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GEOLOGY, MINERALOGY AND GENESIS OF YENİDOĞAN (SİVRİHİSAR) SEPIOLITE DEPOSIT

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ABSTRACT. - In addition to the lump sepiolite known as the meerschaum, it has been known that there also exist some layered sepiolite deposits in the Eskişehir Neogene basin since 1960's. Sepiolite deposit, which is found nearby the Yenidoğan village, southern Sivrihisar is one of the most important one among them. Here, sepiolite occurs as two separate beds in the upper part of the Pliocene sequence, which is made up of the alternation of dolomites and dolomitic marls. The lower sepiolite bed is up to 3 m. thick and consists of sepiolite clay and dolomitic sepiolite. The upper one has maximum thickness of 10m. and it regularly extends over 750 000 square meters. It is made up of the alternation of sepiolite clay and sepiolite-rich layers and lenses. Sepiolite clay consists of over 90 % sepiolite mineral and also organic material in varying proportions but not exceeding 10 %. It may also contain quartz, feldspar, illite, dolomite and pumice grains less than 5 %. Dolomitic sepiolite is the most abundant sepiolite-rich material in the upper bed. Its dolomite content is less than 50 %, and in some cases, illite and quartz grains may also be found in trace amounts. Sepiolite has been deposited at the shallow margins of alkaline lake, short-living ponds and marshlands. Si^{4+} and Mg^{2+}-rich solutions with 8-8.5 pH values have probably favoured sepiolite formation. Under these conditions, sepiolite was formed by direct crystallization and precipitation from the lake water. It was also formed from the solutions circulating through the intergranular space and along the desiccation cracks during and after diagenesis.

INTRODUCTION

Meerschaum occured near Eskişehir, has been used to make pipes and ornamental goods for centuries owing to convenient physical features. The meerschaum exists as lumps in Neogene aged conglomerates, has been known as the only kind of commercially valuable sepiolite. The existence of sedimentary and layered sepiolites was discovered in this region by MTA researches in 1960's. Technical reports of MTA investigations on economical evaluation mention these sepiolites as "layered meerschaums". First published study on this subject belongs to Akıncı (1967). The sepiolite occurrence located in southwest of Eskişehir was investigated in this work. The position of sepiolite in the sequence was described along a section and some mineralogical information was given. In 1960's, few amount of sepiolite from the sepiolite deposits in the south of Sivrihisar country which is the subject of this text, was exported in order to use as drilling mud. Later, any exploitation or exploration on these sepiolites has not been done.

Layered sepiolites form deposit which presents economic reserve due to their occuring manner. Owing to their physicochemical features, the sepiolites have become on interesting industrial mineral which is served increasing number of usages during last several decades. The study of the subject of this text is one of works based on deposition, mineralogical and original characteristics of this kind of sepiolites which has not been sufficiently investigated and has not been submitted for industrial usage yet. The sepiolite deposite in the south of Sivrihisar which is considered as one of the most important occurrences owing to its reserve, is descripted in this article (Fig. 1).

GENERAL GEOLOGY

Pre-Tertiary and Neogene aged rocks outcropped in investigated and surroundings area. Pre-Tertiary rocks form morphological heights which extend in northwest-southeast trend. In a field about 25 km. southwest of investigated area, this old lithology is mostly represented by recrystallized limestones and serpentinites that are occasionally in dolomitic character and contain schist layers (Yeniyol, 1982). Marbles, recrystallized limestones, gneiss, schist and granodiorites are located in about 12 km. northwest of the area, and ultramafics are outcropped in an island shape about 30 km. northwest of the area due to erosion of Neogene aged cover. Limestones, marbles, schist and gneiss are in Mesozoic(probably Cretaceous) age (Niehoff, 1964). The emplacement age of ultramafics mostly represented by serpentinites and intrusive rocks in which granodiorites are dominant, is Upper Cretaceous (Erentöz, 1975; Yeniyol, 1982).

The region has been affected by structural movements in uplift and subsidence character between Lutetian and Neogene (Erentöz, 1975). The morphology which is almost today's morphology has been exposed by

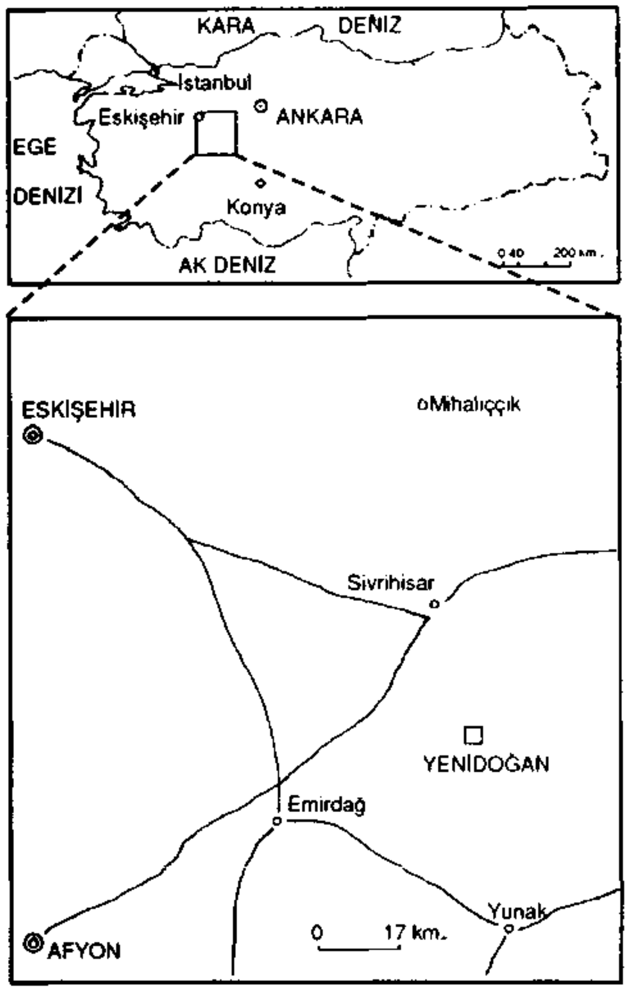

Fig. 1 - Location map.

these movements of initial regional gravity faultings which extend in northwest-southeast trend and subsequent tectonic lines extending in northeast-southwest trend. Neogene sedimentary rocks have been deposited in subsidence areas bounded by the morphologic heights of peneplanated old lithology, and coarse-grained material has been deposited in especially marginal sections, and the thin, clastic material has been deposited in inner sections during the first period of sedimentation in which tectonics was active. Rocks produced by chemical precipitation have been deposited at upper part of the sequence during the subsequent period of slow and quiet tectonic activity. Volcanic products which have been occasionally developed in Miocene and have been increased in Pliocene (Erentöz, 1975), were also added to sedimentation.

Entire investigated area is covered by Neogene sedimentary rocks (Fig. 2). These rocks form a 200 m. thick sequence from the valley floor of Sakarya River which runs nearby the east boundary of the area. Stratigraphic sequence may almost be described as three rock assemblages according to sedimentation environments and some lithologic differences.

First section of the sequence from the basement is approximately 80 m. thick and consists of dolomite, dolomitic marl, tuff, sandstone and alternation of silty and clayey rocks. Hard and micritic dolomites are occasionally loose. Some dolomite beds contain abundant freshwater gastropoda fossils. Numerous dolomite beds are silicified probably due to volcanic activities. The dolomite beds are located in 5-10 m. intervals and their maximum

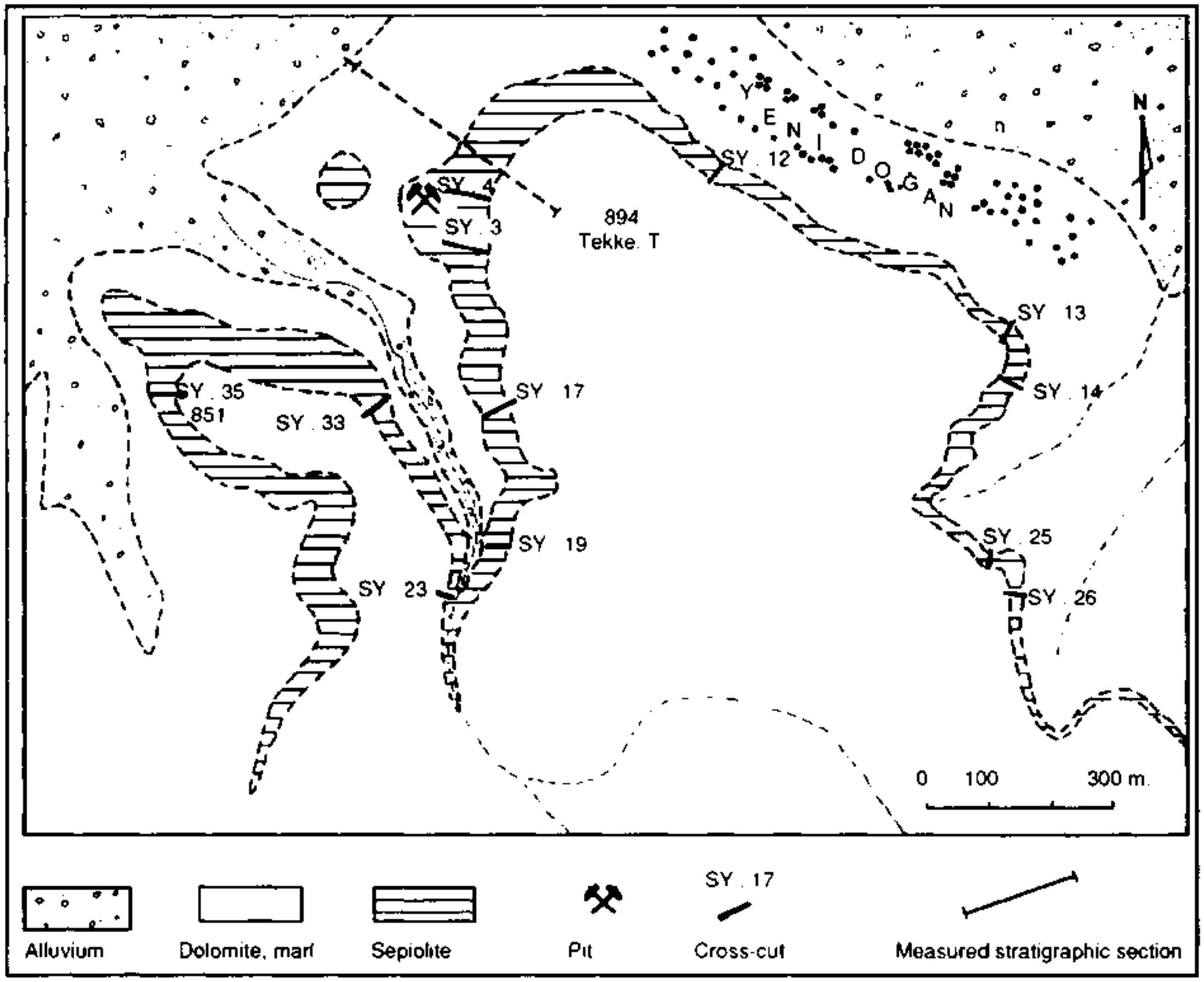

Fig. 2 - Geological map of Yenidoğan (Sıvrıhısar) sepiolite occurrence.

thickness is 10m. in some places. Acidic tuff and volcanic material-bearing sandstone are frequently alternated with dolomites in this section of sequence. Dolomitic marl, detrital sandstone and silty-clayey beds are added this alternation in the upper section of sequence, and 1-1,5 m. thick, hard, silicified dolomite bed is located at the top (Fig. 3).

The following rock assemblage which is dominated by dolomitic sedimentation, is approximately 40 m. thick and comprises of dolomite and dolomitic marl alternation. The base of the assemblage is 1-2 m. thick crystalline gypsum. Green and brown chlorite-corrensite clays deposited in brackish environment are added the dolomite-marl alternation in the middle and upper sections.

Rock assemblages described above are formed a dome structure in the outside and in the east of the studied area by vertical movements occured after sedimentation. Rocks outcropped in southwest of studied area have dips to north and northwest as continuation of this structure. The uppermost rock assemblage which comformably overlies the others, has dips to the same directions. It is thin in southwest of investigated area. The dip decreases in north, in west and in northwest of the area, and the layers become almost horizontal layers. The thickness exceeds up to 70 m.

The observable succession of this assemblage starts with a light green-white coloured, loose, over 2 m. thick magnesite mudstone bed (Fig. 3; YD-1). Dolomite and dolomitic marl alternation that contains two main sepiolite beds, overlies the magnesite mudstone. The uppermost bed is a hard, over 3,5 m. thick micritic dolomite.

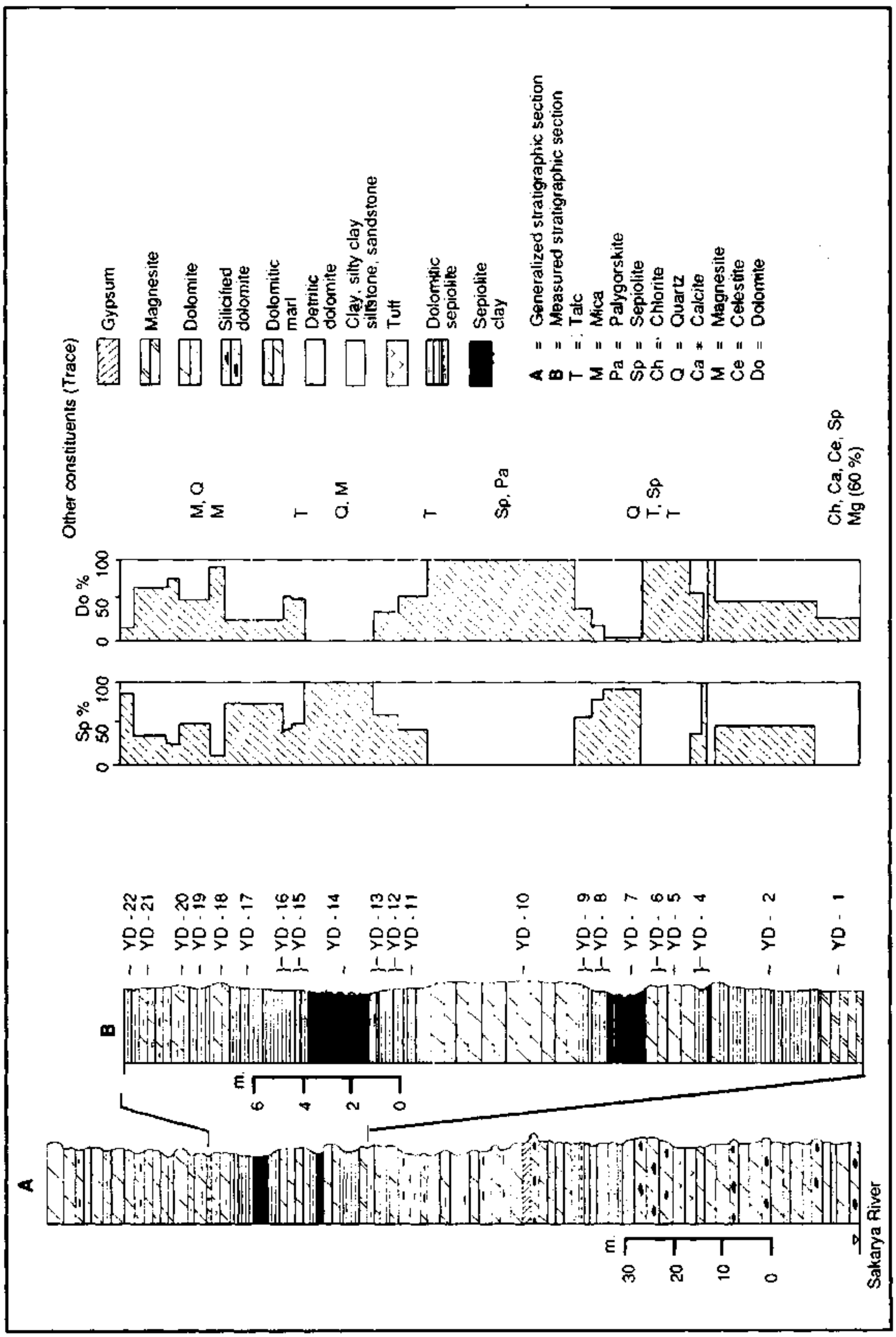

Fig. 3 - Stratigraphic section and diagrams that show lithologic sequence and mineral compositions.

Dolomites are dark white-beige coloured, usually hard, tight and micritic, and occasionally are loose and chalky and in detrital texture. Main mineral in composition is dolomite. Besides trace amounts of talc mineral is located in some beds as a product of chemical precipitation (Isphording, 1984).

Dolomitic marls comprise 50 % dolomite and 50 % clay minerals. Accompanying clay mineral is sepiolite in lower sections. It is possible to classify that composition of marls as "sepiolitic marls". Trioctahedral smectite (Stevensite ?) ± sepiolite in the upper sections, smectite and chlorite in the uppermost sections of assemblage are located as clay components of marls.

Both dolomites and marls contain very few amount of thin, angular quartz, muscovite and rounded volcanic glass grains. Moreover there may be sparse and having maximum 1 mm. diameter reworked material grains such as rounded dolomite, sepiolite and smectite in some beds. They have been added to sedimentation probably during arid periods.

Frequent or sparse organism burrows that indicate shallow sedimentation environment are secondary structures which are observed in many beds. Fenestra and boxwork structures are formed by desiccation cracks with secondary dolomite fillings are also observed in some beds (Fig. 3; YD-3, 19, 20). They are developed vertical or parallel to bedding and indicate that sedimentary materials were occasionally exposed above the water level during extremely arid periods.

SEPIOLITE

Sepiolite formations as in two separate beds outcropped at the lower half of uppermost rock assemblage (Fig. 3). 3 m. thick lower sepiolite bed is observed along the "measured stratigraphic section". Lower and upper sections of this bed are dolomitic sepiolite in detrital character (YD-8). It is composed of sepiolite matrix and dolomite grains. Laminated and 50-60 cm. thick sepiolite clay is situated in the middle section (YD-8). This sepiolite-rich bed is definitely bordered by dolomites at bottom and top of it. The thickness laterally decreases, and the composition grades to dolomitic sepiolite.

The upper sepiolite-rich bed regularly extends and can be observed along the slopes in entire investigated area. Maximum thickness is 10m. in southwest-and northwest of Tekke Tepe (Fig. 3, 4). Thickness regularly decreases southwards and southwestwards, and finally the bed disappears. It comprises sepiolite clay, sepiolitic marl and the alternation of layers and lenses composed of sepiolite and dolomite at various rates.

Sepiolite clay is as lower and upper separate layers (Fig. 4). It has been occured that small size lenses came together and above each other. Lateral continuity of lower sepiolite layer is shorter than the other, and maximum thickness is 2,5 m. in some places. Upper layer continues in entire area except an interruption is observed at the morphologic defile in south of Tekke Tepe. Maximum thickness is 3,5 m.

Sepiolite clay in soft wax characters when it is wet. The colour is beige or brown in general, and is dark brown or even is black when it includes organic matter. Dry sepiolite clay is too light and its colour is light beige or beige. Sepiolite clay in some places has homogeneous appearance, and is laminated or thin bedded. It is splitted into thin sheets parallel to lamination when it gets dry. These sheets resemble mountain leather. Rounded intraclasts composed of sepiolite may occasionally be located in sepiolite texture at varying rates. Sepiolite clay in some places has massive structure and detrital character that the bedding is not developed well like on the quarry in west of Tekke Tepe.

Thin tuff, diatomite and chert intercalations located in sepiolite clay are observed at some trenchs in southwest of Tekke Tepe (Fig. 2, 4; 13, 14, 25, 26). Tuff consists of white acidic glass (pumice), vermicular biotite in 1 - 2 mm. size and accessory muscovite. Tuff is situated as thin beds of 0.5-10 cm. in thick, as alternated with sepiolite or as disseminated angular detrital material in sepiolite. Diatomite is located close to tuff material and as disseminated diatom tests in sepiolite or as a few cm. thick beds that have been formed by intensive diatom test aggregate. Chert is as nodules in *a* few cm. size or as thin bands.

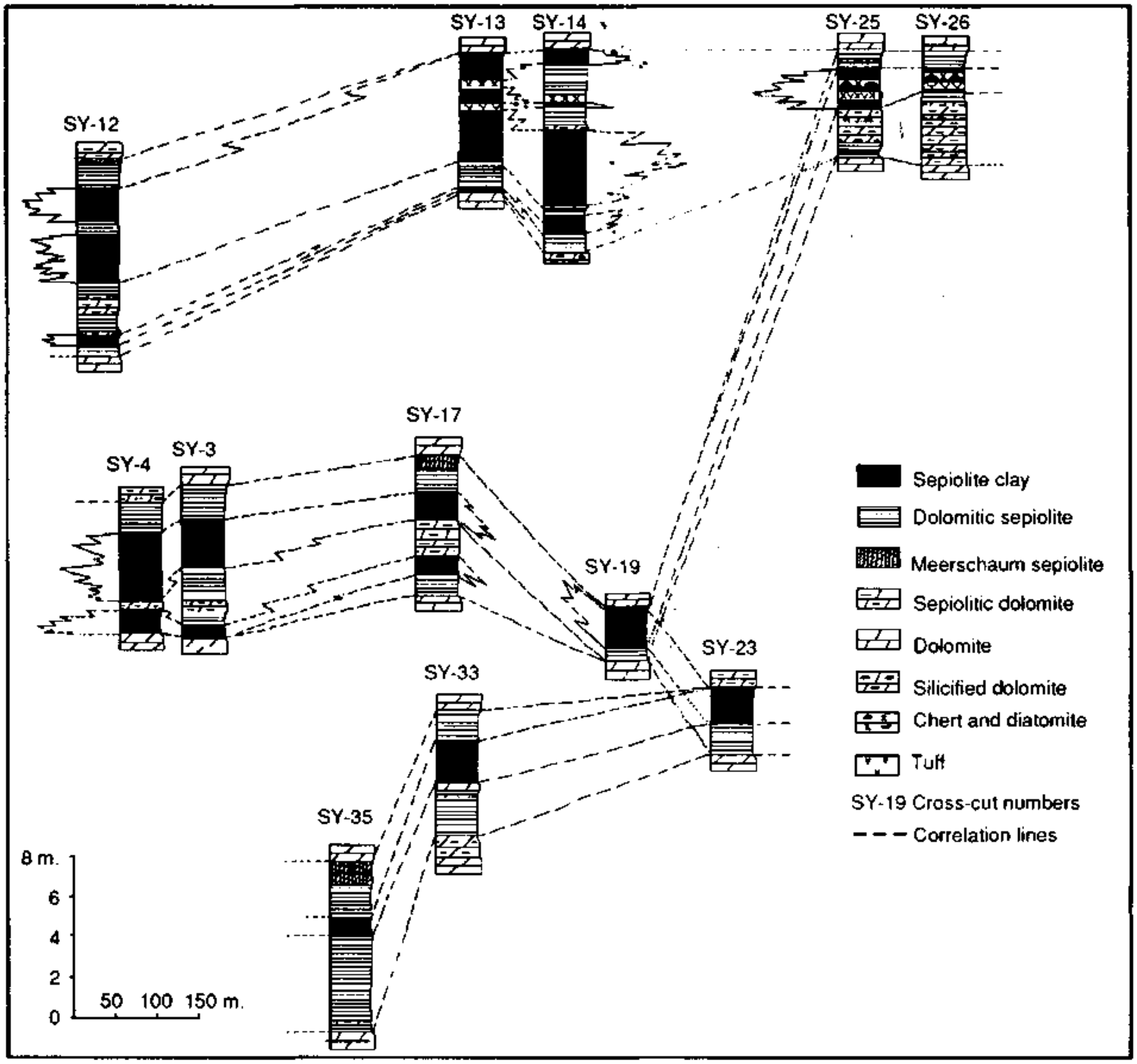

Fig. 4 - Diagram of lithologic correlation.

The material described as "dolomitic sepiolite" which contains over 50 % sepiolite, constitutes the biggest portion of the volume in upper sepiolite bed. The colour of dolomitic sepiolites varies from white to light beige and beige according to sepiolite content in composition, and their unit volume weights decrease.

Dolomitic sepiolites have massive structure, their beddings are not developed well in general. Some of them are produced by chemical precipitation and are fine-grained. They occasionally have detrital structure and contain intraclasts which their maximum size is 1 cm. in some places but generally in sand size or finer. These intraclasts are sepiolites and dolomites belong to same aged sediments. When dolomitic sepiolites get dry, form columnar desiccation cracks that have been developed in various dimensions at outcrops. These cracks are occasionally vertical to beddings.

Dolomitic sepiolites are occasionally in meerschaum character at upper sections of the main sepiolite-rich bed that described above. This white or occasionally light beige coloured matter is not dispersed in water. It can easily be chiseled and be treated. Meerschaum has detrital texture and porcelain appearance, and is fine-grained. Sparse and 1-2 cm. opened poligonal desiccation cracks have been formed in wet condition at outcrops. This maximum 1.4 m. thick and roughly lense shaped meerschaum has a specific economic importance among the other sepiolite-rich materials in the deposit.

Young sepiolite formations as thin veins and the tracks of plants and organism burrows which indicate the depositional environment are observed in both dolomitic sepiolites and sepiolite clay. Besides fenestras and box-works that have been occured concerning arid periods are observed. (Fig. 3; YD-12, 16, 9, 20).

Sepiolite clay and dolomitic sepiolites laterally grade to each other. This gradation vertically lasts a short distance. There is also a sharp boundary relation between them in some places.

The upper sepiolite bed described above, is bounded at the base by a hard, varying thick dolomite layer (YD-10). A hard dolomite bed with relief which is occasionally in dolomitic sepiolite composition overlies the upper sepiolite bed (Fig. 3; YD-18, 19, 20). This bed in which detrital character and fenestra structure are observed, is occasionally overlain by thin magnesite and magnesite-rich clay formations. Dolomitic sepiolite with lateral continuity in some places and the beds composed of sepiolite+triocthedral smectite (probably stevensite) which occasionally have fenestra structure and paleosol character are also located.

MATERIAL AND METHODS

Measured stratigraphic section of the upper of the sequence in which sepiolite formations are located, is prepared in order to detailly observe and to describe the superposition manner and the textural features, mineral composition and its variation. Furthermore, 34 trenchs in sepiolite-rich beds vertical to bedding are opened. 170 samples are collected from various lithologic units, from the stratigraphic section and trenchs, from wells and the quarry for investigations at laboratory. These samples are firstly examined under binocular microscobe. Later XRD analysis of 38 required samples, microprobe analysis and scanning electron microscobe (SEM) analysis of 5 samples and the chemical analysis of 46 samples are carried out.

Qualitative mineral determination are also carried out by Philips XRD equipment. Analysis are created on non-oriented powder preparatories that are prepared by grinding the samples in natural state. In the same records, integral field of the first pique (110) belongs to sepiolite and the maximum pique heights of the other minerals are compared and the semiquantitative composition is estimated.

As an approach, estimation of the quantitative composition on dolomitic sepiolites are carried out by means of a prepared working curve. Both CaO analysis and the XRD records of the samples taken from sepiolite occurrences in Eskişehir area, are carried out. These samples have different dolomite/sepiolite ratios. CaO percentage values which are calculated from chemical analysis, are accepted as abscissa and the ratios of the most severe piques of XRD records belong to dolomite and sepiolite minerals (DO/ASp) are accepted as ordinate (Fig. 5), and a curve is prepared in this way. During the routine works about to determine the composition of the only samples which are taken the XRD records, this curve is used.

Samples in different composition and textural features are used on electron microscobe investigations. Samples are firstly plated by a thin gold film. Later, analysis are carried out by using JEOL-733 electron microprobe and JSM-T330 scanning electron microscobe.

Only the CaO analysis is carried out in order to calculate the dolomite percentage in dolomite-bearing samples. For this purpose, carbonate in samples is solved with 1M Hcl solution. Later, CaO percentage is determined by atomic absorption. Dolomite percentage tn composition is calculated from these values. Entire rock analysis is carried out to define the chemical composition of sepiolite clay. Firstly, sample in natural state is roasted at 1000°C for two hours. Later chemical analysis is carried out by combination of atomic absorption and the wet method. Oxide percentage values that are turned into normal temperature according to total water loss and the analysis results of a classical meerschaum type sepiolite are given in Table 1 for comparison. Oxide percentages in Table 1 are usual values for sepiolite mineral. However, Al_2O_3 and Fe_2O_3 values of sepiolite clay are higher and MgO value is lower than meerschaum. This indicated that octahedral Mg is substituted with more amount of Al and Fe in sepiolite clay.

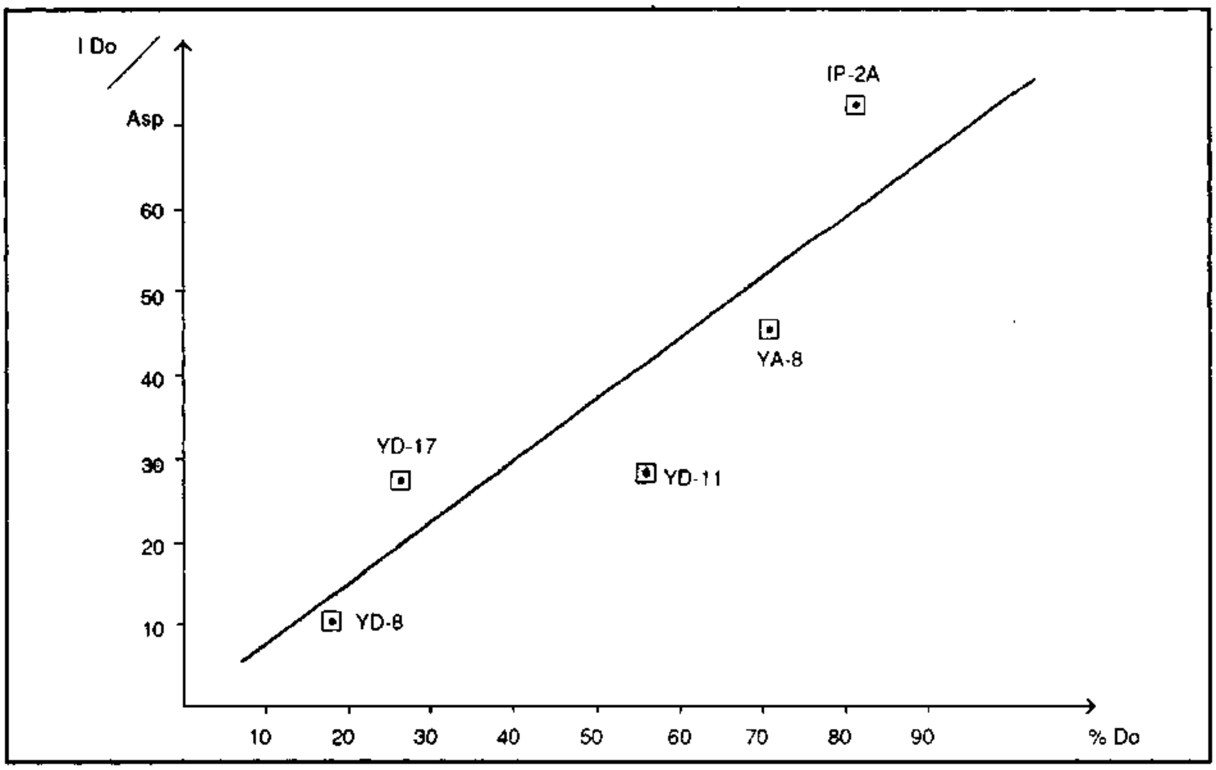

Fig. 5 - Diagram that shows the relation between the dolomite/sepiolite pique ratios at X-ray powder difraction patterns of the samples and the dolomite content. YD: Yenidoğan, YA: Yörükakçayır, IP: İlyaspaşa

Table 1 - Chemical composition of sepiolite clay

	(1)	(2)
SiO_2	54.04	54.02
Al_2O_3	2.85	0.19
Fe_2O_3*	1.08	0.51
MgO	20.69	23.13
MnO	0.01	-
CaO	0.19	0.06
Na_2O	0.11	0.02
K_2O	0.69	0.02
A.Z.	20.07	21.63
Total	99.74	99.58

* Total iron.

(1) Massive sepiolite clay

(2) Meerschaum (Yeniyol and Oztunalı 1985)

TEXTURE

It is observed that laminated sepiolite clay is formed by sepiolite fibers under scanning electron microscobe. Occasionally ondulated fibers are suited for bedding plane, are stacked as parallel or almost parallel to each other. They cause the lamination at this type of sepiolite. Round, having diameters of less than 0,5 mm. sepiolite grains of eolian origin are sparsely located in sepiolite groundmass of laminated sepiolite clay in some cases. Sparse or intensive intraclasts are located in sepiolite groundmass in some beds and in some places. They are in varying size and their maximum diameters 1-2 cm. in some cases. Primary laminar structures at sepiolite composition are kept in intraclasts. The shapes of intraclasts are flat or round and their corners are rounded. It is observed that intraclasts are made up of dolomite in some cases. Furthermore, muscovite, vermicular biotite and volcanic material such as volcanic glass and tuff grains are situated in sepiolite groundmass. They form sharp boundary with sepiolite groundmass in some cases.

Massive sepiolite clay consists of intraclasts and groundmass. Volumes of intraclasts are irregularly dispersed. They may up to 2-3 cm. in size, but generally are in sand size or smaller. These laminated, subrounded and flat intraclasts are in sepiolite composition. Their corners are also rounded. Detrital texture is clear under microscobe. It is observed under SEM that the material consists of grains in 2m-15m size and sepiolite in fiber structure which fills the intergranular space. After the grains have been deposited and during the diagenesis period, the sepiolite has been lined up parallel to grains, later has laterally become larger from grain surfaces, and has covered the volume. The length of sepiolite fibers is 0.5-1 m. Over 15m. long fibers which are grown up in later period can occasionally be observed (Plate I, fig. 1).

Some dolomitic sepiolites in detrital character have textural features similar to massive sepiolite clay. However, intraclasts may be sepiolite and groundmass is sepiolite or intraclasts may be dolomite and groundmass is sepiolite. In some cases, intraclasts comprise of both sepiolite and dolomite at varying rates. As a result of these variations, material has a gross composition of dolomitic sepiolite character in any case.

Dolomitic sepiolites which are products of chemical precipitation consists of dolomite and sepiolite minerals that are smaller than 1m. Homogenous structure of dolomitic sepiolites which can be observed both by microscobe and naked eye, due to different crystal morphologies, mixed dispersion at volume of two minerals and their flocculation after precipitation in electronic environment.

Sepiolite in meerschaum character is fine-grained and has detrital texture. Grain size varies from very fine sand to 2m. Sepiolite fibers which have reciprocally become larger and have clamped as vertical to grain surfaces in the intergranular space, probably have caused that the material does not disperse in water (Plate I, fig. 2). Occasionally observed calcite formations which have been occured in intergranular space after forming of sepiolite, also probably have caused that the material does not disperse in water and has a white colour.

MINERALOGY

Clay mineral component in all kinds of sepiolite-rich materials is the sepiolite mineral which is pretty well crystallized in some cases (Fig. 6). The sepiolite mineral exists over 90 % in composition of laminated sepiolites. Organic matter is also located in composition of almost every sepiolite clay of this type. But the ratio of organic matter which causes the dark colour sepiolitic clay, is not over 10 %. Both intraclasts and groundmass in sepiolites with massive structure, are made up of the sepiolite mineral. This type of sepiolite does not contain organic matter. Its sepiolite content is over 90 %. Dolomite intraclasts, detrital quartz and sericite, feldspar and rounded volcanic glass grains may also be located in composition. Their total proportion in composition is not over 10 %.

Dolomitic sepiolites usually include 50 % or more sepiolite. Principal component except sepiolite is the dolomite mineral (Fig. 6). There are occasionally 5-10 % illite, very few detrital quartz and volcanic glass in dolomitic sepiolites at upper sections of main sepiolite bed. The material becomes sepiolite-rich dolomite where the sepiolite content decreases under 50 %. However, sepiolite is 10 % or more in almost every case at main sepiolite bed. Meerschaums include 50-70 % sepiolite, few dolomite and in some cases very few calcite.

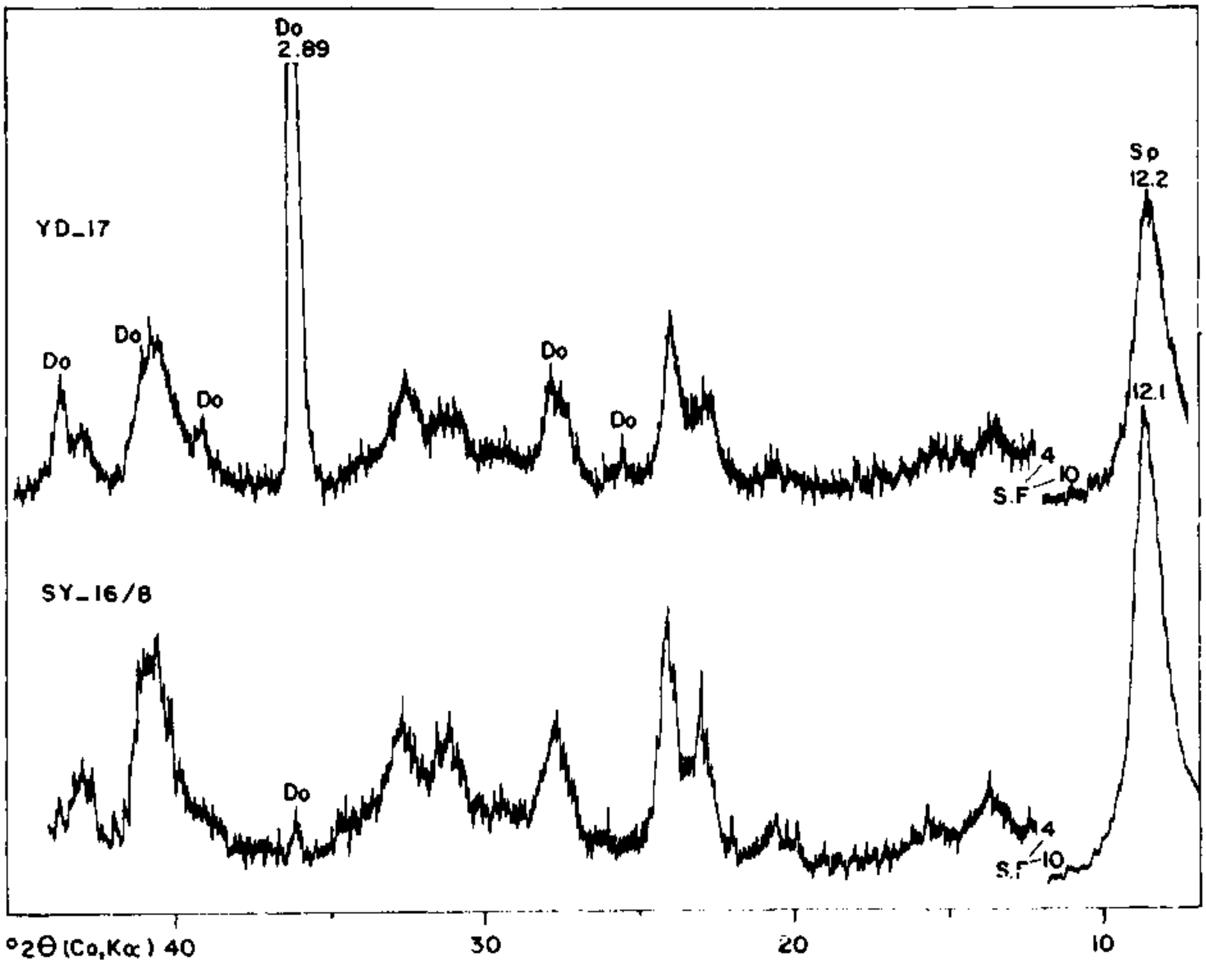

Fig. 6 - X-ray powder difraction patterns. YD-17: dolomitic sepiolite, SY 16/8: sepiolite clay (SY-16/8 sample is taken from a trench opened between SY-3 and SY-17 trenchs). DO: dolomite, SP: sepiolite, SF: scale factor.

ENVIRONMENT AND GENESIS OF SEPIOLITE

Sedimentation basin in which Neogene lithology deposited is an alkaline lake covers broad depression areas connected with each other in regional scale and shallow lakes and ponds which have been separated from the main mass during the arid periods caused that the lake became smaller and have been combined with main lake mass during the rainy periods. Sedimentation in this playa or similar to playa kinds of lakes have occured under evaporite conditions and generally in chemical precipitation way. Limited detrital and volcanic material have also been deposited during in some periods.

Stratigraphic and lithologic features indicate that the seasonal rainy, arid or semi-arid climates have dominated in the region. Under these climatic conditions, pre-Neogene aged rimrocks have been subjected to chemical weathering, and the materials mainly in ion and gel state have been transported to basin by surface waters with low energy during the rainy periods. Recrystallized limestones which are the most regional widespread rimrocks are principal source of Ca^{2+} ions that have been transported to sedimentation basin. There is no other widespread rimrock which can be the source of this ion needed for dolomites which is the dominated lithology in the sequence. Ultramafics which are secondly most widespread rocks and their derivative rocks (serpentinites) are main sources of Mg^{2+} ions needed to dolomites and magnesium clays. Furthermore, Mg^{2+} presentation as at few rates from dolomitic sections of recrystallized limestones is probable. Ultramafics have provided Si^{4+} ions together with Mg^{2+} ions to basin. During these phases, additional silica has been also presented from devitrification of volcanic glass and ash which has fallen into water by volcanism that occasionally accompanied with sedimentation.

Slightly uplift of rimrocks by occasionally occured vertical movements and slightly folding of the sediments by progressive subsidence of the basin caused that the detrital materials together with ions have been transported from rimrock to basin. However, this detrital material have reached to inner sections of the basin at limited rate and during the periods in which the surface waters have had high energy. Another source of clastic material is acidic volcanism. Volcanoclastic materials such as thin tuff, ash and glass (pumice) have been added to sedimentation environment by volcanic activity. The sediments have come up to atmosphere and have got dry due to narrowing of the lake area during arid periods. They have been eroded during the following wet periods, and have been transported by winds and waters. They have deposited again, so clastic materials have been added to sediments.

Quartz, feldspar, biotite, sericite and illite are the minerals which have been transported from rimrocks or have been added with volcanic activity. Calcite, dolomite, magnesite, celestite, gypsum, corrensite, chlorite, talc and sepiolite are authigenically formed. The formation of these authigenic minerals have been controlled by Ca^{2+}, Mg^{2}+, Si^{4+}, SO_4^{2-} ions and their abundance, partial press of CO_2, temperature of environment, evaporation, organic catalytic and the other environmental conditions.

The formation of dolomite is still discussible. It has been formed during arid periods with chemical precipitation owing to increasing of Mg^{2}/Ca^{2+} activity in lake water by precipitation of magnesium silicates. Dominating climate and other conditions at basin were generally convenient for dolomite formation. Gypsum, corrensite-bearing clays, magnesite and sepiolite have been formed in extreme climate conditions.

Lithologic features at middle section of the sequence indicate that the lake water occasionally has become brackish by adding SO_4^{2-} ions. Chlorite-corrensite clays and gypsum formations have occured under hypersaline environment conditions during very arid periods owing to extreme evaporation (Weaver, 1984). During very extreme evaporation periods which the lake has nearly got dry, magnesite with over 10 pH values has been precipitated due to decreasing the other cations and increasing Mg^{2+} concentration in environment (Alderman, 1965). Magnesite may also have formed owing to high hidrate character of Mg^{2+} ion. In this way, magnesium probably has been formed at first as an hydrous magnesium mineral such as hydromagnesite or nesquehonite, later by dehydratation of them (Langmuir, 1965). Calcite has been occured during the post-diagenesis phase which was convenient to form calcite, probably by ground water that was in about 8 pH value needed for sepiolite forming, in the intergranular space and cracks (Galan and Ferrero, 1982).

Formation of sepiolite which is an indicator of paleoclimate, have taken place under the seasonal rainy, arid or semi-arid climate conditions (Gallon, 1984), but during the rainy periods as clearly observed with field data. The environments in which sepiolite has been precipitated are the marginal sections of lake basin which its pH has decreased by feeding of surface waters, short-lived ponds which have located at the edges of main water mass and their mixture zones which have exchanged water with main lake mass and the marshlands in which short-lived plants could have lived.

The pH value must be between 8-8.5 in order to form sepiolite according to works related to sepiolite and the investigations purposed synthesis of this mineral (Siffert, 1962; Wollast et al., 1968; Hegelson et al., 1969; Singer and Norrish, 1974; Khoury et al., 1982; Galan and Castillo, 1984; Abtahi, 1985; et al.). The low rates of Al^{3+} in the environment have made the sepiolite formation possible as a stable mineral phase instead of palygorskite which occurs under the same environmental conditions.

The Ca+Mg/Si ratio has decreased owing to dolomite precipitation. Sepiolite with about 8-8.5 pH values has been formed by convenient saturation index which have provided with Mg^{2+} and Si^{4+} ions that have been added to lake water by surface waters during rainy periods (Khoury et al., 1982). Field and laboratory investigations are demonstrated that there is not a direct relationship between sepiolite formation and volcanism. However, devitrification of volcanic glass might have provided an indirect aid in order to increase the Si^{4+} proportion

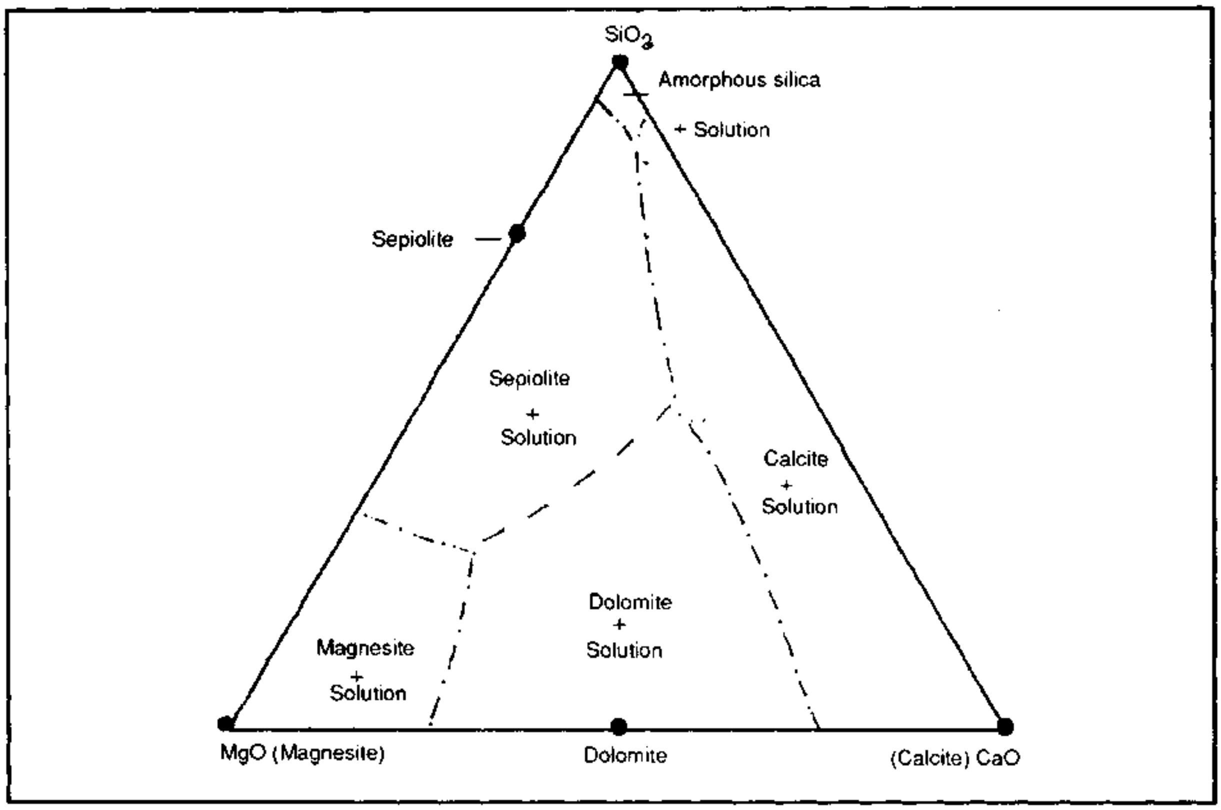

Fig. 7 - Saturation diagram for CaO-MgO CO_2-SiO_2-H_2O system at 25°C and 1 atmosphere (Hegelson et al., 1969).

needed for sepiolite formation. Therefore, sepiolite has been formed under appropriate environmental conditions in three different ways and phases; 1) direct chemical precipitation from lake water, 2) precipitation from intergranular solutions during diagenesis phase, 3) precipitation as crack filling during post-diagenesis phase.

In small ponds and marshlads which are fed with fresh surface waters, sepiolite has been formed with direct crystallization and precipitation defined as chemical precipitation. In the environments which the electrolytic concentration was low so flocculation was not effective, the sepiolite fibers have lined up as their long axis parallel to base, and caused the sepiolite clay has had a laminated structure. Under the conditions which fresh water has mixed with lake water, sepiolite and dolomite have together been formed by chemical precipitation with the solutions which their compositions are seen between dolomite and sepiolite areas on the Hegelson et al. saturation diagram (1969) (Fig. 7). Because of the different crystal morphologies of these two minerals, flocculation effect of the electrolytes in environment and stable precipitation conditions, a massive structure is observed in this type of sepiolite material.

Formed sepiolite and related sediments have occasionally got dry when they have outcropped by shrinking of lake area during arid periods. These sediments have been eroded, transported by surface waters and deposited again during the following rainy periods. The material has rapidly been deposited in this way, and has formed detrital "dolomitic sepiolites" which have varying dolomite/sepiolite ratios according to kind and spreading of the outcropped sediments.

During diagenesis phase which represents the second formation way, sepiolite has been formed in the intergranular spaces of the detrital sepiolites and the sediments composed of sepiolite and dolomite. Sepiolite has occured with appropriate pore solutions by growing up from grain surfaces and vertical to these surfaces as fibers. Growing fibers in this way have reciprocally been clamped, and have caused dolomitic sepiolites do not disperse in water and have meerschaum character in some cases.

Besides two formation ways considered above, sepiolite has also been formed during post-diagenesis phase or later phases. In these phases, sepiolite has produced thin veins as filling of desiccation cracks by precipitation from ground waters.

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PLATE

PLATE -I

Fig. 1 - Scanning electron micrograph of massive sepiol
Linear scale = 10 micron.

Fig. 2 - Scanning electron micrograph of meerschaum.
Linear scale = 10 micron.