BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION

Foreign Edition **2000** **Number : 122**

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POSTAL ADDRESS

Maden Tetkik ve Arama Genel Müdürlüğü
Bilimsel Dökümantasyon ve Tanıtma Dairesi
Neşrişat Servis Şefliği
06520 Ankara - TURKEY

The Bulletin of the Mineral Research and Exploration (MTA) is published twice yearly. Each issue appears in Turkish and foreign editions. It covers the whole range of Geology (Paleontology, Mineralogy, Geochemistry) and Mining.

ISSN 0026 - 4563

Mineral Res. Expl. Bul., 122, 1-21, 2000

DEPOSITIONAL ENVIRONMENTS AND SEQUENCE STRATIGRAPHY OF GLAUCONITES OF WESTERN BLACK SEA REGION

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ABSTRACT.- Glauconitic sediments which are subject to this study, have been deposited with different age and facies characteristics around Devrek-Zonguldak and Kastamonu regions. Glauconies within Lower Cretaceous sequence of Western Black sea region, developed in siliciclastic units which had been deposited in outer shelf by transgressive conditions. Typical occurrences, are found in Sapca formation of Zonguldak region. Glauconitic sandstones have preferably been accumulated in sand bars during sea level changes controlled by eustatic and tectonic factors. These sediments are characterised by large and small scale cross beddings, sheet sands with parallel lamination, and bioturbation. Glaucony grains within the sandstones have autochthon and allocton characteristics according to their depositional environments. The movements within the environment of glaucony formation had been accomplished by long and short distance displacements. In consequence limestone, quartz, feldspar and mafic rock grains which had been subjected to different degrees of glauconitisation were concentrated in off shore sand bars. The glauconies have been cemented by argillaceous matrix that shows different degree of glauconitisation or rarely cemented by carbonate within the silicislastics. The glauconitisation in Kastamonu region is observed within Lower Eocene units. This mineralisation had been developed in carbonate facies which differs from Zonguldak region. The areas where Lower Eocene limestones of reefal characteristics laterally pass to open sea facies, have prepared suitable environmental conditions for the glaucony formations. Fossil, intraclast and pellet type carbonate grains in this level have been glauconitised by different degrees and exhibit hard ground and complete authocthon properties. Glaucony occurrences of the region have widely been controlled by sea level changes. Autochthon glauconies of silisiclastics of Zonguldak region which had especially been formed in periods of maximum transgression, were transported to the lower system tracts by regression of the sea. Glaucony formation of Kastamonu region occurred in hard grounds which marked upper surface of reefs when they had been drowned by rapid rising of sea level.

INTRODUCTION

Glauconitic facies which are characterised by green grains of sand-gravel size within sedimentary sequences, have been formed in recent continental shelfs with their common occurrence within 50° S - 65° N latitudes. Although this mineral is not considered as an exact depth indicator, it occurs most widespreadly within outer shelf-upper slope environment and in 200-300 m water depth (Hein and others, 1974). Despite its preference to source grains of fossiliferous carbonate, intraclast and pellet, glaucony mineral with marine affinities can also form by diagenic change of silicate minerals such as mica, quartz, volcanic glass and pyroxene, (Ojakankasr and Keller, 1964; Triplehorn, 1966; Odin and Matter, 1981). Potassium necessity of glaucony formation is provided from sea water (Odin and Matter, 1981). For this reason, continual sea water exposure of the hard grounds, facilitate ionic exchanges leading to glaucony formation. Similarly, suitable conditions of glauconite formation are prepared at the sea floor ekposure during short sedimentational hiatuses (Clari and others, 1995; Varol and Şerifi, 1995).

In recent years glaucony is commonly used as an index mineral in sequence stratigraphy. It especially gets concentrated during the periods of sedimentary hiatuses of rapid sea level rises or at maximum flooding surfaces (Amorossi, 1995).

This study, has target to describe glauconies which have been formed within different facies (silisiclastic and carbonate) and different time intervals (Lower Cretaceous/Lower Eocene) from petrographic, environmental and sequence stratigraphic point of view.

GEOLOGICAL BACKGROUND

Stratigraphy comprising the glaucony bearing units within Zonguldak-Devrek area (Fig.1a) has previously been established and the formation names have been obtained from this early studies (Yergök and others 1987). Paleozoic units within our geological map area have been mentioned as basement rocks. The glaucony occurs within Kilimli, Sapca and Cemaller formations of Aptian-Cenomanian age. Among them the oldest glaucony occurrences are seen in Kilimli formation (Aptian) and the youngest glaucony occurrences are observed in the Cemaller formation (Cenomanian). These time overlapping formations one over each other

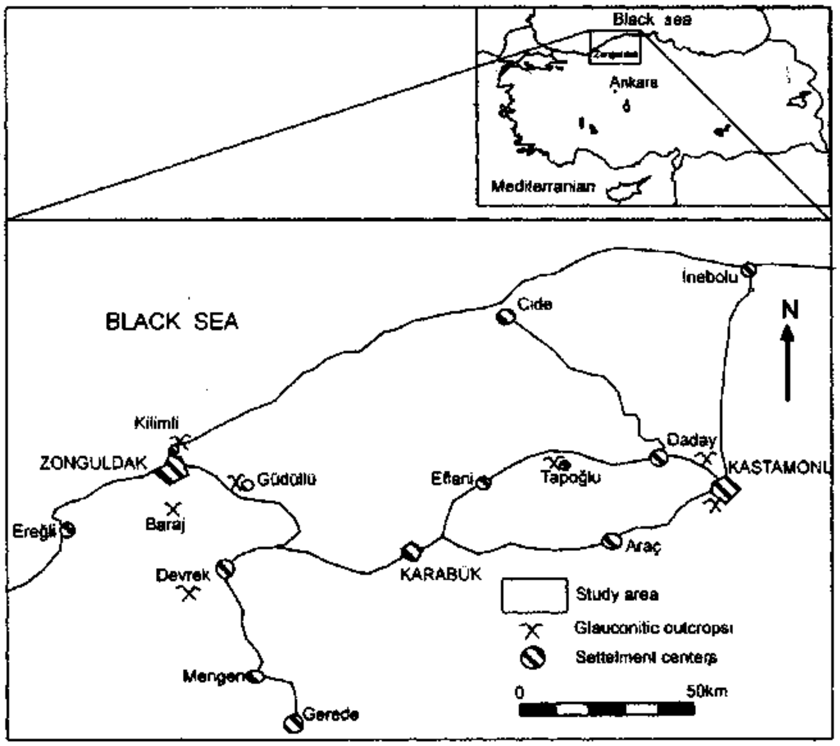

Fig. 1a- Location map of the study area.

resulted from the geodynamic evolution which caused age differences of glauconitisation. Kilimli formation formed only at the present Black sea coast in the north, but younger Sapca and Cemaller formations have been deposited in further south and became thickened by control of the southward transgression. Silurian-Devonian and Upper Jurrasic units maked up uneven basement topography. This topography which constitutes transgressional surface of Lower Cretaceous, tectonically and gradually rises towards south. In this frame; Aptian-Cenomanian glauconitic units indicate the mentioned north-southward age rejuvanation (Fig. 1b).

Glauconitic occurrences of Tertiary basin in Kastamonu region (Fig. 1a) have Lower Eocene age and are included in İnözü formation. Tertiary sequence of the region starts with Paleocene alluvial and submarine fan deposits and they are overlied by carbonates, upper surface of which is glauconitic. Fossil content of the carbonates indicate Lower Eocene age (Barkut and others, 1990). 3-8 m thick uppermost level of these carbonates with shallow marine and sparcely reefal characteristics contain glaucony grains. Alternation of pelagic limestone-tuffite levels of Budamis. formation start above it. Glauconies diminish and finally disappear upwards in a few metres from the base of the pelagic unit.

MATERIAL AND METHOD

This study has been carried out in two parts which consist of field and laboratory studies. Outcrops of the glauconitic units have been mapped by using 1:25000 scale topographic maps of Zonguldak F 27-b1, b2, c2, Kastamonu F 31-b1, b4 and F 30-a2 sheets. 6 stratigraphic sections with 58-150 m thickness have been measured under the names of Zonguldak-Kilimli, Devrek, Kozlu barajı, Güdüllü-Sofular, Kastamonu merkez and Tapoğlu mah. Stratigraphic locations of the glauconitic levels have been marked on them. The sequences have been interpreted from the sequence stratigraphic point of view.

Mineralogy and petrography of the glauconitic material have been studied under polarisation microscopes, x-ray diffractometer and electron microscope. However, the laboratory studies, have been carried out by petrographic-mineralogic determinations glaucony has been recognised by its green colour in single nicol and by medium relief and again more green colour properties in cross nicol. In addition, it has also been recognised by 9.92 Ao, 4.97 Ao, 4.52 Ao, 2.58 Ao peaks in X-Ray studies belonging to (001), (002), (020), (130) faces. Terminologically, while its grain or facies

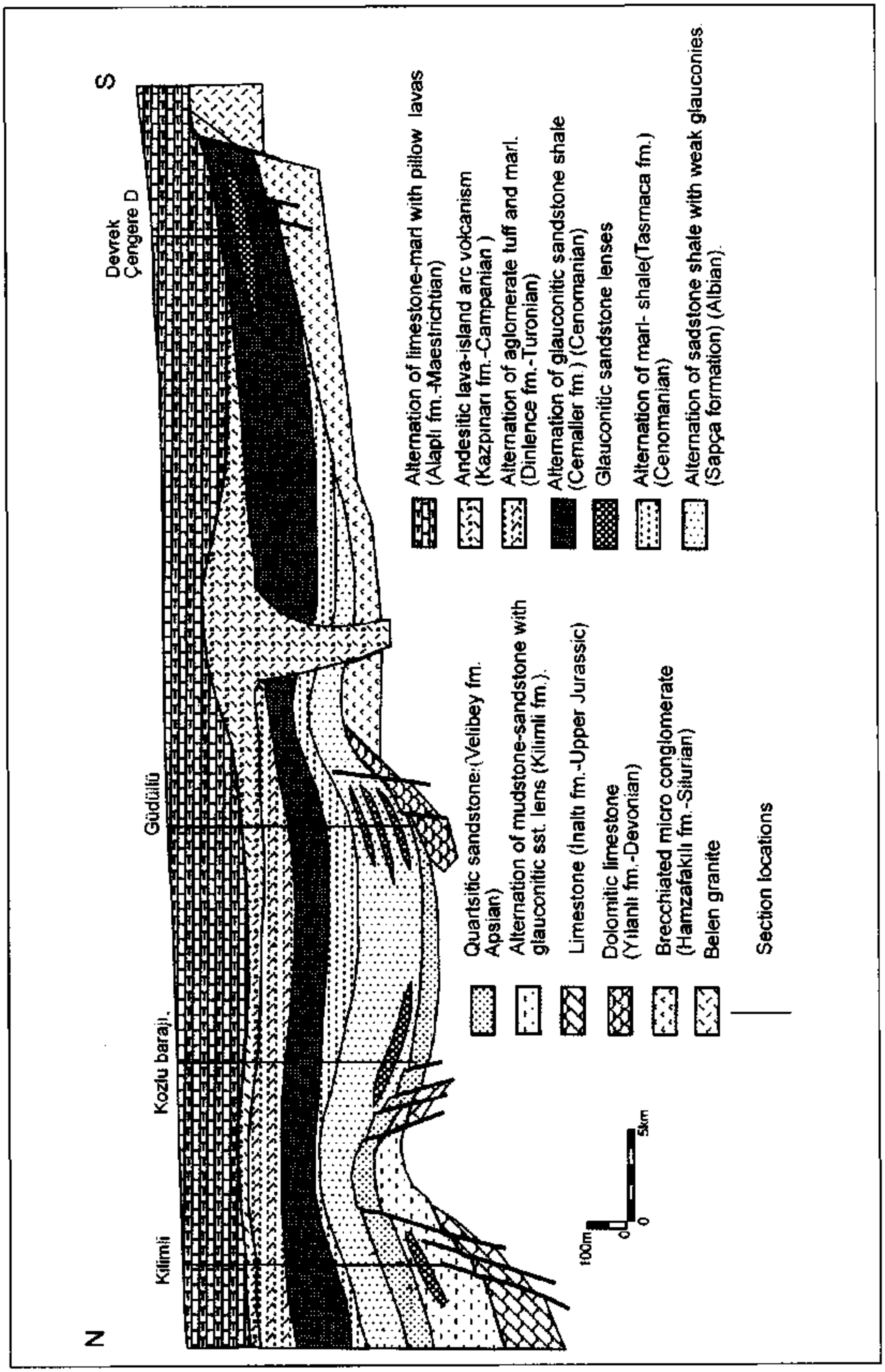

Fig. 1b- Schematic section showing stratigraphic relations of glauconitic sandstone lenses during Cretaceous in Zonguldak region.

properties are questioned; word glaucony (glaucony grain, sandstone with glauconies) and while its mineralogical properties are pointed, word glauconite (glauconitised grain) have been utilised (Odin and Matter, 1981). As to the intensity of glauconitisation; its colour index has been used (Table 1). Accordingly, dark green coloured grains are separated as strongly glauconitised grains while light green coloured grains are distinguished as weakly glauconitised particles. Glaucony grains have been separated by acid treatment of the samples and some of them have been chosen under binocular. Electron microscope (Jeol. JSM 840 model) image analyses of six different types of glaucony grains with fossil, fossil cast, intraclast, pellet, rock fragment and mineral shapes have been carried out. Their chemical compositions have been determined by FDS (Tracor TN- 5502 model) with % 90 accuracy.

Table 1- Comparison of chemical and other descriptive properties of Kastamonu-Zonguldak glauconies with mean standart values for glauconies.

		MEAN CHEMICAL COMPOSITION OF GLAUCONIES							
Sample No	Sample Location	% MgO	% Al_2O_3	% SiO_2	% K_2O	% Fe_2O_3	%FeO/ TiO_2	Glaucony colour	Probable source rock by means of S.E.M measurements
Mean	WORLD	2.6-4.6	5-8	47.5-50	3-8.5	19-27	1-3.2/ 0.1-0.2	Lightgreen Darkgreen	Mostly limestone and various rocks
GL-1	KASTAMONU	4.29	11.24	57.28	6.78	20.41	–	Darkgreen	Limestone grain
GL-2	"	4.74	11.64	51.58	6.75	25.28	–	Darkgreen	Limestone grain
GL-5	"	2.84	7.35	39.94	7.84	42.03	–	Darkgreen	Goethite grain
GL-7	"	4.23	12.94	58.27	6.19	18.37	–	Darkgreen	Fossil crust
GL-9	"	3.30	14.91	60.94	7.19	13.67	–	Darkgreen	Reef crust
GL-10	"	2.84	13.88	67.55	5.97	9.76	–	Green	İllitic clay pellet
GL-13	ZONGULDAK	1.22	11.04	79.86	2.2	3.86	-/1.82	Lightgreen	Quartz grain
GL-14	"	4.10	17.87	56.33	6.38	15.32	–	Darkgreen	Pellet
GL-16	"	1.95	26.37	59.04	5.91	5.80	-/0.93	Lightgreen	İntraclast
GL-18	"	–	1927	66.27	13.18	0.55	-/0.73	Lightgreen	Potash feldspar

GLAUCONITIC SEQUENCES

Four glauconitic sequences between Zonguldak-Devrek area and 2 glauconitic sequences within Kastamonu region have been examined and sampled. Their typical sections and definitions have been given below according to their locations.

Zonguldak-Devrek section.

The section has been measured from the road cut passing through Yörükoğlu village. Glauconitic levels of this location are situated in silisiclastic units. Thickness of traceable glauconitic sandstones of the area changes between 70-110 m and can show mapable outcrops. Glauconitic levels with SW-NE trends between Yörükoğlu-Keloğlu villages, approximately constitute 4 km long lens shaped body (Fig. 2a).

The best observable location of this glauconitic lens within Cemaller formation is Keloğlu village. The total thickness in that location is 110 m. This sequence begins with silty-argillaceous level which sits disconformably over Silurian rocks and is 174 m thick with 5 % or less over all glaucony content. Overlying sandy, silty and in places with carbonate levels are in the form of 7-18 m thick packages showing alternate levels with 7-35 % glaucony grains. In the uppermost part, it ends with a level with 5 % glaucony content or less. Maximum glaucony occurrence is located within 8 m thick sandstone lens at the 43,5 th m of this sequence (Fig. 2b).

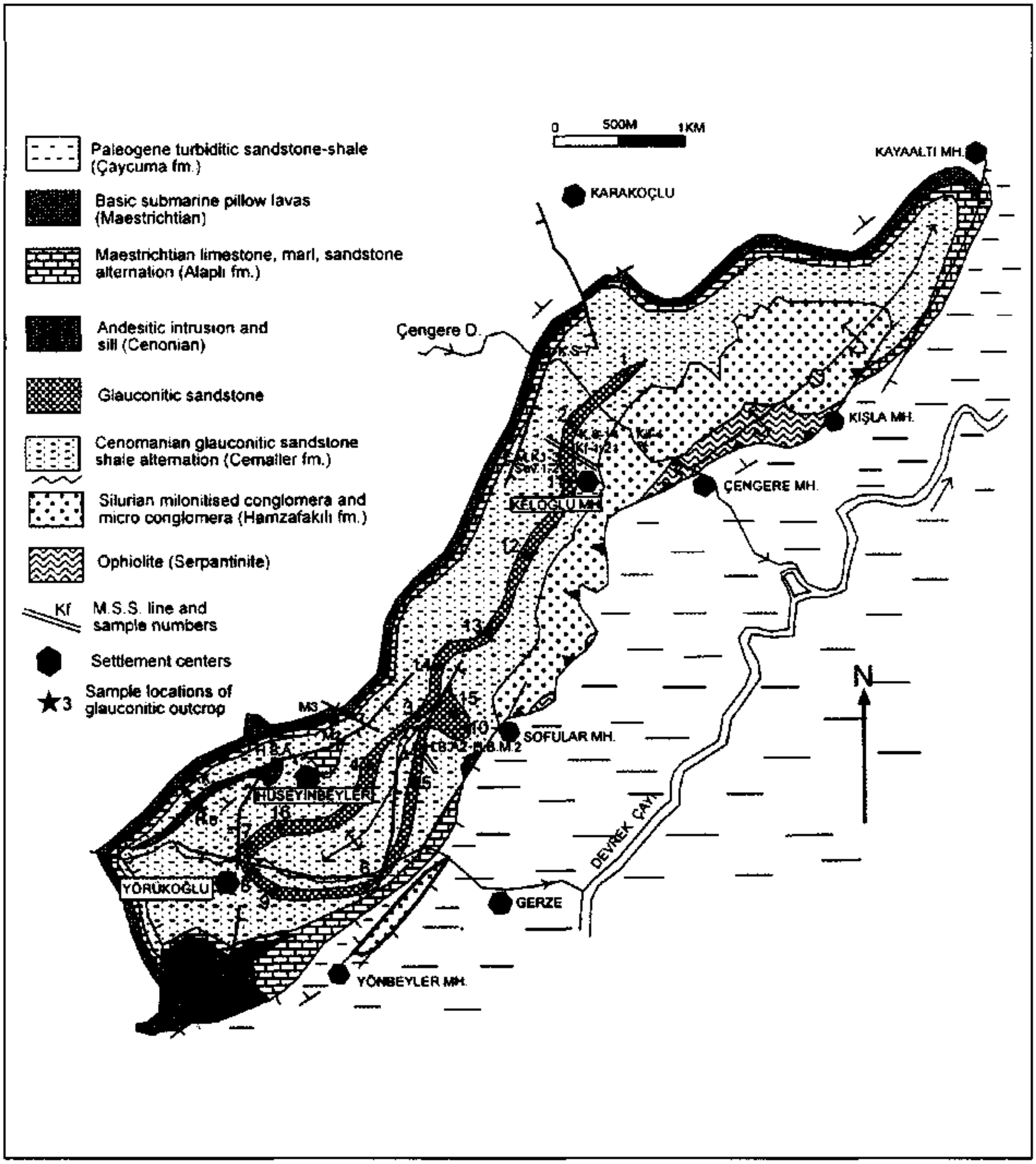

Fig. 2a- Geological map of glauconitic sandstones of Zonguldak-Devrek region.

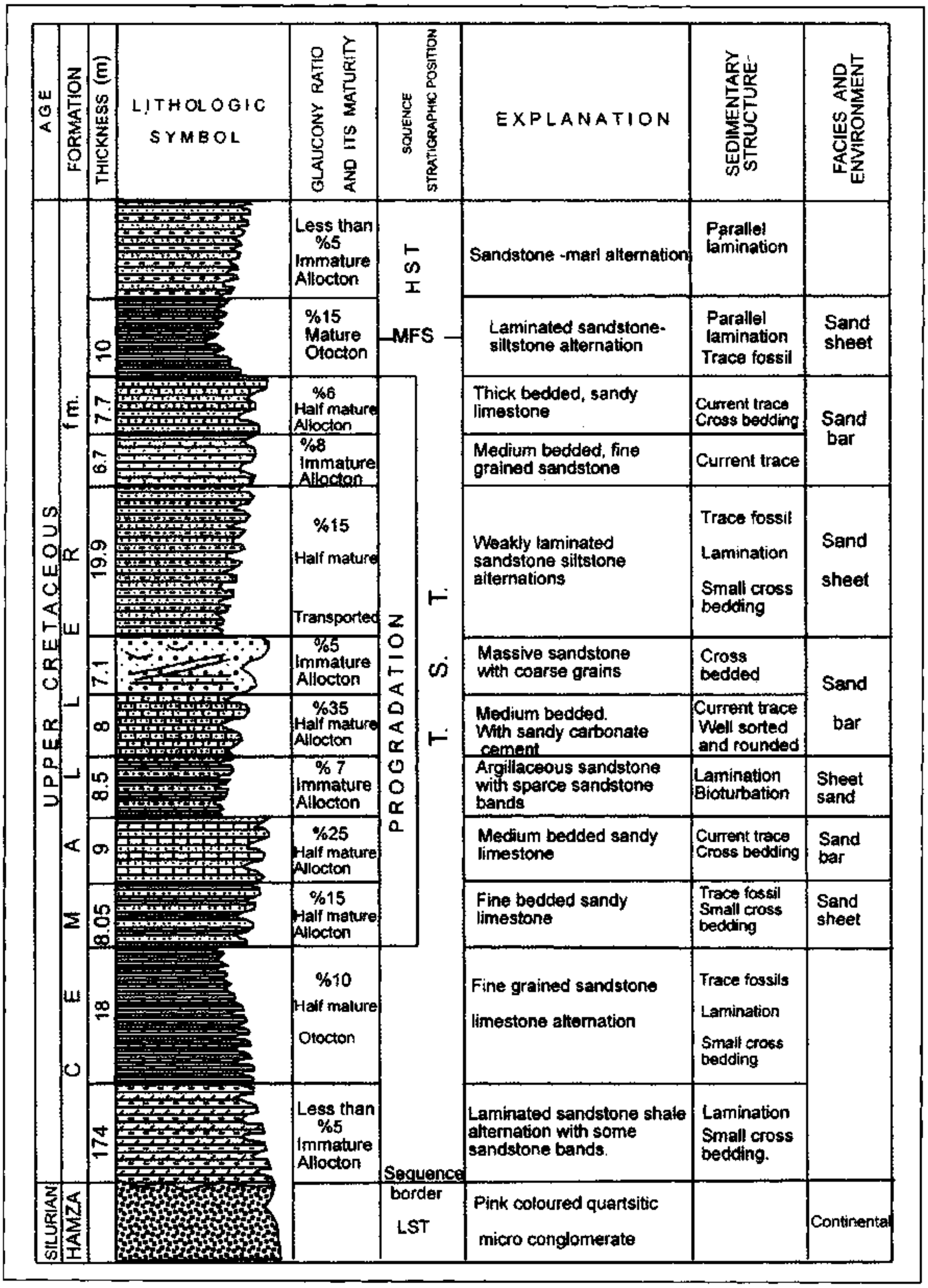

Fig. 2b- Vertical section of glauconitic unit of Zonguldak-Devrek region.

Zonguldak-Kozlu dam section

The section was measured from the road cut passing beside the Kozlu dam. Glauconitic levels of this region is located within 50-60 m thick sandstone sequence. Glauconies are scarcely observed only in uppermost part of underlying Velibey formation which has widespread outcrops in the region. They get prominent concentration within overlying Sapca formation of silisiclastics sandstone-claystone alternation. Glauconitic sandstones in Sapça formation (Albian) are observable in an outcrop of 500 m lateral extention that has been bordered by two faults. In addition, glauconitic sandstone lenses of a few metres dimension are found in limited outcrops in Gaca stream valley (Fig. 3a).

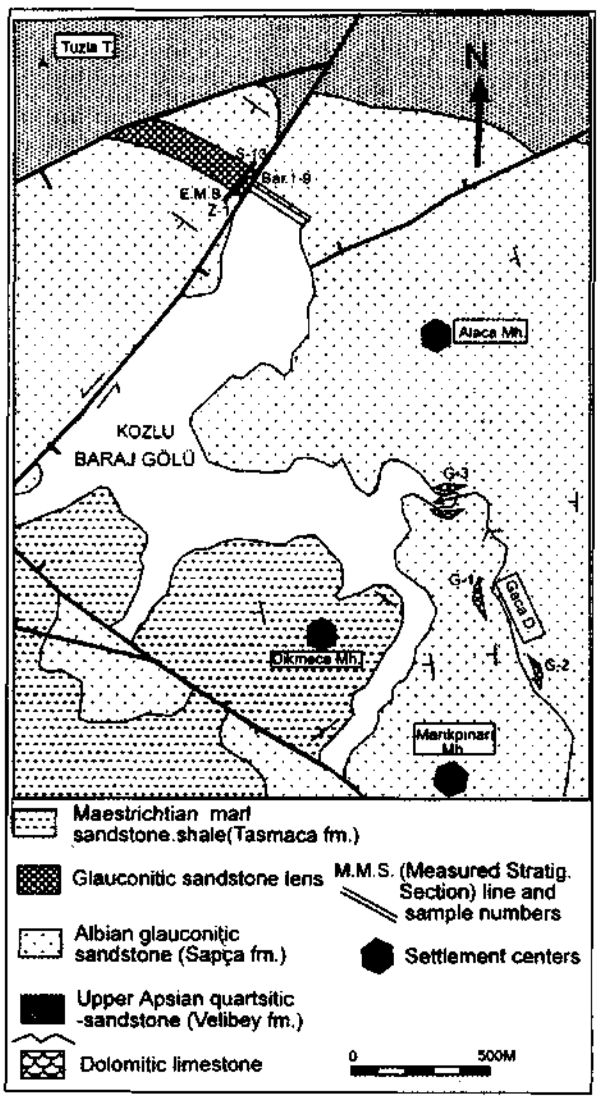

Fig. 3a- Geological map of glauconitic sandstones of Zonguldak-Kozlu dam region.

Levels with 12-19 % glauconitised grains are found within 56 m thick section that has been measured nearby Kozlu dam. This sequence is overlain by 100-200 m thick argillaceous silty, sandy levels that contain scarce glaucony minerals (Fig. 3b).

Zonguldak-Kilimli section

Glaucony occurrences of Kilimli region are observable in a restricted area of 1/2 km^2. Greater part of the outcrop is situated under the sea. In the hand specimens ratio of glaucony grains doesn't exceed % 10-15 (Fig. 4a). Measured 64 m thickness constitutes the upper levels of Kilimli formation. Continuous alternations of mudstone, siltstone, marl are overlain by a channel fill coarse conglomerates. Their gravels are made up of glauconitic sandstone, but the matrix was subjected to scarce glauconitisation. Glauconies are concentraled in quartzitic sandstones at upper levels which also contain black plant fragments and fossil shells (Fig. 4b).

Zonguldak-Güdüllü section

The sequence has been measured between Dedehasan çukuru Location and Güdüllü village. The first glauconitic unit in the region is located on the 10 m thick sandstone overlying the basement. In this region quartsitic Velibey formation is also seen to be deposited in places with time overlapping transgression. Since the glauconitic sandstone, siltstone, marl lenses of mapable size are cropping out in three different levels, they are named as G1, G2 and G3 (Fig. 5a).

Glaucony quantities and thicknesses of these levels are changing in different places and they are richest in the valley situated north of Taşlıgüney hill (Fig. 5a). The lower level has thickness changing between 4,5-18 m. Its averege glaucony ratio is 15 %. The middle level with 8-23 m thickness contains 12-22 % of glaucony, thickness of the upper level varies between 4,5-7,5 m and contains 7-13 % glaucony grains. The ends of these levels get thinner and become lens shaped. They are separated by siltstone sandstone, marl intercalations with weak glaucony content (5 % and less). Laminae made entirely of glaucony grains can be observable within the glauconitic sandstone lenses (Fig. 5b).

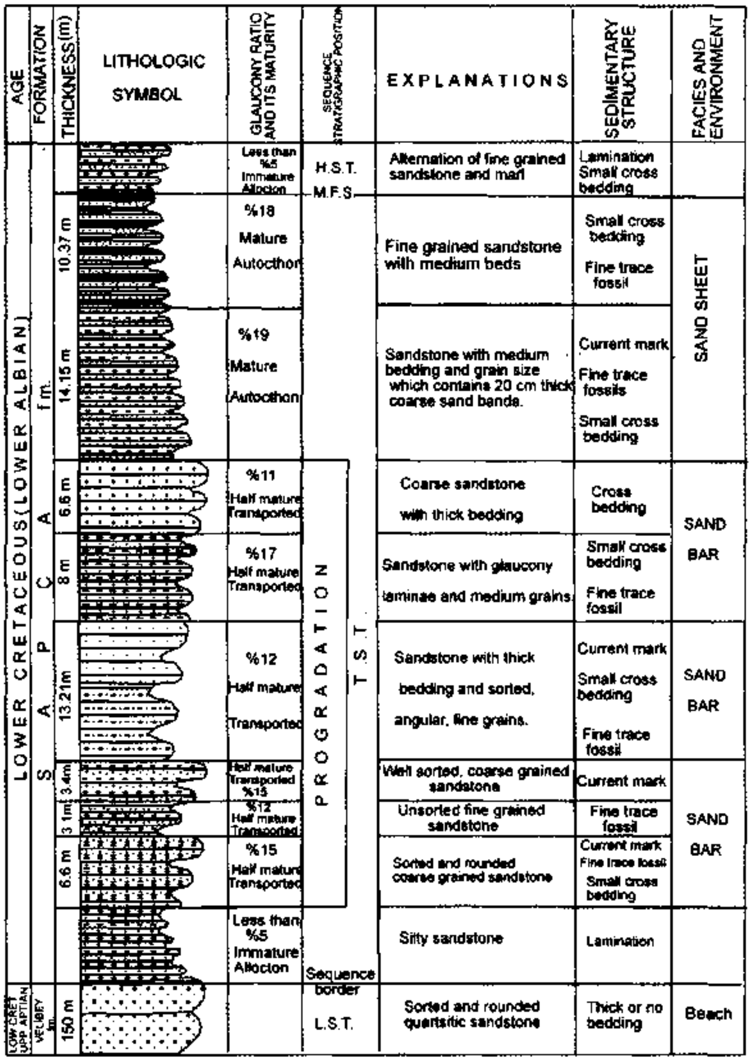

Fig. 3b- Vertical section of glauconitic unit of Zonguldak-Kozlu dam region.

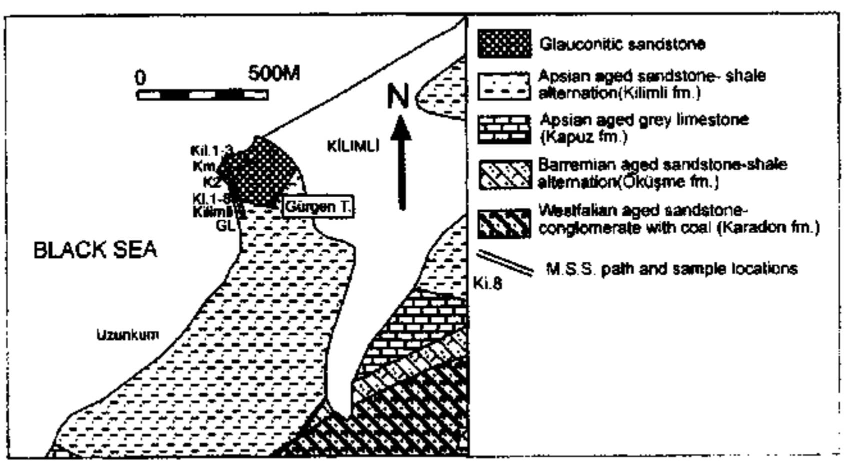

Fig. 4a- Geological map of glauconitic sandstones of Zonguldak-Kilimli region.

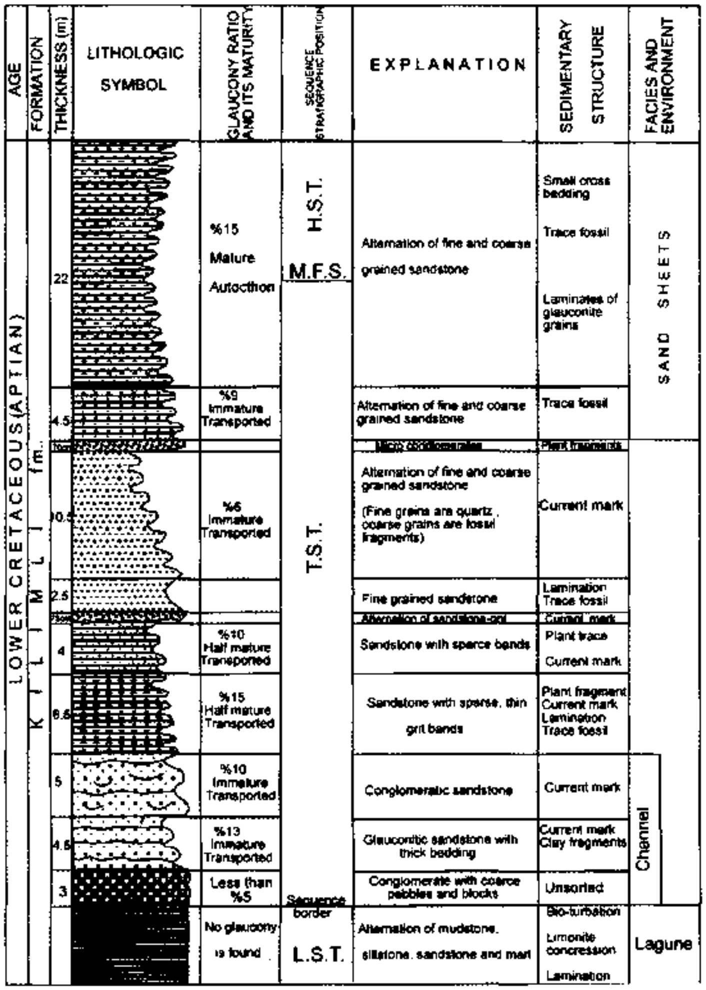

Fig. 4b- Vertical section of glauconitic unit of Zonguldak-Kilimli region.

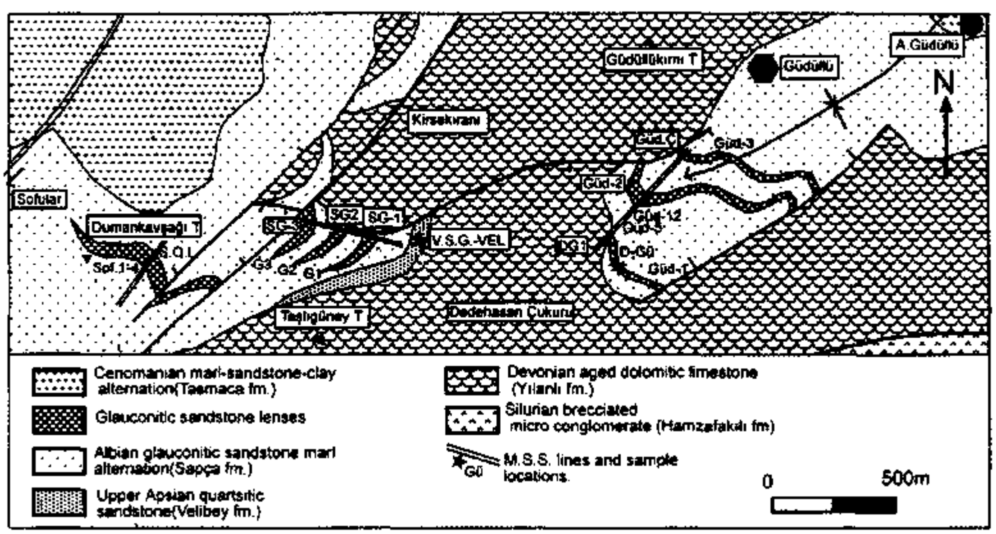

Fig. 5a- Geological map of glauconitic sandstones of Zonguldak-Güdüllü region.

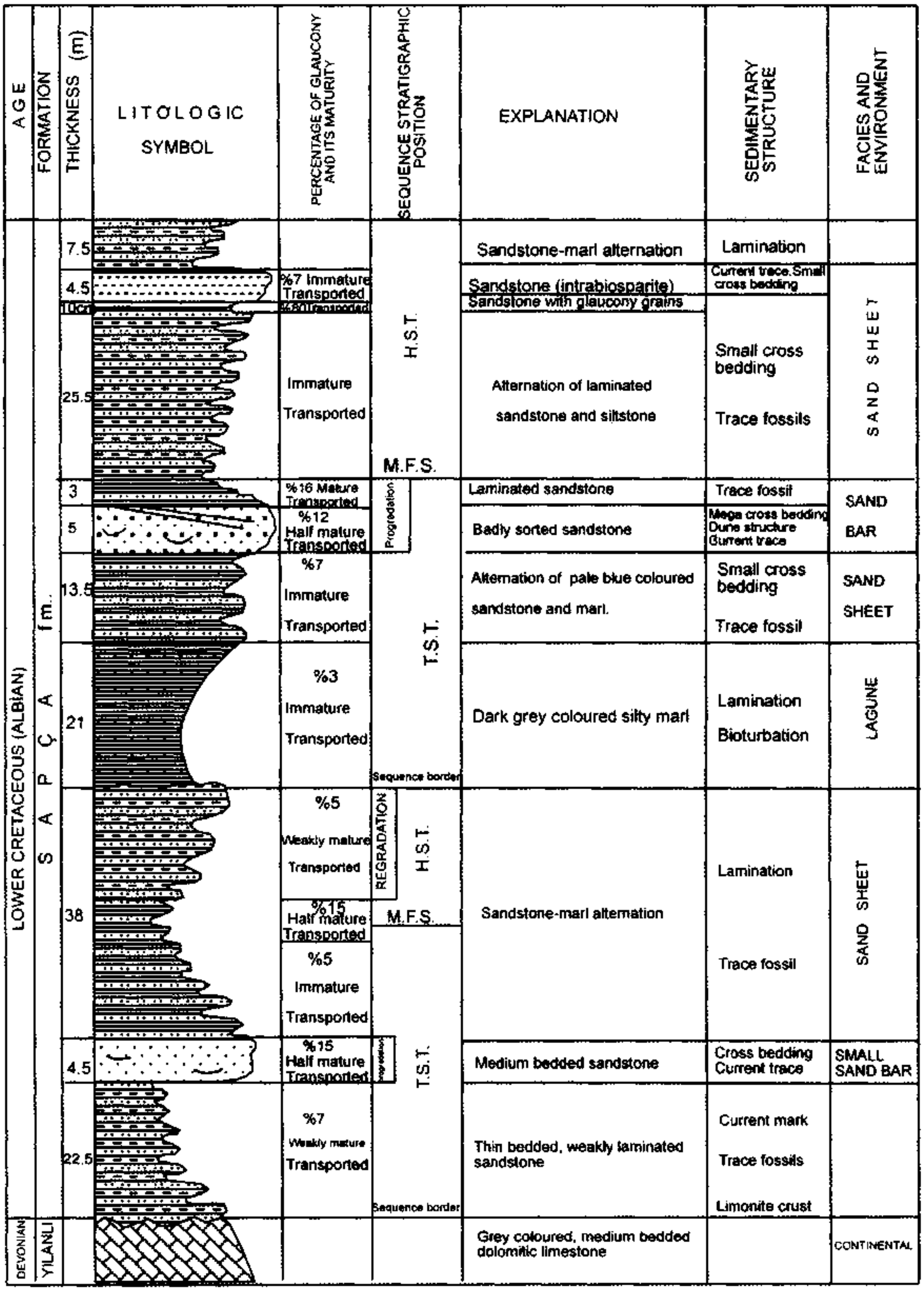

Fig. 5b- Vertical section of glauconitic unit of Zonguldak-Güdüllü region.

Kastamonu section

Here, Paleocene aged deltaic conglomerates discordantly overly Triassic schists. 3-8 m thick glauconitic level constitute the uppermost part of Lower Eocene reefal limestones (İnozü formation) which overly the mentioned Paleocene deltaic conglomerates. Glauconitic lenses occurring at the same stratigraphic level are concordantly overlain by pelagic marls and tuffites which has small amount of glaucony.

One glauconitic lens with 1,5 km outcrop length and NW - SE direction is situated in the west of Kastamonu. Another glauconitic limestone lens outcrop further south in Kızıllar Tepe and is 500 m long and has N-S orientation (Fig. 6a and Fig. 6b). Basal parts of these glauconitic lenses have hardground characteristics and partly brecciated limestone properties. These surfaces contain trace fossils and aboundant glaucony grains within solution cavities and average glaucony ratio of the overlying level is 15-20 % and has completely been generated from replacement of carbonate grains.

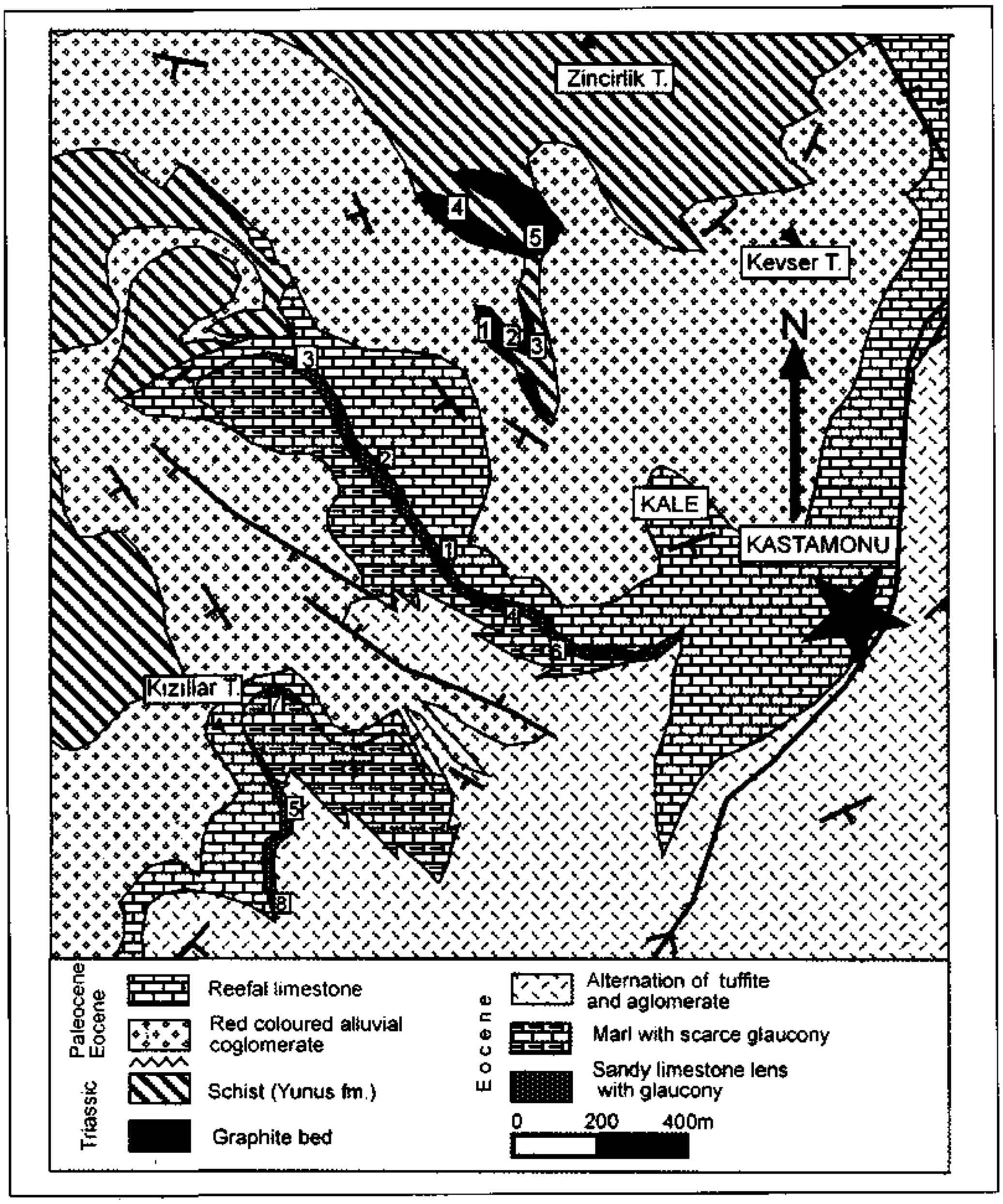

Fig. 6a- Geological map of glauconitic unit of Kastamonu region.

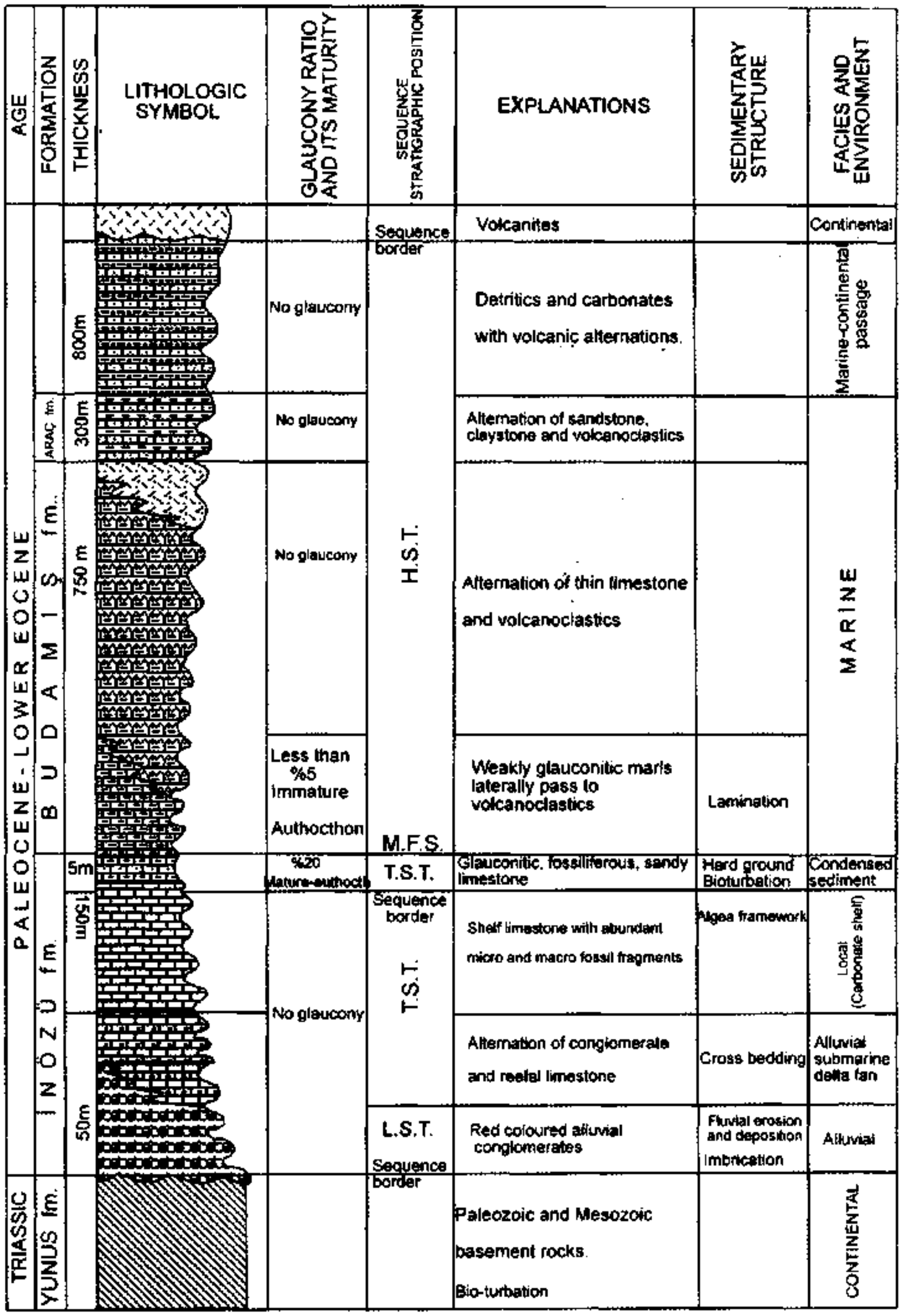

Fig. 6b- Vertical section of glauconitic unit of Kastamonu region.

Kastamonu-Tapoğlu section

The section has been measured at the south of Tapoğlu village. Here the sequence begins with delta conglomerates which discordantly overlies. Triassic basement schists. All are concordantly overlain by reefal limestones (Safranbolu formation). The glauconitic lens with 3,5 km length here follows uppermost border of the reefal limestone. To the south of the study area it thins out and dissappears within pelagic marls and silty limestone levels. Glauconies which are only found in the basal level of the pelagics gradually decrease and diminish upwards (Fig. 7 a, b).

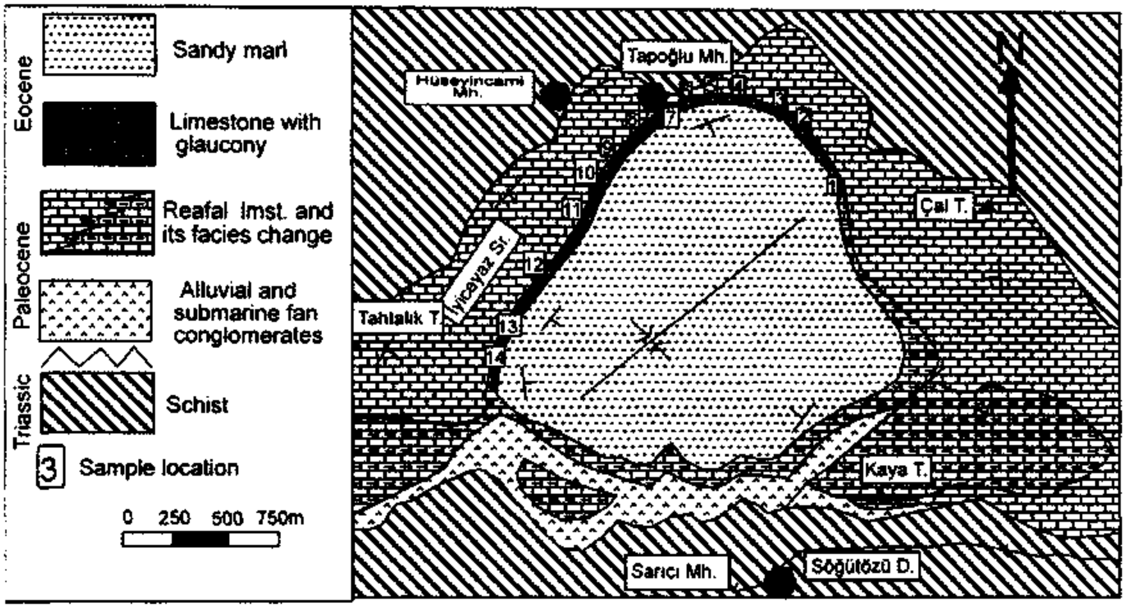

Fig. 7a- Geological map of glauconitic unit of Kastamonu-Daday-Tapoğlu Mahallesi.

PETROGRAPHY

Detailed studies on petrographic characteristics of glaucony minerals have been carried out and published by many workers (Odin and Matter, 1981; Amireh and others, 1988; Varol and Şerifi, 1995). Various petrographic types and their developing conditions have been explained on micro and macro environmental scale. In this article, only basic petrographic types have been selected and their chemical compositions and their images under normal and electron microscope have been correlated and discussed. Maturity index, related to their green colour (Odin and Matter, 1981) has been applied and the parameters such as immature, moderately mature and mature have also been utilised in all samples of the stratigraphic sections (Table 2). In addition; potassium oxide increase that is proportional to the increase of green colour which reflects the maturity of glauconitic mineralisation and behaviour of other elements, have been tested in such a way as shown in Table 2.

Table 2- Genetic classification of glauconies and related facies (after Odin and Matter, 1981).

FACIES	TEXTURE		AUTHIGENIC MINERAL (001)	K_2O	ENVIRONMENT		
GLAUCONY	GRANULAR GREEN	highly evolved	glauconitic mica 10A°	%8	Glaucony mineral	No deposition 10^5—10^6 yıl	Open sea
		evolved		%6	EVOLUTION		
		weakly evolved	14A°	%4			
		nascent	glauconitic smectite			No deposition 10^3—10^4 yıl	
	FİLM green		glauconitic minerals		Various minerals	Break in sedimentation	

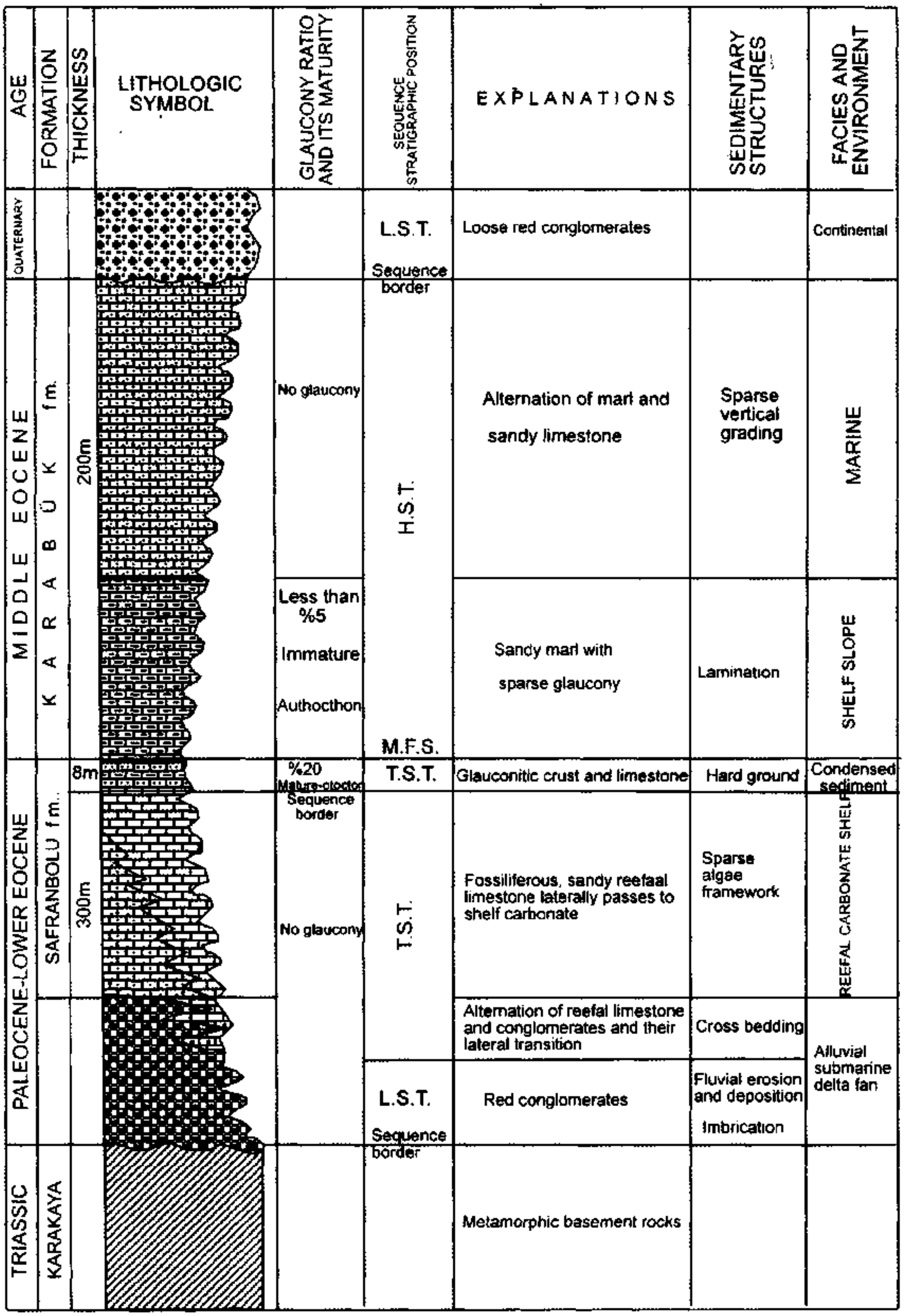

Fig. 7b- Vertical section of glauconitic unit of Kastamonu-Daday-Tapoğlu Mahallesi.

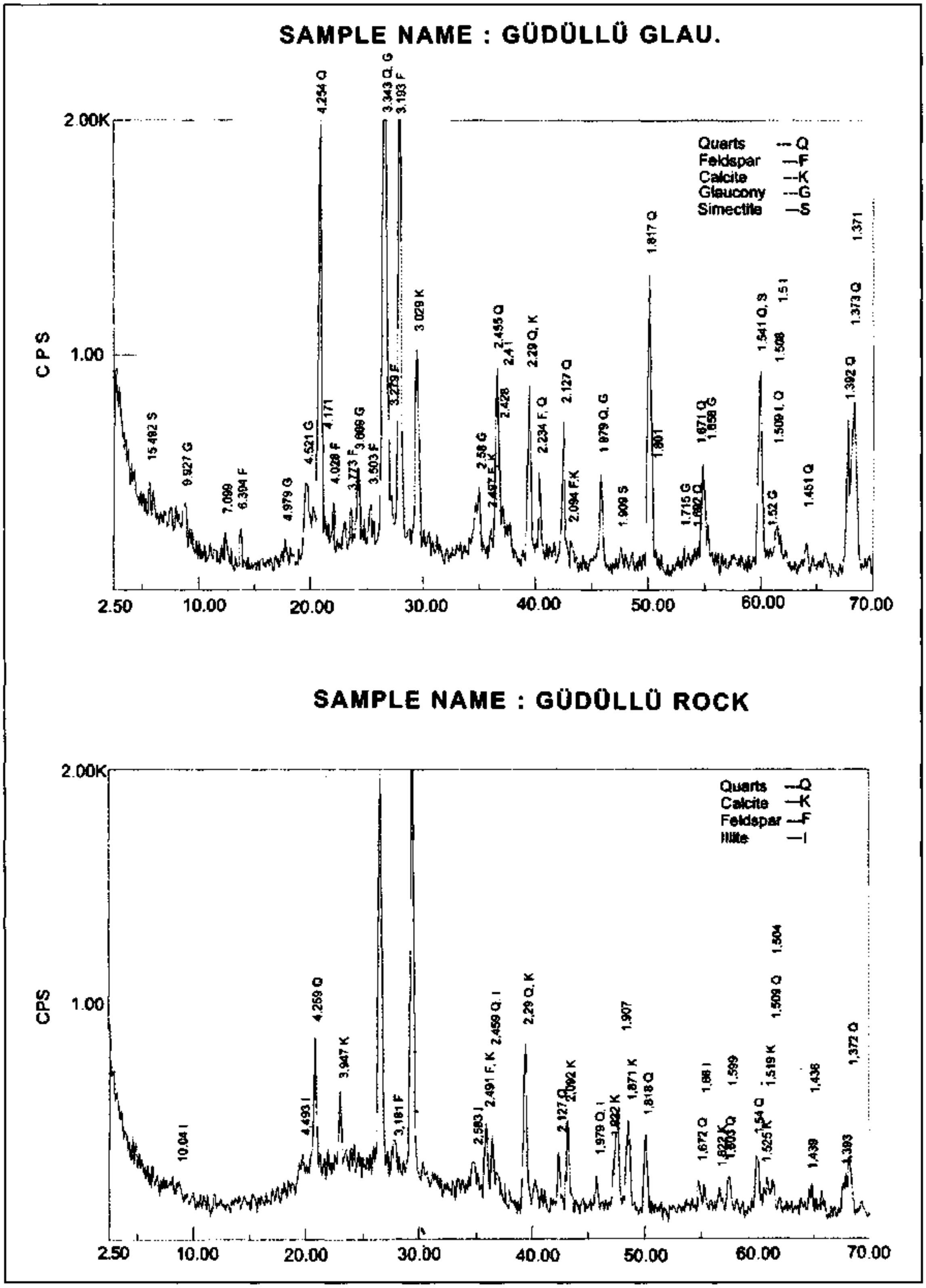

Fig. 8- X - Ray micrograpy of glauconitic sandstone of Zonguldak - Güdüllü region.

Under the light of these data; the grains which contain K_2O upto 4 % and with light green-colourless appearence have been classified as immature, the grains that contain K_2O between of 4-6 % and with green colour have been grouped as moderately mature and grains which contain K_2O between 6-8 % and with dark green colour have been classified as mature.

Glaucony grains which fit into the above groupings have silicate and carbonate origins. Glaucony grains with silicate origin dominate Albian-Cenomanian silisiclastic levels of Zonguldak region. The silisiclastic level is basically made of 75 % quartz, 15 % feldspar and 10 % volcanic rock fragments. Evolutions of glaucony mineralisation of this kind of grains have been discussed by various researchers (Wermund, 1961; Odin, 1972; Hein and others, 1974). In our samples, especially quartz grains have been glauconitised at different intensities (Huges and Whitehead, 1987; Ojakangasr and Keller, 1964). Among these, immature glaucony grains have very faint green colour with K_2O ratio up to 4 %. In electron microscope images the fractures can easily be seen on the weakly glauconitised quartz grains (Plate I, fig. A). However in quartz grains with increased intensity of glauconitisation; crystal surfaces have been covered with a crystal plate like growths (2-4 micron) which reflects glauconitisation texture (Plate I, fig. B and fig. C). In addition to these, some grains with poor glaucony mineralisation have very high potassium oxide (12-13 %) and aluminium oxides. These anomalies have probably been produced by alkaline feldspar grains. Petrographically determined alkaline feldspars which show poor glaucanitisation have chemical analyses with high K_2O and Al_2O_3 values since they greatly conserve their chemical compositions (Plate I, fig. D).

Glauconies which have been evolved from carbonate grains, characterise Lower Eocene sequence of Kastamonu region. These have been formed by replacement of carbonate grains such as bioclast, intraclast, pellet or by filling of fossil cavities. In comparison with those of Zonguldak silisiclastics they constitute glaucony grains of higher degree maturity (mean K_2O contend is between 5-7 %). Other kinds, have filled fossil lobes or microcavities of crusts of these organisms. In electron microscope views these glaucony infillings show small spheric patterns (Plate II, fig. A and fig. B).

Common property of glaucony mineralisation as result of replacement of carbonate grains such as intraclast and bioclast is the formation of fructured structure. These fractures have deep penetrations and in places they break the grains completely (Plate II, fig. C and fig. D). Many researchers have attributed these fractures to series of events occurred during glaucony mineralisation. According to Mc Rae (1972) and Odin and Matter (1981); during evolution of maturity stages from simectitic glauconite which represents first phase of glauconitisation, to glauconitic mica which represents final product, volumetric shrinkage developes by expelling the crystal water that is the cause of these fractures. Actually the grains which had experienced this kind of glauconitisation have dark green colour (highest degree of colour index) and well developed lamellar structure (5-6 micron) of glauconitic texture (Plate II, fig. E). On the other hand, abundant carbonate remains have been observed within poorly mineralised and light green-white coloured grains.

DEPOSITIONAL PROPERTIES

Descriptive depositional properties of Albian-Cenomanian glauconitic silisiclastic units of the Zonguldak-Devrek area:

1) Bedding.- Bedding characteristics and types within glauconitic sequences have shown conspicuous differences from one stratigraphic section to another. Similarly bedding thickness changes from 10 cm to 100 cm. However, bedding and lithologic characteristics at lower and upper boundaries of glauconitic sandstone levels in all sequences are rather similar to each other. They are generally represented by fine grained sediments which consist of fine bedded, laminated marl, mudstone and siltstone. Glauconitic levels which could be followed in lateral and vertical extent have lens geometry. Among these the maximum lateral extent is seen in Devrek area where the lens is 4-6 km long then the glauconitic levels laterally pass into sandstones without glaucony and disappear.

Conspicous differences in the bedding properties are seen in Kilimli region. Here, at the bottom glauconitic sandstone sequence begins with the level of glauconitic channel fill conglomerates and gets thinner upwards. On the other hand, upward thickening sequences without channel fills have been observed in the other locations in the Zonguldak region. Generally upward thickening sequence is characteristic of glauconitic sandstones (Mc Cubin, 1982).

Cross beddings of glauconitic sandstones are conspicuous in places. Beside large scale cross bedding types small scale ones are also frequently observed. The greatest cross beddings within the region have lower angle and has 10m approximate set thickness (Devrek-Gerzedere and Kozlu dam Gacadere) (Plate III, fig. A). Their paleocurrent directions are seen to be towards the inner basin. Parallel beded glauconitic sandstones which overlie cross beded glauconitic sandstones have widespread inner lamination.

Glauconitic sheet sands which overlies cross-bedded levels in Güdüllü region has widespread extention in the area (Plate III, fig. B). All these bedding properties, support that the glauconies concentrated either in paleo offshore sand bars or in sand sheets (Jeray kievicz and Wojeweda, 1986 and Surly and Noe-Nygaard, 1991). Hydrodynamic conditions of their deposition will be explained in sequence stratigraphy.

2) Biogenic Structures.- Abundance and importance of biogenic structures and trace fossils in relation with glaucony genesis have been explained by several investigators (Bromley, 1975). These biogenic activities increase during hiatuses of sedimentation. In glauconitic levels of the study area the following kinds have been observed.

Horizontal biogenic traces, are seen within laminated glauconitic mudstone, siltstone, claystone alternations of sheet sand struptures, which had been deposited in outer shelf of Zonguldak region. Horizontal biogeic traces have also been developed, within glauconitic carbonate lenses and especially in their basal hard grounds. These traces are about 1 cm wide.

Horizontal bioturbation activities that indicate decrease in sedimentation rate is commonly seen in fine grained silisiclastic levels where authigenic glauconite precipitation had been concentrated. In addition, there is a comparable increase of fossil shell fragments within these levels (Plate III, fig. C). U shape and vertical biogenic traces are more prominant in allocton glauconitic coarse grained silisiclastics which indicate rapid deposition on near shores. Abundant biogenic traces with 0,3 cm widths are observable at bedding surfaces of glauconitic sandstones of Kozlu dam. This type of fine but intense biogenic activities indicate partly stagnant environmental conditions (Rhoads, 1976).

3) Lamination.- It can be seen in most part of glauconitic levels within the silisiclastic levels. Glauconies have been concentrated in laminae planes and reach 15-20 % abundance. Parallel and cross laminations are typical especially in sand sheet levels. This lamination has been, formed by lining of fine and medium size grains of the glauconitic sands and also by vertical micro grading of the particals. Cross and parallel laminated levels dominate and alternate in most part of the sequence in Güdüllü (Plate III, fig. B). Black plant fragments are also seen within glauconitic laminates of Kilimli region (Plate IV, fig. A).

Alternations of mudstone and siltstone laminates of thin bedded levels underlying and overlying the glauconitic sand bars are readily seen. Their glaucony content is about 5 %.

Laminated claystone-siltstone levels with scarce glaucony occur as intercalated packets in glauconitic sandstone lenses in Devrek. Cementations of Kozlu dam and Kilimli glauconitic sandstones are stronger since carbonate content of laminated levels of glauconitic sandstones is higher. Here, carbonate cement together with glauconitised grains have again been glauconitised at different degrees.

4) Hardground.- It has been accepted by many investigators that submarine hard grounds constitute suitable environmental conditions for glaucony, phosphate and mangan mineralisations (Clari PA. and others, 1995). While sea bottom begins to be hardened during sedimentational hiatuses, the necessary elements for glaucony formation is either provided from the sea water or from the clays. According to Odin and Matter, 1981; minimum time required for the extraction of potassium from sea water which is necessary for glauconite mineralisation is 1000 - 10000 years. In other words for glaucony formation at least such a minimum period of sedimentational hiatus is necessary.

Hardground surfaces are absent in Zonguldak region within Albian-Cenomaian glauconitic silisiclastic levels. However, levels with concentration of biogenic activity material and early diagenetic glauconitised cements, may indicate short periods of sedimentational hiatuses.

Typical hardgrounds with glauconitic mineralisation have been observed in Lower Eocene limestones of Kastamonu region. The percentage of glaucony grains (40-60 %) within hard grounds at the upper surface of reefal limestones has high order. This amount falls to 5 % in the immediately overlying pelagics and in a few metres upwards glauconies dissappear completely. These mineralised hardgrounds contain a lot of biogenic traces, caverns and cavities of solution surfaces and neptunian dykes which vertically or diagonally cut the bedding plane as pointed out by Tucker and others, 1992. Glaucony grains have been drived from altered intraclasts, bioclasts and pellets within the hardground and have filled all the cavities above the hard ground. Therefore glaucony mineralisation in hardgrounds is a kind of cavity filling rather than widespread precipitation.

SEQUENCE STRATIGRAPHY OF GLAUCONITIC SECTIONS IN KİLİMLİ, KOZLU, GÜDÜLLÜ, DEVREK, KASTAMONU AREAS

Amorossi (1995), has stressed the importance of distribution pattern of glaucony concentrated levels, maturity of the glauconies (that is K_2O percentage or intensity of their green colour) and genetically their allocton or autocthon characteristics from point of view of interpreting the sequence stratigraphy of silisiclastics. He explained that more concentrations of authocthon glaucony grains have been found in condensed levels, on the maximum flooding surfaces (M.F.S.) in transgressive system tract levels and in lower levels of high system tract (H.S.T.). In the upper levels of T.S.T. abundance and maturity of the glauconies increase while in that of H.S.T. they decrease. From point of view of glaucony concentration and maturity, condense level and maximum flooding surface (M.F.S.) are far more richer in comparison with the levels below and above. Allocton, outer sequence (detrital) glauconies are found in lower system tracts (L.S.T.) where the general level of the sea is lower. These are also seen in T.S.T. and H.S.T. systems. Detrital glauconies generally show less concentration and less maturity than their authocthon equivalents.

Sequence stratigraphy of Kilimli region

The sequence in this outcrop is thinning upwards which is reverse to the normal thickening upward sequence of glauconitic sand bars. However in the erosional channel of sand bars thinning upward sequence is normal (Moslow, 1983). Erosional channel that had been carved during a sand bar formation took place at the base of the sequence which sits on sandstone, mudstone, siltstone alternation with limonite concretions and trace fossils in this location.

Non-existence of clay within the lower part of the glauconitic sequence is an indication of dominant role of waves. The section indicates that erosional process of the channel didn't stop within the sand bar but continued and cut down into the underlying sediments. This also indicates that the sand bar sequence is transgressive (Moslow, 1983). Waves and storms cut some fragments from sand bar and deposited them at the base of the channel.

Base of the channel represents lower boundary of the transgressive sequence. Glauconies occurring in the lower part are light green coloured, immature or moderately mature and had been transported. Dark green coloured and fractured, authigenic glauconies are seen to have been deposited at the maximum flooding surface (MFS) where upward thinning of the sequence ends. The glauconies deposited at this level are both more mature and have higher concentration (Fig. 4b).

The glaucony grains within 6,5 m thick part of the transgressive sequence with 15 % concentration (Fig. 4b) were probably transported by waves and tide currents so that their percentage selectively increased. They are less mature than the glauconies of the maximum flooding surface.

Sequence stratigraphy of Kozlu dam section

Base of the sequence concordantly overlie the Velibey formation beach sandstones and contains small amount of immature, light green glauconies. It is observable that maturity and percentage of glaucony grains increase and gain authocthon character upwards in the sequence towards maximum flooding surface (M.F.S.). The glauconies at the M.F.S. surface are dark green and fractured. In further upward levels towards H.S.T. it is clearly observable that glaucony percentage and maturity decrease (Fig. 3b).

Thick bedded glauconitic sandstone lens shows thickening upward and contains bands with coarse quartz grains, transported glauconies and tiny bioturbation traces. This section is thought to be prograding within whole general transgressive sequence. The overlying fine grained section contains micro cross bedding, trace fossils and scarce authocthon, mature glauconies both in the cement and also in the grains and probably represents washover part of the sand bar (Moslow, 1983).

Sequence stratigraphy of Güdüllü section

Two different depositional systems have occurred within the sequence. First transgressive sequence discordantly overlies Devonian dolomitic limestones and contains moderately mature glaucony grains with ratio of 15 %. Rising of the sea level continued up to maximum flooding surface (M.F.S.). 4,5 m thick glauconitic sandstone lens with 15 % allocton glaucony grains has progradated. H.S.T. sequence occupies the upward levels which have been influenced by regression and their glaucony contend decreases. It is deduced that the sea level became lower down to the base of the lagoon sequence which consists of dark grey, silty, laminated marls with trace fossils. Base of the lagune sequence marks both the end of the first sequence and begining of the second sequence. Even the new sequence started transgressively and continued with sandstone levels having 7 % immature glaucony grains which was subsequently transported towards the open sea probably by tectonic uprising and was deposited within off shore sand bar with low angle mega cross beddings (Plate IV, fig. B) (Jeraykievicz and Wojeweda, 1986; Surlyk and Noe-Nygaard, 1991). Sheet sand levels which immediately overlie the lens contains 15 % mature glauconies and represent M.F.S. level. In the further up levels glaucony ratio and maturity decrease and H.S.T. of the second depositional sequence develop (Fig. 5b).

Sequence stratigraphy of Devrek section

Glauconitic sandstone sequence of the area began by transgression of Upper Cenonian sea over the shelf. The transgression ended when it reached the maximum flooding surface where off shore sand bar formed. This level has a washover platform fades which contains parallel lamination and well sorted, authocthon, increased quantities of glaucony grains (Fig. 2b). Towards the upper levels; glaucony ratio decreases, the shelf gets shallower character and high system tract (H.S.T.) sequence is represented.

Glauconitic sandstones show 20°-25° mega cross bedding at the road cut of Gerze Dere valley (Plate III, fig. A). The current direction is approximately parallel to the shore. High glaucony contents reaching to 25 %-35 % occur in middle part of sand bar sequence which consist of transported glaucony grains. Clay patches which contain tiny quartz and glaucony grains can be seen in these levels. In addition, alternations of thin beds of bad sorted angular quartz grains and well sorted, rounded quartz grains are also observable. These structures representing agitation and quiet periods, can also indicate selective transportation of glaucony grains by currents.

Horizontal trace fossils which are frequently seen within the sequence, developed during the calm periods of transgression, no deposition took place. However vertical and U shape fossil traces eitrter developed in rapid depositional or during the lowering periods of sea level.

Sequence stratigraphy of Kastamonu section

Discordant basal contact of Paleocene delta conglomerates constitutes the lower boundary of the sequence while the upper surface of the overlying reefal limestone which is base of the hard ground forms the upper boundary of the sequence. Alluvial conglomerate part at the base of the sequence represents low system tract (L.S.T.) and the upper reefal limestone part to the glauconitic hard ground constitutes transgressive system tract (T.S.T.).

Reefal carbonate production developed parallel with the transgression. In consequence of sudden faulting the reefal limestone sunk down under the photic zone and drowned under the pelagic sediments. Hence a new stratigraphic sequence started. Glaucony formation period in the hiatus of the sedimentation just after the faulting, represents transgressional system of the second sequence (Wolfgang, 1991; Clari and others, 1995). Upper boundary of the hard ground indicates beginning of the sedimentary deposition and upper boundary of the glauconitic level constitutes maximum flooding surface (M.F.S.). Remaining part of the above sequence which was deposited up to the Tertiary basin closure which represents high system tract (H.S.T.). This upmost discordant surface signifies the upper border (SB) of the second sequence (Fig. 6b).

Marl and tuffite sedimentation over the glauconitic limestone lens marks the end of sedimentation hiatus, then glauconite deposition couldn't be possible. Hence, the thickness of glauconitic limestone lens couldn't develope more than 8 m. Glaucony deposition, transportation and redeposition which all caused the development of thick glauconitic sequences in Zonguldak silisiclastics can not be seen in the Kastamonu carbonates.

CONCLUSIONS

Glaucony occurrences in Zonguldak-Devrek region have Albian-Cenomanian age and deposited in open shelf environment of silisiclastics. Different ages of glauconitisation, are related to time overlapping transgresions from north to south within the mentioned period. These depositional systems where off shore conditions dominated, have generally been deposited in the form of sand bars and sand sheets. Glaucony grains which were transported within active shore environment from time to time, were deposited in silisiclastics that show microcross lamination, microlamination and vertical grading. Transportation of glaucony grains, must have probably been accomplished in shoaling periods related to sea level changes. General transgressive development of the region was cut by regresive interphases. Black plant fragments which are seen in glauconitic occurrences also support this shoaling and sea level changes. Carbonate deposition occurred in local areas where silisiclastic movements couldn't reach. These relative sea-level changes have repeated the development of glauconitic levels as characteristic sequences.

All glauconitic off shore sand bars which were situated in different locations within Cretaceous open shelf basin of Zonguldak region, constitute upward thickening packets within transgressive system sequences. In the main bodies of sand bars, immature, moderately mature, mature and transported or semi-transported glauconies have been found. Mature and autochthon glauconitic levels, are situated immediately over the sand bars and indicate that the water depth increased in such a way that a new sand bar could not be formed.

However, Lower Eocene reefal limestone also occurs in a transgressive system in Kastamonu region. This system, begins with delta and submarine fans and continues with reefal limestones by the time until open sea conditions get realised. 5-8 m thick glauconitic limestone lens with hard ground basement that is composed of abundant glauconies, benthic and pelagic fossils, represents maximum transgressional period in the region. Synsedimentary fractures developed on the upper surface of the reefal mass indicate that the mass must have suddenly gone down under water and drawned during this maximum transgression. In addition, these reefal limestones and overlying pelagics and transition zone of the reef derived bioclastic, glauconitic sandy limestone between them support sea level changes during glaucony formation and during subsequent period.

ACKNOWLEDGEMENTS

This study was carried out within the Western Black sea Phosphorite Exploration Projects 97-12A, 98-11F of MTA in 1997-1998. We thank to the MTA authorities for the support we received.

Suggestions made by the Publication Department of M.T.A. and by the referees towards improving the text are acknowledged.

Dr. Selahaddin Kadir who kindly did some X-ray work on the samples.

Last but not the least we are gratefull to Dr. Tandoğan Engin of MTA who improved the English of the text.

Manuscript received November 8, 1999.

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PLATES

PLATE-I

Fig. A- Partly preserved fractures on the surface of glauconitised quartz grains (S.E.M. view).

Fig. B- Glauconitised intraclast grain (S.E.M. view) (Zonguldak region).

Fig. C- Mature glauconitisation of argillaceous pellet with rosette structure (S.E.M. view) (Zonguldak region).

Fig. D- Immature glauconitisation of alkaline feldspar grain (S.E.M. view) (Zonguldak region).

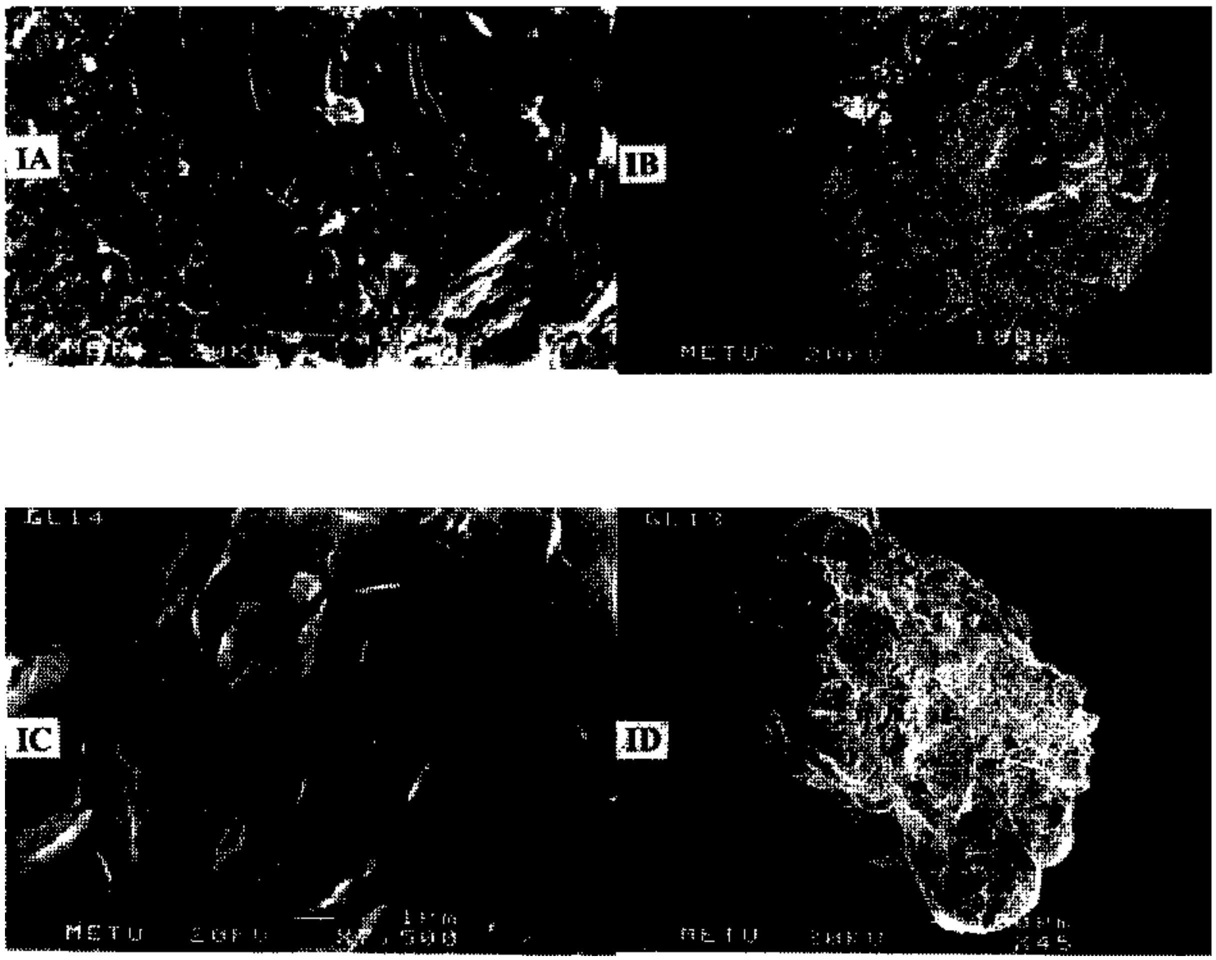
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PLATE-II

Fig. A- Authigenic glauconies developed within the crust of coral organism (S.E.M. view). Glauconies filled all micro cavities on the crust (Kastamonu region).

Fig. B- Enlarged view of Fig. A (S.E.M. view).

Fig. C- Completely glauconitised reef fragment. Dark green coloured mature glaucony with high K2O ratio (Kastamonu region).

Fig. D- Micro fractures on glauconitised surface. These may have developed with volume change which caused by expulsion of water during transformation from simectitic to illitic sturcture (S.E.M. view).

Fig. E- S.E.M. view of well developed glaucony crystals within a micro fracture in Fig. D. Micro cavity and fractures in glauconitic areas.

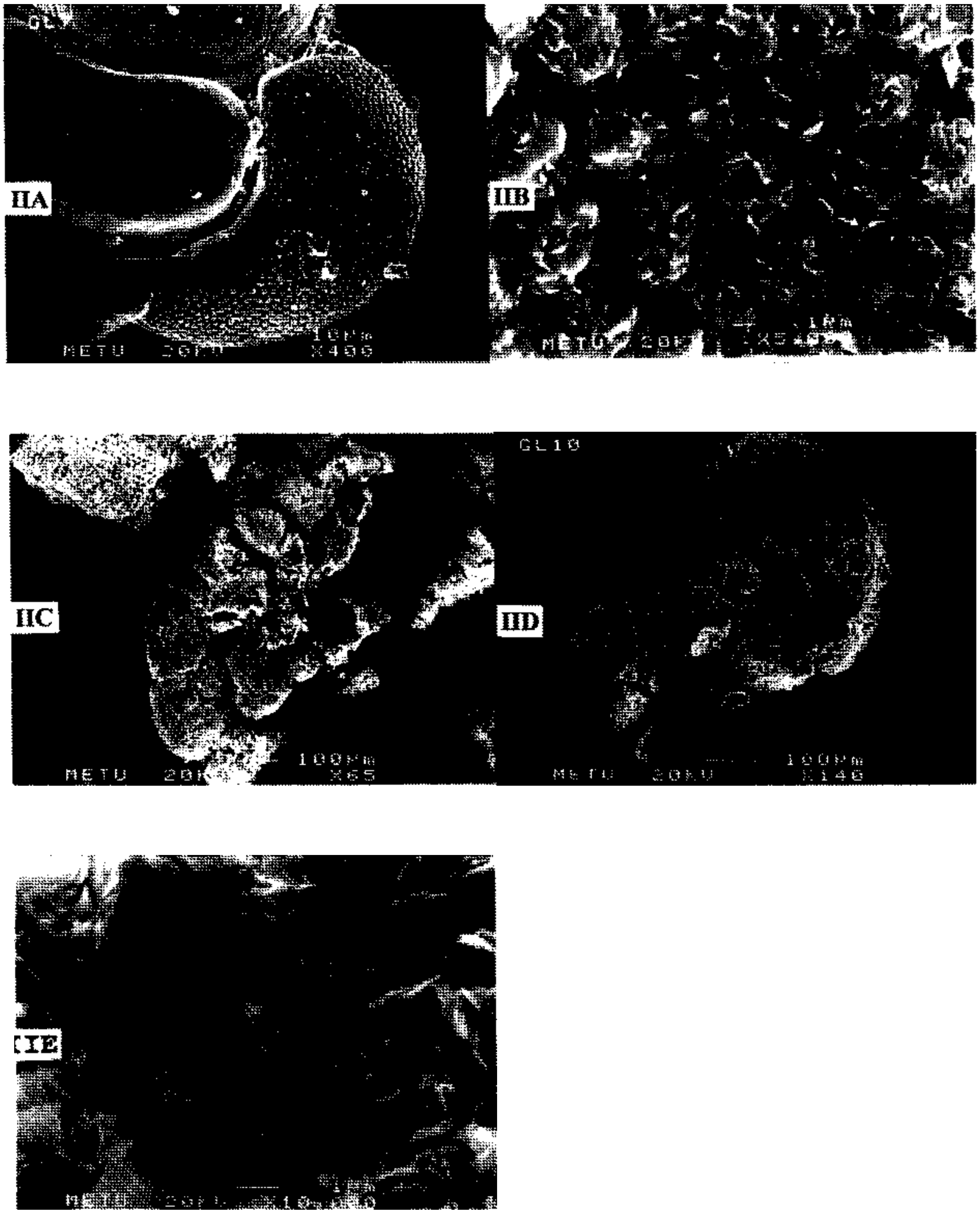
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PLATE-III

Fig. A- Mega cross beddings in glauconitic sand bars (Zonguldak-Devrek-Yörükoğlu Mahallesi, Gerze dere valley road cut).

Fig. B- Low angle small cross beddings in the sheet sand beds.

Fig. C- Glauconitic hardgrounds with glaucony filled trace fossils (Kastamonu region).


IIIA

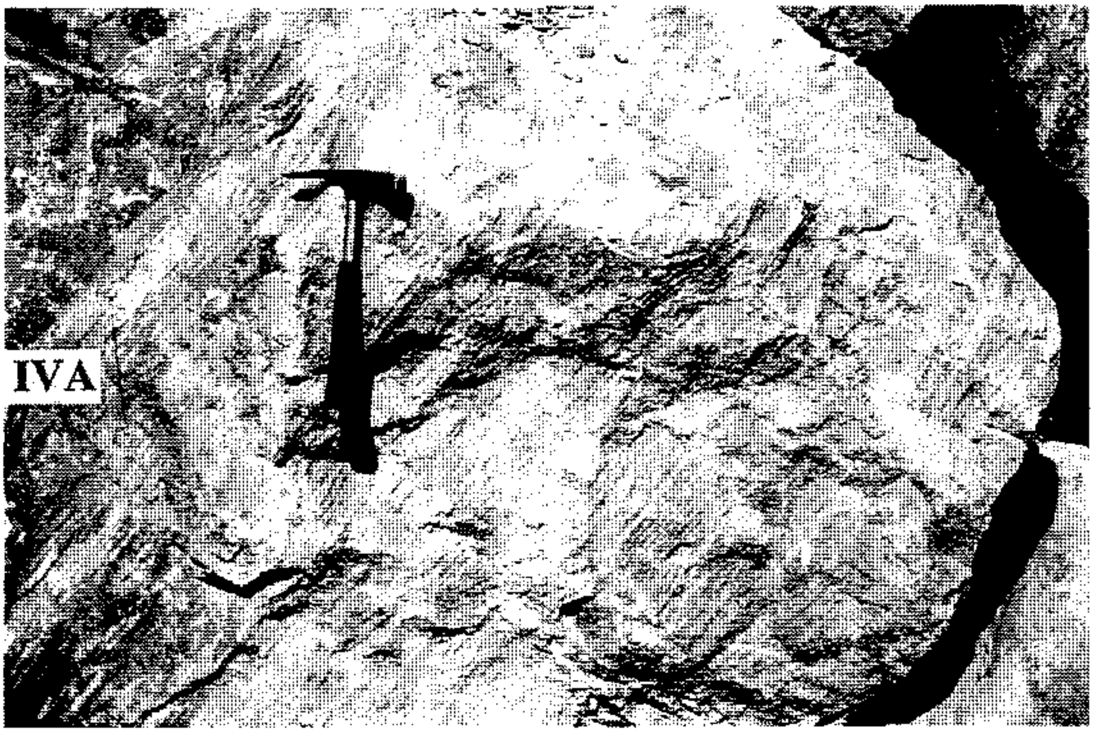

IIIB


IIIC

PLATE-IV

Fig. A- Alternation of glaucony and quartz sand laminates. Carbonised plant remain painted the laminate black at the lower left corner of the photograph (Kilimli region).

Fig. B- Glauconitic sand bar and low angle cross bedding (Zonguldak-Güdüllüköy road cut, 300 m far from Güdüllü village).



IVA

IVB