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SEDIMENTOLOGY OF CALICHE (CALCRETE) OCCURRENCES OF THE KIRŞEHİR REGION

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ABSTRACT.- Study was conducted in the Kırşehir region. Carbonate occurrences within the upper Miocene-Pliocene deposits forming the subsidence basins surrounded by the Kırşehir massive, are described as caliche. These caliche deposits in the alluvial fan-meandering river and lacustrine environments are found in three different zones. In the measured, sections, conglomerate comprises the basement and is overlain by a transition zone made of sandy mudstone (Zone I). Above them is the rarely nodular carbonaceous zone with horizontal and vertical positions in the reddish mudstone-siltstone (Zone II). Finally, laminated caliche (calcrite) comprises the upper most part (Zone III). Carbonates in the basement, country rocks, and in the soil are dissolved in the acidic environment and become a solution saturated with calcium bicarbonate. This solution is transported to the sediments and capillary rises through the sediments during arid-semi arid seasons. Carbondioxide in the Ca and HCO_3-bearing solution is removed from the system and as a result, calcium carbonate nodules and laminated caliche are formed. These stromatolite-like laminated caliche occurrences show a criptoalgal structure under polarized microscope and scanning electron microscope (SEM), and they contain microerosional surfaces and caliche pisolites that are formed by dissolution. Caliche occurrences are believed to be source of camotite, thorium, vanadium, sepiolite, huntite, dolomite, and magnesite.

INTRODUCTION

Study area comprises around of the city of Kırşehir in the Central Anatolia (Fig. 1A and 1B). In this region, nodular and laminated carbonate occurrences are observed particularly in upper Miocene-Pliocene rock units that are bordered by the Kırşehir metamorphic basement at north of Kızılırmak river. In the previous studies, these occurrences are stated to be the products of shallow lake-playa (caliche) environment (Atabey et al., 19875; Atabey, 19895; Kara and Dönmez, 1990). This study revealed that this type of laminated carbonate occurrences are in fact caliche (calcrete) deposits that are found as nodules in a vertical position in soil zones of upper Miocene-Pliocene rock units, mudstone-siltstone, and partly in conglomerates at the upper most section of the sequence. The purpose of the present study is also to investigate sequence characteristics, position, geometry, lithology features, microtextural properties, and formation mechanism of such occurrences.

In a general sense, caliche is described as secondary carbonate formation and calcareous, semi-consolidated aragonite or early diagenetic calcite forming in loose materials (Walls et al., 1975), such as pebble, sand, silt, and soil under semi-arid and arid climate regimes. The term of caliche is used as a synonymous of calcrete and also known as calcrete crust and limestone crust (Bretz and Horberg, 1949; Brown, 1956; Mutter and Hoffmeister, 1968; Aristarain, 1970; Reeves, 1970; Goudie, 1972; Esteban, 1976; Hay and Reeder, 1978; Read, 1976; Hubert, 1978; Esteban and Klappa, 1983). Wright et al., (1988) used the term of laminated calcrete for limestone and calcrete-bearing deposits. Klappa 1980b, Seminiuk and Meagher (1981), Arakel and McConchie (1982), and Carlisle (1983) point out that these occurrences are formed in capillary zones of wide soil areas. Textural classification of calcretes is made by Knox (1977) and Reeves (1970). Calcretes were mineralogically and petrologically described by Hay and Reeder (1978). Kahle (1977) and Aristarain (1970) studied calcretes biologically and chemically. Hubert (1978) and Arakel (1979) worked on climatic and geographic features of calcretes.

It is given in the literature that caliche occurrences are associated with some element and minerals, such as carnotite, thorium, vanadium, sepiolite, magnesite, huntite, and dolomite (Szalay,1964;Goudia, 1972; Arakel and McConchie, 1982; Esteban and Klappa, 1983; Carlisle, 1983).

Some conditions required for the formation of caliche are country or basement rocks be a carbonate type, presence of carbonate in the soil zone of the area, climate regime of semi-arid to arid, widespread capillary activity, and the presence of CO_2 in the environment. As a result, caliche occurs to be a product of carbonization process. Carbonization is defined as reacting of carbonate (CO_2) and bicarbonate (HC_3) ions with bases to form carbonates (Ketin, 1982). Carbonic acid facilitates disintegration of rocks. CO_2 content of air and rain water is 0.03% and 0.45%, respectively. Carbonic acid is existed with the reaction between water (H_2O) and carbondioxide (CO_2). $CO_2 + H_2O = H_2CO_3$. This acid dissolves Ca- and Mg-bearing rocks and forms solutions saturated with calcium and magnesium carbonates.

$$\underset{\text{(limestone)}}{CaCO_3} \text{ or } \underset{\text{(dolomite)}}{CaMg(CO_3)_2} + \underset{\text{(carbonic acid)}}{H_2CO_3} = \underset{\text{(Ca-bicarbonate)}}{Ca(HCO_3)_2} + \underset{\text{(Mg-bicarbonate)}}{Mg(HCO_3)_2}$$

These Ca- and Mg-bicarbonate saturated waters move downward percolating generally through loose soil and mudstones. Then, they rise to the surface by capillary effect and evaporation during arid and semi-arid seasons. Carbondioxide (CO_2) in the solution on the surface is evaporated while water becomes stagnant. Thus, carbondioxide (CO_2) and water (H_2O) are removed from bicarbonate-saturated solution. Following this separation, as shown in the reaction given below, nodules consisting of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) form vertical and lateral carbonate occurrences. Carbonate rock of this type is described as caliche in a geological sense.

$$Mg(HCO_3)_2 + Ca(HCO_3)_2 = \underset{\text{(Ca carbonate)}}{CaCO_3} + CO_2 + H_2O \text{ or } \underset{\text{(Mg carbonate)}}{MgCO_3} + CO_2 + H_2O$$

Caliche is mostly observed in lacustrine, river, and alluvial fan deposits (Reeves, 1970; Platt, 1989; Esteban and Klappa, 1983; Hubert, 1978) and fresh water and vadose diagenetic environments (Steinen and Mathews, 1973; James, 1972; Land, 1970). Many studies were carried out on definition, facies features, diagenesis, chemistry, mineral content, occurrence, and deposition environment of caliche in Lebanon, Syria, Spain, Australia, Unites States of America, South Africa, and several other countries in North Africa. In Turkey, caliche occurrences are commonly observed in young rock units in Aegean, Mediterranean, and Central Anatolia. Studies on such deposits in Turkey are recently initiated. The city of Kırşehir was selected for a new investigation area and measured sections on caliche exposures in Seyrek village, Malhüyük hill at south of Çoğun village, city center of Kırşehir, Tilkideresi at south of Tepesidelik village, Kepez village, and Yenifakılı town were studied (Fig. 1B and 2). Samples collected were examined with polarizing microscope and scanning electron microscope (SEM). Samples were also analyzed with XRD and their microtextural features were determined by a paint technique. In addition, considering lithologic data, sedimentologic features and depositional environments of caliche occurrences in the area were examined.

STRATIGRAPHIC SETTING

The basement in the area is represented with a Paleozoic-Mesozoic unit cbmposing of metamorphic and magmatic rock assemblages (Fig. 1B and 2a). Above this metamorphic-magmatic basement, is the sedimentary upper Miocene-Pliocene rock units with an angular unconformity. This unit is described as the Kızılırmak formation by Birgili et al., (1975), Oktay (1981), and Kara and Dönmez (1990) and later as the Pecenek formation by Uygun (1982), Atabey et al., (1987a), Atabey (1989a), and Atabey (1989b). The same unit at north and east of Çiçekdağı was defined to be Kızılırmak and Bozkır formations by Erdoğan et al., (1996) and based on the palinologic data, its age was assigned as middle-upper Miocene. This unit is widely observed around the Kızılırmak valley and subsidence basins in the vicinity of the city of Kırşehir. Unit is composed of loosely cemented conglomerate, red mudstone-siltstone, and thin bedded carbonate cover in the upper parts of the sequence, all deposited in alluvial fan, meandering river, and lacustrine environments (Fig. 1B and 2a). Based on some vertebrate fossils, such as *Cyprideis cf. ventroundulata* Kırstıc, Cyprideis torosa Jones, and *Hypparion gracile* Kaup, and molar tooth of *Choerolophodan pentelici,* bone and tooth pieces of *Proboscidea family* (elephants), the unit is aged to be upper Miocene-Pliocene (Kara and Dönmez, 1990). Its thickness is about 15-300 m. White-gray, yellowish colored, clastic, porous, banded, lenti-

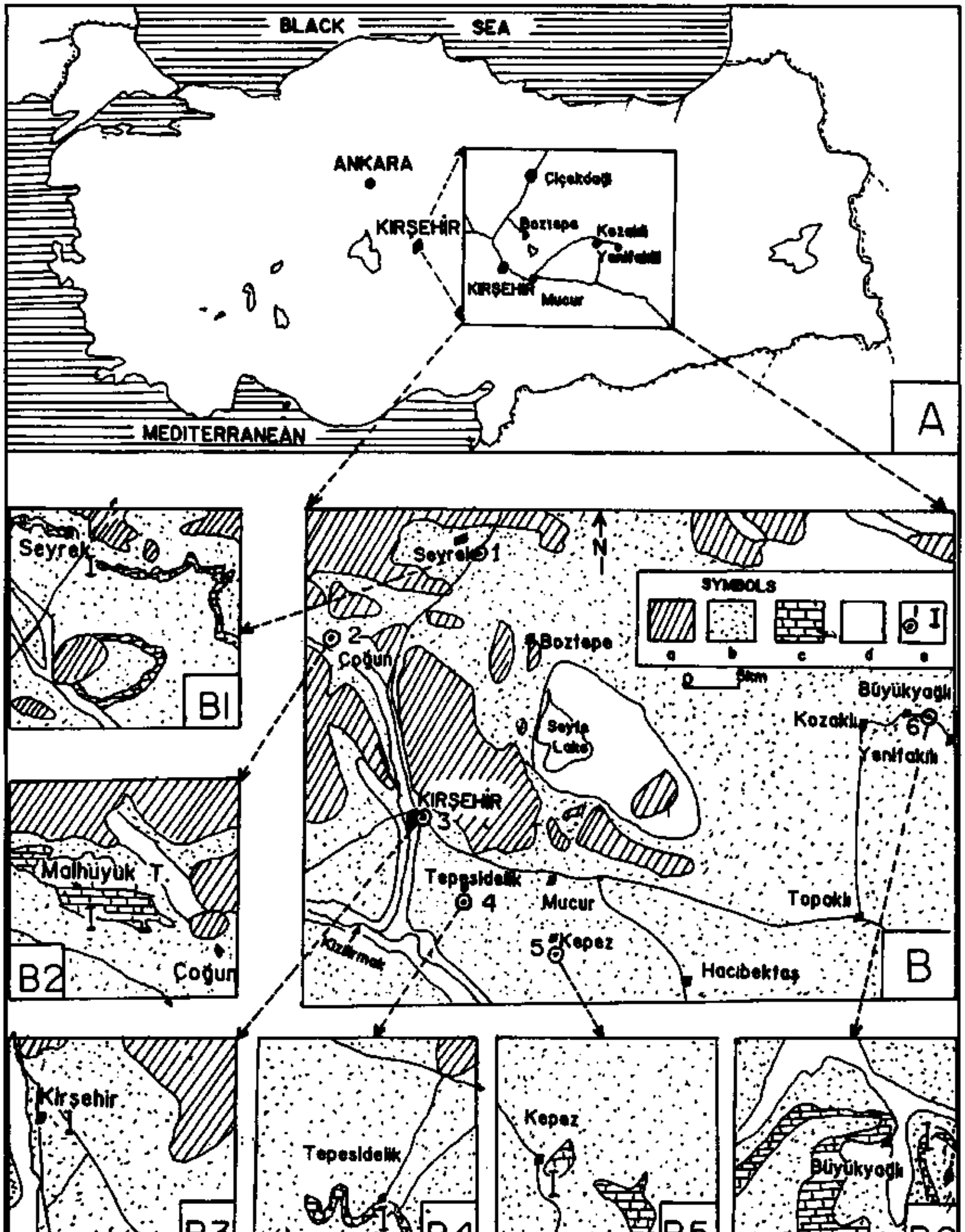

Fig. 1- A- Location map, B- Geology map (a- Metamorphic-magmatic rock units, b- Upper Miocene-Pliocene clastics, c- Upper Miocene-Pliocene carbonates, d- Alluvium), B1, B2, B3, B4, B5, and B6- Location of measured sections and their detailed geology maps.

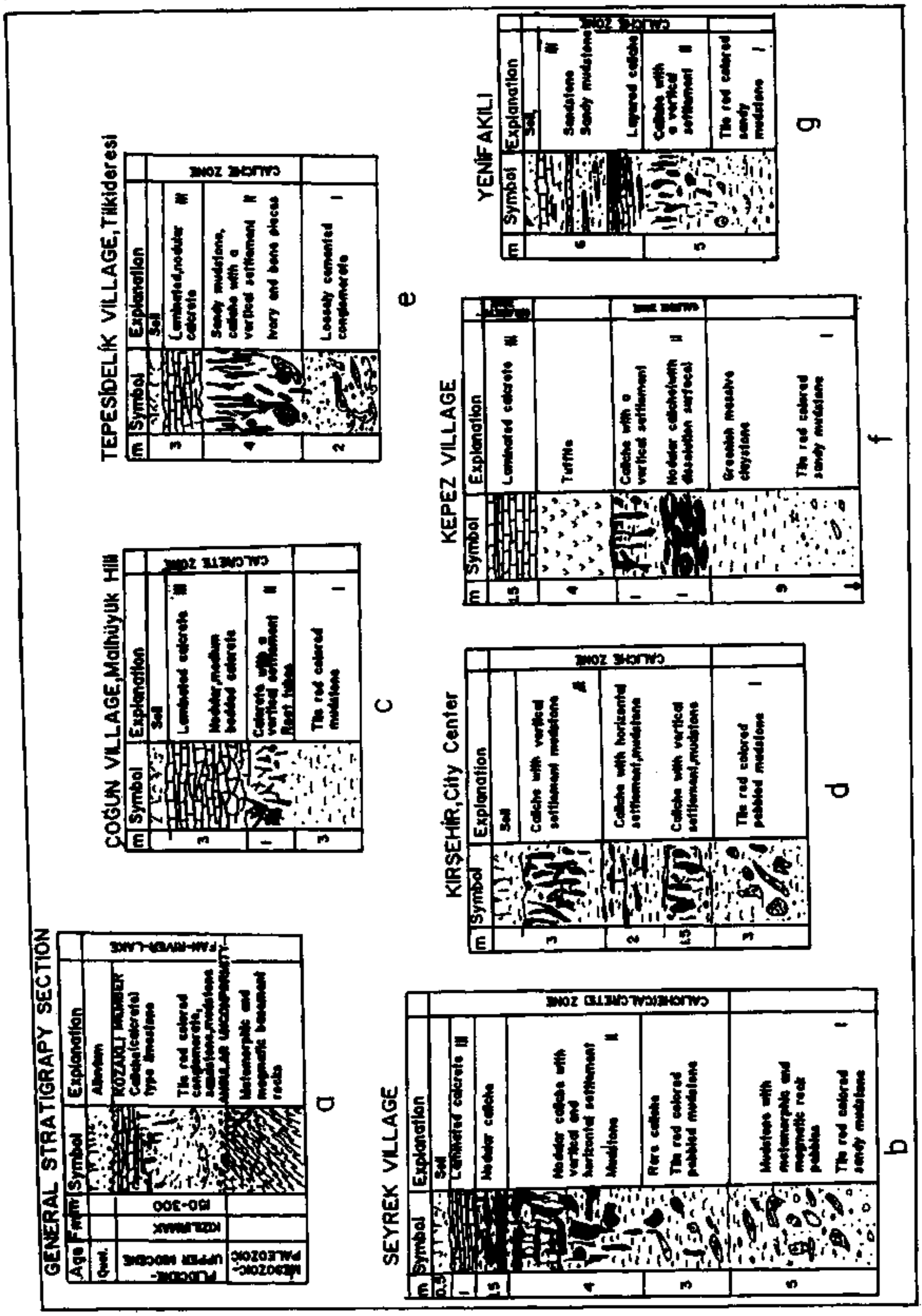

Fig. 2- a- General stratigraphic section, b, c, d, e, f, and g-Measured sections.

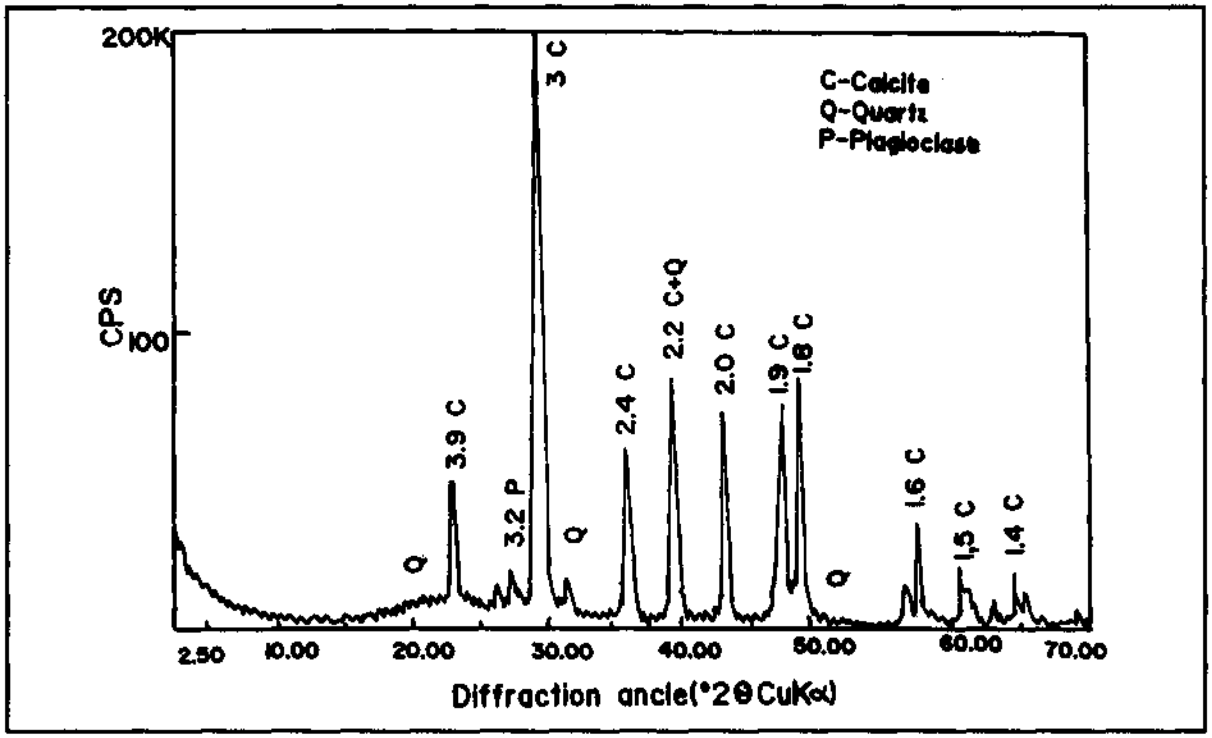

Fig. 3- X-Ray diffractometry chart of caliche (calcrite) (Seyrek village). Calcite is the dominant mineral phase.

cular lacustrine limestones covering upper parts of the Kızılırmak formation are named as Kozaklı limestone member (Kara and Dönmez, 1990), while laminated, thin bedded lacustrine limestones are called as Aksaklı limestone member (Atabey et al., 1987b; Atabey, 1989b) (Figs. 1 B1, 1 B2, 1 B4, 1 B5, 1 B6, and 2a). Caliche occurrences under investigation are observed as white colored, nodular calcite occurrences with horizontal and vertical settlements in sandstone and mudstone- siltstone levels of the unit mentioned above. Laminated lacustrine limestones at the top of the sequence are also defined as caliche (calcrete).

Descriptions of measured sections

Sections measured from caliche exposures in the Kırşehir region are described as below (Figs. 1 and 2).

Measured section from the Seyrek village.- It is at 40th km of the Kırşehir-Çiçekdağı road and located in J32-b1 quadrangle (Section marked with 1 in Fig 1.B and with b in Fig. 2). Its coordinates are x: 66600 and y: 10250 and has a thickness of 15 m. Sequence at the bottom is composed of mudstone 5 m in thickness containing metamorphic and magmatic pebbles, tile red colored sandy mudstone, and nodular calcite of 2-15 cm in size (Fig. 2b and Plate I). It changes to tile red colored pebbled mudstone with a thickness of 3 m containing rare caliche nodules and to mudstones of 4 m consisting of calcite nodules with horizontal and vertical long axes. Above that is partly nodular carbonaceous mudstone with a horizontal long axis of 1.5 m (Plate I, fig. 2, 4). The top of sequence is made up with laminated and thin bedded carbonates (caliche) (Plate I, fig.2).

Measured section of Malhüyük hill at south of Çoğun village.- It was measured in the Malhüyük hill southwest of Çoğun village at north of Kırşehir and is located in J32-a4 quadrangle (Section marked with 2 in Fig. 1 B and with c in Fig. 2). Its coordinates are x: 53800 and y: 92800 and has a thickness of 7 m. The basement is composed of tile red colored sandy mudstone level with a thickness of 3 m. Above that is a level consisting of root tubes and pipes with a vertical long axis of 1 m (Fig. 2c and Plate II, fig. 1). To the top, nodular, massive and layered limestone (calcrete) of 3 m is observed.

Measured section from the city center of Kırşehir- It was measured on the Kayseri road in the city center of Kırşehir and is located J32- d2 quadrangle (Section marked with 3 in Fig. 1 B and with d in Fig. 2). Its coordinates are x: 33800 and y: 01700 and has a stratigraphic thickness of 9.5 m. Section is composed of mudstones consisting of rare carbonate nodules overlain by carbonaceous mudstone- siltstone level with vertical horizontal long axes of 3.5 m. The upper most part consist carbonaceous mudstone with a vertical settlement of 3 m (Fig. 2d and Plate II.fig.3).

Measured section from the Tilkideresi at south of Tepesidelik village.- It was measured from the Tilkideresi at south of Tepesidelik village in Kırşehir city and is located in J32-d3 quadrangle (Section marked with 4 in Fig. 1 B and with e in Fig. 2). Its coordinates are x: 22000 and y: 07500. Its thickness is 9 m. At the basement of the section it is composed of loosely cemented conglomerate of 2 m in thickness that is overlain by tile red colored sandy mudstone of 4 m. In the mudstone, nodular carbonates with vertical long axes, ivory, and bone pieces are detected. The top of section consists of laminated calcrite (Fig. 2e and Plate II, figs. 2, 4).

Measured section from the Kepez village.- It was measured in the Kepez village of the city of Nevşehir and is located in K32-b1 quadrangle (Section marked with 5 in Fig. 1 B and with f in Fig. 2). Its coordinates are x: 16700 and y: 18750. It has a stratigraphic thickness of 16.5 m. The basement of section is composed of tile red colored mudstone and greenish blue colored massive limestone of a total of 9 m in thickness. They change to nodular carbonate (caliche) zone of 1 m with a surface of dissolution signs. Above that is volcanic tuffite of 1 m. The most upper part is made up with layered-laminated partly massive carbonate (caliche) of 4 m in thickness (Fig. 2f and Plate III, figs. 1, 3).

Measured section from the west of Yenifakılı town.- It was measured on the road excavation between Büyükyağlı village and Yenifakılı town of the city of Yozgafarid is located in J33-b1 quadrangle (Section marked with 6 in Fig. 1 B and with g in Fig. 2). Its coordinates are x: 44250 and y: 69800. It has a thickness of 11 m. Section is represented at the basement by sandy mudstone of 5 m in thickness and calcite (caliche) zone with a vertical settlement overlain by a thin bedded (6 m) calcite zone (Fig. 2g and Plate III, fig. 4).

CALICHE FACIES

Considering the lithologic descriptions of measured sections; three main caliche zones were differentiated. They are transition zone nodular calcareous zone, and laminated caliche (calcrete) zone described by Esteban (1976) and Esteban and Klappa (1983) (fig. 2).

Transition zone (1st zone): It is the transition zone found at the bottom of sections. It is composed of pebbled-sandy mudstone, sandstone, and partly loosely cemented lenticular conglomerates. Pebble components are derived from metamorphic-magmatic basement. Grains are 2-15 cm in size, angular, sub-angular, sub-rounded, and poorly sorted (Plate I, fig.1). In addition, grains display some signs of orientation and brick-like packing. Tile red color is dominant. They rarely contain nodular, white colored chalk-like carbonate occurrences of 5-10 cm in size (Plate I, Plate II; figs. 1, 2, 3, 4 and Plate III, figs. 1, 4). This zone is repeated in the section measured from the city center of Kırşehir (fig. 2d).

Nodular zone (2nd zone): This zone is composed of red tile colored mudstone-siltstone and nodular, chalky carbonate (caliche) occurrences with vertical and horizontal settlement. It is observed in all the sections. It is partly erosional and transitional with rarely nodular, mudstone at the basement (1st zone). 1st and 2nd zones cannot be exactly distinguished from each other (Plate I, figs. 1, 2; Plate II, figs. 1, 4 and Plate III, figs. 1, 4). Calcite nodules are 5-10 cm in size and spherical or oval in shape. In some cases, nodules are laterally adjacent (Plate I, fig. 4). Root remnant and molds, root tubes, and vertical pipe structures are also observed (Plate II, fig. 1).

Laminated zone (3rd zone): It is the zone in which layered and laminated calcite (caliche) is vastly detec-

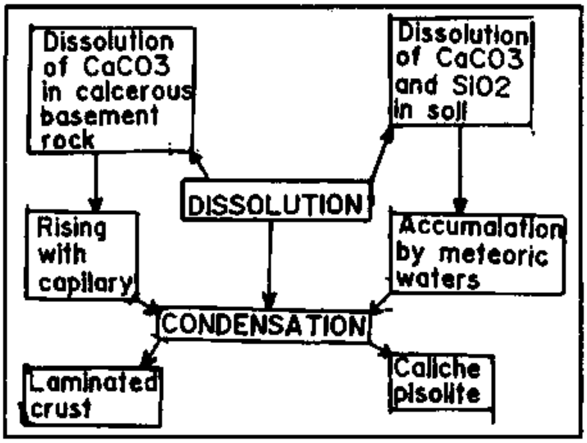

Fig. 4- Evolution of caliche pisolite in the study area.

ted. It is observed in the sections from the city center of Kırşehir and Yenifakılı town. (Plate II, fig. 3 and Plate III, fig. 4). It is widely exposed in the sections of Seyrek and Kepez villages. Zone consists of thin bedded, laminated locally massive, horizontal carbonate occurrences. It is gray, white, dirty yellow colored. Surface of carbonate layer shows dissolution signs and stromatolite-like algal structure. Their view from the top reveals that calcareous crust covers alluvial-lacustrine sediments (1st and 2nd zones) (Walls et al., 1975) (Fig. 2; Plate I, fig. 2; Plate II, figs.1, 2, 4 and Plate III, fig.1). Freytet and Plaziat (1982) used the term of exposing calcareous crust zoning for laminated calcrites.

MICROTEXTURAL FEATURES

In order to determine microtextural features of samples collected from caliche exposures, thin sections were examined by means of polarizing microscope while rock samples were examined with scanning electron microscope (SEM), X-Ray diffractometry (XRD), and paint technique.

Samples from transition zone of caliche facies (1 st zone) have a completely porous texture (Plate IV, fig. 1). Detritic quartz and volcanic and magmatic rock fragments are the dominant grain component. Overlying rarely nodular chalky caliche (2nd zone), however, display a carbonaceous mud texture (Plate IV, fig. 2). Nodules in this zone are accompanied by detritic gra; ins (Plate IV, figs. 3, 4). Root molds, root tubes and pieces are also observed. These root tube and molds are circular- and ellipsoidal-shaped and are generally filled by a low-magnesium calcite cement (Klappa, 1980b). In thin section, dissolution voids (Plate IV, fig. 2), vadose silt structure (Plate IV, fig. 3), and micro fissures (Plate IV, fig. 4) around the grains and within the carbonaceous mud are widely detected. According to Esteban and Klappa (1983), this type of micro fissures within or around the grains are formed by washing and drying. These micro fissures and voids forming by dissolution are filled with sparry calcite (Plate IV, figs. 2, 3, 4). Stylolite cement is developed in massive calcrites (Plate V, fig. 1). Samples collected from laminated calcrites at the top (3rd zone) exhibit cryptoalgal structures (Plate V, figs. 2, 4). They are undulated like stromatolites but differ from stromatolites with their texture consisting of very fine calcite crystals (Read, 1976) and forming of blue-green algae. In thin section, in addition to laminated structure, micro erosion surfaces (Hay and Reeder, 1978) and caliche pisolites with micritic membrane are also observed (Plate V, figs. 2, 3, 4). These caliche pisolites have irregular membrane and their nucleus is asymmetrical and larger than membrane (Plate V, fig. 3). Due to dissolution and reworking, micro erosion surfaces and lamina may be repeated. Following the dissolution process, this laminated structure is formed by recementing of calcium bicarbonate ($CaHCO_3$) of micritic size (Harrison and Steinen, 1978).

SEM studies of cryptoalgal laminated caliches reveal that dissolution process is effective (Plate VI, fig. 3). Dissolution process is indicative of an acidic environment and fresh water effect. Voids formed are filled by late diagenetic calcite (Plate VI, fig. 1) and autogenie quartz crystals (Plate VI, fig. 2). Root tubes are partly observed in the rock (Plate VI, fig. 4).

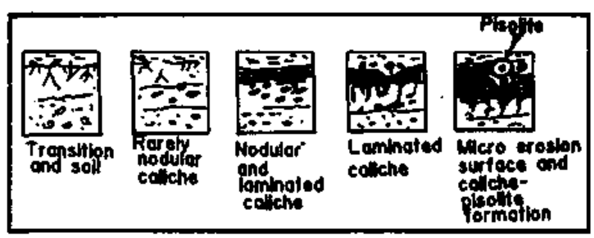

Fig. 5- Development model for laminated caliche and caliche pisolite in the area.

When thin sections are painted with a mixture obtained from alizarin-Red S and potassium ferrocyanide, all samples show a pink color. This indicates that caliche nodules and laminated carbonates are completely composed of calcite.and that they do not yield any color indicative of iron or manganese enrichment.

X-Ray diffractometry results of six examined samples also indicate that calcite is the dominant mineral phase (Fig. 3 and Table 1). In addition to calcite, smectite, illite, chlorite, plagioclase, and kaolinite are the other minerals observed (Table 1). Smectite and illite most probably originated from alteration of plagioclase- and K-feldspar-bearing micaceous rocks while chlorite is formed due to shallow diagenesis in acidic soils as a result of washing and oxidation (Tucker, 1981).

1-Carbonates in basement rocks are dissolved by carbonic acid. As stated previously, carbonic acid is formed by the reaction between rain water and carbondioxide (CO_2) in the air and expelling from fracture and fissures around $CO_2 + H_2O = H_2OCO_3$ (Fig. 4). Carbonate dissolved by carbonic acid then changes to a calcium bicarbonate-rich solution. It is carried as calcium bicarbonate in alluvial fan, river, and lake sediments. This solution that can also be percolated to the ground water level rises to the surface by capillary during arid and semi-arid seasons. Rising solution loses carbondioxide (CO_2) being in contact with air and precipitates as calcium bicarbonate ($CaCO_3$) (calcite). This calcium carbonate ($CaCO_3$) forms caliche type nodules (Fig. 6 and 1 st and 2nd zones shown in figure and sections).

Table 1- X-Ray diffractometry results of some caliches and laminated calcrites collected from measured sections in the area.

SAMPLE LOCATION	SAMPLE NO	MINERALS
Seyrek village	9	Calcite, quartz
	10	Calcite, smectite, illite, quartz, plagioclase
	19	Calcite, plagioclase, quartz
Çoğun village-Malhüyük hill	21	Calcite, plagioclase, mica, quartz
Kepez village	67	Calcite, plagioclase, mica, quartz
Yenifakılı	128	Calcite, plagioclase, quartz, mica
	105	Calcite, plagioclase, mica, quartz, chlorite
Tepesidelik village	122	Calcite, plagioclase, smectite, chlorite, illite, quartz, kaolinite

CALICHE FORMATION

The area where caliche deposits are exposed is a subsidence basin comprising upper Miocene-Pliocene sediments on the Paleozoic-Mesozoic basement (Fig. 1 B and 6). Nodular and laminated carbonates (caliche) with vertical and horizontal settlements within mudstone and siltstone are derived from two different sources.

2- Percolating of calcium-bicarbonate solution, forming by redissolution of caliche or carbonate available within carbonate caps (lacustrine carbonates) and soil, through the mudstone-siltstone and conglomerate (Fig. 6). Solution concentrated along the ground water level rises by capillary effect during arid and semi-arid seasons (Fig. 4). Carbondioxide (CO_2) in rising solution is removed and, like in first case, it is precipitated as $CaCO_3$ and forms caliche type carbonates. At the top of the sequence, depending on the position of ground water level, a laminated carbonate crust or massive type caliche with a horizontal settlement is developed (3rd zone) (Plate I.fig. 2; Plate II, fig. 1; Plate III, fig.1 and fig. 5, 6). This accumulation may be also associated with meteoric waters (Walls et al., 1988). Laminated crust developing due to condensation is dissolved in acidic conditions (high pH) in time and as a result, microerosional surfaces are formed (Plate V, figs. 2, 4). In places where alluvial fan-meandering river intersect with the lake water (Fig. 6), due to fluctuation of ground water level, irregular-shaped caliche pisolites are formed (Hubert, 1978) (Plate V, figs. 2, 3, 4 and fig. 5). Intense accumulation of these pisolites is appeared to be brecciated (Dunham, 1969b). As dissolution and reaccumulation processes are repeated (Fig. 4), laminated carbonate crust is also alternated and thus, stromatolite-like structures with no stromatolite origin (Read, 1976) are developed (Plate V, fig. 2).

Tectonism plays an important role in the caliche formation. Carbondioxide expelling along the fracture and fault systems combines with rain water to form carbonic acid. Carbondioxide-rich an acidic environment is created due to heavy industrialization as widely observed in various European countries. Carbonaceous rocks or carbonaceous soils in the acidic environment are dissolved and transformed to calcium-bicarbonate saturated solutions. This solution generally facilitates the formation of caliche type carbonate nodules or laminated caliche in soils.

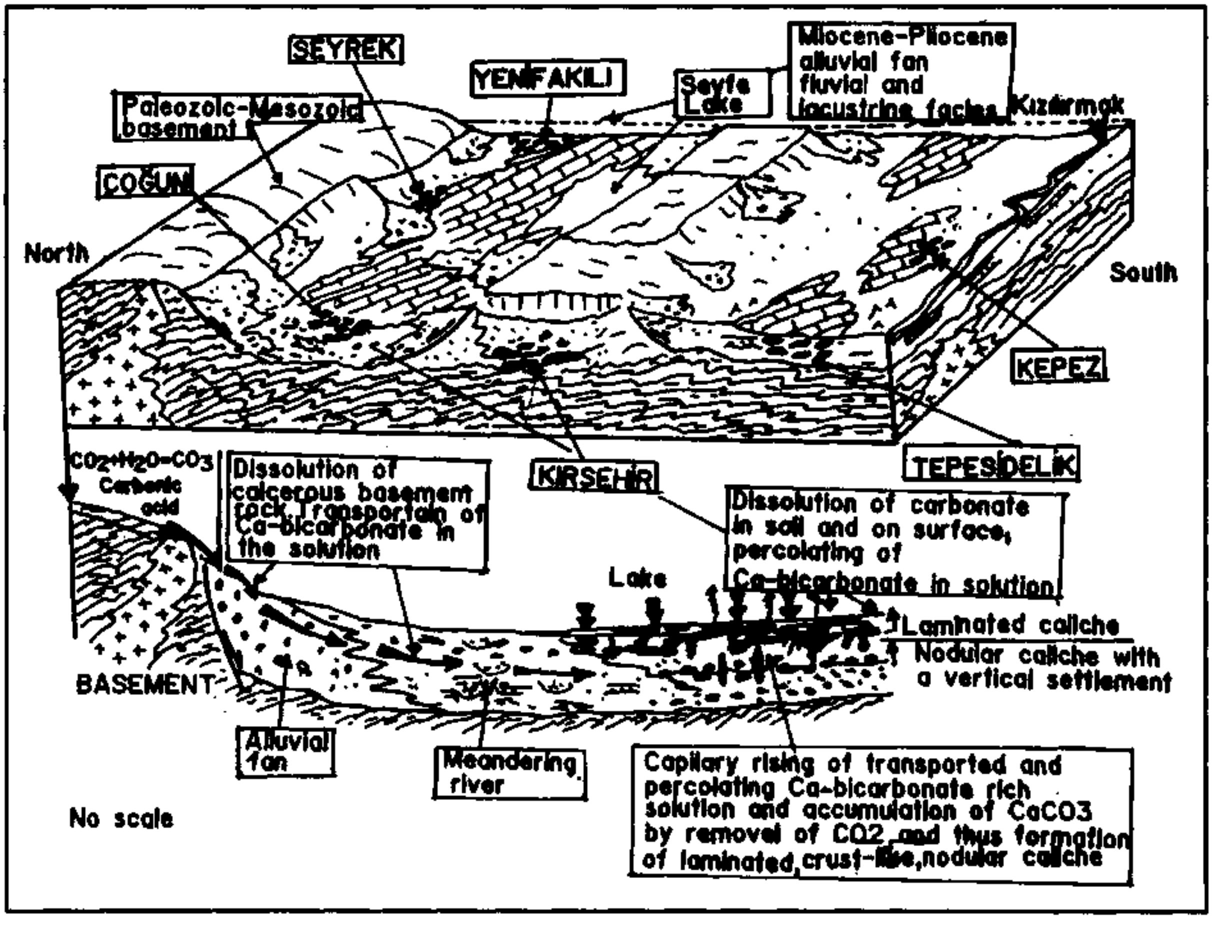

Fig. 6- Formation model for caliches in the area.

RESULTS

Caliche occurrences in the study area are found in conglomerate, sandstone, mudstone, and siltstone belonging to alluvial fart, meandering river, and lacustrine environments. Based on deposit character, water chemistry, and water movement, these caliche deposits are observed in three different zones. Basement rock and carbonates in the soil are the main sources of the occurrences. These carbonates are dissolved and form bicarbonate-rich solutions, which are transported through the sediments and rise by capillary effect, and finally form calcium carbonate nodules and caliche crusts observed in the area. In the present study, carbonates previously described as lacustrine carbonates were determined to be the laminated caliche (calcrite) occurrences and are composed completely of cryptoalgal structures.

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PLATES

PLATE-I

Caliche exposure in the Seyrek village:

Figs. 1, 2- Metamorphic-magmatic pebbled-sandy mudstone zone (1st zone), zone of calcite nodules with vertical and horizontal long axes (kn) (2nd zone) and layered-laminated caliche (calcrite) (Lk) zone (3rd zone).

Fig. 3- Calcite nodules of lateral continuity within red mudstone-siltstone (kn).

Fig. 4- Close view of metamorphic pebbles (mç) and calcite nodules (kn).

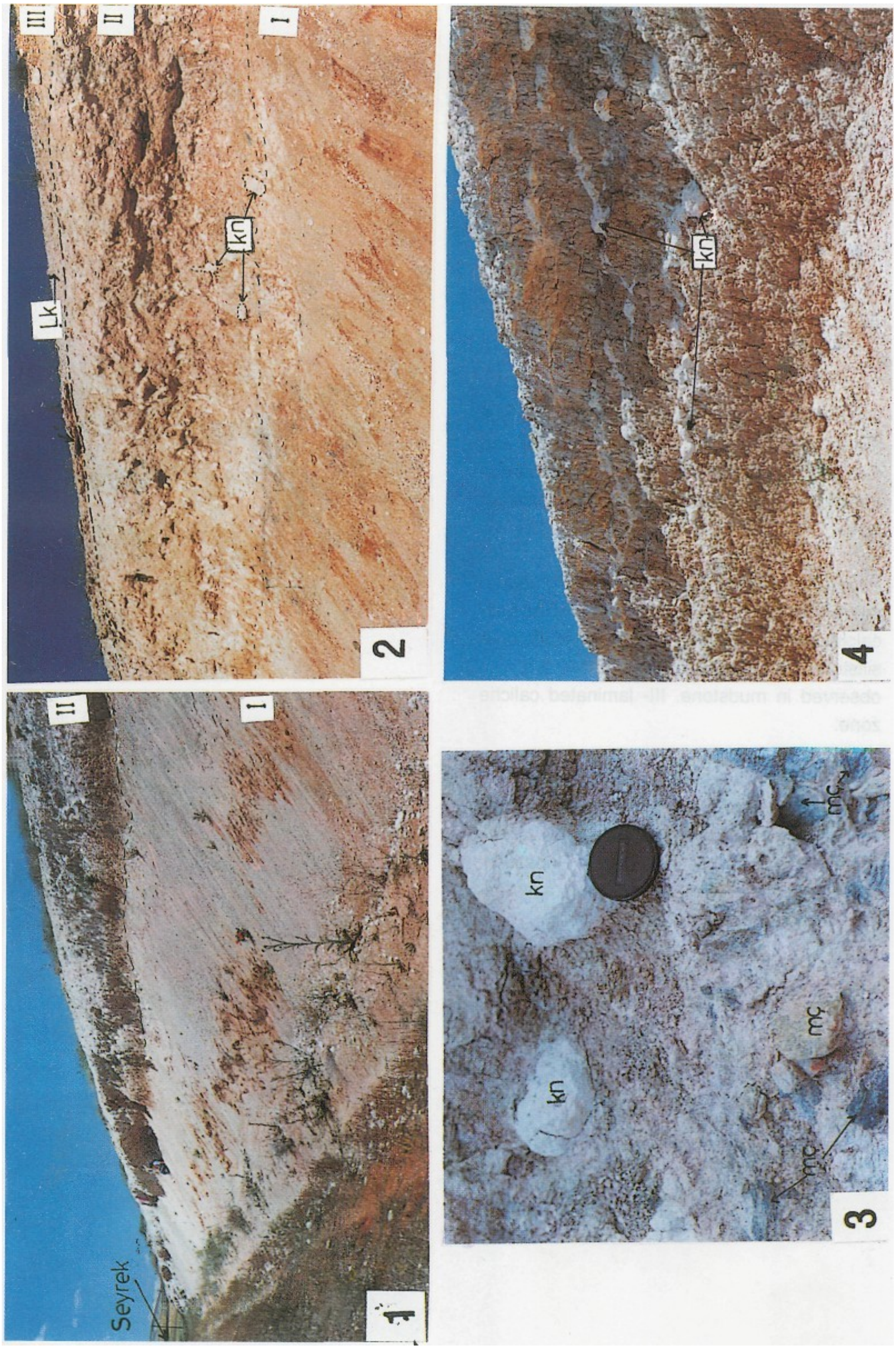
1
Seyrek
I
II
2
I
II
III
Lk
kn
3
kn
kn
mç
mç
mç
4
kn

PLATE-II

Fig. 1- Caliche exposure in Çoğun village-Malhüyük hill: I- Transition zone, II- Root tubes (kt) and calcite occurrences with vertical settlement in red mudstones, III- Massive caliche (calcrite) zone.

Figs. 2, 4- Tepesidelik caliche exposure:I-Conglomerate-sandstone zone. II- Caliche zone of nodular calcite with vertical long axes in red mudstone-siltstone, ivory (fd) and bone pieces are also observed in mudstone. III- laminated caliche zone.

Fig. 3- Central Kırşehir section: I- Calcite nodules (kn) in red mudstone-siltstone and calcareous caliche zone with vertical longaxes. II- Caliche zone with horizontal long axes. Repetition: I- Caliche zone with vertical long axes, e- Erosion surface.

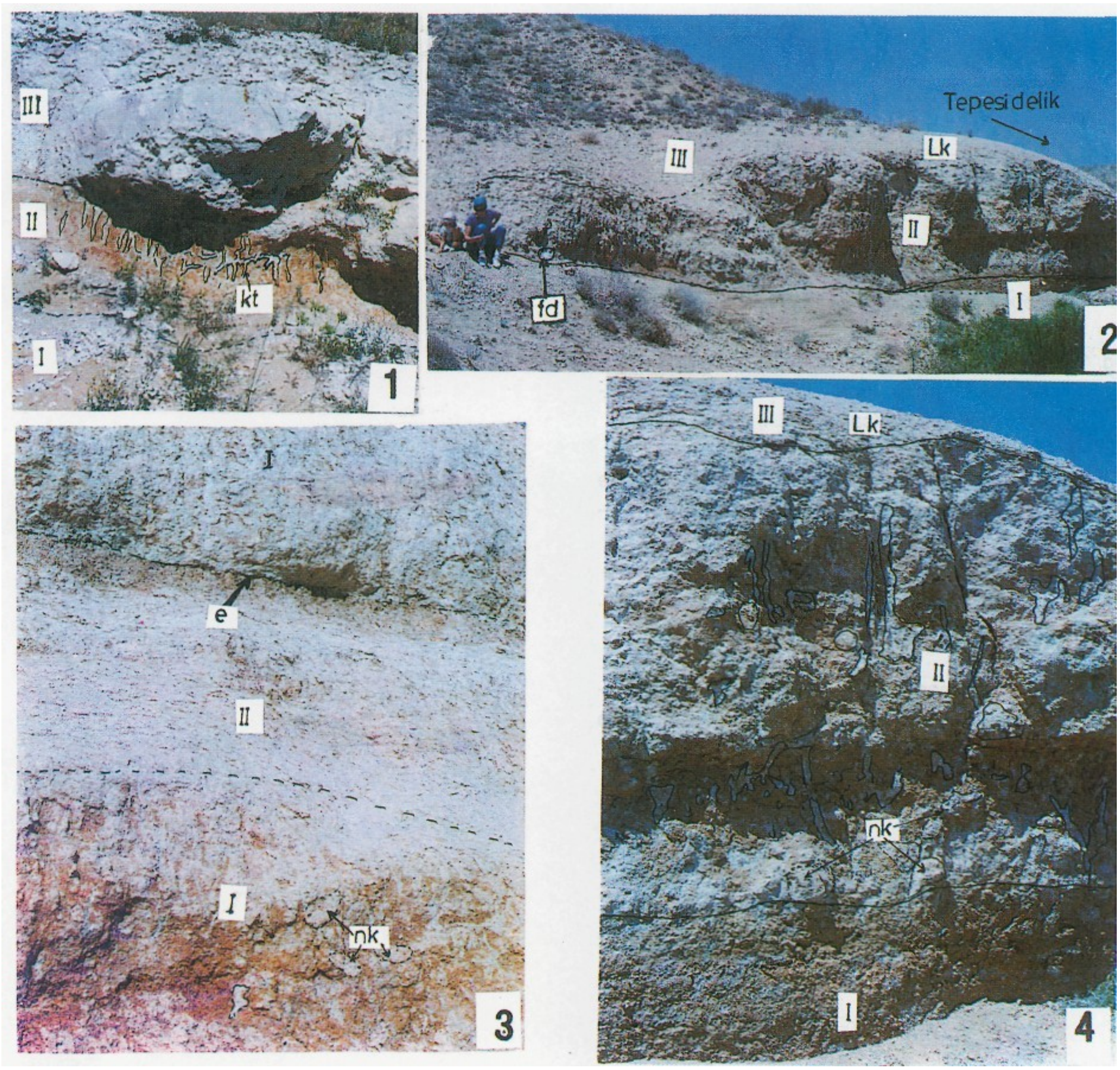
III
II
kt
I
1
Tepesidelik
III
Lk
II
fd
I
2
I
e
II
I
nk
3
III
Lk
II
nk
I
4

PLATE-III

Figs. 1, 2,3- Caliche occurrence in lacustrine sequence of Kepez village:

Fig. 1- I- Claystone-mudstone zone, II- Platy and nodular calcite (nk) zone. T-Tuffite. III- layered-laminated caliche (calcrite) (Lk) zone.

Fig. 2- Calcite nodules (their upper surfaces are bowl-shaped and rough due to dissolution process).

Fig. 3- Calcite nodule and caliche pisolites (kp). T-Tuffite level, e- Erosion surface.

Fig. 4- Caliche exposure in Yenifakılı town: I- Mudstone-siltstone zone. II- Nodular carbonaceous caliche zone with vertical settlement.

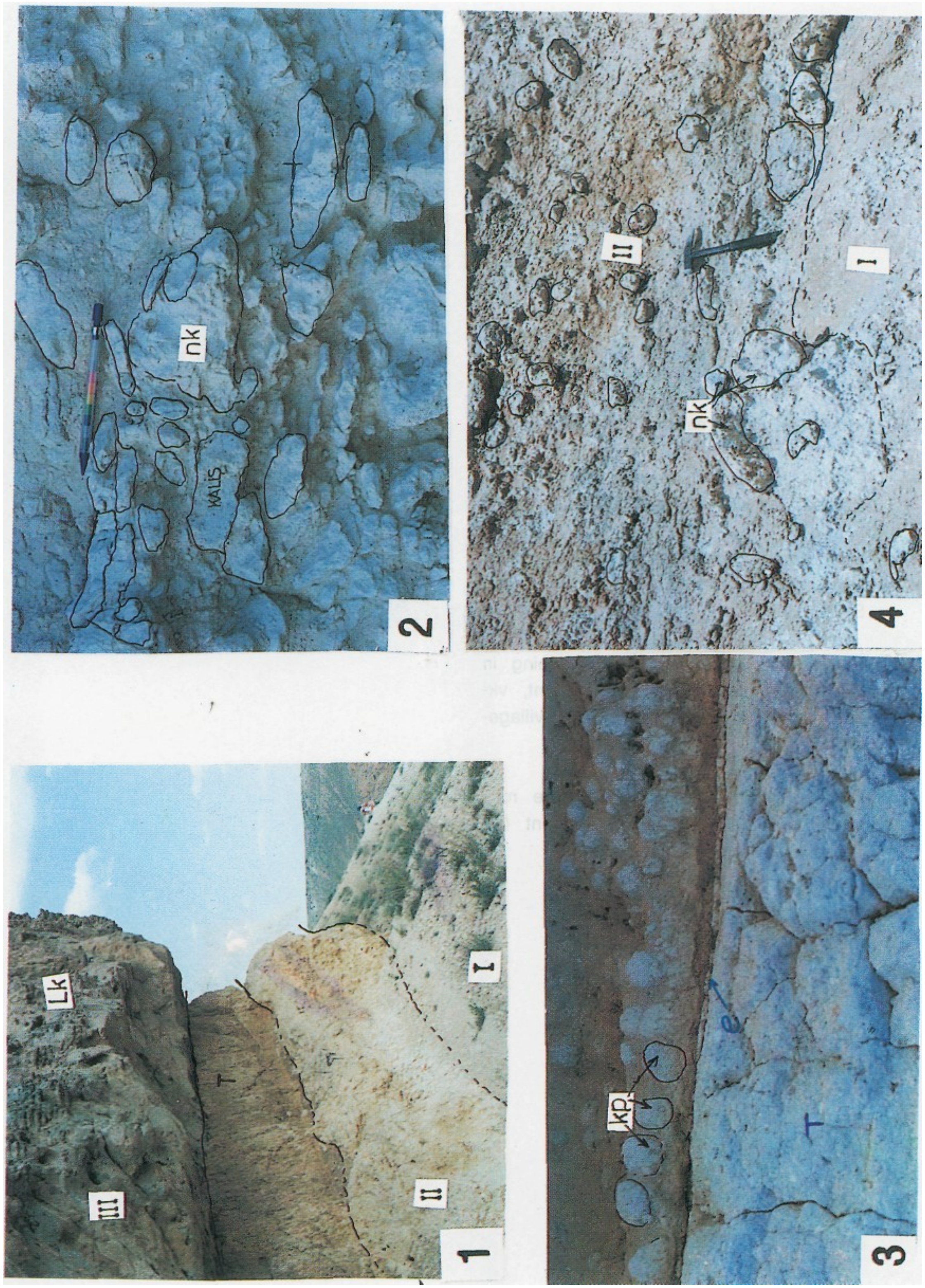
2
nk
KALIŞ
4
II
I
nk
1
Lk
III
T
II
I
3
kp
T

PLATE-IV

Polarizing microscope view of caliches (calcrite):

Fig. 1- Calcrite. Micritic textured and detritic quartz-grained. Tepesidelik village - Tilkideresi.

Fig. 2- Dissolution voids and sparry calcite (sk) filling these voids, root mold (kk) and pieces (kp). Seyrek village.

Fig. 3- Vadose silt structure (vs) developing in dissolution void. Ç- Calcite cement, vk- Volcanic rock fragment. Çoğun village- Malhüyük hill.

Fig. 4- Circular micro fissures around the rock fragment filled with caliche cement (ç). Tepesidelik village - Tilkideresi.

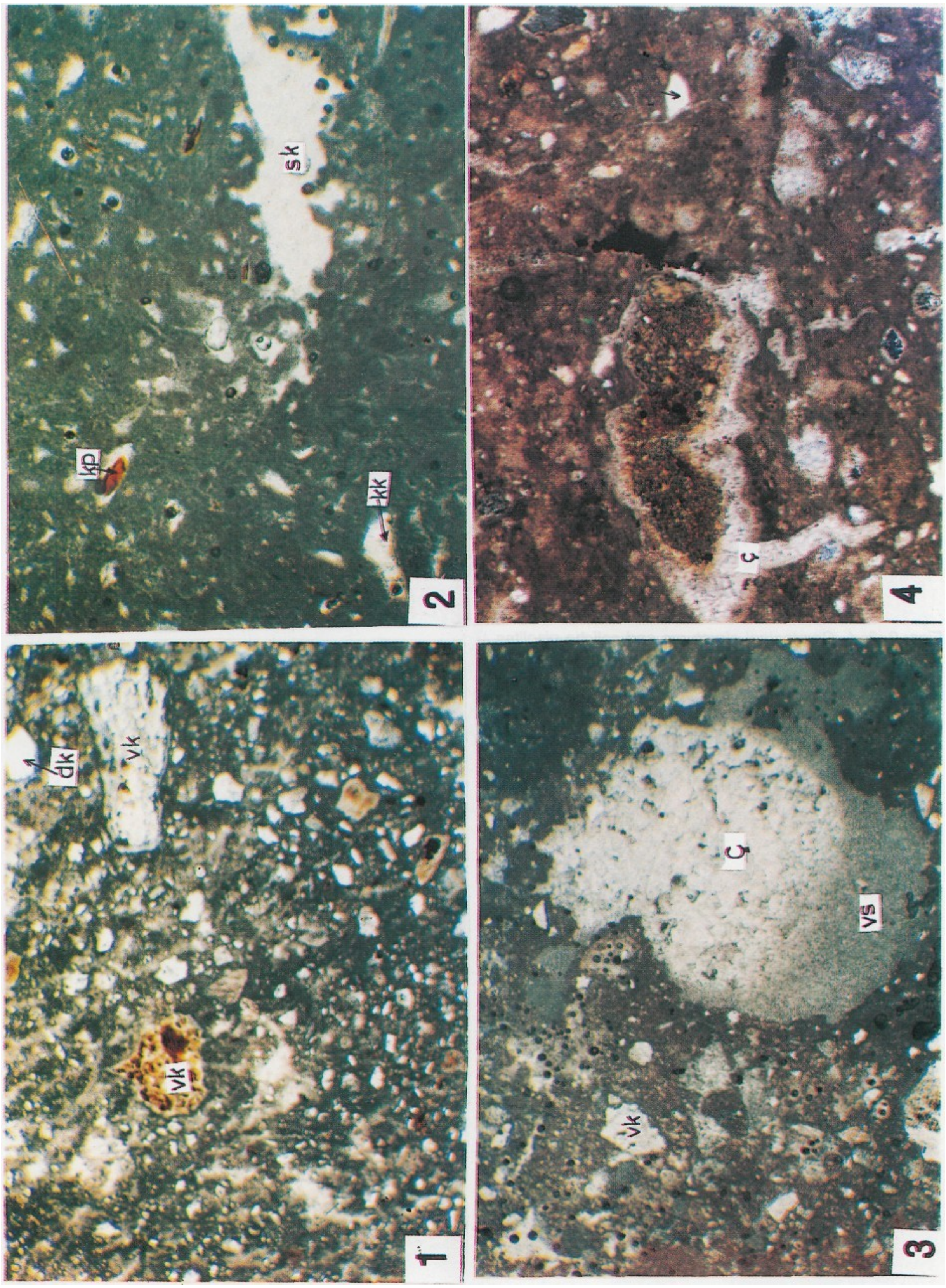
1
vk
dk
vk
2
sk
kp
kk
3
Ç
vs
vk
4
ç

PLATE-V

Fig. 1- Caliche cement. Çoğun village - Malhüyük hill and Figs. 2, 3, 4- Caliche pisolites (Seyrek village): Caliche cement: ç- Stylolite cement, b- Void not filled with calcite.

Figs. 2, 3, 4- Cryptoalgal structures and caliche pisolites (p). me-Microerosion surface, micritic laminated caliche pisolite (p), ml-micritic lamina (membrane), 5- calcite cement (white parts) cryptoalgal laminae (kal).

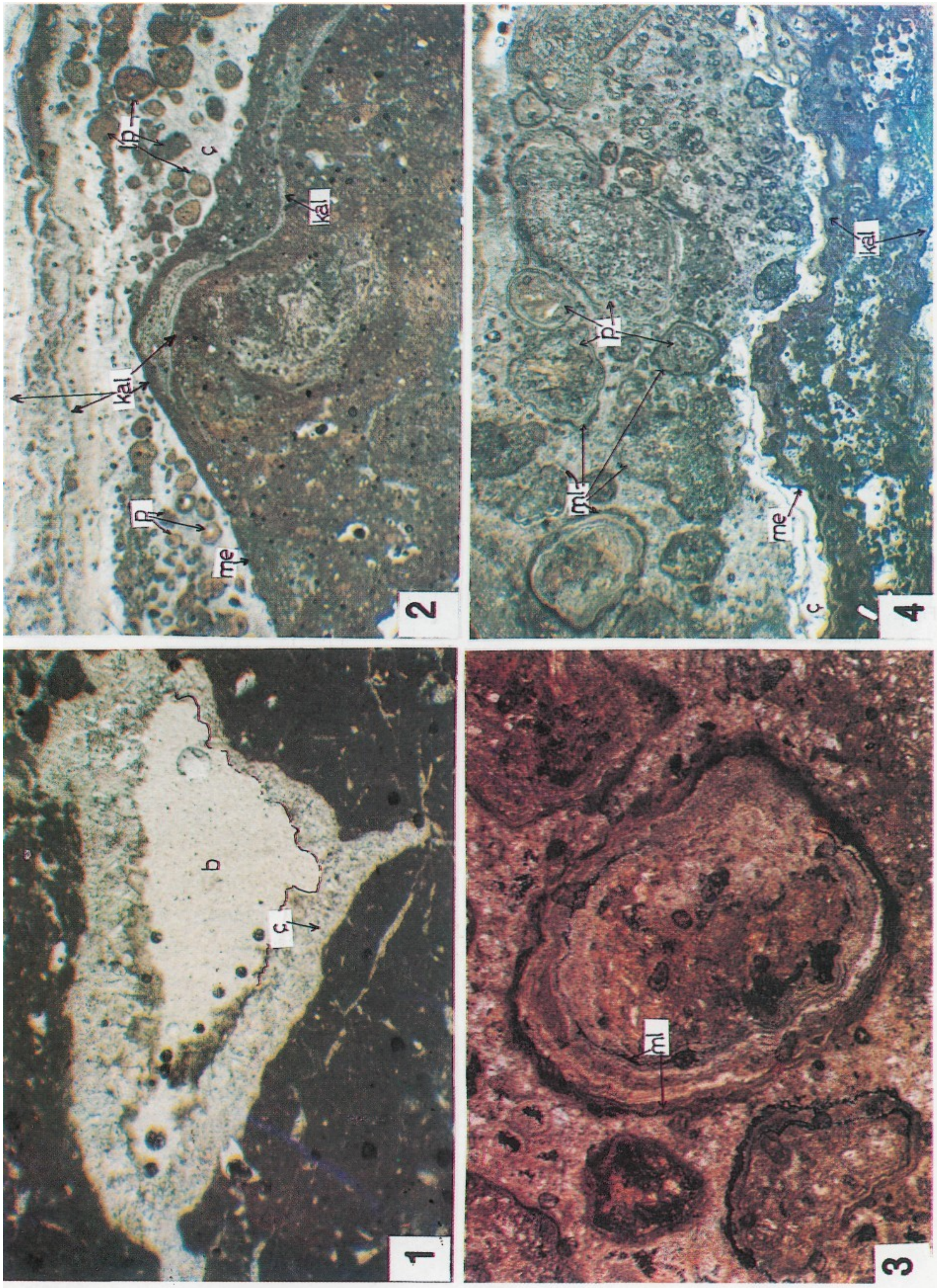
1
b
ç
2
kal
p
me
ç
3
ml
4
kal
p
ml
me
ç

PLATE-VI

SEM image of laminated caliche (Seyrek village):

Fig. 1- Space-filling secondary calcite crystals (K).

Fig. 2- Autogenic quartz crystals (Q) growing towards the center of space.

Fig. 3- Calcite crystals (K) with dissolution surface.

Fig. 4- Root tube (Kt) within the carbonaceous mud.

PLATE-VI