



## Early Ludlovian (early Late Silurian) palynomorphs from the Paleozoic of Çamdağ, NW Anatolia, Turkey

*Çamdağ Paleozoyiğinde Erken Ludloviyen (erken Geç Siluriyen) palinomorfları, KB Anadolu*

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### ABSTRACT

In the Çamdağ area in north-western Anatolia, newly discovered tectonic slices including the Shale-Siltstone Member of the Fındıklı formation yielded a diverse palynological association with determinable acanthomorphic acritarchs and prasinophyte algae and tabular structures. From these, the short-ranging species *Ammonidium ludlowense*, *Eisenackidium wenlockium*, *Gorgonisphaeridium listeri listeri* and *G. succinum* are of biostratigraphical interest as they are restricted to the early Ludlow. This is so far the first early Late Silurian palynological data from NW Turkey and suggests that the deposition in the Çamdağ area was more proximal, compared with the relative units in the Perigondwanan İstanbul and Balkan Terranes.

**Key Words:** Çamdağ, early Late Silurian, NW Turkey, paleogeography, palynomorphs.

### ÖZET

KB Anadolu'da Çamdağ yöresinde yeni saptanan bir tektonik dilimde yüzeylenen Fındıklı formasyonuna ait Şeyl-Silttaş Üyesi tanımlanabilir özellikteki akantomorfik akritarklar, prasinofit algler ve yassı yapılardan oluşmuş zengin bir palinolojik topluluk içermektedir. Bunlardan *Ammonidium ludlowense*, *Eisenackidium wenlockium*, *Gorgonisphaeridium listeri listeri* ve *Gorgonisphaeridium succinum* gibi türler kısa konaklı olduklarından biyostratigrafik açıdan önemlidirler ve erken Ludloviyen yaşına işaret ederler. Bu bulgu, KB Anadolu'daki ilk erken Geç Siluriyen palinolojik bulgusudur ve bu dönemde Çamdağ alanının Perigondwana kökenli İstanbul ve Balkan tektonik birliklerine göre kıtaya daha yakın konumda olduğunu gösterir.

**Anahtar Kelimeler:** Çamdağ, erken Geç Siluriyen, KB Anadolu, paleocoğrafya, palinomorf.

### INTRODUCTION

The Paleozoic of NW Anatolia between İstanbul and Cide (Figure 1) along the Black Sea coast is incorporated to the "İstanbul Nappe" of Şengör and Yılmaz (1981) or "İstanbul Zone" of Okay (1989). The Paleozoic formations in this

unit are classically known as the "Paleozoic of İstanbul" and considered previously as part of the eastern European "Hercynian chain". Based on stratigraphic dissimilarities it had been shown recently (Göncüoğlu et al., 1997; Göncü-

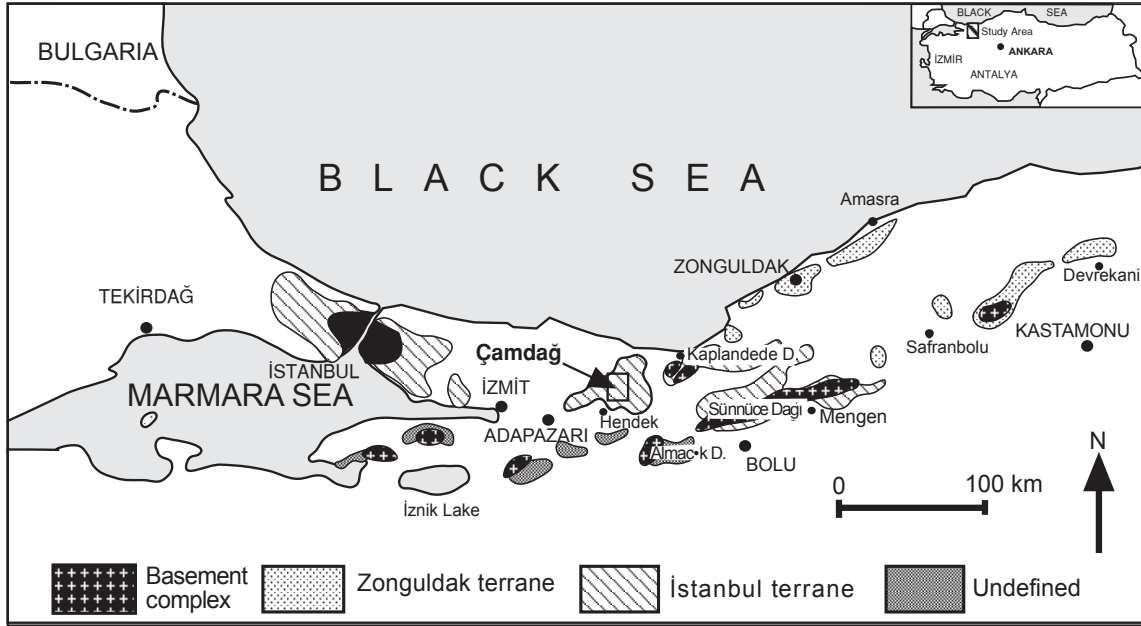


Figure 1. Distribution of the Paleozoic rock units in the İstanbul and Zonguldak terranes in NW Anatolia and the location of the Çamdağ area.

Şekil 1. KB Anadolu'da İstanbul ve Zonguldak birliklerinde Alt Paleozoyik kayalarının dağılımı ve Çamdağ alanının konumu.

oğlu, 1997; Göncüoğlu and Kozur, 1998, 1999) that the "İstanbul Nappe" actually includes two different terranes: "İstanbul Terrane s.s." in the west and the "Zonguldak Terrane" in the east (see Figure 1). The Çamdağ "Massif" (Kipman, 1974) geographically located between them, remained as a problematic area. In the previous studies it was univocally accepted that the Çamdağ area was a "paleo-high" through most of the Ordovician and Silurian (Kaya, 1988; Önalın, 1982; Aydın et al., 1987; Derman and Tuna, 2000), as no Silurian rocks were identified in this region. Recent studies (Kozlu et al., 2002; Gedik and Önalın, 2002; Göncüoğlu and Sachanski, 2003), however, have shown that the thick succession of low-grade metamorphic black shales with minor black siltstone and limestone interlayers (Yayla Formation of Kipman, 1974, or Fındıklı formation of Yazman and Çokuğraş, 1984) is in fact of Silurian age.

The Fındıklı formation includes numerous thrust sheets. Based on a correlation between these tectonic units, Kozlu et al. (2002) differentiated from bottom to the top three informal units: the Black Shale Member, Shale-Siltstone Member and the Shale-Limestone Member. The upper part of the Black Shale Member yielded Upper

Llandoveryan (Telychian) graptolites, whereas the "Orthoceras Limestone" interlayers in the upper part of the Shale-Limestone Member was dated as Pridoli.

In this study, the authors present their first early Late Silurian fossil findings from the Shale-Siltstone Member of the Fındıklı formation and revise the stratigraphy of the Silurian succession in the Çamdağ area. The early Ludlovian (early Late Silurian) palynomorph data reported in this study are so far the first findings in NW Anatolia and have important constraints on the paleogeography and the depositional environment of the middle Silurian in this region. Finally, the Silurian stratigraphy of the Çamdağ area is being correlated with the neighboring areas in Turkey and with those of tectonic units in the eastern Balkan Peninsula in order to evaluate its paleogeographic position in regard with the Gondwanan/Peri-Gonwanan terranes.

## GEOLOGY AND STRATIGRAPHY

The Çamdağ "Massif" is located between the towns Hendek and Karasu to the NE of Adapazarı and covers an area of approximately 400 km<sup>2</sup> (see Figure 1). The Paleozoic rocks in

Çamdağ are highly deformed and slightly metamorphosed. The lower part of the Paleozoic succession is mainly represented by variegated arkoses, quartz-sandstones, siltstones and mudstones (Soğuksu, Kocatöngel, Bakacak, Kurtköy and Aydos formations in Aydın et al., 1987; Gedik and Önal, 2002) that cover the southern part of the massif. Except a single pterineid pelecypod finding with a wide age range (Gedik and Önal, 2002) no fossil findings had been reported from these units in the Çamdağ area and the suggested Ordovician age in the previous work is mainly based on the correlations with the better-dated units in İstanbul and Zonguldak areas. The contact to the overlying Fındıklı formation is generally faulted.

The Fındıklı formation crops out mainly in the central and northern parts of the massif within a roughly E-W trending anticline, dissected by numerous south-verging thrust-faults. The revised columnar section of the Ordovician to Devonian rocks in the Çamdağ area with a brief description of the rock-units is given in Figures 2 and 3. Fındıklı formation in its upper part displays a gradational transition to the overlying Lower Devonian Bıçkı Member of the Kartal Formation.

The studied part of the Silurian rocks is located between Mollahasan Tepe and Karadere Village on the Hendek-Karaali road in the central part of Çamdağ (see Figure 2). The studied section starts at a thrust-fault at the Süngüt road-junction where recrystallized, thick-bedded Devonian limestones (limestone member of the Kartal Formation) juxtapose the violet-red-gray, silica-cemented slates with sandstone interlayers that resemble the Ordovician Bakacak Formation. Along the road-section, Fındıklı formation rests with a thrust-contact on the Bakacak Formation and the Kartal and Aydos formations are not represented. The studied section terminates in the north at the contact between Fındıklı and Kartal formations to the south of Karadere Village.

The lower part of the Fındıklı formation was informally named as the Black Shale Member of the Fındıklı formation by Kozlu et al. (2002). It is mainly composed of a thick and monotonous succession of gray to greenish gray, well-cleaved shales with minor black siltstone and limy shale interlayers. Very thin-bedded black shales

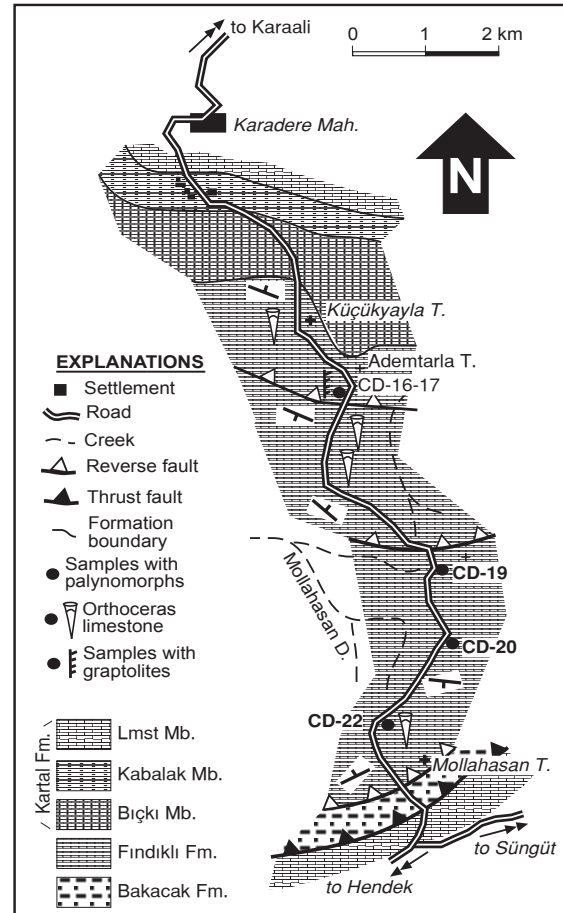


Figure 2. Geological map of the study area.  
Şekil 2. Çalışma alanının jeoloji haritası.

alternating with gray and brownish siltstones in the lower 10th m of the member include *Spirograptus spiralis* (Geinitz), *Spirograptus falx* (Suess), *Monoclimacis vomerina* (Nicholson), *Monograptus priodon* (Bronn), *Monograptus parapriodon* Bouček, *Monograptus (Globosograptus) mancki* Hemmann, *Monograptus curvus* Manck, *Diversograptus ramosus* Manck, *Retiolites angustidens* Elles and Wood, *Cyrtograptus (Barandeograptus) pulchellus* Tullberg, indicative for the *spiralis* Zone of the Late Llandovery, Telychian (Göncüoğlu and Sachanski, 2003).

The overlying Shale Siltstone Member displays a gradational contact to the Black Shale member and is characterized by alternations of dark gray-greenish black siltstones and shales with dark green-black, pyrite-bearing limy siltstones. In contrast to the siltstones of the underlying Black Shale Member, the siltstones here are

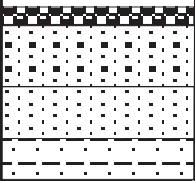
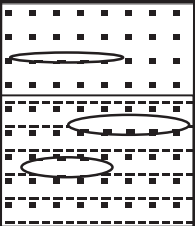
SYSTEM	STAGE	FORMATION	LITHOLOGY	EXPLANATION
DEVONIAN	Ems	Kartal		<p>Red, cross-bedded sand- and mudstone with conglomerate bands, lenses and limey nodules</p> <p>Yellowish brown sandstones with brachiopoda and plant detritus</p> <p>Gray-brown, graded bedded sandstone and siltstone</p>
				<p><b>Shale-Limestone Member:</b> black shale with dark gray- brown limestone and dolomitic limestone interlayers with Nautiloids</p> <p><b>Shale-Siltstone Member:</b> black shale with light gray quartz-rich siltstone and rare limestone interlayers</p> <p><b>Black Shale Member:</b> black-greenish gray, well-cleaved shale, minor black siltstone and limey shale interlayers with Graptolites</p>
ORDOVICIAN		Aydos		<p><b>?Unconformity</b></p> <p>White-buff, silica-cemented, cross-bedded quartz-arenites with siltstone interlayers and conglomerate lenses</p> <p>Red-violet sandstone and mudstone with conglomerate lenses</p> <p>(not-to-scale)</p>
		Kurtköy		

Figure 3. Generalized columnar section of the Ordovician to Lower Devonian rocks in the Çamdağ area.  
Şekil 3. Çamdağ alanında Ordoviziyen-Alt Devonyen istiflerinin genelleştirilmiş stratigrafik dikme kesidi.

very rich in mica detritus. The shales are finely laminated and include tiny flakes of sericite. The siltstones display grading and lamination and include sub-rounded clasts of feldspar and quartz next to coarser-grained detrital white mica. The individual limy siltstone bands are up to 4 m thick and massive. From several samples taken from the Shale-Siltstone Member only one sample (CD-19, Figure 2) yielded more or less preserved indicative fossils of middle Silurian age, as presented in the next chapter.

The siltstones and shales of the Shale-Siltstone Member grade upward into black shales with limestone and dolomitic limestone interlayers of the Shale-Limestone Member. The limestones of the member are dark gray to brown in color, and very rich in up to 30 cm long orthocone cephalopods, crinoids and brachiopods and can be

used as marker horizons to decipher the very complex folding and faulting. They include Pridolian conodonts (Kozlu et al., 2002).

### PALYNOLOGICAL FINDINGS AND THEIR IMPLICATIONS

Pilot samples have been taken from all three members of the Findıklı Formation. Among them, five samples (CD- 16, CD-17, CD-19, CD-20 and CD-22) yielded organic-walled microfossils. The samples have been processed using the standard palynological technique by solution with HCl and HF. As a whole, the palynological material is scarce, dark, opaque, coalified, flattened and hardly determinable, sometimes as silhouette forms. After lightening using HNO<sub>3</sub> during 60 minutes, acritarchs available in sample CD-19 have become transparent and determinable.

### Black Shale Member

The samples CD-16 and CD-17 are taken from the Black Shale Member, which was recently dated on graptolites as Telychian by Göncüoğlu and Sachanski (2003). The palynological association is very poor and mainly consists of colified opaque acantomorphic acritarchs and three species of tubular structures of Anteturma *Trichomoformis* Burgess and Edwards (1991): *Laevitubulus tenuis* Burgess and Edwards, *L. crassus* Burgess and Edwards and *Porcatitubulus strupus* Wellman. These species were previously reported from Upper Llandovery to Lochkovian continental deposits in the British Isles (Wellman, 1995), as well as from Pridoli to Emilian marine shales from the Moesian Terrane in Bulgaria (Lokava, 2001).

### Shale-Siltstone Member

The samples CD-19 and CD-20 are taken from the Shale Siltstone Member whose age was not determined on fossils till now. The palynological

association of the sample CD-19 is diverse in terms of organic-walled microfossil groups: opaque trilete spores (Plate 1 Figures 1, 13, 17 and 18), single cryptospores - spore dyads (Plate 1 Figure 5) and tetrads (Plate 1 Figure 6), chitinozoans (Plate 1 Figure 14), scolecodonts (Plate 1 Figure 16), ?mazuellids (Plate 1 Figure 19), as well as determinable acanthomorphic acritarchs and prasinophyte algae and tubular structures. The following acritarch and prasinophytes species occur in CD-19 sample:

*Ammonidium ludloviense* LISTER, 1970 (DORNING, 1981) (Plate 1 Figure 11)

*Cymatiosphaera* sp. cf. *C. octoplana* DOWNIE, 1959 (Plate 1 Figure 3)

*Comasphaeridium brevispinosum* (LISTER, 1970) MULLINS, 2001 (Plate 1 Figure 4)

*C. williereae* (DEFLANDRE and DEFLANDRE-RIGAUD, 1965) SARJEANT and STANCLIFFE, 1994

*Eisenackidium wenlockense* DORNING, 1981

*Gorgonisphaeridium listeri listeri* MULLINS, 2001 (Plate 1 Figure 8)

Series	Llandovery	Wenlock	Ludlow	Pridoli	Lower Devonian
Taxa \ Stage			Gorstian		
<i>Ammonidium ludloviense</i>		—	—		
<i>Cymatiosphaera octoplana</i>	—	—	—	—	
<i>Comasphaeridium brevispinosum</i>		—	—	—	
<i>Comasphaeridium williereae</i>	—	—	—	—	
<i>Eisenackidium wenlockense</i>	—	—	—		
<i>Gorgonisphaeridium succinum</i>		—	—	—	
<i>Gorgonisphaeridium listeri listeri</i>			—		
<i>Oppilatala ramusculosa</i>	—	—	—	—	
<i>Veryhachium trispinosum</i>	—	—	—	—	—

Figure 4. Known ranges of the acritarch and prasinophyte taxa recorded from the Shale Siltstone Member in Camdağ area. (Sources: Lister, 1970; Dorning, 1981; Le Herisse, 1989; Molyneux et al., 1996; Mullins, 2001).

Şekil 4. Çamdağ alanında Fındıklı formasyonunun Şeyl-Silttaş Üyesinden alınan CD-19 nolu örneğin akritark ve prasinofit türlerinden bazılarının stratigrafik konakları (Kaynaklar: Lister, 1970; Dorning, 1981; Le Herisse, 1989; Molyneux et al., 1996; Mullins, 2001).

*Gorgonisphaeridium succinum* LISTER, 1970 (Plate 1 Figure 12)  
*Lophosphaeridium* sp. indet.  
*Oppilatala ramusculosa* (DEFLANDRE, 1945) DORNING, 1981 (Plate 1 Figure 2)  
*Verychachium trispinosum* (EISENACK, 1938) STOCKMANS and WILLIERE, 1962.

The tubular structures in sample CD-19 are represented by four species: *Constrictitubulus cristatus* (Plate 1 Figure 15), *Porcatitubulus annulatus* (Plate 1 Figure 7), *Porcatitubulus strupus* and *Ornatifilum granulam*, all four previously reported from Upper Llandovery to Emsian continental and marine succession from England, Wales, Scotland, Ireland, Sweden, Norway, USA, Bulgaria (see Wellman, 1995; Lakova, 2001). The sample CD-20 is much poorer in organic-walled microfossils - only single opaque silhouettes of spores and acanthomorphic acritarchs and two species of tubular structures: *L. tenuis*, and *L. crassus*.

#### Shale Limestone Member

The age of this member is Pridoli on conodonts and nautiloids (Kozlu et al., 2002). The palynological record of sample CD-22 from this member is very scarce, consisting of only single indeterminate chitinozoans resembling the genus *Calpichitina*, as well as the tubular species *L. crassus* (Plate 1 Figure 13).

All acritarchs and prasinopyte species recorded from the Shale Siltstone Member occur in the Silurian worldwide. *A. ludloviense*, *E. wenlockium*, *G. listeri listeri* and *G. succinum* are of biostratigraphical interest as these are short-ranging species restricted to the Wenlock and Ludlow in England, Sweden and Ukraine (Dorning, 1981; Le Herisse, 1989; Molyneux et al., 1996; Mullins, 2001).

The species *C. brevispinosum*, *E. wenlockense* and *G. succinum* start their ranges at the base of the Upper Wenlock - Sheinwoodian Stage. On the other hand, *A. ludloviense*, *E. wenlockense* and *G. listeri listeri* are not known above the Gorstian Stage (the Lower Ludlow) (Figure 4). It should be mentioned that *E. wenlockense* and *G. listeri listeri* which are of very short stratigraphical occurrence were recorded only in the Welsh Borderland in England (Dorning, 1981;

Mullins, 2001) and it is possible these are not their complete ranges.

As a whole, the acritarch and prasinophyte association recorded in the Çamdağ area (sample CD-19) is of early Late Silurian age and of wide geographical distribution over three paleocontinents - Avalonia, Baltica and Gondwana. Several species, such as *C. octoplana*, *C. brevispinosum*, *C. williereae*, *O. ramusculosa* and *V. trispinosum* were reported from England, Ireland, Belgium, France, Sweden, Norway, Ukraine, Austria, USA, Canada, Argentina, Spain, Libya and Saudi Arabia (Le Herisse, 1989; Mullins, 2001). The acritarch association from the Shale-Siltstone Member contains some indicative species suggesting early Ludlovian age. The ranges of these species, as well as the scarcity of specimens do not allow a more fine and precise age determination.

Along with the marine microphytoplankton (acritarchs and prasinophytes), there is a relatively common record of land plant microfossils such as trilete spores and cryptospores and tubular structures. Despite the identified tubular structure species are too longer-ranging forms to be of biostratigraphic use, the occurrence of allochthonous land plant elements clearly indicates that a more or less constant fluvial terrestrial sediment input existed in the Çamdağ area during mid-Silurian time.

#### CORRELATION WITH OTHER SILURIAN ROCK-UNITS IN NEIGHBORING TERRANES (NW TURKEY, TAURIDES AND THE BALKAN MOUNTAIN)

The detailed stratigraphy of the middle Silurian rocks in NW Anatolia is only known in the İstanbul (Yalçınlar, 1956; Haas, 1968; Kaya, 1988) and Safranbolu (Dean et al., 1997; 2000) areas (see Figure 1). To the east of İstanbul (Gebze area, see Figure 1) the early Late Ludlovian succession is mainly characterized by the "Akviran Serie" of Haas (1968) which corresponds to the "Halysites-Limestone" of Peackelmann (1938). The "Tavşan Tepe Schichten" in the lowermost part of the Akviran conformably overlies the variegated clastics of the Upper Ordovician and is composed of greenish marls that grade into "flaser-limestones" by increasing lime contents. The brachiopods and conodonts

(Walliser, 1964) from this succession indicate a Wenlockian age. The following “Baglarbasi Schichten” mainly includes sandy limestones with *Pentamerides* of Wenlockian. Upward follows reddish crinoidal limestones with corals of Wenlockian-Late Ludlovian age. The conformably overlying “Cakillidere Schichten” of the “Akviran Serie” is made up of gray, irregularly bedded, fine-grained limestones with conodonts and has been ascribed to the *siluricus*-Biozone (Ludlovian) of Walliser (1964). They are followed by stromatopora and tabulata-rich, irregularly bedded limestones (“Untere Pelitli Schichten” belonging to the *latialatus* and *crispus* zones of Ludlovian) that grade into nodular limestones (Obere Pelitli Schichten of *crispa* and *eosteinhornensis* biozones of Walliser (1964) and hence the Ludlovian-Pridoli boundary according to the recent stratigraphic nomenclature). There is an overall agreement between the previous researchers (Haas, 1968; Kaya, 1973, 1988; and Önal, 1982) that the Wenlockian-Ludlovian part of the succession in İstanbul area is represented by reef-type carbonate deposition. Starting with the deposition of flaser and nodular limestones of Early Pridoli age a transition to basin-type deposition is suggested.

The Paleozoic succession in the Karadere-Zirze area (Safranbolu, Figure 1) in the Zonguldak terrane was studied by Arpat et al. (1978) and Dean et al. (1997, 2000). In this area, the Fındıklı formation in its lower part includes black siliceous shales with graptolites of middle Llandovery (Aeronian) age and acritarchs (*Dixellophasia remota* (Deunff), *Tylotopalla* sp. and *Veryhachium europaeum* Stockmans and Willié). Following a lack of exposures of about 80 m, gray, schistose mudstones monograptid graptolite-bearing shales with *Monograptus flemingii* (Salter) and *Pristiograptus* cf. *parvus* (Ulst) were reported. This part of the succession did not yield acritarchs but the graptolites are indicative for the upper part of the Wenlock series. The black shales are unconformably overlain by Devonian conglomerates and carbonates, so that the “Orthoceras Limestones” found in the Çamdağ were not encountered in this succession.

Compared with the İstanbul and Safranbolu areas, there are still fragmentary data on the Silurian rock-units in the Çamdağ area. However, the new data (Göncüoğlu et al, 2003) indicate that

almost the entire Silurian may be represented in different tectonic slices of the Fındıklı Formation. The depositional environment of the Silurian rocks in Çamdağ differs from the İstanbul area, where reef-type carbonate deposition dominates.

In the Taurides in southern Turkey, Silurian rocks rest with a parallel unconformity on the late Ordovician glacier-related sediments (Göncüoğlu and Kozlu, 2000; Ghienne et al., 2001). The overlying Puşcu Tepe Shale formation is composed of thinly bedded, laminated black to light-gray fissile shales. The lower part is siliceous with fine bands of shales, whereas the upper part is carbonaceous with bands of black lydites. In its lower part it includes thin layers of gray “Orthoceras Limestones” that yielded conodonts of middle Llandovery to latest Llandovery - earliest Wenlock age (Göncüoğlu et al. 2004). In the Central Taurides, in Konya area, dark colored siltstones and shales alternating with tuffaceous layers and distal turbiditic black cherts (ribbon cherts) within the low-grade metamorphic Turbidite Unit (Göncüoğlu et al., 2000) yielded *Muellerispherida* of Wenlock age (Kozur, 1999). The middle and upper parts of the Silurian in the Taurides is represented by the Yukarı Yayla and Karataş formations (Demirtaşlı, 1984; Dean and Monod, 1990). It is transitional to the underlying Puşcu Tepe Shale formation and consists of alternations of black shale and dark gray limestone. The limestone at the bottom is medium-bedded, brown to dark-gray, wavy bedded, coarsely nodular and rich in nautiloids. The middle part of the formation is characterized by black, thin-bedded shales with concretions containing brachiopods and trilobites. The upper member consists of an alternation of black shales and dark-gray limestones and is conformably overlain by Devonian shelf-type limestones.

Late Early Silurian acritarchs were reported yet only from south-eastern Turkey (Dadaş Formation around Diyarbakır) by Erkmen and Bozdağ (1979) and Steemans et al. (1996). The assemblage from Dadas Formation is younger and differs in species from that of Çamdağ area in north-western Turkey. In Bulgaria, sedimentary rocks of Wenlock to Pridoli age occur in two areas - in the Moesian Terrane (Moesian Plane, north Bulgaria) and in the western part of Bal-



kan Terrane (the core of Svoge anticline to the north of Sofia). In the Moesian Terrane, only two boreholes penetrated Wenlock and Ludlow deposits, both in the NE Bulgaria (Yanev, 1992, 1998). In R-2 Vetrino well, the Llandovery to Pridoli is represented by ca. 1200 m thick sequence - between depths of 1500-2700 m, of mainly black and gray shales, calcareous shales and some marls and limestones (Spasov and Yanev, 1966), Llandovery age being proved on conodonts. In OP-2 Michalich well, the Llandovery to Pridoli represents a more than 500 m thick series - between depths of 3200-3761 m, of monotonous black shales and siltstones (Lakova and Yanev, 1989; Lakova, 1992). The Wenlock and Pridoli were dated on chitinozoans. In western part of the Moesian Terran, in R-1 Dalgodeltsi well, Pridoli series is represented by less than 80 m uniform black shales dated on chitinozoans (Lakova, 1985).

In the Balkan Terrane, the Wenlock and Ludlow Series are represented by the black graptolitic shales of the Mala Reka Formation (90 m thick) and the laminated siltstones of Yabukov Dol Formation (ca. 230 m thick), the stratigraphic age being based on rich graptolitic faunas (Sachanski and Tenchov, 1993; Sachanski, 1998).

When compared to the Çamdağ succession, the Silurian in the Balkan Terrane is similar in certain extent, as it consists of black shales of Wenlockian and Gorstian age covered by laminated slates of Ludfordian and Pridoli age, with only single limestone lenses with *Scyphocrinites* and bivalves. On the contrary, the Silurian succession of the Moesian Terrane is rather different, as it is represented mainly by black shales and black to gray siltstones of much greater thickness and without graptolites.

## CONCLUSIONS

A early Late Ludlovian microphytoplankton discovered in the middle part (Shale-Siltstone Member) of the Fındıklı formation in Çamdağ (Adapazarı, NW Anatolia) contains some organic-walled microfossil groups: opaque trilete spores, single cryptospores - spore dyads and tetrads, chitinozoans, scolecodonts, ?mazuelloids, as well as determinable acanthomorphic acritarchs and prasinophyte algae (*Ammonidium ludloviense*, *Cymatiosphaera* sp. cf. *C. oc-*

*toplana*, *Comasphaeridium brevispinosum*, *C. williereae*, *Eisenackidium wenlokense*, *Gorgonisphaeridium listeri listeri*, *Gorgonisphaeridium succinum*, *Lophosphaeridium* sp. indet., *Oppilatala ramusculosa*, *Verychachium trispinosum*) and tabular structures (*Constrictitubulus cristatus*, *Porcatitubulus annulatus*, *Porcatitubulus strupus* and *Ornatifilum granulatum*). This association contains some indicative species suggesting early Late Ludlovian age and is so far the first palynomorph data from NW Anatolia.

The lithologies and the organic-walled microfossils of the Shale-Siltstone Member suggest that it was deposited in an anoxic shallow-marine environment with clastic sediments supply from a fluvial source, rich in white mica. The rock units of the same age in İstanbul and Tauride basins are significantly different and suggest a relatively deeper depositional environment. Consequently the Çamdağ area was probably located nearshore at this period. In the Zonguldak basin, there is a stratigraphic gap between the graptolite-bearing upper Wenlock series and the unconformably overlying Emsian shallow-marine carbonates, being the characteristic feature of the Zonguldak terrane. A far-distance correlation with the middle Silurian deposits in Bulgaria suggests that the studied succession in the Çamdağ area is similar to the Balkan Terrane rather than the Moesian one.

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## PLATE 1/ LEVHA 1

Diverse palynomorphs from the mid-Silurian of Çamdağ Section. (All figures from sample CD-19, x700, except stated otherwise).

Çamdağ kesidindeki Orta Siluriyen kayalarındaki palinomorflar. (Tüm görüntüler CD-19 nolu örnektendir. Başka şekilde belirtilmemişse büyütme x700 dür).

1. Trilete spore (*trilet spor*).
2. *Oppilatala ramusculosa* (Deflandre, 1945) DornIng, 1981
3. *Cymatiosphaera* sp. cf. *C. octoplana* Downle, 1959
4. *Comasphaeridium brevispinosum* (Llster, 1970) MullIns, 2001
5. Spore dyade.
6. Spinate spore tetrade.
7. Fragment of *Porcatitubulus annulatus* Burgess and Edwards, 1991
8. *Gorgonisphaeridium listeri listeri* MullIns, 2001
9. ? Land plant fragment (*Karasal bitki parçası*), x440.
10. Trilete spore (*trilet spor*).
11. *Ammonidium ludloviense* Llster, 1970 ex DornIng, 1981.
12. *Gorgonisphaeridium succinum* Llster, 1970
13. *Laevitubulus crassus* Burgess and Edwards, 1991, CD-22, x700.
14. *Calpichitina* sp. indet.
15. *Constrictitubulus cristatus* Burgess and Edwards, 1991.
16. Scolecodont.
- 17, 18. Indeterminable trilete spores (*tanımlanamayan trilet spor*).
19. ?Mazuelloid.

**PLATE 1/LEVHA 1**

