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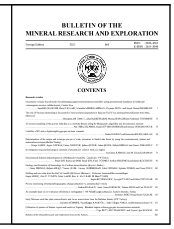

Early Miocene seed like plant remain fossils and facies associations from the Nallıhan district (NW Turkey)

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ABSTRACT

Seed like fossils recognized by their distinctive orbicular in shape are seen in the early Miocene of the Nallıhan area (NW Türkiye). We examined more than one hundred specimens and facies associations for interpreting of fossil morphology and its paleoenvironment. The fossils as dark crystallized dots on the bedding surface of clayey limestones are characterized by a thick edged lenticular shape with a smooth one side and concave another side with circular nucleus. Their internal structures have circular a few whorlings, too often radial calcitic lamellae on the upper side and a few circular coiling at the bottom side. SEM, EPMA and RAMAN data of soft nucleus, hard part, filling materials and surrounding sediments support its plant origin. The Paleogene aged Kızılbayır formation and early Miocene aged Karadoruk and Akpınar formations include the following facieses: non-channelized red sandstone and mudstone (F1), channelized “confined” reddish-beige pebbly sandstone and conglomerate (F2), medium to coarse siliciclastics (F3), mudstones interbedded with sandstones (F4), thin bedded clayey limestone bearing plant fossils (F5) medium to thick bedded limestone (F6) and rhythmic siliciclastics - clayey limestone including coal occurrences (F7). Abundant plant fossils indicate a planted shallow lake margin with low topography during the early Miocene.

1. Introduction

The Beypazarı-Ayaş Miocene Basin is a well-known terrestrial area extending from the west of Ayaş to the east of Nallıhan (W, NW Ankara) (Figure 1). Due to the significance of Miocene sediments from the mentioned basin to palaeontologists, stratigraphers, sedimantologists and field geologists, the majority of previous literature has been associated with the sediments stratigraphy, sedimantology and coal occurrences (Siyako, 1983; Inci et al., 1988; Helvacı and Bozkurt, 1994; Yağmurlu and Helvacı, 1994; Yağmurlu et al., 1988, 1990; Karadenizli, 1995). However, plant remains fossil occurrences and their origin within the Miocene lacustrinal sediments have not been fully understood and no studies have been carried out to investigate the Miocene aged seed like fossil records. The first record of the Miocene plant remain fossils in Turkey is assumed to be a significant discovery for the Miocene palaeogeography and sedimantological approaches. The problems are what they are, where they were deposited, and what the facies associations are? The aims of the study are to present the first seed like plant remain fossil records from the Miocene sediments of the north- western Turkey, to define their morphological features based

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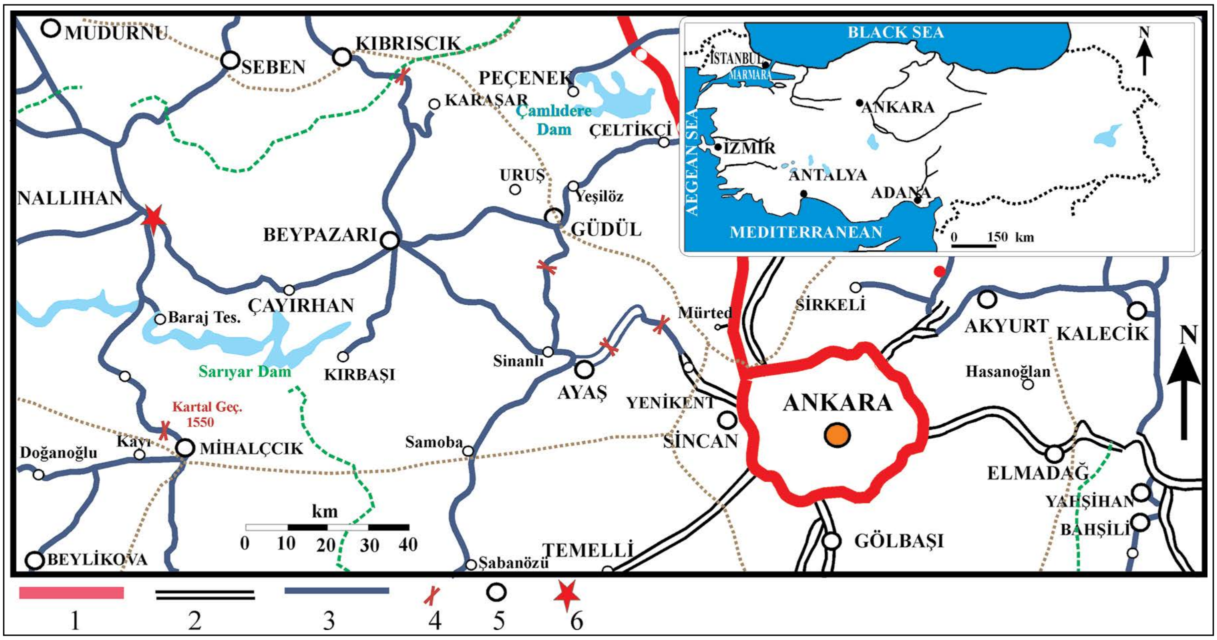


Figure 1- Location map of the study area. 1) highway, 2) divided road, 3) road, 4) mountain pass, 5) settlement, 6) study area.

on field and laboratory observations with thin sections, SEM, EPMA and RAMAN data and to discuss their palaeoenvironmental and facies associations.

2. Geological Setting

At the both sides (east and west) of the Beypazarı-Ayaş Miocene Basin, the Palaeozoic metamorphics are seen at the basement. The lithostratigraphy of the investigation area from basement to top include the following geological units: The Palaeogene aged Kızılbayır formation comprising of red terrestrial siliciclastics; early Miocene aged Karadoruk formation, limestones, clayey limestones in lithologies; siliciclastics of the Akpınar formation, Acısu formation including dirty white coloured clayey limestones and tuffits; Plio-Quaternary clastics and alluvium (Figures 2-3). The names of the formations are based on Siyako (1983).

The Miocene sediments including various mainly lacustrinal lithologies overlie unconformably the Mesozoic carbonates and Palaeogene red clastics in the studied area (Figures 2, 3). Although many studies deal with the Miocene basin (Siyako, 1983; İnci et al., 1988; Helvacı and Bozkurt, 1994; Yağmurlu and Helvacı, 1994; Yağmurlu et al., 1988, 1990; Karadenizli, 1995), geological units (Stchepinsky, 1941 *a, b*; Tekin, 1977; Altınlı, 1978; Kalafatcıoğlu and Uysallı, 1964; Saner, 1980; Önal et al., 1988) and palaeontological, sedimantological data (Kazancı, 1979, 1980; Tunç, 1980; 1984; Varol, 1980; Varol and Kazancı, 1980; 1981; Alkaya, 1987, 1989 *a, b*), seed fossils from the Miocene sediments have not been mentioned. Figure 4 shows selected field views of the studied Kızılbayır, Karadoruk and Akpınar formations and their lithologies.

In the area, a few small anticline and syncline axis, one to a few kilometres in length extends from west to east. They are more or less parallel to the North Anatolian Fault known as a strike-slip fault in the Bolu-Gerede area, the Sekli overthrust and Davutoğlan Fault that is near to the study area (Kalafatcıoğlu and Uysallı, 1964; Saner, 1980; Önal et al., 1988; Siyako, 1983). Neotectonic compressional tectonism in north-south direction affected the all Palaeogene to Miocene sediments.

3. Methodology

The plant remain fossils come from the clayey limestones of the Karadoruk formation outcropping around Sarıkafa and Çoban Hill, 15 km east of the Nallıhan (NW Ankara) (Figures 2-3). Red to yellowish coarse to medium sized clastics of the Kızılbayır formation (Siyako, 1983) are at the base of anticline exposing at the northern part of the studied area. The

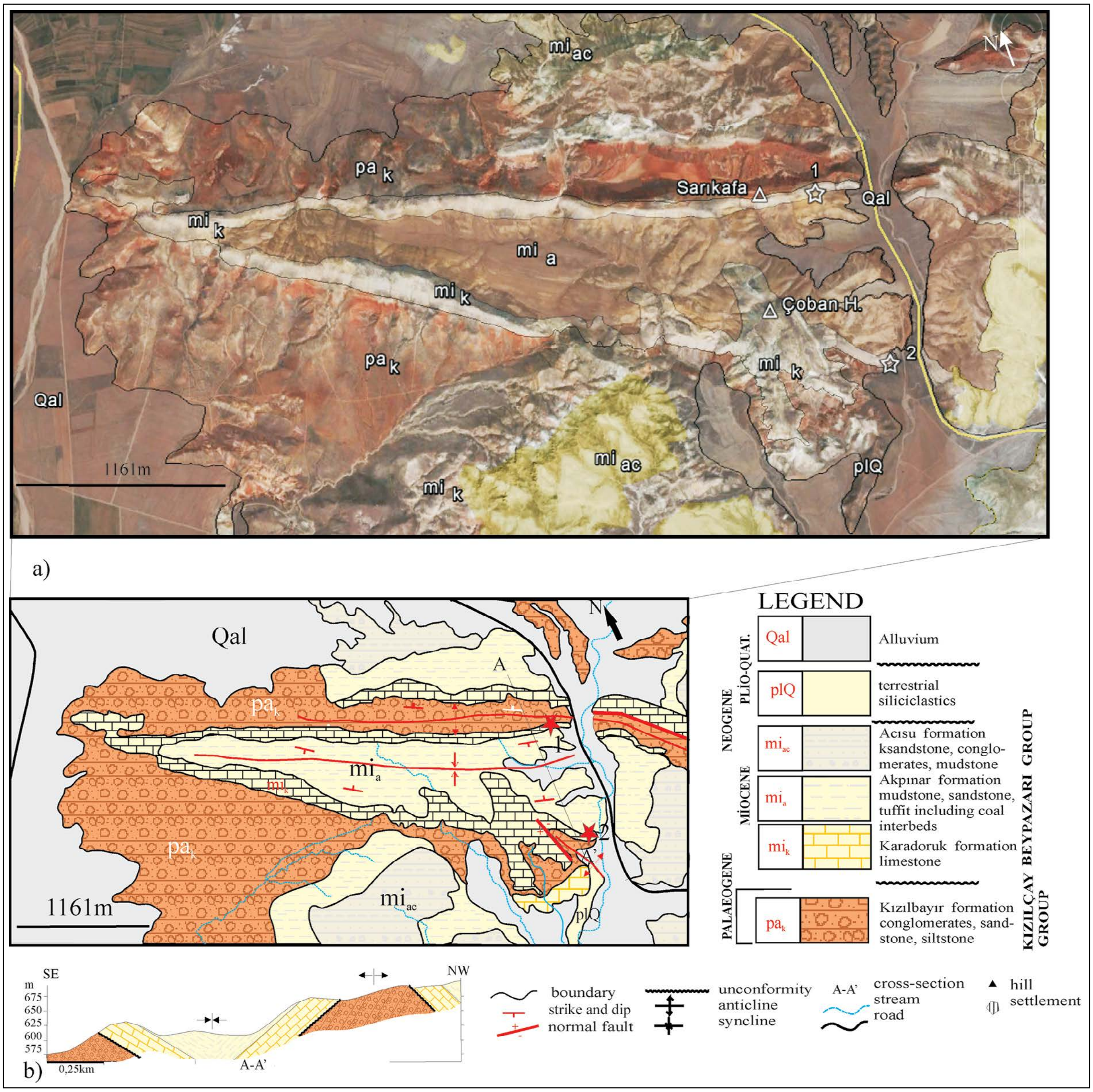


Figure 2- GoogleEarth view, a) and geological map of the study area, b) stars 1 and 2 show the Miocene plant remain fossil locations.

following syncline limbs including seed fossils appear in the middle part of the area (Figures 2-3). On the northern limb of a syncline near to Sarıkafa, white, gray coloured limestones of the Karadoruk formation conformably overlie the Kızılbayır formation. Total thickness of the Karadoruk formation herein is about 25 meters. On the southern limb of the syncline near to Çoban Hill, the Karadoruk formation thickness is about 30-40 meters. Two measured sections were performed at the north and south limbs of the syncline in the Karadoruk formation. Another section is approximately 500 meters far from the south limb of the syncline (Figures 2-3). 30 hard rock samples, 3 mudstone samples and more than one hundred plant remain specimens were collected. Hard rock thin sections from the measured sections and spot samples, and individual seed thin sections comprising their vertical and horizontal views were prepared. Mudstone samples including coal occurrences were evaluated for aging of the sediments based on the spore and pollen data (written and oral communication, Dr. Zühtü Batı, TPAO, 2017). SEM photographs have been taken in the Institute of Nuclear Science of the Ankara University. Electron microprobe (EPMA) analyses

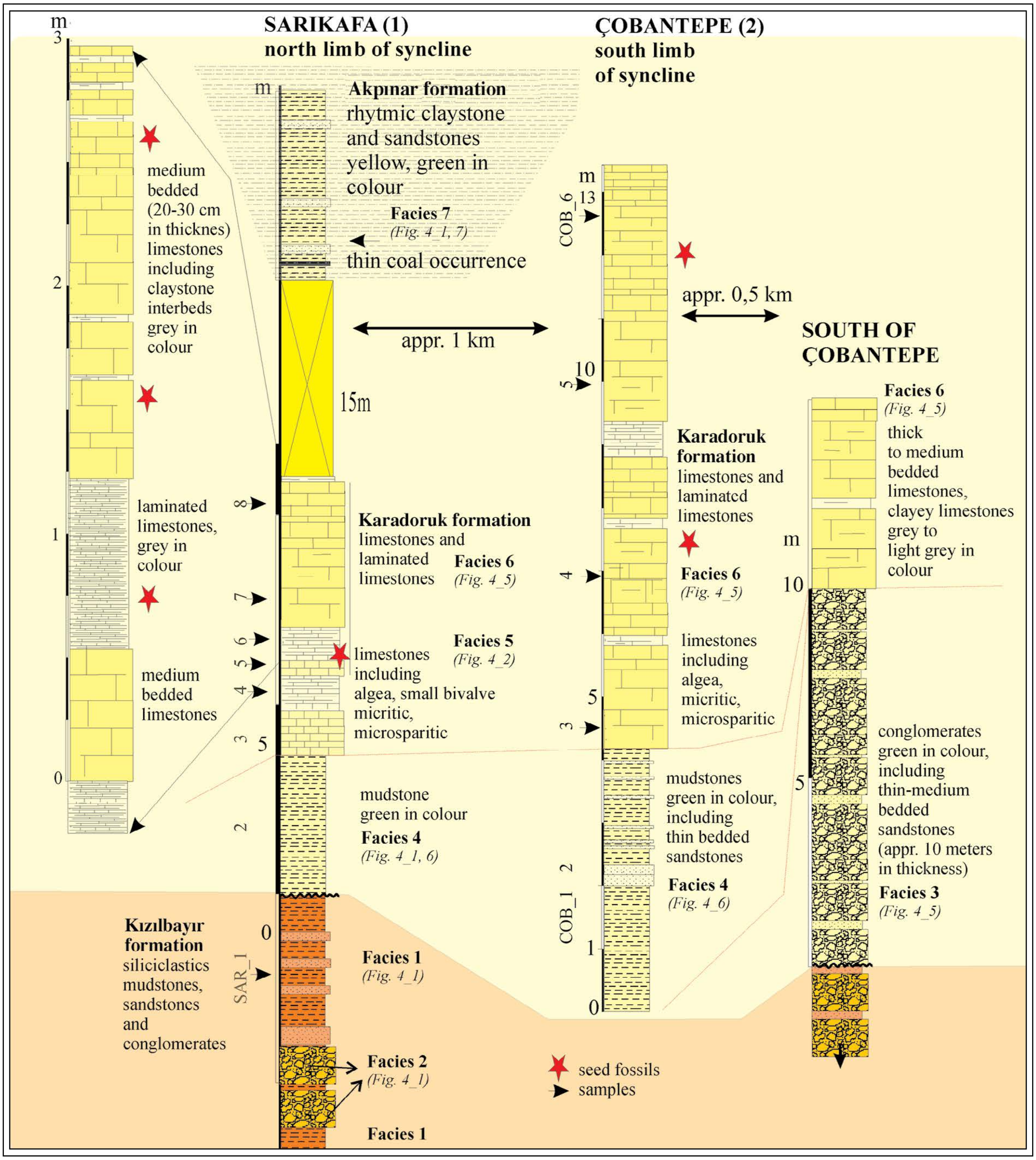


Figure 3- Correlation of measured sections in the investigation area.

were performed on polished thin sections using a JEOL JXA–8230 instrument which is equipped with 5 wavelengths–dispersive spectrometers at the Earth Sciences Application and Research Centre (YEBIM) of Ankara University. Operating conditions were 20 kV accelerating voltage, 10 nA beam current and a 2 µm spot size. Detection limits for Na, Mg, Al, Si, Fe, Mn, K, Ca and Ti are below 0,04 wt% oxide. Natural oxide and mineral reference materials were used for calibration and measurements. Matrix effects were corrected using the ZAF software provided by JEOL. Carbon coating were made by using Quorum Q150T ES machine at YEBIM. The seed specimens were also studied in thermo confocal Raman Spectroscopy in order to identify the natural chemical bond composition for comparison with the lived seed. Confocal Raman Spectrometer is a well-known method for the analyses of minerals however; it has not yet been widely

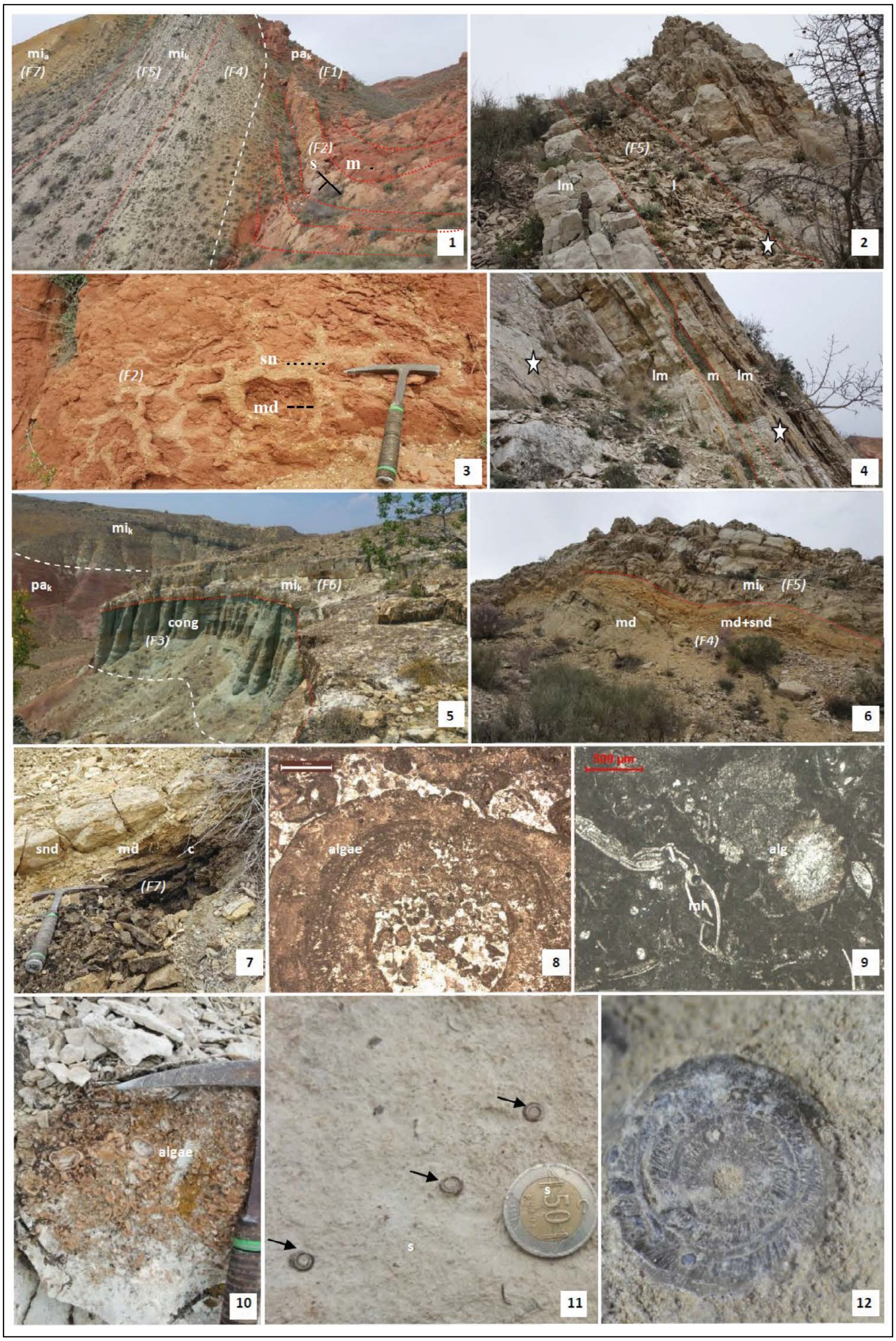


Figure 4- Field and thin section views of the geological units from the study area. 1) A view of the Kızılbayır formation (pa_k), Karadoruk formation (mi_k) and Akpınar formation (mi_a) looking towards to west of the northern limb of the syncline; s. sandstone beds, m. mudstone beds, 2) alternating of limestones (lm) and laminated limestone (l) looking towards to east of the northern limb of the syncline; 3) mud-crack within the Kızılbayır formation-facies 1; sn. sands, md. muds, 4) Seed like plant remain fossils limestone levels including mudstone interbed (m); 5) Karadoruk formation (mi_k) including conglomerates at the base of the Miocene, Kızılbayır formation (pa_k); 6) Karadoruk formation (mi_k) including mudstone and mud-sand litologies at the base of the formation; 7) a view from the base of Acısu formation (mi_{ac}) showing coal (c), mudstone (md) and sandstone (snd) layers; 8-9) thin section views from the base of Karadoruk formation, algea (alg), small mollusc shells (ml); 10) silicified algea bed from the Karadoruk formation; 11-12) seed fossil external views within limestone around Sarıkafa Hill.

applied on fossil seed identification and determination. Raman measurements were performed with a Thermo equipped with a laser operating at a wavelength of 633 nm. An electrical cooled charge coupled device (CCD) detector was employed to acquire spectra, and the laser spot was focused on seed surface with 10X or 50X long focused objectives, which allow a 65 and 13 mm working distance, respectively, and a lateral resolution of 5 and 2 µm respectively. Polarization of the incident laser beam was selected parallel to the preferential domain orientation of samples and spectra were collected in a strict backscattering geometry. The seed like fossils have been kept in the Geology Department of the Ankara University by the first author.

4. Early Miocene Seed Like Plant Remain Fossils and Their Geochemical Analysis

Plant remain fossils from the early Miocene sediments in the east of the Nallıhan district provide a unique opportunity to explore ancient terrestrial bio communities and facies associations. Figure 5 shows a schematic three dimensional external and internal views together with their thin section views of the fossils.

4.1. External Views

They are mainly on the bedding surface of the cream to beige coloured clayey limestones as dark crystallized dots (Figures 4.11-4.12). Their colour is nearly black in many specimens (Figures 6-9). But, some individuals colour is yellowish to brown (Figure 6-7). Mold and cast of the seed fossils are light beige in colour (Figure 7). They are more or less in the same size changing from 5 to 7 mm in diameter and 0,5-1,2 mm in thickness (Figures 7, 9). One side of the seed like plant remain fossils has a smooth surface while another side comprises concave in shape (Figures 5-6). Annular external view is composed of compressed the initial part, and thicker edges. The shape of the plant remain fossils is

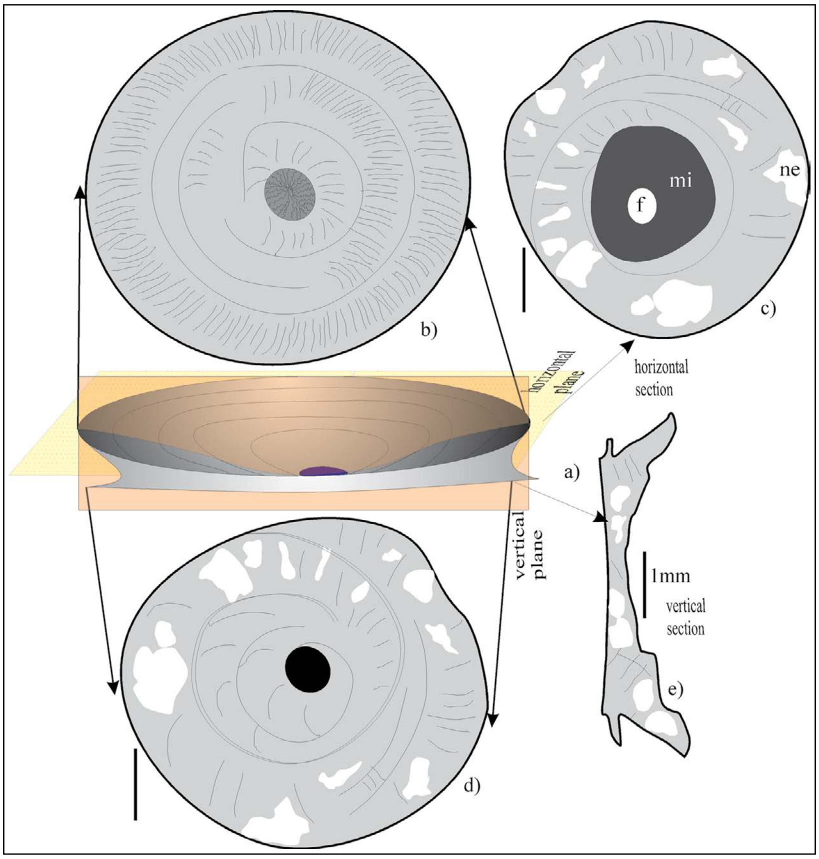


Figure 5- Schematic views of a seed like plant remain fossil, a) schematic block diagram, b) external view (upper concave part) with a nucleus view, c) vertical thin section view, d) external view (lower flattened part), e) horizontal view, f) initial part without nucleus, mi. micritic filling, ne. neomorphic filling.

similar to a tray or a pan. At its centre, there has been a circular initial cave in many specimens (Figure 9). One of the specimens includes a soft nucleus in the middle of the seed (Figure 6). Later 4 or 5 orbicular lines comprise too often calcitic radial and curved internal lines. When we pour the hydrochloric acid on it, all tests was melt. It means coating part of the seed is re crystallized. As mentioned above, one of the specimen includes a semi soft nucleus in the initial part.

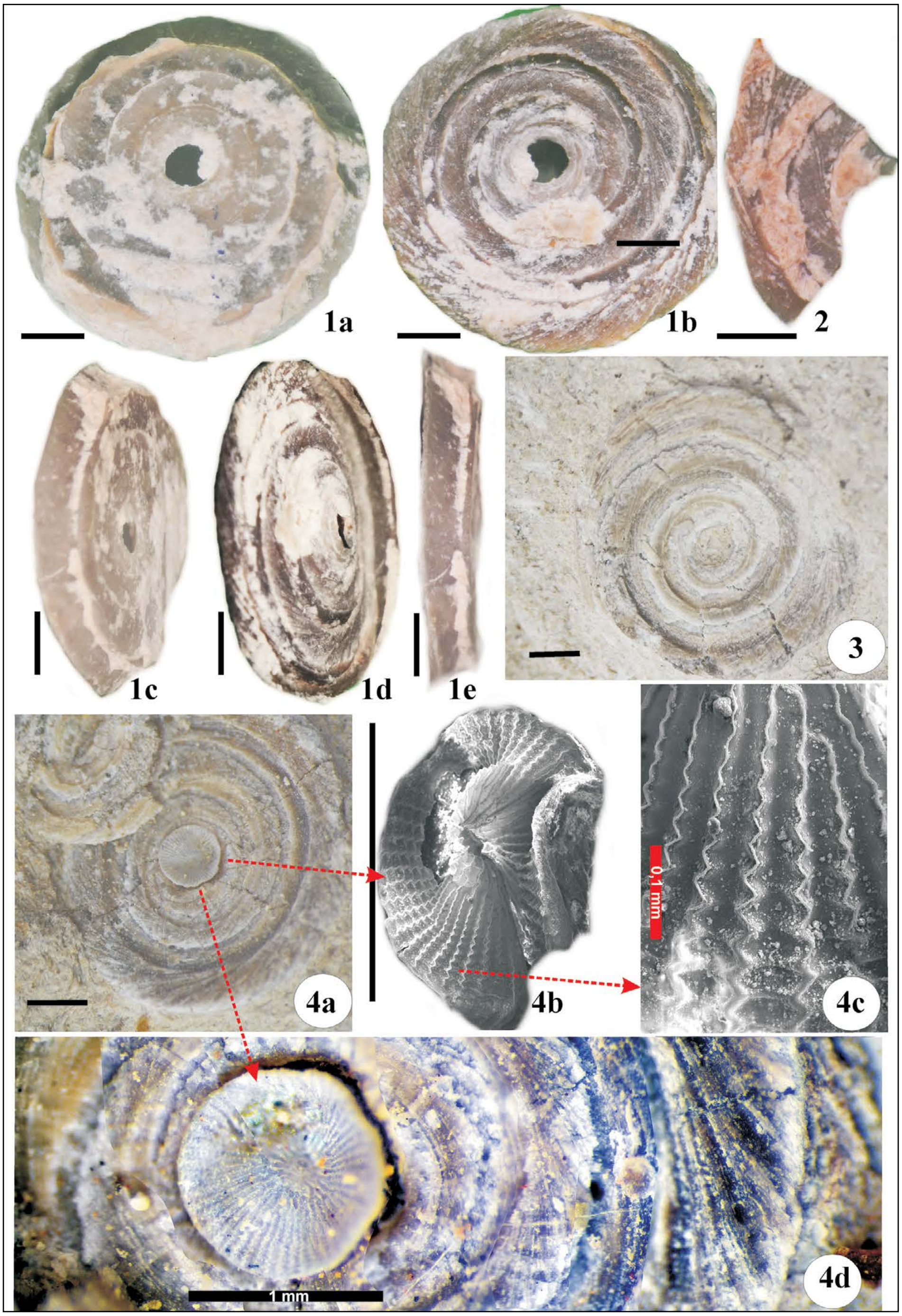


Figure 6- External and SEM views of seed like plant remain fossils and its nucleus details. 1a) flattened part view, 1b) concave part view, 1c-d-e) side views, 2) closest view of concave part, 3) a seed like plant remain fossil within clayey limestone, 4a) a seed plant remain fossil including a nucleus part, 4b-c) closer SEM views of the nucleus, 4d) closer external view of the nucleus (scale 1 mm).

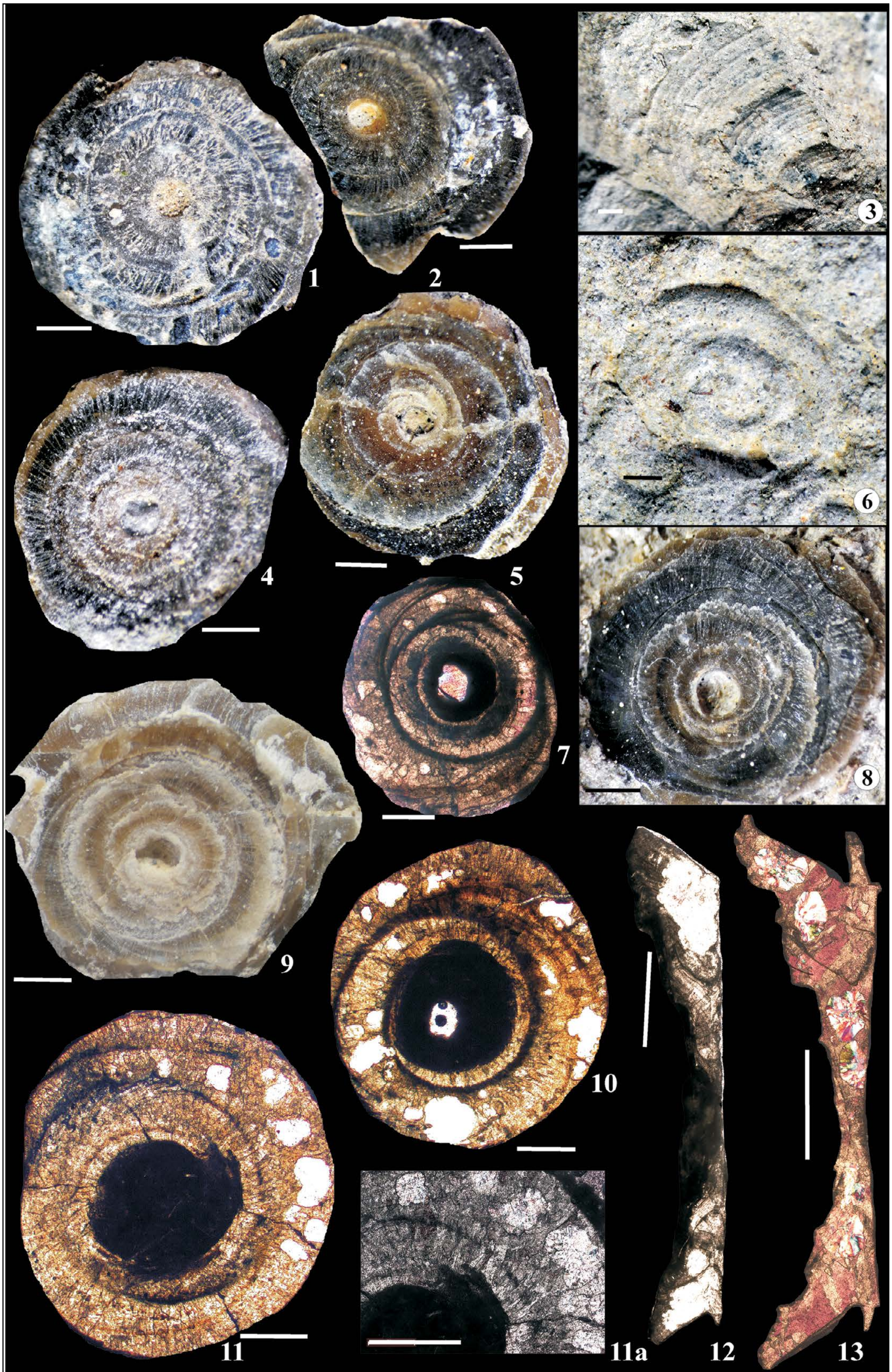


Figure 7- Seed like plant remain fossil views. 1,2,4,5,8,9 external views, 3,6 mold and cast of the seed like fossils, 7,10,11 horizontal views, 12,13 vertical views, scale shows 1 mm, all specimens are from the northern and southern limb of the syncline between Sarıkafa and west of the Çoban Hill.

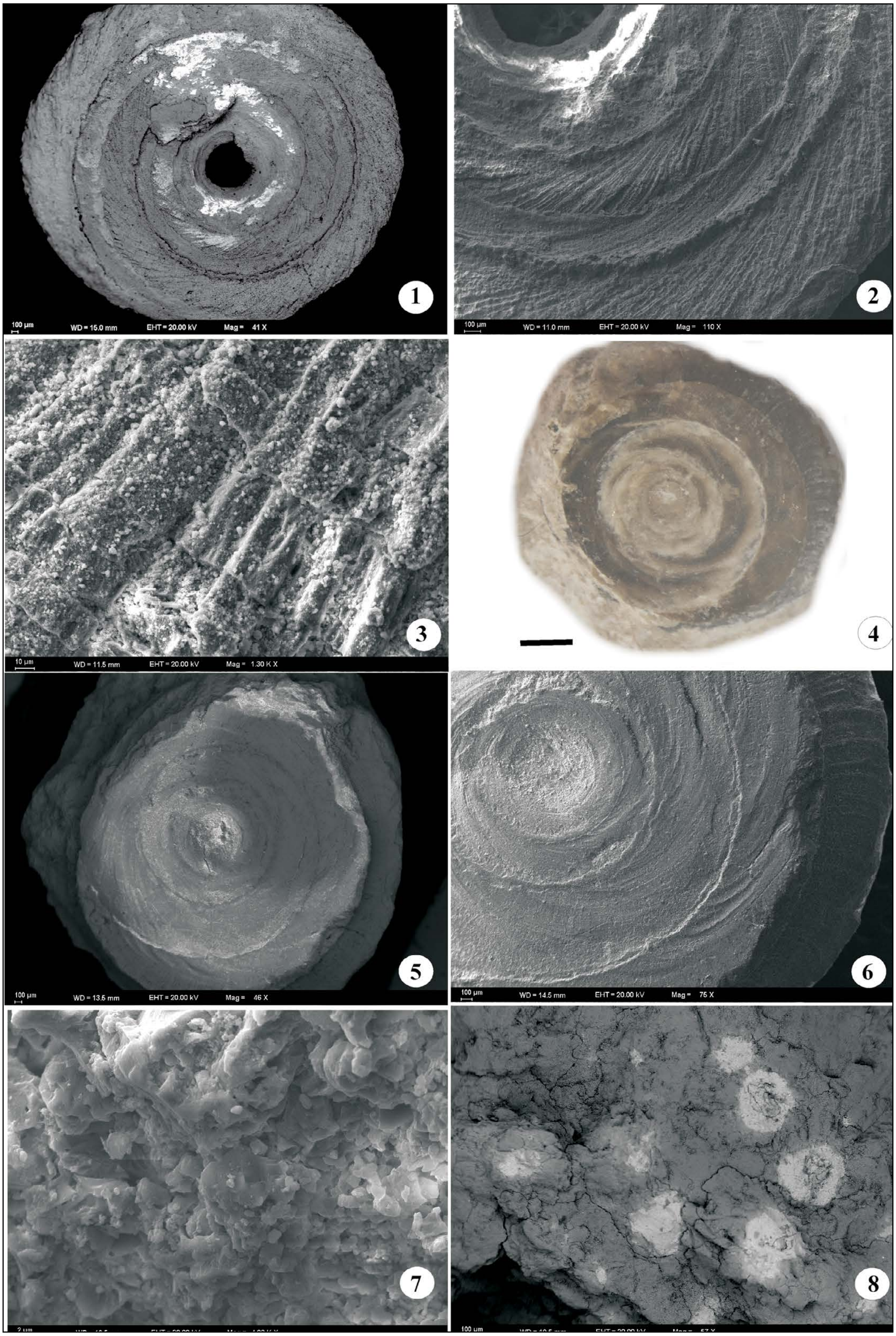


Figure 8- SEM seed like plant remain fossil views (1-3, 5-6) and SEM views of surrounding lithologies. 1) Concave part view, 2) details of radial ornament, 3) closer view of the radial part, 4) flattened part view, 5) flattaned part SEM view, 6) closer view of the initial part, 7) closer view of clayey limestone, 8) closer view of dark nodules with iron richness within clayey limestones.

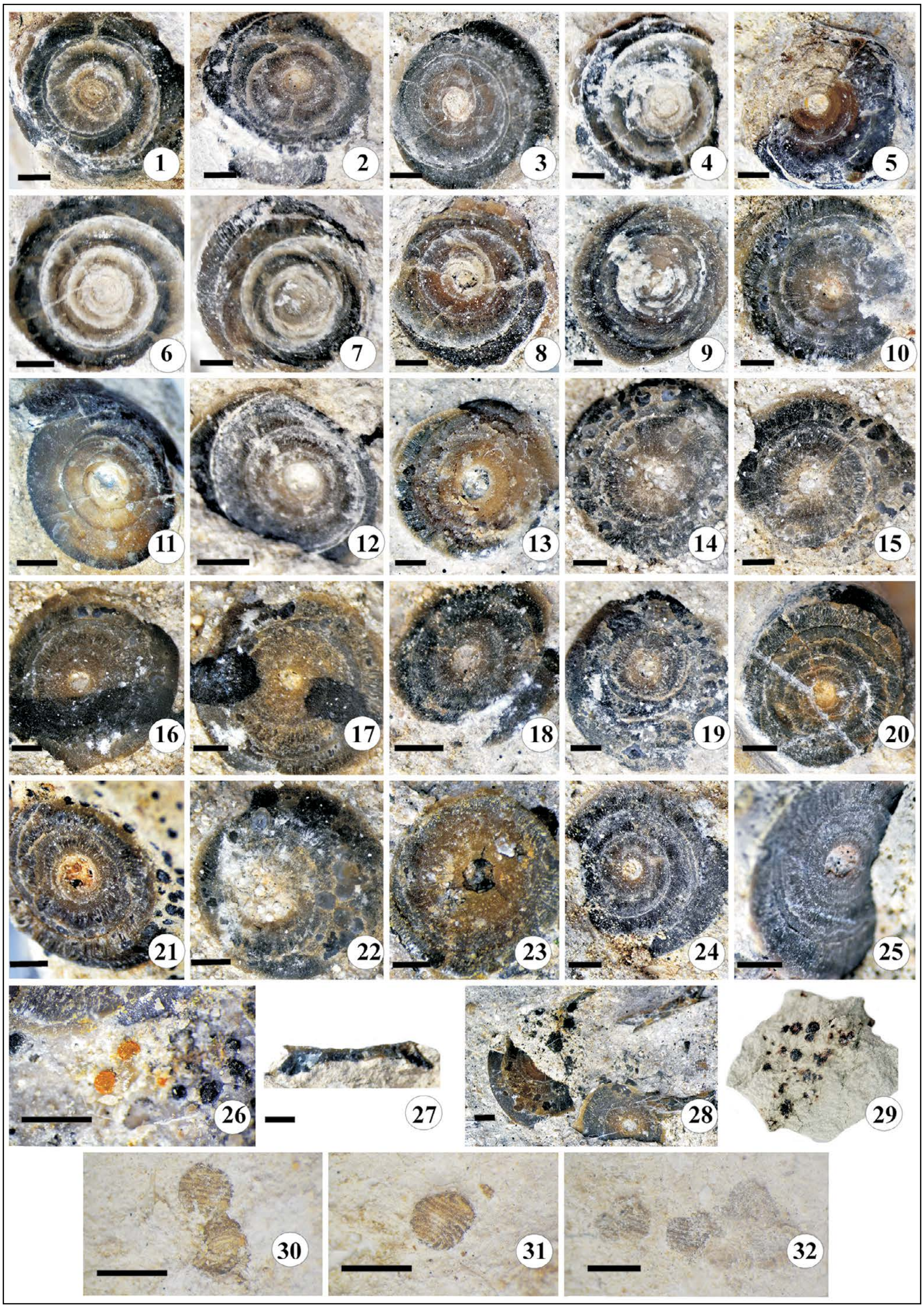


Figure 9- Various seed like plant remain fossil views (1-25), 26) Sulfur (S) nodules within clayey limestone, 27) side view of a seed fossil, 28) side and oblique views of seed fossils within clayey limestone, 29) iron nodules within clayey limestones, 30-32) *Chara globularis* within clayey limestone.

4.2. Internal Views

Micritic initial part and sometimes neomorphic cave up to 0,5 mm in size are in the centre of the fossil. They have calcitic circular, curved radial internal structures. Within the individual thin sections, calcitic small caves within the whorls are also usual. Circular whorlings are clearly seen. As mentioned before, only one specimen includes a nucleus at the centre. The nucleus is about 1 mm in diameter and includes radial internal lines (Figure 6.4). The lines are Z in shape (Figure 6.4c).

4.3. Associated Flora and Age

Associated flora is *Pediastrum* spp., *Botryococcus braunii, Ovoidites* spp., *Tricolpopollenites* spp., *Pinus* spp. Gramineae and Polypodiaceae. They were determined within the claystones and coals overlying the limestones with seed fossils. *Pediastrum* spp. is abundant form within the sediments. It is organic green algae. *Botryococcus braunii, Pinus* spp. Gramineae are rare (maximum up to 10 individuals) while *Ovoidites* spp. and Polypodiaceae are seen as usual forms (between 20-50). *Tricolpopollenites* spp. is between 5-20. Due to appearances of Gramineae pollens in the western Anatolia at the beginning of Miocene, the age of the sediments may be accepted as early Miocene and their paleoenvironments as shallow lacustrinal paleoenvironment having so many river transportation due to abundance of Polypodiaceae (written and oral communication Dr. Zühtü Batı, TPAO, 2017).

4.4. Geochemical Results

The nucleus, seed, surrounding lithologies and flora were analyzed geochemically to bring out the differences between similar organisms and seed fossils (Figures 10-11-12, Tables 1-2). According to SEM EDS analysis results, two points (A and B) in the nucleus include more carbon element (Figure 10). Point C is composed of Ca contents (Figure 10). Point D in the hard part of *Chara globularis* which is seen with the seed fossils also has similar composition with point C. Within the clayey limestones, very small nodules, point E and matrix of clayey limestones comprise Si, Al and Fe contents. Particularly dark nodules, point F includes rich Fe element (Figure 10).

The EPMA analysis results (Table 1) are as follows: N changes between 47,79 and 48,56% within the seed test. It decreases within the clayey matrix from 43,29 and 43, 31%. CaO within the seed is higher than CaO values of clayey matrix. Besides V_2O_5, Mn, FeO and SO_3 were found within the plant remain fossils in higher values. They are undetermined or very low values within the matrix. In contrary, MgO and SiO_2 has low values within the seed while the clayey matrix contain more Mg and Si elements (Table 1, Figure 11).

RAMAN analyses in the nucleus part show that it is an organic part of the seed. Because surface of three analyzed points A, B, C on the nucleus were burnt after analysis and two points of nucleus comprise organic composition (Figure 12). All obtained geochemical data show that the fossils are related to the Miocene are seed like plant remain fossils.

4.5. Comparison

In comparison with the similar organisms such as snails, differences are presented in table 3. Properties on the shape, size, ornament, geochemical compositions of nucleus and hard parts of the organisms show that our specimens are not gastropoda or other animal organisms.

Table 1- EPMA results for the seed like plant remain fossils, points 1 and 2: hard part of the seed, points 3 and 4: initial part cemented with clayey fillings without nucleus.

	1	2	3	4
Elements	mass%	mass%	mass%	mass%
N	48,56	47,79	43,31	43,29
F	2,07	2,03	2,1	2,03
CaO	47,41	47,72	42,71	40,21
Na_2O	0,02	0,07	0,09	0,02
MgO	0,32	0,28	0,45	0,44
Al_2O_3	0,16	0,23	2,12	2,83
SiO_2	0,28	0,37	6,22	8,14
P_2O_5	0,07	0,01	0,06	0,11
SO_3	0,5	0,43	0,37	0,21
Cl	0,01	0,02	0,01	0,02
K_2O	0,02	0,02	0,99	1,39
TiO_2	0,05	0,05	0,1	0,06
V_2O_5	0,01	0,04	0,01	nd
Cr_2O_3	0,03	0,03	0,09	0,11
Mn	0,06	0,04	nd	nd
FeO	0,66	0,52	0,36	0,42
CoO	0,02	nd	0,03	0,01
NiO	0,11	0,1	0,01	nd
CuO	0,03	0,06	0,05	0,01
ZnO	0,05	nd	nd	0,04
Ga	nd	0	nd	0,07
Rb_2O	0,11	0,04	nd	nd
SrO	0,16	0,11	0,33	0,41
Ba	nd	0,03	0,1	0,05
PbO	0,18	0,09	0,05	nd
	100,89	100,08	99,56	99,87

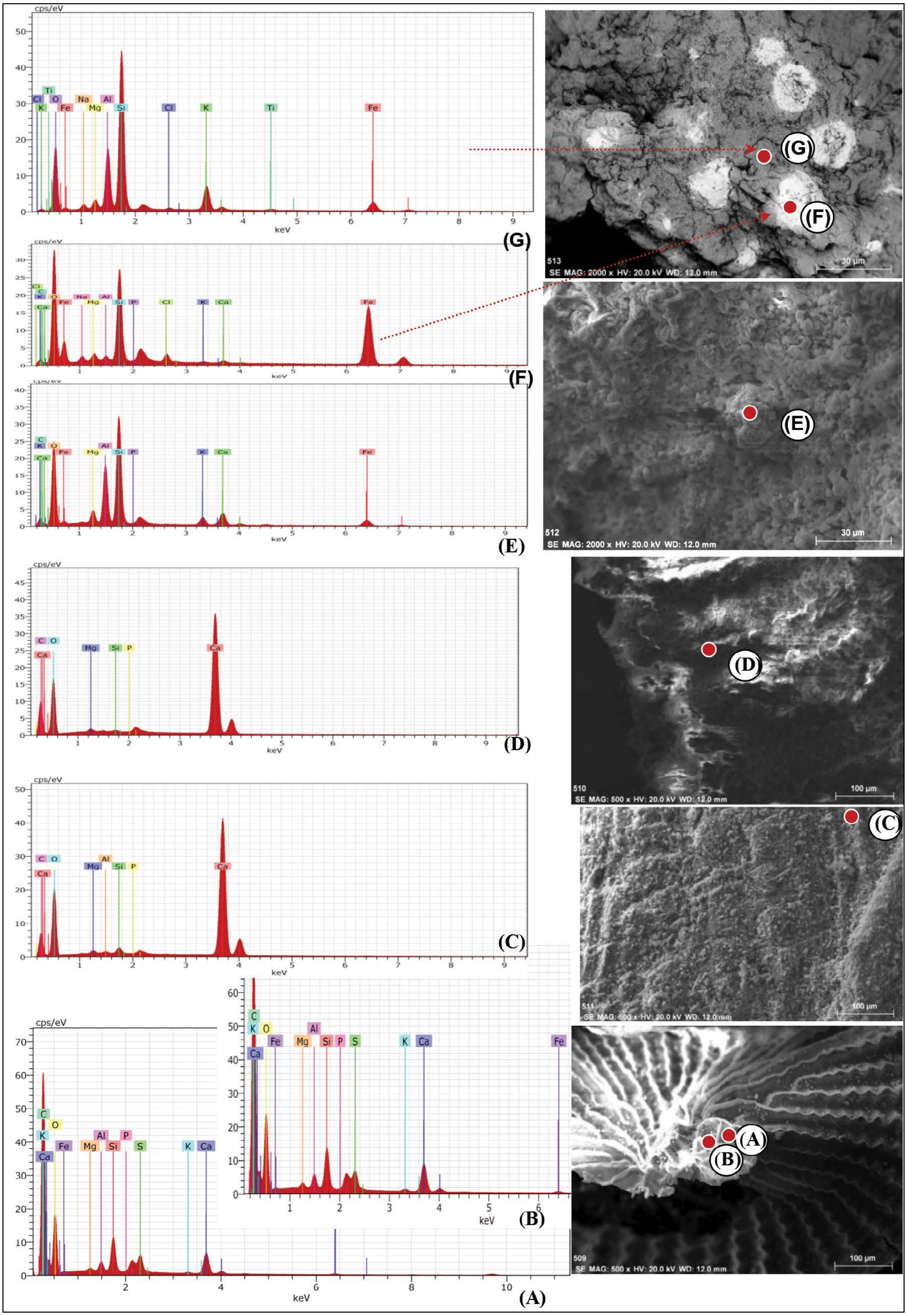


Figure 10- SEM EDS analysis diagrams, A-B) nucleus of a seed like plant remain fossil, C) hard part of a seed like plant remain fossil, D) *Chara* test, E) tiny silicified nodules, F) nodules with iron richness, G) surrounding lithology.

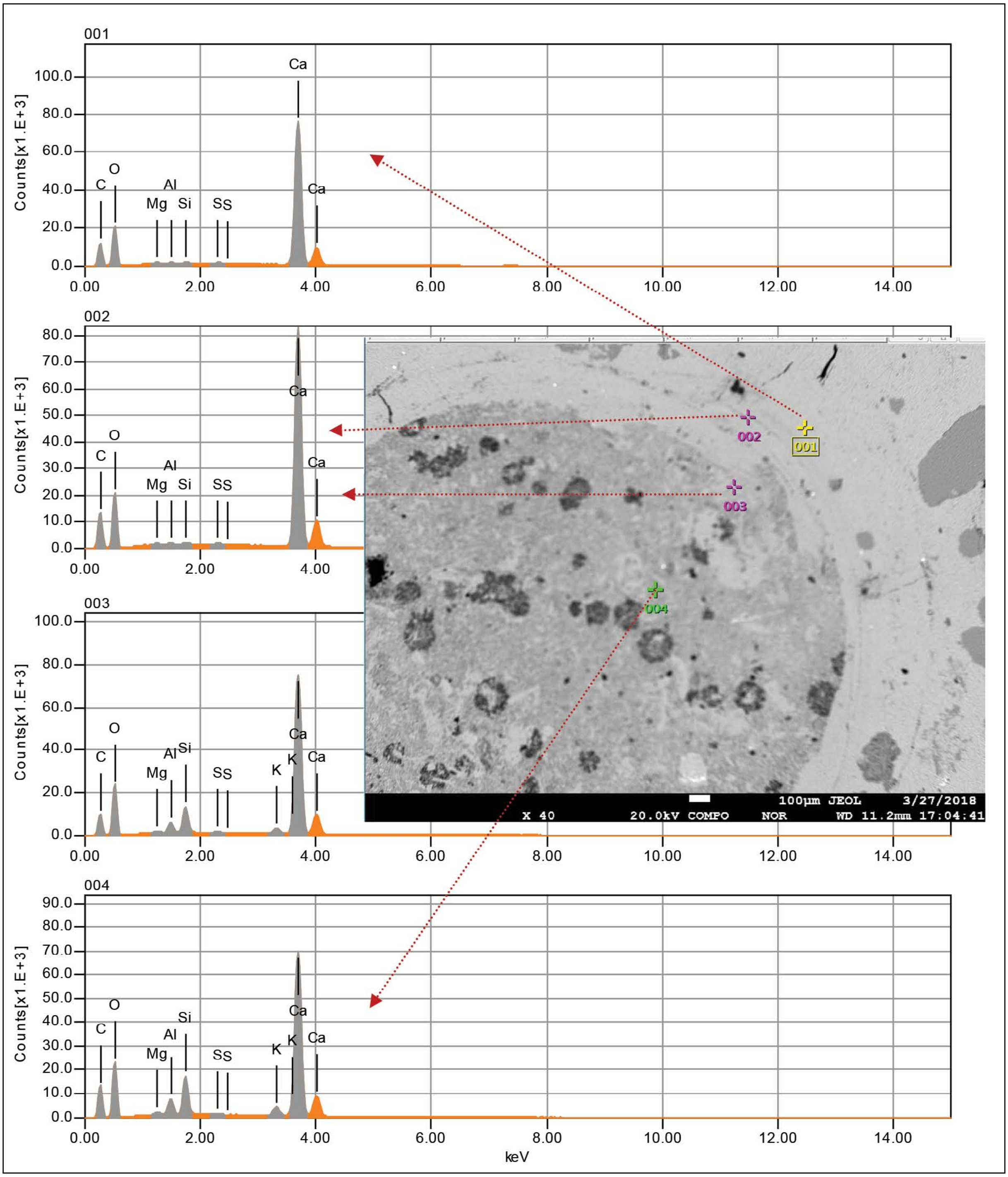


Figure 11- A seed like plant remain fossil EPMA analysis results (points 1-3 seed fossil hard parts, point 4 filling material in the initial part).

5. Facies Associations

The facies association studies mainly concentrate on the three main litostratigraphic units known as Kızılbayır formation, Karadoruk formation and Akpınar formation. The Kızılbayır formation comprises red bed coloured medium to coarse sized siliciclastic deposits and divided into two facies (F1 and F2). These are non-channelized red sandstone and mudstone (F1) and channelized "confined" reddish-beige pebbly sandstone and conglomerate (F2). Clayey limestones of the Karadoruk formation

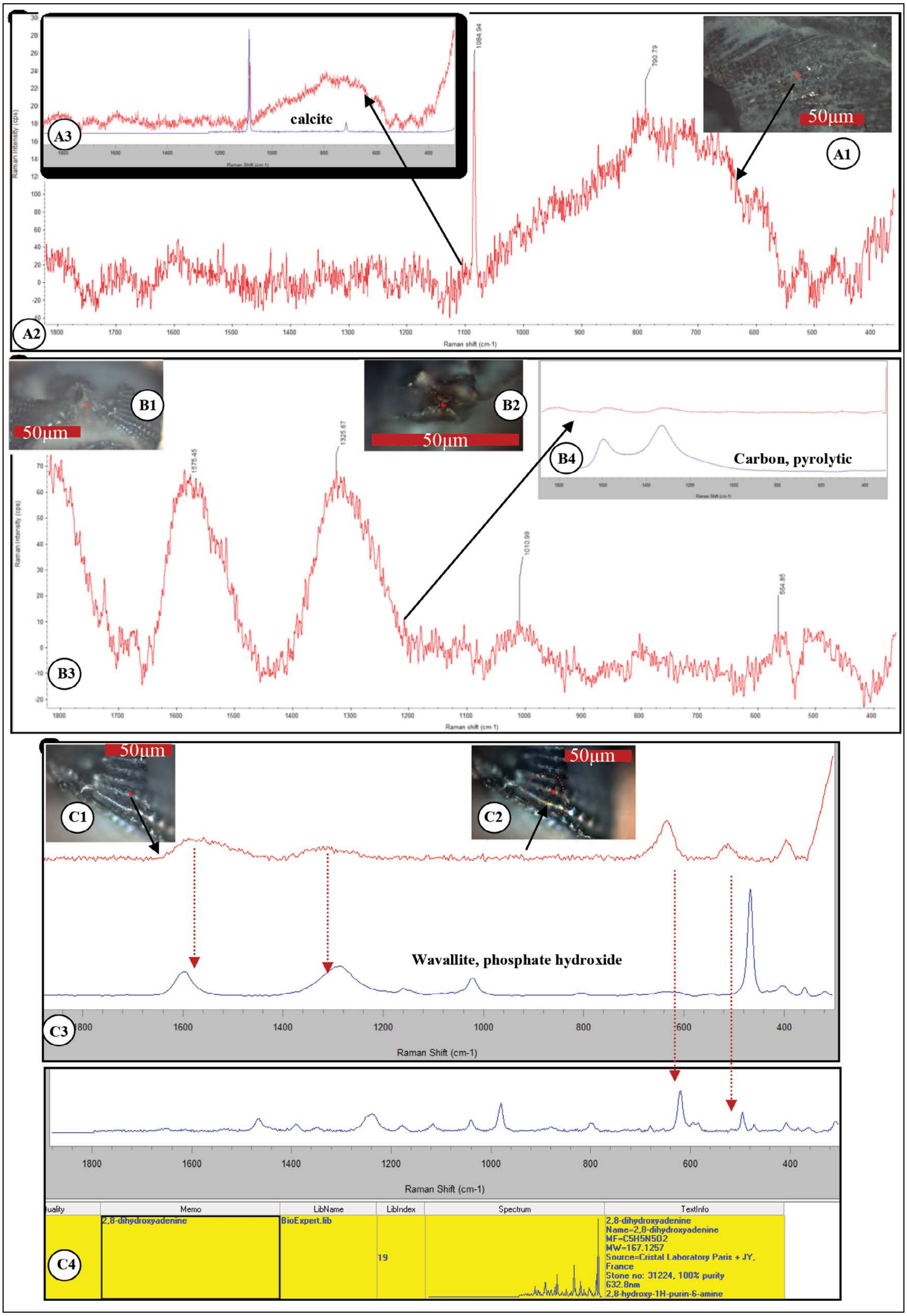


Figure 12- RAMAN analysis results of seed like fossil nucleus (point views A1, B1-before analysis, B2-after analysis, laşer burnt point view, C1-before analysis, C2-after analysis, laser burnt point view) (Raman shifts A2, B3) (Comprasion shift views between standart mineral shifts-blue in colour and obtained shift values-red in colour, A3, B4, C3, C4).

Table 2- SEM EDS results for the seed like plant remain fossils, Nuc_1 and 2. nucleus; *Chara* test, Seed_1 and 2, surrounding parts of nucleus, Ndl_1 and 2. nodules within the clayey layers.

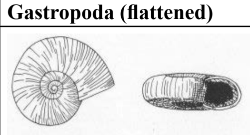
	Nuc_1	Nuc_2	Chara	Seed_1	Seed_2	Ndl_1	Ndl_2
O	56,62	55,08	57,86	57,96	50,07	35,73	40,50
C	**34,09**	**30,29**	12,46	7,98	0,21	0,18	–
Ca	3,90	4,89	**28,99**	**30,43**	4,31	0,51	–
Si	1,75	2,80	–	0,89	**18,90**	12,56	**30,80**
S	1,72	2,16	–	–	–	–	–
P	0,76	1,38	0,40	0,91	3,17	3,88	–
Al	0,44	1,35	–	0,60	11,68	1,42	14,41
Fe	0,40	0,62	–	–	5,96	**37,98**	1,38
K	0,20	0,38	–		2,09	0,20	5,15
Mg	0,11	1,05	0,28	1,24	3,61	2,60	3,40
Na						3,32	3,07
Cl						1,61	0,63
Ti							0,66
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00

conformably rest on the basal siliciclastic red bed unit. However coarse clastics of the formation overlie unconformably the basement at the south of the investigation area. The Karadoruk formation and overlying siliciclastics of the Akpınar formation include the following facies association's namely as medium to coarse siliciclastics (F3), mudstone dominated siliciclastics (F4), plant remain-bearing placket, thin bedded clayey limestone (F5) medium to thick bedded limestone (F6) and rhythmic siliciclastics - clayey-marly limestone including coal occurrences (F7) in ascending order (Figure3).

5.1. Non-Channelized Red Sandstone and Mudstone (F1)

Thickness of the facies is more than 100 meters. They have large lateral persistence (200 -500 m), but display little thickness variations which are generally between 30-40 cm. The sandstones are fine grained in size, represented by a non-channelized depositional character composed of homogenous and stacked beds with sharp and gradational bases that are separated by thin (5-15 cm thick) immature palaeosol levels**.** In some places, upper parts of the beds confined fine laminate sets, mostly horizontal and climbing laminations.

Table 3- Properties comparison between gastropoda and seed like plant remain fossils of this study.

Properties	**Gastropoda (flattened)**	**Seed like fossil (this study)**
Hand specimen view	 http://bioteaching.com/the-steinheim-basin-snail-series-part-1/	 see Figs. 5-9
Size	4-7mm, micromolluca	4-5 mm
Shape	compact spiral shape both sides are more or less same views	One side is smooth, another side is concave
Ornament	stripes on the both sides	many stripes on concave side less stripes on smooth side
Coiling	planspiral, low trochospiral, heights of last whorls increase in size	circular, planspiral
Nucleus	-	circular nucleus with radial lines with Z in shape, see Fig. 6.4
Seed shell composition	Calcite	Calcite
Seed nucleus composition	No nucleus	Calcite and organic material (see Fig. 12)
Thin section view	neomorphic sparite	Neomorphic sparite with small porosites
Associated flora	Other lacustrinal mollusca and organisms	algea, *Chara globularis*, spor and pollens
Environment	Lake	Lake

The sandy beds are sometimes cut by small (10-20 cm) ephemeral channels filled with fine-pebbles. In some parts, the pebbles show patch distributions on the sandy matrix or penetrated as injections within the sandstones. Mudstone interlayers are thinner (15-25 cm thick) than sandstones and contain root casts and mud cracks filled with sandy materials (Figures 4.1, 4.3).

Interpretation: Determined sedimentary structures in the F1, represented by lack of channelization "non-confined" and narrow flood plain are cut by laterally wedge-shaped lobate sandstones. The extensive sharp bases sandy deposition, little thickness variations and horizontal and climbing laminations indicate that the sheet flood-type flows deposited (Lopez-Gomez and Arche, 1993; Martinius et al., 2002; Hampton and Horton, 2007). On the other hand, dispersive or patchy pebble accumulations within the fine-medium-grained sandy matrix would be reflection of high flows flashing that occurred in the seasonal periods of the arid/semi-arid. High rates of sediment accumulation and tectonic subsidence of the Beypazarı Paleogene basin would provide suitable accommodation space and depositional conditions leading to long-term maintenance of a sheet flow system rather than braided and meandering fluvial systems (Hartley, 1993; Hampton and Horton, 2007).

5.2. Channelized "Confined" Reddish-Beige Pebbly Sandstone and Conglomerate (F2)

The facies is characterized by channel – fill deposits bedding with erosional bottom surface. The conglomerates and sandstones lenticular in shape were developed and show lateral extent between 20 and 50 metres, and they merge or interfinger with the sheet red sandstone and floodplain mudstone (F1). Bedding thickness varies from 40 cm to 100 cm (Figure 4.1). Of which pebbly sandstones having with matrix-supported texture exhibit weak stratification, poor sorting character and a wide spectrum of grain sizes with respect to channelized conglomerate with clast-supported texture. Channelized conglomerates record fining/coarsening upward trend, lensoidal – shaped channel lag pebbles, scour - fill structure and planar cross-stratification (Figure 4.1). Where cross-stratification orientations suggest that the flow regime took place in the direction of from NE to SW.

Interpretation: The channelized "confined" facies (F2) would be result of seasonal climate with high rate sedimentation which favoured for the construction of the ephemeral stream and/or ephemeral flashing high flow regime (Abdullatif, 1989) involving a mixed load of pebble, sand, silt and mud. The channel-fill deposits characterized by planar cross- stratification, pebbly channels and upward - coarsening conglomeratic bar sheets could be linked with basin margin alluvial fan or a braided – stream distributary network (Nemec and Postma, 1993).

5.3. Medium to Coarse Siliciclastics (F3)

They expose at the bottom of Karadoruk formation at the south of Cobantepe Hill (Figure 4.5). The facies lithologies are mainly green coloured coarse siliciclastics, medium to thick in bedding. Bedding thickness changes between 1,5 and 2 meters. Total thickness of the facies is about 20 meters. Matrix and clast supported textures, poor sorting character and a wide spectrum grain sizes are seen within the green to red conglomerates and sandstones.

Interpretation: Its restricted geometry, lithological characteristics and unconformity relation with the underlying Kızılbayır formation show that they were derived from the terrestrial areas by rivers. They may be compared with lake margin alluvial fan or a braided – stream distributary network (Nemec and Postma, 1993).

5.4. Mudstones Interbedded with Sandstones (F4)

The facies is between the basal conglomerates (F3) and plant remains-bearing clayey limestone (F5). Rhythmic green coloured mudstones and brown coloured sandstones are the main lithologies of the facies (Figure 4.6). Thickness of the bedding changes from 5 cm to 1 meters. Total thickness of the facies changes between 5 and 15 meters. Thin sections of sandstones of the unit include very small bivalve cross-sections and algae.

Interpretation: Its restricted geometry, lithological characteristics and fauna-flora such as algae and very small mollusc contents show that they were related to very shallow part of the lake. They were probably deposited within the inner part of the lake.

5.5. Placket, Thin Bedded Clayey Limestone Bearing Plant Remain Fossils (F5)

Its measurable thickness of the facies is about 40 metres. The facies is mainly composed of alternating beds of limestones and laminated limestones (Figure 4.2). The alternating beds are organized as upward –fining sets, each one consists of several beds separated by greenish mudstone interlayer's (0.5-20 cm thick) (Figure 4.4).

At the northern limb of the syncline in the middle of the study area (Figures 4.1, 4.2, 4.4), succession of the Karadoruk formation starts with cream coloured siltstones. The total thickness of the base deposits changes between 5 to 10 meters. Siltstones and clayey limestones, including algae are dominant (Figures 4.8, 4.9, 4.10). Clayey limestones and limestones, including many fractures and laminated limestones towards the upper part of the formation have mainly thin to medium beddings, 2- 30 cm in thickness. Grey to yellowish grey coloured siltstone interbeds, a few cm in thickness are seen within the laminated limestones. Seed fossils are clearly observed on the bedding limestone surfaces, up to %1-2 in ratio (Figures 4.11-4.12). Plant remain fossils (?Menispermacea) is well fossilized and disseminated within the limestone beds mixed with various amount of woody plant, root materials and fresh water pelecypod fossils. The limestone facies contains very low rate of clayey minerals (≥% 10 and). Low-magnesium calcite is formed the main mineralogical composition in this facies, which precipitated as micrite matrix and void-filling spar cement particularly in the open space of the mud crack and root cast.

At the southern part of the syncline in the middle of the study area (Figures 4.5, 4.6), greenish coloured siltstones, and mudstones including tuffit interbeds are at the base of the Karadoruk formation. Its succession continuous with yellowish coloured rhythmic mudstones and clayey limestones, totally 5 meters in thickness. In the succession, the bed thickness is from 5 to 15 cm. Limestones and clayey limestones are at the upper part of the formation. Silicified nodules known as beekyte are seen within the limestones at the upper part of the succession. Seed fossils as seen at the northern side of the syncline are within the bed surface of the limestones at the upper parts of the Karadoruk formation.

Interpretation: The facies represents a transgression of the lake upon the Palaeogene terrain that started with a major climatic changes evolved from arid-semiarid (terrestrial red bed deposits) to humid (lacustrine limestone) environments (Mueller et al., 2016). Fining-upward limestone cycles dissected by thin mudstone precipitations suggest that lake level fluctuations existed during the initial phase of the transgression. Abundant plant remain (?Menispermacea) fossil is indication of planted shallow lake margin with low topography (Yabe, 2009). On the other hand, very low terrigenous contribution into the lake waters support to existence of an oligotrophic lake through the carbonate precipitation. It is thought that the lake received poor nutrient supply and had little aquatic plants mixed with flowering plant (?Menispermacea) on the land.

5.6. Medium to Thick Bedded Limestone (F6)

They are seen at the top of the Karadoruk formation. They have facies changes with plant remain (?Menispermacea)-bearing clayey limestone. It is characterized with silicified nodules and thick beddings (Figures 4.5). Their colour is light beige. The total thickness is between 20 and 30 meters.

Interpretation: Clayey limestones outcrops widespreadly in the Beypazari basin and known as lacustrinal sediments (Siyako, 1983; Yağmurlu and Helvacı, 1994; Karadenizli, 1995). Lithological characteristics in the study area show that they were deposited within lake.

5.7. Rhythmic Siliciclastics - Clayey Limestone Including Coal Occurrences (F7)

The Akpınar formation fine to medium sized siliciclastic includes rhythmic mudstones, clayey marly limestones, siltstones and sandstones, 20 cm in bed thickness. Black to dark brown coloured coal occurrences, 2-3 cm in thickness are within the mudstones and sandstones (Figure 4.7). They are mainly yellowish in colour and overlie conformably the deposits of the Karadoruk formation. Whole facies is thicker than 30 metres and it is distinguished from the basal limestones by greyish yellow appearance, abundant plant material but lack of the seed like fossils.

Interpretation: Lignite-bearing basal level and high rate terrigeneous influx supported by clayey/ marl limestones were deposited during the time of drastically changes of the lake hydrology, presumably evolved from shallow oligotrophic to deeper eutrophic lake (Cayelan and Rydin, 2011), where the progressively deepening commenced with swamp environment, and then low-drainage river, running on the low topography, carried suspension load into the lake environment.

6. Discussion

The Miocene seed like fossils look like nummulits, and may be confused with annular benthic foraminifera. But the studied seed like fossils' shape and internal structures are so different than *Nummulites* and/or other living organisms and fossils. It may also be assumed as small gastropods. But its initial part view, vertical and horizontal structures are also so different from the gastropods (Table 3). Some Eocene, Miocene fossil seeds may be compared with our fossil seed data (Friis, 1985; Burge and Manchester, 2008; Herrera et. al., 2011; Wang et. al., 2013; Collinson et al., 2012; Pan et al., 2012; Lin et al., 2013; Huang et al., 2015; Hounslow et. al., 2016).

The mean size of our seed like plant remain fossils is around 6 mm and its mean diameter is about 0,7 mm. The size and its structure seem to be a Eocene species of Menispermaceae (Collinson et al., 2012). It may be compared with *Karinschmidtia rotulae.* However, its initial part is so different.

Due to the following reasons, our fossil findings are the first possible seed records from the lower Miocene sediments (?Menispermaceae): (1) Its shape-concave upper part, flattened bottom side, narrow thickness (Figure 6.1), (2) inner side of concave part includes radial, often lines (Figures 6.1b, 2; 8.2), it is impossible for gastropoda inside view, (3) having a semi-organic nucleus part with Z shaped often radial lines (Figure 6.4), (4) nucleus composition comprise organic material based on geochemical data (Figures 11-12), (5) associated flora and fauna, particularly seeing lacustrinal *Chara* (Figure 9.30-32), spore, pollen and coal occurrences (Figure 4.7), (6) they are seen on the clayey limestone beds (Figure 4.11).

The facies associations studied here provide a good example to interpret the environmental and paleoclimatic evaluations of the early Miocene succession in the Beypazarı –Nallıhan basin. The first depositional pocket (F1,2,3) was generated by fluvial system located near the centre of the basin, formed by low- sinuosity channels, braided river and seasonally channelized or non-channelized ephemeral flows supplied the high rate of siliciclastic sediments (Bridge and Gabel, 1992). Whereas basin margin setting alluvial fans might be active by alluvial fans during the flushing period of wet seasons (Abdul Aziz et al., 2003). The transition from the fluvial to lake deposition was highlighted by a drastic climatic changes developed from dry to humid, which was responsible for the onset of the new tectonic regime across the basin and constrained the establishment of a lake dominated -new drainage system along with topographic lowering and consequent retraction of the fluvial system. Shallow lake environment (facies 4-6) was initially filled by clayey limestone received abundant plant material (?Menispermacea) from the flat–edged lake margin. In the final stage (Akpınar and Karadoruk formations) lake relatively became deeper and rimmed by local swamps along the lake margin (facies 7). In this time period, high inflow of suspended load had involved a massive precipitation of marly limestones in the deeper part of the lake. Sedimentation and hydrological changes in a lake realm are related to humidity and other climate factors (Runge 2012).

7. Conclusions

The study focuses on Miocene plant remain fossil occurrences and their palaeoenvironment. So, the seed like plant remain fossil data from the east of Nallıhan area provide useful information on the terrestrial occurrences to interpret the early Miocene lake history. EPMA, RAMAN and SEM EDS results support seed like fossil appearances in the area. According to field and laboratory observations, seven facies associations were determined from the upper Paleogene to lower Miocene sediments. The Kızılbayır formation in the investigation area includes basin margin alluvial fan or a braided and meandering fluvial systems at the bottom related to arid/semi-arid conditions (F1, F2). The lacustrinal sediments of the Karadoruk and Akpınar formations comprise various lithofacies (F3-F7). The lake water is assumed as an oligotrophic lake through the carbonate precipitation, which received poor nutrient supply and having little aquatic plants contrasting to flowering plant

(?Menispermacea) on the land. Deeper eutrophic lake including swamp coal occurrences are seen towards the upper part of the Miocene.

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