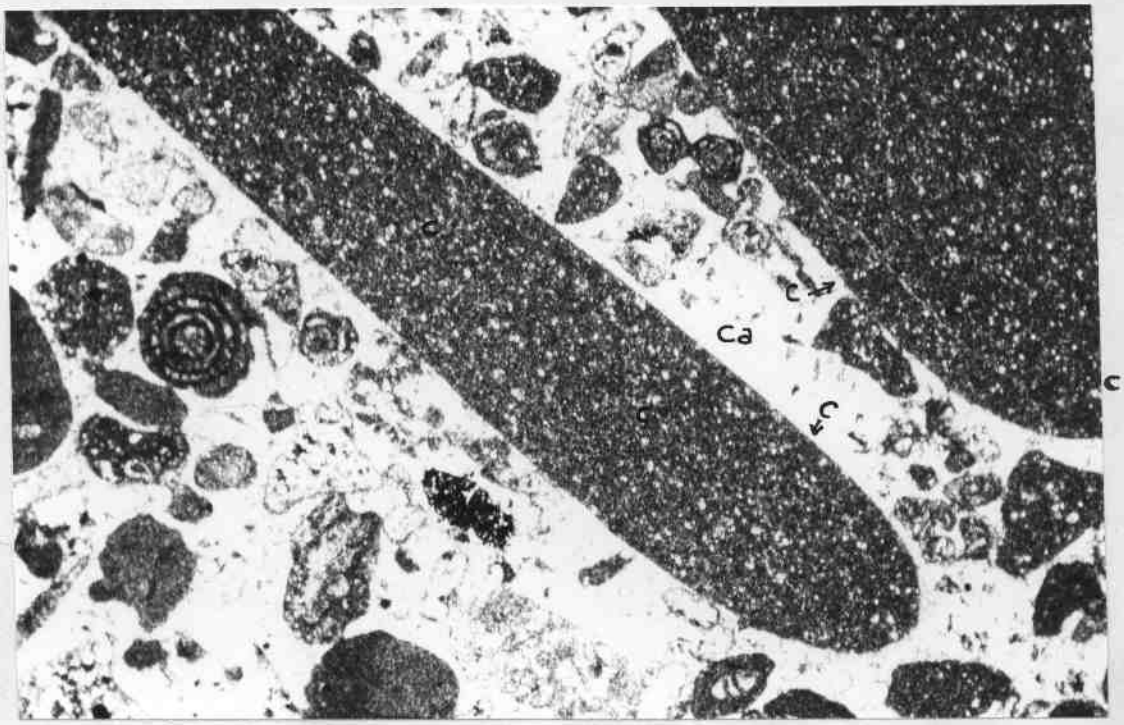
From the above descriptions, the lithology of pebbles of the conglomerate may be summarized as follows:

1 - White, light brown mudstone and packstone pebbles of the Cretaceous are found to be the predominant lithologic type in most places where the basement rock is also formed of the same lithology.

2 - Although they are not common, the dark coloured recrystallized limestone pebbles of the Palaeozoic become predominant in some areas where the basement rock is formed of the same recrystallized

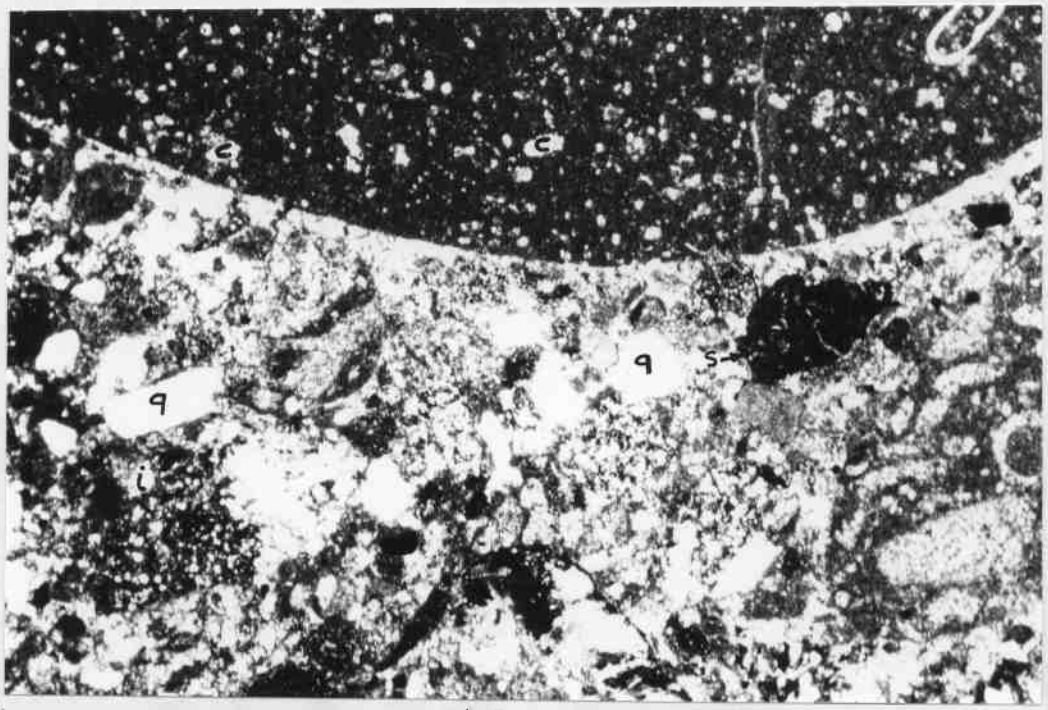


Plate (33): Monomict conglomerate in the section of Eminlik (III) (Em_3). The clasts are of white, fine grained carbonate mudstone pebbles derived from the Cretaceous limestones. The conglomerate becomes a breccia in some beds in this section.



X 17

Plate (34): A limestone conglomerate of the Kabalak Tepe Member in the section of Eminlik (III) (Em_3) (c = clasts of the Cretaceous carbonate mudstone, Ca = Calcite).



×17

Plate (35): Polymict conglomerate of the Kabalak Tepe Member in the section of Kessektepe (c = clasts of the Cretaceous limestones, s = serpentinite, q = quartz, i = igneous rock fragments).

Palaeozoic limestones.

3 - Pebbles of volcanic rocks and those of the Cretaceous ophiolitic complex are not found everywhere but they increase in amount towards the northeastern margin of the basin where the conglomerate is overlain by sandstones. This occurrence may also give an additional support to the evidence for a source in the north, northeast or northwest, which are discussed later.

(iv) Matrix of the conglomerate:

A) General: This consists of poorly sorted skeletal sand grains set in either a fine grained carbonate mud or a calcite cement. The skeletal grains consist of, in decreasing order of abundance: whole tests of small benthic foraminifera (miliolids and Alveolinellids), fragments of coralline algae, molluscs, corals, and echinoderms, in addition to lesser amounts of quartz, cherts, and rock fragments. However, in one or two of the sections, e.g., in the section of Kessektepe (Kt), quartz, chert and rock fragments are predominant and constitute the bulk of the matrix. The matrix of the conglomerate which may generally be thought as skeletal packstone exhibits interesting texture and diagenetic alterations and this will briefly be examined here.

B) Framework grains:

a) Skeletal grains:

- Small benthic foraminifera: Miliolids and Alveolinellids are common and are well preserved among the other fragmented skeletons. Their chambers are filled either by calcite cement or carbonate mud. Replacement of the tests of these foraminifera by micrite, and microspar are seen. Crushing of the thin-walled skeletons of these organisms due to compaction is also observable (Plate 36).

- Coralline algae: These are usually fragmented and show an extremely variable grain size ranging from a few microns up to a few millimetres. Only in one of thethin sections do the coralline algae appear to perform a binding function within the matrix of



× 67

Plate(36): Crushing of the thin-walled skeletons of the small benthic foraminifera against a carbonate lithoclast(right).

the conglomerate. Fracturing, replacement of the coralline algae by micrite, and pressure-solution contacts between these and some inorganic grains (rock fragments) are also seen (Plate 37).

- Molluscs: These occur as whole or fragmented pieces and are replaced by sparry calcite and have micrite envelopes surrounding them (Plate 38).

- Echinoderms: They are generally broken and do not show any overgrowth.

- Other fossil fragments: These may include corals, bryozoa, and some other unrecognisable skeletons.

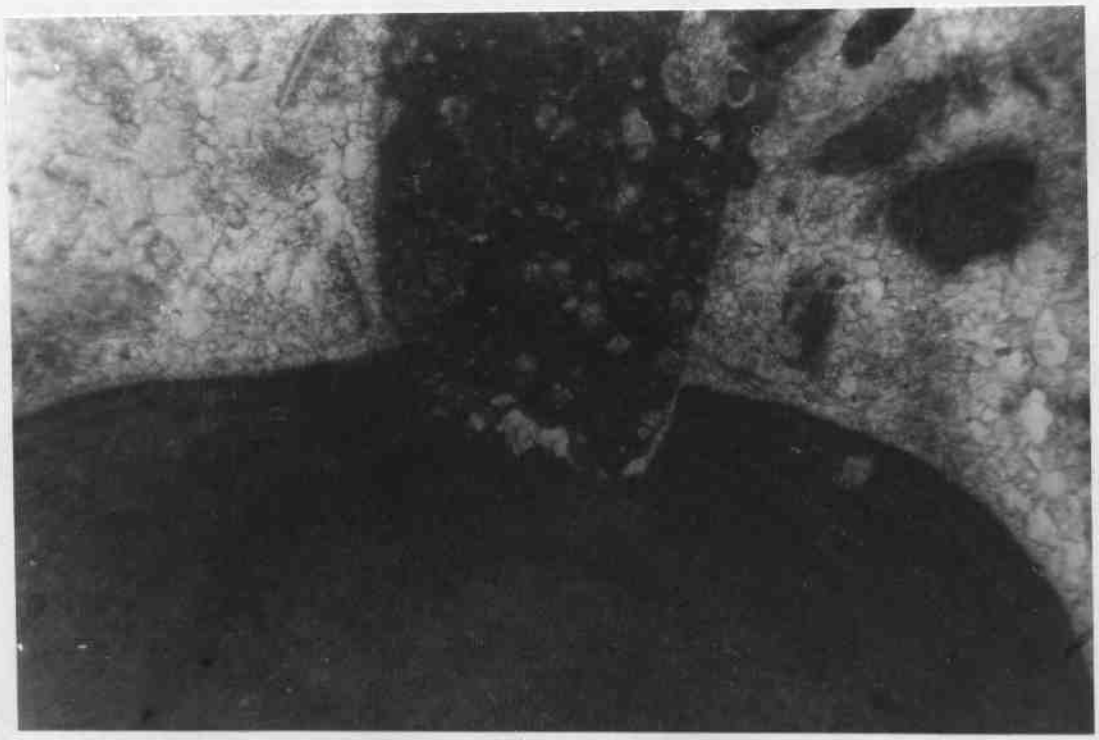
b) Non-skeletal grains: These are abundant in the section of Kessek Tepe and are composed mainly of quartz, cherts, igneous rock fragments, and fragments of serpentinite(Plate 35). The quartz grains generally have straight and sometimes irregular grain boundaries; whereas most show straight extinction some may show undulose extinction.

The chert grains are usually angular to subrounded and are microcrystalline in texture.

Igneous rock fragments commonly show a prophyritic texture which is characterized by few large phenocrysts of feldspars enclosed in a groundmass of microcrystalline feldspar and quartz. A few serpentinite grains are also present.

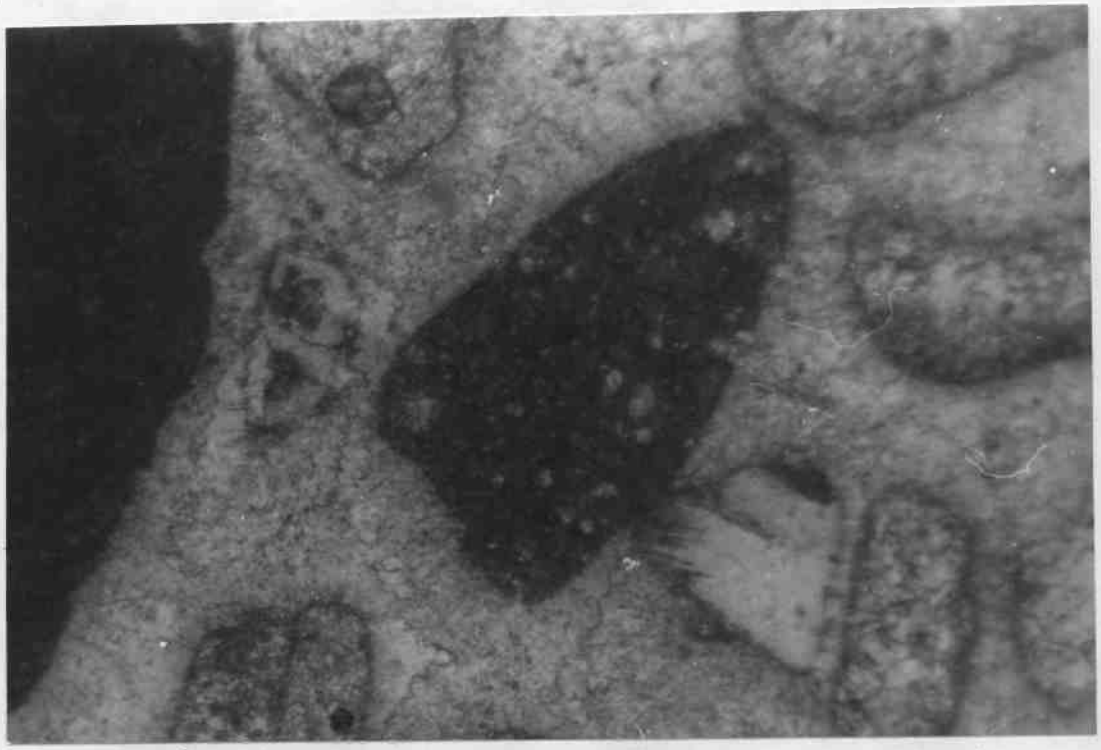
c) Groundmass: The skeletal and non-skeletal grains of the matrix of the conglomerate are in some cases set in a dark brown, sub-translucent carbonate mud groundmass which encloses some tiny fossil fragments or inorganic grains (Plate 39). In other cases they may be set in a sparry calcite cement (Plate 38). The sparry calcite is sometimes, however, formed by recrystallization of an original matrix. Fracturing of the groundmass due to compaction is common (Plate 39).

d) Cement: The granule to fine grained packstone



X 80

Plate (37): Pressure-solution contacts between a coralline algal fragment (bottom) and a carbonate mudstone lithoclast (derived from the Cretaceous formations) (top).



X80

Plate (38): Calcite casts of the originally aragonitic molluscan fragments (bottom and on the right). The dark outer rims around these grains represent micritic envelopes. Note the coarsely crystalline sparry calcite cement between the clasts.



×40

Plate (39): A non-tectonic fracture within the ground-mass of the conglomerate of the Kabalak Tepe Member.

matrix of the conglomerate is usually cemented by sparry calcite. This sparry calcite cement is, in most thin sections, overlain and succeeded by a fine carbonate mud matrix. The occurrence of the cement is mostly restricted to the sheltered areas (Plate 40).

3.2. Sandstone:

(i) General description: This is generally calcareous, carbonaceous, friable to well cemented, and ranges from medium to very fine sand grade. It is characteristically massive or occurs in beds several centimetres thick and commonly includes pebble and conglomerate beds throughout the unit (Plate 41).

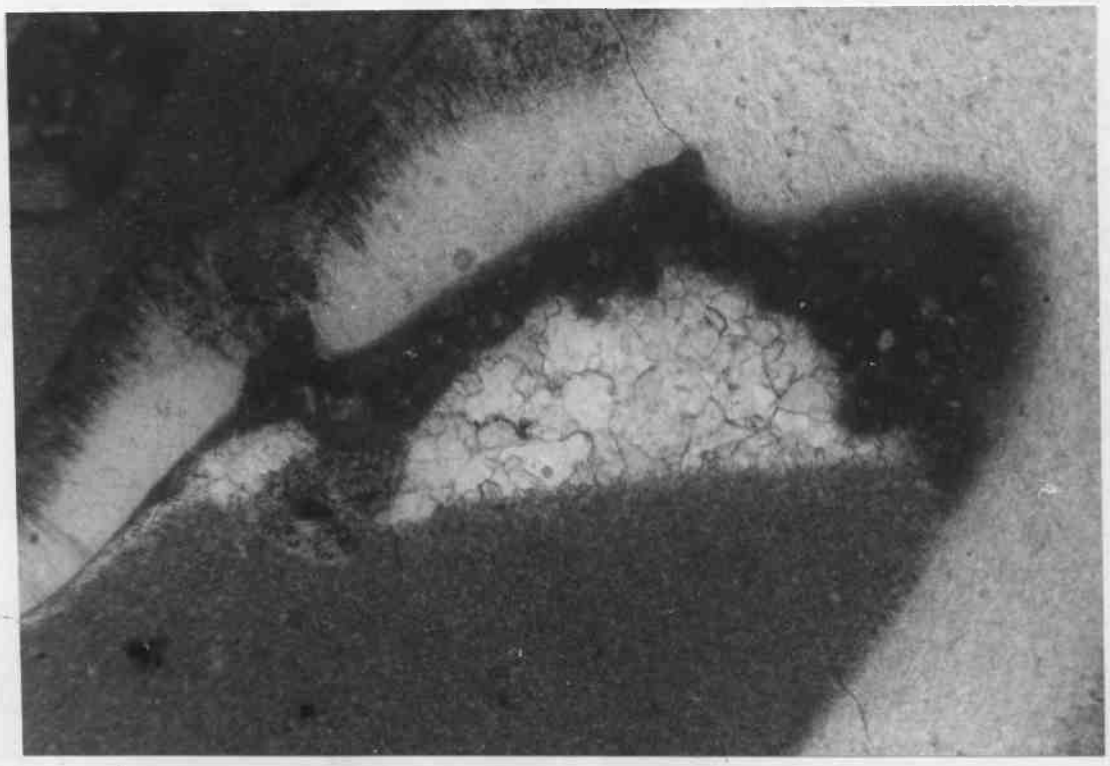
The sand grains are chiefly, in decreasing order of abundance; lithoclasts of fine textured mudstone and recrystallized limestone together with quartz, cherts, iddingsite, and feldspar. Well preserved shells of bivalves are abundant in most beds of this lithology. Vertical burrowing with individual burrows as long as 30 centimetres appears to be the most characteristic sedimentary structure of this rock (Plate 42).

(ii) Microscopic description (Plate 43)

A) Framework grains:

a) Carbonate lithoclasts: These are generally subrounded to rounded lithoclasts of fine grained mudstone and recrystallized limestone. These lithoclasts constitute the majority of the grains and range in grain size from 100 to 500 microns. The lithoclasts of the mudstone are dark grey or dark brown colour under plain light. They sometimes are very similar in appearance to the micritized coralline algal fragments in which all the cellular structure has been destroyed. Generally the lithoclasts of the carbonate mudstone are more abundant than the lithoclasts of the recrystallized limestone.

b) Quartz: The single grains are generally angular to subrounded and are euhedral and have straight extinction; composite grains with undulose extinction are also commonly found in this lithology. Although most of the quartz grains are free from inclusions, some of the



×80

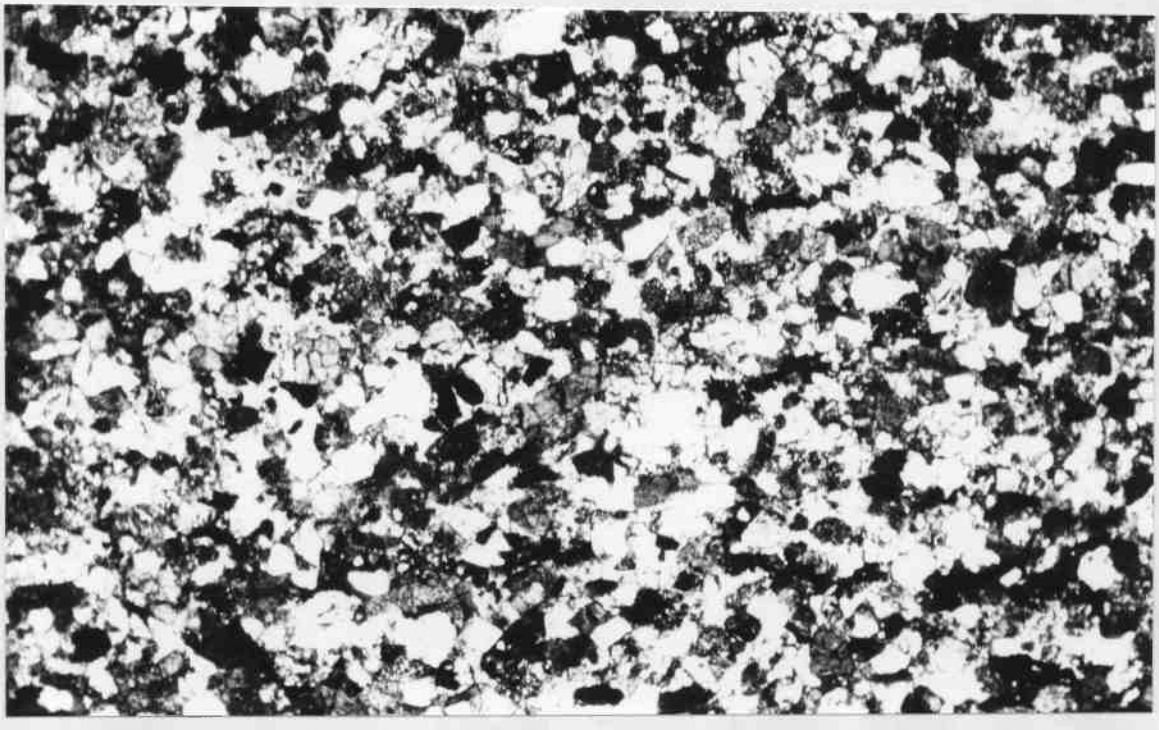
Plate (40): Growth of the sparry calcite cement under the protection of a large molluscan skeleton (umbrella effect). It is interrupted and succeeded by the deposition of fine carbonate mud matrix (bottom).





Plate (41): Conglomerate (bottom) and sandstone (top) of the Kabalak Tepe Member in Nergizlik.

Plate (42): A burrowing structure in the sandstone in the section of Nergizlik (I) (Nz_1).



X17

Plate (43): General view of the sandstone of the Kabalak Tepe Member (The dark grains are mostly lithoclasts of the Cretaceous carbonate mudstone. The light grains are composed mainly of quartz, chert, and iddingsite).

composite grains may contain inclusions. The grains are variable in grain size ranging from a few to 400 microns.

c) Chert: Microcrystalline aggregates occuring as angular to subrounded grains with perfectly straight sides are common. They vary in size from 100 microns to about 700 microns.

d) Iddingsite: Grains of iddingsite are characterized by a reddish brown colour. They represent a complex alteration product of the crystals of olivine common in certain types of basaltic rocks. They are generally subrounded to rounded and vary in grain size from 100 microns to 500 microns.

B) Accessory components: Feldspar, which is mainly plagioclase, is the main accessory component of this sandstone. The plagioclase consists of both fresh and altered grains and usually exhibits albite twinning.

Igneous rock fragments and some large brown biotite flakes are the only other minor constituents of these rocks.

C) Fossils: Some whole, well preserved large benthic foraminifera, fragments of echinoderms, and coralline algae are present in this lithology. Common well preserved molluscan shells (bivalves) are found as macro-fossils in the field exposures.

D) Matrix: The matrix of the sandstone which usually appears to be poorly sorted and cloudy under the microscope is composed predominantly of fine to coarsely crystalline sparry calcite with some minor amounts of detrital materials, such as fine grained quartz, clay minerals, etc.

E) Cement: Sparry calcite is the most common cement in the sandstone.

F) General texture: The sandstone is similar in texture and composition to the red sandstones of Cakmak Member. It is poorly sorted, medium to very fine grained, containing: abundant carbonate lithoclasts, quartz, cherts, and iddingsite, all of which are set in

a fine to coarse grained sparry calcite matrix and/or cement with a tight packing.

G) Petrographic name: Calcareous lithic arenite (Williams et al; 1954).

3.3. Siltstone

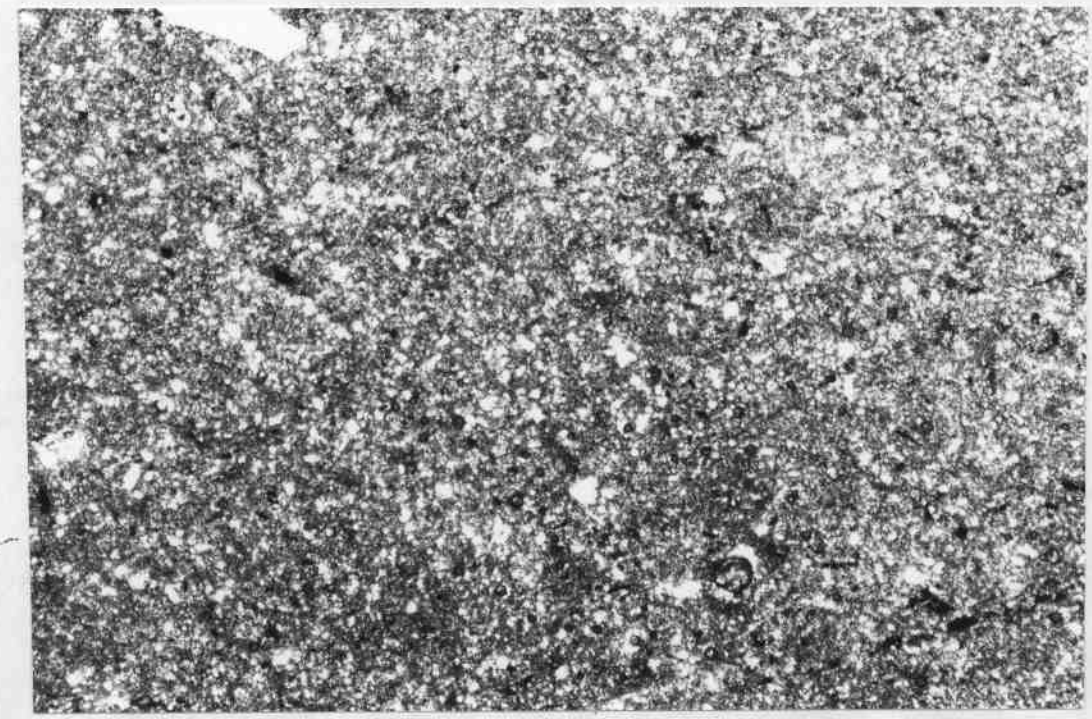
(i) General description: Sedimentary structure and bedding properties of the siltstone are usually difficult to detect. It appears to be structureless, although thin horizontal beds and ripple-laminated sets are present locally. It is calcareous, friable to well cemented and contains, in decreasing order of abundance, carbonate lithoclasts, quartz, cherts, and some igneous rock fragments enclosed in a predominant carbonate-mud matrix (Plate 44).

Common molluscan shells, burrows, and carbonaceous material are often observed in field exposure of this lithology.

Interbedded with the grey siltstone, light grey, hard, and 10 to 20 centimetres thick, carbonate mudstone layers are seen throughout the unit. This carbonate mudstone is fine grained and contains a few detrital grains, such as quartz, cherts, and limestone fragments.

3.4. Distribution, thickness, and field relations of the Kabalak Tepe Member: The conglomerate, sandstone, and siltstone of this member crop out in Ucurge Suyu and Kocadere, near Nergizlik, and on the pre-Miocene topographical highs, along the margin of the Miocene basin (Map 1). These rocks overlie the Cakmak Member of the Gildirli Formation: conformably in the depressions and grade vertically and laterally into the Guvenc Shales in these low areas; they lie unconformably on thepre-Miocene rocks on the topographical highs where they also intertongue with, or grade vertically into, the rocks of the Karaisali Formation.

The thickness of the Kabalak Tepe Member varies considerably: it is no greater than 10 metres on the pre-Miocene topographical highs but it is at least more than 40 metres in the depressions. The actual thickness of these rocks is not known, but the total thickness of the two members is



×17

Plate (44): General view of the siltstone of the Kabalak Tepe Member (The white grains are composed mostly of carbonate lithoclasts, quartz, and chert).

more than 300 metres (Schmidt, 1961).

3.5. Source area and environment of deposition of the Kabalak Tepe Member: The sources of the sediment of which the conglomerate, sandstone, and siltstone of the Kabalak Tepe Member are composed are evidently the rocks of the Palaeozoic and the Cretaceous formations which are widely exposed in the Taurus Mountains and in the study area respectively.

The abundance, type, and state of preservation of the fossils and the coarseness of the conglomerate on the pre-Miocene topographic highs suggest a high energy, marine environment of deposition for these rocks. Their sheet-like geometry and their close association with the Small benthic foraminiferal-algal packstone subfacies of the Karaisali Limestone, which represents landward littoral shoal areas of the coral-algal bank growth of the same formation, indicate that this high energy environment was most probably a beach or nearshore area which was lying along the rocky coasts of the Miocene sea in the region.

The skeletal grains of the matrix of the conglomerate are mostly fragments of coralline algae, small benthic foraminifera, corals, echinoderms, bryozoa, and molluscs. These are the characteristic fossils of the Karaisali Formation and were evidently either living "in situ" or were brought to the depositional site of the conglomerate from nearby: probably from the areas where the coral-algal bank growth was taking place. They accumulated and were cemented together with the pebbles of the pre-Miocene rocks which were carried in by rivers from the mountainous hinterland bordering the basin in the north or in the depressions by reworking of the lower member. The sparry calcite cement of the conglomerate is restricted to the sheltered inter-particle areas and is overlain by the later deposited matrix. This carbonate mud matrix was probably brought in either during the stormy conditions or perhaps more likely formed locally during quiet phases. Alternatively and most likely it could have percolated down into the conglomerates after the deepening of the

Miocene sea.

The conglomerate is interbedded and interfingers with the sandstone and siltstone in the depressions of the pre-Miocene land surface. All these fine grained clastics contain common carbonaceous materials, well preserved, unabraded molluscan shells, and burrows, and show lateral and vertical gradings to the open marine Guvenc Shales, all of which indicate a low energy environment. It is most likely that these sandstone and siltstone units were deposited under the shallow water conditions in the topographic lows while the conglomerate accumulated to landward in a beach, or nearshore zone. The interbedding of the conglomerate, sandstone, and siltstone probably resulted from frequent changes or local variations in energy conditions. The general vertical sequence of these clastics at Nergizlik, which are high energy shallow-water conglomerates in the lower part grading to quieter water sandstone and siltstone deposits at the top, records the marine transgression. The geographic location and the general stratigraphy of the area suggest that the transgression was from a general southerly direction.

II.4. THE AGE OF THE GILDIRLI FORMATION: As far as the author is aware, no diagnostic fossils, which enable the true age of this formation to be determined, have been found in the rocks of the Gildirli Formation; or if they have, they have not been described in any publications. It has been assigned a Lower Miocene (Aquitanian to Burdigalian) age, chiefly on the basis of its stratigraphic position (Ternek, 1953; Ternek, 1957; Stucker, 1960; Schmidt, 1961). It overlies unconformably the rocks of the Palaeozoic and the Cretaceous formations and passes laterally and vertically into the Karaisali Formation which contains fossils of Burdigalian age and the Guvenc Formation which contains fossils of both Burdigalian and Helvetian age (Ternek, 1953 and 1957) (see related chapters).

CHAPTER III. THE KARAISALI FORMATION

III. 1. GENERAL: The Karaisali Limestone is a yellowish grey (10 YR 8/2) complex carbonate unit of variable grain size which contains an abundant fauna, including (in decreasing order of abundance): coralline algae, corals, foraminifera, echinoiderms, molluscs, bryozoa, etc. It is dominantly a well indurated, tight, non to poorly bedded bioclastic limestone, although some well bedded varieties are common. Both non-bedded and bedded varieties frequently interfinger. The Karaisali Limestone is relatively pure in most parts but some subfacies of this carbonate unit are argillaceous and contain noticable amounts of quartz, and clay minerals.

The range in size of individual grains of the bioclastic units of the Karaisali Limestone appear, on megascopic inspection, to be generally from a few microns to 3 or 4 centimetres in length. The larger grains consist mainly of algal and coral fragments, and of large benthic foraminifera. Sorting is generally poor to moderate.

The Karaisali Limestone ranges from a few centimetres to possibly more than 350 metres in thickness in the area which has been studied: it may be less than a metre at some places in the north, such as in the vicinity of Kesli, Eminlik, Dari Cukuru near to Karakilic, etc. and usually becomes thicker southward reaching a maximum thickness of about 350 metres in Gulesdagi, near Kuzoluk (Map 1, Measured section G1).

Six rock types are common within the Karaisali Formation (Fig. 11). These are (in the terminology of Dunham, 1962) as follows:

(1) Coral-algal packstone and boundstone

(2) Small benthic foraminiferal-algal packstone

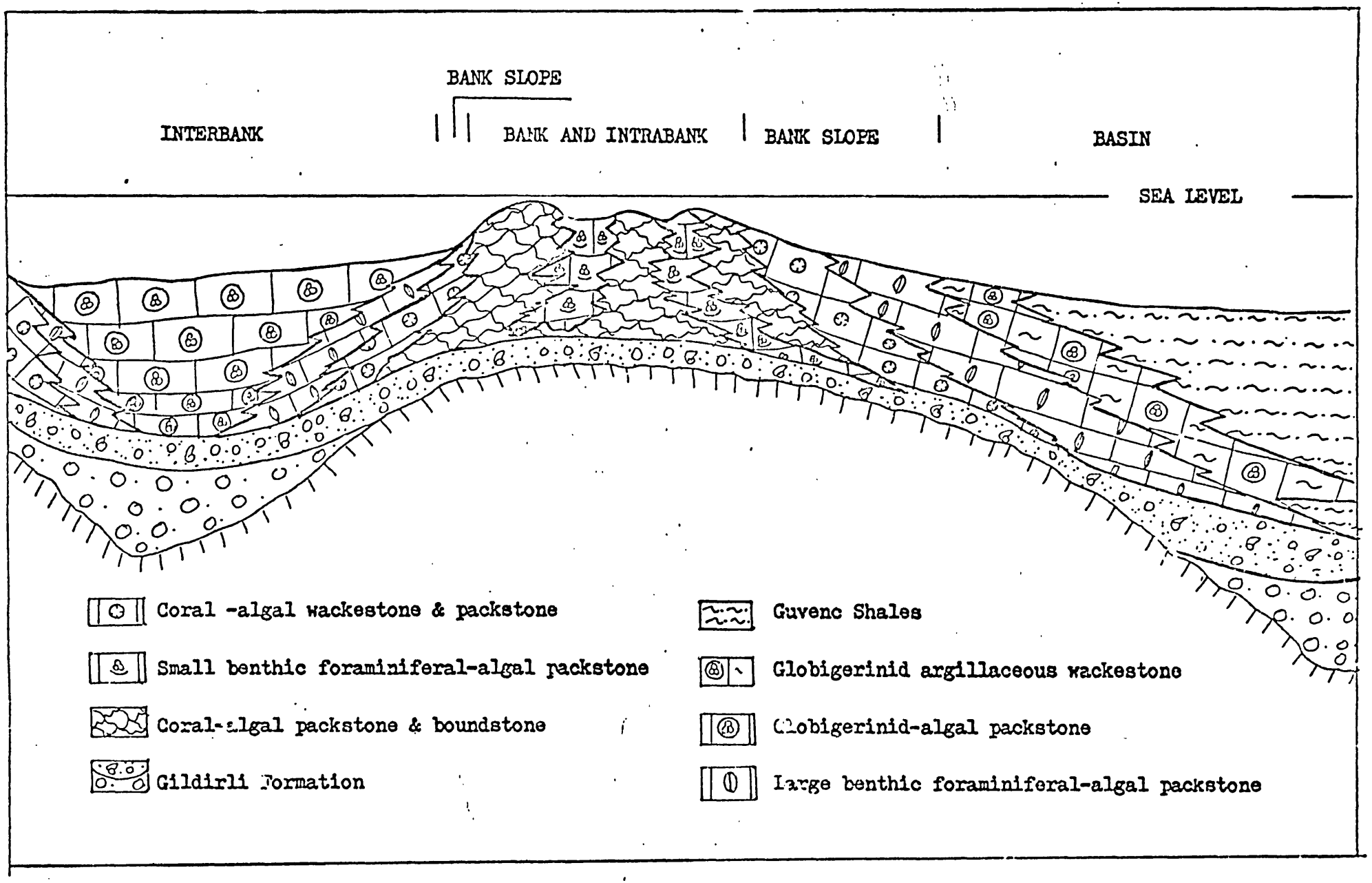
(3) Coral-algal wackestone and packstone

(4) Large benthic foraminiferal-algal packstone

(5) Globigerinid-algal packstone

(6) Globigerinid argillaceous wackestone.

Each of these rock types constitutes a distinctive subfacies of the



Fig(II): Subfacies of the karaisali Limestone

Karaisali Formation and is characterized by both a diagnostic texture and fossil content. Both of these properties are closely related to one another and simply reflect differences in depth of deposition. They are dependent also upon the lateral distance to the pre-Miocene topographical highs which were the sites of intensive algal-coral growth. All of these rock types grade into one another and, although the bedding properties are often very helpful, they have been distinguished from each other in the field mainly on faunal evidence (Fig. 11). None of these subfacies, except the Globigerinid argillaceous wackestones and Globigerinid-algal packstones which occupy the depressions between the pre-Miocene topographical highs are mappable units.

III. 2. CORAL-ALGAL PACKSTONE AND BOUNDSTONE SUBFACIES:

2.1. Lithology and field relations: This subfacies consists of a yellowish grey (10 YR 8/2), poorly or non-bedded (Plate 45) carbonate rock which shows a considerable variation in depositional texture (Plates 47 and 48). It appears to be a packstone when the rock is made up of unoriented fragmental debris (in decreasing order of abundance) of: coralline algae, corals, foraminifera, echinoderms, and molluscs (Plate 47). Whereas it may be classified as a boundstone when it shows a growth structure which is dominated by the above organisms which are held together by the coralline algae and the encrusting foraminifera (Plate 48). Both of these rock types are found intimately mixed with each other throughout the outcrops and together form this complex subfacies which provided some problems in its classification and correlation.

It is very difficult to demonstrate whether this subfacies originally represented a welded growth structure of sessile organisms in which detritus of the same fossils and of others infilled the framework to give a packstone texture or whether it is a bioclastic packstone which was essentially formed by insitu fragmentation and deposition of the above skeletons with some algal and foraminiferal encrustations developed



Plate (45): Poorly or non-bedded carbonate rocks of the Coral-algal packstone and boundstone subfacies in Koytepe, Yanikkisla.

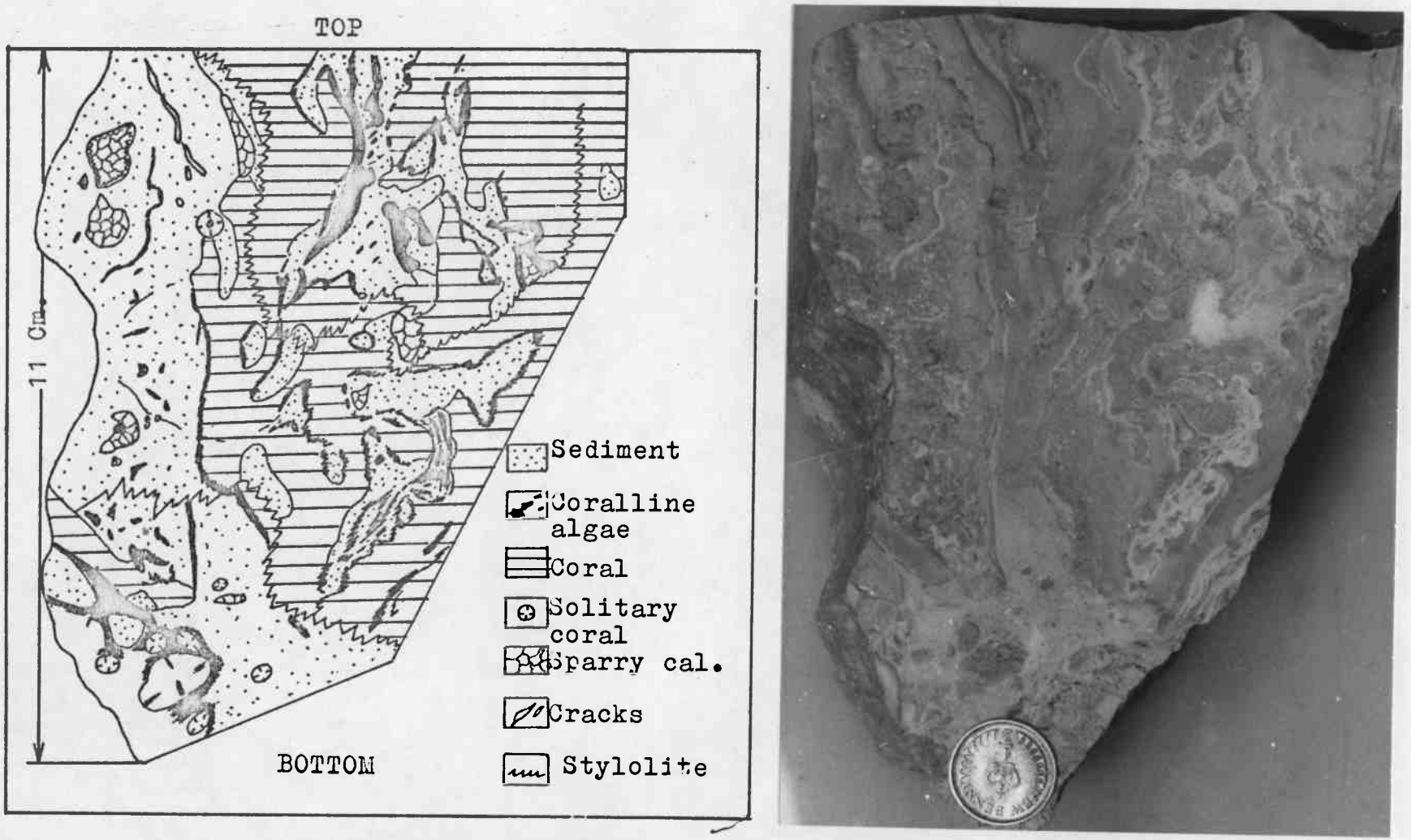
on these skeletal components. In order to demonstrate which of these possibilities was correct, some large slabs were collected and examination of these samples suggested that this subfacies is generally a mixture of both of the above rock types, but is mainly detrital in nature (Figs. 12 and 13). However, large solitary coral heads are commonly found in growth positions in this unit at scattered localities throughout the area.

The Coral-algal packstones and boundstones show lateral and vertical transitional contacts with almost every other subfacies of the Karaisali Limestone. They interfinger with the Small benthic foraminiferal-algal packstone, Coral-algal wackestone and packstone, and Large benthic foraminiferal-algal packstone subfacies in the locations where the sections have been measured (Measured sections Tp, Kt, Em_1, Em_2, Em_3, Gl, Ct_2, etc., Map 1 and Plate 46).

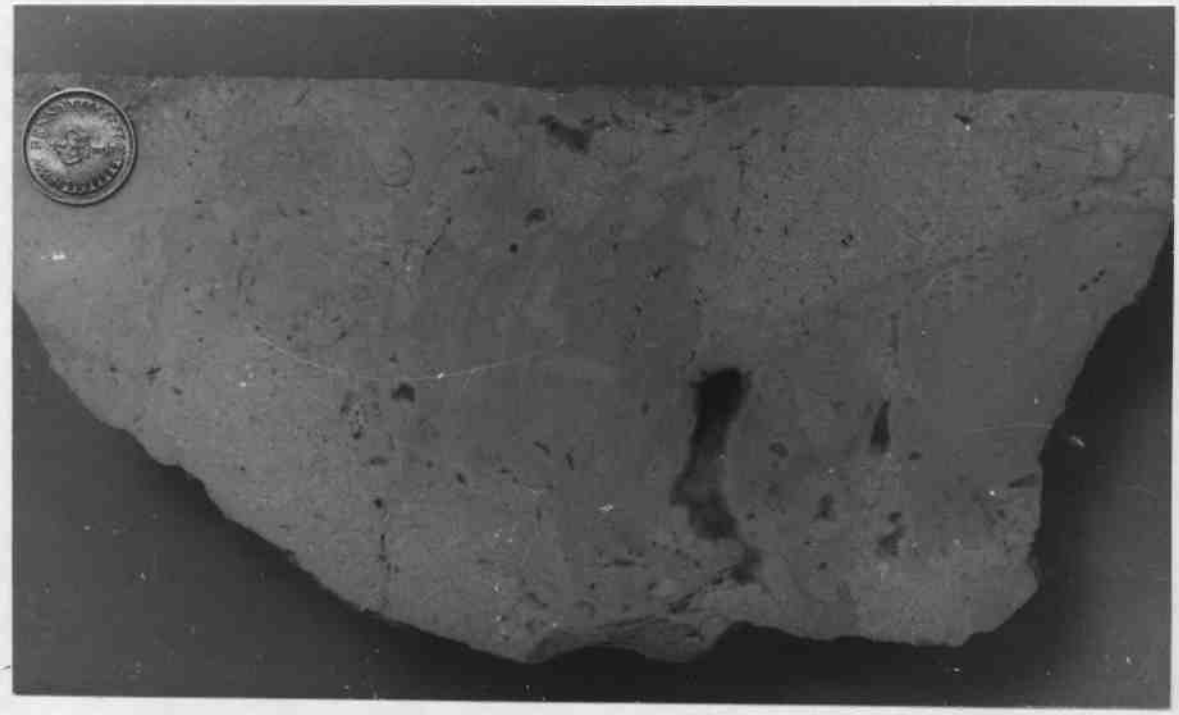
2.2. Thickness, areal distribution, and typical occurrences: The Coral-algal packstones and boundstones are well exposed throughout the area and their best exposures are seen at Topusur Tepe, Kessek Tepe, and Eminlik (Map 1, Measured sections Tp, Kt, Em_1, Em_2, Em_3).

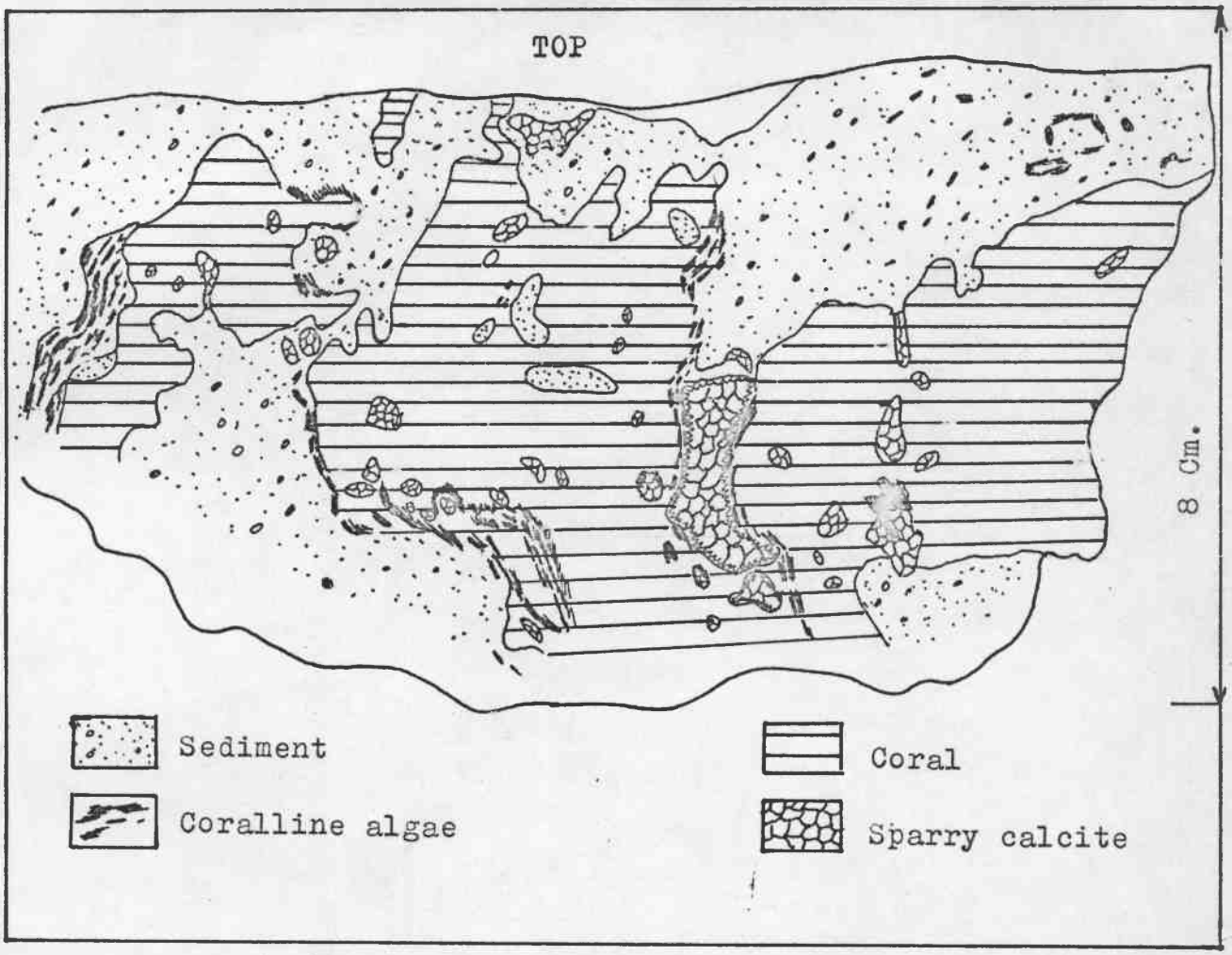
It is the most widely distributed and the thickest subfacies of the Karaisali Formation. The maximum observable thickness measured was around 200 metres at Kessek Tepe (Kt) and it appears to be even greater at Gules Dagi (Gl) where this subfacies interfingers with the other associated units (Map 1, Measured sections Gl and Kt). Generally it is thinner in the north and becomes thicker to the south, following the general pattern of the thickness variation of the Karaisali Formation.

2.3. Microscopic description: Microscopically, rocks of this subfacies are seen to consist of (in decreasing order of abundance): coralline algae, corals, and encrusting foraminifera and less abundant small benthic foraminifera, echinoderms, and molluscs, set in a matrix of micrite, microspar, and sparry clacite (terminology of Folk, 1965). Bryozoans and green algae may locally be important. The size of the



Fig( ):A typical textural appearance of the Coral-algal packstone and boundstone in a hand specimen(sample no:53,taken from the section of Cam Tepe(2))





Fig( ):A typical textural features of the Coral-algal packstone and boundstone (sample no:36,from the section of Yanikkisla 4)



Plate (46): Interfingering of the Coral-algal packstone and boundstone with the Globigerinid argillaceous wackestone through the Coral-algal wackestone and packstone and the other associated subfacies.

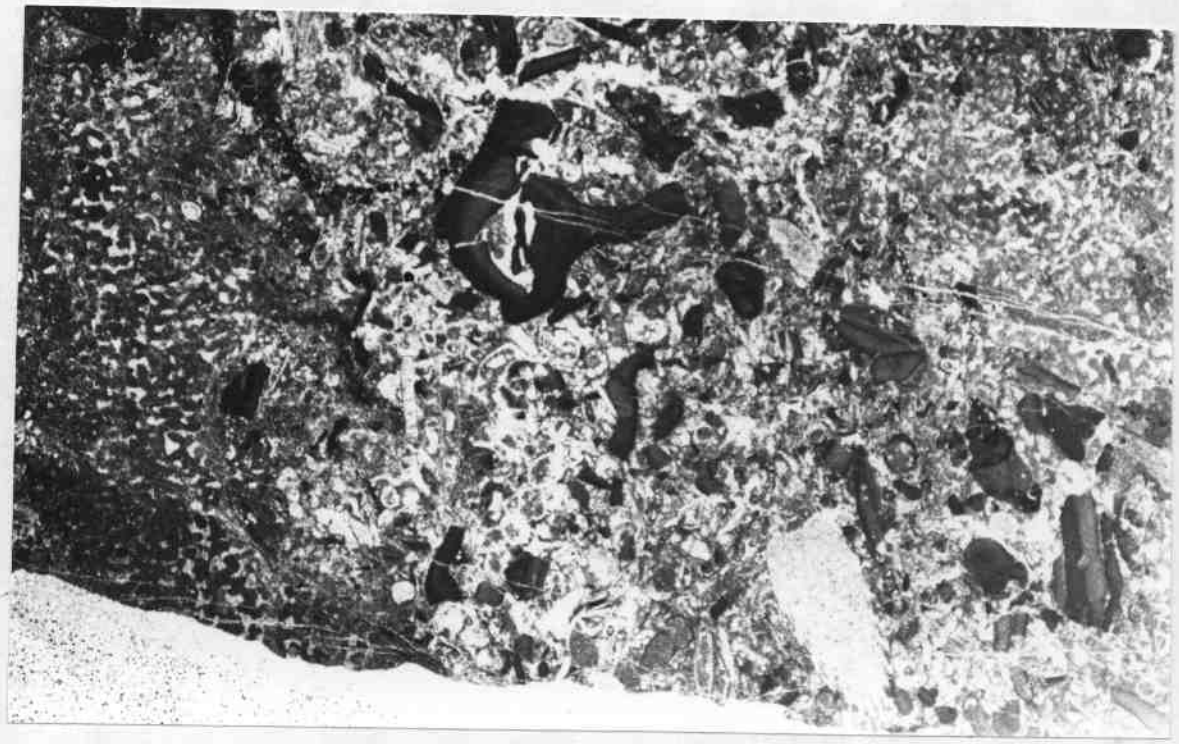


Plate (46): Interfingering of the Coral-algal packstone and boundstone with the Globigerinid argillaceous wackestone through the Coral-algal wackestone and packstone and the other associated subfacies.

grains is variable, ranging from a few microns up to a few millimetres or centimetres. The fabric of this subfacies ranges from that of a packstone to that of a boundstone. When a packstone, it is composed mainly of the above organisms without any obvious sorting and orientation (Plate 47). However, it appears to be comparatively better sorted than most of the other packstones of the Karaisali Limestone Formation. Coralline algae are always fragmented and retain sharp edges while the other organisms may be found intact as well as broken in rocks with this type of fabric. Algal and foraminiferal encrustations are absent or entirely restricted to the individual grains. On the other hand, when the rock is a boundstone, it includes abundant encrusting algae, corals, and encrusting-type foraminifera with whole and broken skeletons of other organisms (Plate 48). The encrusting coralline algae together with the encrusting foraminifera perform a binding function in this lithology, as they bind and encrust the individual skeletons together. In addition, they may alternate with one another as laminae on a single skeleton, particularly on coral as well as on other skeletal detritus and sometimes those encrustations enclose areas of the matrix as well, i.e.; they have bound loose sediment in a way analogous tothe behaviour of a blue-green algal mat.

The matrix of the Coral-algal packstone and boundstone subfacies may be composed of skeletal micrite, microspar, and sparry calcite or a mixture of all these types (Plates 47 and 48). It fills the original cavities and the spaces between the sessile organisms where it sometimes overlies the first phase cement. The source and the modes of formation of the matrix are variable and not restricted to a certain source or time (see discussion on the diagenesis of the Karaisali Formation). Burrowing, boring, and fracturing of the matrix are of special interest.

The sparry calcite content of this subfacies is mainly due to inversion of tests of originally aragonitic sessile organisms,



X24



X24

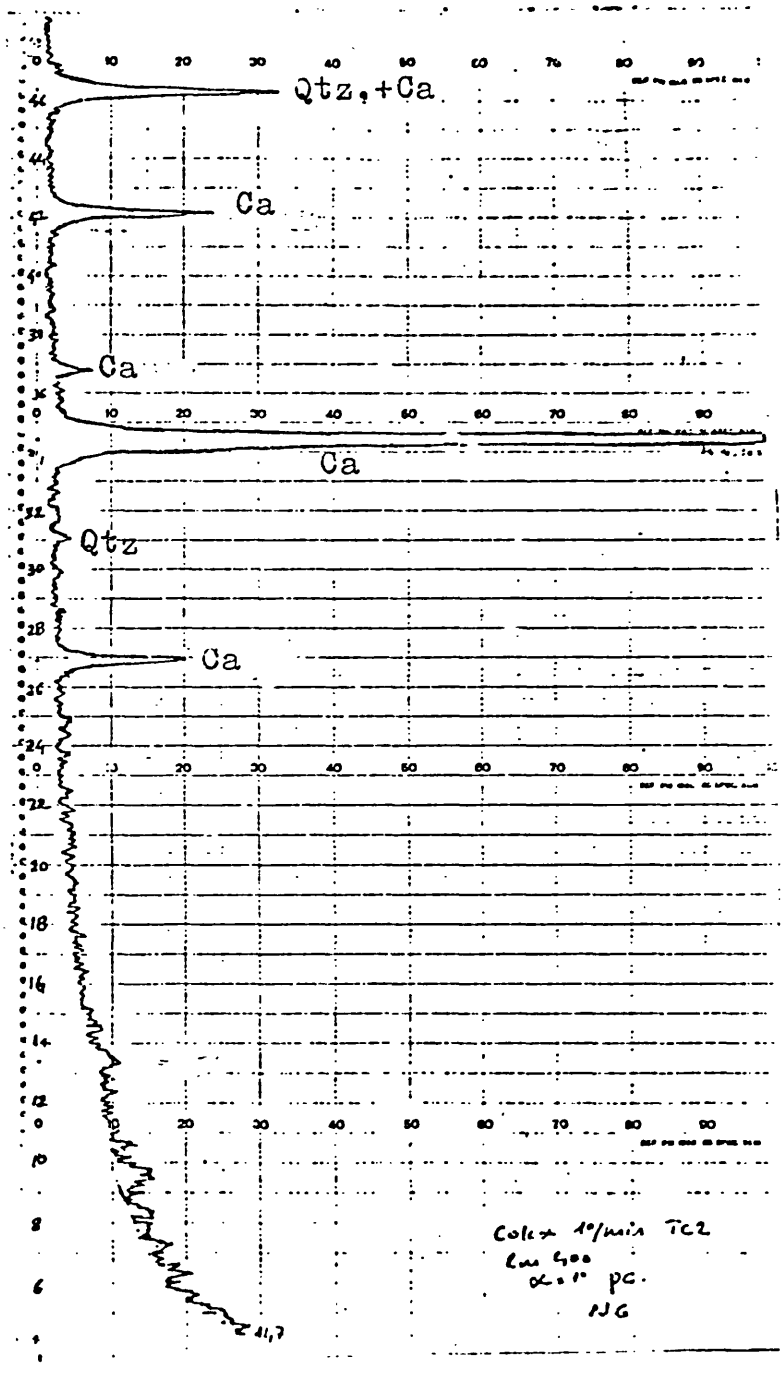
Plate (47) and (48): The two different depositional texture of the Coral-algal packstone (Plate 47) and boundstone (Plate 48).

such as corals, green algae, bryozoans, etc. In addition, neomorphism of the matrix, recrystallization of some fossils, solution-cavity filling, and cementation are the other mechanisms which contribute more sparry calcite to this lithology (see discussion on the diagenesis of the Karaisali Formation). Cementation is largely the result of precipitation in open spaces or from the development of echinodermal overgrowths.

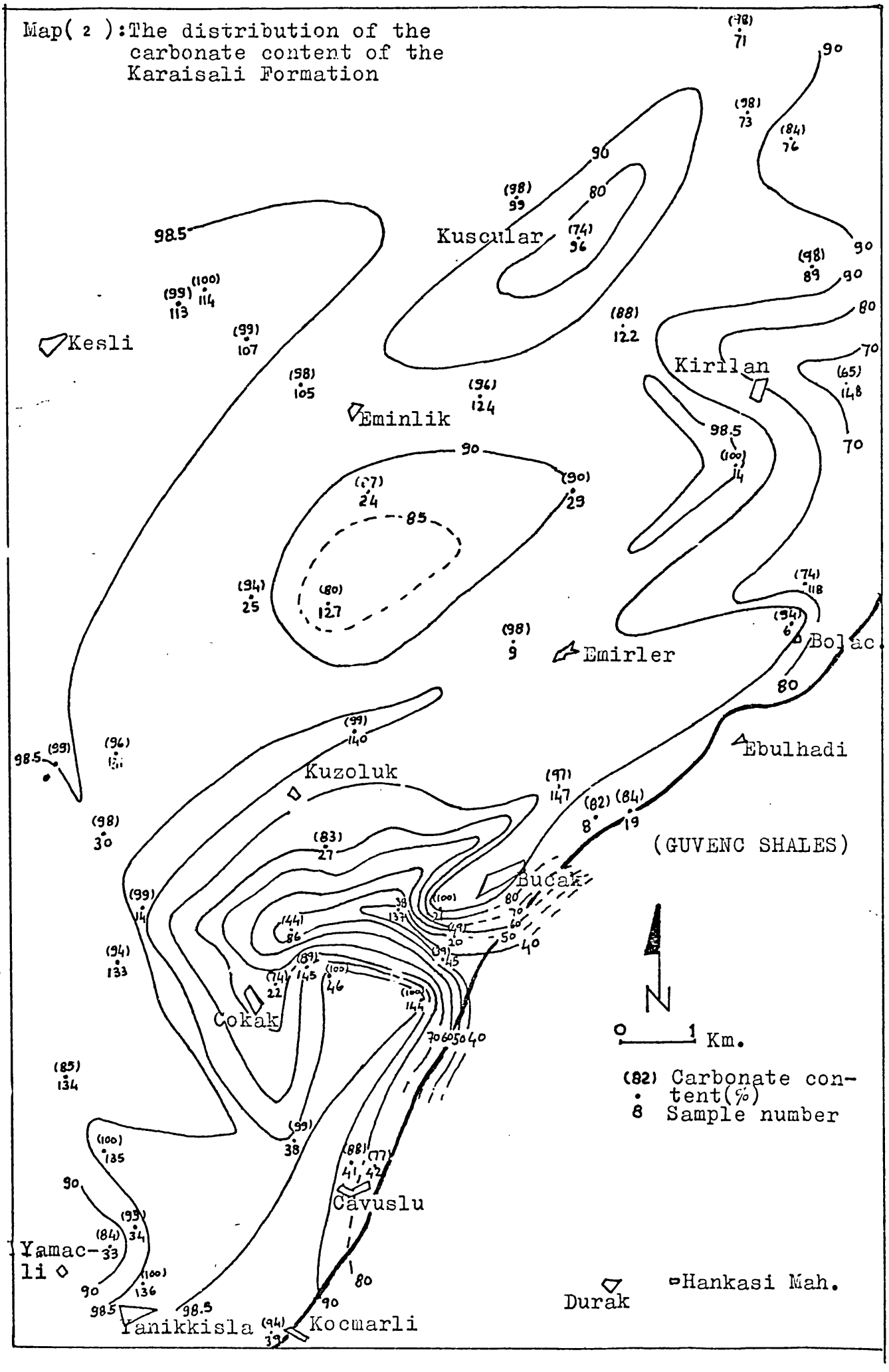
2.4. Mineralogy and carbonate content: Coral-algal packstones and boundstones are the purest lithology of the Karaisali Limestone. Mineralogically they are dominated by predominant calcite with a little dolomite and quartz (Fig. 14). The quartz grains are particularly well rounded and range from 30 to 150 microns in size. Most of them are detrital in origin and are concentrated between the foraminiferal and algal encrustations. However, they are also found scattered in the matrix among the skeletal components. The carbonate content of this lithology has been determined to be as high as 99% $CaCo_3$ (Map 2).

2.5. Environment of deposition: The Coral-algal packstone and boundstone subfacies appears to have formed on a bank in shallow, well agitated normal marine water as indicated by the lithologic character and by the fauna and the flora of these rocks. The abundance of coralline algae and corals suggest that the water depth of the depositional environment of this subfacies was probably less than 30 metres and the salinity of the water was perhaps between 27°/oo and 38°/oo. The temperature of the water can also be approximated and possibly ranged from 25° to 30°c (Vaughan, 1919; Boschma, 1956; Heckel, 1972; Milliman, 1974).
The currents and wave activity were sufficiently vigorous to break and abrade many of the skeletons of the organisms.
The field occurrence and relationship of the Coral-algal packstone and boundstone subfacies to the other units of the Karaisali Formation indicate that these banks formed on the top or on the margins of the pre-Miocene topographical highs. Abundant coralline algae, corals, and encrusting-type foraminifera and less abundant small benthic foraminif-

Fig(I4):An x-ray diffraction trace of
a characteristic sample of the
Coral-algal packstone and boundstone



Map(2):The distribution of the carbonate content of the Karaisali Formation



era, echinoderms, bryozoa, and green algae lived near the surface of water on the margins of the highs. Coralline algae probably played an important role in construction of the banks playing an encrusting and cementing role as well as being a sediment contributer (Marsh, 1970; Milliman, 1974). They, together with the encrusting foraminifera, encrusted and bound the corals and the skeletons of other organisms to form, in places, a rigid, welded growth structure. However, close examinations of this subfacies in the field and in the laboratory showed that despite the presence of the coral-algal boundstone and the coral heads in their growth position; the rock of this subfacies is dominantly detrital in character. Therefore, the bank was originally formed by "in situ" fragmentation and deposition of the above organisms without the presence of a rigid internal skeletal framework which was wave-resistant during the formation of the bank. As any other growth structure on a shallow shelf, the sediments of this bank were subjected to wave agitation and were fragmented as the bank grew, thus giving rise to its essentially detrital nature. However, it was sufficiently wave resistant to build up above the general level of the adjacent sea-floor as indicated by the occurrence of the tongues of the Coral-algal wackestone and packstone subfacies which dips away from this growth structure. The presence of solitary coral heads on the bank, which are in their original growth position, also supports this suggestion.

The presence of matrix in the sediments of such a high energy environment suggests that coralline algae, corals, bryozoa, and some other organisms acted as baffles to entrap both lime mud and some terrigenous mud. Muddy carbonate matrix between the coral and algal heads is commonly seen in modern reefs of the Persian Gulf, where it is evident that the irregular growth forms are able to produce relatively sheltered micro-environments (Graham Evans personal communication, 1977). The coralline algae which are the predominant component of the sediments of the bank were mostly responsible for the creation of this organic baffle

system since they play an important role in sediment entrapment and stabilization (Newell and Rigby, 1957; Ginsburg and Lowenstam, 1958; Wray, 1971; Marsh, 1970; Bathurst, 1971). According to Davies (1970), the calcareous algae on the levees of the banks of Shark Bay are subordinate in importance to the sea-grasses in the trapping and binding of coarse and fine carbonate sediment. However, the latter author also suggested that an organic baffle of the coralline algae may behave very similarly and perform a similar function to the sea-grasses. As in modern sediments, the carbonate matrix of this lithology was probably derived both from the breakdown of the coralline algae and of the other skeletal material; this matrix was entrapped within the organic baffle formed by the coralline algae and to a lesser extend by the scattered corals (see diagenesis of the Karaisali Limestone).

III. 3. SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE SUBFACIES:

3.1. Lithology and field relations: This subfacies typically consists of yellowish grey (10 YR 8/2), medium to fine grained, poorly sorted bioclastic packstone which is generally rich in coralline algae and small benthic foraminifera, such as miliolids and Alveolinellids. Large fossil fragments are uncommon, except in some beds of this medium to fine grained unit which contains abundant coralline algal fragments as much as 20 millimetres in diameter. The beds in the small benthic foraminiferal-algal packstone are mostly 10 centimetres thick, and the bedding planes generally exhibit a smooth surface which is wavy (Plate 49).

Because of the intertonguing of this subfacies with other units of the Karaisali Limestone, the contact-relations are difficult to describe, and the reader is referred to the stratigraphic sections (Measured sections Tp, Kt, Em_1, Em_2, Em_3, Us, By_1, Gl, Ct_2, etc.). In general, the Small benthic foraminiferal-algal packstone subfacies often intertongues in a complex manner with the Coral-algal packstone and boundstone and occurs repeatedly with this subfacies throughout the outcrops. However, it may show gradational lateral and vertical contacts with the Large benthic foraminiferal-algal packstone, Coral-algal wackestone and packstone, and Globigerinid-algal packstone subfacies of the Karaisali Limestone in the areas where the Coral-algal packstone and boundstone subfacies was originally absent during the deposition of these sediments (this latter relationship has not been shown in the simplified Fig. 11 showing the usual arrangement of the various subfacies).
This subfacies overlies, and intertongues with, the Kabalak Tepe Member of the Gildirli Formation on the pre-Miocene topographic highs. The relation between these two units is best seen in Karakilic and Kesli regions (Plate 50, Measured sections Tp, Kt, Em_1, Em_2, and Em_3).

3.2. Thickness, areal distribution, and typical occurrences: The Small benthic foraminiferal-algal packstone subfacies is variable in



Plate (49): A typical outcrop of the Small benthic foraminiferal-algal packstone subfacies showing the characteristic thin-bedding with wavy bedding planes.

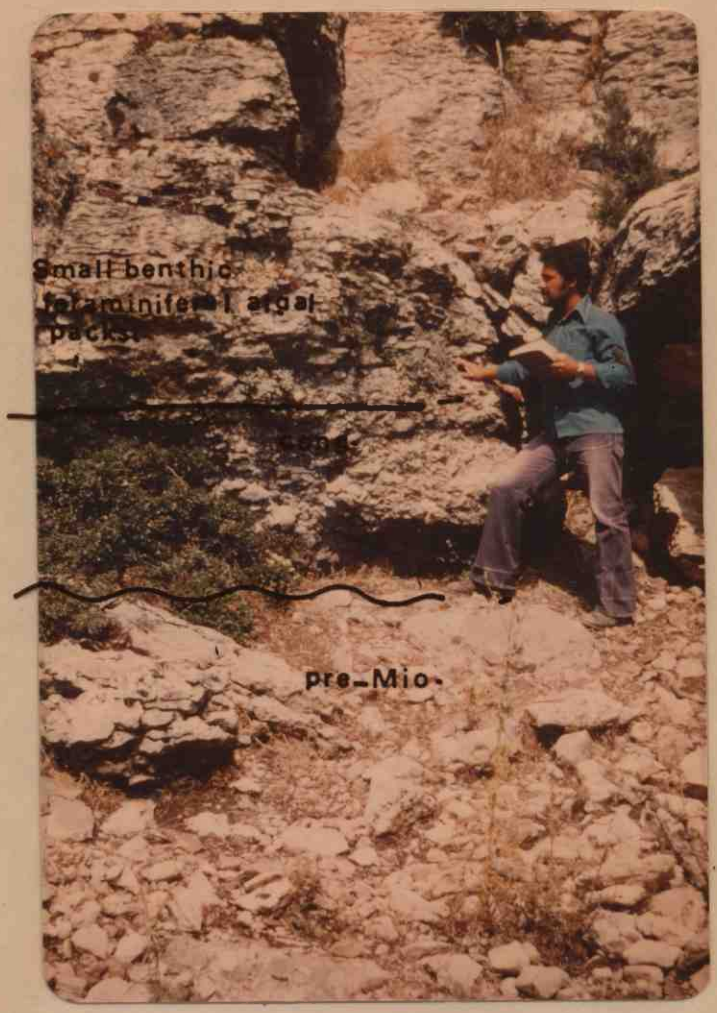


Plate (50): The Small benthic foraminiferal-algal packstone overlying the Kabalak Tepe Member of the Gildirli Formation on the pre-Miocene topographic high in the section of Eminlik (II) (Em_2).



Plate (50): The Small benthic foraminiferal-algal packstone overlying the Kabalak Tepe Member of the Gildirli Formation on the pre-Miocene topographic high in the section of Eminlik (II) (Em_2).

thickness due to intertonguing of this unit with the Coral-algal packstone and boundstone subfacies. The thickness of the individual tongues may range from 1 to 15 metres in the sections measured. However, this subfacies may have a considerable total thickness together with the closely associated Coral-algal packstones and boundstones.

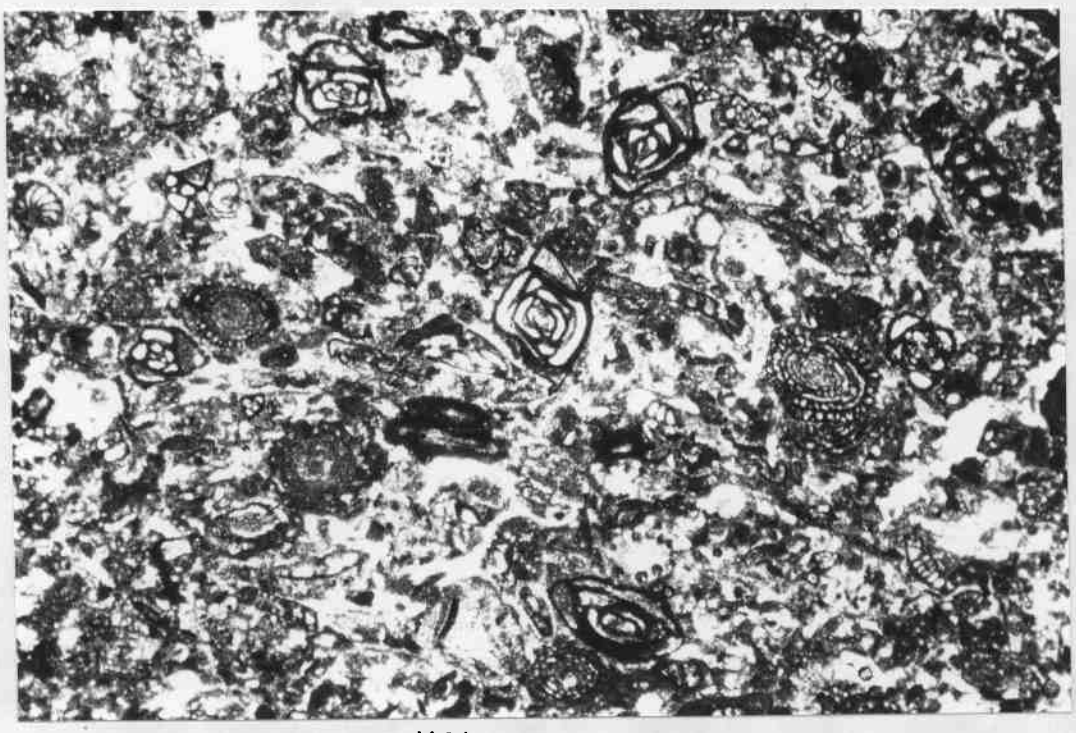
It is well exposed in the north and northeastern parts of the area where deep valleys have been cut through the whole successions of the Miocene rocks to expose the pre-Miocene formations in the vicinity of Karakilic, Eminlik, Kesli, etc., (Map 1). It is distributed discontinuously in the western and southwestern parts of the area and appears to have a patchy occurrence on the isolated pre-Miocene topographic highs (Map 1).

3.3. Microscopic description: Microscopically, the Small benthic foraminiferal-algal packstone subfacies can be seen to consist of a wide variety of mixtures of whole and broken fossils which are packed closely together in a microspar or micrite matrix. The most common fossils, in decreasing order of abundance, are: coralline algae, small benthic foraminifera, echinoderms, and molluscs (Plate 51). Worm tubes, bryozoa, and coral fragments may also be present in varying proportions throughout this subfacies.

Coralline algae are usually finely broken and are knobby and rod-like in shape. Their size is extremely variable ranging from a few microns up to 1 or 2 centimetres. These algal particles are sometimes too small to differentiate from the skeletal matrix and they show unclear fuzzy outlines.

Small benthic foraminifera, such as miliods and Alveolinellids are sufficiently abundant to characterize this subfacies. They are mostly well preserved but a few of them may be broken due to compaction. Their chambers are filled either by microspar or by micrite.

Echinoderms, which may be both whole or broken consist mostly of crinoid plates and spines. They are usually found in this subfacies with large



×24

Plate (51): General texture of the Small benthic foraminiferal-algal packstone subfacies.

overgrowths which are, however, mostly restricted to their undersides. Molluscs may be locally important in this subfacies. They are particularly abundant in the transitional zone between this subfacies and the marine conglomerate and the sandstone of the Kabalak Tepe Member of the Gildirli Formation. Well preserved and broken pelecypod and gastropod shells may vary in amounts throughout this unit. Their size is variable but generally is of the order of millimetres.

The formation of the sparry calcite of the Small benthic foraminiferal-algal packstone subfacies is generally the result of various mechanisms, such as: cementation, inversion, recrystallization, and vein filling. Cementation due to the precipitation of sparry calcite occurs as cavity filling and as overgrowth from the echinoderm fragments into the original pore spaces and in the sheltered areas where the large skeletal grains, including echinoderms, show umbrella effects (for the discussion of this occurrence see the diagenesis of the Karaisali Limestone). It also occurs in filling moulds of molluscs in this lithology.

Sparry calcite, which is produced by recrystallization and inversion, can be seen in the coralline algae, small benthic foraminifera bryozoa, and coral fragments.

The matrix of the Small benthic foraminiferal-algal subfacies is composed mainly of microspar intermixed with poorly defineddark pellet-like features, ghosts of fine bioclastic debris, and some tiny shell fragments. It is poorly sorted and fills most of the intergranular pore spaces where it interrupts and overlies the echinodermal overgrowths. It is generally neomorphic in origin, but it may be a true micrite in some cases where it shows a dense opaque character. In the latter case, it is rather similar to the algal fragments in the process of disintegration and may suggest that this matrix is largely of algal origin (see diagenesis of the Karaisali Limestone).

3.4. Proportional variations of the textural components: Vertical and lateral variations in the proportion of the textural elements of the

Small benthic foraminiferal-algal packstone subfacies are observable throughout the area. The main framework grains which, in decreasing order of abundance, are: coralline algae, small benthic foraminifera, echinoderms, and molluscs may at some places exceed one another in proportions and change the general character of the lithology. In this way, this subfacies may be turned into algal-small benthic foraminiferal packstone, echinoidal-algal packstone, and algal-molluscan packstone. Although it is rare, the lithology may sometimesgain a wackestone appearance due to an increase in the amounts of matrix. In each case, the small benthic foraminifera are present in varying proportions in these lithologies. The proportional variations of the textural components are particularly conspicuous in the places where the Small benthic foraminiferal-algal packstone subfacies passes into the other lithologies. As an example, molluscs and the non-skeletal lithoclasts may be important in the part of this unit which is transitional to the marine conglomerate and the sandstone of the Kabalak Tepe Member of the Gildirli Formation. Algae may become predominant as the lithology grades into the Coral-algal packstones and boundstones. Evidently these proportional variations of the textural components are expected in these areas and they resulted from the changes of the environmental conditions which control the texture. However,the change of the environmental conditions are not always the cause of these textural variations as these may also be diagenetic in origin. Recrystallization or micritization may completely destroy any grain and contribute more sparry calcite or micrite to the matrix. Consequently, the dominant textural element of a lithology may in this way be turned into an accessory component. This phenomenon is commonly observed in the Small benthic foraminiferal-algal subfacies. It is plain, from the above explanation, that an original packstone may be converted into a wackestone during the course of diagenesis and it may not reflect the energy conditions of the depositional environment at all (for more information on this point, see the diagenesis of the Karaisali Limestone).

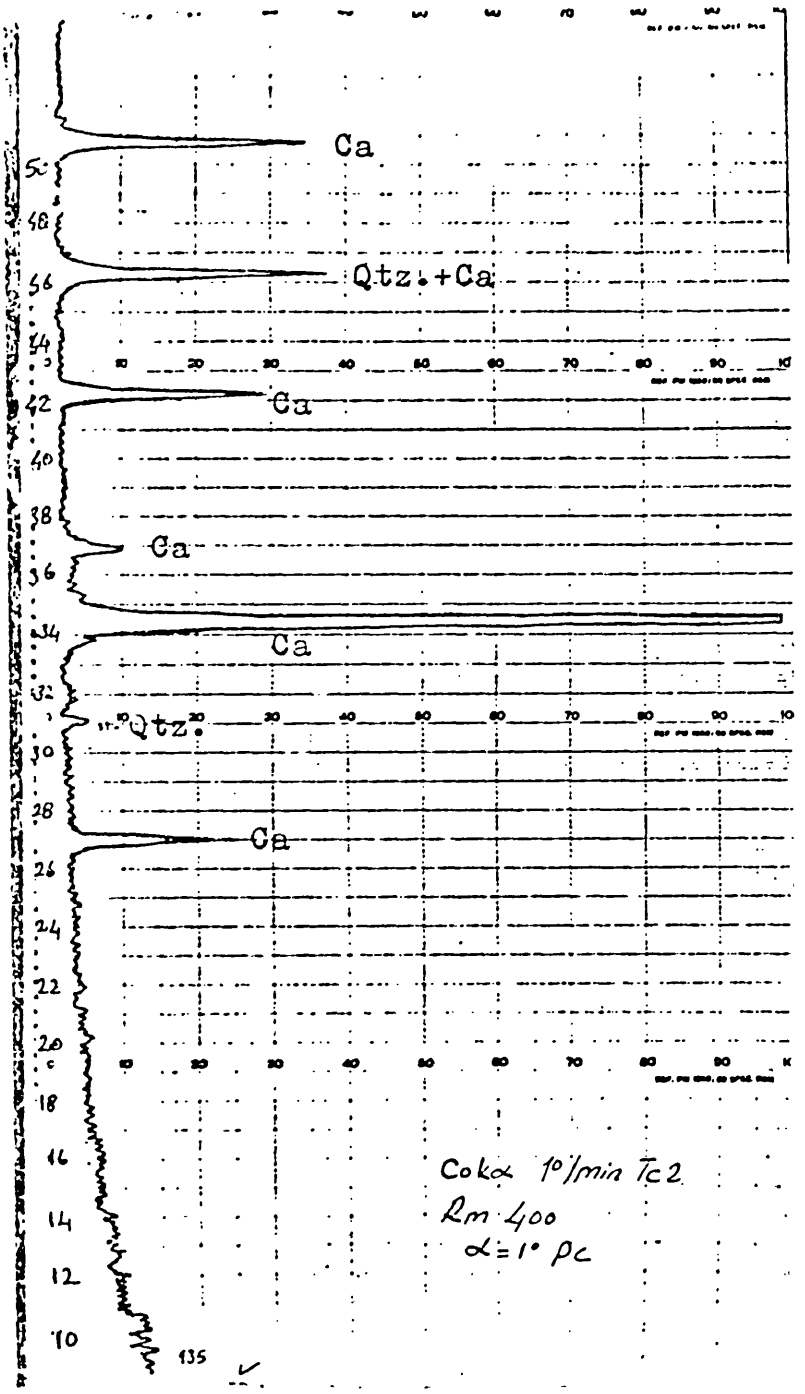
3.5. Mineralogy and carbonate content: Terrigenous fine sand and silt size quartz, very small amounts of chert, and well rounded small limestone pebbles of the Cretaceous and the Palaeozoic formations are seen among the other skeletal components. They constitute volumetrically only a minor part of the subfacies. Although most of the chert is derived from the pre-Miocene rocks, some insitu replacement by silica may be observed.

Minor amounts of dolomite, which appears to have formed within the algal microenvironments, may be found in some thin sections. An X-ray diffraction trace of a characteristic sample of this subfacies showed it to consist predominantly of calcite with small amounts of quartz (Fig. 15). The $CaCo_3$ content of some representative samples showed that the Small benthic foraminiferal-algal packstone subfacies is, in most places, a pure limestone with a $CaCo_3$ content of over 90%. However, slight variations of the composition and the mineralogy are to be expected as this subfacies interfingers with clastics.

3.6. Environment of deposition: The abundance of the unbroken small benthic foraminifera among the intensively fragmented coralline algae, poor sorting, and the presence of the matrix suggest that this subfacies was deposited in water of only moderate turbulence. Much of the sea-floor was probably populated by miliolids, and Alveolinellids as indicated by their abundance and their good preservation.

It is more likely that the fragments of coralline algae were brought in from the more agitated adjacent water where the Coral-algal packstone and boundstone subfacies was being formed as a bank, although they could of course have formed in situ.

Miliolid and Alveolinellids foraminifera are found living profusely in warm and shallow water of the lagoons of the Marshall islands where they occur commonly associated with marine algae (Cushman, 1940). Also they are often considered to be indicative of reef (or bank) and back-reef environments in ancient rocks (Henson, 1950; Forman and Schlanger,



Fig(15):An x-ray diffraction trace of a characteristic sample of the Small benthic foraminiferal-algal packstone subfacies.

1957; Schlanger, 1964).

A detailed examination of the Karaisali Limestone throughout the area has made it clear that a true extensive lagoon did not develop during the deposition of this carbonate complex. The Small benthic foraminiferal-algal packstone subfacies is in most places developed in isolated patches rather than in more continuous belts and is intricately intermingled with the Coral-algal packstonesand boundstones. Because of such an arrangement and the lithologic character of this unit, it is considered that the Small benthic foraminiferal-algal subfacies was probably deposited in essentially the same environment as the Coral-algal packstones and boundstones on the broad platforms and isolated highs of the pre-Miocene topography; with, however, the difference that it appears to have developed in slightly lower areas of the sea-floor which were rather more protected from the waves and currents by the baffle system of the organic community of the bank, situated on the edges of these highs.

Similar miliolid limestones have been described from the Middle East, Louisiana, and Guam where they were interpreted as being back-reef deposits by Henson (1950), Forman and Schlanger (1957), and Schlanger (1964). Some miliolid limestones of the Middle East, which were formed on the bank-reefs, appear to have a very similar occurrence to the Small benthic foraminiferal-algal packstone subfacies of the Karaisali Limestone.

III. 4. CORAL-ALGAL WACKESTONE AND PACKSTONE SUBFACIES.

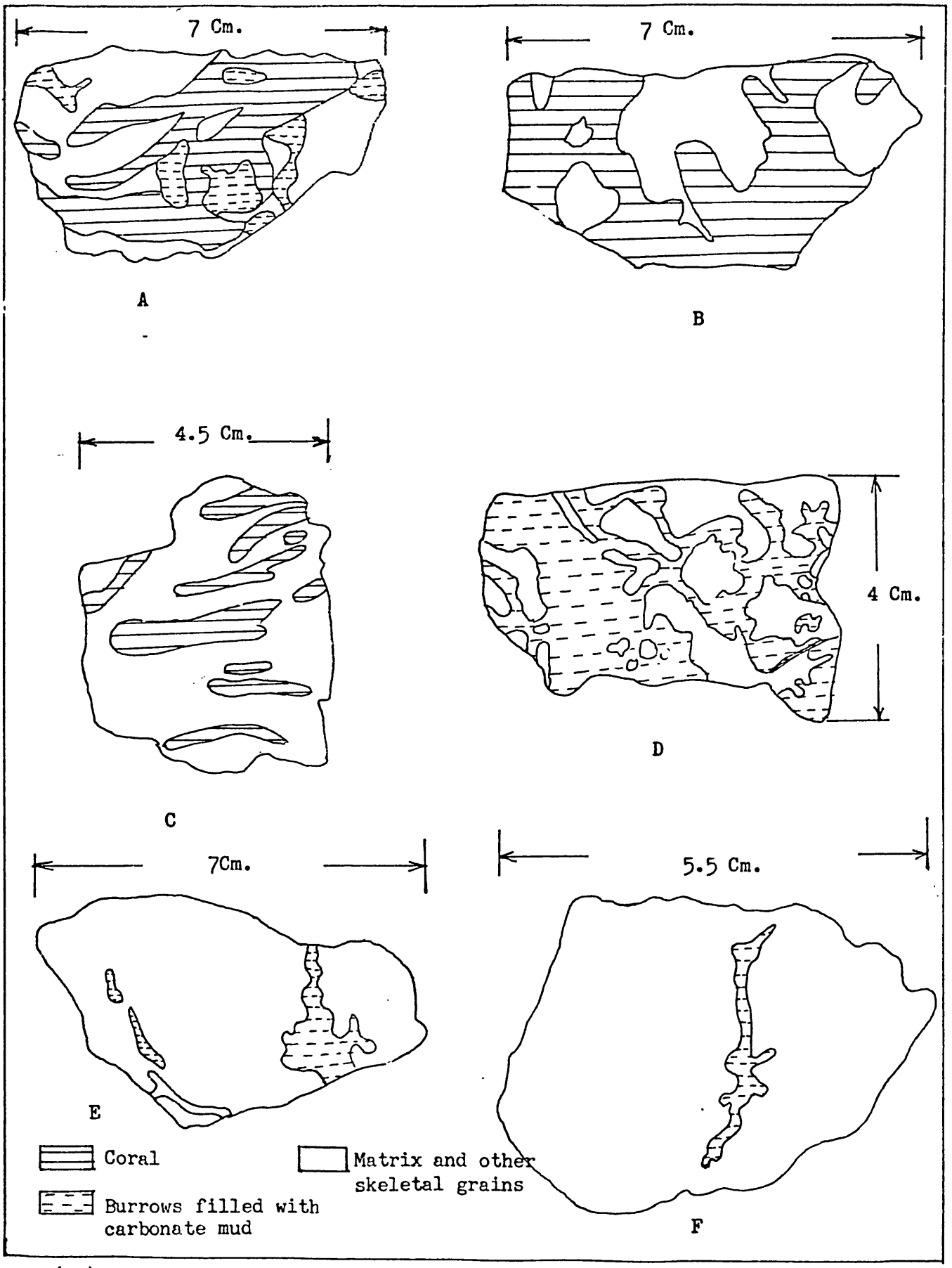
4.1. Lithology and field relations: This yellowish grey (10 YR 8/2), characteristically well bedded unit is found showing bedding inclined away from the adjacent Coral-algal packstones and boundstones at angles which may be as great as 30° (Plates 4 and 52). In decreasing order of abundance, it is composed mostly of fragmented coralline algae, green algae (Halimeda), corals, echinoderms, bryozoa, molluscs, and small and large benthic foraminifera all of which are set in a matrix of micrite or very fine grained skeletal detritus. The faunal composition, the size of the organisms, and the amount of the matrix varies over very short distances in both horizontal and vertical directions. On the upper slopes, immediately adjacent to the massive or poorly bedded strata of the Coral-algal packstones and boundstones, the rock is largely a wackestone and contains predominant corals, Halimeda, and small amounts of coralline algae. The latter may occur as algal crusts on the corals or as pebbles to very fine grained detritus (Plate 53). The corals appear to have very irregular growth forms which often encloses the clay-size carbonate matrix and give the appearance of a boundstone (Fig. 16A and B). However, as it is traced down the slope away from the adjacent Coral-algal packstones and boundstones, the character of the wackestone becomes obvious (Fig. 16C). These rocks show abundant stylolites and burrowing structures in this upper zone; the burrows are usually filled with yellowish grey (5 Y 7/2) clay-size carbonate mud (Fig. 16D). Near the toe of the slope, where bedding planes are better marked than in the higher beds, the rocks show a packstone texture. Corals and Halimeda are of decreasing importance, the coralline algae increase in importance in this lower unit. Some beds consist almost entirely of large and small fragments of coralline algae and have a brecciated appearance (Plate 53). The grain size of the coralline algal fragments range from a few microns up





Plate (52): Well bedded Coral-algal wackestone and packstone subfacies. It is inclined away from the Coral-algal packstones and boundstones in the section of Camtepe (II) (Ct_2).

Plate (53): Coralline algal fragments on the surface of a bed of the Coral-algal wackestone and packstone subfacies. They occur as algal crusts or as pebbles in this subfacies.



Fig(16):A and B:The irregular growth forms of the corals which enclose the carbonate mud matrix and give an appearance of boundstone to the Coral-algal wackestone and packstone subfacies.C:Typical wackestone texture of this subfacies.D,E,F:Burrowing structures which have been filled with carbonate mud.

to few centimetres on these beds. However, most of the rocks are granule to fine grained, poorly sorted packstones which are distinctive in having generally rich concentration of the coralline algae, corals, echinoderms, small thick-walled foraminifera, and molluscs. Burrowing is also observable in the deposits of the lower slopes (Fig. 16F).

As noted above, the Coral-algal wackestone and packstone subfacies is closely associated with the poorly or non-bedded and nearly horizontal Coral-algal packstones and boundstones of the Karaisali Formation. Its contacts with these bank deposits are at some places marked by an abrupt change from strongly dipping foreslope to massive unbedded strata (Plate 52). The Coral-algal wackestones and packstones pass into the Large benthic foraminiferal-algal packstone subfacies as they are traced basinward. However, they may also show lateral and vertical transitional contacts with the Globigerinid-algal packstone, the Globigerinid argillaceous wackestone, and the Small benthic foraminiferal-algal packstone subfacies (Measured sections Em_2, Kal, Us, By_1, Yk_1, Bc, Ct_1, Ct_2, etc.).

4.2. Thickness, areal distribution, and typical occurences: The Coral-algal wackestone and packstone subfacies shows a great similarity to the Coral-algal packstone and boundstone subfacies both in the field and in isolated hand specimens. It is thus generally difficult to differentiate these two rock types in the field unless the Coral-algal wackestones and packstones show well developed bedding and initial dips. The typical occurrence of this subfacies is found in Cambepe, near Kestepe (Map 1, Measured sections Ct_1-Ct'_1). It is about 31 metres thick in the type section which was measured in this particular part of the area (Measured sections Ct_1-Ct'_1).

4.3. Microscopic description (Plate 54): The wackestone and the packstone will here be described together because they are closely associated. They both contain the same fossil fragments set in a carbonate-mud matrix of variable proportions. In the wackestones,



×24

Plate (54): General view of the Coral-algal wackestone and packstone subfacies.

corals and Halimeda are predominant and mud supported, whereas in the packstones abundant coralline algal fragments, corals, echinoderms, small thick-walled benthic foraminifera (mainly rotalids), and molluscs are found with small amounts of matrix (Plate 54). Both rock types are poorly sorted and show an extreme range in grain size from a few microns to 40 millimetres. The large grains are mainly corals, coralline algae and large benthic foraminifera. The large and the small benthic foraminifera, and the echinoderms appear to be well preserved while the coralline algae, the corals, and the Halimeda are intensively broken. These skeletal grains often show stured contacts in the packstones which probably resulted from compaction. Stylolites also commonly occur and cut across both the matrix and the skeletal grains.

The matrix consists mostly of micrite which is sometimes intermixed with very-fine grained skeletal detritus (Plate 54). It often shows burrow structures and compactional fractures. The burrows are generally filled with carbonate mud which because of its dark colour and fine grain size compared with the host rock makes them easily visable. Rarely, the micritic matrix may be altered to microspar.

Sparry calcite of this subfacies has usually resulted from the inversion of the corals and the Halimeda (Plate 54). However, some sparry calcite is due to normal precipitation of cement in the chambers of both small and large benthic foraminifera and in other original cavities. Vein filling sparry calcite is also observable in some early compactional and tectonic fractures.

4.4. Environment of deposition: The Coral-algal wackestone and packstone subfacies is interpreted as being formed below breaker -level on the slopes of the banks. This satisfactorily explains the initial dips and the similarities of this subfacies to the Coral-algal packstones and boundstones. The bulk of the detrital sediments of the Coral-algal wackestones and packstones came from normal fragmentation by wave action of the growing edges of the banks at the margins of the pre-Miocene top-

ographic highs. The bioclastic detritus was carried seaward and deposited as a talus deposit on the steep submarine slopes of these features where it was mixed with some "in situ" produced sediment. This produced a well developed seaward dipping bedding and with a wedge or sheet-like geometry.

One of the most noticeable features of this subfacies is the increase in importance of the green algae Halimeda which in contrast to other areas appears to be best developed on the seaward, ie., most exposed slopes rather than in the more sheltered areas on the bank (Ginsburg et al., 1972). Perhaps this is because, as has been stated in the description of the Small benthic foraminiferal-algal packstone subfacies, a true sheltered lagoonal area never appears to have developed. The small intra-bank depressions did not appear to provide a satisfactory ecological niche for the Halimeda.

III. 5. LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE SUBFACIES:

5.1. Lithology and field relations: This is mainly yellowish grey (10 YR 8/2), coarse to fine grained, moderate to poorly sorted packstone. It is distinctive in generally containing a rich concentration of coralline algae and camerinid type large benthic foraminifera, such as Heterostegina and Cycloclypeus(?). Besides these fossils, it includes common and locally abundant echinoderms, scattered corals, bryozoa, worm-tubes, and molluscs. It is marked by well developed bedding with strata 10 centimetres or more in thickness (Plates 55 and 56). Locally, this subfacies is interbedded with a light coloured, friable, and very thinly bedded lithology which is composed entirely of large benthic foraminifera (Plate 56). These friable, large benthic foraminiferal beds are unique in appearance and perhaps should have been described separately from the Large benthic foraminiferal-algal packstone subfacies as another distinct rock type of the Karaisali Limestone. But, because they are so thin and only occur locally they are more conveniently considered as part of the Large benthic foraminiferal-algal packstone subfacies. This lithology is only seen in the upper part of the section of Camtepe (II) (Ct_2) (Map 1).

Tongues of the Large benthic foraminiferal-algal packstones may be both underlain and overlain by tongues of the Coral-algal wackestone and packstone, Coral-algal packstone and boundstone, Globigerinid-algal packstone, and Globigerinid argillaceous wackestone subfacies of the Karaisali Limestone. However, gradational lateral and vertical contacts of this subfacies with the Small benthic foraminiferal-algal packstone subfacies may be seen in some measured sections. It also, in some localities, overlies the marine sandstones of the Kabalak Tepe Member of the Gildirli Formation, eg., in the section of Kessektepe (Kt).

5.2. Thickness, areal distribution, and typical occurrences: In general, the Large benthic foraminiferal-algal packstone subfacies shows variations in thickness. It usually thins from the depressions towards





Plate (55): Well developed bedding in the Large benthic foraminiferal-algal packstone subfacies in the section of Camtepe (Ct_2) (note also the lateral transition of this subfacies to the non-bedded Coral-algal packstones and boundstones, top right of the photograph).

Plate (56): Interbedding of the Large benthic foraminiferal-algal packstone with the very thinly bedded lithology which is composed entirely of large benthic foraminifera.

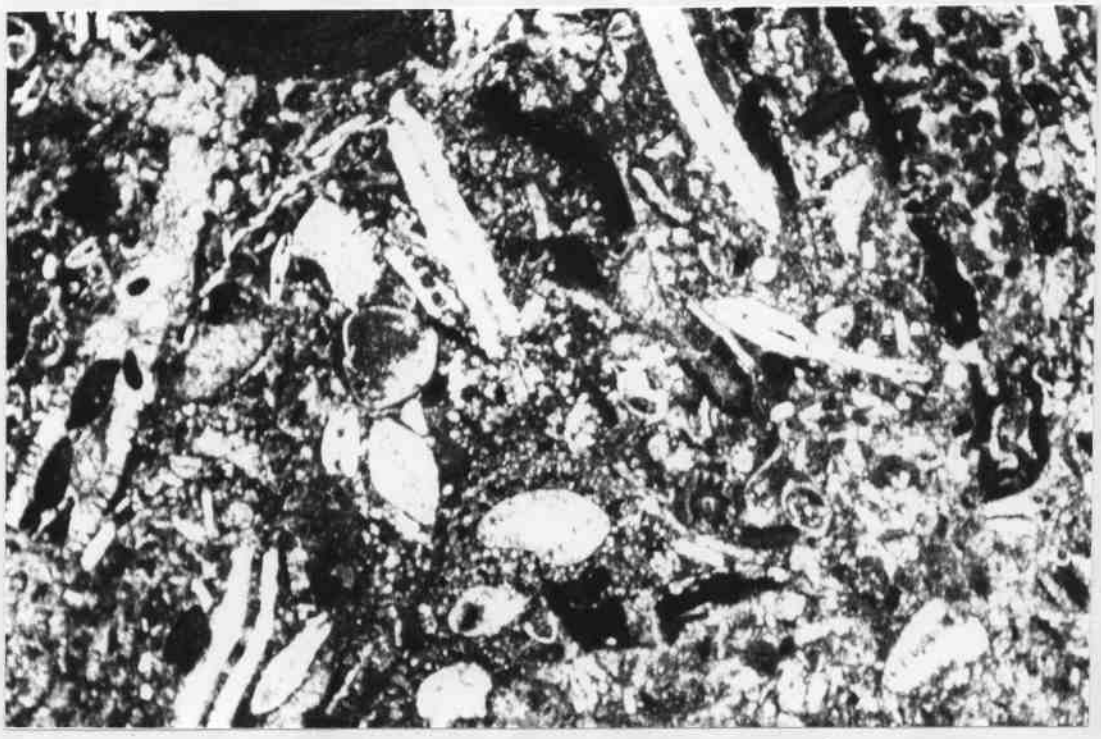
the pre-Miocene topographic highs. The thinning resulting largely from intertonguing of this subfacies with the Coral-algal packstones and boundstones and Small benthic foraminiferal-algal packstones in these areas. On the other hand, it thickens as it passes into the Globigerinid-algal packstone and Globigerinid argillaceous wackestone subfacies of the Karaisali Limestone. The thickness of its tongues may range between 1,5 and 20 metres in the sections which have been measured. Maximum measured thickness of this subfacies is 75 metres and this is seen in the section of Bolacali (Measured section Bl). However, it may have attained considerably greater thickness together with the Coral-algal packstone and boundstone subfacies.

The best exposures of the Large benthic foraminiferal-algal packstones are at Bolacali, Cam Tepe, Kuzoluk, and Usunlu (Map 1, Measured sections Do, Kt, Em_1, Us, By_1, Kal, Gl, Ko, Ko_1, Ct_2, etc.).

5.3. Microscopic description: Microscopically, the Large benthic foraminiferal-algal packstone is seen to be moderate to poorly sorted and consists of closely packed whole tests and broken skeletal fragments of coralline algae, large benthic foraminifera, and echinoderms in a microspar or sparry calcite matrix of neomorphic origin (Plate 57). Fragments of molluscs, bryozoa, corals, planktonic foraminifera, and worm tubes are also present in variable amounts. The coralline algae usually occur as broken and worn fragments of variable grain size, ranging from 25 microns to 3 millimetres. However, they average about 250 microns.

The large camerinid type foraminifera (Heterostegina and Cycloclypeus) are found to be broken or as whole tests. When whole, they range between 3 to 5 millimetres in length. Broken fragments are also of millimetres size but they may be as small as 125 microns in length. They have sharp edges and usually show a rough orientation to the bedding surface.

Echinoderms may occur as whole tests or broken fragments which range



×24

Plate (57): General texture of the Large benthic foraminiferal-algal packstone subfacies (the dark grains are mostly fragments of coralline algae).

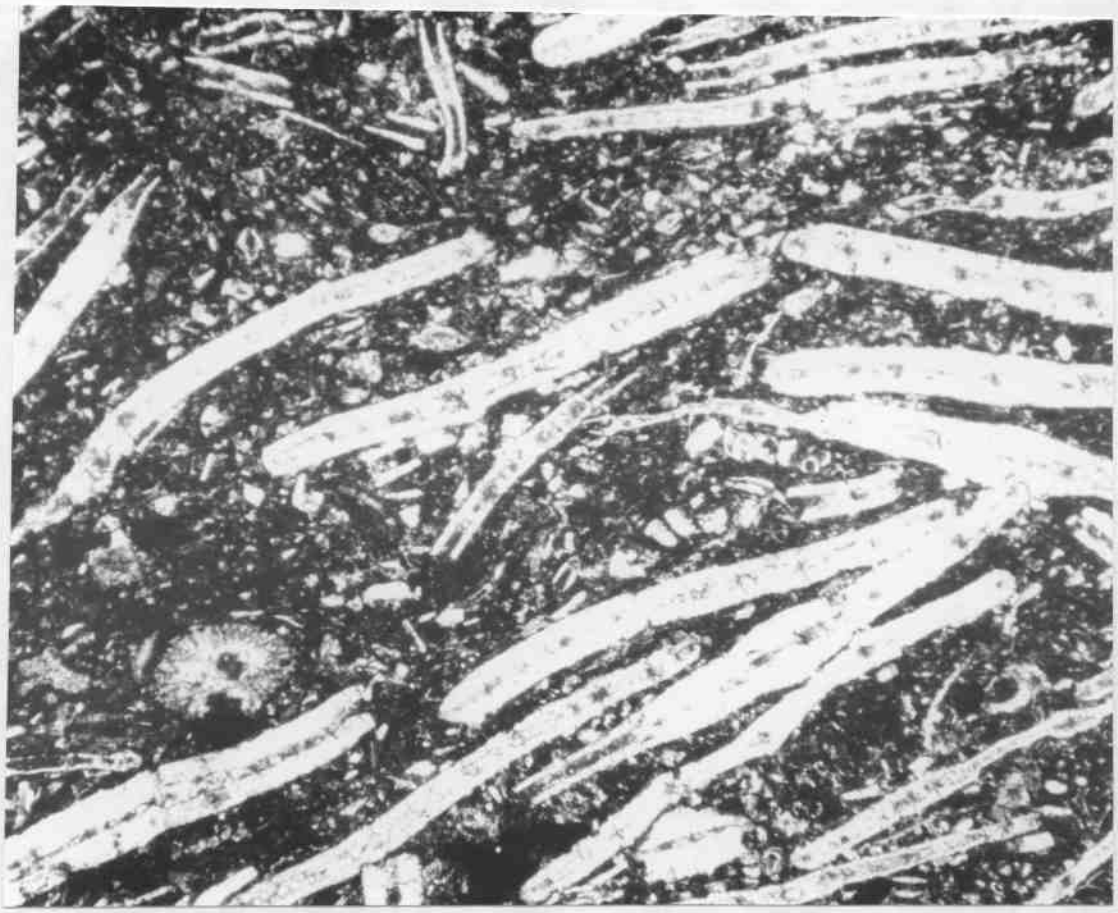
from 1 to 3 millimetres in size and show large overgrowths.

The matrix of this subfacies is generally poorly sorted and neomorphic in origin. It consists of a mixture of sparry calcite and microspar with small amounts of micrite. The areas of the microspar and the micrite appear to be indistinct and cloudy in the matrix. Very fine grained bioclastic debris, particularly minute fragments of the coralline algae may sometimes be recongnisable in this neomorphic matrix.

Sparry clacite is common in this subfacies. It constitutes the matrix, the cement, and the vein fillings. The sparry calcite and microspar of the matrix result mostly from neomorphic alterations and make up a considerable fraction of the total calcite of this subfacies. Overgrowths of echinoderms usually fill the spaces between fossils as a cement. Besides these large overgrowths, chambers of the large benthic foraminifera may also be filled by cavity filling cements. In addition, some late diagenetic and tectonic fractures often contain sparry calcite in some thin sections.

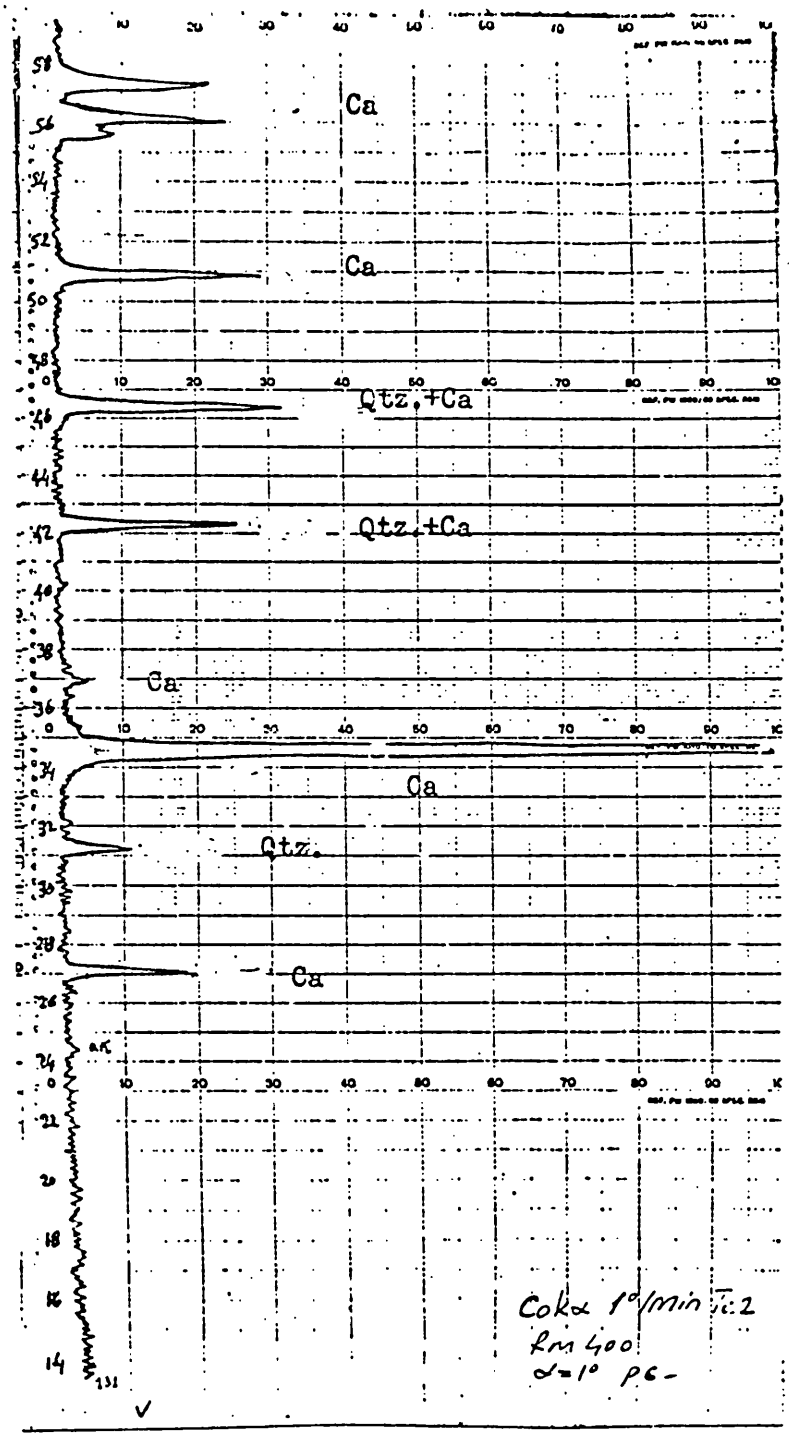
The friable, and very thinly bedded lithology which is interbedded locally with the Large benthic foraminiferal-algal packstone subfacies generally contains abundant well preserved large benthic foraminifera which are set in a matrix of micrite. Only a few small broken fragments of coralline algae can be seen in this lithology (Plate 58).

5.4. Mineralogy and carbonate content: This lithology consists predominantly of calcite with small amount of quartz (Fig. 17). However, this is not of constant abundance throughout the area and considerable variations of the proportions of this mineral may be seen. This is particularly apparent when the lithology passes into the Globigerinid argillaceous wackestone subfacies. In the transitional zone between these two subfacies quartz may be present in appreciable amounts. Its concentration may also be high in places where the marine clastics of the Kabalak Tepe Member grade upwards into this subfacies. Other



X 24

Plate (58): Large benthic foraminiferal packstone. This lithology is interbedded with the Large benthic foraminiferal-algal packstone subfacies in the upper-part of the section of Camtepe (II) (Ct_2).



Fig(I7):The x-ray trace of a characteristic sample of the Large benthic foraminiferal-algal packstone subfacies.

than these extreme types, the rocks of the Large benthic foraminiferal-algal packstone subfacies are generally composed of chemically pure limestone with a content of $CaCo_3$ which may be over 90%.

5.5. Environment of deposition: The Large benthic foraminiferal-algal packstone subfacies appears to have been deposited under conditions similar to those described for the Coral-algal wackestone and packstone subfacies. However, the fauna and the poor sorting suggest that the water was deeper. Water depth cannot be determined accurately, but it was surely not less than the depth of wave base. The large berthic foraminifera of this subfacies, which are mainly represented by the family of Camerinidae, including Heterostegina and Cycloclypeus are deeper-water benthonics and show a considerable depth ranges in the present seas. Heterostegina can commonly be seen in depths of 46 to 59 metres and Cycloclypeus may live in waters ranging from 44 to 1034 metres in depth. The average depth for the Cycloclypeus is about 330 metres (Cole, 1957). In general, both of these foraminifera are found to be most numerous in areas adjacent to modern reefs and are considered as diagnostic organisms of fore-reef and off-reef habitats of ancient reefs (Henson, 1950; Forman and Schlanger, 1957; Schlanger, 1964). Although the Karaisali Limestone has been interpreted as a Bank and not a reef by the author, the stratigraphic position and the geographic location of the Large benthic foraminiferal-algal packstone subfacies confirm that this subfacies was deposited in an environment slightly deeper and marginal to the adjacent shoal water facies.

Both geographically and stratigraphically this subfacies occurs between the Coral-algal wackestone and packstone and the Globigerinid-algal packstone or Globigerinid argillaceous wackestone subfacies and is usually intimately interbedded with these lithologies. Since the globigerinid bearing sediments are thought to have been deposited in basinal or open marine conditions, the Large benthic foraminiferal-algal packstone subfacies must have been deposited in the areas adjacent to the bank.

Abundant organic debris which were derived from the coral-algal bank on the pre-Miocene topographic highs were brought in these areas and were mixed with the large benthic foraminifera to form the poorly sorted packstones of this subfacies. The presence of the whole and the broken large benthic foraminifera possibly indicates that these organisms were living in different depths of water. Those foraminifera which are broken probably occupying the slopes of the bank and these were broken during the transportation to the depositional sites where the same species were living. Alternatively they could have been broken "in situ" by sediment ingesting organisms. Interbedding of the Large benthic foraminiferal-algal packstone subfacies with the light-coloured, friable, and very thinly bedded large benthic foraminiferal packstone beds also supports this conclusion. As described before, the latter beds contain abundant well preserved and orientated large benthic foraminifera in a matrix of micrite. A general scarcity of matrix in this subfacies indicates that the production of skeletal debris either "in situ" or from the adjacent banks to the relatively quiet deep water environment of this subfacies was at a faster rate than the mud was accumulating.

III. 6. GLOBIGERINID-ALGAL PACKSTONE SUBFACIES:

6.1. Lithology and field relations: This subfacies is a yellowish grey (10 YR 8/2), very fine to medium grained, and poorly sorted packstone; in which, in decreasing order of abundance: whole and broken skeletons of coralline algae, globigerinid foraminifera, echinoderms, and molluscs are abundant. Large benthic foraminifera, corals, bryozoa, and worm tubes are present in various amounts throughout this lithology. Echinoderms are found in some localities as large and well preserved mega-fossils on bedding surfaces.

The Globigerinid-algal packstone subfacies is well bedded with strata varying from 10 to 30 centimetres in thickness (Plate 59). Unfortunately, its bedding properties can be observed only in few places as, because of the comparatively softer nature of this subfacies, it usually develops a thick soil cover (Plate 60). Locally, the Globigerinid-algal packstone subfacies passes into a yellowish grey (10 YR 8/2), soft marl which shows exfoliation (Plate 61).

The Globigerinid-algal packstones form a transitional facies between the Large benthic foraminiferal-algal packstone and the Globigerinid argillaceous wackestone subfacies. However, it may also display lateral and vertical transitional contacts with the Coral-algal wackestone and packstones (Measured sections Kal, Pr, Dr, By_1, Ko, Ko_1, etc., Map 1).

6.2. Areal distribution and typical occurrences: The Globigerinid-algal packstone subfacies is exposed in the low-lying ground between the uplands of the previously described hard subfacies of the Karaisali Limestone. They are narrow, elongated patches in the northeast and become connected to form areas of wider extent in the southwestern parts of the area (Map 1).

Typical occurrences of this subfacies are found in the vicinity of Eminlik, Kuzoluk (Partavut), Usunlu, and Emirler (Yanaarmut) Map 1).

6.3. Microscopic description (Plate 62): Microscopically the

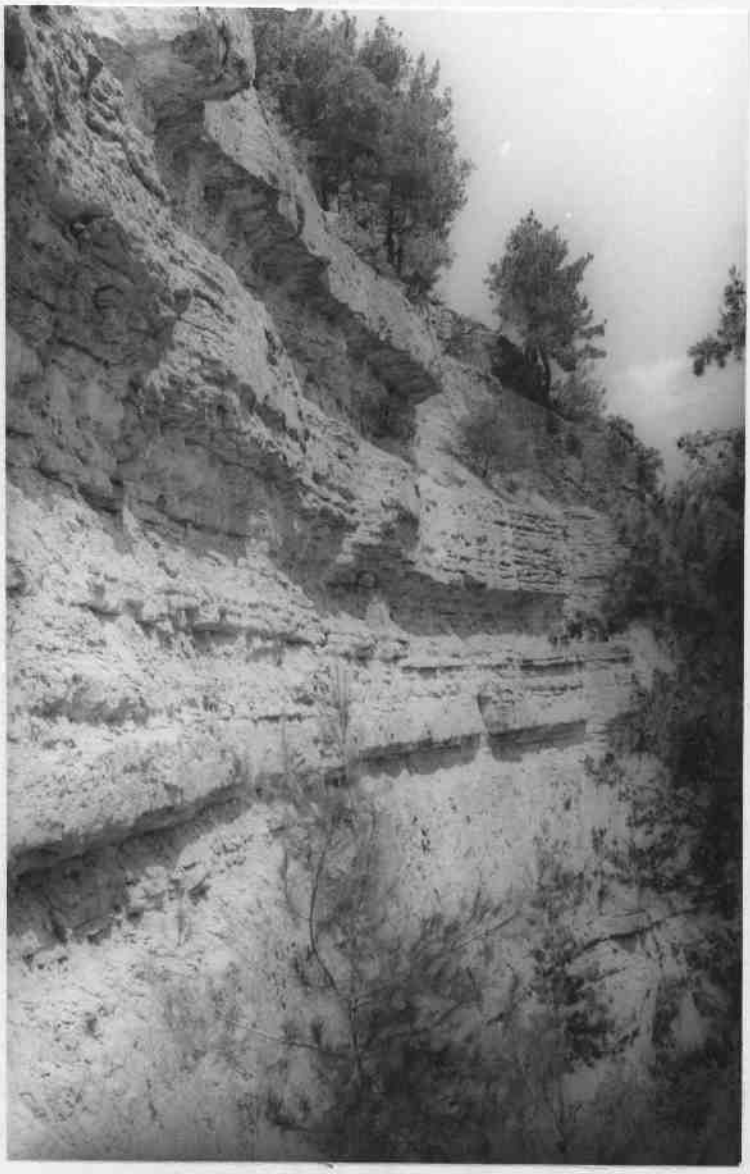


Plate (59): Well bedded Globigerinid-algal packstone subfacies in Yoruk Dere, Bucak.





Plate (60): A typical exposure of the Globigerinid-algal packstone subfacies in the low-lying grounds between the limestone uplands (covered with vegetation in Eminlik).

Plate (61): Soft marl which shows exfoliation. This lithology sometimes replaces the Globigerinid-algal packstone in some localities, e.g., Eminlik.



X17

Plate (62): Typical texture of the Globigerinid-algal packstone subfacies.

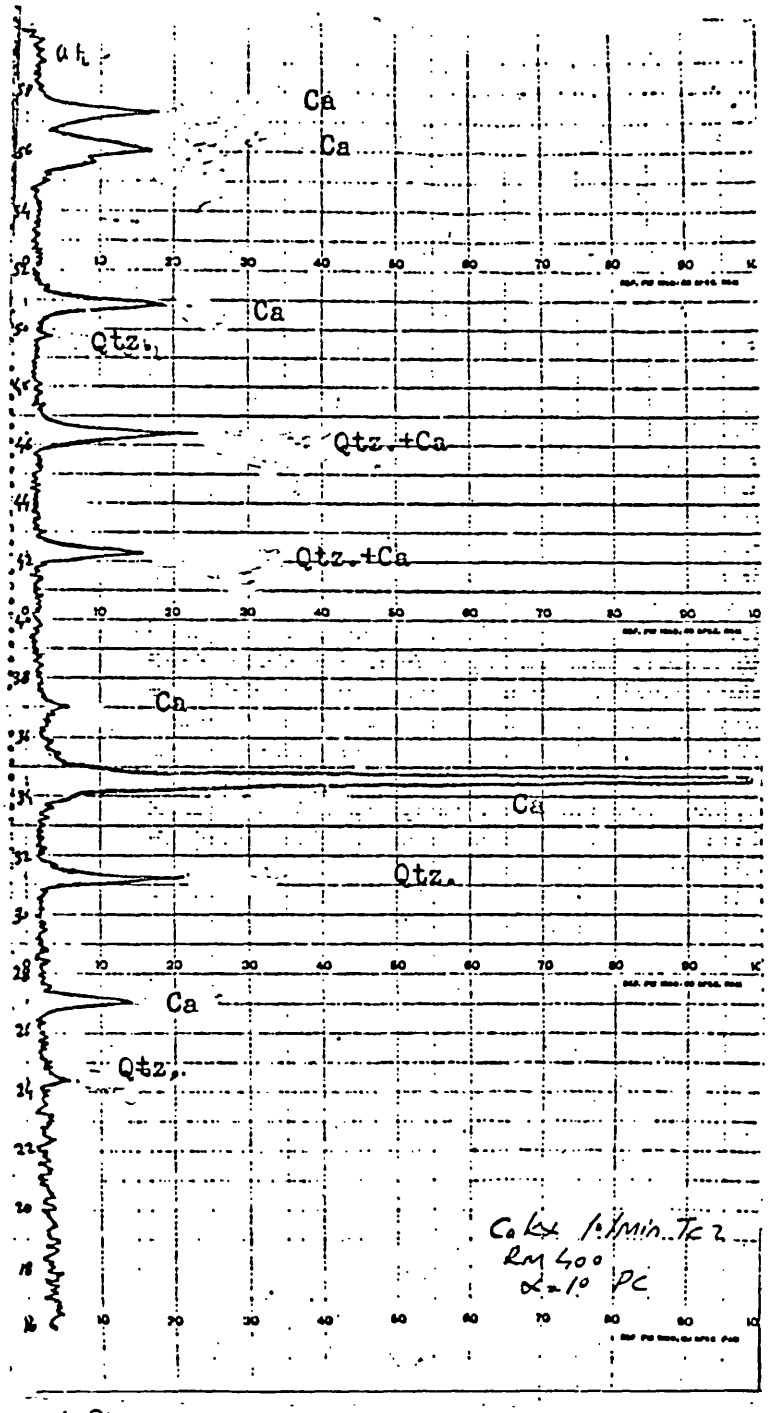
Globigerinid-algal packstone subfacies is seen to consist of a wide variety of mixtures of whole and broken fossil fragments of all sizes, micrite, microspar, and clear medium-grained crystalline sparry calcite. The most common fossils are coralline algae, globigerinid foraminifera, echinoderms, and molluscs. Fragments of large benthic foraminifera, corals, bryozoa, and worm tubes are also found. Fragile tests of the globigerinid foraminifera are characteristically well preserved in this subfacies, while the skeletons of the coralline algae, molluscs, corals, etc., are generally broken and retain sharp edges.

The matrix is similar to that of the other subfacies of the Karaisali Limestone and consists mainly of dark to light brown micrite which may have been altered to microspar or sparry calcite.

The clear sparry calcite occurs as infilling moulds of molluscs, as patches, and as cement in the original cavities of the packstones together with the matrix. Some sparry calcite produced by inversion of the originally aragonitic skeletons are also present.

6.4. Mineralogy and carbonate content: Examination of a typical sample of this subfacies, by X-ray diffraction techniques, showed that calcite is the major constituent of this lithology with minor amounts of quartz and clay minerals (Fig. 18). The carbonate content of this subfacies has been determined to be around 90% $CaCo_3$.

6.5. Environment of deposition: The generally fine grain size, the characteristically poor sorting, and the abundance of the well preserved globigerinid tests in association with the fragmented shallow water organisms, such as coralline algae, echinoderms, molluscs, corals, etc., indicate deposition in an environment of deeper and quieter waters in the proximity of the coral-algal bank growth. The stratigraphical and the relative position of this subfacies to the other subfacies suggest that it accumulated in the depressions between the pre-Miocene topographic highs on which the shallow-water bank carbonates were being deposited. Detritus from the bank was washed into these bathymetrically deeper



Fig(I8):The x-ray trace of a characteristic sample of the Globigerinal-algal packstone subfacies.

small basins where it was mixed with the finer-grained, deeper-water globigerinid bearing deposits.

The grain-supported fabric of this unit shows that the banks supplied large amounts of bioclastic detritus to these basins; at a rate faster than the local production of mud and globigerinid tests. The small basins have been almost enclosed by the upward growing banks in the northeast but were connected to the open sea in the southwestern part of the area where the Globigerinid-algal packstones are replaced by the Globigerinid argillaceous wackestone subfacies which was deposited under open marine conditions. Although the Globigerinid-algal packstone subfacies accumulated dominantly in the inter-bank basins, it was also deposited down slope and in the deeper water to the seaward sides of the bank where it formed a transitional facies between the Large benthic foraminiferal-algal packstone and the Globigerinid argillaceous wackestone subfacies. In the transitional areas, the Globigerinid-algal packstones appear to be very similar to the Globigerinid argillaceous wackestones in both the field and in hand specimens and the differentiation of these two subfacies can only be made under the microscope. The amounts of globigerinid foraminifera and the mud content of the Globigerinid-algal packstones increase basinward and away from the banks and the lithology gradually passes into the Globigerinid argillaceous wackestones.

III. 7. GLOBIGERINID ARGILLACEOUS WACKESTONE SUBFACIES:

7.1. Lithology and field relations: This unit is made up of yellowish grey (10 YR 8/2), hard, very fine to medium grained argillaceous wackestone. It is generally well stratified in beds from 10 centimetres to about 30 centimetres in thickness (Plate 63). It is rich in planktonic foraminifera and echinoderms both of which are embedded in a matrix of micrite (Plate 66). In decreasing order of abundance, some buliminid type foraminifera, worm tubes, coralline algae, sponge spicules, and molluscs are common at some localities. This subfacies, as do the other subfacies of the Karaisali Limestone shows few sedimentary structures other than occasional burrows. These are mostly vertical and approximately 10 centimetres or more in length (Plate 64).

The geographic and stratigraphic position of the Globigerinid argillaceous wackestone subfacies show that it is a transitional lithology between the carbonate rocks of the Karaisali Formation and the calcareous shales of the Guvenc Formation. North of a line from Bucak to Yanikkisla (Map 1) this subfacies passes laterally into the other subfacies of the Karaisali Limestone (Plate 65), but south of this line it underlies and interfingers with the rocks of the Guvenc Formation (Map 1; Cross-sections E-E', F-F', G-G'; Measured section Yk_5). Interfingering of the Globigerinid argillaceous wackestones with the Large benthic foraminiferal-algal packstones and the Coral-algal wackestones and packstones can be observed at Kuzoluk, Yanikkisla, and Kestepe (Measured sections Ko, Ko_1, Yk_1, Yk_2, Yk_5, Ct_3 and Ct). At some locations, this subfacies may show interfingering with the Small benthic foraminiferal-algal packstone subfacies of the Karaisali Limestone where the Coral-algal packstones and boundstones did not form a protective rim. Gradational contacts of the Globigerinid argillaceous wackestones with the Guvenc Shales are seen in the Yoruk Dere, near Bucak (Map 1, Measured section Bc). A gradational vertical contact with the sediments of the

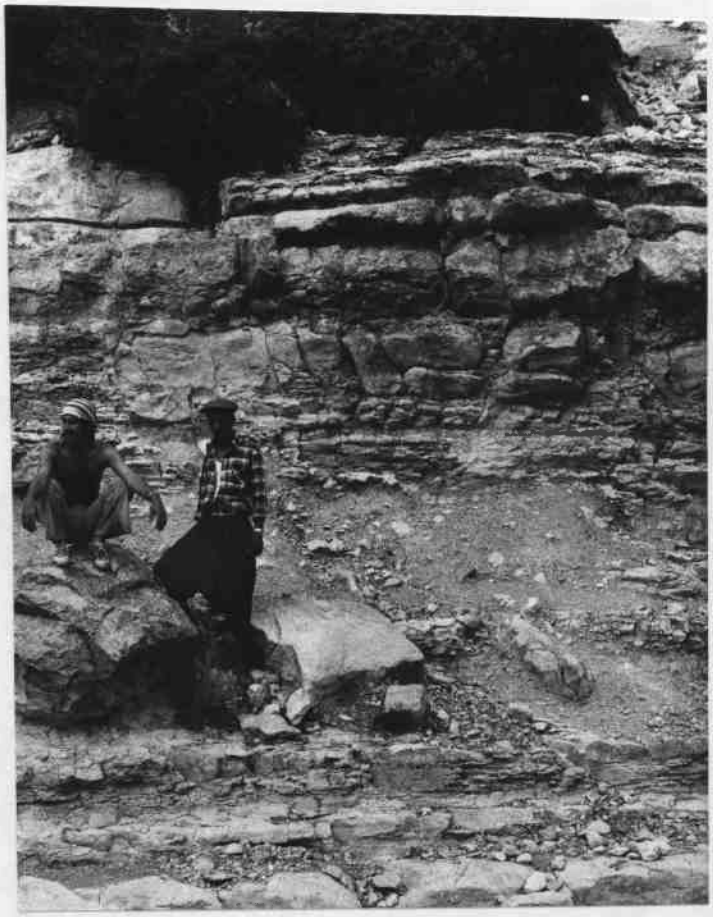




Plate (63): The stratification of the Globigerinid argillaceous wackestone subfacies in Yanikkisla.

Plate (64): A vertical burrowing in the Globigerinid argillaceous wackestone subfacies.

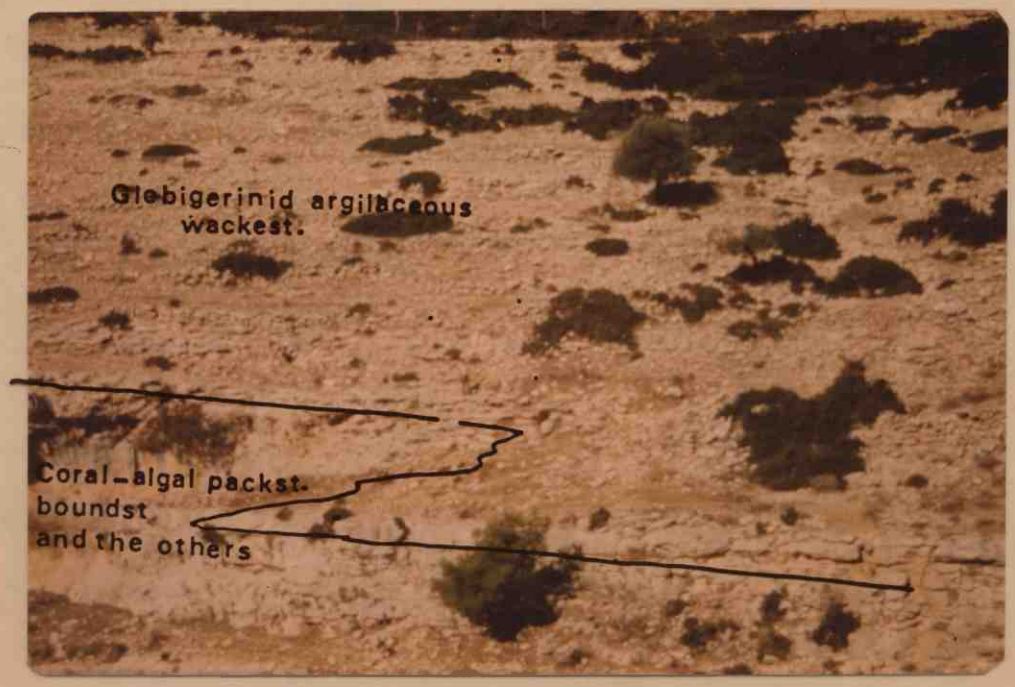


Plate (65): Interfingering of the Globigerinid argillaceous wackestone subfacies with the Coral-algal packstone and boundstone and the other associated subfacies in Yanikkisla.



Plate (65): Interfingering of the Globigerinid argillaceous wackestone subfacies with the Coral-algal packstone and boundstone and the other associated subfacies in Yanikkisla.

Kabalak Tepe Member of the Gildirli Formation is seen in Kuzoluk Harmani Dere, near Cokak (Map 1, Measured section Hr).

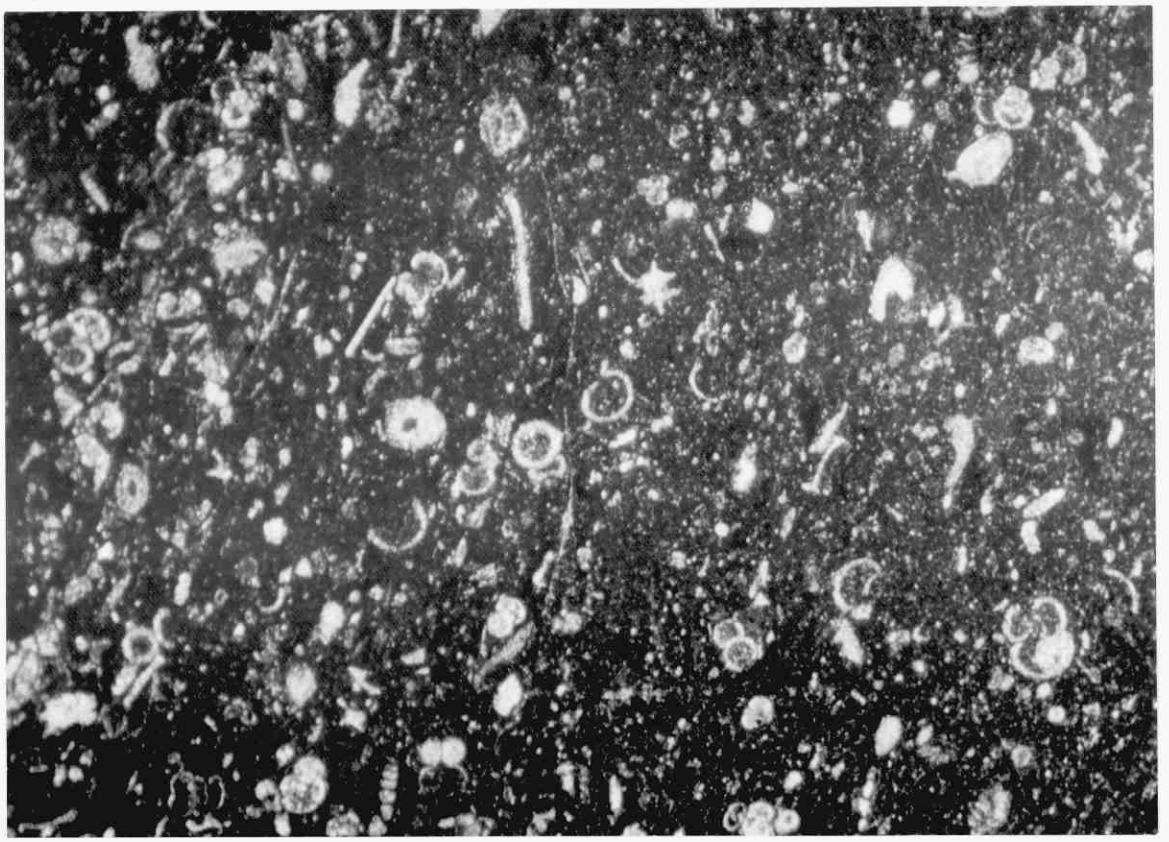
7.2. Thickness, areal distribution, and typical occurrences: The Globigerinid argillaceous wackestone subfacies thins both northward and southward from a maximum of more than 90 metres at Yanikkisla (Map 1, Measured sections Yk_1 and Yk_2). This maximum thickness was measured from a section in which the base of this lithology was not seen and the actual thickness must thus be greater than this figure. The northward and southward thinnings result largely from intertonguing of the Globigerinid argillaceous wackestones with the associated carbonate subfacies and the Guvenc Shales.

The outcrops of this subfacies are widely developed in the southwest of the area. The most typical occurrence and best section of this subfacies are seen in Yanikkisla and Cavuslu (Map 1, Measured sections Yk_1, Yk_2, Cs and Cs_1).

7.3. Microscopic description: Microscopically, rocks of this unit are generally seen to be fine grained, argillaceous wackestones containing predominantly (in decreasing order of abundance): fragile tests of globigerinids, common and locally abundant buliminids, rotalids, and lagenid-type foraminifera; together with calcareous sponge spicules, and echinoderms (Plate 66). Coralline algae, worm tubes, molluscs, ostracods, and corals are also present in small amounts. In contrast to the coralline algae, molluscs and corals, these skeletal remains are well preserved and show no abrasion.

The fragile tests of globigerinid foraminifera, whole tests range in size from 200 to 500 microns, are exceptionally well preserved and their cells are either filled by matrix or a micro mosaic of calcite.

Buliminid, rotalid, and lagenid type foraminifera are found to be common together with the globigerinids at some localities, eg., Cavuslu (cs). They are generally whole and show a range in size reaching up to 1 millimetre in diameter. Their chambers are filled by the micrite



× 40

Plate (66): General texture of the Globigerinid argillaceous wackestone subfacies.

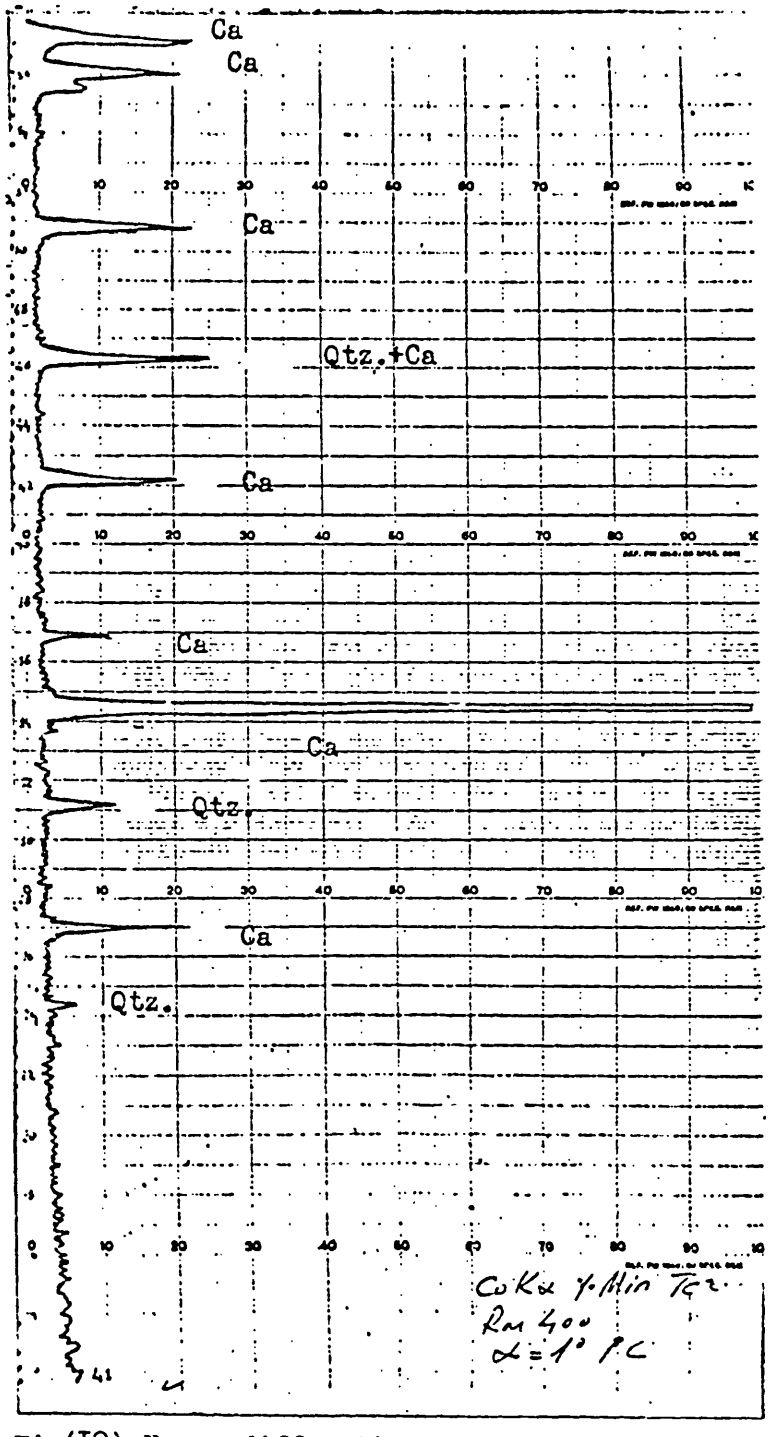
and microspar cement.

Sponge spicules show a preferred orientation and lie parallel to the bedding. They are variable in size, may be as long as 1 millimetre or so in their longitudinal sections, and are replaced by microspar. Echinoderms may occur as whole tests or as fragments and do not show overgrowths in this lithology.

The matrix of the Globigerinid argillaceous wackestones is commonly seen in most of the thin sections, which have been studied, to be micrite. It appears to be dark brown in transmitted light and light brown or sometimes chalky white in reflected light (Plate 66). It sometimes consists of finely crystalline microspar (with a grain size less than 6 microns) intimately mixed with fine fossil debris. Silicification of the matrix is often observed in some of the thin sections which have been studied. Sparry calcite is found either filling the chambers of the foraminifera or replacing the sponge spicules.

7.4. Mineralogy and carbonate content: X-ray diffraction trace of the Globigerinid argillaceous wackestone subfacies shows the dominant minerals to be calcite with fairly abundant quartz and some clay minerals (Fig. 19). But as with other subfacies of the Karaisali Limestone, a considerable variation may be observed as the lithology passes into the other associated units. The carbonate content of the Globigerinid argillaceous wackestones is normally high and is never less than 70% in most of the samples of these rocks which have been analysed.

7.5. Environment of deposition: The fine grain size and abundant well preserved globigerinid tests are evidence for a low-energy marine environment. Studies of the depth distribution of the Recent globigerinids and related genera showed that these planktonic foraminifera populate the open oceans in great numbers and contribute significantly to sediments of these deep-seas. Most of the planktonic foraminifera live within the upper 100 metres of the ocean. However, some genera can live at depths greater than 500 metres (Milliman, 1974). Although concentrations of



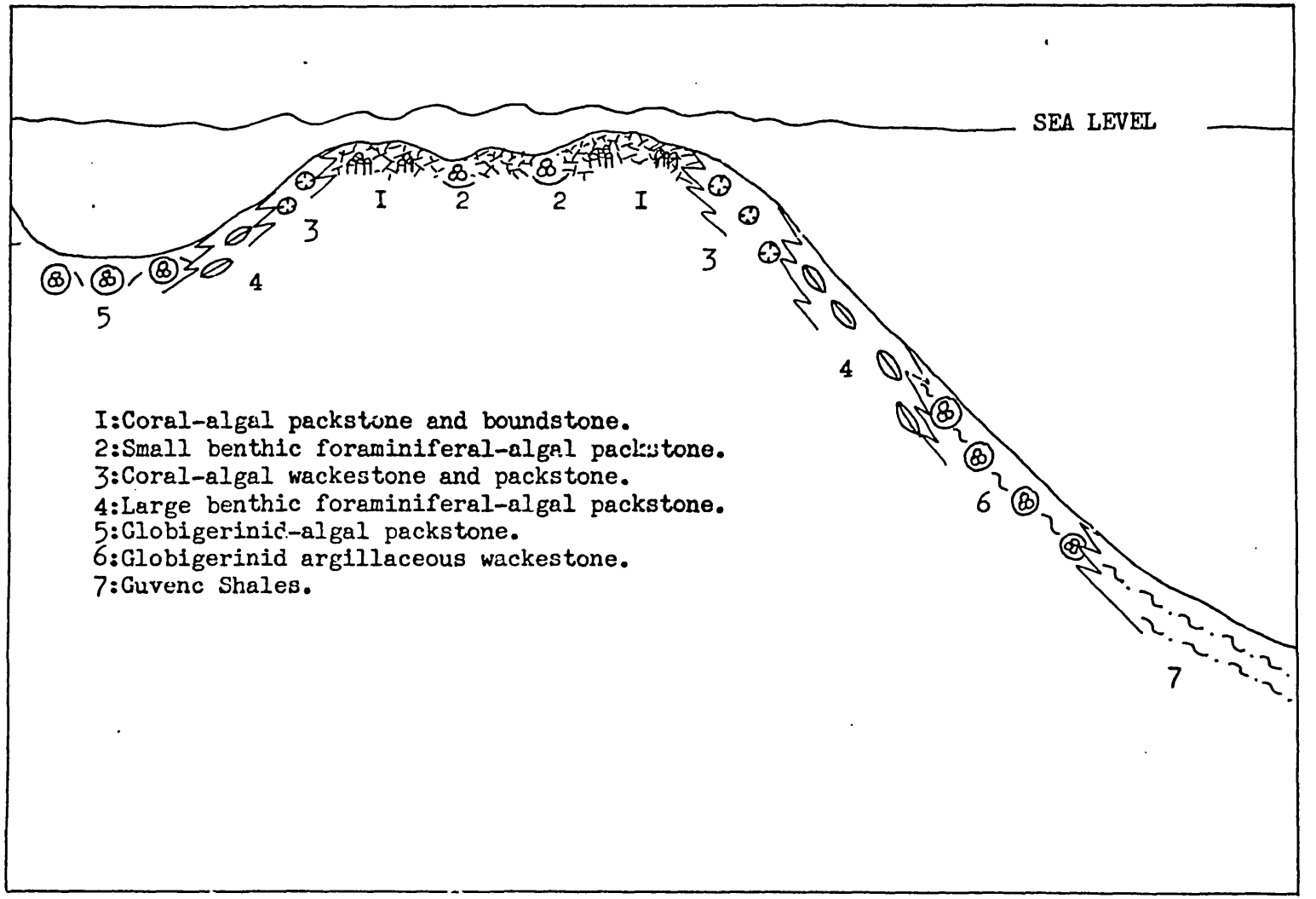
Fig(I9):X-ray diffraction trace of a characteristic sample of the Globigerinal argillaceous wackestone subfacies.

tests of the planktonic foraminifera are characteristic of the deep-water sediments, some globigerinid bearing deposits may be formed under shallow water conditions (Crickmay, Ladd and Hoffmeister, 1941; Heckel, 1972).

In ancient rocks, when tests of the planktonic foraminifera dominate a deposit, it is normally accepted that deeper water conditions prevailed during deposition (Henson, 1950; Forman and Schlanger, 1957; Schlanger, 1964, etc.).

The presence of common calcareous sponge spicules and the other small benthic foraminifera, which are well preserved and do not appear to have been transported, may indicate that the depositional environment of the Globigerinid argillaceous wackestones was probably not particularly deep. Calcareous sponges live only in normal marine shallow water less than 100 metres (Caster, 1941; de Laubenfels, 1957). In addition, the light colour and the short vertical burrows found in this lithology may be in favour of the above interpretation. The field relations and the scarcity of the remains of the bank-forming organisms in this subfacies also indicates that the areas where it was being deposited were probably deeper or more distal than the depositional sites of the Globigerinid-algal packstones from the contemporaneous coral-algal banks. As stated previously, these areas formed a transitional zone between the site of deposition of the bank deposits of the Karaisali Limestone on the one hand and of the Guvenc Shales on the other.

III. 8. RECONSTRUCTION OF ENVIRONMENT OF DEPOSITION OF THE KARAISALI FORMATION: The dominant sedimentary process which led to the development of the Karaisali Limestone complex was bank growth accompanied by sedimentation in adjacent areas. When the transgressive Miocene sea, containing potential bank-forming organisms, invaded the uneven pre-Miocene landscape, some special conditions were created leading to intensive growth of the lime-secreting organisms, such as coralline algae and corals. As noted previously, these organisms require shallow, well agitated, and waters of normal salinity (Vaughan, 1919; Teichert, 1958; Adey and Macintyre, 1973; Milliman, 1974). Obviously, these conditions were best developed on the slopes and the highs of the pre-Miocene topography, thus the concentration of the bank-forming organisms was in such areas. Intensive and extensive competitive organic activity coupled with continuous destruction and local redistribution by waves and currents resulted in the development of banks of bioclastic debris - Coral-algal packstones and boundstones on these relatively shallow areas (Fig. 20). While the algal and coral growths were active on the margins of the highs, miliolid and Alveolinellid types of foraminifera flourished in the protected areas which existed between the areas of intensive bank growth (Fig. 20). They when mixed together with the algal fragments which were being supplied from the banks by wave and current action formed fine to medium grained, poorly sorted packstones - the Small benthic foraminiferal-algal packstones. These deposits were intricately intermingled with the bank deposits in these areas, because of the gradual rise of the sea and possible small scale oscillations or changes in rates of production of sediment. The areas adjacent to the banks became sites for the accumulation of sediments which were characterized by high angle initial dips - Coral-algal wackestone and packstone. These sediments were largely derived from the adjacent banks and partly by the production of bioclastic detritus from organisms which lived both in the overlying waters and on the sea-floor. These deposits were thus laid down as talus deposits on the steep submarine



Fig(20):Reconstruction of the depositional environments of the Karaisali Limestone on a presumed pre-Miocene topographic high.

slopes of the pre-Miocene topographical highs (Fig. 20). Down slope, they passed through the Large benthic foraminiferal-algal packstones into the globigerinid bearing sediments - Globigerinid-algal packstones and Globigerinid argillaceous wackestones. In the slightly deeper areas between the topographical highs which were being greatly influenced by the adjacent banks the Globigerinid-algal packstones were deposited (Fig. 20). Whereas the areas which were more distal from the topographical highs received no materials from the bank and were the sites of accumulation of the fine grained Globigerinid argillaceous wackestones (Fig. 20). To the south towards the centre of the Miocene basin, these sediments were ultimately replaced by the basinal Guvenc Shales.

III. 9. ANCIENT AND RECENT COUNTERPARTS OF THE KARAISALI FORMATION: Comparison of the Karaisali Limestone with some Lower and Middle Tertiary limestones of the Middle East, Louisiana, and Guam shows incredible similarities in lithology and fossil content, although their geological settings differ greatly. The Karaisali Limestone, which was developed on the submerged foot-hills of the Taurus Mountains, is much more similar, in geological setting, to the reefs of the Middle East rather than to the reefs of Louisiana and Guam (Tables 1, 2 and 3) (Henson, 1950; Forman and Schlanger, 1957; Schlanger, 1964).

As far as the author aware, no exact modern counterpart of the Karaisali Limestone is seen today. Although some parallelisms can be seen between the sedimentary pattern of these carbonate rocks and some banks or reefs of Recent age, eg., the carbonate banks in eastern Shark Bay, Western Australia.

III.10. AGE OF THE KARAISALI FORMATION: This formation is variable in age throughout the Adana region ranging from Burdigalian (Lower Miocene) to Messinian (Upper Miocene) (Schmidt, 1961; Ozer etal., 1974; Bizon etal., 1974). In the area which has been studied as well as in the north of Mersin-Tarsus region it is, according to Ternek (1957) who has given a long and comprehensive faunal list for this formation, mostly of Burdigalian

REEFS FROM THE MIDDLE EAST (HENSON, 1950)	LITHOLOGIES	DESCRIPTION	GEOLOGIC SETTINGS
	BACK-REEF SHOALS	Limestone;composed mainly of reef debris and well preserved Miliolidae,Peneroplidae,and Alveolinidae,all of which are set in a fine grained,mostly recrystallized matrix.	Reef growths are developed as fringing-reef ,barrier-reef,shoal-reef,reef-knolls,and bank-reefs in certain sub-littoral zones and on some submerged highs of epeiric seas of Arabian foreland.
	REEF-WALL	Non-bedded limestone;formed by vertical and lateral growth of reef-building organisms,such as corals,coralline algae,bryozoa etc.,with some cavities which are filled by skeletal material and mud.In many places the volume of the matrix exceeds that of organic structures.	
	TALUS-SLOPE	Limestpne;made up of cross-bedded,unsorted,angular reef materials which are broken off by breaker-erosion and deposited below the wave base.Interstices are generally filled with calcareous mud.	
	FORE-REEF SHOALS	Limestone;composed of large benthic foraminifera and fragmentary remains of Echinoidae.Reef-building organisms and molluscs are sporadic.Cementation by lime precipitation is common.Some reef-patches and ill sorted microbreccia of indigenous organisms are also seen in this zone.	
	FORE-REEF TRANSITIONAL ZONE	Represented by tongues of fore-reef detrital limestones alternating and intergrading with sediments of fore-reef basin.	
	FORE-REEF BASIN	Characteristic lithologies are fine grained Globigerinal chalks,shales and limestone.	

Table 1:Reefs from the Middle East

REEFS FROM LOUISIANA AND GUAM (FORMAN & SCHLANGER, 1957)

LITHOLOGIES	DESCRIPTION	GEOLOGIC SETTINGS
BACK-REEF SHOALS LIMESTONE	Consists mainly of well preserved tests of Miliolidae and some other uniserial, biserial, and coiled foraminifera in addition to algal fragments. They are all embedded in fine grained matrix of mud or microspar	The subsurface reefs of Louisiana are found developed both on piercement salt-dome and shallow water shelf area of southern Louisiana. The former is local but the latter is an extensive barrier type reef-complex over a large area. On Guam, reef growth is concentrated on folded and faulted volcanic rocks of Eocene age.
REEF-WALL LIMESTONE	Encrustations of coral mass, detritus, and matrix by encrusting algae and foraminifera are characteristic. The reminder of the rock is made up of unoriented debris of calcareous algae and foraminifera, which are set in a sandy, lime-mud matrix.	
REEF-BRECCIA LIMESTONE	Well bedded lithology closely related to the reef-wall limestones and contains similar fauna. The basic difference is that this limestone is usually detrital in nature. Encrusting algae and foraminifera do not serve and binding function.	
OFF-REEF SHOAL LIMESTONE	Well sorted lithology, made up almost entirely of large foraminifera, mainly Heterostegina and Miogypsinid types, with admixtures of fragments of calcareous algae.	
FORE-REEF DETRITAL LIMESTONE	Characterised by the presence of abundant large benthonic foraminifera and algal detritus set in a fine matrix. The forms are mostly broken and retain angular adges.	
FORE-REEF TRANSITIONAL LIMESTONE	Well bedded, dominated by large benthonic Foraminifera and Globigerinids with some Amphistegina, algae & echinoderms embedded in carbonate mud matrix.	
BASINAL LIMESTONE	Well bedded & contains abundant tests of planktonic foraminifera floating in a relatively pure mud matrix.	

Table 2: Reefs from Louisiana and Guam

KARAISALI LIMESTONE (BANKS) FROM TURKEY

LITHOLOGIES	DESCRIPTION	GEOLOGIC SETTINGS
CORAL-ALGAL PACKSTONE AND BOUNDSTONE.	Poorly or non-bedded,ranging from packstone to boundstone in depositional texture,although mostly detrital in nature.Encrustations of the skeletal constituents and matrix by encrusting algae and foraminifera are seen in the boundstone part.This subfacies developed as banks on the pre-Miocene topographical highs.	The Karaisali banks were formed on the submerged foot hills of the Taurus Mountains.
SMALL BENTHIC FOFAMINIFERAL-ALGAL PACKSTONE	Well bedded,medium to fine grained,poorly sorted packstones which are rich in coralline algae and small benthic foraminifera;such as Miliolidae and Alveolinidae set in a matrix of microspar.This subfacies was deposited in essentially the same environment as the Coral-algal packstones and boundstones.	
CORAL-ALGAL WACKESTONE AND PACKSTONE	Well bedded,composed of fragmented coralline algae,Halimeda,corals,echinoderms bryozoa,and molluscs,all of which are set in a matrix of micrite or very fine grained skeletal detritus.This subfacies was formed as talus deposits on the submarine slopes of the pre-Miocene topography.	
LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	Well bedded,coarse to fine grained,moderate to poorly sorted,and is distinctive in having generally rich concentrations of coralline algae and large benthic foraminifera,such as Cycloclypeus and Heterostegina--with some echinoderms corals,bryozoa,etc.They are set in a micrite matrix.It was deposited at the foot of the submarine slopes.	
GLOBIGERINAL-ALGAL PACKSTONE	Fairly well bedded,very fine to medium grained,and characteristically poorly sorted lithology in which whole and broken skeletons of coralline algae,globigerinid foraminifera,echinoderms,and molluscs are abundant with micritic or neomorphic matrix.This subfacies was deposited in depressions adjacent to the banks.	
GLOBIGERINAL ARGILLACEOUS WACKSTONE	Well bedded,made up of very fine to medium grained argillaceous wackestone. It is rich in concentration of globigerinid foraminifera and echinoderms embedded in a matrix of micrite.This subfacies was deposited in depressions away from the banks.	

Table 3:Karaisali Limestone(Banks) from Turkey

age (Ternek, 1953 and 1957, Stucker, 1960; Schmidt, 1961; Loney and Cain, 1971). Later studies by Ozer etal. (1974) and Bizon etal. (1974) again in the Karaisali region have given Burdigalian age.

CHAPTER IV. DIAGENESIS OF THE KARAISALI LIMESTONE

IV. 1. GENERAL: The term diagenesis has been defined in many different ways in the literature. Because of its complicated nature, it is difficult to make a clear cut definition under which all the related ideas and processes can be included. However, for simplicity, it will be used in this thesis to mean: all biological, physico-chemical, and physical processes, which affect the sediment during or after deposition and which may result in lithification. Of course, this usage excludes metamorphism as a stage of diagenesis. It is considered here that the diagenetic alterations have continued from the deposition of the sediment up to present time.

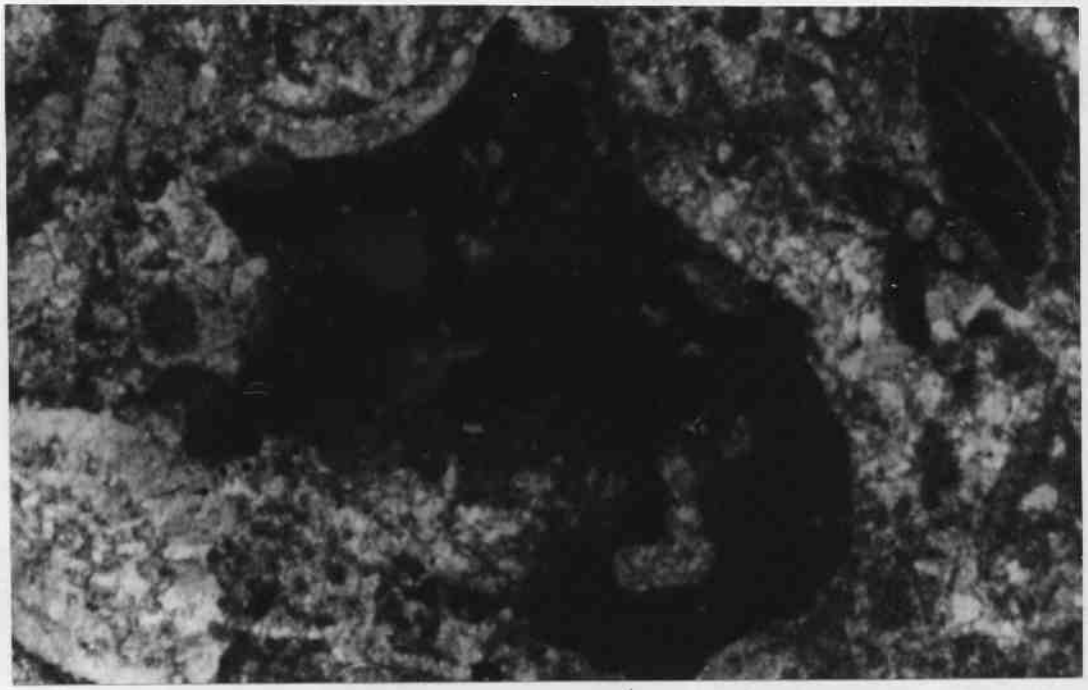
IV. 2. BIOLOGICAL PROCESSES: The Karaisali Limestone was largely formed from the hard parts of organisms which lived, died, and were generally buried in the same local environment. The major part of this limestone complex is composed mainly of unsorted skeletal fragments which generally show little evidence of prolonged transportation and erosion. The presence of many whole and well preserved shells and fine carbonate mud incorporated with the broken skeletons, suggest that biologic agents rather than currents and waves played the most important role in the breakage of these grains. When the loose sediments were lying on the sea-floor, boring and burrowing organisms affected these fragments in their search for food and shelter wherever the substrate was favrourable to life. They caused breakdown of skeletons to a very small size as they normally do in the modern sediments (Ginsburg, 1957; Rhoads, 1967; Shinn, 1968b). Some textural and structural effects of these organic-activities have been preserved as boring and burrowing structures in the various subfacies of the Karaisali Limestone.

2.1. Textural and sedimentary structural effects of the boring organisms: Borings in the components of the rocks which have been studied are characterized by tiny holes which are usually filled by microspar. Their density in the individual grains is variable and they

may be scattered or abundant (Plate 67). Because most of these borings have very narrow cross-sections, they are thought to be algal or fungal in origin (Bathurst, 1971). However, as well as these borings others, which are generally seen in the Coral-algal packstone and boundstone subfacies, are larger and commonly have transverse diameters of about 250 microns and are up to 2 millimetres long. These borings are generally straight and penetrate into the matrix through the skeletal grains. They are often filled by loosely packed skeletal sediments or sparry calcite (Plates 68 and 69). Additionally, an unusual type of boring was observed in the echinoderm fragments in the Small benthic foraminiferal-algal packstone subfacies. These borings are slightly curved and appear to penetrate the matrix of this subfacies (Plate 70). The organisms responsible for these two latter types of borings are unknown.

Another important diagenetic effect produced by the boring organisms, particularly by algae, is one which results in the alteration of the skeletal grains into an apparent mass of micrite. This is a well known process on the present-day sea-floor and its occurence has been reported from many parts of the world, such as Florida, the Bahama and the Persian Gulf. Bathurst (1966) named this process "micritization" and described its role in the preservation of casts of molluscs during the diagenesis. He pointed out that the alteration is centripetal, ie., proceed from the outer rim of the grains inward forming a "micrite envelope" on those particles which are incompletely altered (Plates 71 and 72). When this process reaches a more advanced state, the grains become a structureless mass of micrite and this creates a problem of identification (Plates 73 and 74). Bathurst (1966) proposed that alternate boring by algae and infilling of the borings by micrite was the way in which this micritization developed.

The cumulative effects of the biological activities, particularly the effects of boring organisms, had considerable importance in weakening the skeletal grains. They became more susceptible to break-

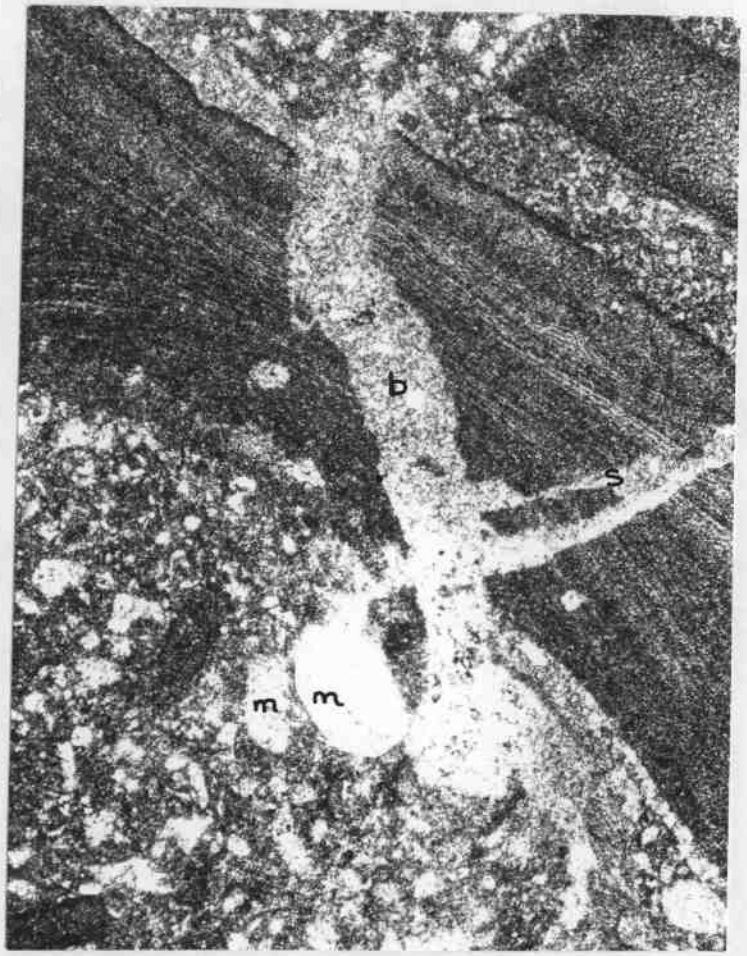


× 67

Plate (67): Tiny algal and fungal bores (?) filled with microspar in a coralline algal fragment.

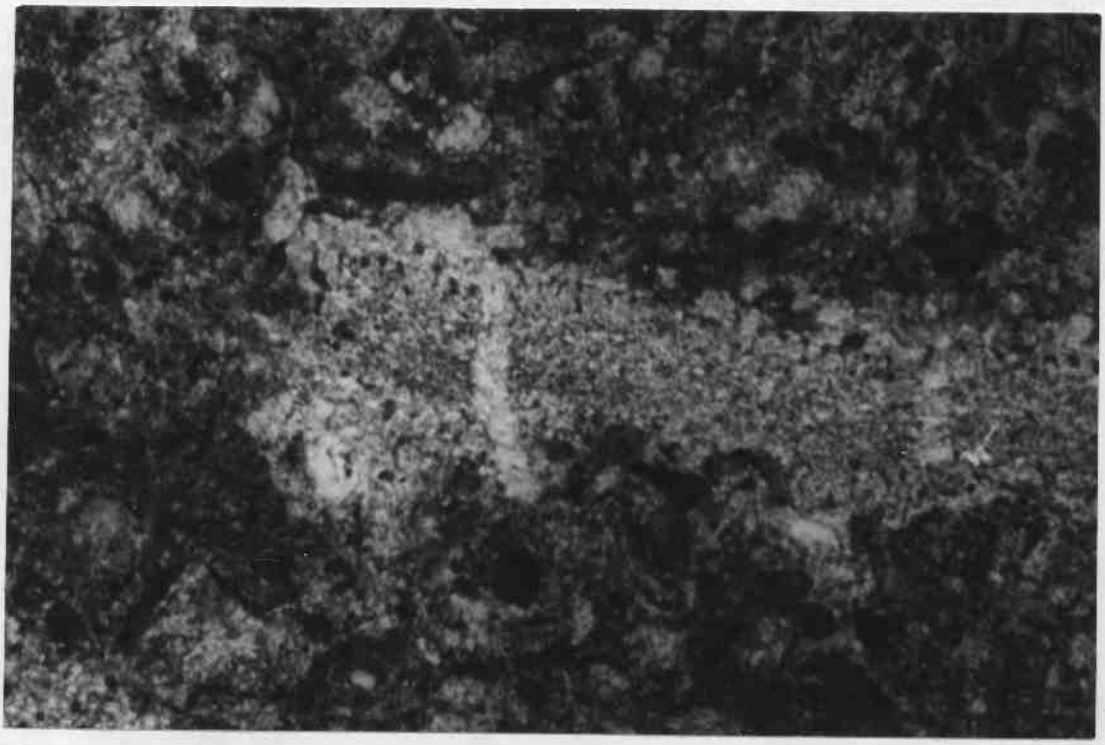


× 53



× 48

Plates(68) and (69): Borings cutting through skeletal grains and penetrating into the matrix. Theyare filled with loosely packed skeletal sediments(Plate68) and sparry calcite(Plate 69) (b=borings, s=skeletal grains, m=matrix).



×40

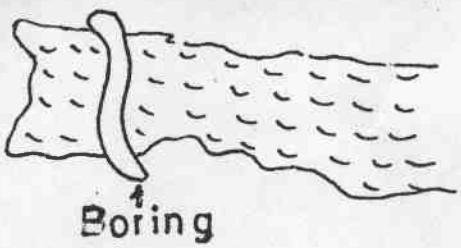
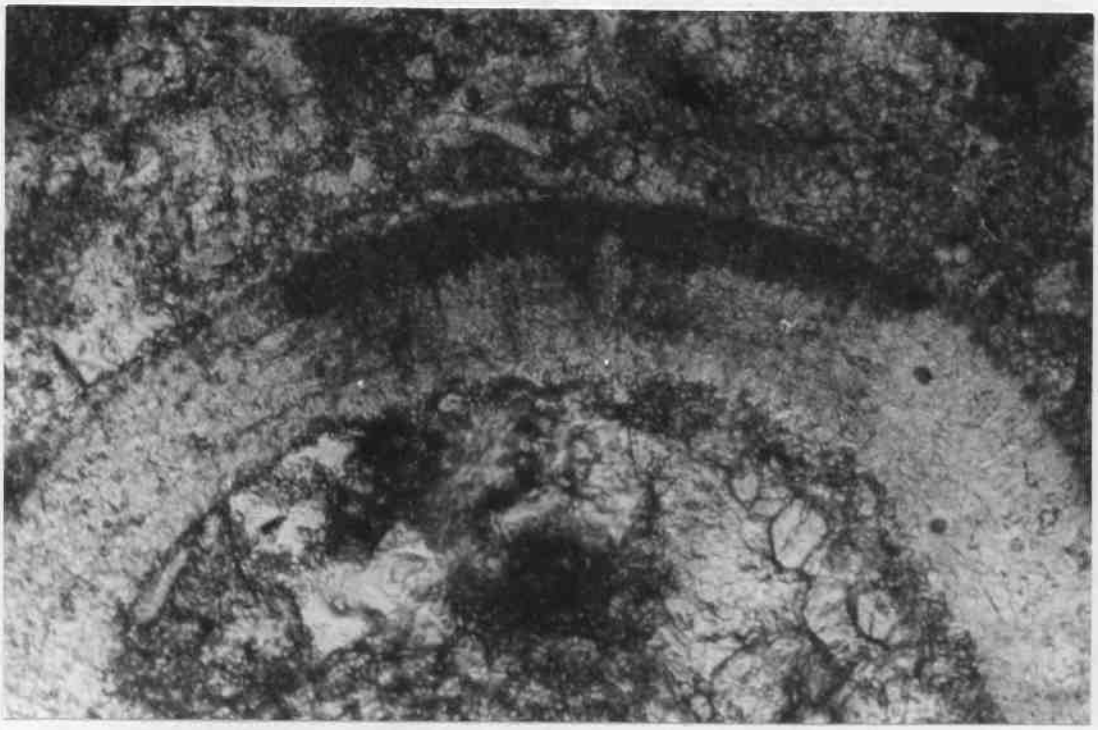


Plate (70): A slightly curved boring penetrating the skeleton of an echinoderm and the adjacent matrix.



×80

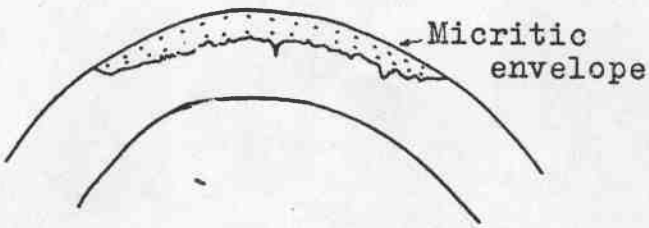
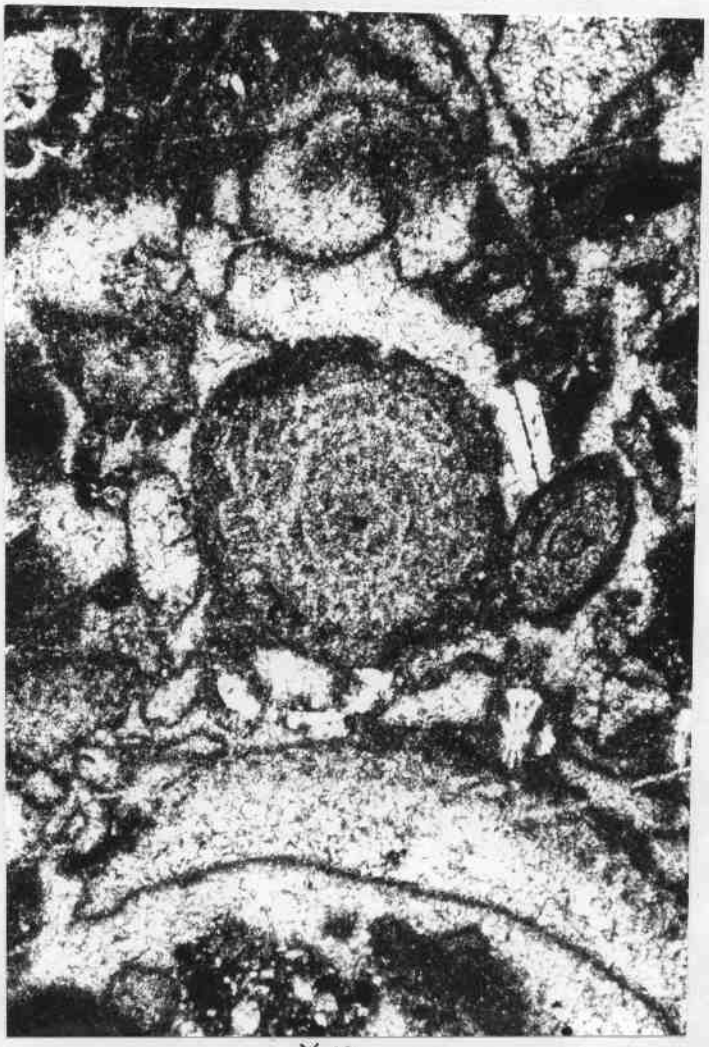


Plate (71): Micritic envelope in a molluscan shell fragment.



X 40

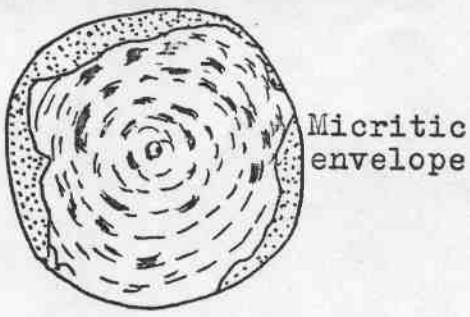
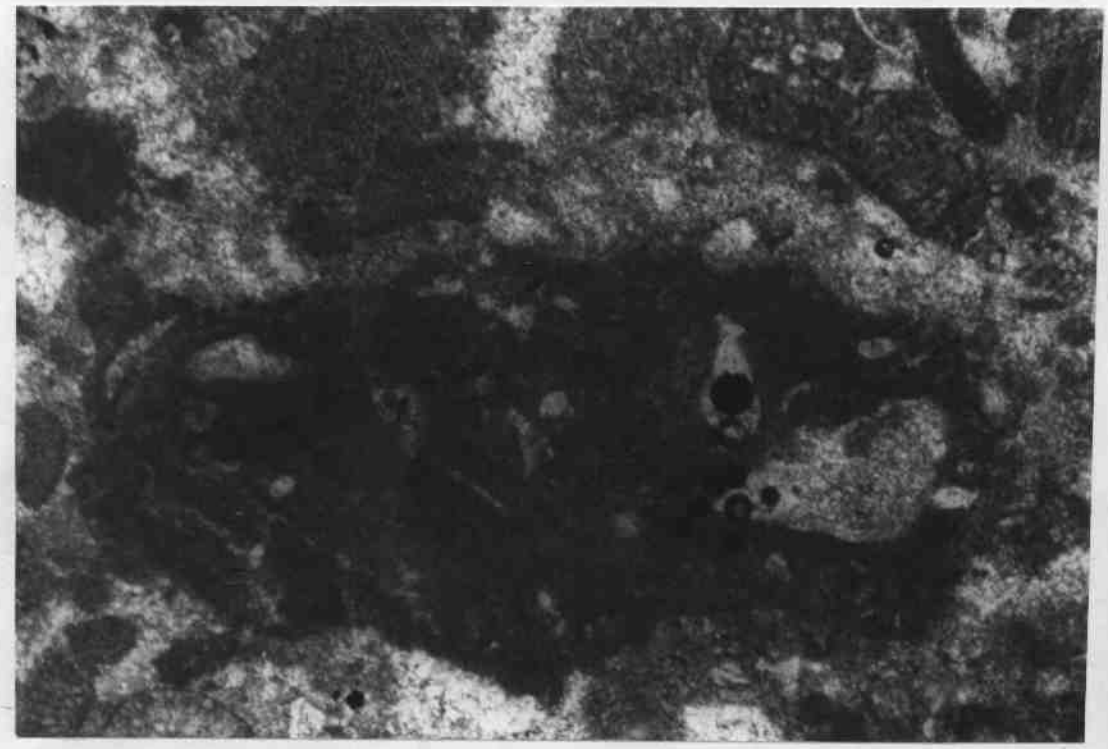
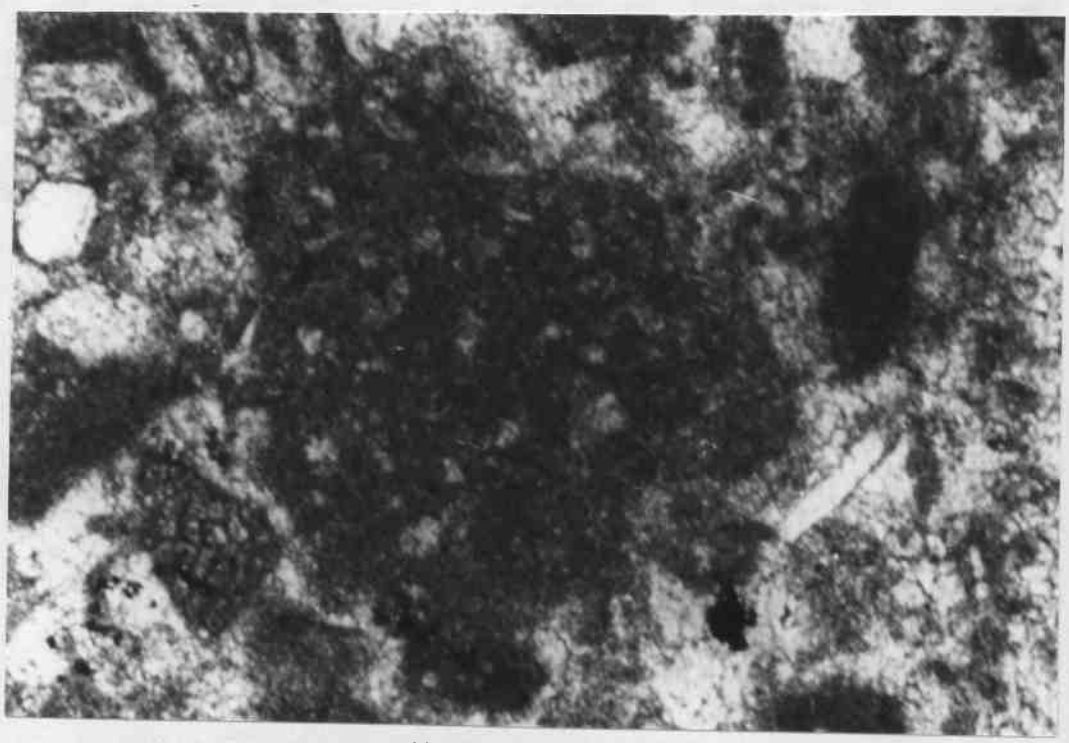


Plate (72): Centripetal replacement of a foraminifera by micrite due to process of algal micritization.



X67



X 160

Plate (73) and (74): Coralline algal fragments in an advanced stage of micritization.

down by the action of waves, currents, burrowing and sediment feeding organisms (Ginsburg, 1957; Bathurst, 1971). Because of this, it is thought that most of the fine carbonate mud of the Karaisali Limestone was probably derived from the breakdown of coralline algae and of the other skeletal material, although some, of course, could have been produced by precipitation due to physico-chemical or bio-chemical processes (Stockman et al., 1967; Neumann and Land, 1969). Some of the muds may have been in the form of feacal pellets before later diagenesis destroyed their original texture and made them unrecognizable.

2.2. Textural and sedimentary structural effects of the burrowing organisms: Evidence of the activity of burrowing organisms is common throughout the whole of the Karaisali Formation, although it is most easily observed on polished rock slabs or in thin sections. Burrowing structures are more abundant in the Coral-algal packstone and boundstone subfacies than in the others; indeed the most obvious feature of this subfacies is that the sediment has been intensively reworked and churned by burrowing organisms. The result of these activities is that a patchy and very ill-sorted texture has been produced. The burrows are often evident as mottling in the rocks because of contrast in colour due to different composition of the burrow fill as compared to the surrounding sediment (Plate 75). They are filled either by sparry calcite or skeletal sediments (Plate 75). Some short, vertical burrows are found in exposures as well as in thin sections of the Globigerinid-algal packstone and Globigerinid argillaceous wackestone subfacies, as described throughout the description of the subfacies of the Karaisali Limestone.

IV. 3. PHYSICO-CHEMICAL PROCESSES: These include cementation, internal sedimentation of micrites, solution-cavity filling, inversion, recrystallization, and replacement.

3.1. Cementation: This appears to be one of the main diagenetic processes operating in the primary and secondary cavities of the Karaisali Limestone and has resulted in their reduction and filling. Five types



×50

Plate (75): A burrow structure infilled with microspar (b = burrow structure, m = Matrix, a = coralline algae).

of cement are commonly observed in the intraparticle and interparticle pore space of this carbonate complex. They are: finely crystalline bladed crusts; tightly packed, finely crystalline fibrous crusts; aphanocrystalline to very finely crystalline equant-spar; fine to medium crystalline equant-spar; and coarsely crystalline overgrowth-cements.

(i) Finely crystalline bladed crusts: Coralline algal and calcitic molluscan fragments are generally coated by this finely crystalline bladed crusts. The calcite crystals of the cement have an approximate length to breadth ratio of 2. But this ratio is not constant in the groups of calcite crystals which may become equigranular around the same host grain. The orientation of the individual crystals on the skeletal components is variable but is generally perpendicular to the grains. They are usually in contact with each other at their bases and separated upward (Plate 76 and 77).

(ii) Tightly packed, finely crystalline fibrous crust: The fibres of this cement are all of the same length, which is about 20 microns. They are in contact throughout their length around the grains (Plate 78). The fibres are generally found around foraminifera and grow into the interparticle void space. But they may also occur growing into the intraparticle voids.

(iii) Aphanocrystalline to very finely crystalline equant-spar: Under the petrographic microscope this cement occurs as a dark, translucent microcrystalline to almost opaque cryptocrystalline cement. It is usually found filling the original chambers of large benthic foraminifera and the algal structures. However, it may rarely line the interparticle spaces (Plates 79 and 80). It can be distinguished from matrix in that is very homogeneousand better sorted than the latter. Also, as well as infilling cavities if forms a distinct coating on skeletal particles in a way that matrix never does (Plate 80).

(iv) Fine to medium crystalline equant-spar: In this type the cal-



×112

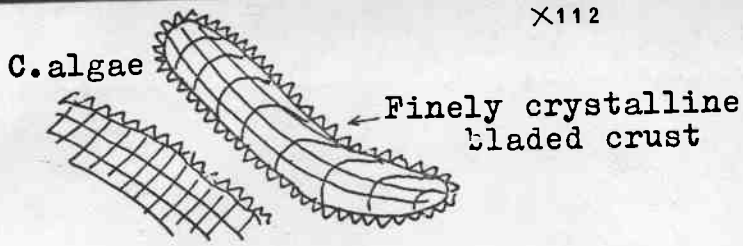


Plate (76): Finely crystalline bladed crust coating coralline algal fragments.



×80

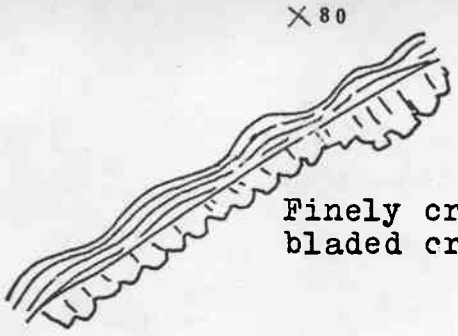


Plate (77): Finely crystalline bladed crust growing downward into the pore spaces from a molluscan shell fragment which has produced an umbrella effect.



× 140



Plate (78): Tightly packed, finely crystalline fibrous crust around a foraminifera.



X 140

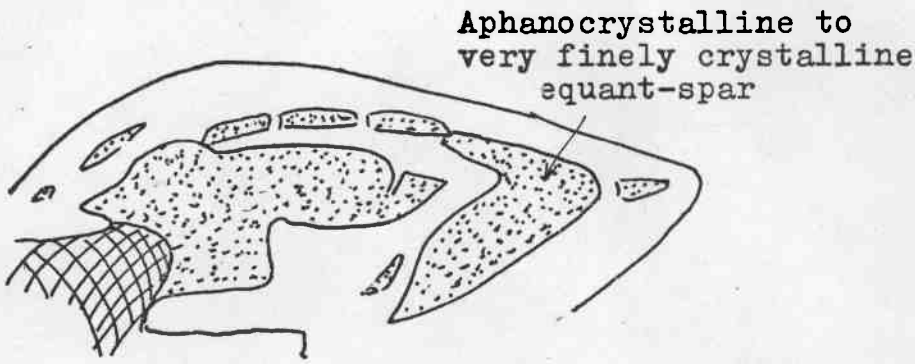
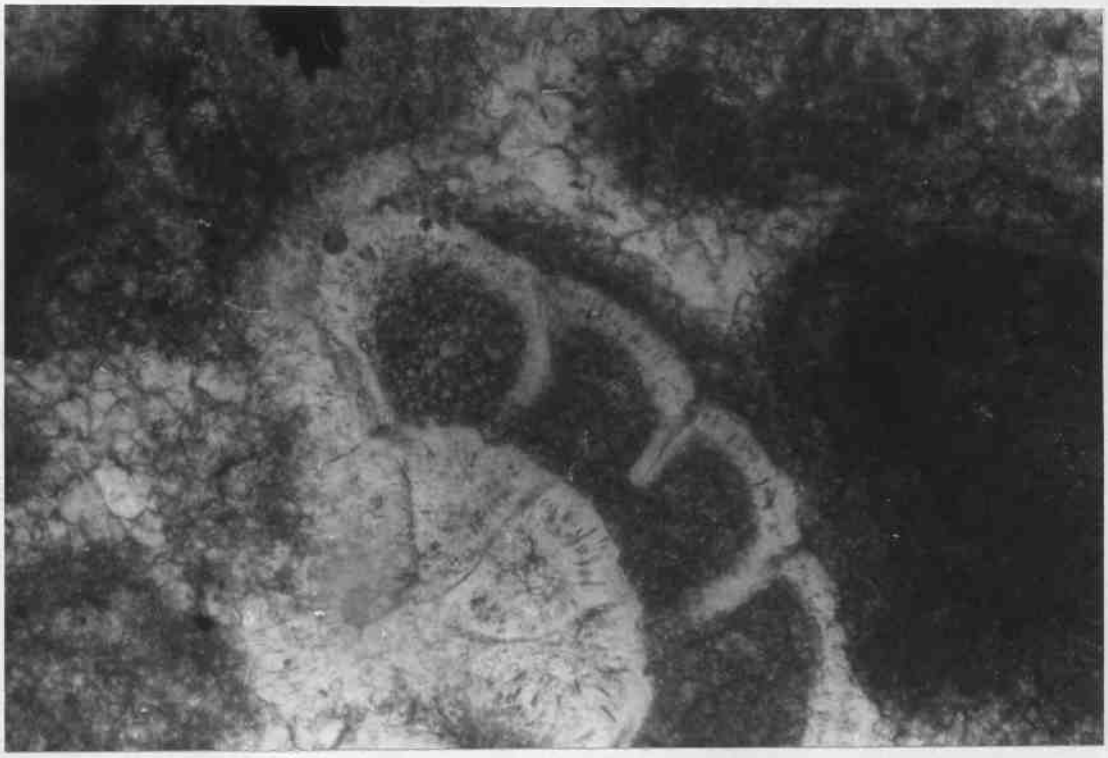


Plate (79): Aphanocrystalline to very finely crystalline equant-spar filling the original chambers of a foraminifera.



×300



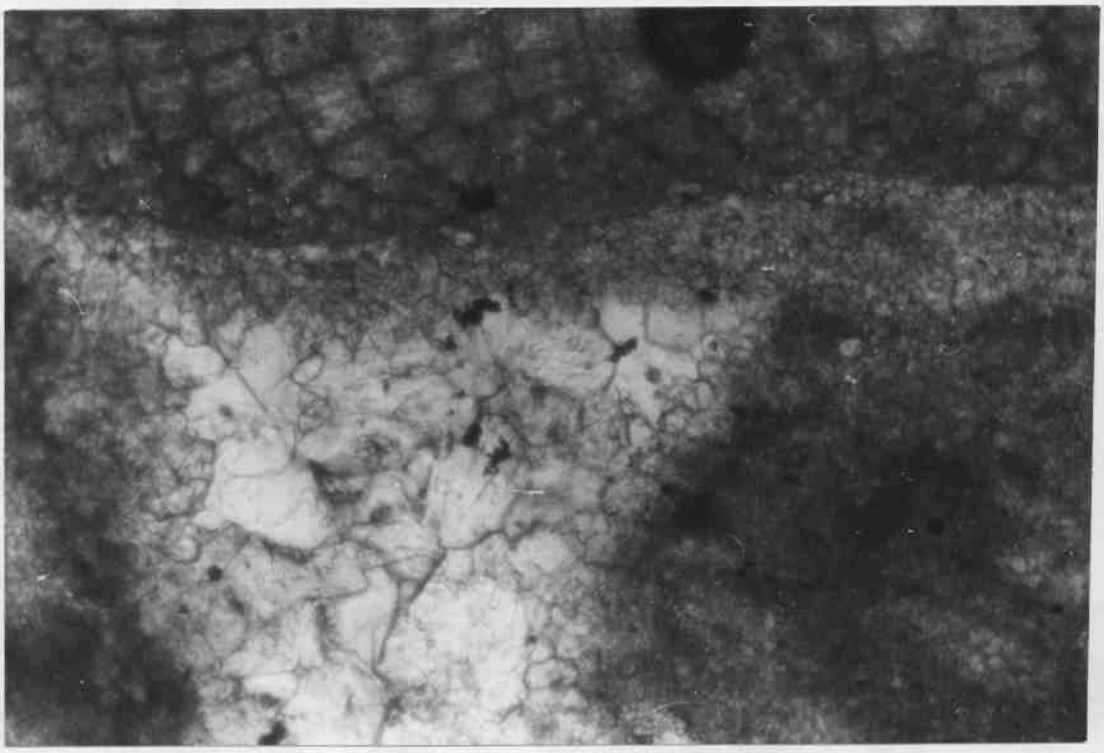
Plate (80): Aphanocrystalline to very finely crystalline equant-spar lining the outer surface of a foraminifera as well as infilling the chambers.

cite crystals show roughly the same diameter in all directions. They tend to be granular and to fill the remaining interparticle and intraparticle pore spaces which are unfilled by the initial fringing crusts. These crystals do not show any obvious foundation control and have a sharp contact with the first phase fringing crusts presumably due to a gap in time between the development of these two cements (Plate 81).

(v) Coarsely crystalline overgrowth-cements: Fragments of echinoderms are common in some of the subfacies of the Karaisali Limestone, such as the Small benthic foraminiferal-algal packstones and Large benthic foraminiferal-algal packstones. They usually show large overgrowths which are coarse crystals of calcite growing in optical continuity with the original single crystal grains of the echinoderms, such as crinoid particles. These overgrowth-cements usually fill the original interparticle void space and develop over the neighbouring skeletal fragments and their associated fringing crusts (Plate 82). An interesting point about these overgrowths is that they are in most cases restricted to the undersides of the echinoderms (Plates 83 and 84).

This perculiar restriction of the echinodermal overgrowths is due to penecontemporaneous internal sedimentation of micrite which will be described below.

3.2. Internal sedimentation of micrites: Internal sediments are generally found in most of the subfacies of the Karaisali Limestone, although they are more abundant in the Small benthic foraminiferal-algal packstones. Many intraparticle and interparticle cavities are partly to completely filled with a dense, pasty, aphanitic to silt-size carbonate which rest on the first phase fringing crusts and the echinodermal overgrowths (Plates 85 and 86). These sediments often appear to be pelleted (Plate 87) and sometimes contain silt-size skeletal fragments. These diagenetic internal sediments produce an important problem as it is difficult to distinguish them from matrix, particularly when there is no cement present.



X300

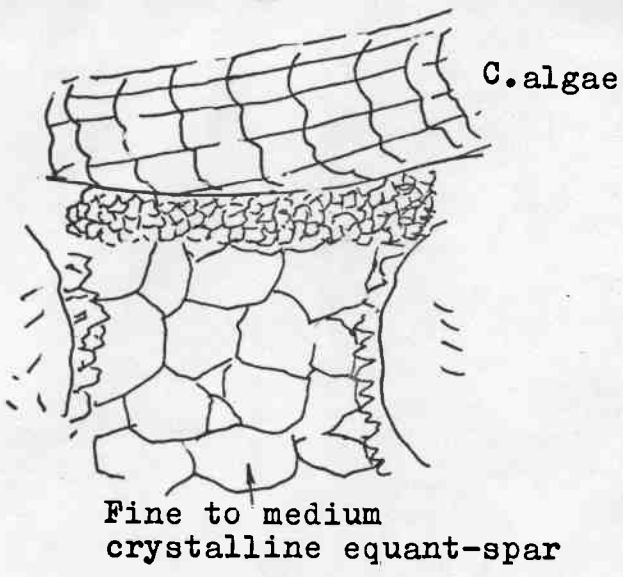
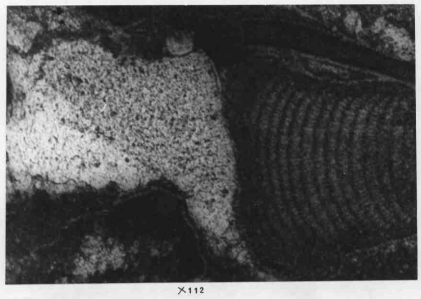
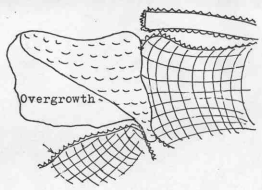
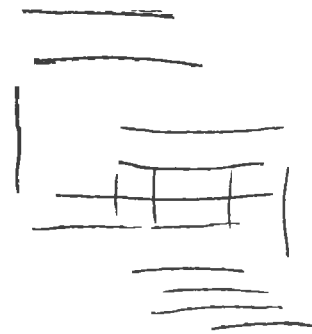


Plate (81): Fine to medium crystalline equant-spar filling the remaining interparticle pore space left empty after the deposition of the first phase cements.



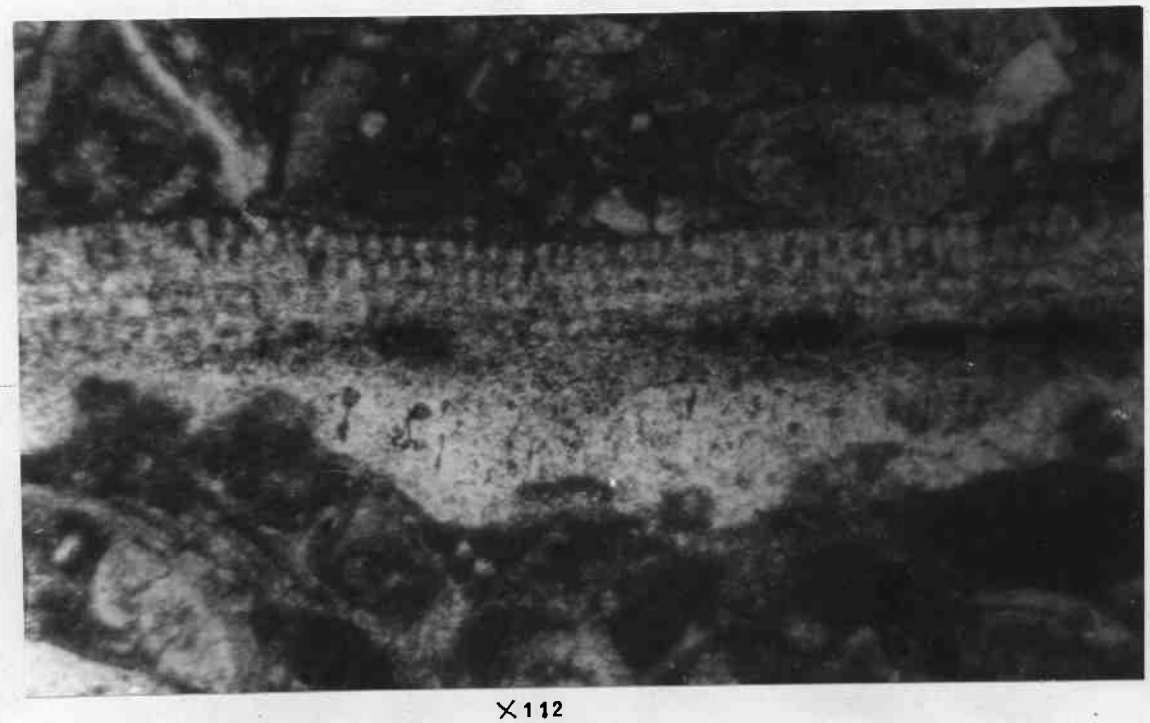
×112



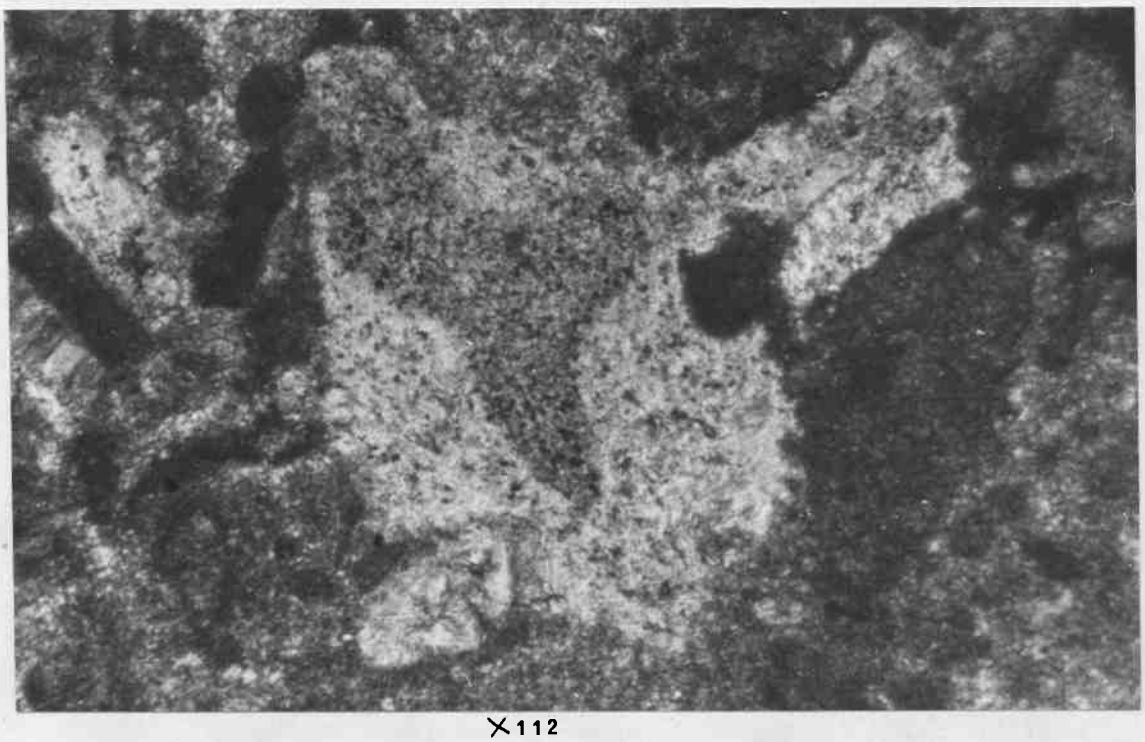


First phase
fringing
crust

Plate (82): Coarsely crystalline overgrowth cement from an echinoderm fragment filling the original interparticle void and overlying the neighbouring skeletal fragments and their first phase fringing cements.



×112

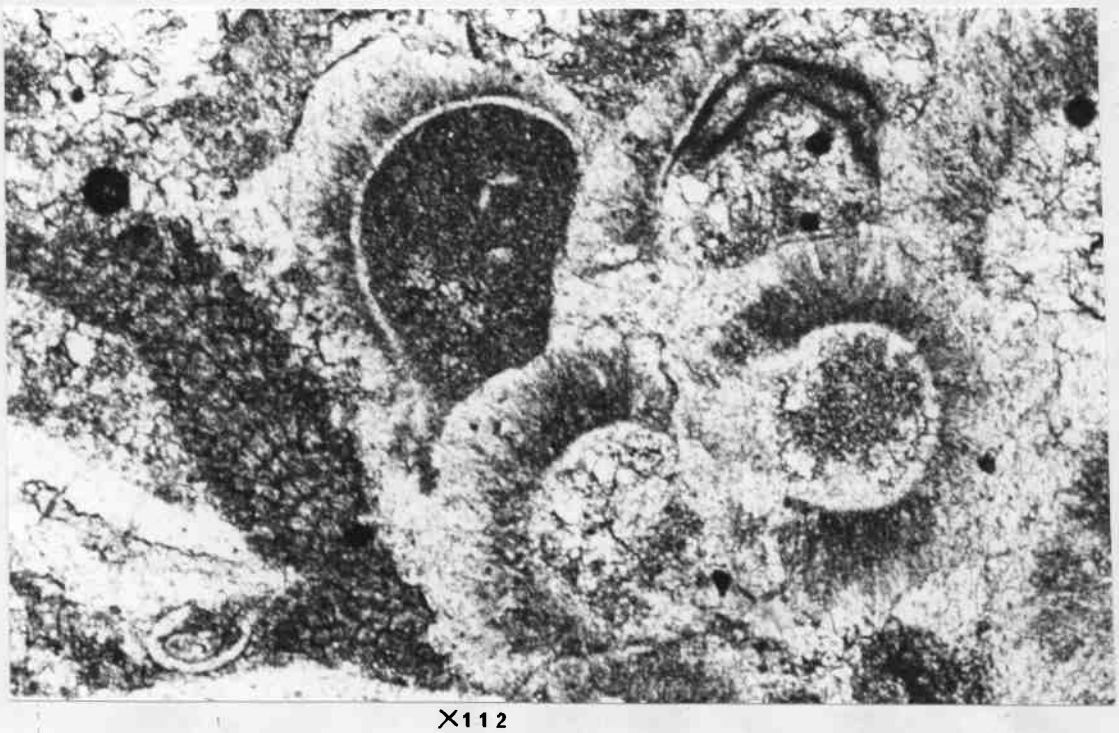


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Plates (83) and (84): Peculiar restriction of the echinodermal overgrowths to the undersides of the echinoderms.

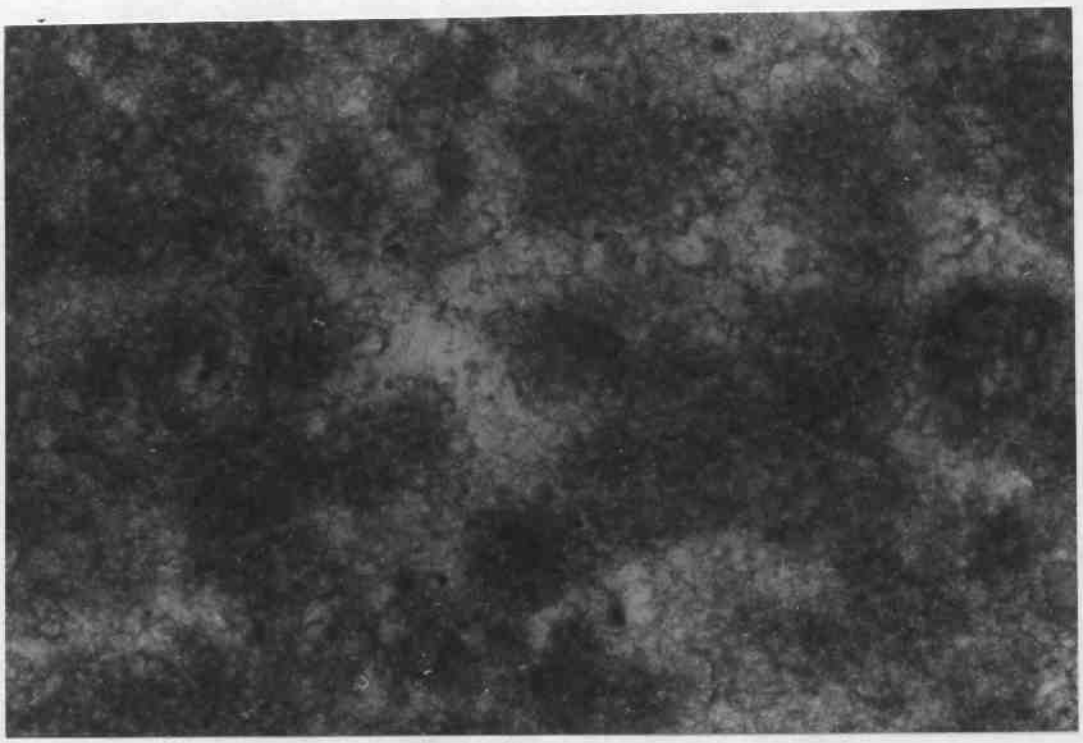


×112



×112

Plates (85) and (86): Infilling of inter (Plate 85) and intragranular (Plate 86) cavities by a dense, pasty, aphanitic to silt size carbonates which rest on the first phase fringing crusts.



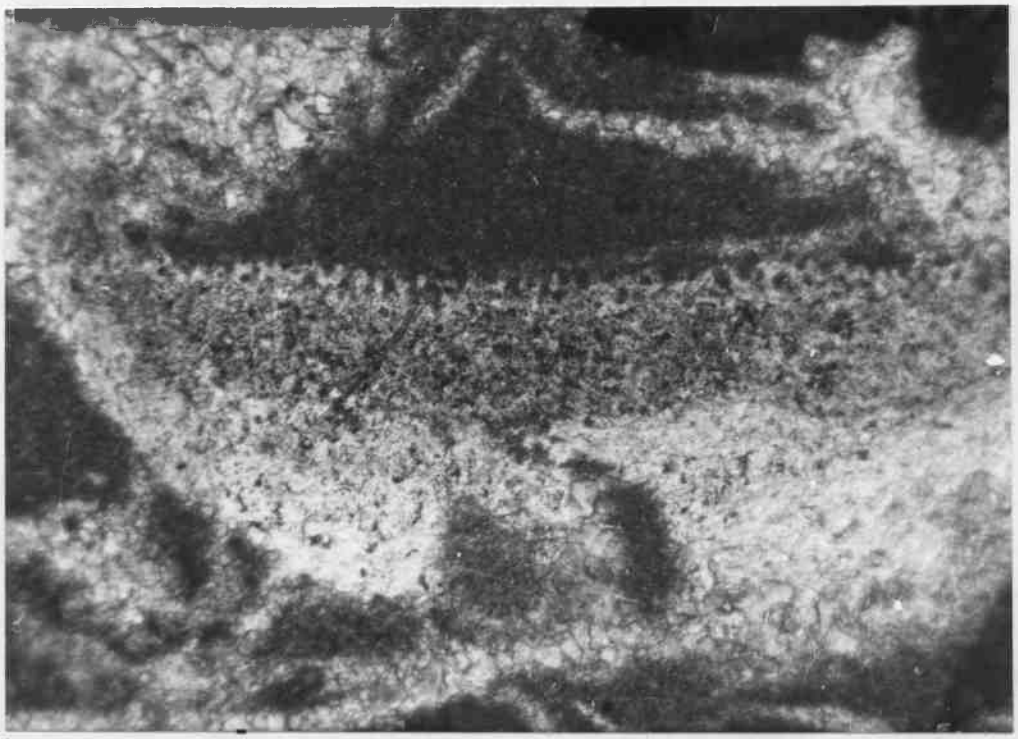
×140

Plate (87): Pelleted internal sediment (structure grumeleuse?).

A very interesting relationship was observed between the echinodermal overgrowths and the internal sedimentation of the micrite. This observation is of particular interest, because it may be a very valuable indicator of the diagenetic environment of the Karaisali Limestone. Before reaching any conclusion, this relationship will be examined here in some detail: echinoderms with large overgrowths are particularly abundant in the Small benthic foraminiferal-algal packstone subfacies and sometimes are found in the Large benthic foraminiferal-algal packstone subfacies. The syntaxial overgrowths are in most cases restricted to the undersides of the echinoderms or to the areas where the large skeletal grains produce an umbrella effect (Plates 82, 83, 84, 88 and 89). The upper surfaces of the echinoderms are usually covered by the internal sediments (Plates 88). In a few cases, however, overgrowths do occur on the upper surfaces but are usually only poorly developed (Plate 84).
These restricted overgrowths may have one of two possible origins: deposition in the marine environment or deposition in the vadose zone after the Karaisali Limestone was uplifted from the sea and exposed to subaerial conditions.

The first possibility may be that the echinodermal overgrowths were formed in the open voids of the sediments in the marine environment but continued along with internal sedimentation which controled the growth pattern of these cements. Where the internal sediments entered the system, they came into direct contact with the echinoderms at their upper surfaces, thus the upward development of the echinodermal overgrowths was either completely prevented or their further development was inhibited. Of course the original sediment may have contained matrix and that the sediment was originally loosely packed that cavities were left under large grains. However, the fact that this matrix overlies the first phase cement on neighbouring grains illustrates that it was introduced later.

The uneven style of the overgrowths was reminiscent



× 70

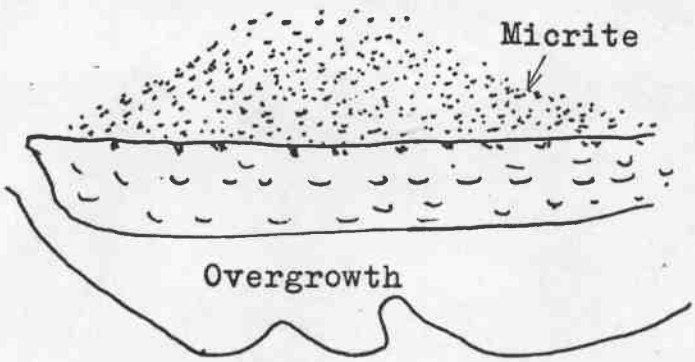
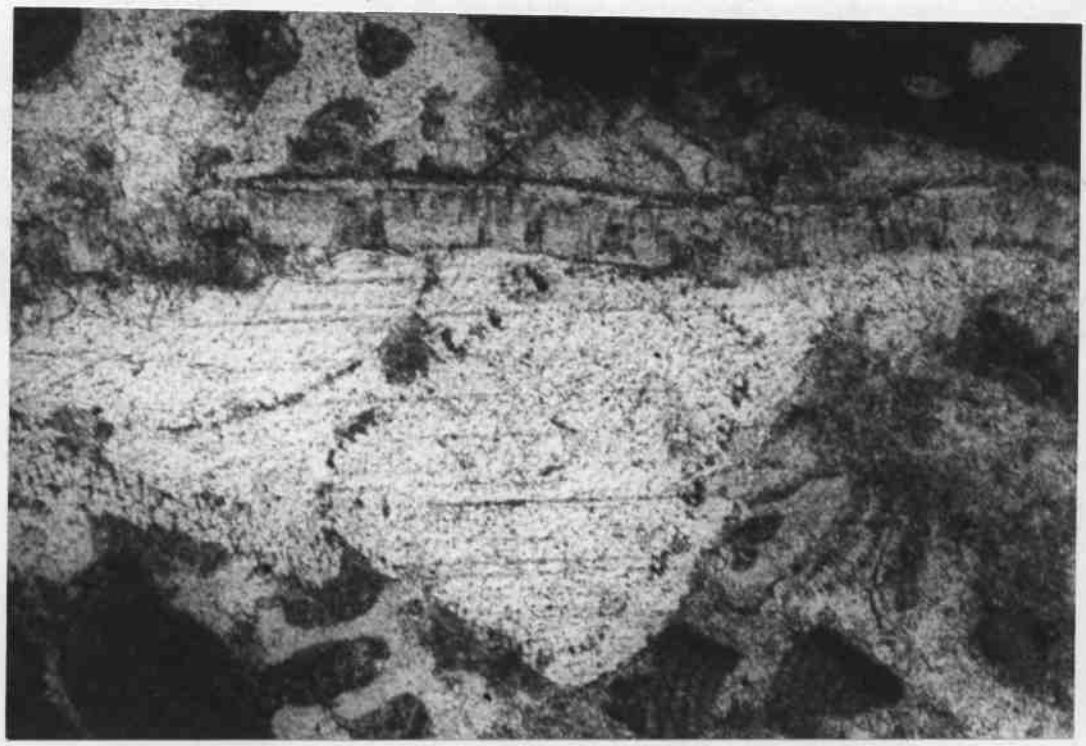


Plate (88): The upper surface of an echinoderm which has been covered by internal micritic sediment while the overgrowth cement continued to develope at the underside of the echinoderm.



× 70

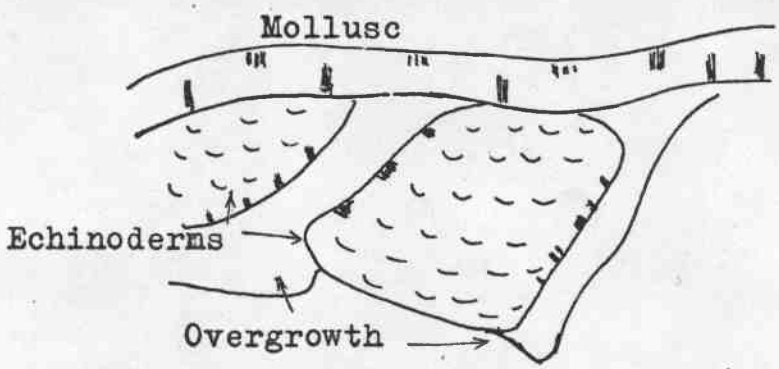


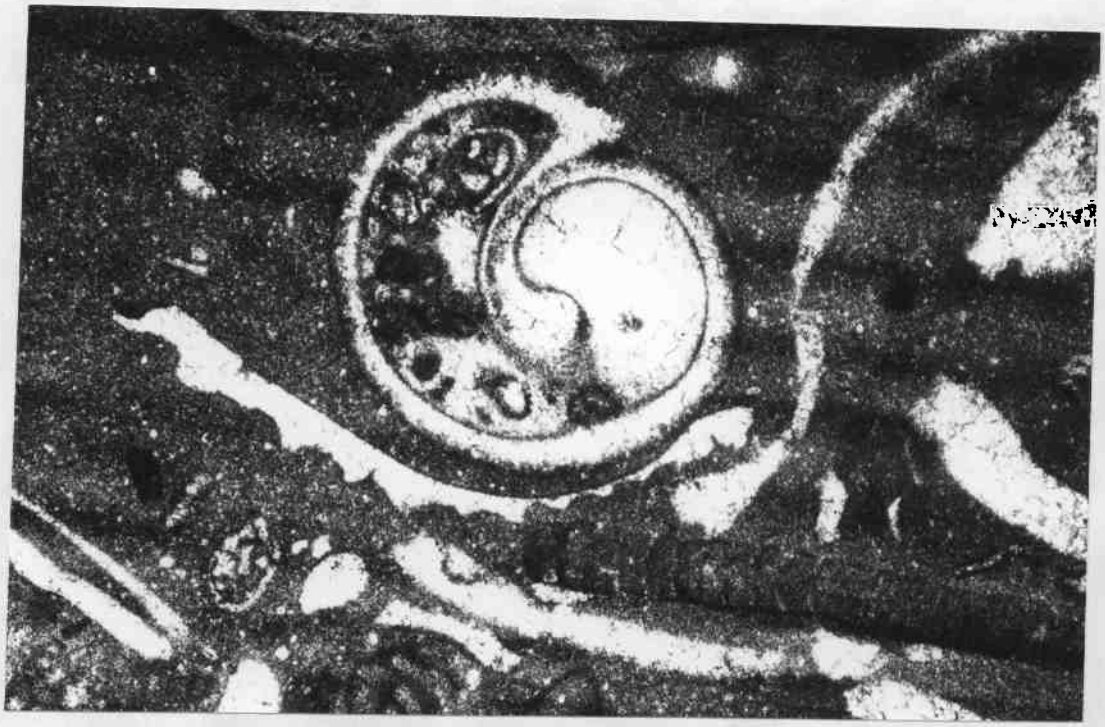
Plate (89): A molluscan shell fragment (with its original structure preserved) which has produced an umbrella effect leading to the formation of the echinodermal overgrowths only in this sheltered area.

of the vadose zone "gravitational" cement described by Muller (1971). In the vadose zone, gravitational cement may be formed by precipitation from a thicker water film which was left by the mobile water, percolating through the sediments, at the lower surface of the grains facing along the direction of the gravity vector (Muller, 1971). Evidently this mechanism can explain not only the restriction of the overgrowths to the lower surfaces of the echinoderms but also explains the deposition of the mud or micrite on the upper surfaces of these grains as it was deposited from downward percolating water.

Despite the attractiveness of the vadose origin for the echinodermal overgrowths, it was concluded that their development took place in a submarine environment. The reasons for this conclusion will be discussed later in the section dealing with the diagenetic environment of the Karaisali Limestone.

3.3. Solution-cavity filling: This is mostly observed on the originally aragonitic molluscan fragments. These organisms are always represented by calcite casts without any trace of the internal structure of the original skeletons (Plate 90). They show a dark outer rim which is generally considered to be a micrite envelope (Bathurst, 1966 and 1971). Preservation of the aragonitic skeletons as moulds and subsequently as casts is a widely known phenomenon and the formation of these moulds is considered to be as follows: at an early stage of diagenesis, the aragonite shells of the molluscs was dissolved away to form moulds which were supported by the micritic envelopes. Later, they are filled by a calcite mosaic and are only preserved as casts without any sign of the original internal fabric (Bathurst, 1971).

It is important to mention here that the solution-cavity filling is different from inversion (see below) and may take place in cavities which are formed by dissolution of any grains regardless of their mineralogy, ie., it is nothing more than a cementation mechanism occuring in the secondary cavities formed by dissolution.

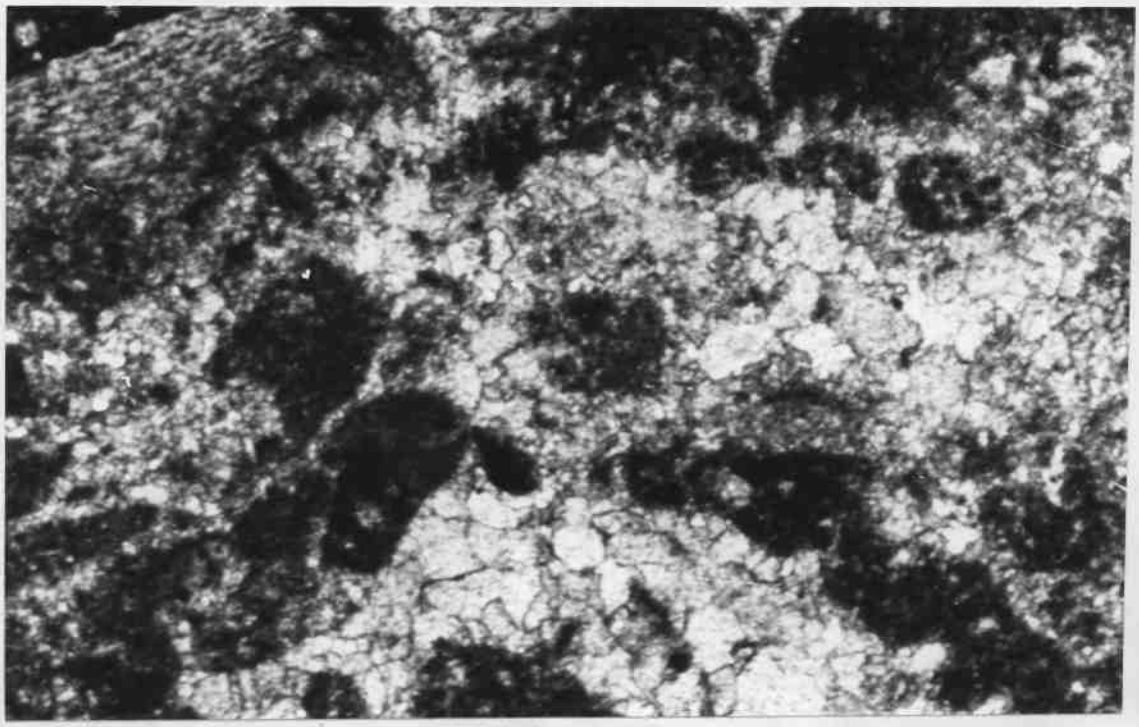


× 58

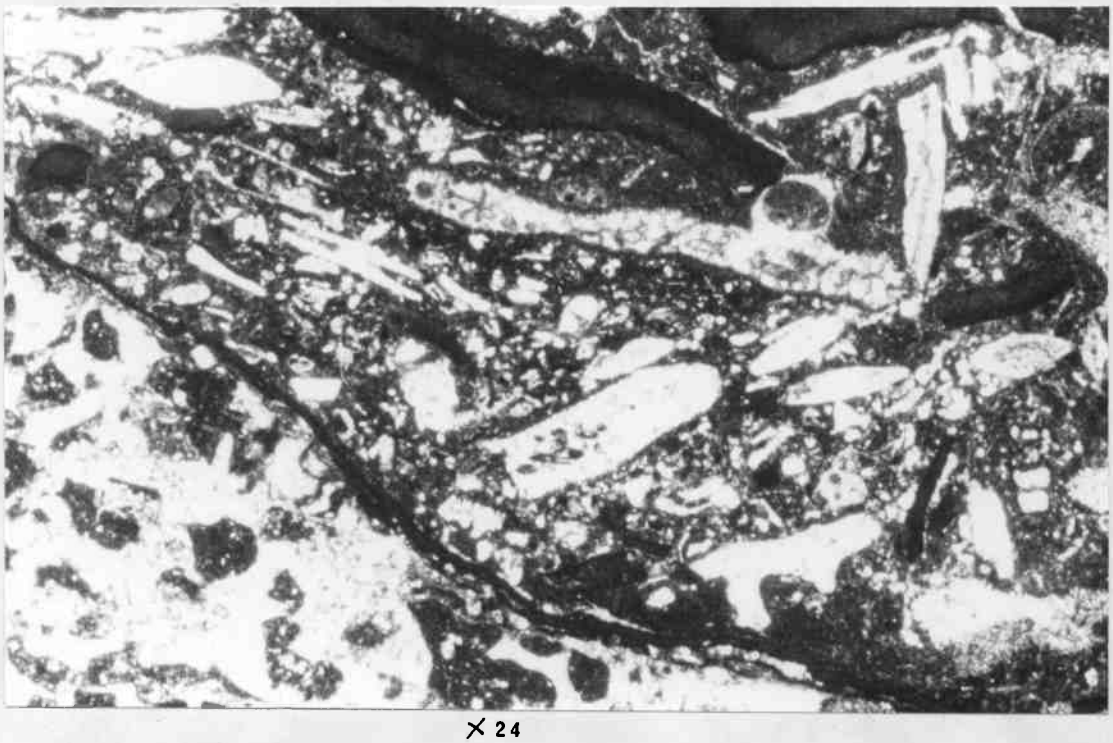
Plate (90): Calcite casts of originally aragonitic molluscan skeletons.

3.4. Inversion: In contrast to complete destruction of the internal structures of the aragonitic molluscs by the solution-cavity filling process, the internal architecture of the aragonitic coral, Halimeda, etc., is partly or wholly preserved after the replacement by a calcite mosaic (Plates 91 and 92). Because of these contradictory occurrences, it may be thought that the latter aragonitic shells must have had different properties or have undergone a diagenetic change which is completely different from the one that has affected the molluscs. Since it is widely accepted that the growth of neomorphic spar is mostly wet in the diagenetic environment (Bathurst, 1971), it is difficult to think of a different process for the formation of the sparry calcites replacing those grains with well preserved internal structures. If the solution-precipitation process is accepted, then an important question remains to be answered, which is: why the aragonitic corals and Halimeda have not undergone solution and redeposition with a total loss of the original structures? Evidently, properties of the original skeletal structures play an important role in the preservation of the internal architecture.

Originally these organisms contain some septas, growth cavities, and internal tubular voids in their skeletons. These primary voids are usually filled by internal sediments and aragonitic or high-magnesian calcite cement during early diagenesis. Besides the primary voids, high-magnesian calcite or aragonite also may be present as a micrite in the small holes which are made by boring organisms in the solid part of the skeletons (Winland, 1971; Bathurst, 1966; Talbot, 1972; Alexandersson, 1972a). During the early diagenesis, when the dissolution of the aragonitic skeletons takes place these internal sediments and the micrite cements may retain their depositional position within the skeletons and reflect the original structures of these organisms even after the completion of the dissolution and reprecipitation process. The survival of the internal sediment from the dissolution may be related to its mineral-



×145



×24

Plate (91) and (92): Inversion of the originally aragonitic coral fragments (Plate 91) and Halimeda (Plate 92) to low-magnesian calcite with a well or partly preserved internal architecture.

ogy and diagenetic history prior to the dissolution-reprecipitation (Windland, 1971; Talbot, 1972). However, although the presence of the internal sediments appears to be a critical factor, it is not always essential for the preservation of the internal textures of the aragonitic skeletons. As, in the rocks studied, many coral fragments with well preserved internal textures which have suffered mineralogical inversion have been found containing no internal sediments or micrite cement. In this case, it is reasonable to suggest that the growth of the sparry calcite has taken place essentially simultaneously with the step-by-step dissolution of the earlier grains (Crickmay, 1945; Schlanger, 1964; Folk, 1965; Bathurst, 1971; Blat et al., 1972).

3.5. Recrystallization: Recrystallization is the main diagenetic process observed on the originally high-magnesian calcite skeletal grains, such as small benthic foraminifera, coralline algae, and some of the calcitic molluscs. This process involves a complete or partial alteration of the individual grains and may lead to a noticeable textural change in the rocks which have been studied. The main alterations involved in recrystallization are: (1) recrystallization of the calcitic skeletal grains to micrite, (2) recrystallization of the same skeletal debris to sparry calcite. Both of these types of alteration of fabric may be observed together in the skeletal grains, although they take place at different times during diagenesis.

(i) Recrystallization to micrite: Small benthic foraminifera and coralline algae in the Karaisali Limestone usually lose their translucency and appear to develop vague outlines when seen under the microscope, due to formation of micrite in the skeletons (Plates 93, 94, and 95). However they are often identifiable andpreserve the elements of the original skeletal fabric (Plates 93, 94 and 95). In a few cases, the skeletons are altered in such a way that it is difficult to know whether the alterations are due to micritization because of algal boring or recrystallization to micrite (Plates 96 and 97). The latter process differs from the micrit-

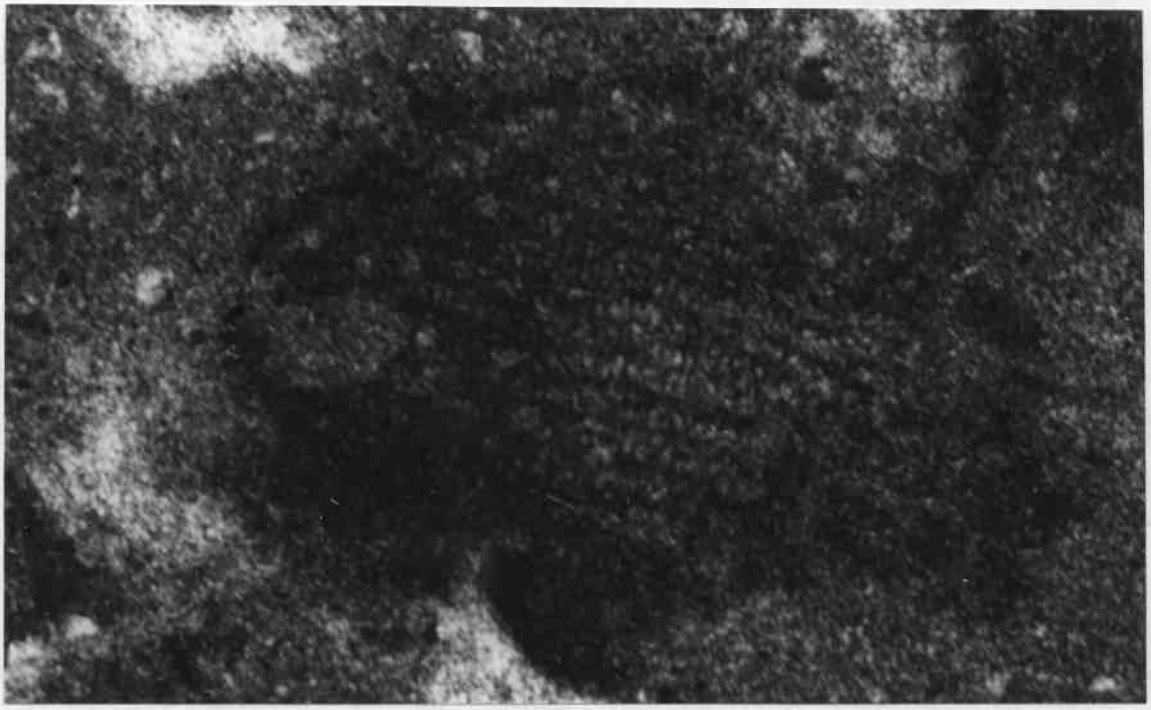


×80



×145

Plates (93) and (94): Recrystallization of miliolids. As a result of this process, the outer wall-layer of these organisms has been altered to produce micrite which has merged with the neomorphic matrix.



×112

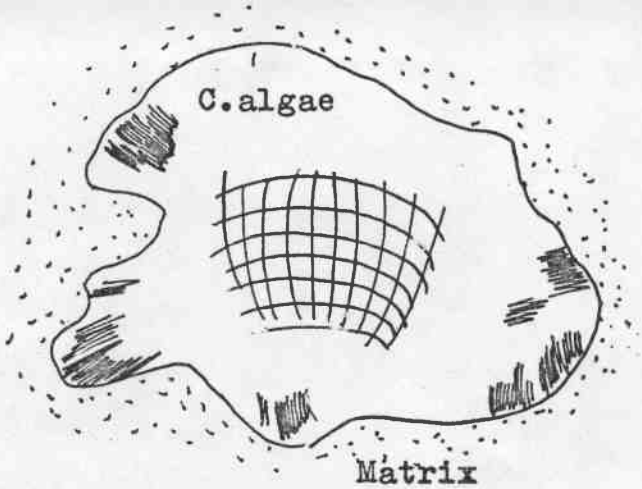
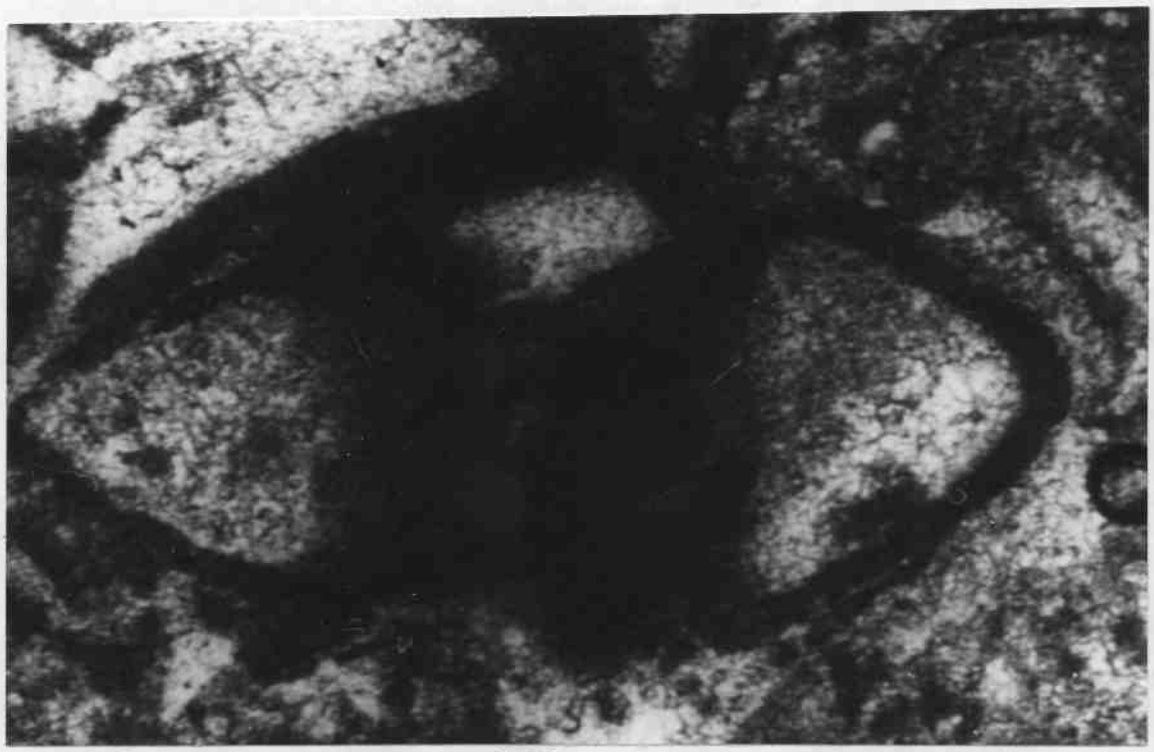
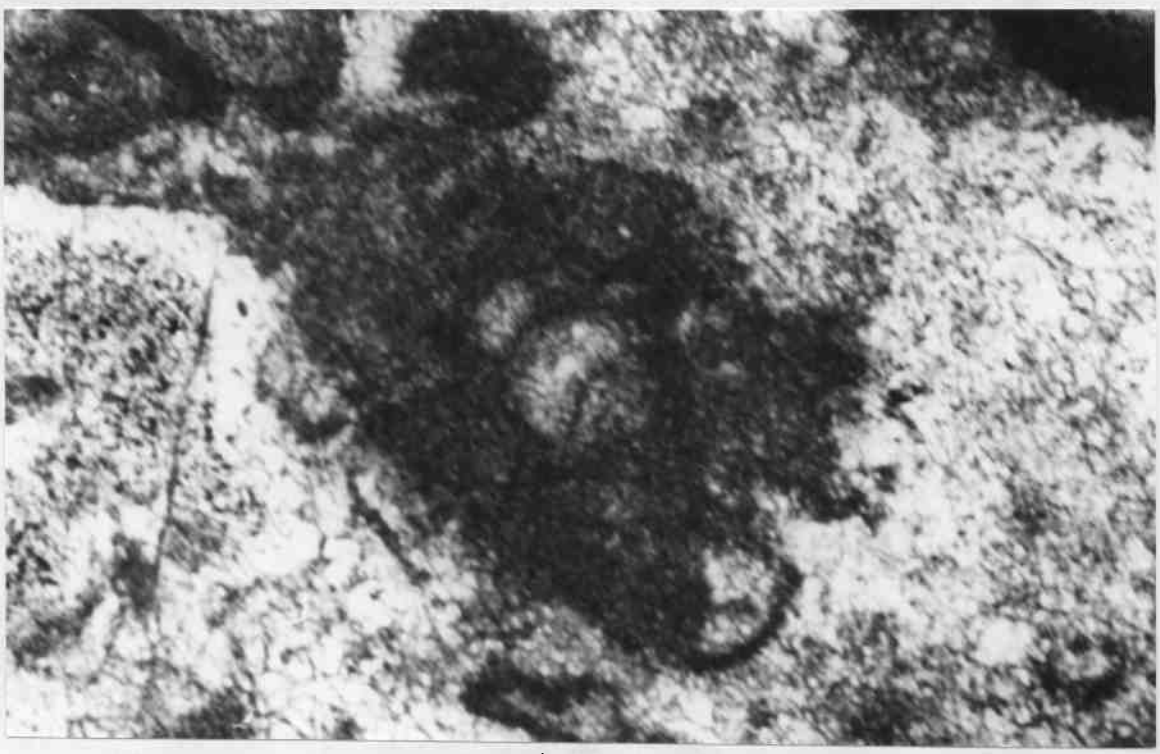


Plate (95): A recrystallized fragment of coralline algae: note that the cellular structure is still observable in the centre while the outer rim merges with the micritic matrix.



×145



×145

Plates (96) and (97): An advanced stage of recrystallization of a foraminifera. In these cases, the skeletal grains appear to have undergone algal micritization.

ization process of Bathurst (1966). According to his scheme, micrite in skeletal particles is formed by an alternation of algal boring and infilling of the borings by micrite cement. In contrast, the micritization under discussion is thought to be a process of piecemeal dissolution-reprecipitation occuring within submicroscopic pores developed in the high-magnesian calcite skeletons, probably, due to removal of Mg^{2+} from these grains or due to differential solution as a result of crystal imperfections (Alexandersson, 1972a). Studies of Recent and Pleistocene limestones reveal thatthe change of the high-magnesian calcite skeletons of coralline algae and foraminiferids to low-magnesian calcite in this way with or without noticeable change is a common phenomenon in these limestones (Friedman, 1964; Gross, 1964; Schlanger, 1964; Purdy, 1968; Gavish and Friedman, 1969; Bathurst, 1971). Similar types of micritization have often been described in the literature from many places, although they were given different names, such as "recrystallization" and "grain diminution" (Banner and Wood, 1964; Wolf, 1965; Colley and Davies, 1969).

Differentiation of the micrite which has been produced by recrystallization from the product of algal-fungal activity may be extremely difficult. However, the following criteria may prove useful:

1. Algal micritization:
   a) This appears to be more destructive than the recrystallization.
   b) Algal micritization involves a centripetal replacement of the grains (Plates 71 and 72), although in places as it will take place from any free surface it can occur throughout any chambered grain; however, it will, even in this case, be concentrated on the outer walls (Bathurst, 1966 and 1971).
   c) Algal micritization can occur in any grain without dependence on mineralogy.
   d) The micrite produced by algal-fungal activities is mostly aragonite which then, of course, changes to low-magnesian calcite

(Bathurst, 1966 and 1971, D.J. Shearman personal communication, 1977).

2. Recrystallization to micrite:

a) This process commonly involves complete or partial preservation of the original texture of the skeletons.

b) Recrystallization occurs mostly in originally high-magnesian calcite skeletons.

d) The micrite produced by recrystallization is not aragonite but low-magnesian calcite.

(ii) Recrystallization to sparry calcite: This process has been observed in coralline algae, small benthic foraminifera, molluscs, and some other unrecognised skeletal grains, all which have a high-magnesian calcite composition. This process is more destructive than the process of recrystallization to micrite and may certainly result in the alteration of whole skeletons of the above organisms, without leaving any noticable trace of the original texture. Particularly, small benthic foraminifera often have suffered severe destruction and have in most cases been gradually replaced by the clear calcite (Plates 98, 99, 100 and 101). When the replacement is completed, the only features which remain are some patchy clouds floating in the clear sparry calcite (Plate 102).

Coralline algae, though it is not common, are also wholly or partly replaced by sparry calcite with or without preservation of the original algal cellular structure (Plates 103, 104, 105 and 106). When the replacement process involves a complete destruction of the algal fabric, it is generally initiated at the centre of the algae with a slight increase in translucency. Then the centres of the individual grains become clearer as the sparry calcite replaces the algal structure (Plates 103, 104 and 105). During this replacement process some opaque materials which are presumably organic matter have been extracted from the algal-structure and pushed aside by the replacive calcite crystals. Because of its composition, this opaque material has not been included in the grow-

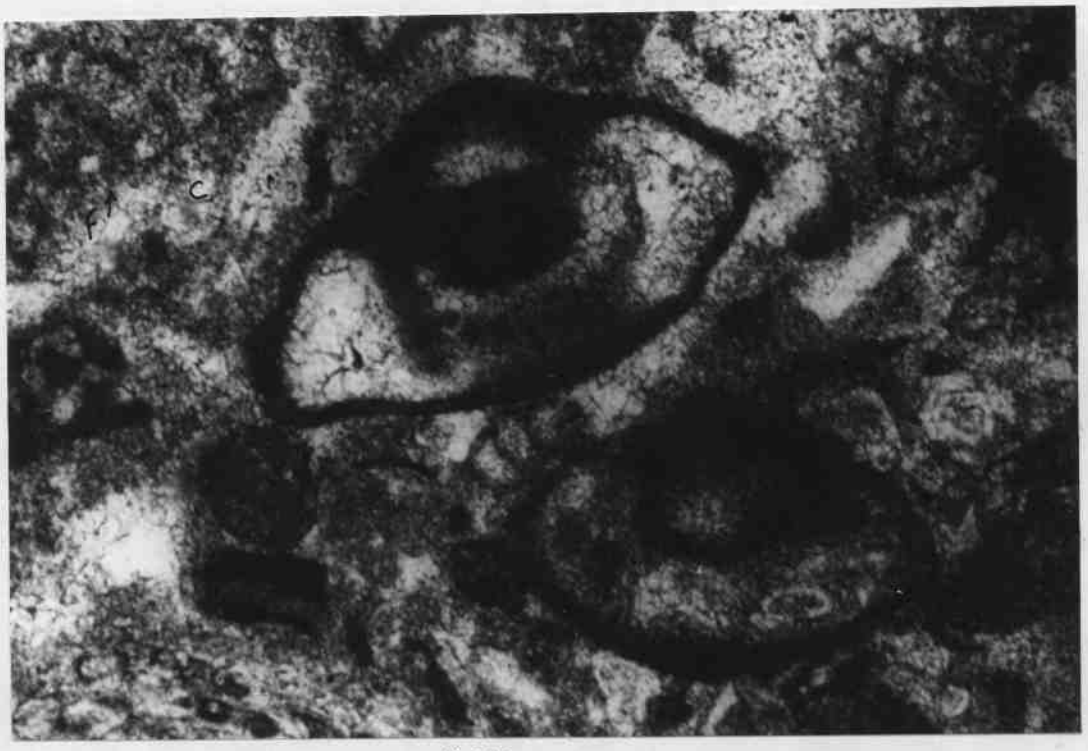


×120

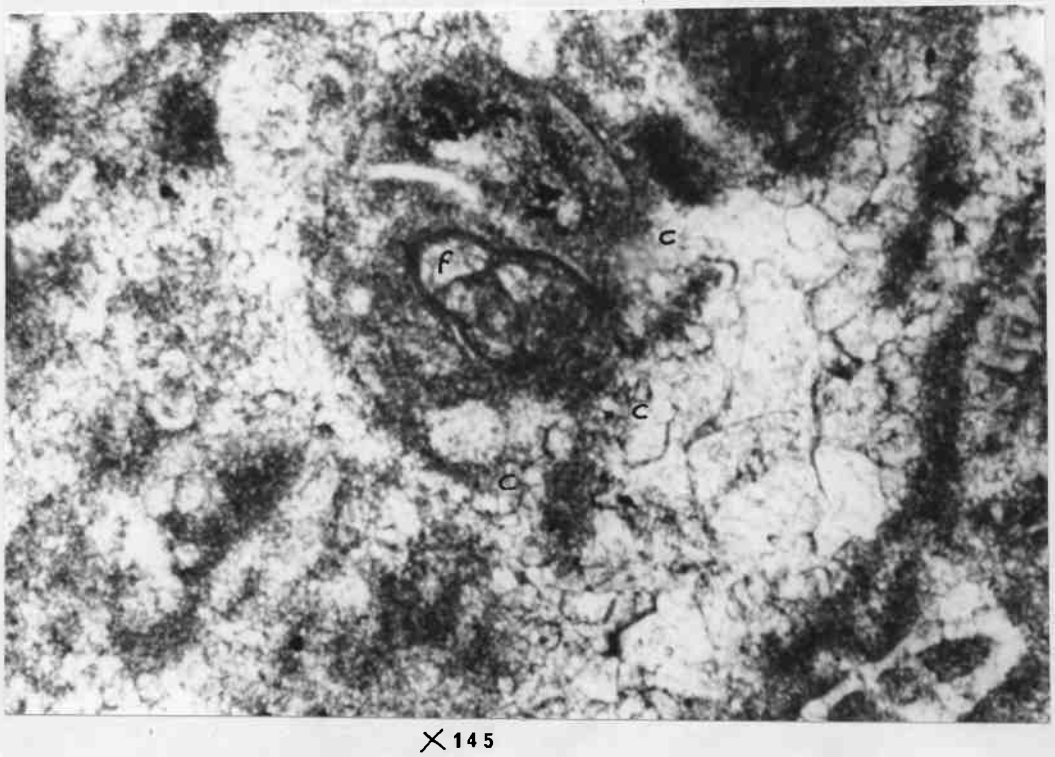


× 40

Plates (98) and (99): Partially or completely altered miliolid foraminifera. Notice the transection of these fossil skeletons by sparry calcite (f = foraminifera, c = caclite)

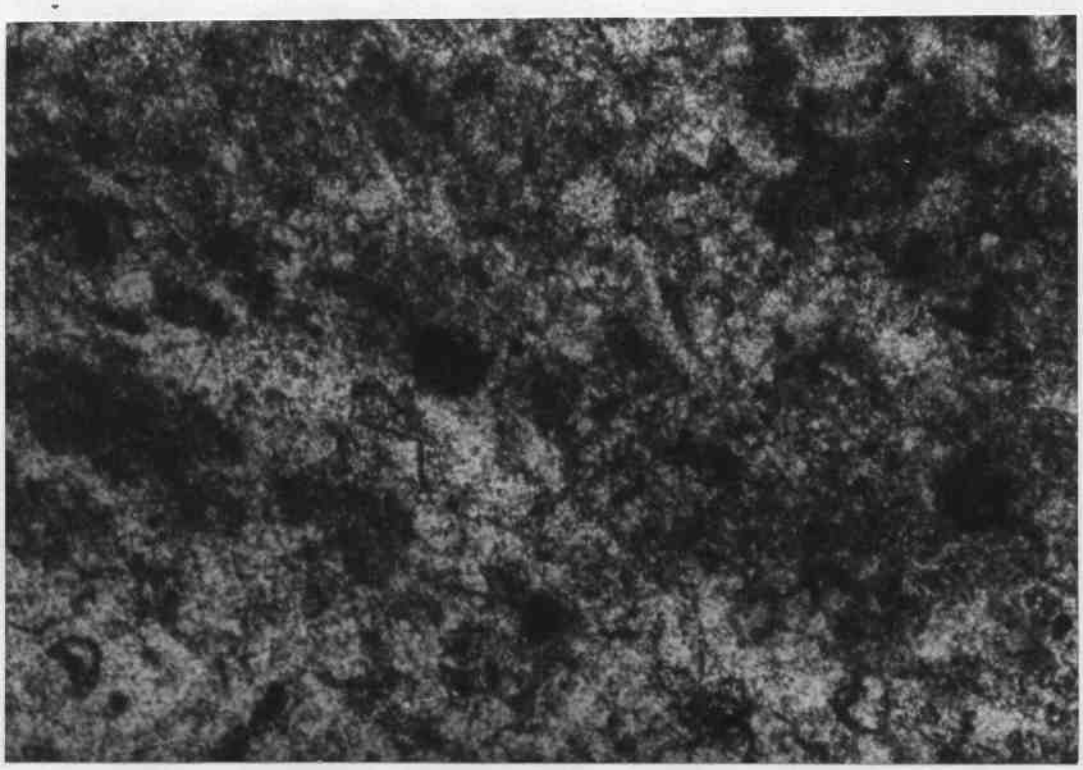


×112



×145

Plates (100) and (101): Small benthic foraminifera which have been destroyed and gradually been replaced by sparry calcite (f = foraminifera, c = calcite).



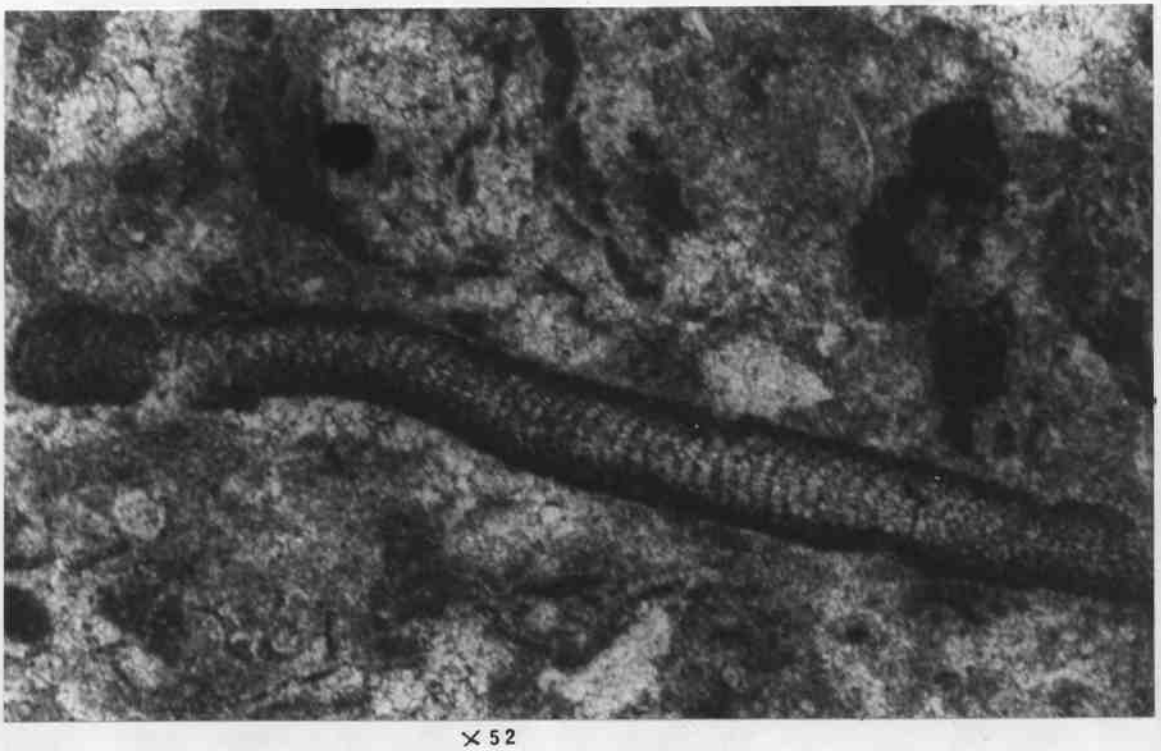
×80

Plate (102): A final stage of recrystallization: the replacement of the skeletal grains by sparry calcite has been completed, some patchy clouds are left behind floating in the clear sparry calcite.

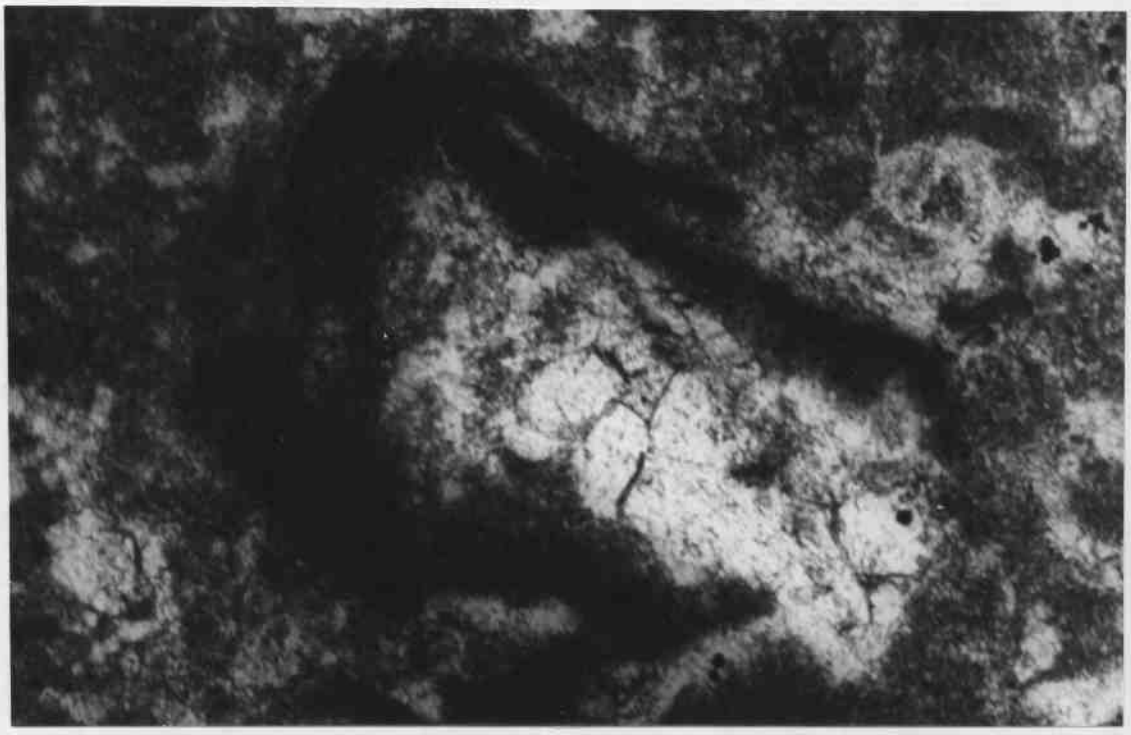


145

Plate (103): A coralline algal fragment (in the centre) which has been replaced by sparry calcite with the preservation of the original cellular structure.



×52



×145

Plate (104): Recrystallization of the coralline algae initiated at the centre of the algae with a slight increase in translucency.

Plate (105): The centre of the algae has become clearer as the sparry calcite has replaced the algal structure.

ing calcite crystals, but it has migrated towards the margins of the individual grains leaving behind a mosaic of equant crystals of calcite. Thus the replaced algal grains are surrounded by dark rims which preserve the original shapes of the fragments and which look like micrite envelopes that described by Bathurst (1966) (Plate 106). A very similar type of replacement of coralline algae by sparry calcite was described by Maxwell (1962) in the Heron Island reef.

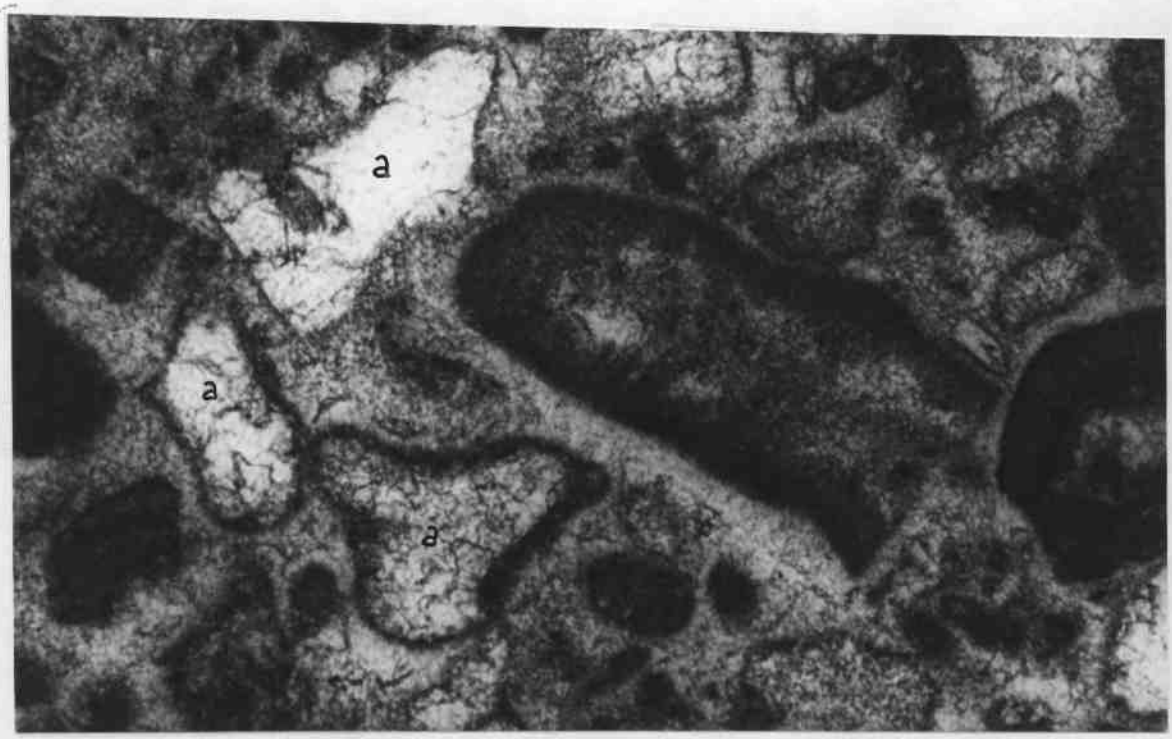
Partial or complete replacement of originally calcitic molluscan shells by coarse sparry calcite is rarely seen in the rocks which have been studied. The original fibrous structure of the molluscan walls is easily recognisable even when they are wholly replaced by the coarse calcite crystals (Plate 107).

Some other unknown fossil fragments (bryozoa?) sometimes display multiple generations of recrystallization and show a great complexity. They firstly became neomorphised to uniform microspar and this in turn is partially replaced by coarsely crystalline sparry calcite (Plate 108).

Recrystallization is of special interest here, because of its destructive effects on the depositional texture of the rocks which have been studied. It is obvious from the above descriptions that skeletal grains, particularly small benthic foraminifera, may be completely destroyed by recrystallization and contribute more micrite or sparry calcite to the rocks studied. As noted in the previous chapter, the depositional texture of the Small benthic foraminiferal-algal subfacies has been significantly altered in this way.

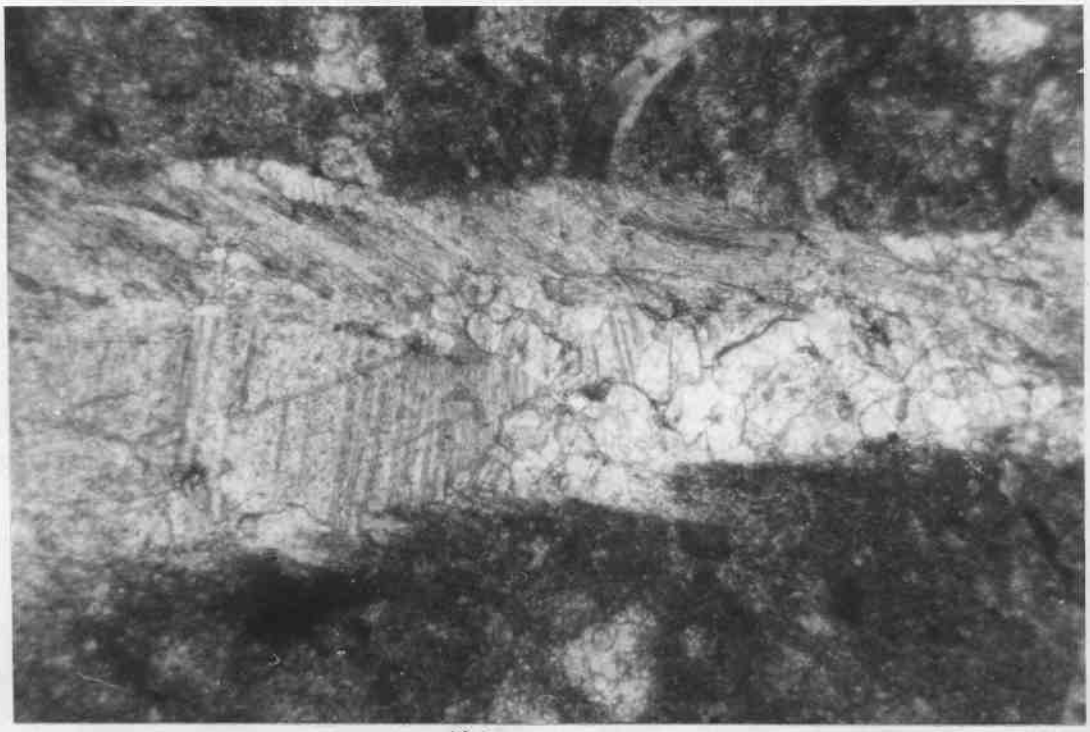
3.6. Replacement: Two replacement processes which occured during the diagenesis of the Karaisali Limestone are silicification and dolomitization. The effects of both of these diagenetic processes are rarely seen in the skeletal grains and in the matrix respectively (Plates 109, 110, and 111).

IV. 4. PHYSICAL PROCESSES: The Karaisali Limestone has suffered



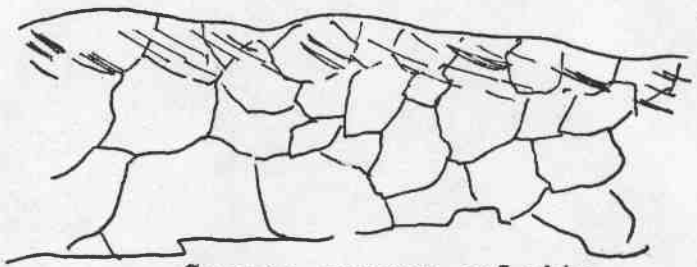
×80

Plate (106): Opaque material, presumably organic matter, extracted from the algal structure during the replacement of the coralline algal fragments by sparry calcite and pushed aside by the replacing calcite leading to formation of a dark rim around these grains similar to micrite envelope described by Bathurst (a = replaced coralline algae with dark outer rim).



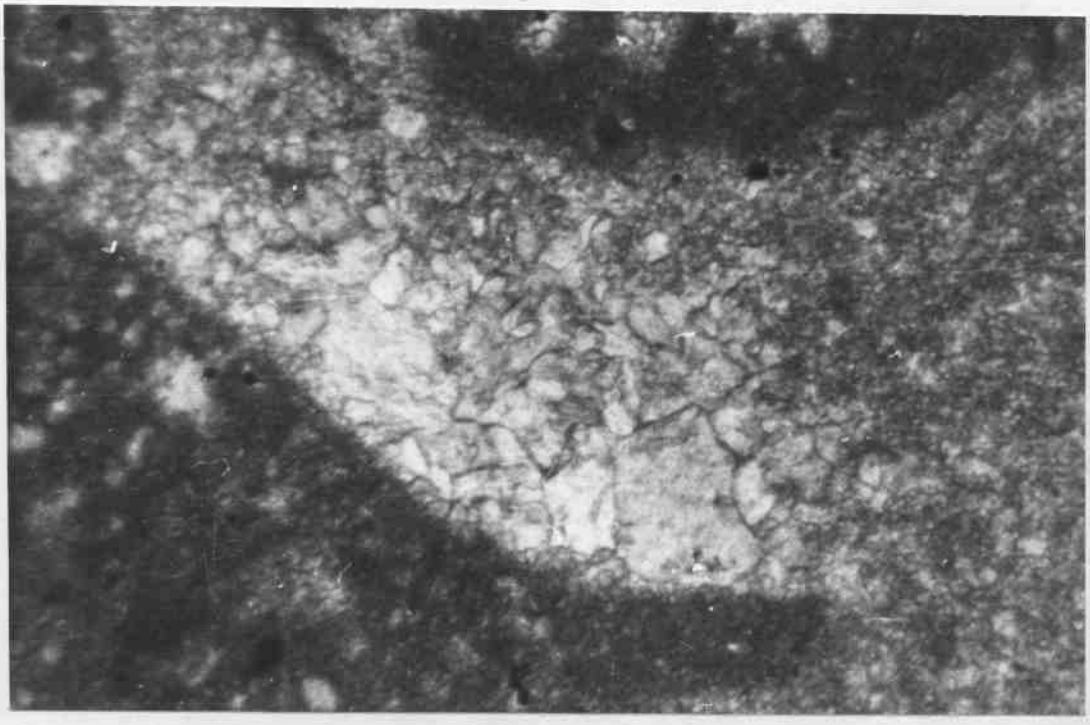
×60

Original fibrous structure



Coarse sparry calcite

Plate (107): Replacement of an originally molluscan shell with the development of coarse sparry calcite. Note the original fibrous structure of the wall of mollusc is still evident. This may have been originally an aragonitic or mixed aragonite-calcite fragment.



×80

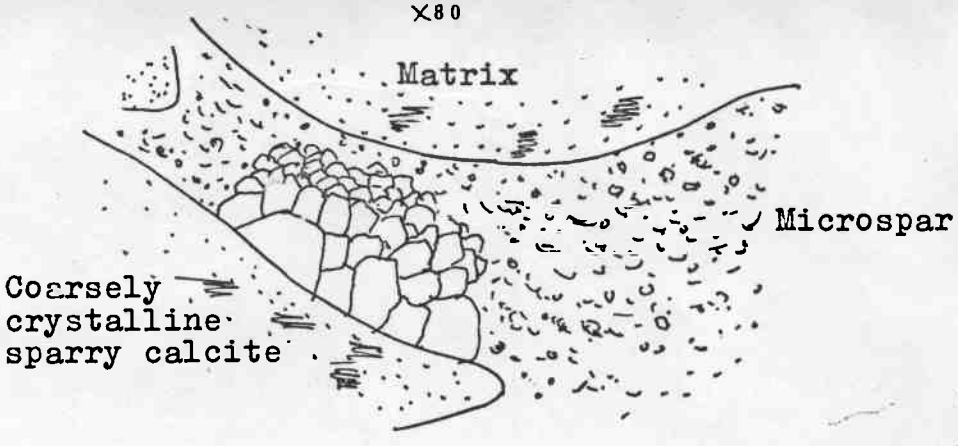
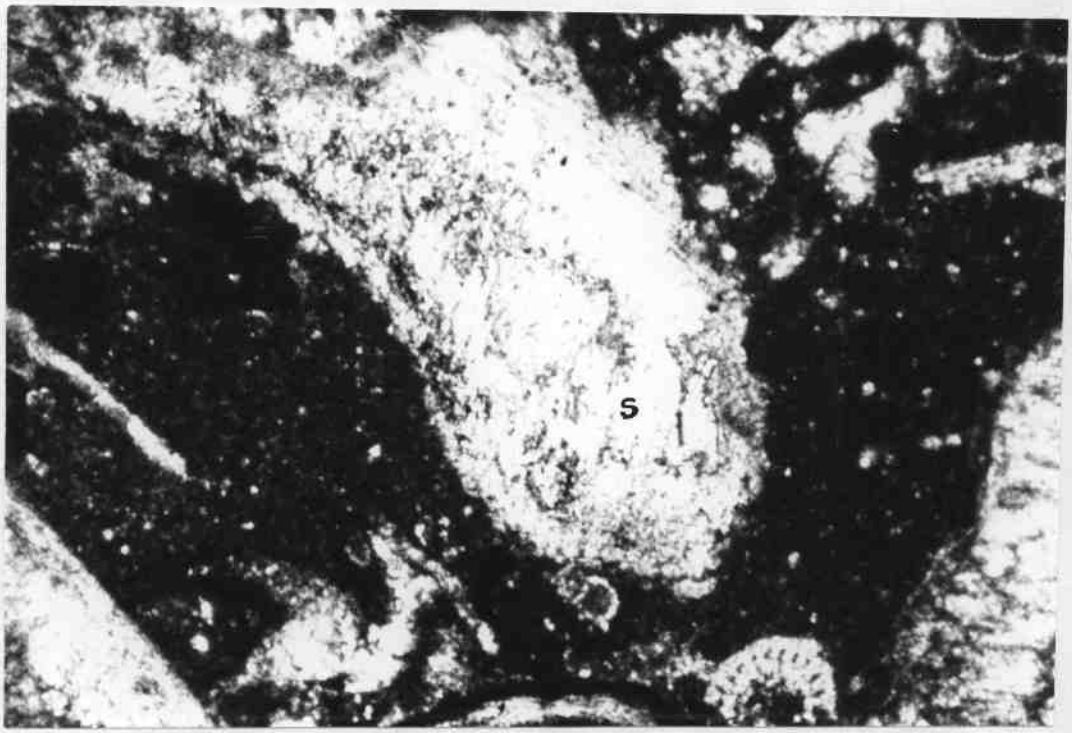
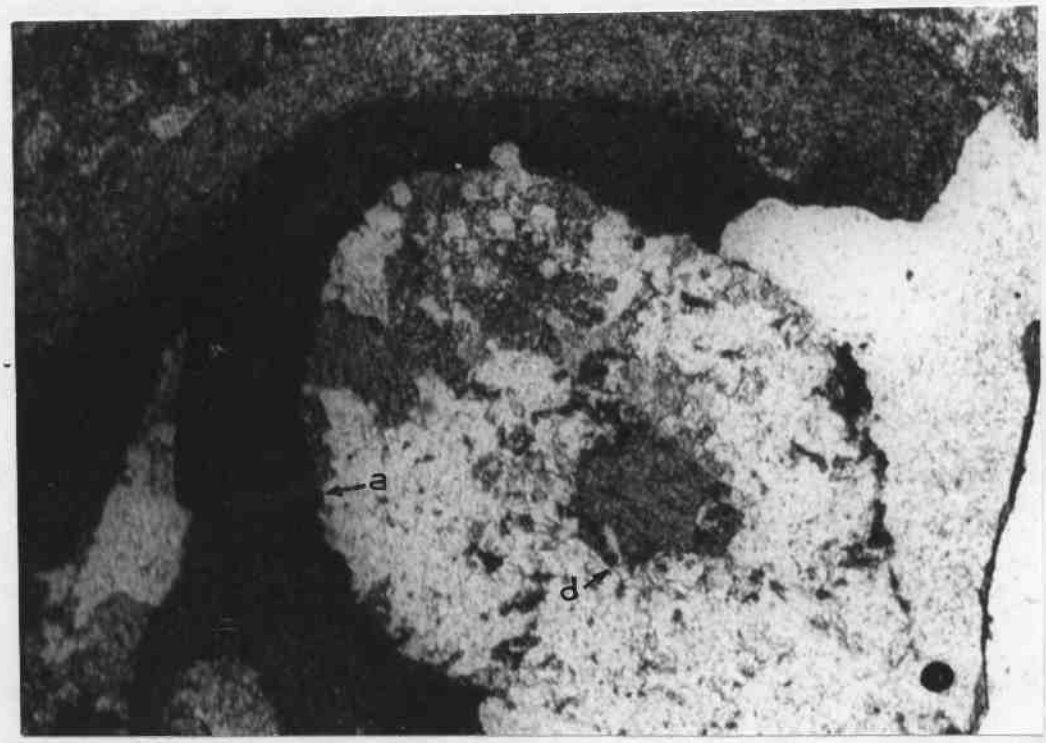


Plate (108): Multiple generations of replacement of an unknown skeletal grain by calcite. It firstly became neomorphised to a uniform microspar which is in turn recrystallized to coarsely crystalline sparry calcite.

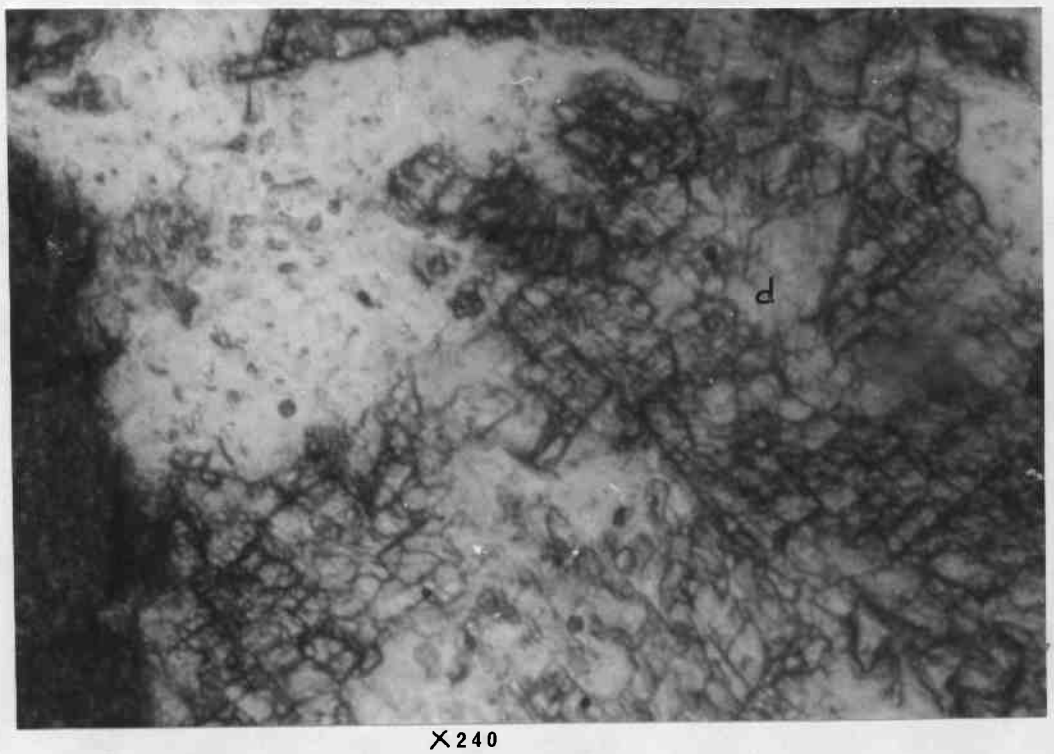


×58

Plate (109): Silicification of a molluscan skeleton (s = silica).



×80



×240

Plates (110) and (111): Dolomite within a coralline algal micro environment (a = coralline algae, f = encrusting foraminifera, d = dolomite).

Plate (111) is a close-up picture of Plate (110).

enormously from compaction as indicated by the abundance of fractures, stylolites, and pressure-solution contacts (Plates 112, 113, 114, 115, 116, 117, and 118).

4.1. Fractures: Petrographic examination shows that coralline algal fragments have suffered comparatively much more than the other components from fracturing and stylolitization. Most of the fractures are minute and filled by sparry calcite and do not cut across the matrix between the skeletons (Plates 112 and 113). From such appearance, the fractures of the coralline algae may indicate that they were either formed when there was no supporting matrix or the matrix was soft when fracturing occurred. However, it is difficult to prove either of these two possibilities, because the matrix of subfacies of the Karaisali Limestone in which this phenomenon was observed are neomorphic in origin and are now converted to sparry calcite. In addition, some similar fractures are found to extend from the algal grains into the recrystallized matrix. The possibility of some of these originating from recrystallization (Plate 113) further complicates the problem (Folk, 1959). However, from the detailed microscopic examination, it appears that mechanical forces are mostly responsible for these fractures. As well as these small fractures, which are mostly confined to the skeletal grains, some other comparatively larger fractures are often found cutting across the grains as well as the matrix. Some of these are short and discontinuous, but the others may show well developed continuous sets intersecting at different angles (Plates 114 and 115). The formers are thought to be compactional while the latters are probably of a tectonic origin.

Most of the fractures described above are probably due to continuous bank growth in the transgressive Miocene sea, which caused presure on the presiously deposited parts of the banks.

4.2. Stylolites and pressure-solution contacts: Well developed stylolites are commonin most of the subfacies of the Karaisali Limestone. They cut across both grains and matrix and are not merely pressure-solution contacts which are restricted to neighbouring grains. The sur-



×40

Plate (112): Fracturing of a grain of coralline algae (note that all fractures restricted to the coralline algae and do not cut across the matrix).



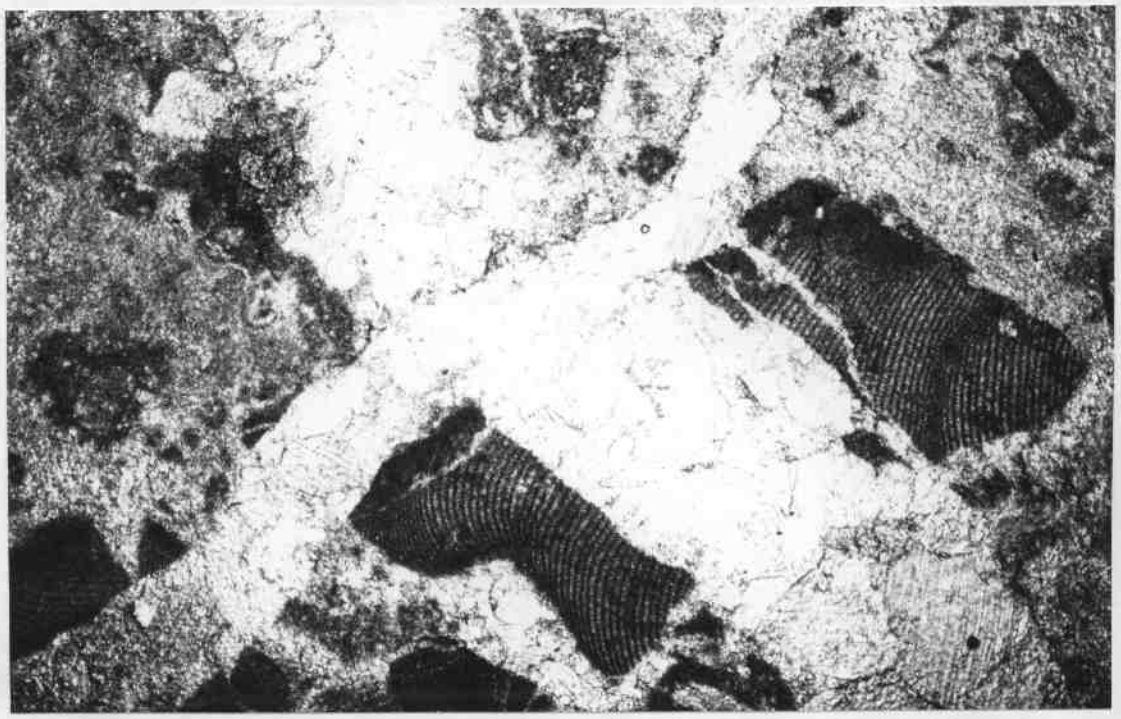
X 80



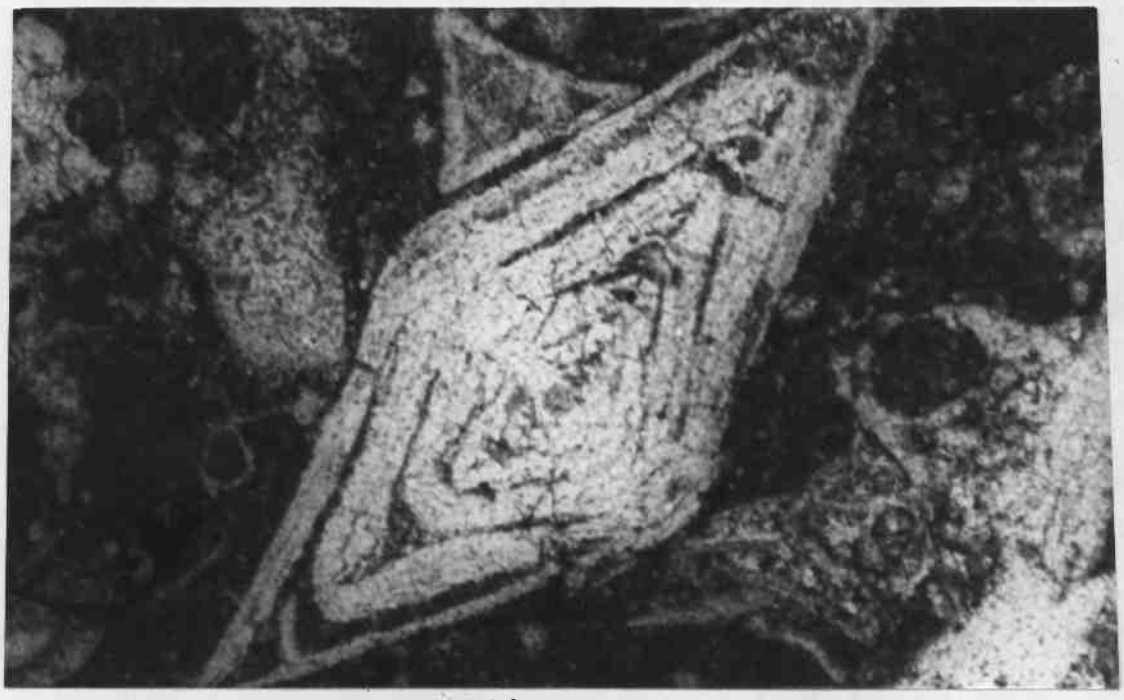
X 40

Plate (113): Fracturing of a fragment of coralline algae due to recrystallization.

Plate (114): Short discontinuous fractures cutting grains and the matrix.



X 40



X100

Plate (115): Well developed continuous tectonic fractures intersecting one another. Note that they are filled with coarsely crystalline sparry calcite.

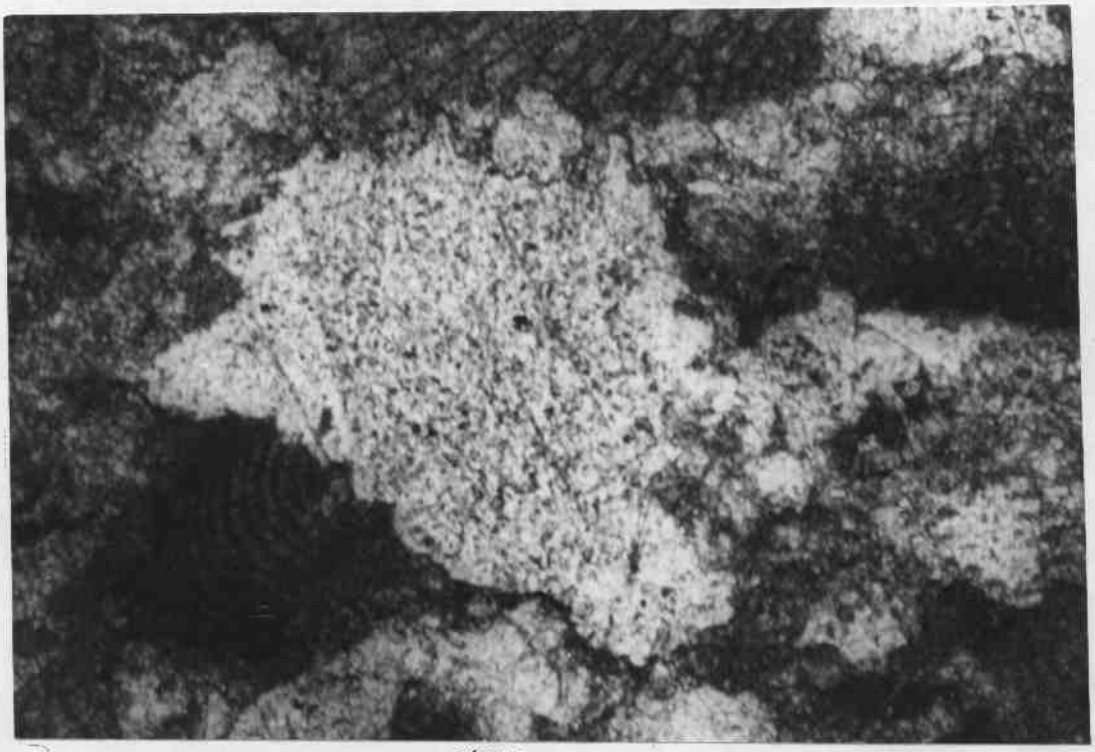
Plate (116): Fracturing of a benthonic foraminifera.

faces of the stylolites are generally parallel to the bedding and are marked by concentrations of some dark brown impurities, probably clay minerals. Stylolites are post-cementation in origin, because they transect as well as bound the echinodermal overgrowths in the Small benthic foraminiferal-algal packstone subfacies (Plate 117). However, considering the pressure-solution contacts and the fractures which have already been described, it could be that stylolites were formed in the sediments which were only lightly cemented.

Pressure solution contacts between adjacent grains are not as abundant as the stylolites and mostly occur in the rocks of the Large benthic foraminiferal-algal packstone subfacies (Plate 118). However, they may be locally common in the other subfacies of the Karaisali Limestone.

IV. 5. DIAGENETIC HISTORY OF THE KARAISALI LIMESTONE: On the basis of the previous description of the diagenetic changes, it is concluded that the major part of the diagenetic changes which have affected the Karaisali Limestone occurred in the marine environment. This conclusion is supported by the following:

1. The fabrics of the early diagenetic cements of the Karaisali Limestone appear to be the most common today in both submarine and intertidal environments (Shinn, 1969; Purser, 1969).
2. The fine grained clotted matrix is apparently common in submarine limestones (Bricker, 1971; Milliman, 1974).
3. Internal sediment resting on the first phase fringing crusts surrounding the grains is a common feature in both Holocene and ancient submarine cemented sediments (Ginsburg, et al., 1971; Zankl, 1971; Schmidt, 1971).
4. The absence of features such as birds' eye structures, stromatolites, evaporites, etc., all which are evidence of intertidal or supratidal sedimentation.
5. The Karaisali Limestone is always overlain by the Guvenc Shales which



×112

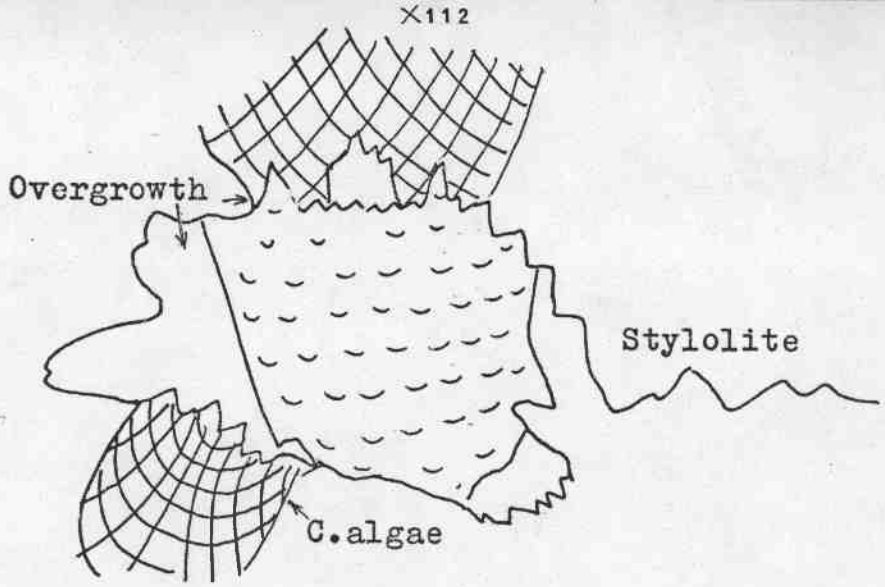


Plate (117): A stylolite bounds and transects the echinodermal overgrowth, thus indicating that it is post-cementation in origin.



×58

Plate (118): Pressure solution contacts between large benthonic foraminifera.

contain an open marine fauna, including abundant Globigerinidae. Despite the occurrence of some slight discontinuities in these sediments, there is no major erosional surface indicating subaerial exposure between the deposition of these two formations in the area which has been studied. The slight unconformable relationship of the Karaisali Limestone with the Guvenc Shales in some localities are submarine and depositional in origin (see the section of structural geology).

The Karaisali Limestone began as an accumulation of carbonate sediments which were composed of a mixture of coralline algae, foraminiferids, and echinodermal fragments (high-magnesian calcite), corals, molluscs, and Halimeda debris (aragonite), and some lithoclasts of pre-Miocene rocks (low-magnesian calcite).

During or soon after the deposition of these sediments, intense biological, chemical, and physical processes started to operate and resulted in their lithification. In the preceding sections, the diagenetic effects of these processes have been described in some detail. Here, an attempt has been made in order to place these diagenetic phenomena into a time sequence. The following order in diagenetic change has been suggested:

1. Biological erosion was one of the earliest diagenetic processes which affected the sediments. Continuous activities of boring and burrowing organisms caused breakdown of many skeletons to very small size. As a result of these activities, some micritic internal sediments were produced in addition to the primary matrix. The same processes probably resulted in the formation of the originally high-magnesian calcite aphanocrystalline to very finely crystalline equant-spar cement of the Karaisali Limestone (Alexandersson, 1969).
2. Closely following deposition and the biological comminution of the skeletal grains was the development of first-phase cements either as syntaxial overgrowths on the echinoderms or as fringing crusts on the other skeletal grains. The cementation occurred simultaneously

with, as well as after, the internal deposition of the micrite, while the communication with the sea-water still existed. The diagenetic internal sediment in contrast to the primarily deposited matrix may have two possible origins.

Firstly, due to biological breakdown and secondly by deposition during the rise of sea-level. The bored skeletal grains were weak and probably required only minor agitation to disintegrate. There can be little doubt that the internal micrites percolated in and together with any micrite which was deposited originally with the skeletal debris were distributed in the pores where the cementation was taking place. Consequently the cementation was restricted to the sheltered areas or to such places where the large skeletal grains produced "umbrella effects". The calcium carbonate necessary to provide the first phase cement was probably derived from the sea-water. Restriction of the echinodermal overgrowths to mostly the Small benthic foraminiferal-algal packstone subfacies, which often intertongues complexly and repeatedly with the Coral-algal packstone and boundstone subfacies throughout the outcrops, indicate that the cementation and internal deposition were early diagenetic phenomena in the Karaisali Limestone Formation.

3. Concurrently or soon after the cementation and the internal sedimentation, high-magnesian calcite skeletons probably lost their Mg^{2+} and consequently recrystallized to low-magnesian calcite micrite with or without the preservation of the original fabrics. However, they mostly retained their original fabrics after this process.

4. As noted before, when the coral-algal banks were being built, as the sea-level was gradually rising, the earlier parts of the banks became compacted and this caused fracturing of some of the skeletal grains. The brittle rigid skeletons of the coralline algae suffered far more than the thin-walled foraminifera and other skeletal grains. This was probably due to the presence of the first phase cements within

the chambers of these latter grains. This observation, again stresses the point that the cementation of the Karaisali Limestone probably occurred simultaneously with as well as after the deposition of this carbonate complex.

5. The change from aragonite to low-magnesian calcite probably took place during or followed the early compaction occuring in the continuously growing banks. This change sometimes resulted from the complete solution of the aragonitic skeletons. The micrite envelope and the first phase cements prevented the resulting moulds from collapsing until they were subsequently filled by a mosaic of calcite crystals. The original skeletal textures were not preserved when this process was completed. When the conversion of the aragonitic skeletons to the low-magnesian calcite took place as a result of a process of step-by-step dissolution and reprecipitation, their original textures have usually been preserved. Some calcium carbonate which might have been produced during these changes probably made a contribution to the cements of the Karaisali Limestone.

Closely following or during this stage, recrystallization and neomorphism were also active. They affected both the matrix and the skeletal grains; particularly the small benthic foraminifera and the coralline algae which had already recrystallized to the micrite. As a result of these changes, most of these grains and the primary or diagenetic matrix was altered as they were replaced by coarsely to finely crystalline mosaic of sparry calcite. Growth of the neomorphic spar was encouraged where the extra small grains were already in existence, either as primary skeletal detritus or as products of recrystallization or inversion. This perhaps explains why some of the skeletal grains display multiple generations of replacement by calcite.

The pelleted texture of the matrix in the rocks of most of of the subfacies of the Karaisali Limestone was probably produced at

this stage due to neomorphism, although, of course, some pellets may have been present originally in the matrix.

This interpretation is based on petrographic study and the sequence in which this texture developed is thought to have been as follows: the matrix was originally unsorted and composed mainly of aragonite, and high-magnesian calcite of biologic origin; growth of the sparry calcite was initiated at many points by dissolution and reprecipitation of aragonite on a micro-scale; once started this continued to invade and replace the whole matrix. During this process, the original high-magnesian carbonate mud and tiny skeletons were mostly untouched because they had already been converted to low-magnesian calcite. However, because of their fine grain size, they were sometimes partly or wholly replaced by sparry calcite. This interpretation easily explains the process of the cloudier and darker areas which are distributed irregularly in the calcite mosaic. Examiniations of these cloudy areas showed that they are mostly formed of disintegrated and recrystallized coralline algal debris. These algal residues in some cases preserve their original cellular structures, although they are commonly converted to a micritic mass. Besides the undigested coralline algal fragments, some inclusions of clay or organic matter were probably also excluded from the crystalline matrix and the skeletal grains to form these cloudy areas.

6. Continuous deposition in the Miocene sea caused burial of the Karaisali Limestone by the Guvenc Shales. When the overburden reached a critical thickness, pressure solution and stylolitization with final filling of the remain voids took place. These processes may have been accelerated as the banks became larger and adjusted to their surrounding.

7. Silicification was probably the first late-stage diagenetic feature. On the other hand the dolomitization may have been much earlier in the diagenetic history of the Karaisali Limestone.

CHAPTER V. THE GUVENC SHALES:

V.1. LITHOLOGY AND FIELD RELATIONS: This formation is predominantly olive grey (5 Y 4/1), silty, calcareous, and locally finely carbonaceous shale with an abundant microfauna, such as Globigerinidae, and pteropods. It usually includes some very thin beds of sandstone and siltstone which occur in varying proportions throughout the area (Plate 119). These sandstone and siltstone are composed, in decreasing order of abundance, mainly of: quartz, feldspars, and rock fragments; they are calcareous feldspathic arenites and/ or Calcareous lithic arenites (Williams, et al, 1954) and appear to be very similar to the sandstones of the Cingoz Formation (see chapter VI). Because the weathering of the shale often produces a thin layer, a few centimetre or more in thickness, of loose fluffy shale particles covering the exposures, it is very difficult to examine its bedding properties in the field. However, where there can be seen, it appears to be massive or thickly bedded.

Under the microscope only the larger grain can be identified with any certainty and these are mainly of coarse silt size. They are composed generally of quartz with minor amount of feldspar, biotite and chert. They appear to be angular, equant, and unsorted.

Some samples of the Guvenc Shales were studied by X-ray diffraction to identify the mineralogical composition of the finer components, particularly of the clay minerals. Ten selected shale samples were studied. The conclusions resulting from these studies may be summarized as follows:

1. All the samples contain the same minerals and these show very little variations in their abundance. The principal minerals, in a decreasing order of abundance, are: quartz, clay minerals, calcite, and feldspar with some minor amounts of dolomite.
2. Five clay minerals have been found in all of the samples. These, in decreasing order of abundance, are: smectite, illite, kaolinite, chlorite, and chlorite-smectite regular mixed layer clays.

The carbonate content of the Guvenc Shales often ranges



Plate (119): Guvenc Shales including very thin beds of sandstone and siltstone, north of Karaisali.

from 20 to 30 percent in most of the samples which have been studied, although it may be as high as 49 percent in some samples which were taken from where the shales pass into the Karaisali Limestone. The carbonate content of the Guvenc Shales sharply decreases in the northeast of the area where they are associated with the other marine clastics, eg.; Gildirli Formation and Cingoz Formation. It is of interest to note that the faunal content of the Guvenc Shales appears to show a very similar distribution pattern to that of the carbonate content: where faunal remains are abundant the carbonate content is high and vice-versa.

In the northeastern part of the area, the Guvenc Shales are carbonaceous and contain some microfossils, such as molluscs, and foraminifera with only a few globigerinid foraminifera. In the south and southeast of the area where the Karaisali limestone banks have been extensively developed, the shales contain foraminifera with abundant tests of globigerinids.

The stratigraphic relations of the Guvenc Shales to the adjacent deposits have already been briefly covered in the discussion of the Gildirli and Karaisali Formations. There, it was pointed out that lateral and vertical transitions are the characteristic feature of most of the contacts between these units. The contacts of the Guvenc Shales with the Gildirli and the Cingoz Formations are the best exposed and they can be easily mapped in the northeastern part of the area (Map 1). The contact between the Guvenc Shales and the Karaisali Limestone is very variable: in the southwest these two formations are conformable, elsewhere a lateral and vertical transition southward from the Karaisali Limestone into the Guvenc Shales can be seen particularly in the Yoruk Dere, near Bucak; however, to the northeast, the contact between these two formations occurs along the foot of high scarps and seems to be disconformable but as noted before in the section dealing with the structural geology of the area, this disconformity is depositional in origin

and due to sedimentary onlap. The strata of the Guvenc Shales in the northeast are probably not of the same age as those which are seen in the southwest but lie stratigraphically above them (for more information on this point, see the section dealing with the scarps and collapse structures in the structural geology of the area).

V. 2. THICKNESS, AREAL DISTRIBUTION, AND TYPICAL OCCURRENCES: Along the southern margin of the limestone highlands and in the north of Karaisali, the Guvenc Shales are only a few metres thick, but they thicken southward to over 2000 metres (Schmidt, 1961).

The Guvenc Shales crop out widely and typically in most parts of the area which has been studied, particularly in the south of the limestone highlands of the Karaisali Formation (Map 1).

V. 3. SOURCE AREA AND ENVIRONMENT OF DEPOSITION: The Guvenc Shales may have been derived from various sources. The mineral composition of the silt size materials of the shales and of the interbedded sandstones indicate that they were probably derived from the pre-Miocene rocks (which include sedimentary, igneous, and metamorphic rocks) of the Taurus Mountains. If the clay minerals faithfully reflect the source rocks and have not undergone too much diagenetic alterations, then it may be suggested that the clay minerals in the Guvenc Shales probably originated from the volcanic rocks of the Taurus Mountains, as suggested by the types of the clay assemblages. However, this is only a possible source for the clay minerals and cannot be conclusively shown from the available evidence. In addition, calcium carbonate was added to the sediments either by direct precipitation or due to the deposition of tests of the organisms; also, some of the carbonate may be detrital having been derived by erosion of the Palaeozoic and the Cretaceous limestones.

Both the stratigraphic and geographic position of the Guvenc Shales together with their lithological character and their faunal content suggest that they were deposited mainly as marine basinal

muds when the Miocene sea had advanced northward across the area which has been studied. Elsewhere, however, the Guvenc Shales show shallow marine characteristics, with abundant molluscs and carbonaceous materials, where they pass into the marginal clastics of the Miocene sea, eg., The Gildirli and the Cingoz Formations.

V.4. AGE OF THE GUVENC FORMATION: Fossils found in this formation indicate a Helvetian (Middle Miocene) age (Ternek, 1953, and 1957; Stucker, 1960; Schmidt, 1961; Loney and Cain, 1971; Ozer etal., 1974; Bizon etal., 1974). However, as noted before, in some partsof the area which has been studied, the Guvenc Shales interfinger with the Karaisali Limestone which contains fossils of Burdigalian age. Thus the Guvenc Shales may also in part be of Burdigalian age.

CHAPTER VI. THE CINGOZ FORMATION

VI. 1. GENERAL: The Cingoz Formation is named after a village which is located outside and to the northeast of the area which has been studied. It consists of a thick sequence of conglomeratic sandstone (Ayva Member) and a series of alternating sandstones and shales (Topalli Member). These members interfinger with each other (Cross-section A-A', Measured sections N_{z9}, Er). They are best exposed in the northeastern part of the area where they were mapped and examined in detail (Map 1).

VI. 2. THE AYVA MEMBER:

2.1. Lithology and field relations: The Ayva Member is mainly yellowish grey (5 Y 7/2), granule to medium grained, and moderately well sorted conglomeratic sandstone. The sand grains are generally angular to subrounded. In decreasing order of abundance, they consist mainly of: quartz, feldspar, and rock fragments, and are cemented by sparry calcite (Plate 122). The conglomeratic units in this member usually includes clasts of carbonate mudstone, recrystallized limestone, and some igneous rocks; most of which have been derived from the pre-Miocene formations exposed in the area. Clasts are commonly rounded and mostly appear to be of pebble size, although they may be as large as boulders (70 x 140 centimetres) at some localities.

The sandstone is usually well indurated and has moderately well developed bedding with individual strata 15 to 30 centimetres in thickness (Plate 120). Medium to large scale tabular planar cross-stratification (Plate 121) and occasional local slump structures are seen in this lithology throughout the area. The conglomerate generally forms lenses or beds a few centimetres to several tens of centimetres in thickness and are sometimes cross-stratified.

The Ayva Member loses its conglomeratic character within a short distance as traced from north to south and instead gradually becomes a granule to medium grained calcareous feldspathic arenite and/or calcareous lithic arenit as it passes laterally and vertically into the Topalli Member of the Cingoz Formation. Because of the interfingering of the Cingoz Formation with the Guvenc Shales, the Ayva Member both overlies and underlies the Guvenc Shales. However, it is always found overlying these shales in the area which has been mapped due to removal of the overlying shale cover by erosion (plate 120). The



Plate (120): Moderately well - bedded Ayva Member overlying Guvenc Shales South of Gildirli.



Plate (120): Moderately well - bedded Ayva Member overlying Guvenc Shales South of Gildirli.



Plate (121): Tabular planar cross-bedding in the Ayva Member.

Ayva Member conformably overlies the Kabalak Tepe Member of the Gildirli Formation in the northeastern part of the area, but its contact with the Cakmak Member of the same formation appears to be erosional at some places, eg.; in the north of Nergizlik and Cakmak Mahallesi (Map 1).

As noted before in the chapter dealing with the general geology of the area, the relationship and the nature of the contact of the Cingoz Formation with the Karaisali Formation have not been observed in the area which has been mapped, except at one locality in the vicinity of the Cakmak Mahallesi where some isolated block-like apparent "in situ" remnants of this limestone formation were found sitting on top of the Ayva Member.

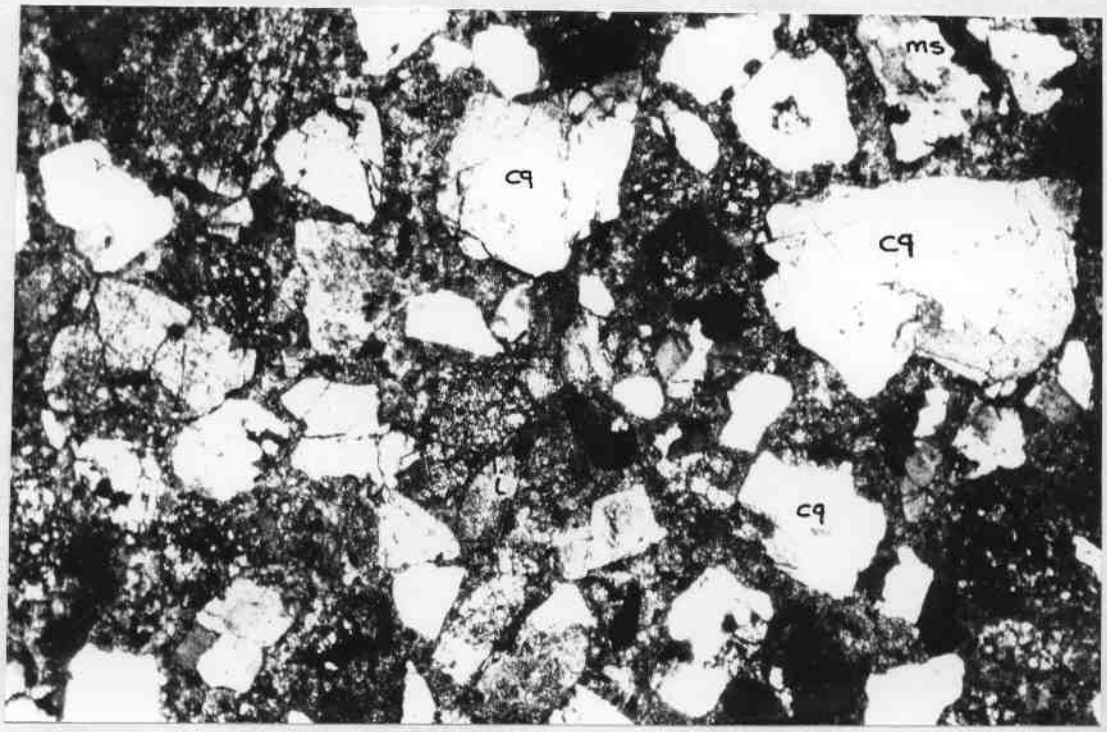
2.2. Thickness, areal distribution and typical occurrences: Because of intertonguing with the Topalli Member, the thickness of the Ayva Member changes abruptly from north to south. This is best seen near Nergizlik and Emirler mahallesi where the Ayva Member pinches out southward as it passes into the Topalli Member (Map 1, Cross-section A-A', Measured sections N_{z9} and Er). The maximum thickness of the Ayva Member measured was about 200 metres in the section of Cakmak II (Ck_2), near Cakmak mahallesi (Map 1, Measured section Ck_2).

The Ayva Member is best exposed along the stream of Kocadere, near Nergizlik and Cakmak Mahallesi (Map 1). Because it is mostly hard and well cemented, compared with the associated clastics, it usually occurs as bold outcrops forming high hills, benches or steep slopes. The most typical occurrence of this member is seen in the east of Cakmak where the section of Cakmak II (Ck_2) was taken (Map 1, Measured section Ck_2).

2.3. Microscopic description (Plate 122):

(i) Framework grains (in decreasing order of abundance):

A. Quartz: The dominant mineral in the Ayva Member is angular to subrounded quartz, occurring as simple and composite grains. Most of the simple grains show straight or slightly undulose extinction and may have mineral inclusions. The composite grains show undulose extinction and often contain mineral inclusions.



X17

Plate (122): General texture of the conglomaritic sandstone of the Ayva Member (Cq = Composite quartz grains, Ms = Metamporphic schist, i = igneous rock fragments (volcanics?)).

B. Feldspars: These are common and include both angular to rounded grains of K-feldspar and plagioclase, although the former is more abundant. The composition of the grains cannot always be determined, but the K-feldspars mostly appear to be orthoclase, microcline and perthite while the plagioclase is usually albite and often show zoning.

C. Rock fragments: These are generally rounded and coarser than the accompanying grains of quartz and feldspar. The major types of rock fragments in the Ayva Member, in decreasing order of abundance are: (1) plutonic rock fragments which are represented only by granite, (2) Metamorphic rock fragments, such as quartzite, phyllite, quartz-albite-chlorite schist and some other metamorphic schist, (3) volcanic, that is, fragments of andesite and recrystallized glasses, (4) sedimentary rock fragments which are of lesser importance but cherts and recrystallized limestones are of local importance.

D. Accessory minerals and fossils: Biotite, muscovite, chlorite, epidote are the main accessary minerals in the Ayva Member.

Fragments of coralline algae, foraminifera, molluscs, and echinoderms (which show overgrowths and seem fairly well preserved) are present in some of the thin sections which have been studied.

(ii) General texture: Moderately well sorted, angular to subrounded and mostly very coarse grains of quartz, feldspars, and rock fragments are closely packed and cemented by fine to coarsely crystalline clear sparry calcite with lesser amounts of micas, chlorite, and epidote. Grain boundaries between the major constituents and the cement are mostly well marked.

(iii) Porosity: This is poor as all the primary cavities and pore spaces are filled by calcite cement.

(iv) Petrographic name: Calcareous feldspathic arenite and/or calcareous lithic arenite (Williams, et al., 1954).

VI. 3. THE TOPALLI MEMBER:

3.1. Lithology and field relations: The Topalli Member consists of interbedded sandstone and shale in about equal proportions (Plate 123). The sandstone is generally light olive grey (5 Y 6/1), hard, very fine to coarse grained and moderately well sorted. It is composed mainly of quartz, feldspar, rock fragments, and some mafic minerals. The sand grains range from angular to rounded, although they are mainly sub-rounded.

The thickness of beds of the sandstone is variable, being generally measurable in centimetres (Plates 123, 124, and 125), though beds over 15 centimetres may locally be common. Internally, these sand beds sometimes show grading (Fig 21) and usually have erosional bases with poorly developed bottom structures including: groove casts, tool marks, scour and fill, and a few flute casts (Plate 124). The top of the individual beds are generally flat and well defined (Plate 125). However, some outcrops show very steep bedding which is thought to be associated with slump features, eg., Emirler (Plates 126 and 127, Map 1).

The interbedded shale is generally greenish grey (5G Y 6/1), fissile, and soft to poorly indurated. It is silty, calcareous, locally carbonaceous, and contains abundant quartz, calcite, feldspar, and clay minerals. Examination of the clay minerals of the shale by X-ray diffraction showed that smectite, illite, kaolinite, chlorite, and some chlorite-smectite regular mixed layer are the main clay minerals present. This shale shows a great similarity in composition to the Guvenc Shales and is, as discussed elsewhere, thought by the author to be stratigraphically equivalent of the latter (Map 1).

The stratigraphic position of the Topalli Member has been referred to in the discussion of the Ayva Member. It was pointed out that the Ayva Member passes laterally into the Guvenc Shales via the Topalli Member. Because of its stratigraphic position the Topalli Member may be considered to be the finer-grained lateral equivalent of

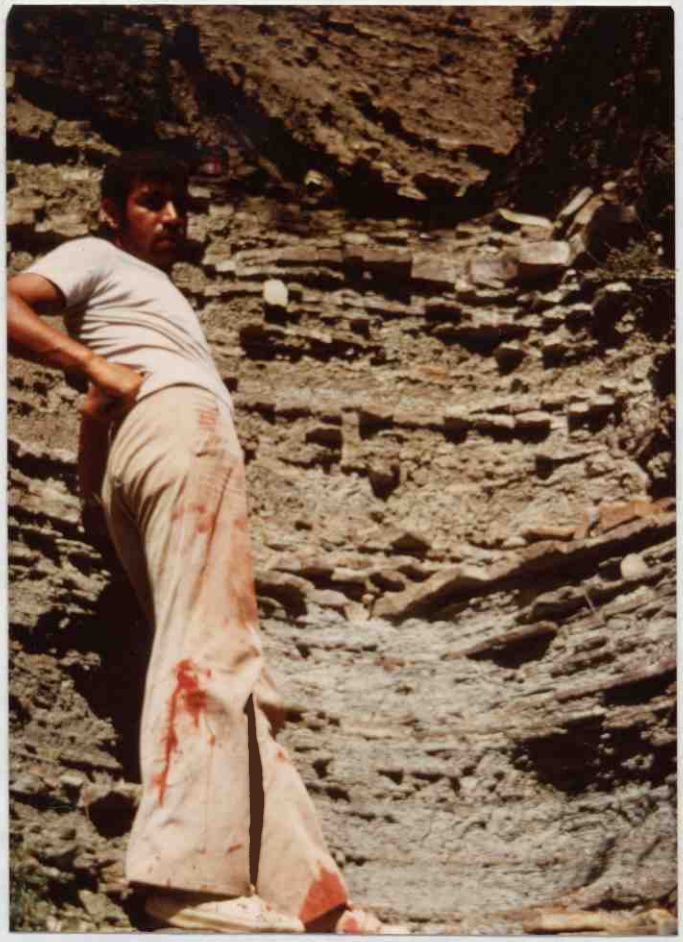
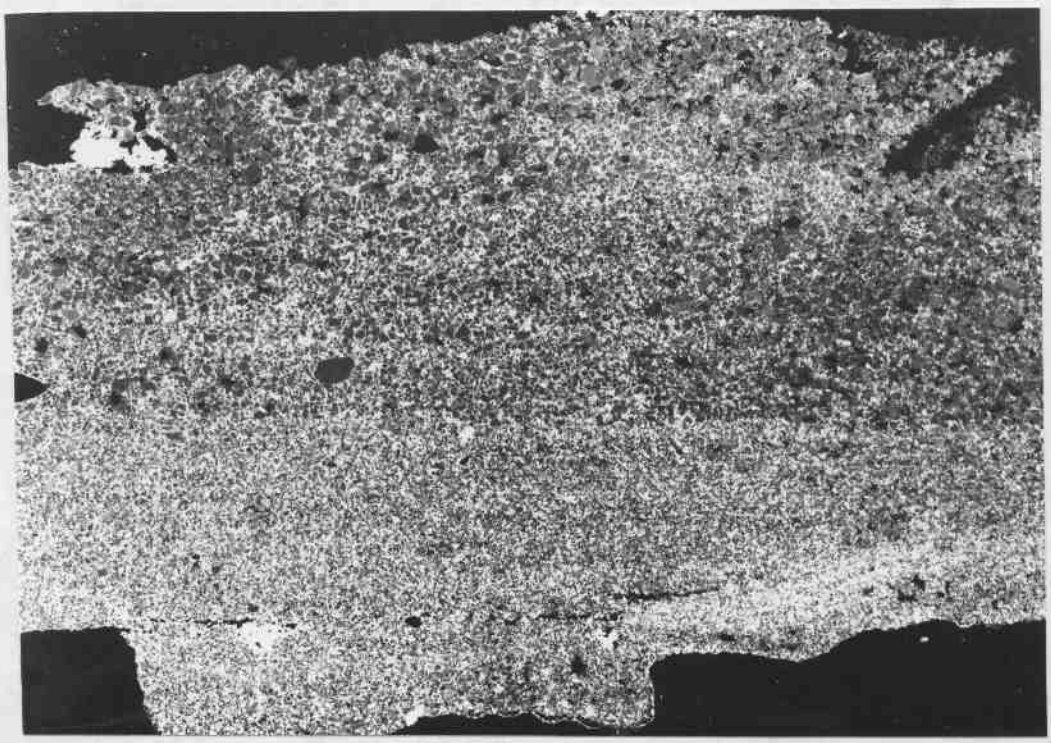




Plate (123): A typical exposure of the Topalli Member in Nergizlik

Plate (124): A sandstone bed in the Topalli Member with a clearly developed erosional base (groove casts).



Fig(21): An example of graded bedding in Topalli Member.

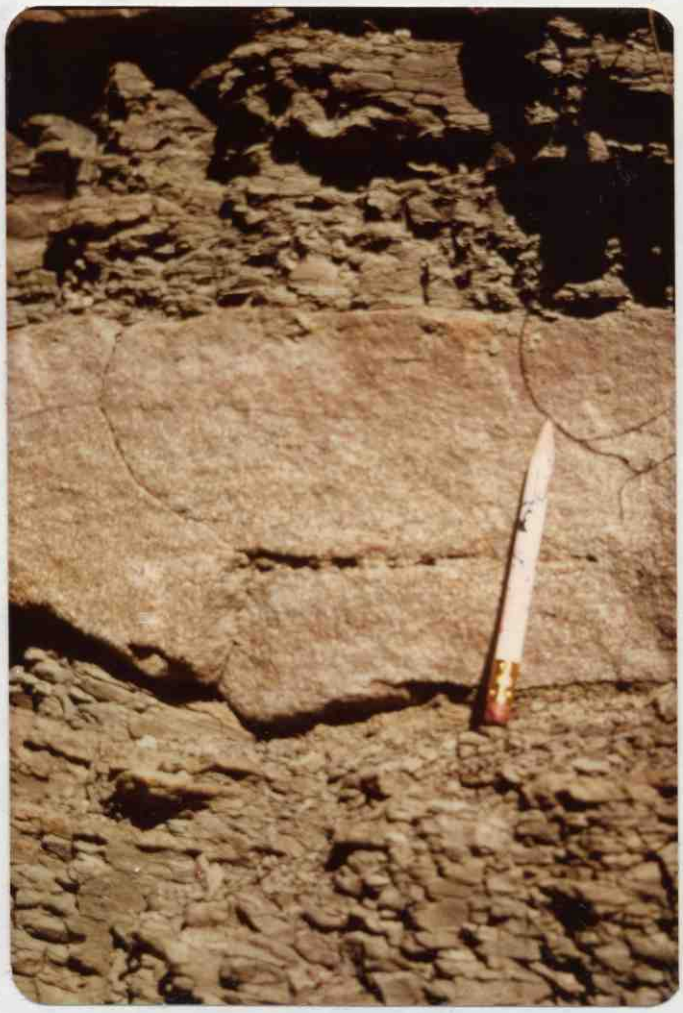


Plate (125): A sandstone bed in the Topalli Member. The top of the bed is flat while the bottom shows an erosional contact with the underlying shale.





Plate (126) and (127): Steeply dipping slump structures in the Topalli Member in Emirler.

the Ayva Member (Map 1, Cross-section A-A'). The Topalli Member eventually dies out as it is traced basinward into the Guvenc Shales (Cross-section A-A').

3.2. Thickness, areal distribution, and typical occurrences: The maximum thickness of the Topalli Member in the area is about 50 metres but it becomes thinner as it passes into the Guvenc Shales. It is well exposed in the area between Emirler and Kelkoy Mahallesi, northeast of Karaisali (Map 1). The typical occurrence of the Topalli Member is seen in Nergizlik where its type section was taken (Map 1, Measured section Nz_2).

3.3. Microscopic description of the sandstones (Plate 128).

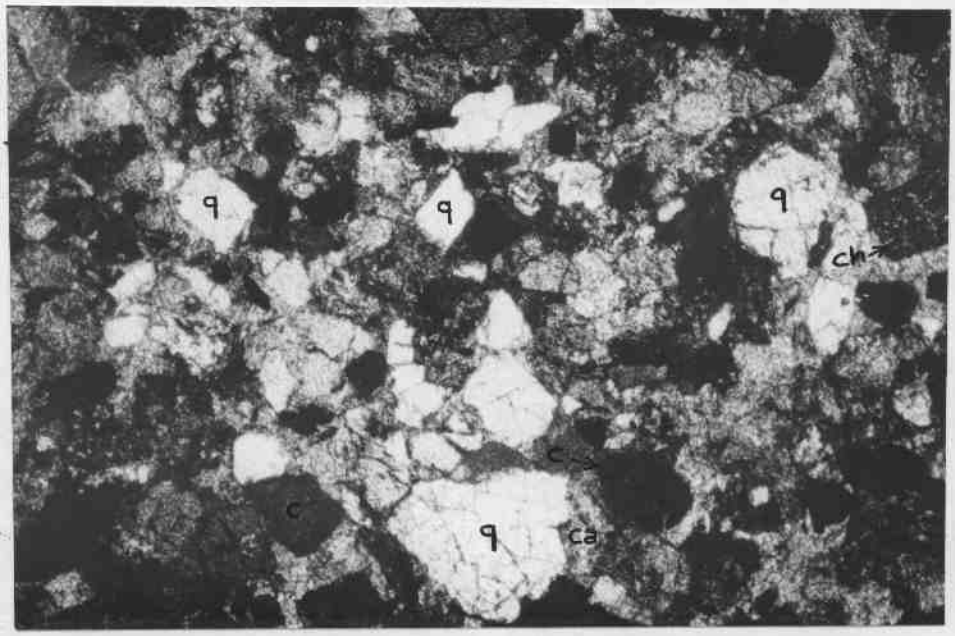
(i) Framework grains (in decreasing order of abundance):

A. Quartz: Detrital quartz grains are usually angular to subrounded, simple to composite in nature and show straight or undulose extinction depending on the nature of the grains: simple grains generally show straight extinction while the composite grains show undulose extinction.

B. Feldspars: These are mainly fresh, angular to subrounded grains of K-feldspar and plagioclase. K-feldspars are generally orthoclase and microcline. Plagioclases commonly show typical albite twinning.

C. Rock fragments: Angular to subrounded pieces of schist, quartzite, phyllite (metamorphic rocks); recrystallized volcanic glass, altered andesite (volcanic rocks); and some chert and recrystallized limestone (sedimentary rocks) are the common rock fragments in the Topalli Member. In contrast to the Ayva Member, fragments of plutonic rocks are sparse; their absence is probably due to fine grain size of the Topalli Member.

D. Accessory minerals and fossils: Biotite, chlorite, tourmaline, rutile, pyrite, and magnetite are minor components of this member.



×17

Plate (128): General texture of the sandstone of the Topalli Member.
(q = quartz, ch = cherts, f = feldspars, c = carbonate lithoclasts, ca = clacite cement).

Foraminifera, echinoderms, and coralline algae appear to be the main fossils of the Topalli Member.

(ii) Cement: Fine to coarsely crystalline sparry calcite fills all available pore space in the Topalli Member.

(iii) General texture: The sandstones are very fine to coarse grained, moderately well sorted and composed mainly of quartz, feldspar, and rock fragments with some accessory minerals, such as biotite, muscovite, chlorite, tourmaline, rutile pyrite, and magnetite. The angular to subrounded framework grains of the Topalli Member are closely packed and cemented by fine to coarsely crystalline sparry calcite.

(iv) Porosity: Because of the abundance of pore-filling sparry calcite cement, the porosity is very poor.

(v) Petrographic name: Calcareous feldspathic arenite and/or calcareous lithic arenite (Williams, et al., 1954).

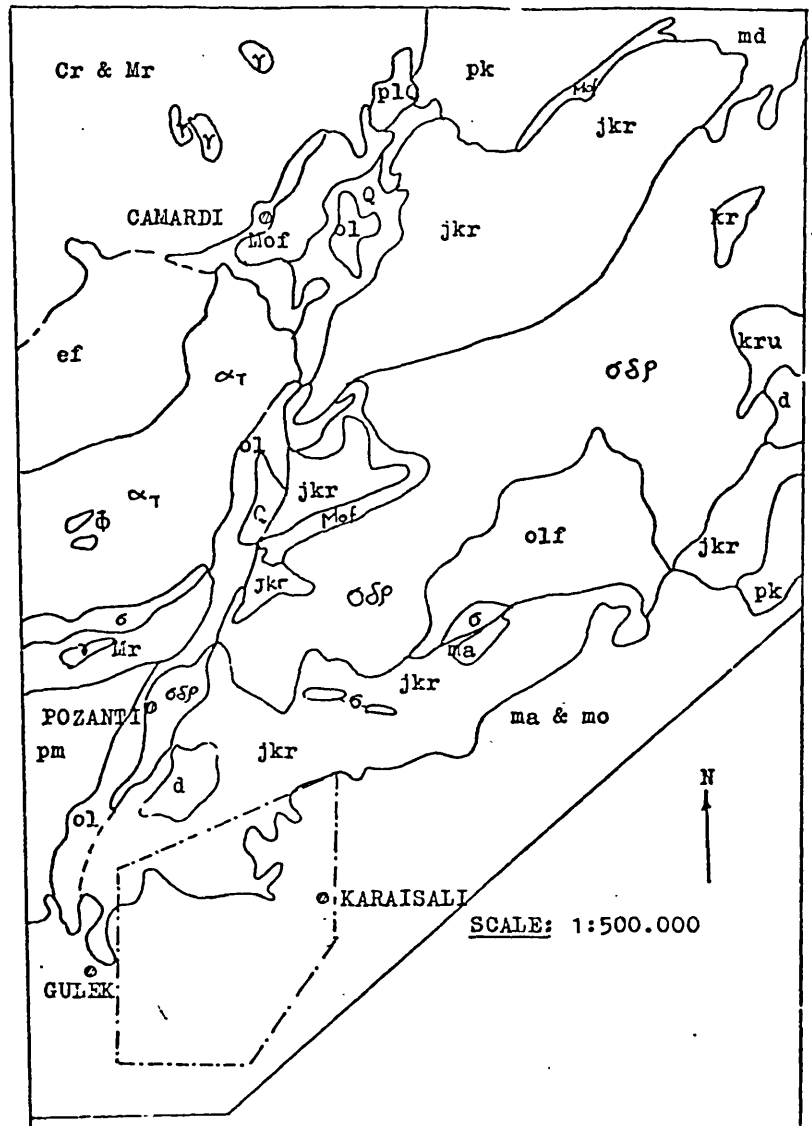
VI. 4. SOURCE AREA AND ENVIRONMENT OF DEPOSITION OF THE CINGOZ FORMATION: Studies of the Cingoz Formation both in the field and in the laboratory suggest a nearby source for the sediments of this formation. The generally poor sorting and the relatively high feldspar content of the Cingoz Formation are strong evidence for this interpretation. Additionally, the paleogeography of the area can also be put forward as further important evidence in favour of a nearby source. From petrographic studies, it can be concluded that the primary source area during the Cingoz time was most probably an extensive igneous and metamorphic highland. Granite, diabase, andesite, and volcanic glasses were the main types of igneous rocks while quartzite, argillite, phyllite, and schists were the metamorphic rocks exposed in this source area. Large areas of sedimentary rock were either originally absent or had perhaps been mostly eroded away to form the earlier deposited clastic sediments of the area. However, the clasts of the conglomerate in the Ayva Member were most probably supplied by local source areas within or to the immediate north

of the basin as was the case in the Gildirli Formation. Examination of the general geological map of the northwestern flank of the Adana Basin confirms the existence of such areas, as suggested by the petrography of these sandstones, in the Taurus Mountains during the deposition of the Cingoz Formation (Map 3). Large volumes of quartz, feldspar, and mostly igneous rock fragments were derived from these areas and transported southward into the depositional sites of the Cingoz Formation (Fig. 22).

The stratigraphical and sedimentological properties of the Ayva Member suggest a marine origin for this sediment. Generally the poorly sorted character and the relatively high feldspar content may indicate that it was laid down mostly below wave base by rapid deposition. Furthermore, this member has many of the characteristics of "proximal turbidites" (Walker, 1967; Stanley and Unrag, 1972). The presence of cross-stratification in these sediments indicates that in part they were transported and deposited by currents rather than by mass-flow. It is then suggested that the Ayva Member was probably formed as submarine valley and fan deposits (Stanely and Unrag. 1972). The depth of water in which these deposits accumulated is not known. However, their geographical location and stratigraphical position indicate that the deposition took place in shallow waters probably below wave base.

Considering the carbonate clasts of the conglomerate in the Ayva Member, whereas it is logical to suggest that relatively distant source areas in the uplands of the Taurus Mountains supplied the bulk of the sandstones while the local sources added the carbonate clasts.

The evenly bedded, more or less distinctly graded alternating sandstones and shales of the Topalli Member display most of the features common to turbidites (Selley, 1972). The presence of these features together with the lithological characteristics and stratigraphical position of this member suggest that the Topalli Member was deposited further basinward and in relatively deeper water than the Ayva Member. Intermittent turbidity currents brought the sand of these sandstones into such places



Q:Quaternary
md:Miocene,marine, undifferentiated
mo:Middle Miocene
ma:Lower Miocene
Ol:Oligocene
ef:Eocene flysch
Mof:Mesozoic(ophiolitic series)
kru:Upper Cretaceous
jkr:Jurassic-Cretaceous
pm:Permian
pk:Permo-Carboniferous
d:Devonian
Cr:Metamorphic series, undifferentiated
Mr:Marble,crystalline limestone, dolomite

γ:Granite,granodiorite, quartz diorite
:Syenite,monzonite
:Serpentinite
:Andesite,spilite,porphyrite
:Diorite,gabro,diabase
:Peridotite,pyroxenite, harzburgite

Map(3):General geological map of the NW flank of the Adana Basin.

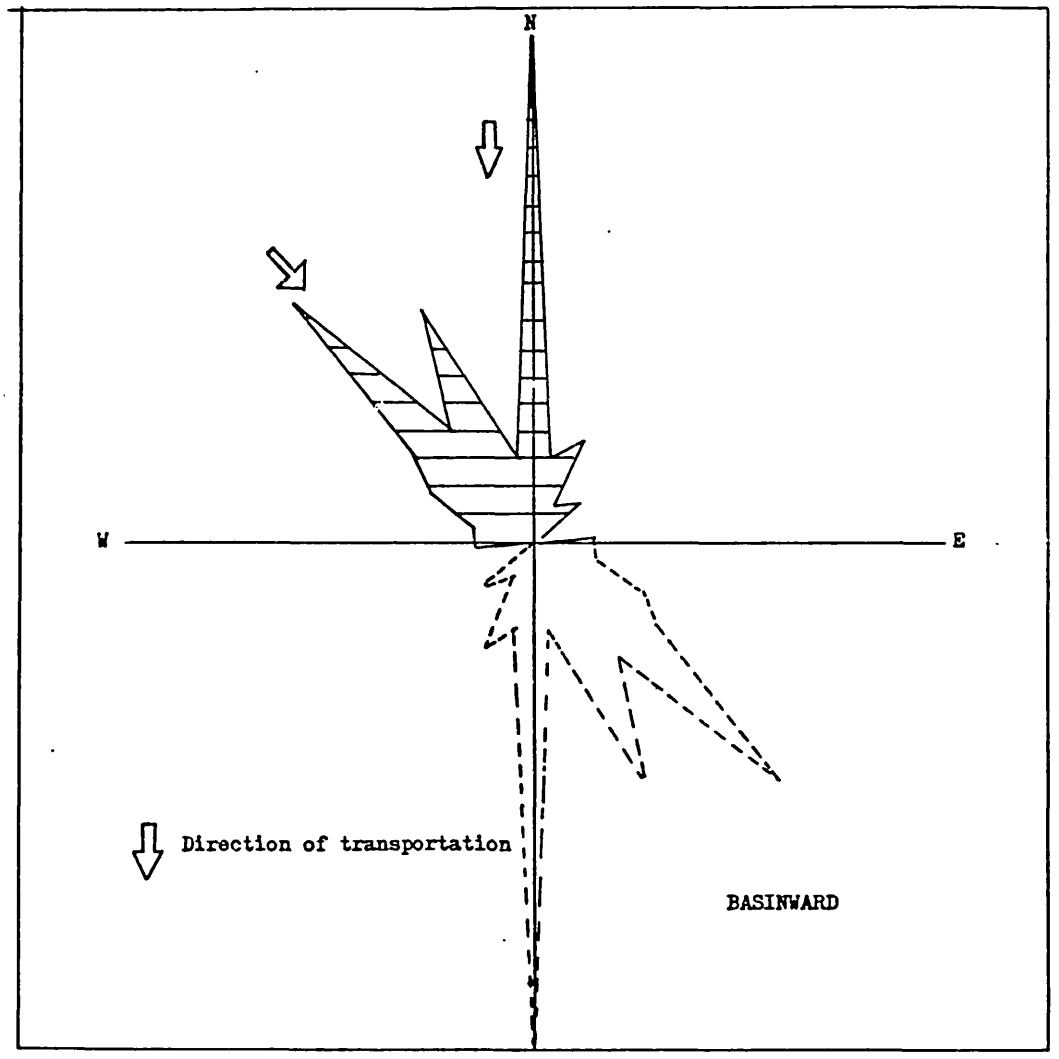


Fig (22): The orientation of bottom structures, mainly groove-casts, from the Cingoz Formation. General stratigraphic relationships indicate that a NW and N source (and not a SE and S) was dominant.

where normally deposition of the Guvenc Shales were taking place. In these areas, the Guvenc Shales are carbonaceous and contain abundant well preserved megafossils, such as molluscs indicating a relatively shallow water depositional environment for the Topalli Member. However, this member may have been deposited in a considerable range of water depths but nowhere is there any evidence to suggest that it was deposited at great depths.

In summary, the rocks of the Cingoz Formation were derived from an adjacent source and deposited as "proximal" and "distal" turbidites. The Cingoz Formation is of the same or partly of the same age as the Karaisali Limestone, although it must be admitted that in the area under discussion the exact stratigraphic relationship of these two formations is still ambiguous.

It appears that the sediment which makes up the Cingoz Formation was brought into the depositional areas while the Karaisali banks were developing. However, as has been previously noted, this formation hardly contains any bank material and perhaps the coral-algal growths of the Karaisali Limestone Formation had been drawned (or they were relatively inactive) when the turbidity currents were bringing sediment into the area to form the Cingoz Formation. What at first appears to be a problem: the apparent separation of the site of deposition of the Cingoz Formation from its source by a Karaisali Limestone complex, seems to be explainable when the distribution of the latter is examined more carefully. This formation has only a patchy development on the isolated pre-Miocene topographical highs to the north of these areas where the Cingoz Formation is found. Wide intervening gaps may therefore have existed through which the turbidity currents transported the detritus to the depositional sites.

VI.5. AGE OF THE CINGOZ FORMATION: Direct fossil evidence concerning the age of the Cingoz Formation is lacking in the area which has been mapped. However, on the basis of the stratigraphic relationships of this formation with the other units, it is thought that it ranges in age from

Burdigalian to Helvetian. This conclusion agrees with that of Schmidt (1961).

CHAPTER VII. SUMMARY AND CONCLUSION: The area which has been studied lies on the northwest flank of the Adana Basin, southern Turkey. It is mostly a broad limestone plateau which is characterized by high carbonate uplands separated by flat lowland areas. A few streams flow over this limestone plateau and these have cut deep valleys and gorges as they descent from the mountains towards the Adana Plain. The area is generally characterized by the typical Mediterranean climate.

The geological structural pattern of the area, as a whole, is simple and reflects primary depositional structures more than tectonic structures. The recognition of initial dips, drape structures and collapse structures as well as faceis changes have played an important part in the understanding of the geological structure of the area.

The rocks exposed in the area range from Palaeozoic to Kainozoic Kainozoic rocks of Miocene age lie unconformably on the pre-Miocene basement rocks which are composed of sandstones, dolomites, and limestone. The Miocene sediments have been assigned to four formations following the earlier work of Schmidt (1961), which are known as Gildirli, Karaisali, Guvenc and Cingoz.

The oldest Miocene strata in the area consitute the Gildirli Formation. It contains limestone conglomerates, calcareous lithic arenites, and siltstones, which are red and unfossiliferous at the base (Cakmak Member) and grey and fossiliferous at the top (Kabalak Tepe Member). The Cakmak Member is of fluviatile while the Kabalak Tepe Member is of marine origin.

The Karaisali Formation, which overlies and interfingers with the Kabalak Tepe Member of the Gildirli Formation, has been divided into six subfacies. These are: Coral-algal packstone and boundstone, Small benthic foraminiferal-algal packstone, Coral-algal wackestone and packstone, Large benthic foraminiferal-algal packstone, Globigerinid-algal packstone, Globigerinid argillaceous wackestone. All these subfacies intertongue complexly with one another and have, as primary constituents, various combinations of coralline algae, corals, foraminifera, echinoderms, molluscs, minor amounts of Halimeda, bryozoa, and

worm tubes. These rocks accumulated on the pre-Miocene topographical highs and in the adjacent areas as bank and associated deposits. Comparisons of the Karaisali Limestone with lower Tertiary limestones from Louisiana, Guam and the Middle East show striking similarities.

Intense biological, phycico-chemical, and physical processes operate during or soon after the deposition of the Karaisali Limestone and these have modified the depositional texture of this carbonate body. Biological agents played an important role by breaking down the skeletons to very small sizes. Physico-chemical processes included cementation, internal sedimentation, solution-cavity fillings, inversion, recrystallization, and replacement.

The Karaisali Limestone also shows effects of compaction as suggested by the abundance of fractures, stylolites, and pressure-solution contacts.

The basinal Guvenc Shale overlies and interfingers with the Karaisali Limestone in the area with various types of contact ranging from transitional to disconformable. It is silty, calcareous, and in some places carbonaceous and contain a rich microfauna. Interbedding of the shale with calcareous feldspathic arenite and/or calcareous lithic arenite and siltstone is common in parts of this formation.

The Cingoz Formation has two members: the Ayva and the Topalli. The Ayva Member consists mainly of granule to medium grained, moderately well sorted conglomeratic calcareous feldspathic arenite and/or calcareous lithic arenite. The Topalli Member consists of interbedded sandstone and shale in about equal proportions. The sandstone beds show internal grading and usually have erosional bases with poorly developed bottom structures including groove-casts, tool marks, scour and fill, and a few flute casts.

Sedimentological properties of the Cingoz Formation indicate a turbiditic origin for this formation with proximal (Ayva Member) and distal (topalli Member) parts.

From the detailed study ofthe Miocene formations in the

Karaisali area, the author has come to the following conclusions:

1 - Before the beginning of the Miocene, erosion led to the development of a landscape with considerable relief cut in the pre-Miocene basement; this relief strongly influenced the later geological development and the subsequent sedimentary pattern of the area.

2 - The highlands of the Taurus Mountains which lie adjacent to the north of the area acted as a source area for most of the clastic formations studied throughout the Miocene (Fig.23).

3 - Before the Miocene sea transgressed over the area, red conglomerate, sandstone, and siltstone of the Cakmak Member of the Gildirli Formation filled the depressions and valleys of the pre-Miocene topography (Fig.23).

4 - The Miocene sea invaded the area gradually from the south and southeast.

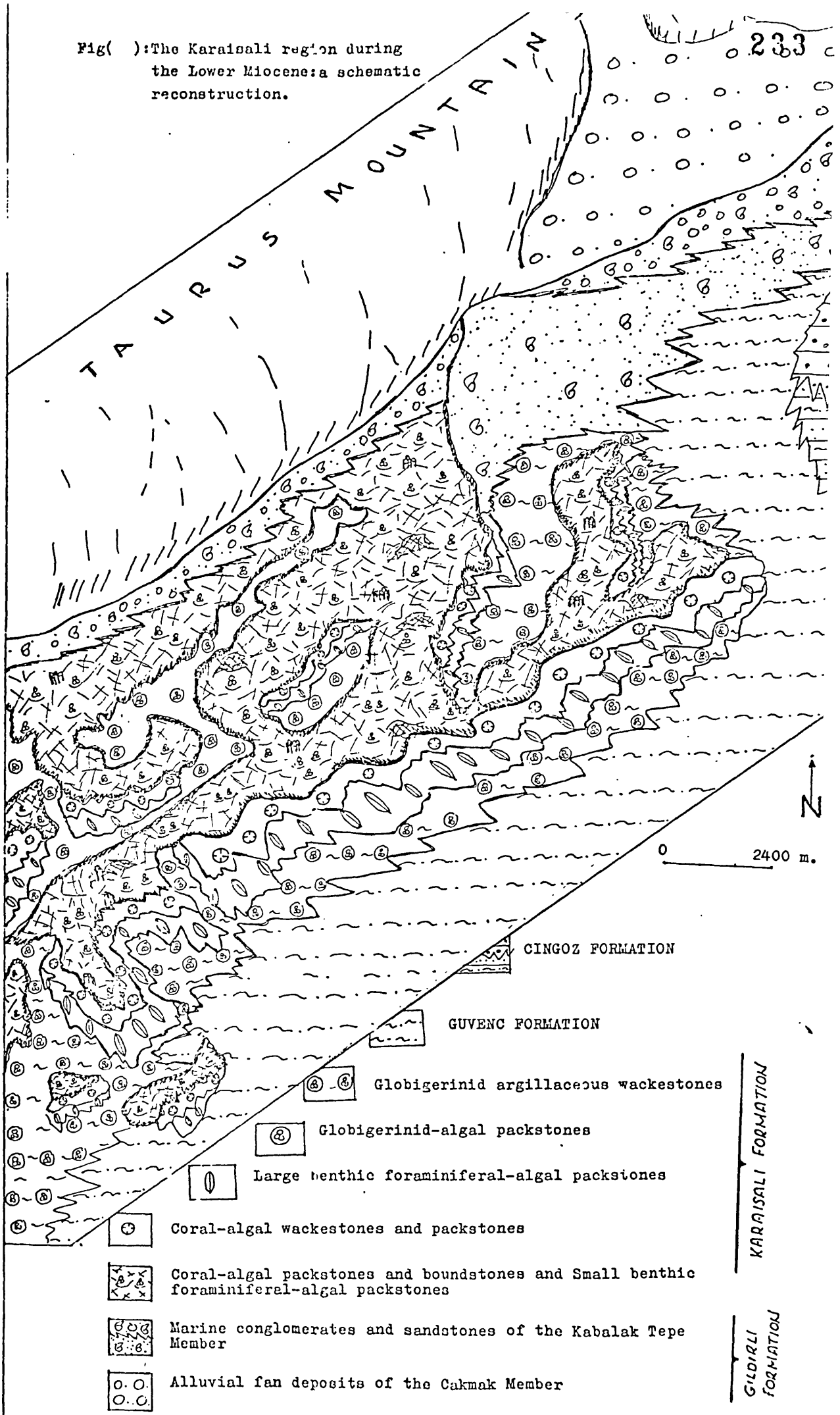
5 - When the area was inundated by the sea, sediment influx from the north appears to have continued and this together with reworking of the red clastics formed the Kabalak Tepe Member of the Gildirli Formation.

6 - The Miocene sea contained potential bank (or reef) forming organisms, such as coralline algae, corals, foraminifera etc., and conditions were favourable for these to flourish.

7 - During the transgression the Karaisali Limestone was developed as a bank-complex on the sun-lit, warm, clear, shallow, and well agitated pre-Miocene topographical highs. Some associated subfacies of this carbonate comples were deposited in the adjacent depressions (Fig.23).

8 - Development of the banks persisted in the north and northeastern half of the area where the pre-Miocene topography was forming a broad platform. The banks grew upwards and were shifted northward as the sea level rose in these areas. Whereas those which were

Fig( ):The Karaisali region during the Lower Miocene:a schematic reconstruction.



initiated on the isolated highs were unable to keep pace with the rise of sea level and were drowned and choked in shale. (This appears to have been the case in the Bulgurdag oil field which is developed in a bank deposit of Miocene age situated on such a high.)

9 - The variation in thickness of the Karaisali Formation suggests that either subsidence or that the rise of sea level was continuing in the area during the deposition of the Miocene sediments.

10 - The Karaisali Limestone has undergone its diagenetic alteration solely under submarine conditions as no evidence of changes which appear to have taken place in the vadose zone have been found. The following sequence of diagenetic modifications have been suggested:

(i) Biological activity

(ii) Cementation and internal sedimentation of micrite

(iii) Leaching of Mg^{2+} ions from the high-magnesian skeletons

(iv) Fracturing and compaction

(v) Change from aragonite to low-magnesian calcite (dissolution-cavity filling, inversion, recrystallization, etc.)

(vi) Stylolitization

(vii) Silicification

11 - The Guvenc Shale was deposited as marine basinal muds and silts

12 - The Ayva and the Topalli Member of the Cingoz Formation are thought to be "proximal" and "distal" turbidites respectively (Fig.23).

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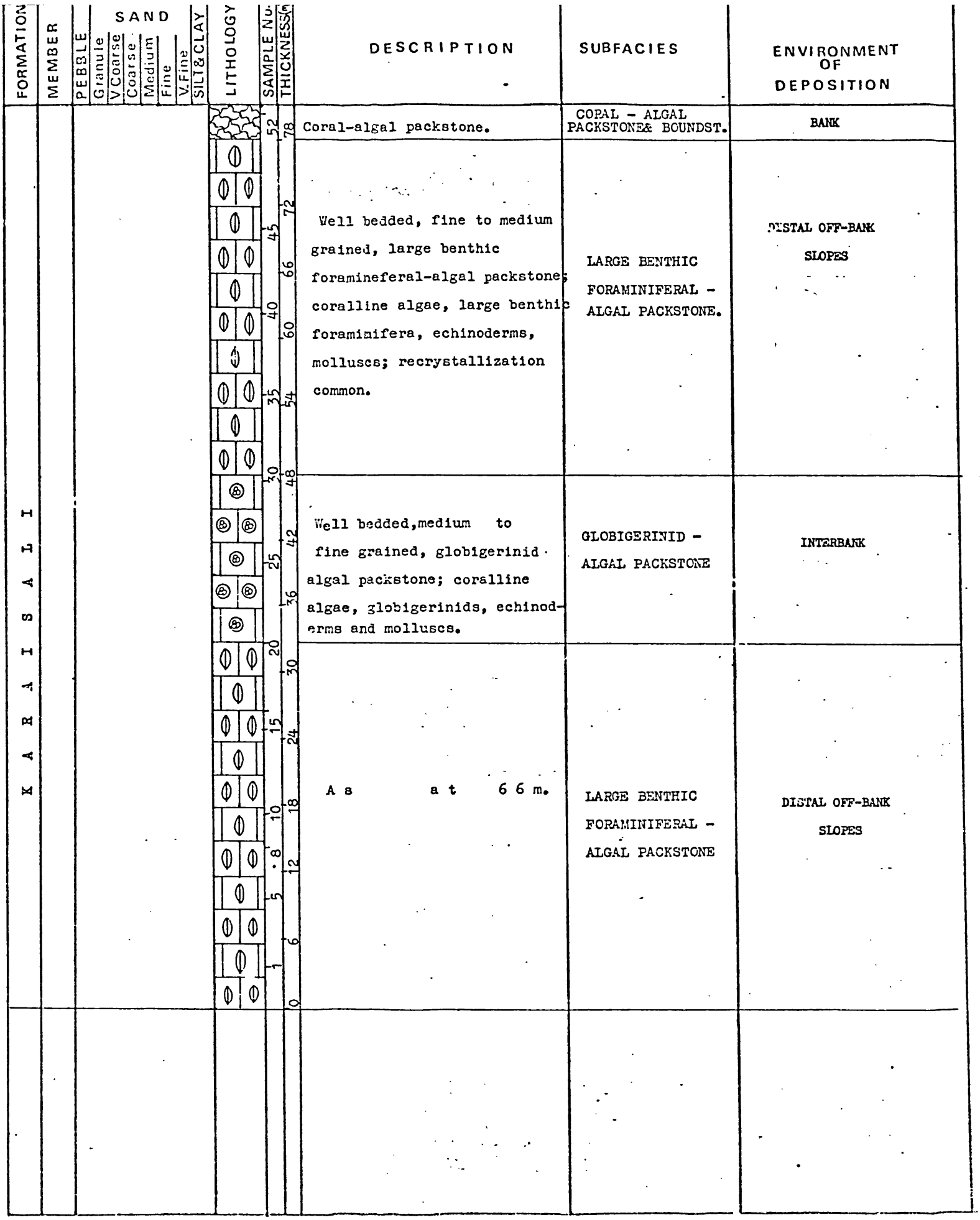
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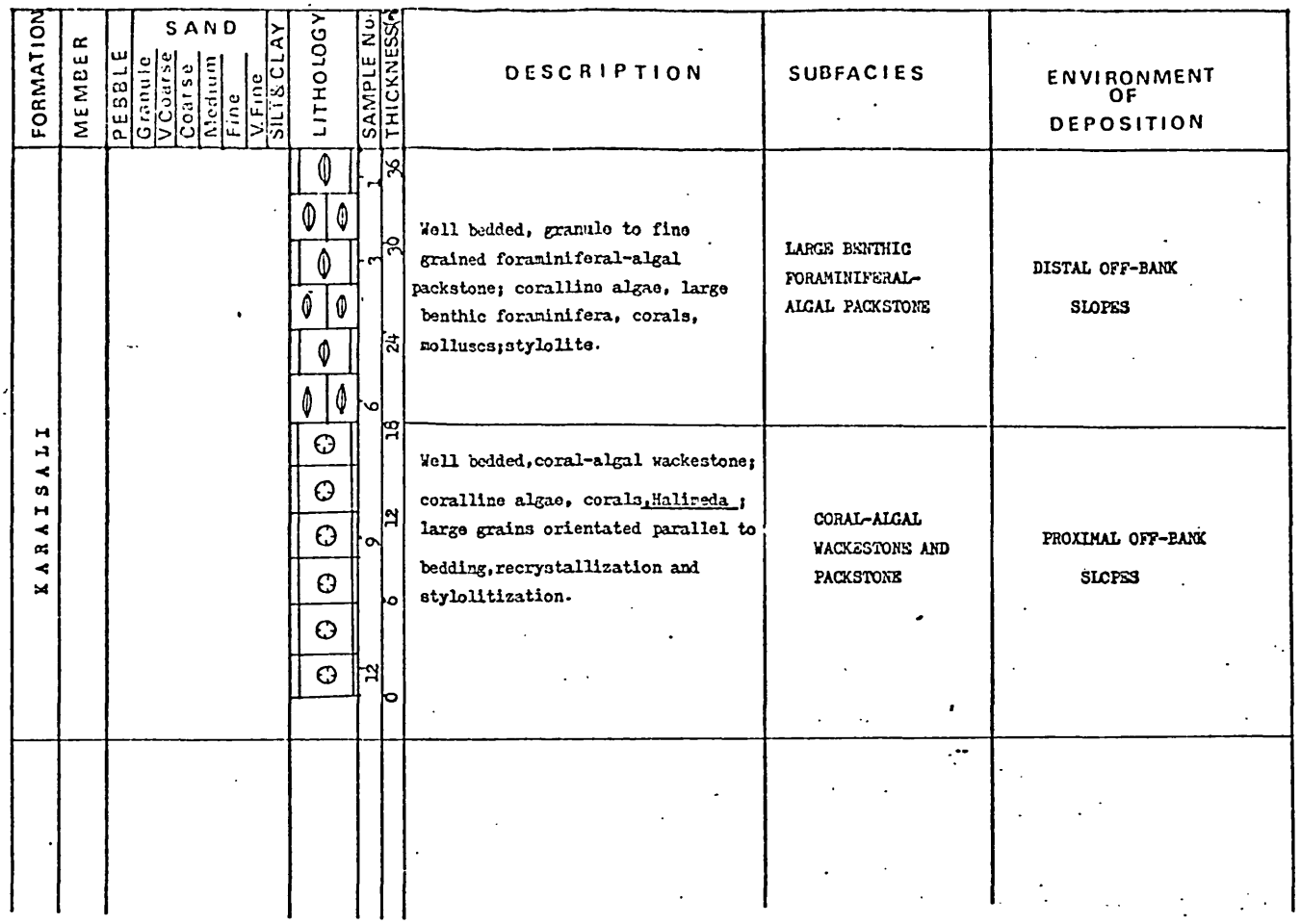
FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
												42	Polymict conglomerate of Quaternary		ALLUVIAL DEPOSITS
											25	36			
											22				
GUVENC												30	Olive grey(5Y 4/1), massive to thickly bedded silty calcareous shale		BASIN
											15	24			
											10	16			
												12			
												6			
											1				
												0	Measured section Aa at Araplar.		



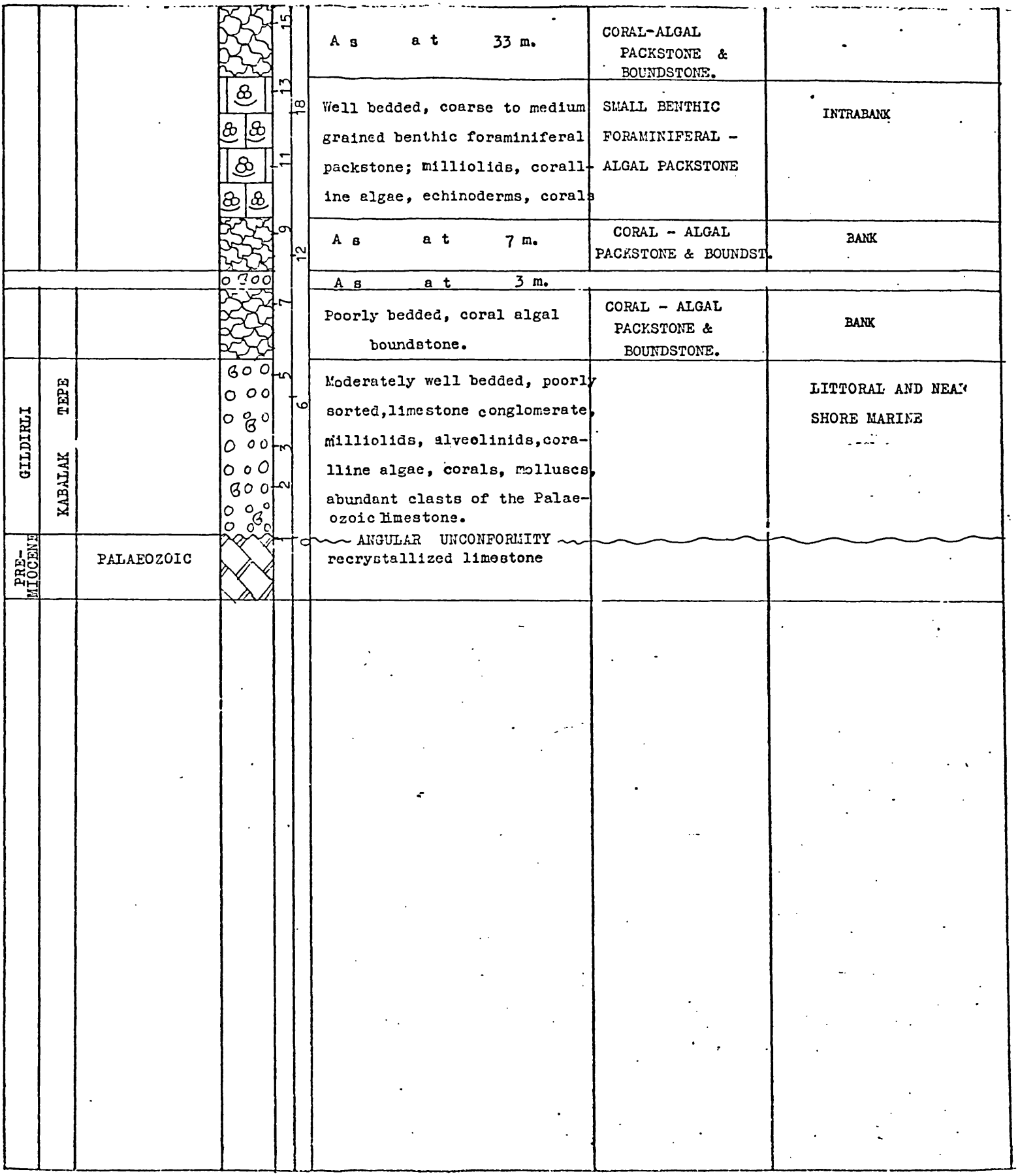
Measured section B1 near Bolacali

FORMATION	MEMBER	PEBBLE / Granule / V.Coarse / Coarse / Medium / Fine / V.Fine / SILT&CLAY (SAND)	LITHOLOGY	SAMPLE No.	THICKNESS m	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				8	12	Moderately well bedded coral-algal wackestone and packstone; coralline algae, corals, Halimeda; echinoderms molluscs; recrystallization common; stylolite abundant.	CORAL-ALGAL WACKESTONE AND PACKSTONE	PROXIMAL OFF-SHORE SLOPES
CUVENC					5	Olive grey(5Y4/1), massive to thickly bedded shale.		BASIN
KARAISALI					6	Well bedded, argillaceous, globigerinid wackestone; globigerinid, echinoderms, molluscs.	GLOBIGERINID ARGILLACEOUS WACKESTONE	BASIN
				3				
				1				
				0				

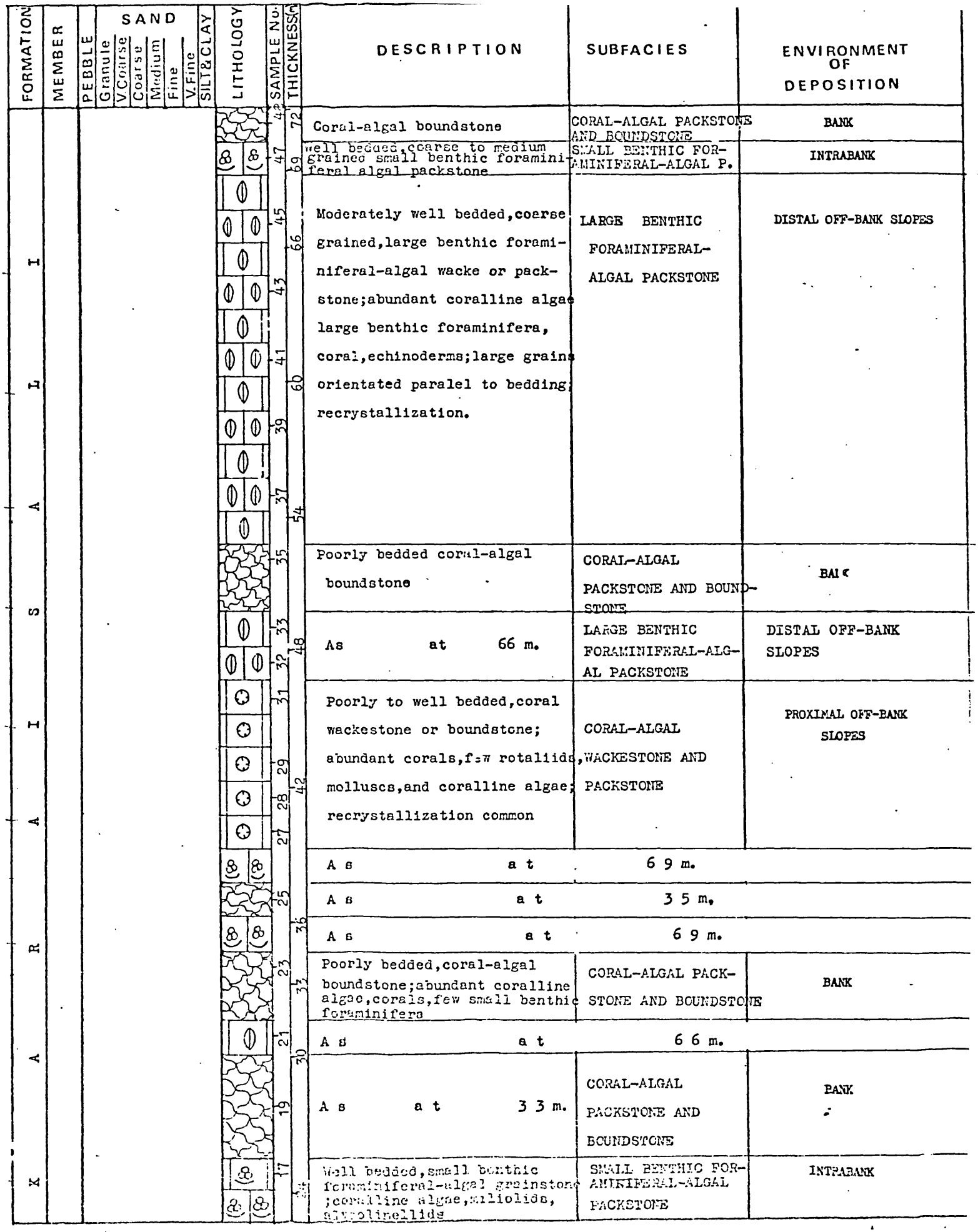
Measured section Ct_4 at Camtepe



Measured section Ct_3 at Camtepe



Measured section Ct_2 continued



Measured section Ct_2 at Camtepe

FORMATION	MEMBER	PEBBLE / SAND / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				1	36	Well bedded, granule to fine grained foraminiferal-algal packstone; coralline algae, large benthic foraminifera, corals, molluscs; stylolite	LARGE BENTHIC FORAMINIFERAL - ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
				2				
					30	As at 18m.	CORAL - ALGAL WACKESTONE& PACKST.	PROXIMAL OFF-BANK SLOPES
				3				
				4		As at 33 m.	LARGE BENTHIC FORAMINIFERAL - ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
					24			
				5				
				6				
				7	18	Well bedded, coral-algal wackestone; coralline algae, corals, Halimeda; large grains orientated parallel to bedding, recrystalization and stylolitization.	CORAL - ALGAL WACKESTONE AND PACKSTONE	PROXIMAL OFF-BANK SLOPES
				8				
					12			
				9				
				10				
					6			
				11				
					12			
					0			

Measured section Ct_1' at Camtepe, Kestepe

FORMATION	MEMBER	PEBBLE / SAND (Granule, V Coarse, Coarse, Medium, Fine, V.Fine) / SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS m	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				1	36	Well bedded, granule to fine grained foraminiferal-algal packstone; coralline algae, large benthic foraminifera, corals, molluscs; stylolite.	LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
				3	30			
					24			
				6				
					18	Well bedded, coral-algal wackestone; coralline algae, corals, Halimeda; large grains orientated parallel to bedding, recrystallization and stylolitization.	CORAL-ALGAL WACKESTONE AND PACKSTONE	PROXIMAL OFF-BANK SLOPES
				9	12			
					6			
				12				
					0			

Measured section Ct_1 at Camtepe

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V Fine	SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G U V E N C											31	48	Olive grey (5Y4/1), massive to thickly bedded?, silty calcareous shale, with abundant microfauna, such as globigerinids; usually includes some very thin beds of calcareous feldspathic arenite and/or calcareous lithic arenite and siltstone in varying proportions.		BASIN
											21	36			
											16	24			
											12	18			
											7	12			
											3	6			
											1	0			

Measured section Co at Coraklik Tepe near Ebulhadi

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
GUVENC											10	15	Olive grey (5Y4/1), massive to thickly bedded?, silty calcareous shale, with abundant microfauna, such as globigerinids; usually includes some very thin beds of calcareous feldspathic arenite and/or calcareous lithic arenite and siltstone in varying proportions.		BASIN
											7	12			
											1	6			
												0			

Measured section Kis in Karaisali

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G U V E N C											0 1 4 6 7 10 12 13 16 18 19 24 30		Olive grey(5Y4/1),massive to thickly bedded?,silty calcareous shale,with abundant microfauna,such as globigerinids;usually includes some very thin beds of calcarous feldspathic arenite and/or calcareous lithic arenite and siltstone in varying proportions.		BASIN

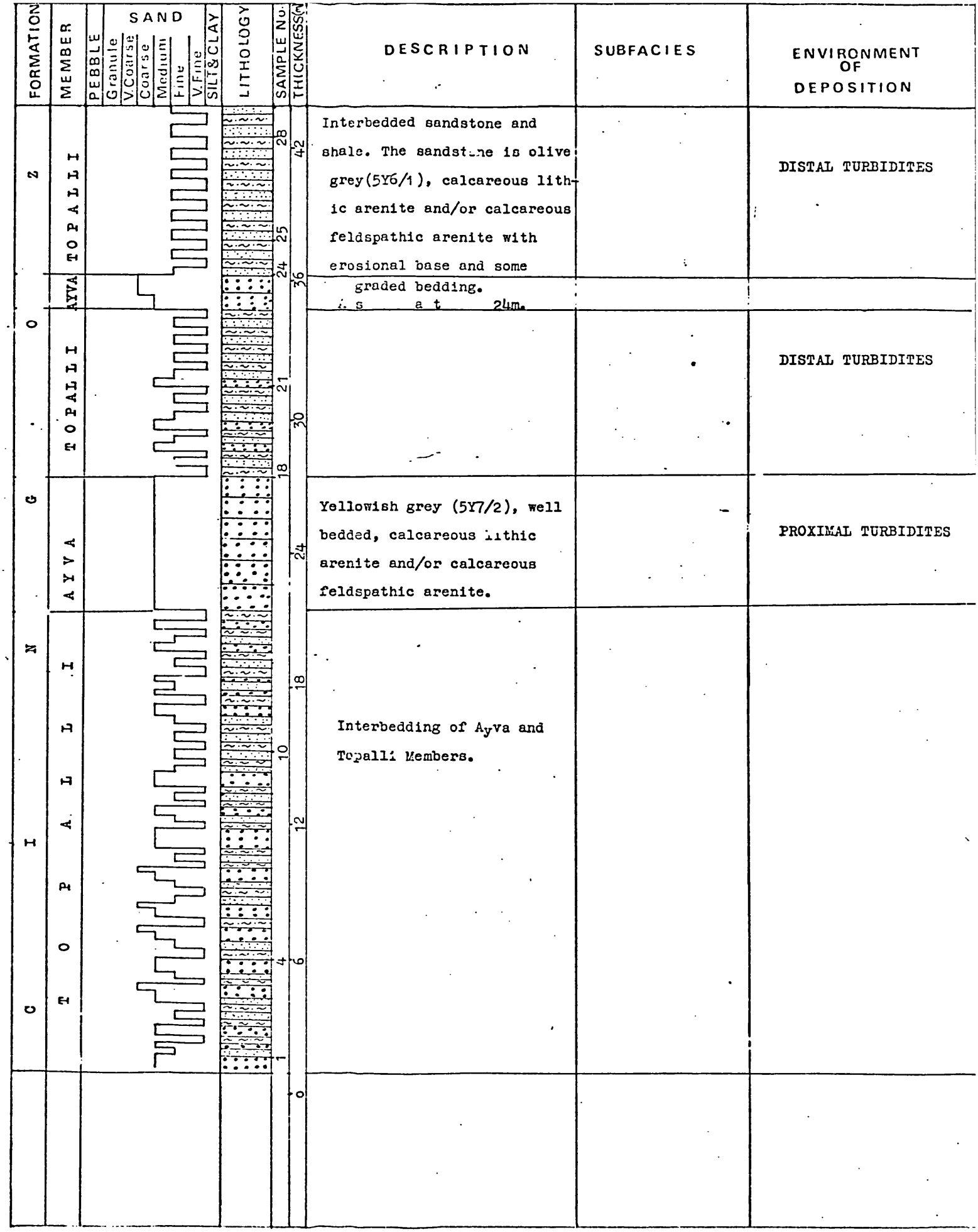
Measured section Gy at Gokyar Tepe,Aktas

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G U V E N C											8	12	Olive grey (5Y4/1), massive to thickly bedded?, silty calcareous shale, with abundant microfauna, such as globigerinids; usually includes some very thin beds of calcareous feldspathic arenite and/or calcareous lithic arenite and siltstone in varying proportions.		B A S I N
											6	9			
												6			
											3				
												3			
											2				
											1				
												0			

Measured section Hh near Hacihasan

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G U V E N C							7,5	Olive grey(5Y4/1), silty, calcareous shale, interbedded with very thin beds of calcareous feldspathic arenite and/or calcareous lithic arenite and siltstone		BASIN

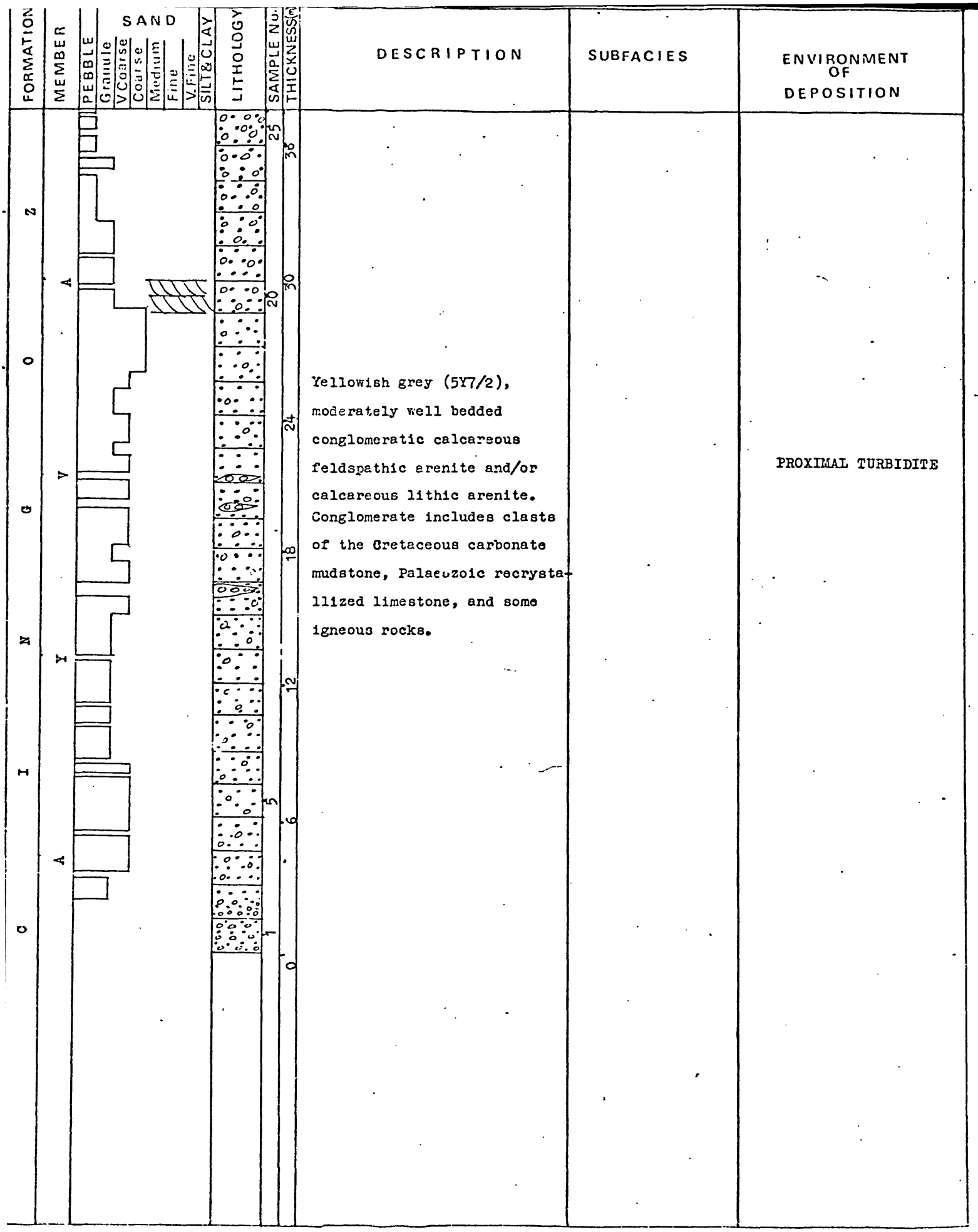
Measured section Un near Camizli



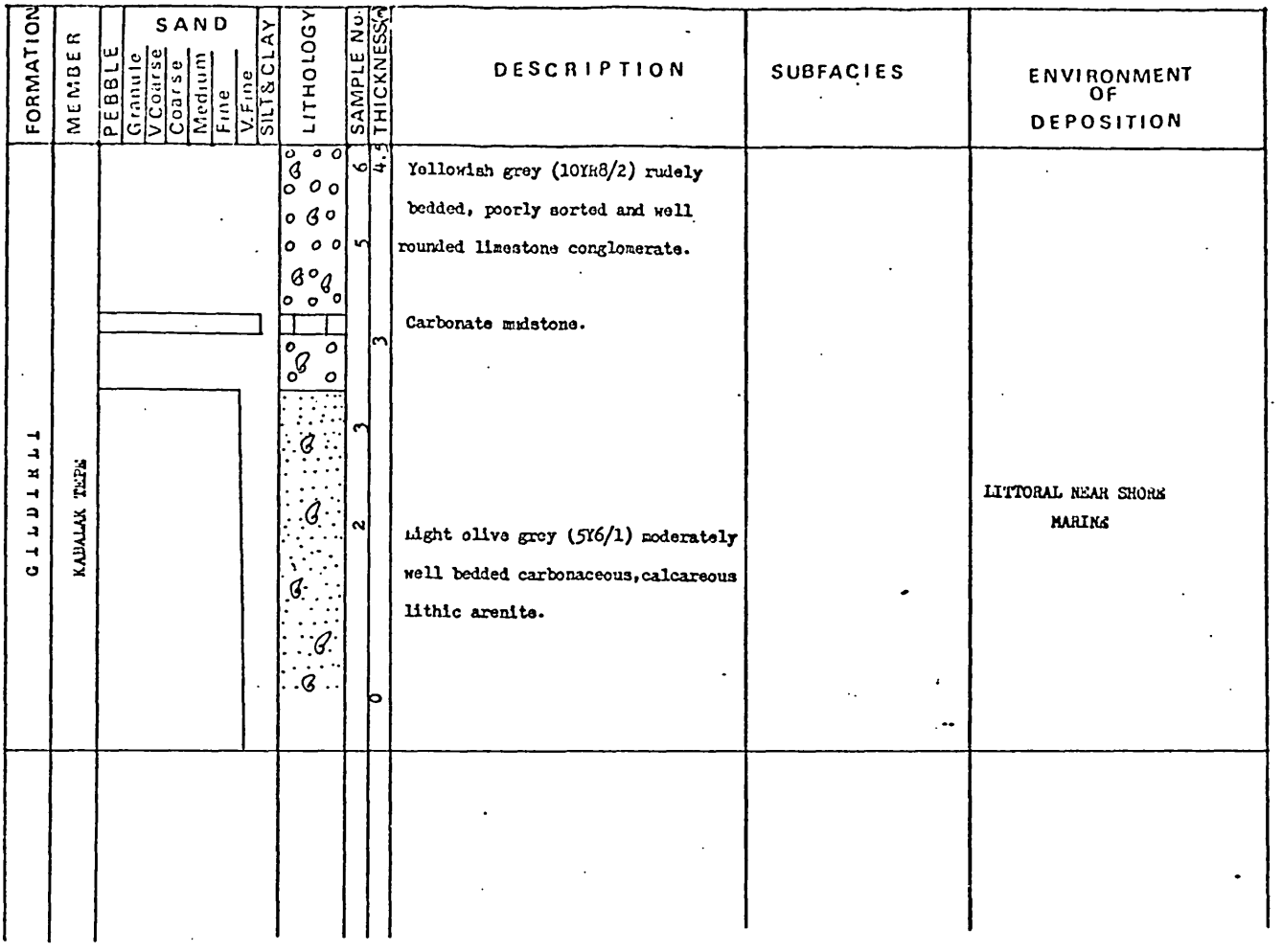
Measured section Er_1 near Emirler

FORMATION	MEMBER	SAND: PEBBLE / Granule / V.Coarse / Coarse / Medium / Fine / V.Fine / SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
NIGDE	AYVA			10	15	Yellowish grey(5Y7/2), well bedded calcareous feldspathic arenite and/or calcareous lithic arenite		PROXIMAL TURBIDITE
	TOPALLI			9		Interbedded sandstone and shale. The sandstone is calcareous lithic arenite and/or calcareous feldspathic arenite and has erosional base with poorly developed bottom structures.		DISTAL TURBIDITE
	AYVA				12	As at 15 m.		
	TOPALLI					As at 12 m.		
	AYVA					As at 15 m.		
	TOPALLI				6	As at 12 m.		
	AYVA					As at 15 m.		
	TOPALLI			3		As at 12 m.		
	AYVA					As at 15 m.		
	TOPALLI			1		As at 12 m.		
GUVENC					6	Olive grey(5Y4/1), massive to thickly bedded, silty calcareous shale with some carbonaceous material.		BASIN

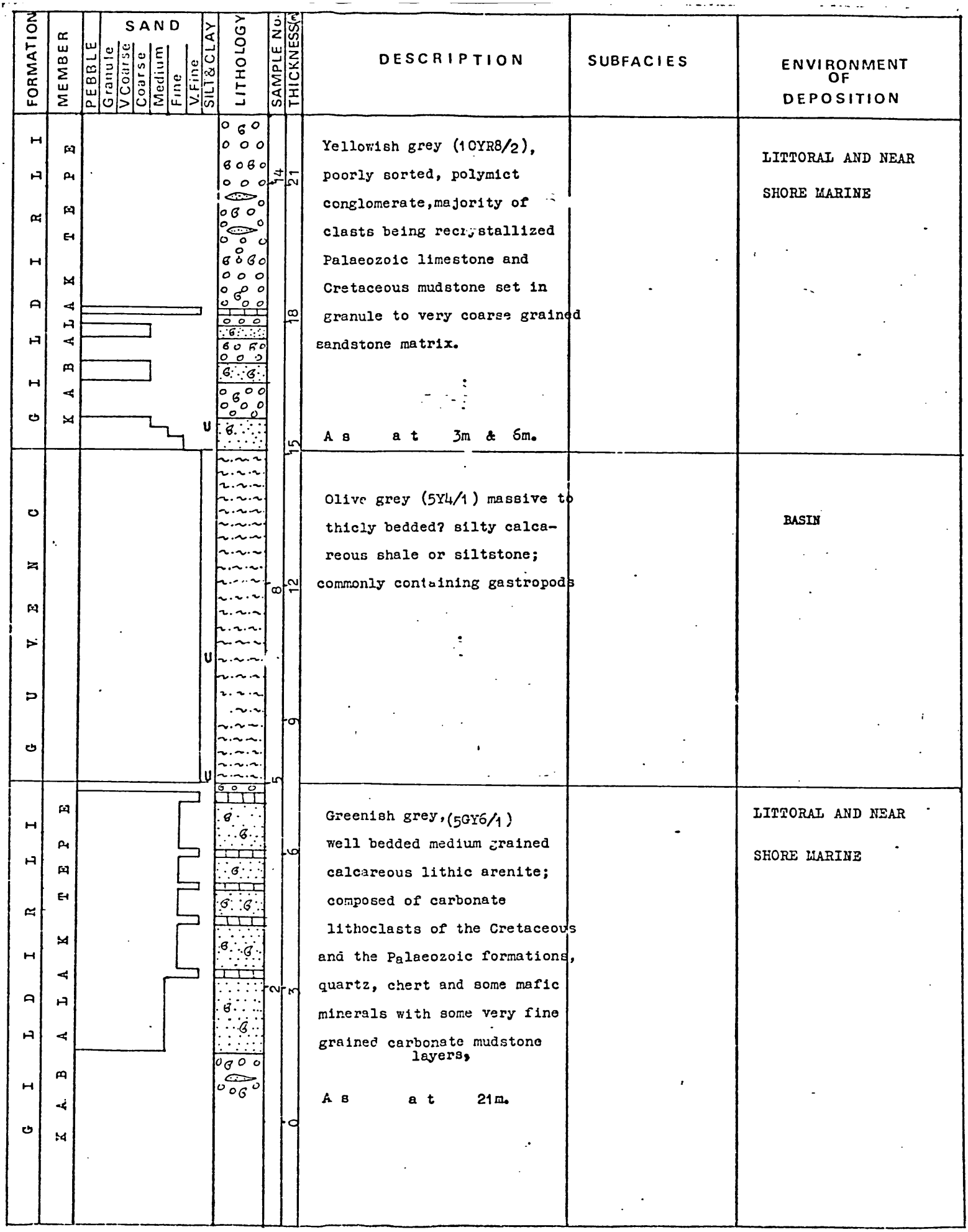
Measured section Nz_9 near Nergizlik



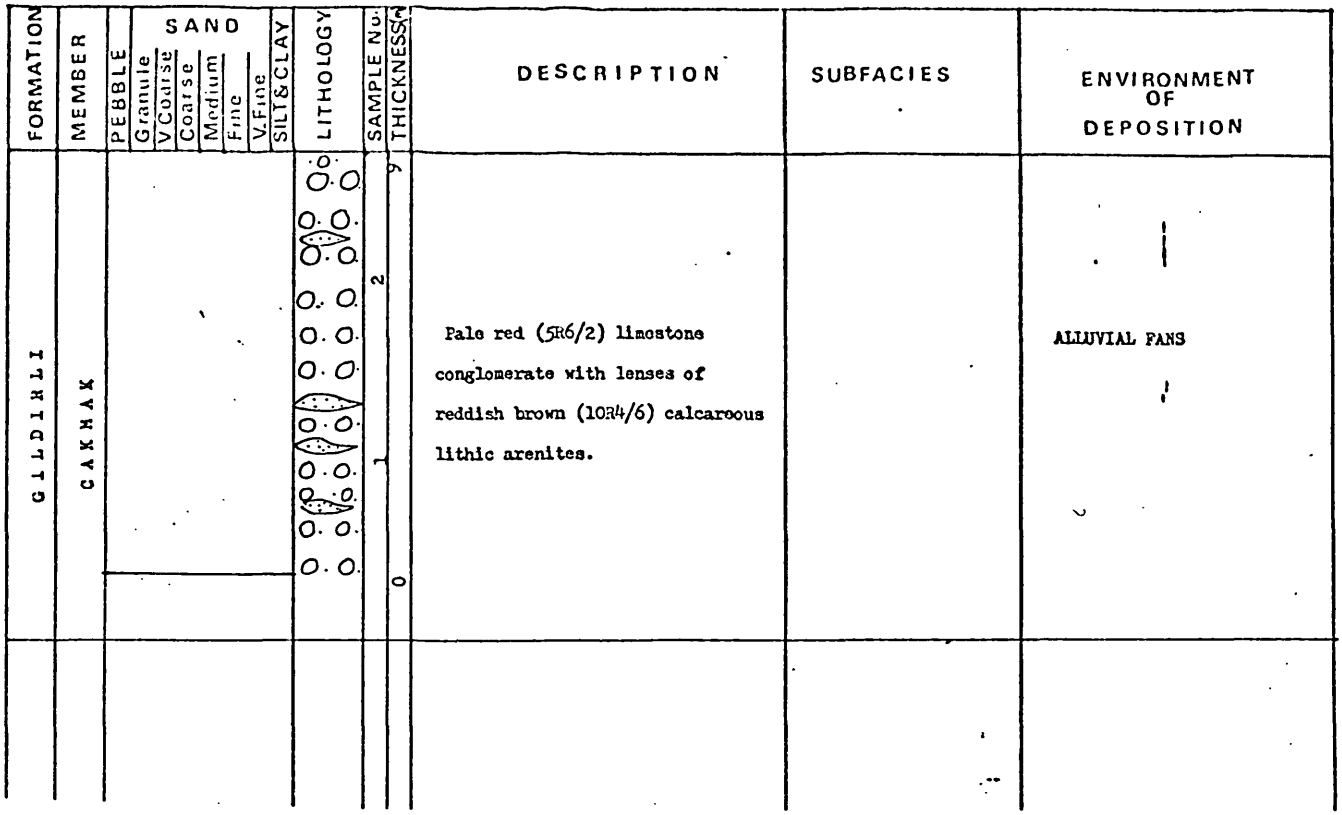
Measured section Nz_8 near Nergizlik



Measured section Nz_7 at Nergizlik

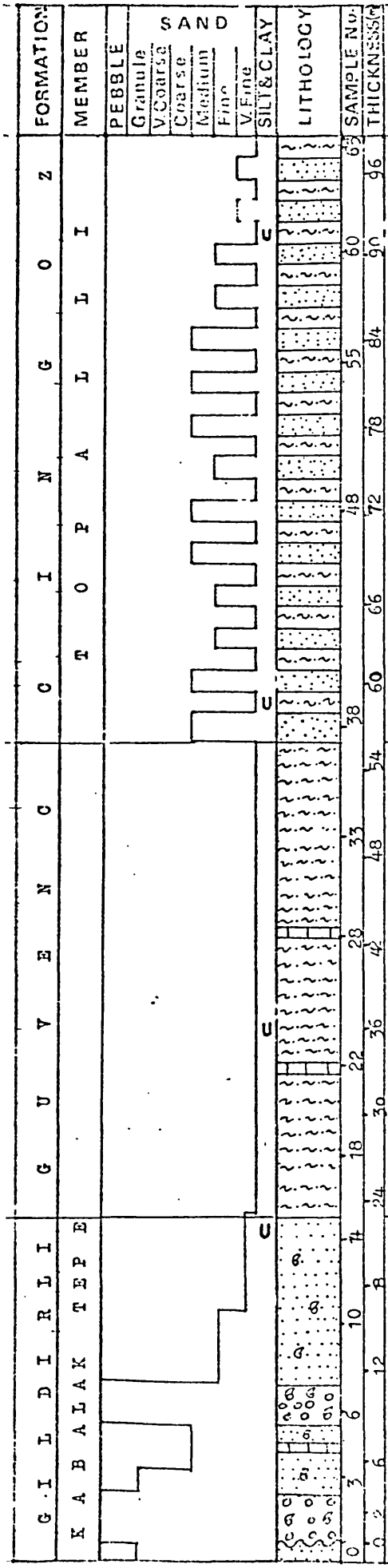


Measured section Nz_6 near Nergizlik



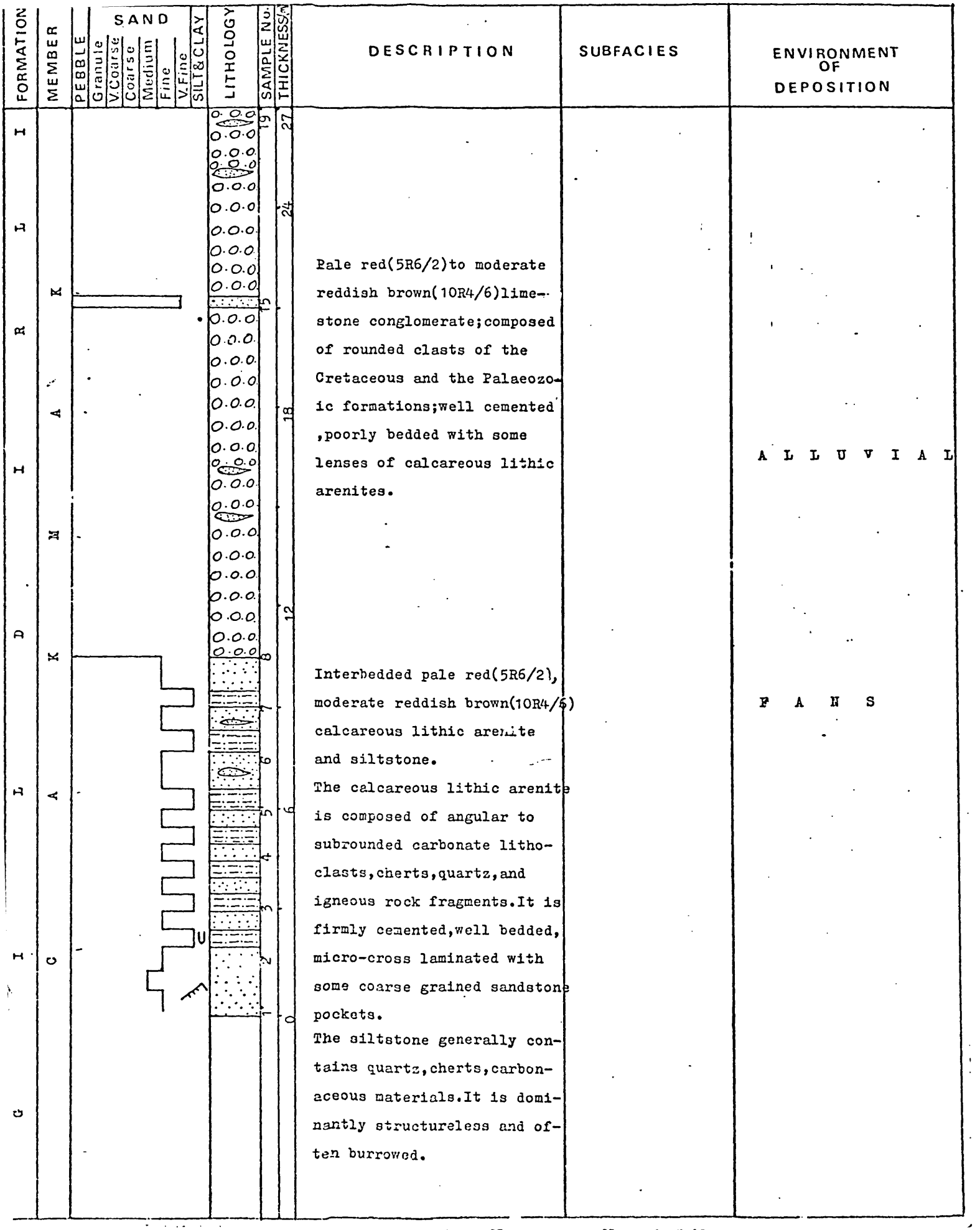
Measured section Nz_5 at Nergizlik

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
GIRDIRLI	CAKMAK					2	3	Pale red (5R6/2) poorly sorted limestone conglomerate; composed of rounded clasts of the Cretaceous and the Palaeozoic formations.		ALLUVIAL FANS
						1	1	Pale red (5R6/2) well bedded calcareous lithic arenite.		
							0	Measured section N24 of Nergiz lit.		

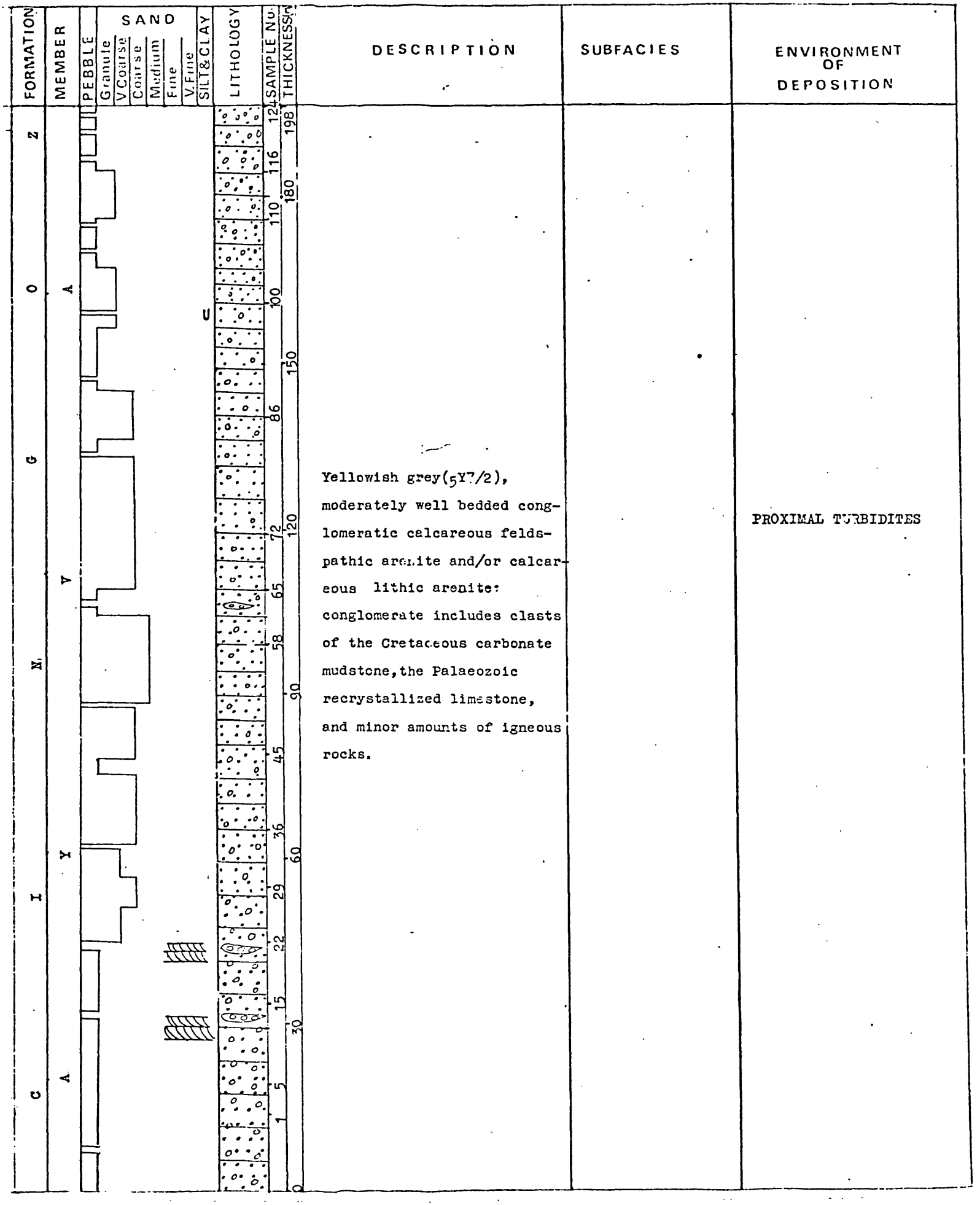


DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
Interbedded sandstone and shale: The sandstone generally is olive grey(5Y6/1),moderately sorted and composed of quartz ,feldspars,and rock fragments. Internally the sand beds show grading and usually have erosional base with poorly developed bottom structure including groove casts,tool marks, and flute casts. The shale is generally greenish grey(5GY6/1),calcareous, locally carbonaceous,and contains quartz,calcites,feldspars and some clay minerals.		DISTAL TURBIDITES
Olive grey(5Y4/1),massive to thickly bedded? locally carbonaceous calcareous shale; molluscs abundant;some thin bands of carbonate mudstone.		BASIN
Light olive grey(5Y6/1),hard to friable,carbonaceous,calcareous lithic arenite;composed of lithoclasts of the Cretaceous and the Palaeozoic limestones,quartz,cherts etc. As at 2 m. As at 18 m. with thin beds of very fine grained carbonate mudstone Yellowish grey(10YR8/2),poorly bedded polymict conglomerate		LITTORAL AND NEAR SHORE MARINE

Measured section Nz_1 and Nz_2 (combined) near Nergizlik



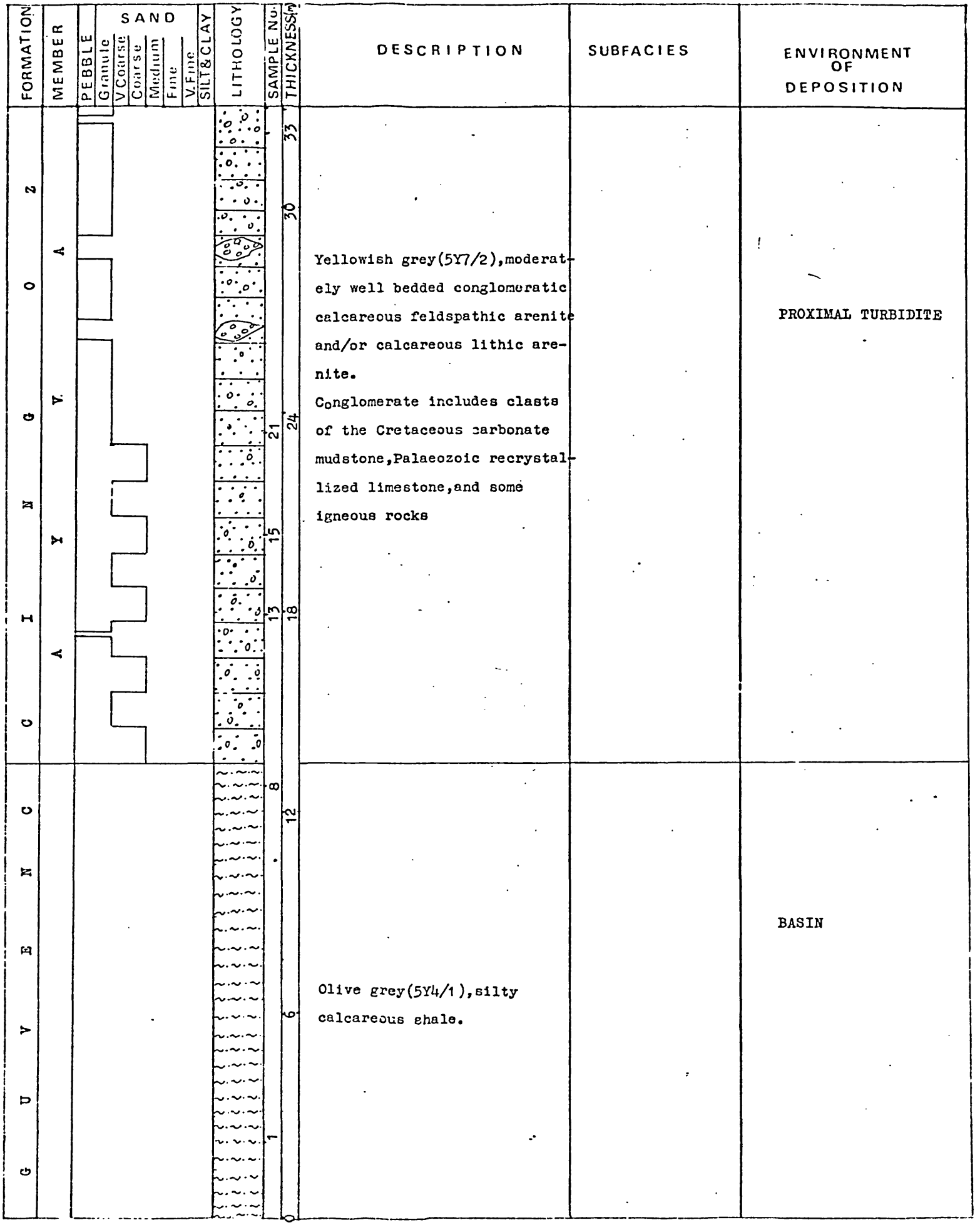
Measured section Nz_3 near Nergizlik



Measured section Ck_2 near Cakmak

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS m	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G I L D I R L I	C A K M A K										99	90	limestone conglomerate composed of pebbles and boulders of white, fine-textured Cretaceous carbonate mudstones and dark coloured recrystallized Palaeozoic limestones in a granule to coarse grained lithic arenite matrix. It is well cemented, poorly bedded with some lenses of calcareous lithic arenites.		ALLUVIAL FANS
											5a	75			
											40	60			
											30	45			
											20	30			
											10	15			
PLIO.	CRETACEOUS										0	0	Angular unconformity		

Measured section Ck_1 near Cakmak



Measured section Ar at Arilitasin Dere

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(cm)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI						39	60	Moderately well bedded, generally medium to fine grained coral-algal packstone intermixed with coral-algal boundstone; coralline algae, corals, benthic foraminifera.	CORAL - ALGAL PACKSTONE AND BOUNDSTONE	BANK
						35	54			
						31	48			
						27	42			
						23	36			
						19	30	Well bedded, fine grained large benthic foraminiferal-algal packstone.	LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
						17	24	well bedded, fine grained, small benthic foraminiferal-algal packstone with common molluscs and echinoderms.	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
						15				
						11	18			
GILDIRLI	CAKKABALAK TEPE					7	12	Light olive grey(5Y6/1), Moderately well bedded, fine grained calcareous lithic arenite; common gastropods and oysters.		LITTORAL NEAR SHORE MARINE
						5				
						4				
						3	6			
						1	0	Pale red(5R6/2) limestone conglomerate and lithic arenite.		ALLUVIAL FANS

Measured section Do at Dokukkaya, Solakli

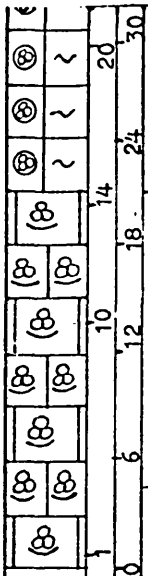
FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
G U V E N C						22	33	Olive grey (5Y4/1), massive to thickly bedded?, silty calcareous shale, with abundant microfauna, such as globigerinids; usually includes some very thin beds of calcareous feldspathic arenite and siltstone in varying proportions.		BASIN
KARAISALI						1	0	Coral- algal packstone and boundstone.	CORAL - ALGAL PACKSTONE & BOUNDST	B A N K

Measured section Yk_5 near Yanikkisla

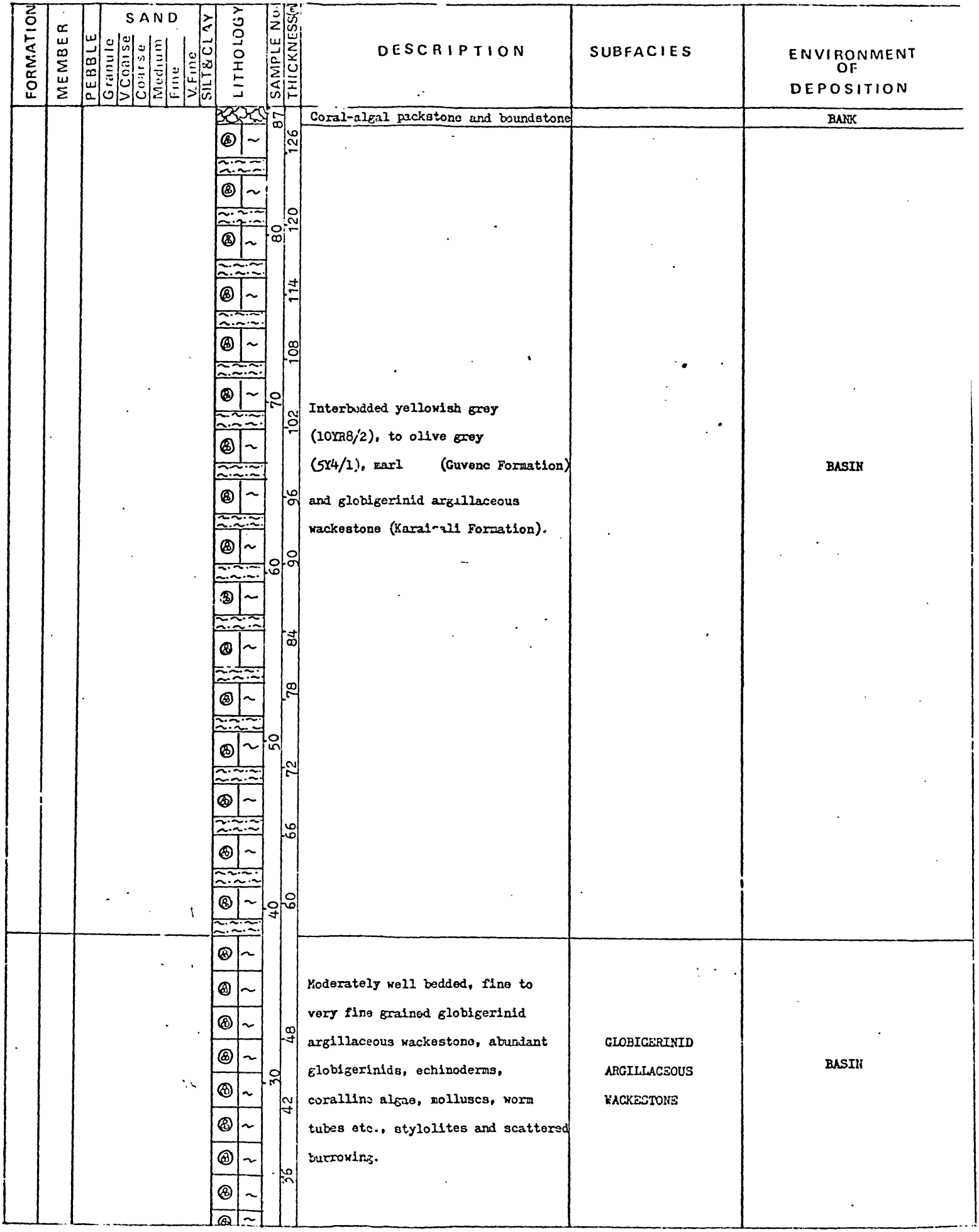
FORMATION	MEMBER	PEBBLE / SAND / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (cm)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				36	54	As at 24		
				32	48	As at 3		
				42		As at 24		
				24	36	Coral-algal wackestone.	CORAL-ALGAL WACKE-ST & PACKST.	PROXIMAL OFF-BANK SLOPE
				20	30	Poorly bedded coral-algal packstone and boundstone or mixture of them, common recrystallization.	CORAL-ALGAL PACK-STONE AND BOUND-STONE	BANK
				16	24			
				12	18			
				8	12			
				4	6	Fine grained small benthic foraminiferal-algal packst. with common coralline algae and small benthic foraminifera.	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
				1				
				0				
						Measured section Yk_4 near Yanikkisla		

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI								AS at 36m.		
							42	Fine grained small benthic foraminiferal-algal packstone	SMALL BENTHIC FORAMINIFERAL ALGAL P.	INTRABANK
						30 27 24 21 18	36 30 24	Poorly bedded coral-algal packstone and boundstone with abundant coralline algae, coral, and foraminifera.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
								As at 2m.		
						10 5 1	18 12 6	AS at 36m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
						1	0	Coral-algal wackestone with common stylolite.	CORAL-ALGAL WACKESTONE AND PACKSTONE	PROXIMAL OFF-BANK SLOPES.

Measured section Yk3 at Yanikisla

		Moderate to well bedded medium to fine grained small benthic foraminiferal algal packstone; coralline algae, miliolids, echinoderms, molluscs.	SMALL BENTHIC FORAMINIFERAL - ALGAL PACKSTONE.	INTRABANK

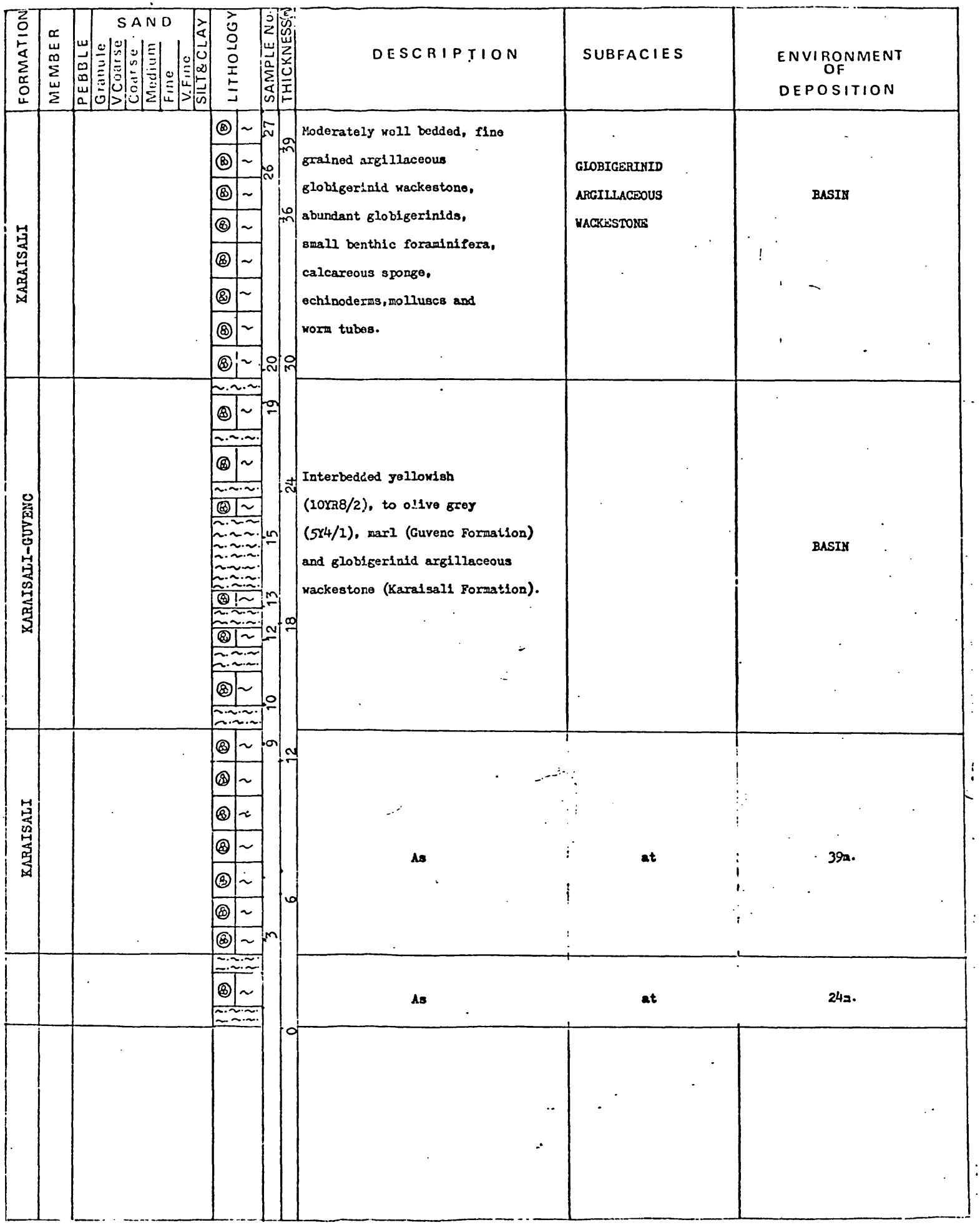
Measured section Yk_2 continued



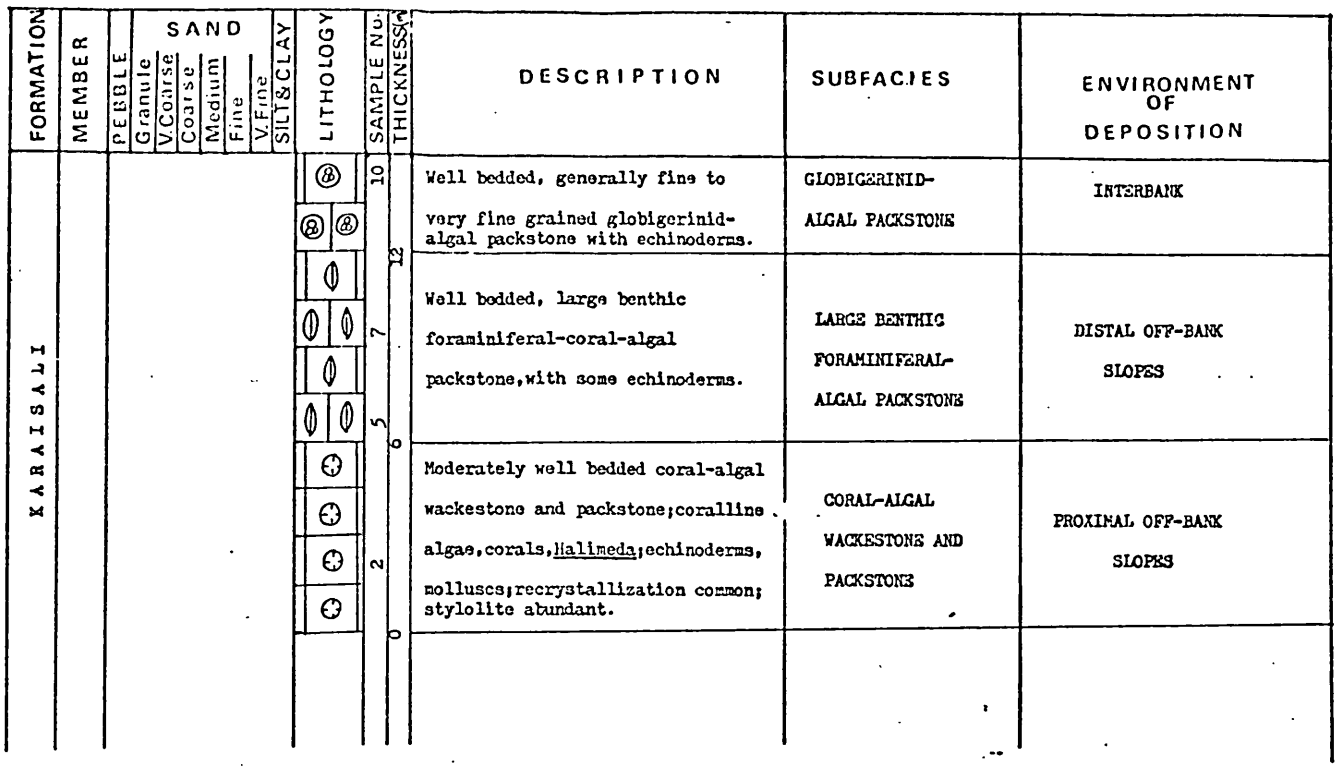
Measured section Yk_2 near Yanikkisla

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI						60	90	Moderate to well bedded fine grained, globigerinid argillaceous wackestone, abundant globigerinids, echinoderms, molluscs, coralline algae, calcareous sponges etc., scattered burrowing.	GLOBIGERINID ARGILLACEOUS WACKESTONE	BASIN
						49	84			
							78			
							72			
						43	66	Moderately well bedded coarse to medium grained coral - algal packstone		
						39	60	As	at	84m.
						35	54	As	at	66m.
						29	48	As	at	84m.
							42			
							36			
						19	30			
							24			
						12	18			
KARAISALI-GUVENC						1	12	Interbedded yellowish (10YR8/2), to olive grey (5Y4/1), marl (Guvenc Formation) and globigerinid argillaceous wackestone (Karaisali Formation)		BASIN
							6			
							0			

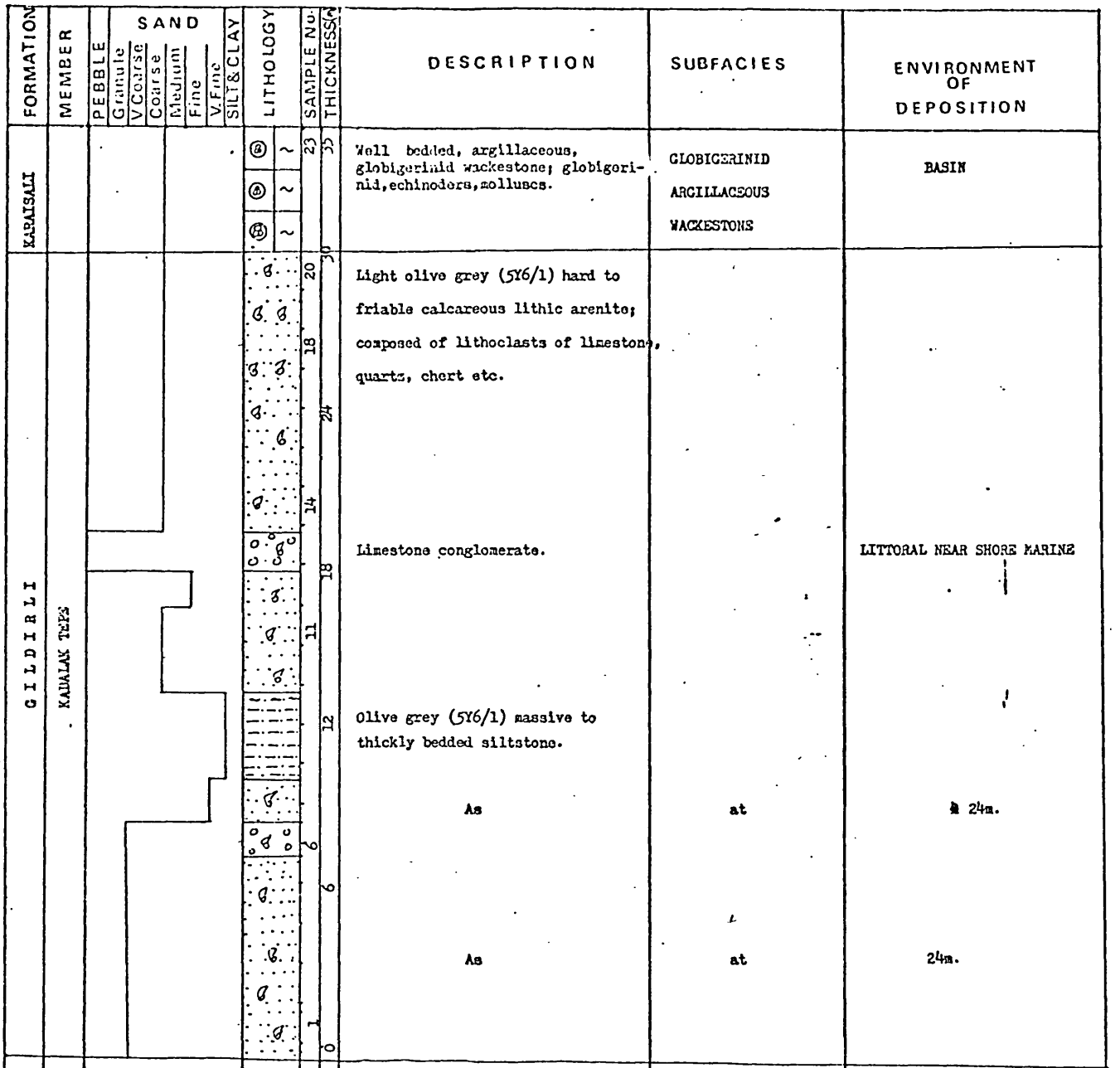
Measured section Yk 1 near Yanikkisla



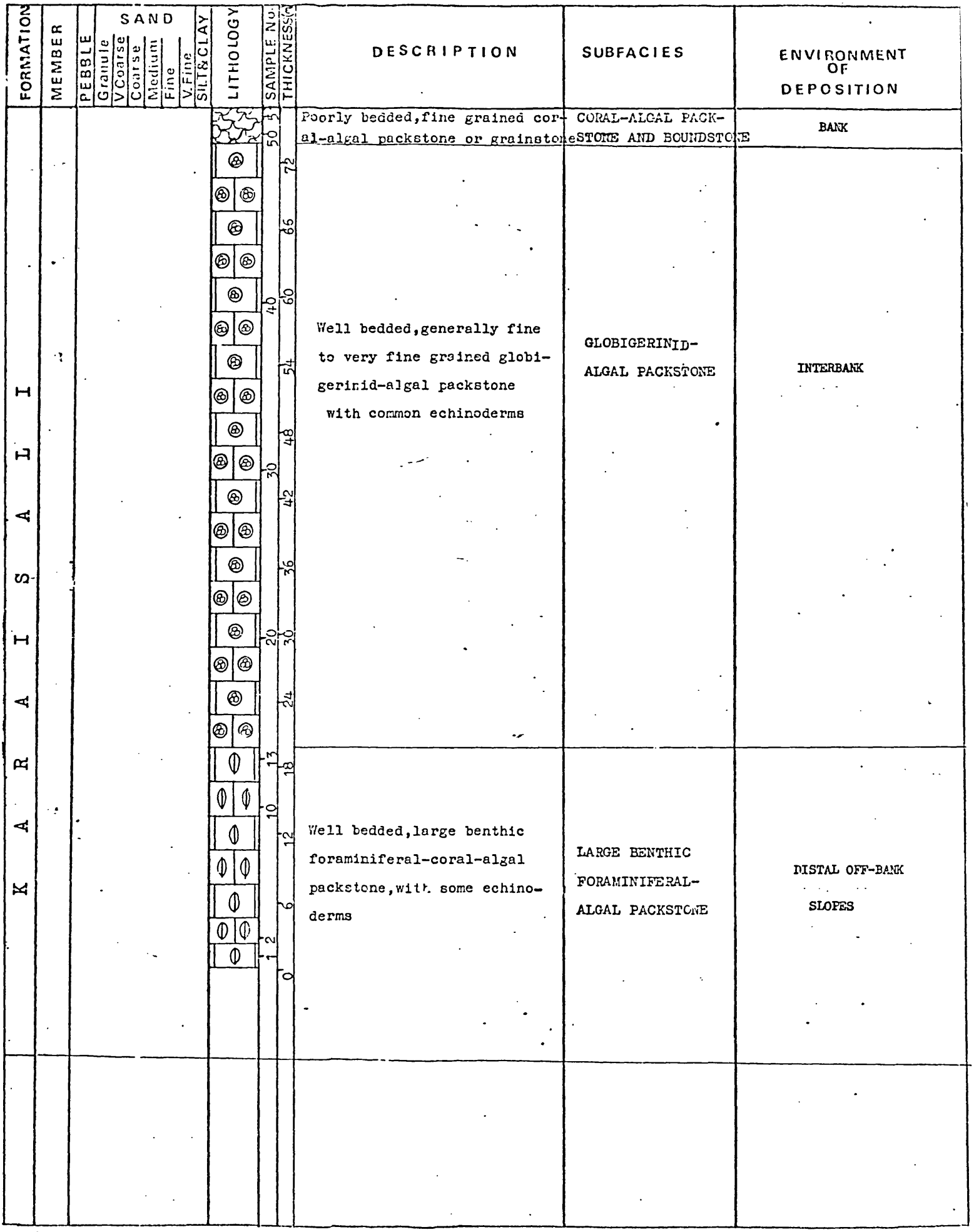
Measured section Cs in Cavuslu



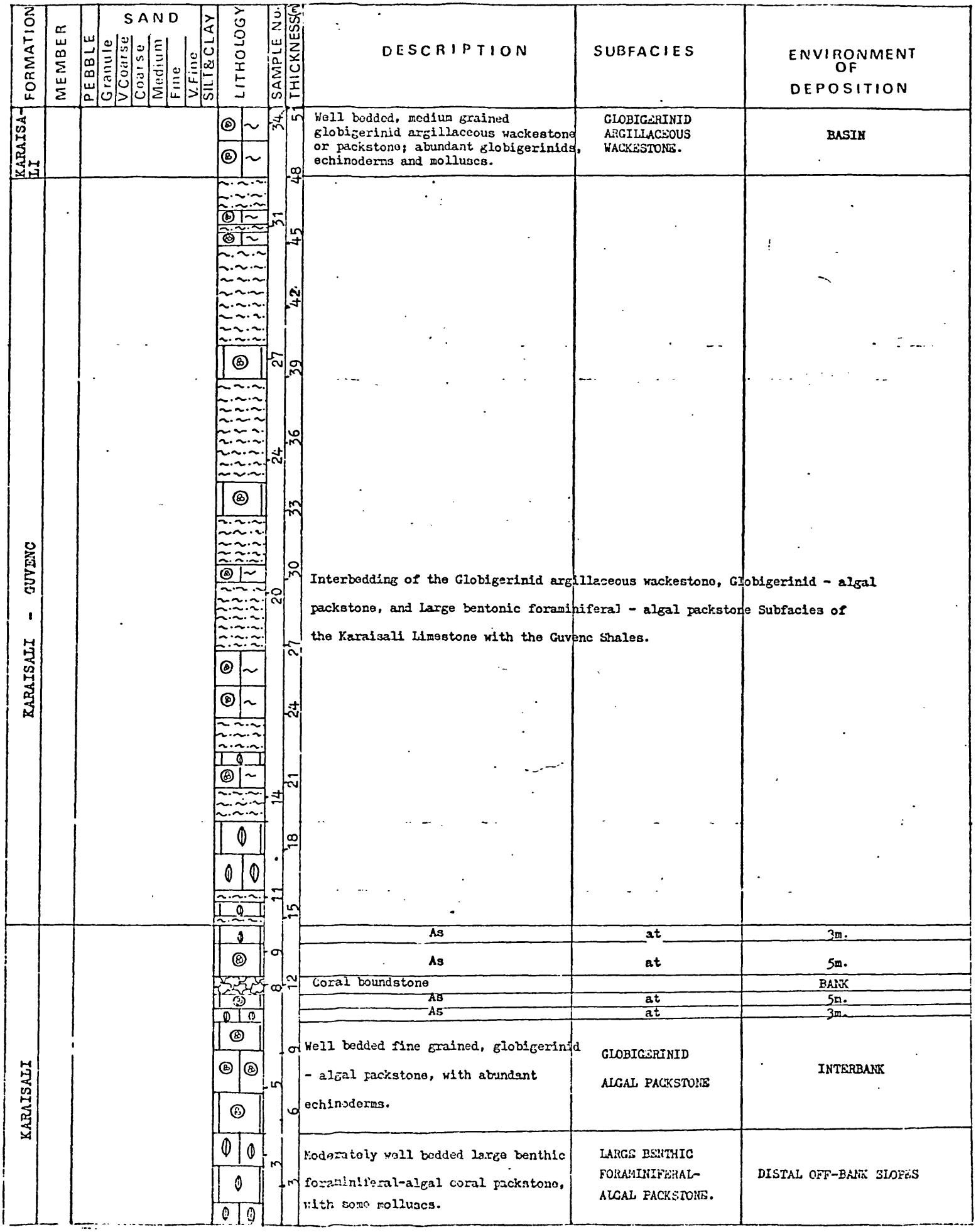
Measured section Cs_1 near Cavuslu



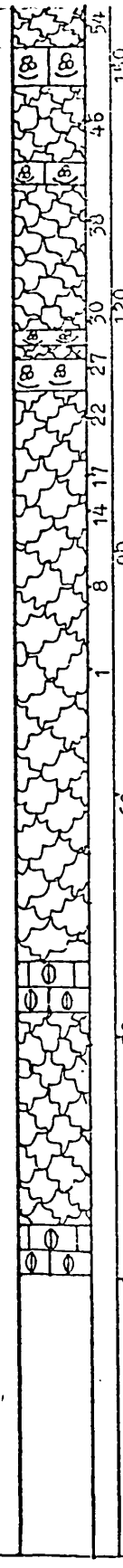
Measured section Hr near Cavuslu



Measured section Ko_1 near Kuzoluk



Measured section Ko near Kuzoluk

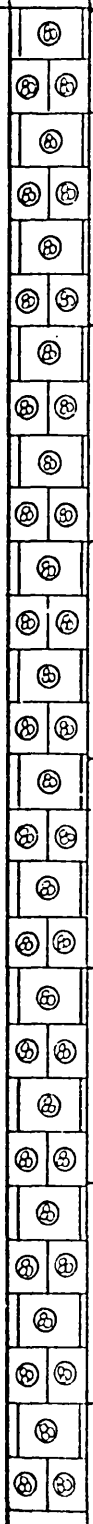


		BANK
A s a t	2 2 2 m.	
As at 330 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
A s a t	2 2 2 m.	
As at 330 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
A s a t	2 2 2 m.	
A s a t	2 2 2 m.	
As at 330 m.	CORAL -ALGAL PACKSTONE AND BOUNDSTONE	BANK
A s a t	2 3 4 m.	
As at 330 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
A s a t	2 3 4 m.	

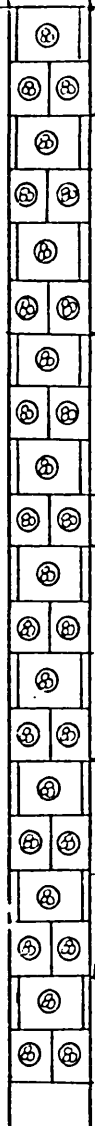
Measured section G1 continued

FORMATION	MEMBER	SAND: PEBBLE / Granule / V.Coarse / Coarse / Medium / Fine / V.Fine / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS m.	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KASAI				179	354	Poorly bedded coral-algal packstone and boundstone or mixture of them; coralline algae, corals, encrusting foraminifera, benthic foraminifera, echinoderms, and molluscs; recrystallization and stylolitization common.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
				171				
				163	330			
				155				
				147				
				139	300			
						A s a t 2 3 4 m.		
				131		As at 330m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
				115	270			
				107				
				100	240			
					234	Large benthic foraminiferal-algal wackestone or packstone; recrystallization common.	LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
				92	222	Poorly bedded, coarse to medium grained small benthic foraminiferal-algal packstone; coralline algae, miliolids etc.	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
				89	210	As at 234 m.	LARGE BENTHIC FORAMINIFERAL-ALGAL P.	DISTAL OFF-BANK SLOPES
						A s a t 3 3 0 m.		
				86		As at 234 m.	LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
				78		As at 222 m.	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
				71	180	As at 330 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
				62				

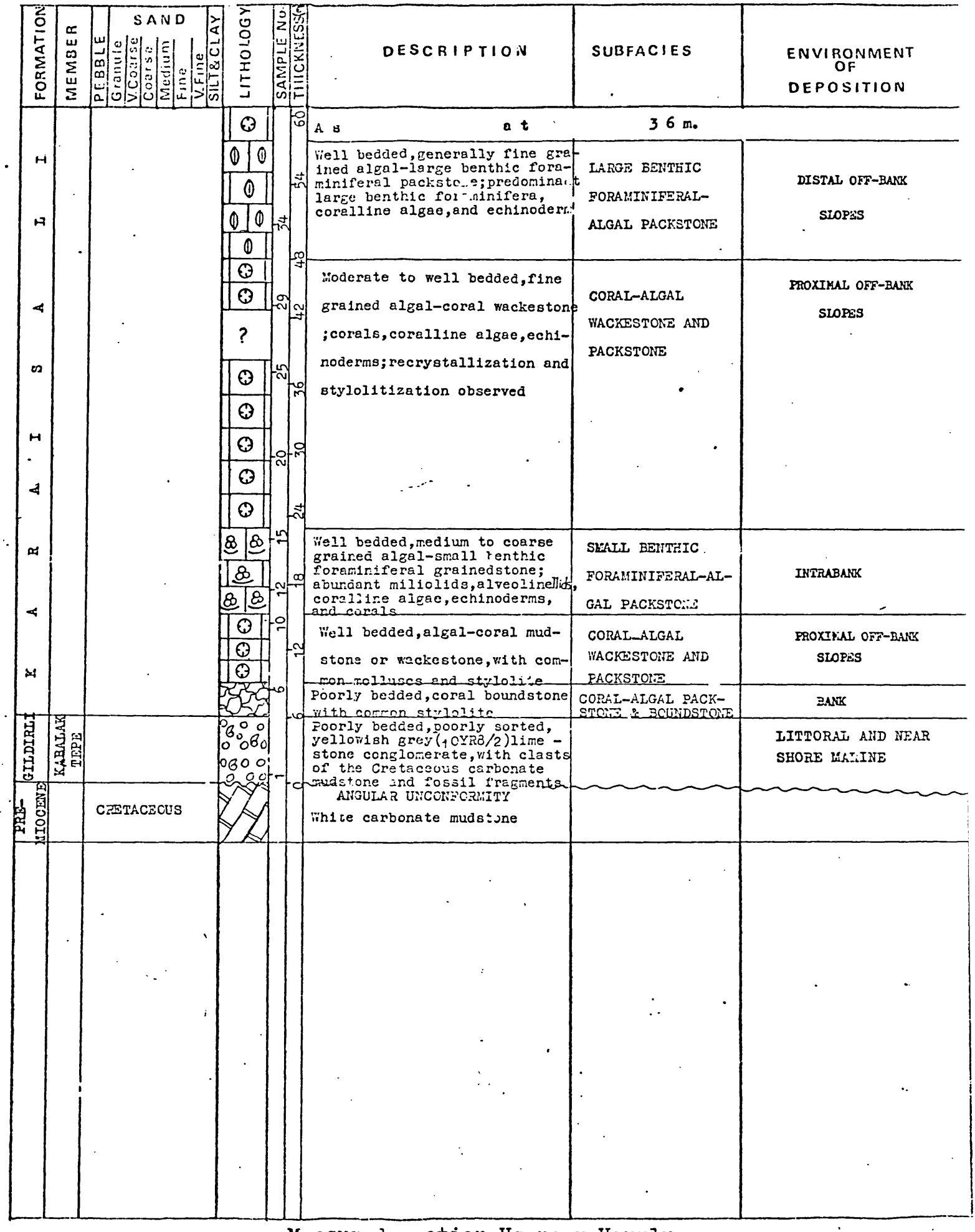
Measured section G1 at Gules Dagi

FORMATION	MEMBER	PEBBLE	SAND: Granule	SAND: V.Coarse	SAND: Coarse	SAND: Medium	SAND: Fine	SAND: V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS(m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI											7 6 5 4 3 2 1	9' 6' 3' d	Well bedded, very fine to fine grained globigerinid-algal packstone with some vertical and horizontal burrowing.	GLOBIGERINID - ALGAL PACKSTONE	INTERBANK

Measured section Dr at Direkli, Usunlu

FORMATION	MEMBER	PEBBLE	SAND: Granule / V.Coarse / Coarse / Medium / Fine / V.Fine	SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
K A R A I S A L I						4 3 2 1 0	7,5 6 3 0	Moderately well bedded, fine grained globigerinid-algal peckstone, with some vertical and horizontal burrowing	GLOBIGERINID-ALGAL PACKSTONE	INTERBANK

Measured section Pr at Partavut, Kuzoluk



Measured section Us near Usunlu

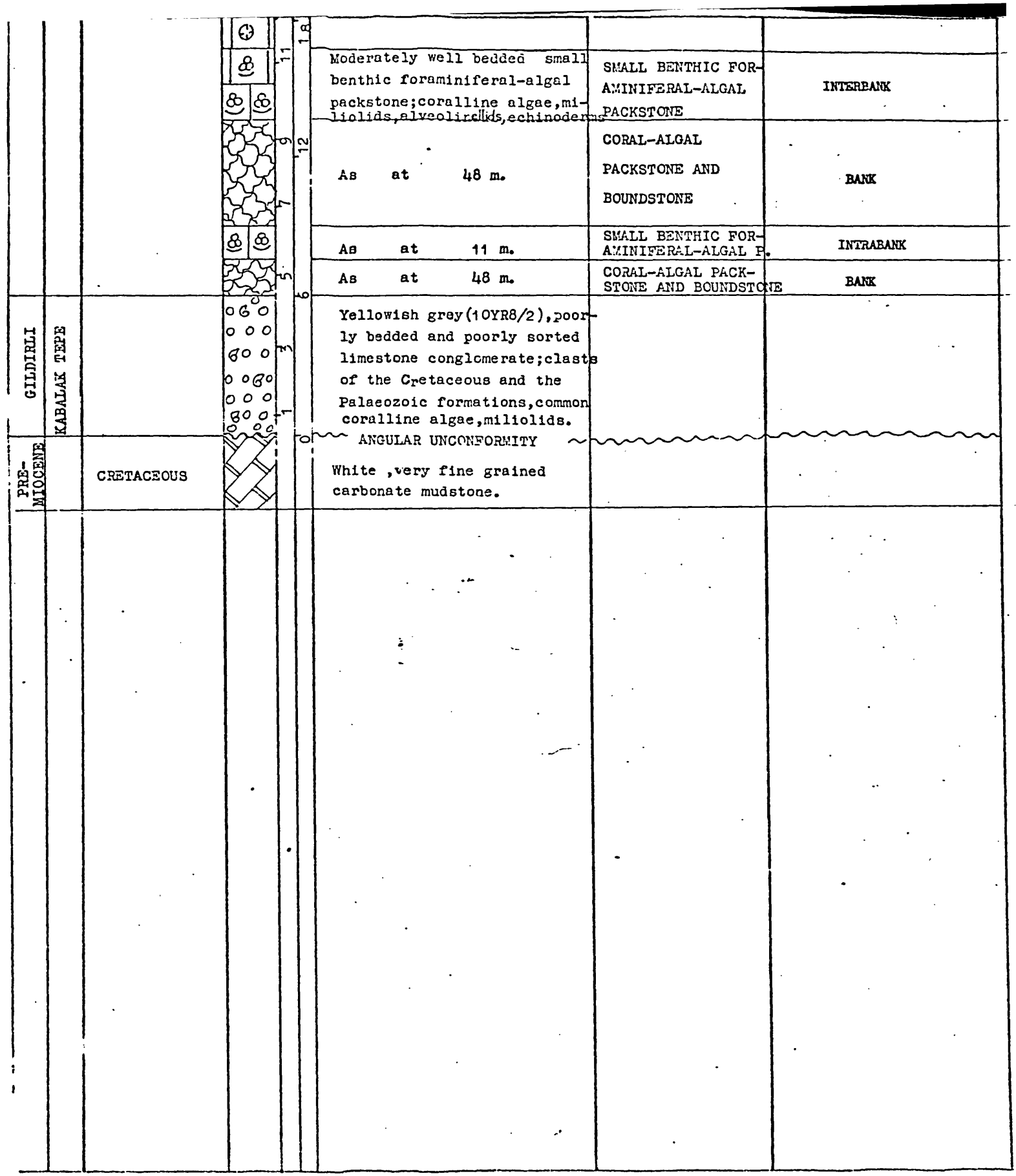
FORMATION	MEMBER	PEBBLE / SAND (Granule, V.Coarse, Coarse, Medium, Fine, V.Fine) / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				36	54	Well bedded, fine grained globigerinid-algal packst. with common echinoderm and worm tubes.	GLOBIGERINID-ALGAL PACKSTONE	INTERBANK
				26	36			
				16	24			
				9	12			
				1	6			
				0		Measured section Gi W of Kuzcluk		

FORMATION	MEMBER	PEBBLE / SAND (Granule, V Coarse, Coarse, Medium, Fine, V Fine) / SILT & CLAY	LITHOLOGY	SAMPLE No.	THICKNESS	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
GHIDIRLI	CAKMAK			10	12	Pale red (5R6/2) well bedded calcareous lithic arenite.		
				7		Pale red (5R6/2) poorly sorted limestone conglomerate; composed of rounded clasts of the Cretaceous and the Palaeozoic formations.		ALLUVIAL FANS
				4	6			
				2		As	at	10m.
				0		As	at	6m.

Measured Section MK2

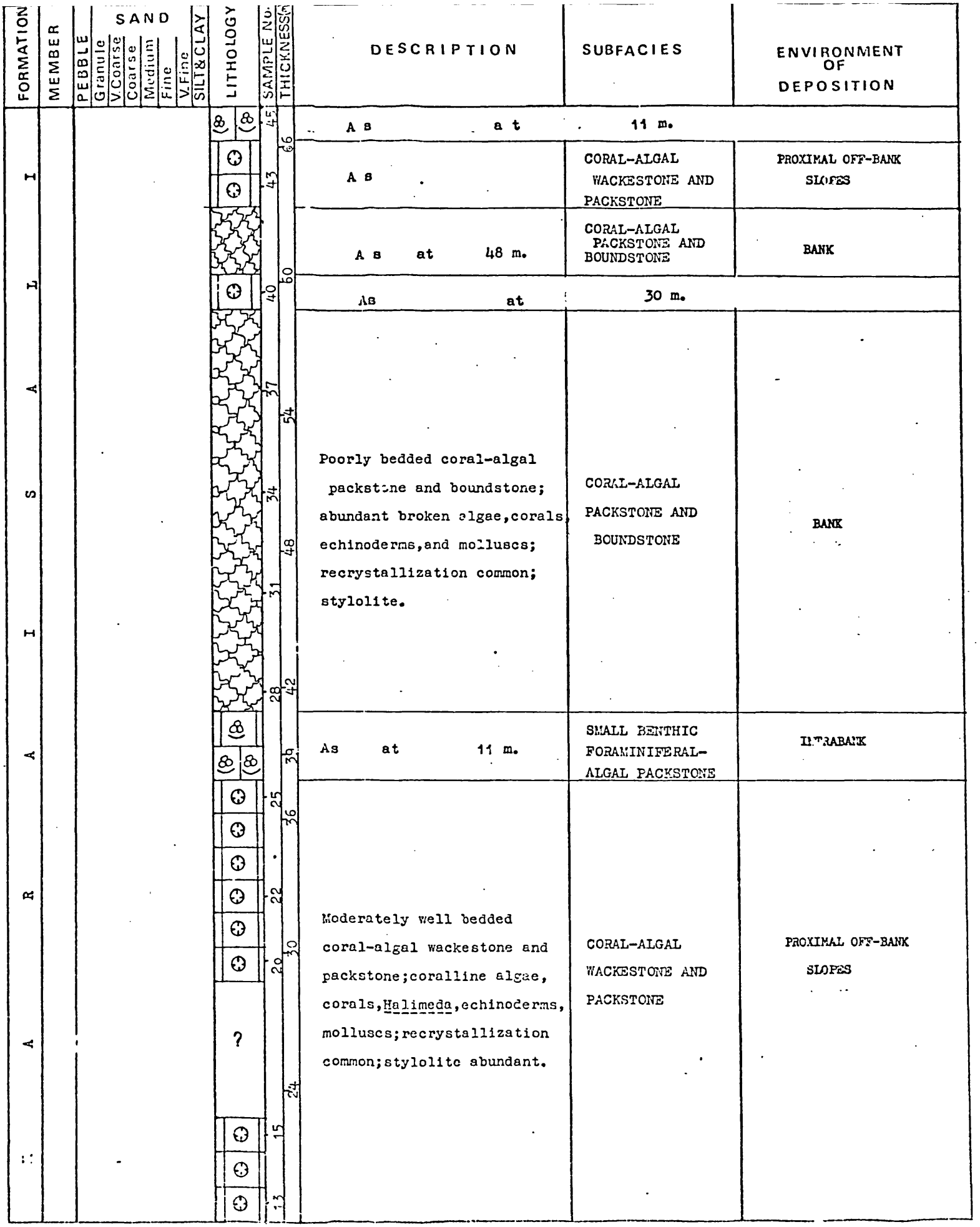
FORMATION	MEMBER	PEBBLE / SAND (Granule, V.Coarse, Coarse, Medium, Fine, V.Fine) / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
GILDIRLI	KABALAK T.			8	12	As at 1,5 m.		LITTORAL AND NEAR SHORE MARINE
KARAISALI				7	9	Well bedded, fine to very fine grained small benthic foraminiferal-algal packstone; coralline algae, miliolids, echinoderms, molluscs; recrystallization observable	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
				5	6			
				4				
				3	3	Recrystallized coral boundstone	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
GILDIRLI	KABALAK TEPE			2	1,5	Yellowish grey(10YR8/2), moderately well bedded limestone conglomerate; composed of clasts of the Cretaceous carbonate mudstone in a granule to very coarse grained skeletal matrix which contains abundant coralline algae small benthic foraminifera, molluscs, corals, echinoderms		LITTORAL AND NEAR SHORE MARINE
				1				
PRE MIOCENE		CRETACEOUS		0		UNGULAR UNCONFORMITY White, very fine grained carbonate mudstone		

Measured section Em_3 near Eminlik

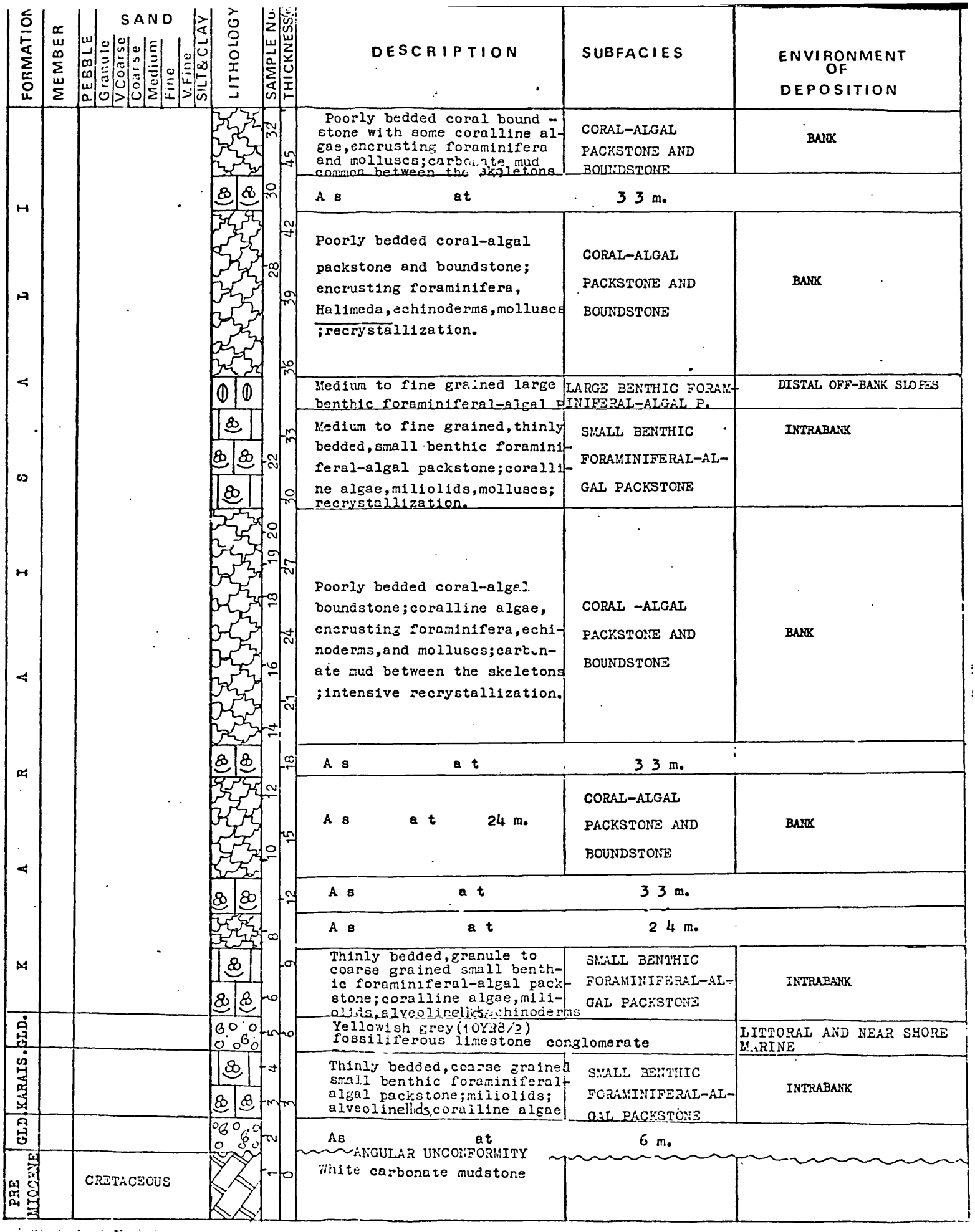


			18			
			11	Moderately well bedded small benthic foraminiferal-algal packstone;coralline algae,miliolids,alveolinellids,echinoderms	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTERBANK
			9	As at 48 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
			7	As at 11 m.	SMALL BENTHIC FORAMINIFERAL-ALGAL P.	INTRABANK
			5	As at 48 m.	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
GILDIRLI	KABALAK TEPE		6	Yellowish grey(10YR8/2),poorly bedded and poorly sorted limestone conglomerate;clasts of the Cretaceous and the Palaeozoic formations,common coralline algae,miliolids.		
			3			
			1			
			0	ANGULAR UNCONFORMITY		
PRE-MIOCENE		CRETACEOUS		White ,very fine grained carbonate mudstone.		

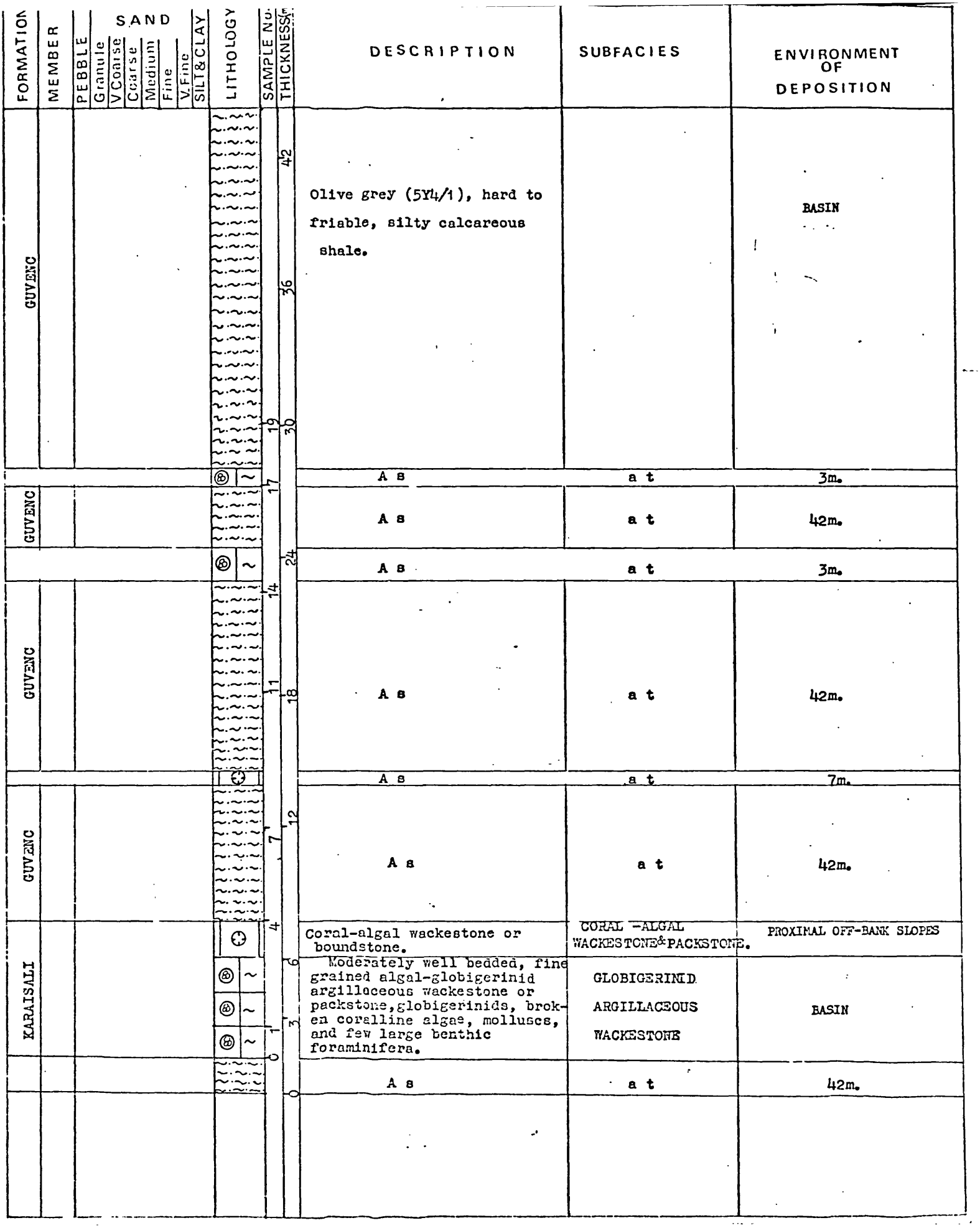
Measured section Em_2 continued



Measured section Em_2 near Eminlik



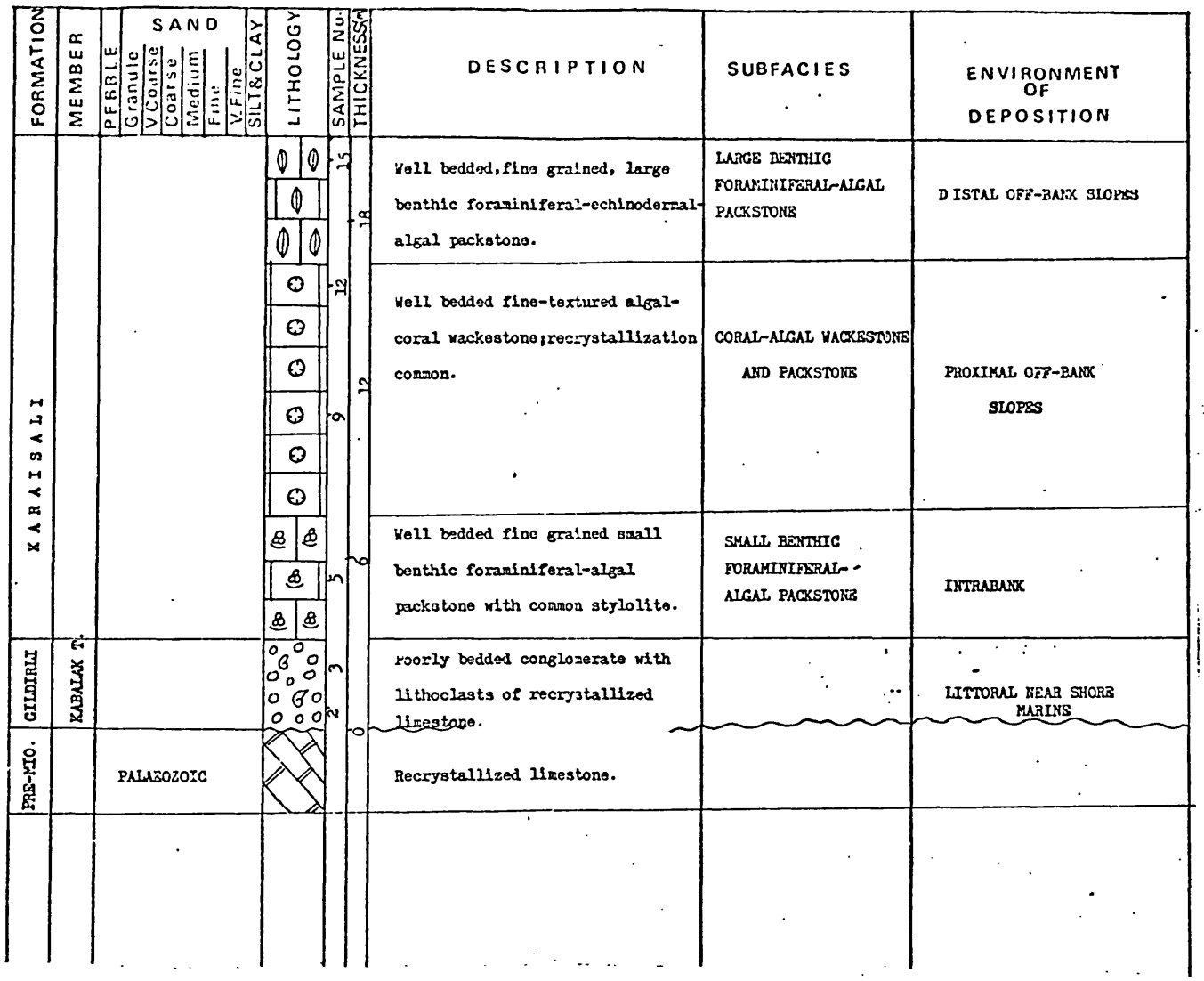
Measured section Em$_1$ near Eminlik



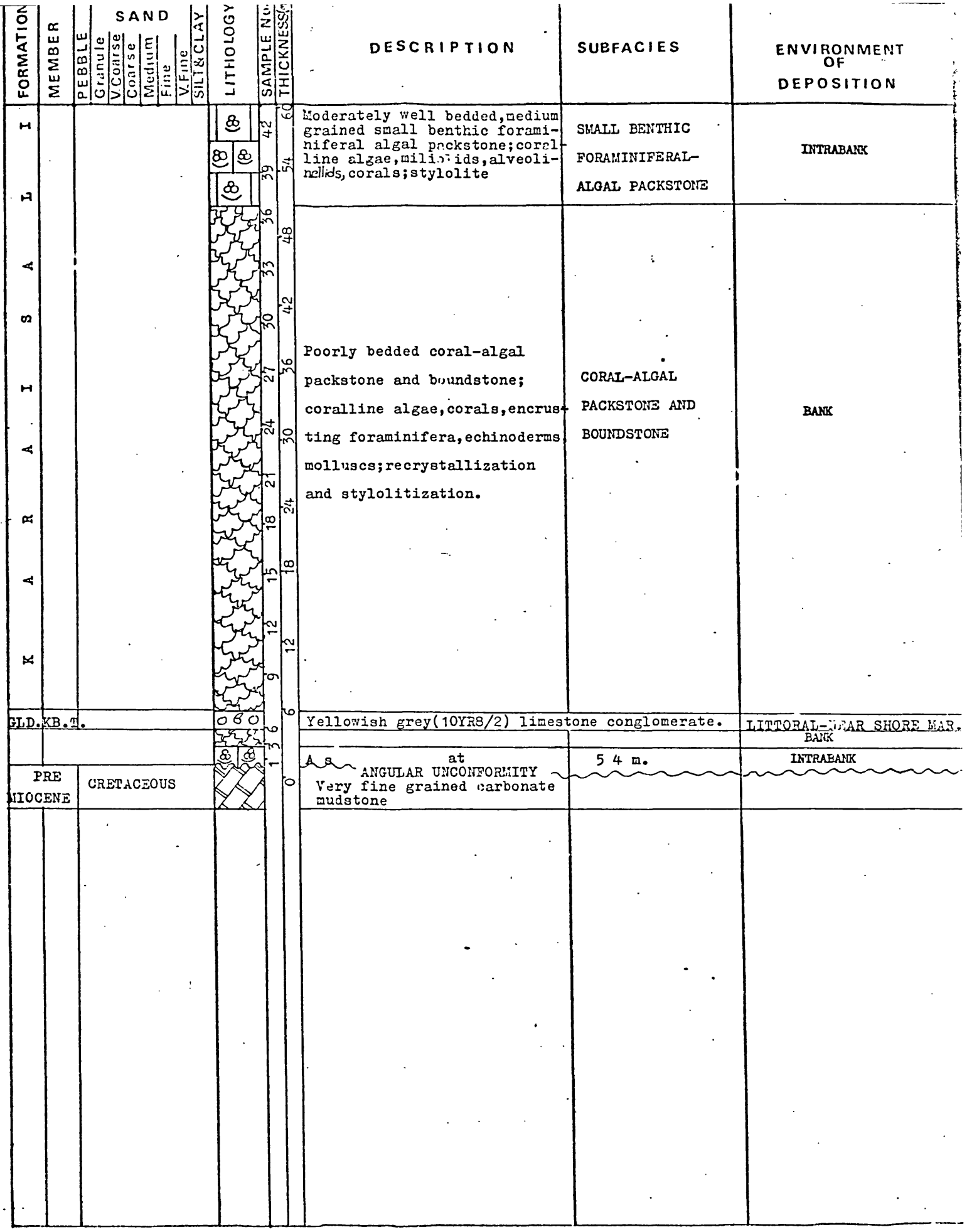
Measured section BC near Bucak

FORMATION	MEMBER	PEBBLE / SAND / SILT&CLAY	LITHOLOGY	SAMPLE No.	THICKNESS (m)	DESCRIPTION	SUBFACIES	ENVIRONMENT OF DEPOSITION
KARAISALI				9	12	Well bedded, generally fine grained, globigerinid-algal packstone; abundant coralline algae, globigerinids, echinoderms, molluscs	GLOBIGERINID-ALGAL PACKSTONE	INTERBANK
						As at 6 m.		
				8	6	Moderately to poorly bedded coral-algal wackestone	CORAL-ALGAL WACKESTONE AND PACKSTONE	PROXIMAL OFF-BANK SLOPES
				5	6	Large benthic foraminiferal-coral-algal packstone	LARGE BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	DISTAL OFF-BANK SLOPES
						As at 9 m.		
						Poorly bedded, coral-algal packstone and boundstone	CORAL-ALGAL PACKSTONE AND BOUNDSTONE	BANK
				1		Small benthic foraminiferal-algal packstone with corals, echinoderms, and molluscs.	SMALL BENTHIC FORAMINIFERAL-ALGAL PACKSTONE	INTRABANK
					0			

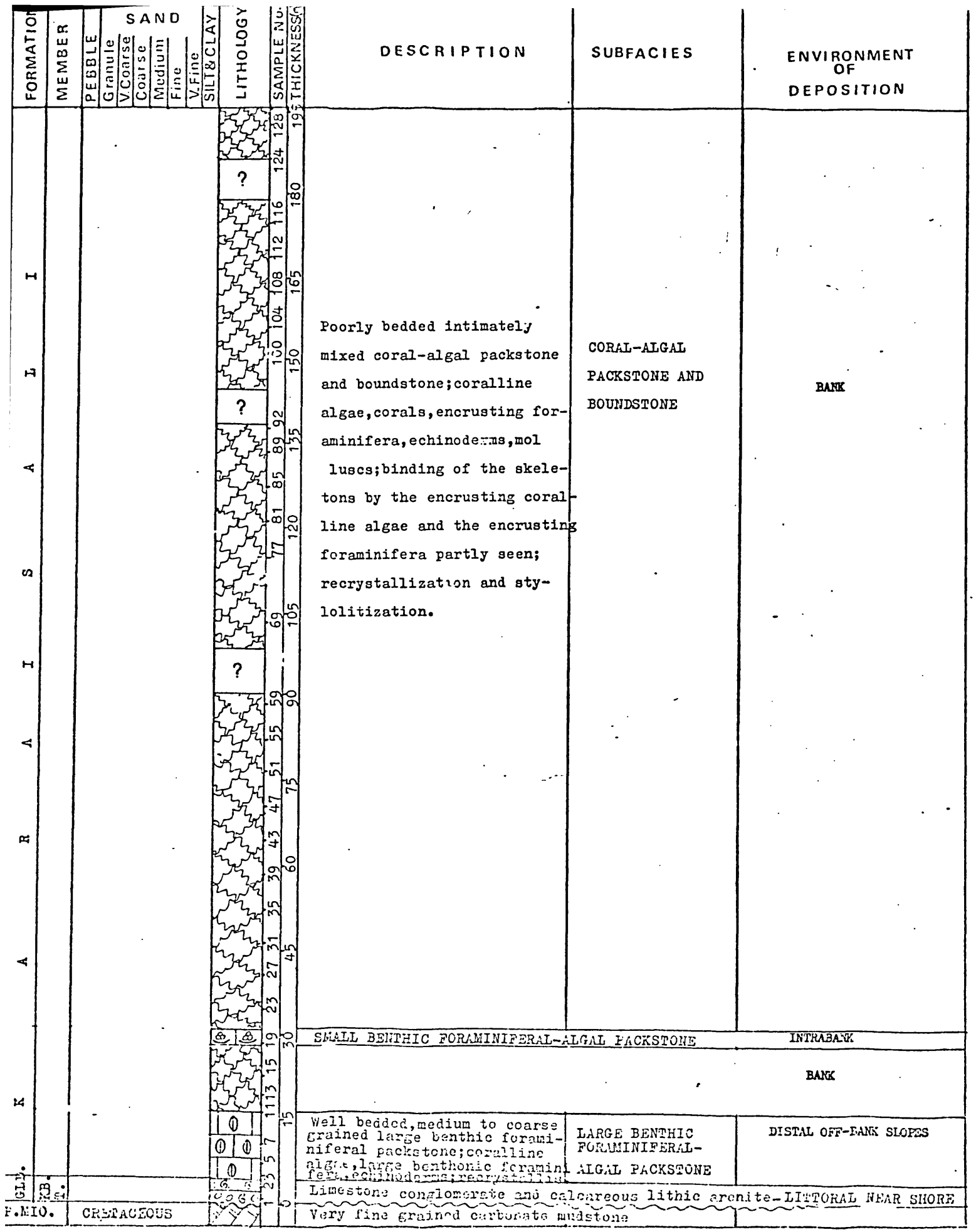
Measured section Kal at Kaldiravik Dagi, E of Eminlik



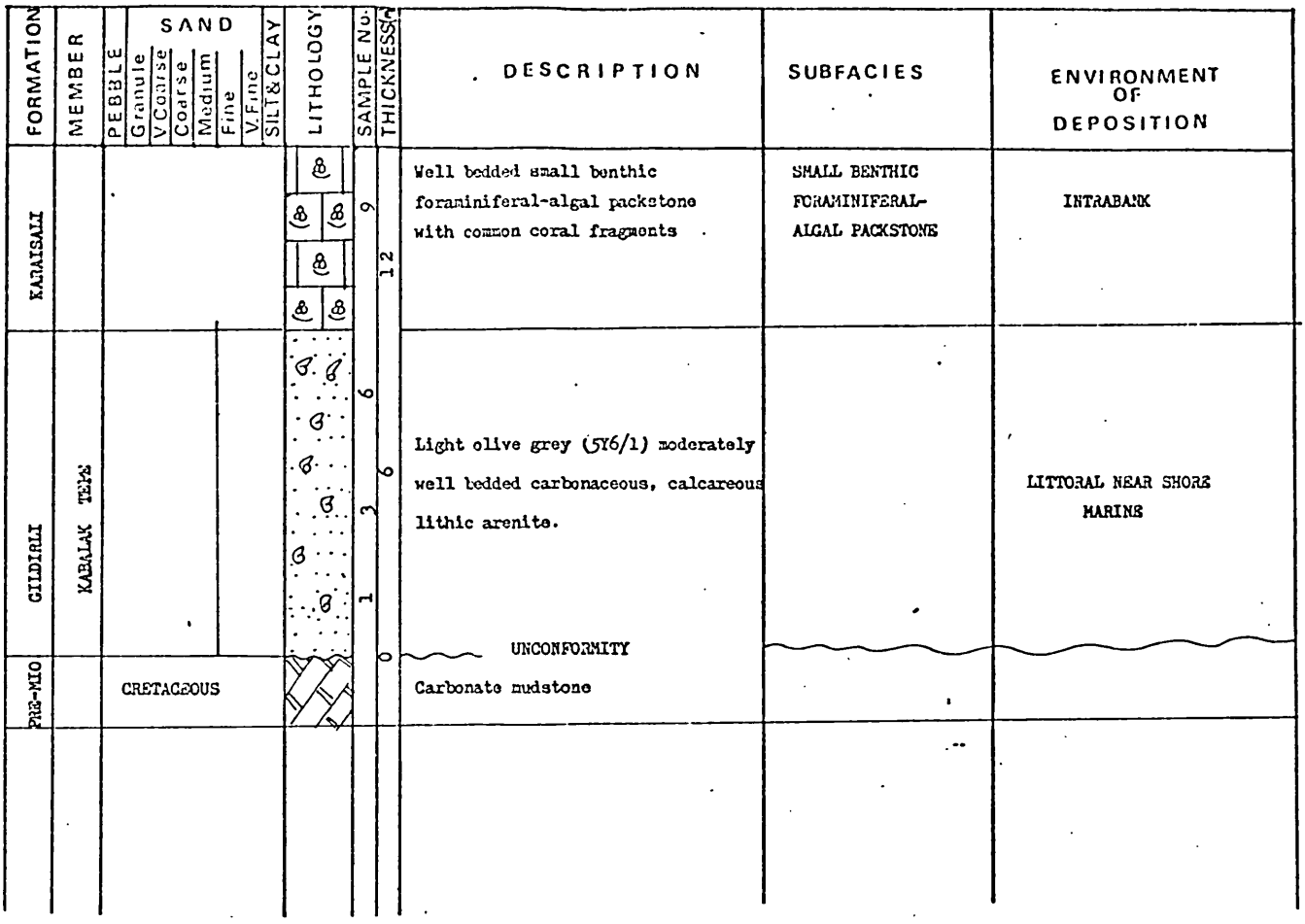
Measured section As at Asartepe ,Emirler



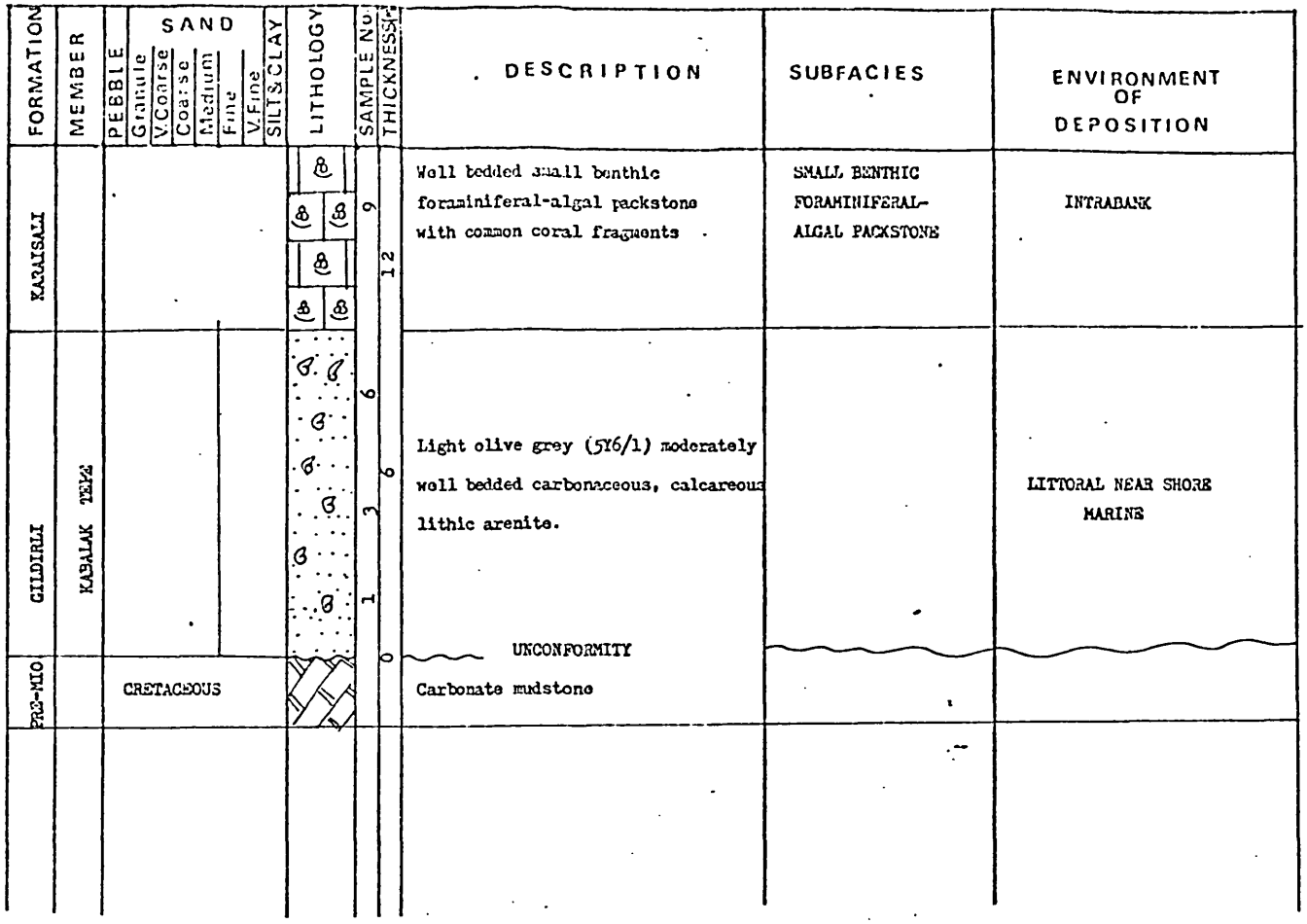
Measured section Tp at Topusur Tepe,Karakilic



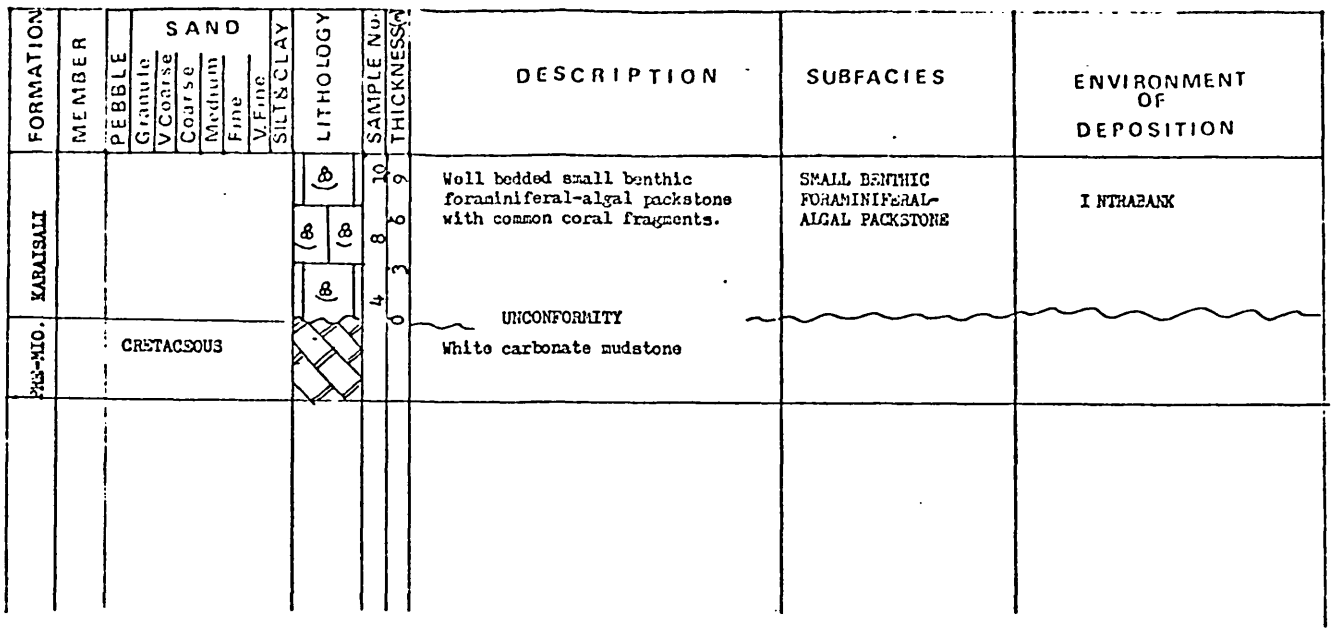
Measured section Kt at Kessek Tepe



Measured section Mk_3 near Karakilic



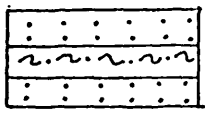
Measured section D at Dari cukuru



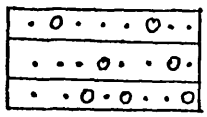
Measured section Ks at Kesli



Alluvium & Caliche

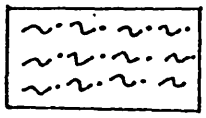


Alternating sendstone and shale (Topalli Member)



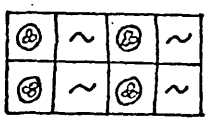
Conglomeratic sendstone (Ayva Member)

} CINGOZ FORMATION

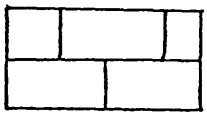


Calcareous shale

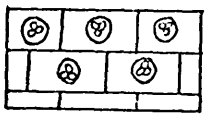
} GUVENC FORMATION



Globigerinal argillaceous wackestone

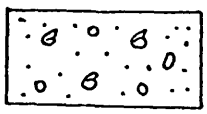


Coral-algal packstone & boundstone;Small benthic foraminiferal-algal packstone; Coral-algal wackestone & packstone;Large benthic foraminiferal-algal packstone

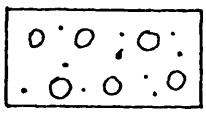


Globigerinal-algal packstone

} KARAISALI FORMATION

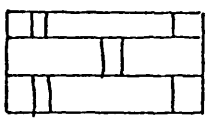


Gray conglomerate sandstone & siltstone (Kabalak Tepe Member)

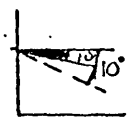


Red conglomerate sandstone & siltstone (Cakmak Member)

} GILDIRLI FORMATION



Undifferentiated carbonates, dolomites & sandstones



Angular exaggeration(true ➡ exaggerated ➡)as used on sections.



Micro-cross lamination



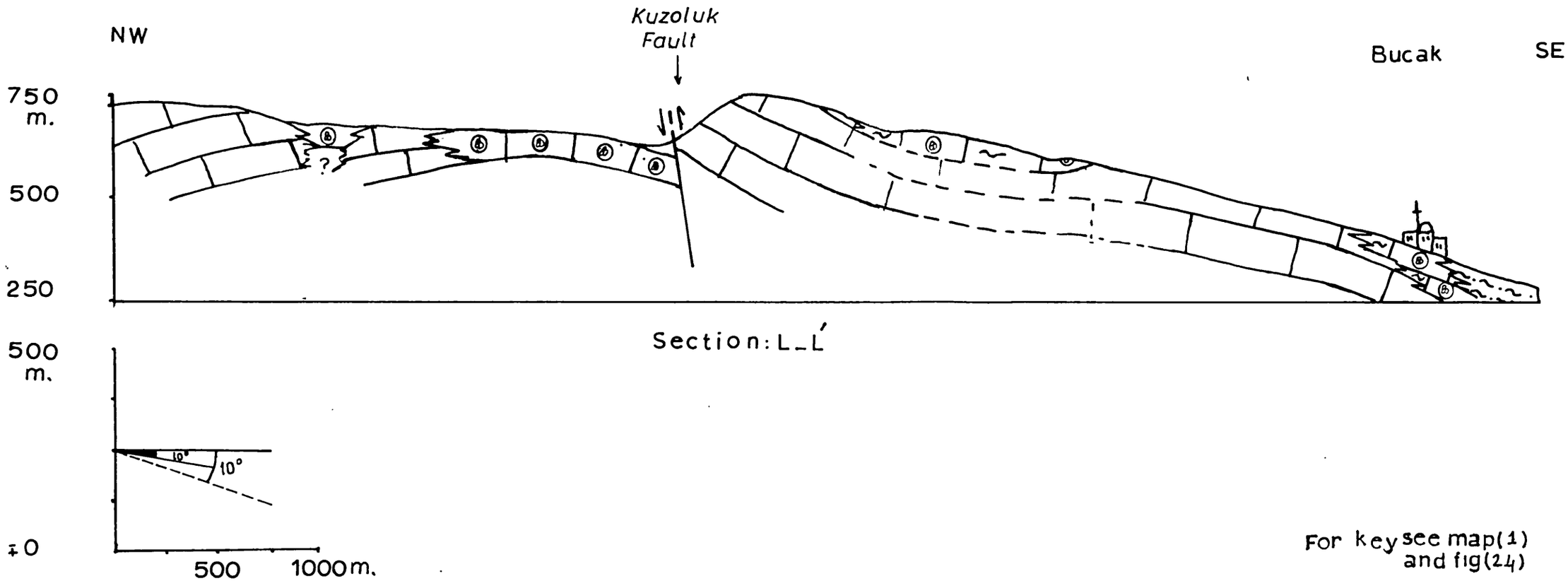
Burrowing

ABBREVIATIONS

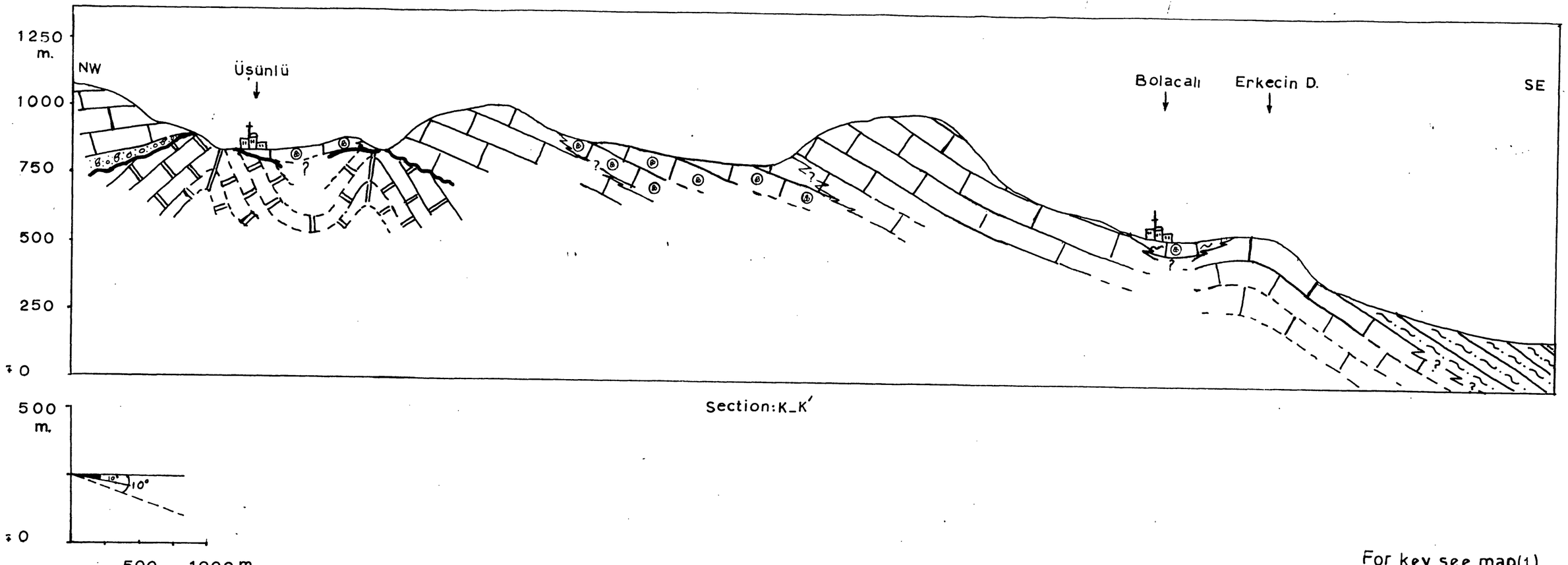
GLD. Gildirli Formation

KBT. Kabalak Tepe Member

Fig(24): Key

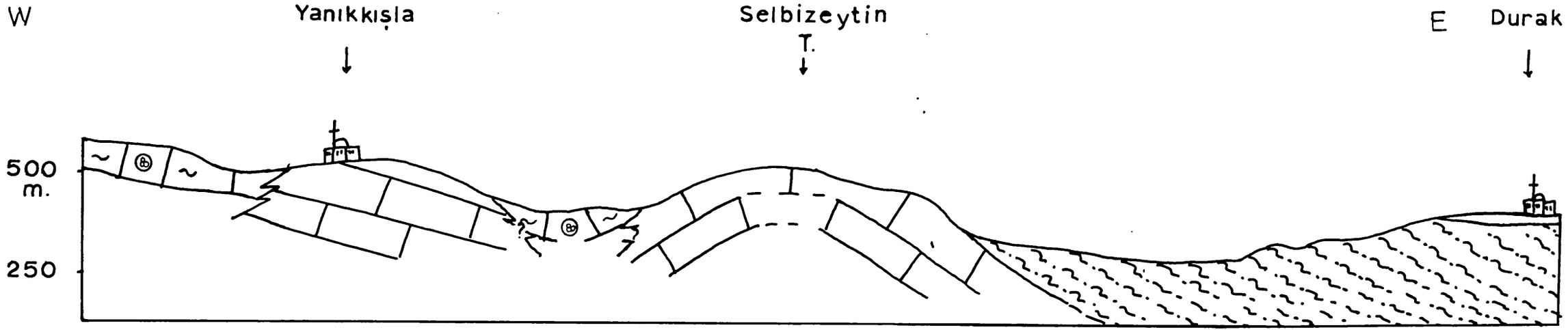


For key see map(1)
and fig(24)

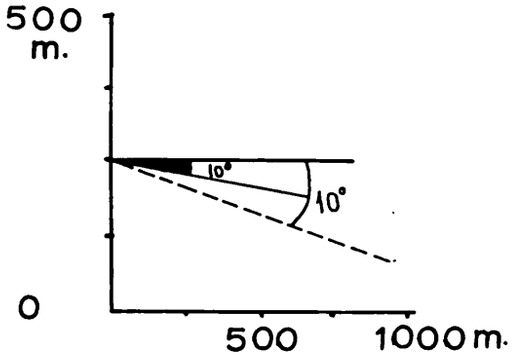


Section: K_K'

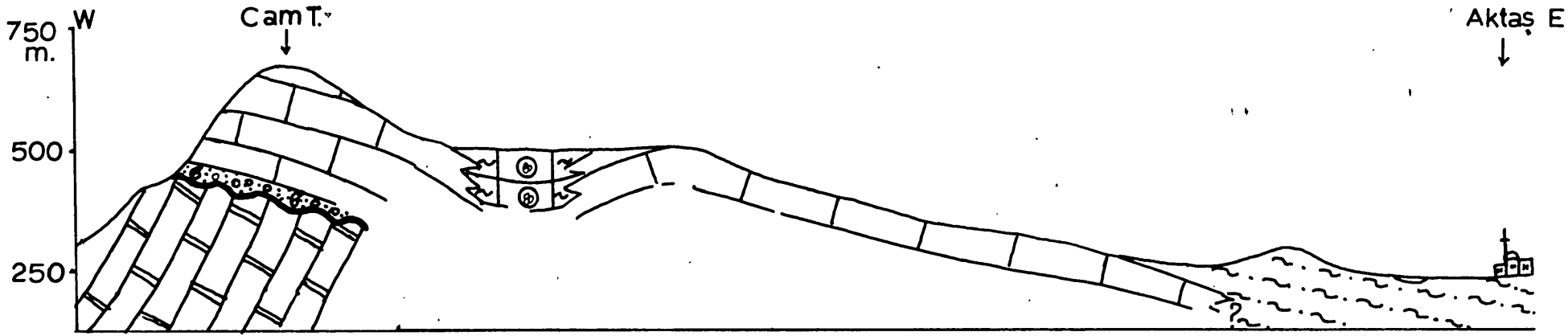
For key see map(1)
and fig:(24)



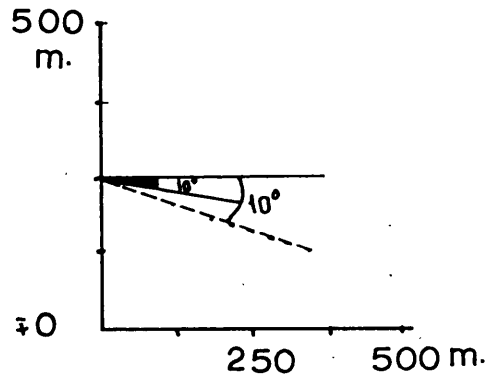
Section: M_M'



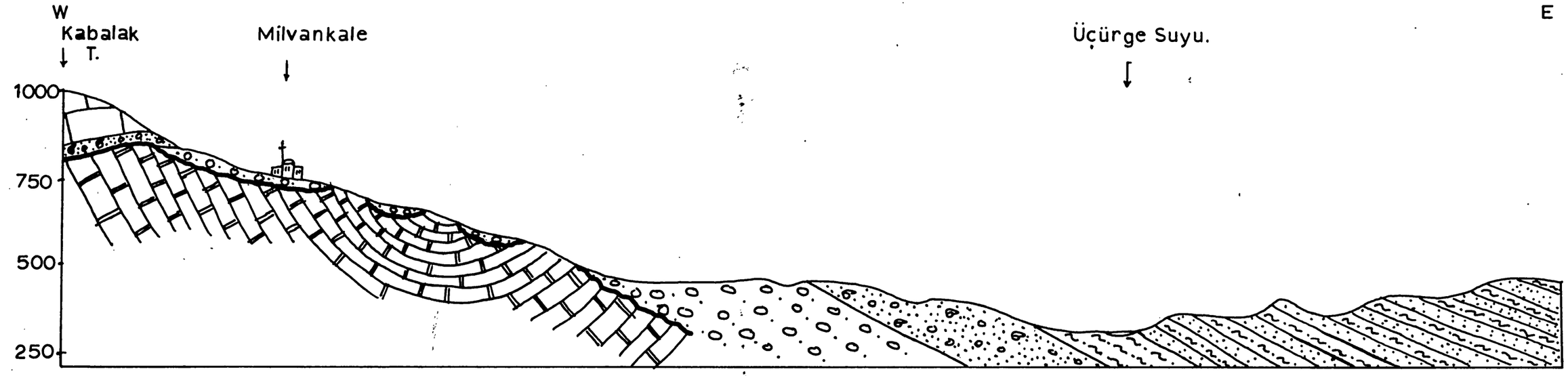
For key see map(1) and fig:(24)



Section: J–J′

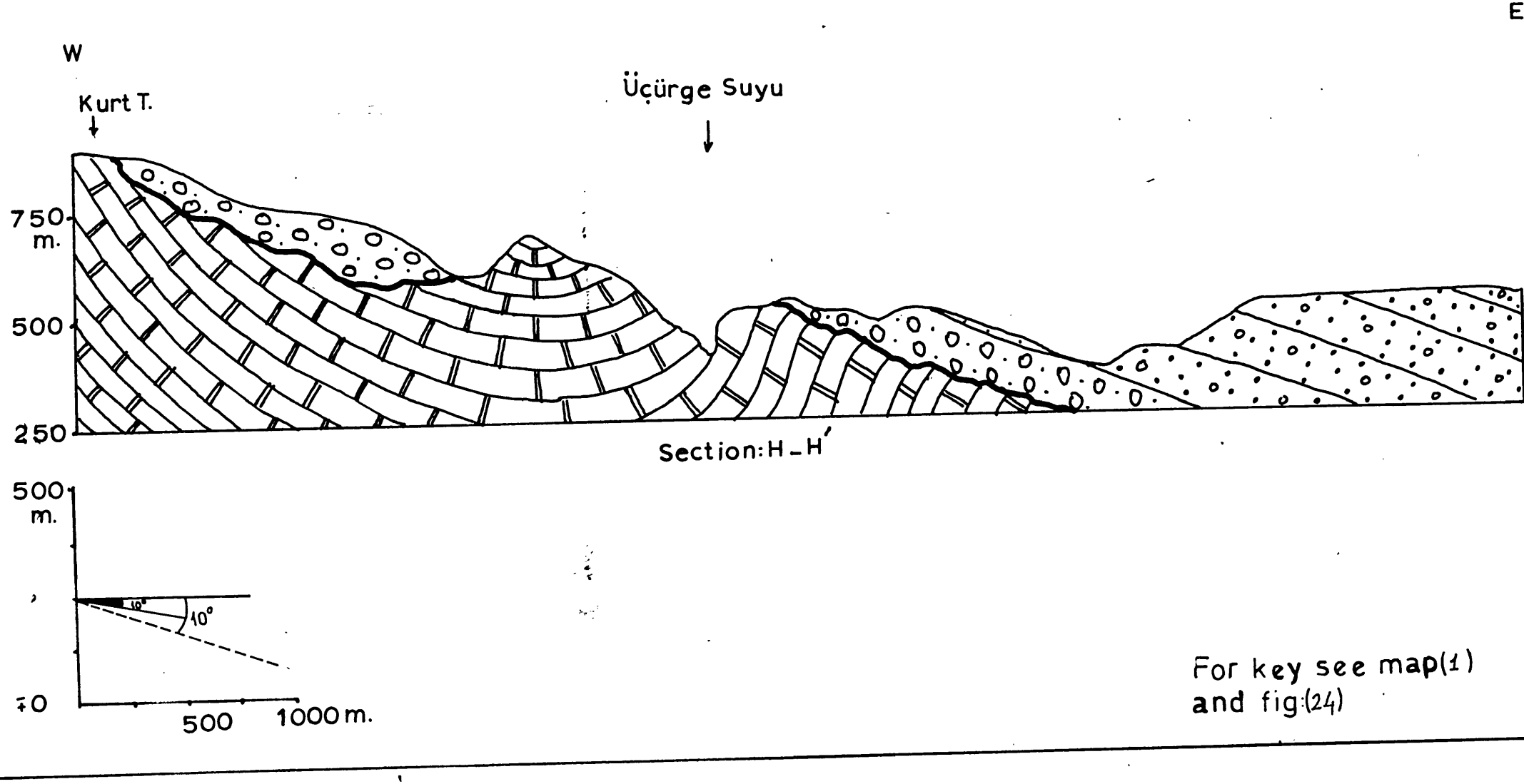


For key see map(1) and fig:(24)

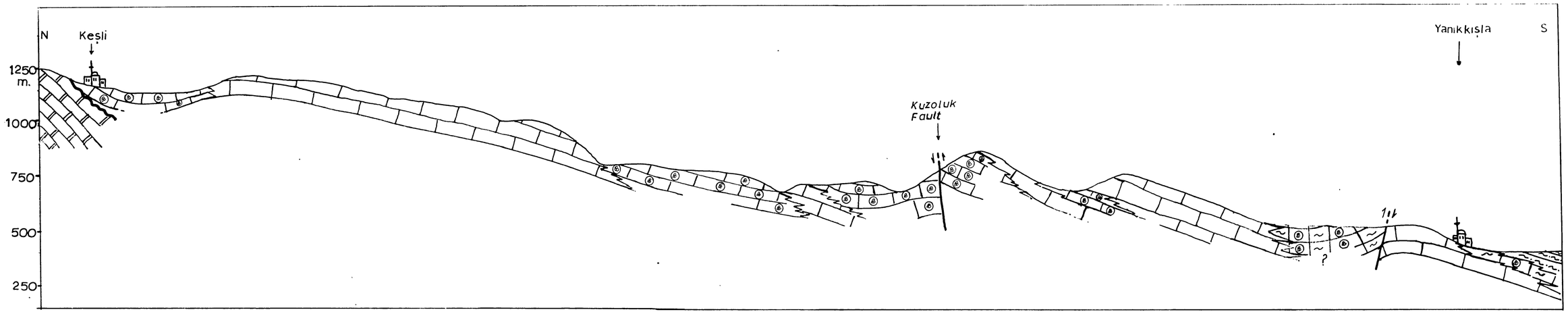


Section: I–I′

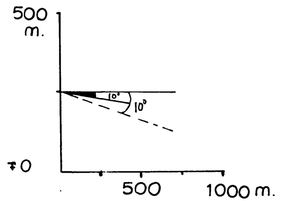
For key see map(1) and fig:(24)



For key see map(1) and fig:(24)

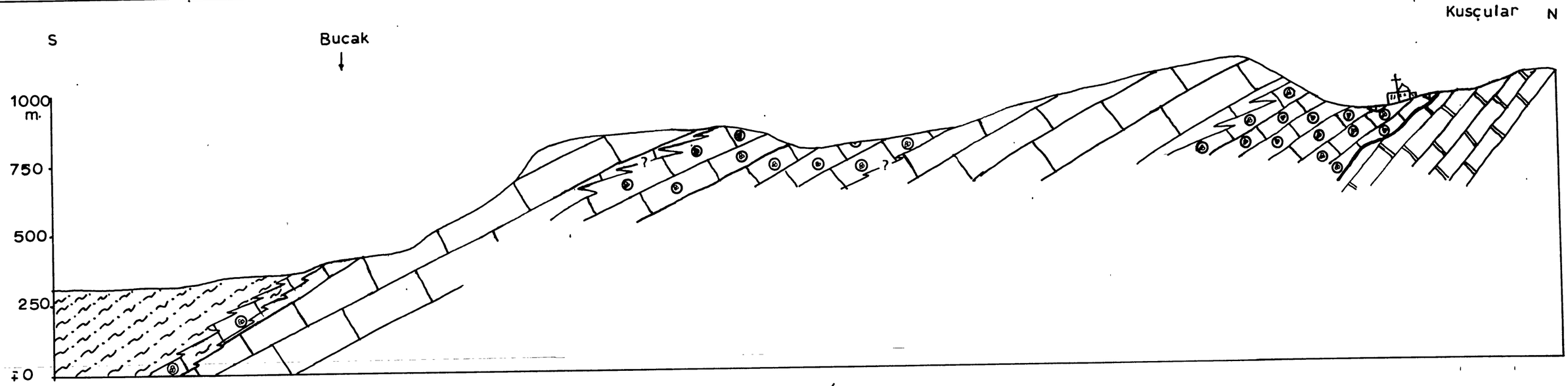


Section: G–G′

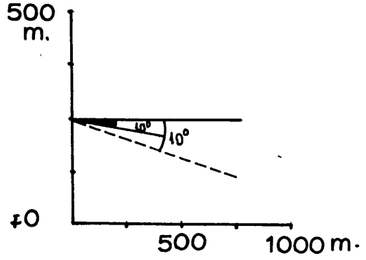


For key see map(1) and fig(24)

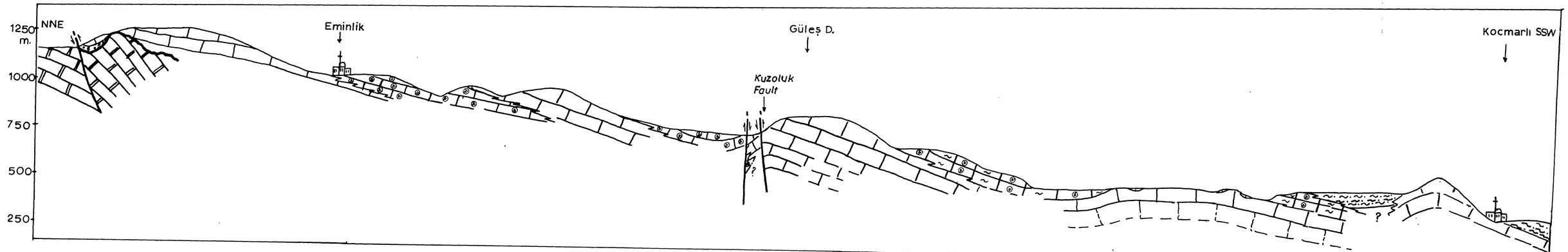
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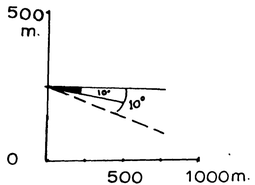
Section: E_E'



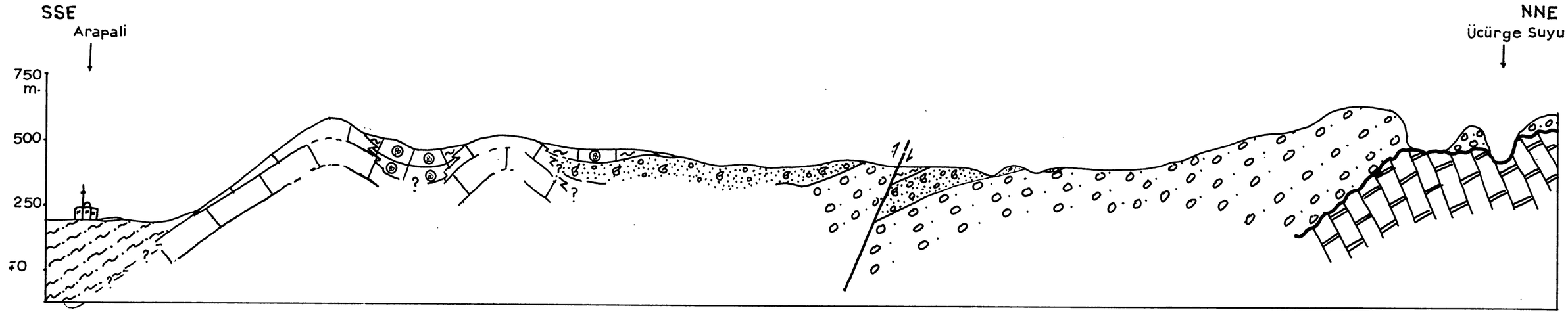
For key see map(1) and fig:(24)



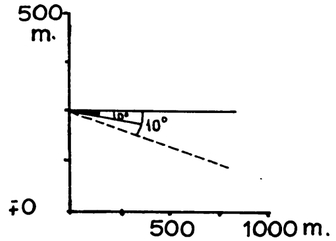
Section: F_F′



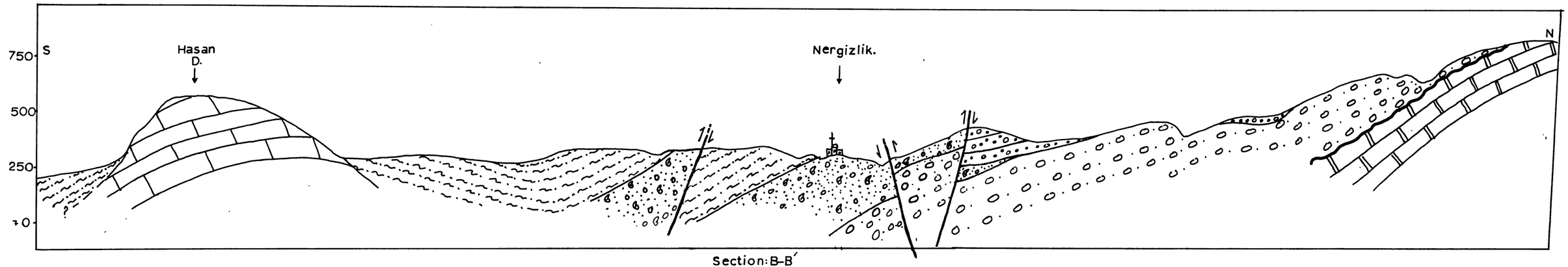
For key see map(1) and Fig(24).



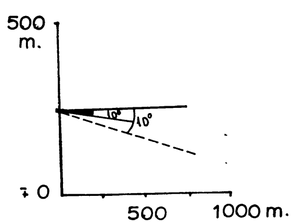
Section: C–C′



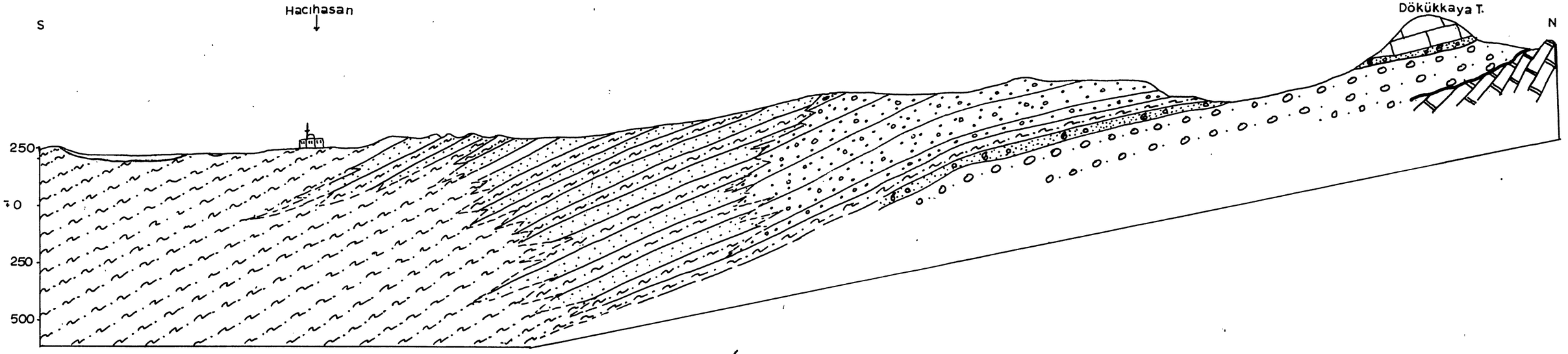
For key see map(1) and fig:(24)



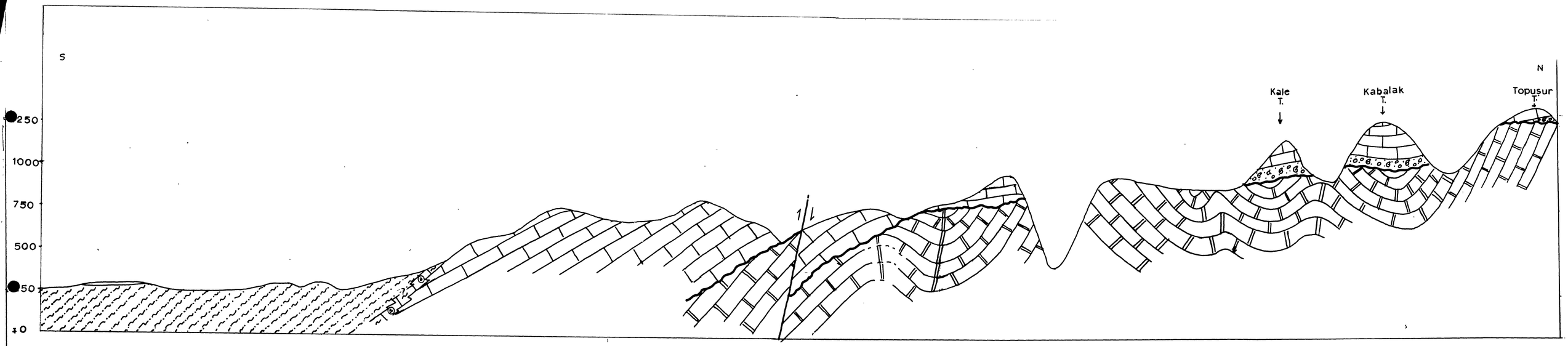
Section: B-B´



For key see map(1)
and fig:(24)



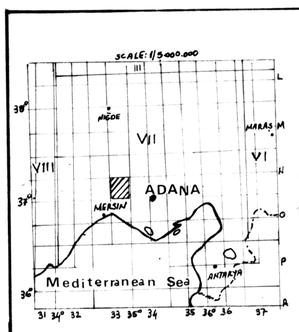
For key see map(1) and fig:(24)

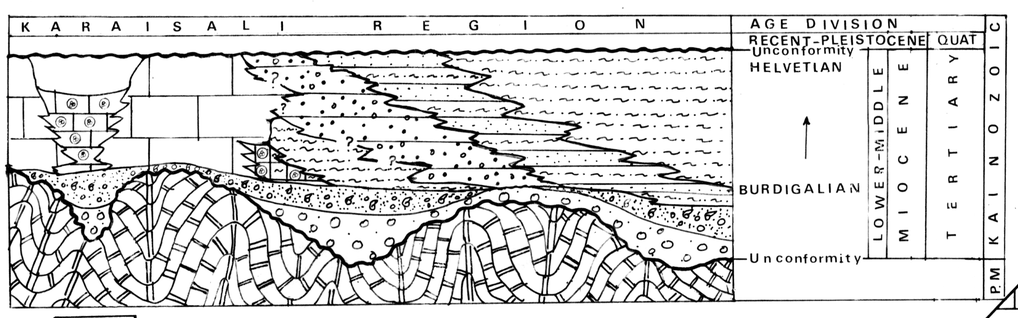


Section: D_D'

For key see map(1) and fig:(24)

GEOLOGICAL MAP OF THE KARAISALI AREA





- Alluvium & Caliche
- Alternating sandstone and shale (Topallı Member) — CINGOZ FORMATION
- Conglomeratic sandstone (Ayva Member) — CINGOZ FORMATION
- Calcareous shale — GUVENC FORMATION
- Globigerinal argillaceous wackestone — KARAISALI FORMATION
- Coral-algal packst.&boundst; Small benthic foraminiferal-algal packst.; Coral-algal - wackest.&packst.; Large benthic foraminiferal-algal packst. — KARAISALI FORMATION
- Globigerinal-algal Packstone — KARAISALI FORMATION
- Gray Conglomerate Sandstone and Siltstone (Kabalak Tepe Member) — GILDIRLI FORMATION
- Red Conglomerate Sandstone and Siltstone (Çakmak Member) — GILDIRLI FORMATION
- Undifferentiated carbonates, dolomites and sandstones

Dökukkaya T. 860
Solaklı
Gildirli
Çakmak
Emirler
Nergizlik
Karakilit
Kabalak T. 1376
Kale T.
Kessek T.
Un
Camizli
Gulüslü
Kelkoy
Hacıhasan
Saydere
Aktas
Camt. 724
Kestepe
KARAISALI
Kis
Hasandagı 639
Kırılan
Eminlik
Kaldıravık dagı
Ebcet dagı
Erkecin dagı
Arapali
Bolacali
Ebulhadi
Haydar.t. 748
Güles dagı
Kuzoluk
Usunlu
Cakit
Kusculak
Cavuslu
Akgedik
Hankası
Durak
Yanıkkışla
Kocmarl
Bucak
Çokak

0 500 1000 m.

- Horizontal Strata
- Dip and Strike
- Fault (u / d)
- Fault Zone
- Formation Boundary
- Unconformity
- Location of Measured Section
- Location of Cross Section
- Spot Height (639)
- Stream
- TOwn & Village (Bucak)
- Railway

By N. GORUR, 1977