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Wenlock (Silurian) graptolitic shales from the Kocaeli Peninsula (Derince–Izmit), NW Turkey

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ABSTRACT:

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Alternating dark grey to black thin-bedded limestones and yellowish-grey calcareous shales in a recently discovered section in Izmit (Derince), eastern Kocaeli Peninsula, yielded graptolites of the middle part of the Wenlock – *Cyrtograptus lundgreni* Zone and possibly Upper *Cy. rigidus-Cy. perneri* Zone. This is the first record of graptolitic shale facies rocks in the Kocaeli Peninsula. The succession described is more akin to the Silurian of the Zonguldak Terrane than the shallow-marine carbonate facies of the Istanbul Terrane. It is therefore suggested that the contact between the Istanbul and Zonguldak terranes should be located to the west of Izmit (Derince).

Key words: Wenlock, Graptolites, Dark shale, Izmit, Zonguldak Terrane, NW Turkey.

INTRODUCTION

The Palaeozoic successions to the east and west of the Bosporus are parts of the classic "Palaeozoic of Istanbul" (e.g. GÖRÜR & *al*. 1997). They are considered as parts of the Istanbul Terrane, a Peri-Gondwanan microplate that accreted to the Variscan Belt by the closure of the Rheic Ocean (GÖNCÜOGLU 1997, 2001; GÖNCÜOGLU & *al.* 1997; YANEV & *al*. 2006). The Silurian rocks in this terrane crop out mainly on the eastern (Anatolian) part of the Bosporus (BAYKAL & KAYA 1965).

Detailed studies of the Silurian succession in this area were undertaken mainly by HAAS (1968). PAECKELMANN (1938) and SAYAR (1964), and ABDÜSSELAMOGLU (1963) contributed to the biostratigraphy. As a whole, the Silurian in this area commences with early Llandovery siltstones and grades into shallow marine (lagoon-type) limestones of late Llandovery–Ludlow age (e.g. Gebze section, Text-fig. 1). The upper part of the succession is characterized by shelf carbonates (GEDIK & *al*. 2005, GÖNCÜOGLU & *al*. 2006).

Towards the east, Silurian rocks were found in the Camdag area (Text-fig. 1), where KOZLU & *al*. (2002), GÖNCÜOGLU & SACHANSKI (2003), and GÖNCÜOGLU & *al*. (2003) have reported an almost complete Silurian succession, dominated by shales, siltstones and graptolitic black shales (Text-fig. 1, Camdag section). The Silurian rocks of the Camdag area were ascribed to another Palaeozoic terrane, namely the Zonguldak Terrane of GÖNCÜOGLU & KOZUR (1998), and the arbitrary boundary between the Istanbul and Zonguldak terranes was drawn just west of Camdag (GÖNCÜOGLU & *al*. 2003).

During a recent field-excursion to the Derince (Izmit) area (Text-fig. 1) the authors, together with members of

the Turkish–Bulgarian Project Group, have discovered a succession of alternating dark grey to black thin-bedded limestones and yellowish calcareous shales with graptolites and tentaculites. This is the first record of graptolitic Silurian rocks east of the Palaeozoic of Istanbul in the Kocaeli Peninsula. It is also the first record of the Wenlock in north-west Anatolia. In this study, the authors will report their fossil finds and correlate the new discovery of middle Wenlock graptolitic shales with coeval lithologies in north-west Anatolia.

GEOLOGICAL SETTING

The Palaeozoic rocks in the Derince area are intensively faulted, so that no continuous sections are ob-

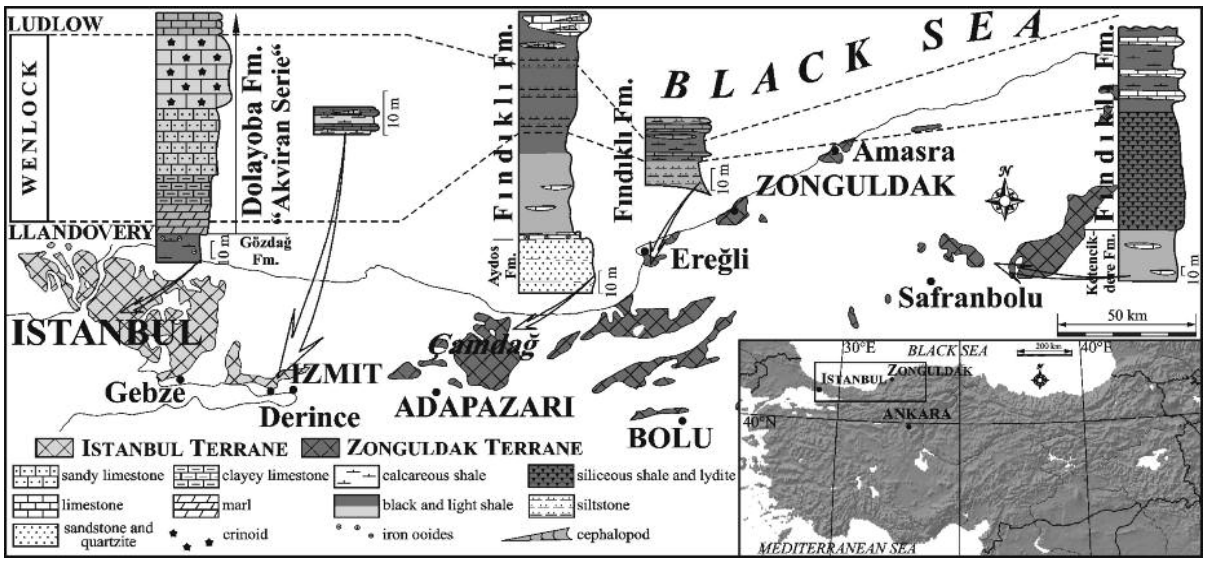

Fig. 1. Location map of the studied section in north-west Anatolia with the Ordovician–Carboniferous outcrops (modified from GONCUOGLU & *al.* 1997; GONCUOGLU 1997) and Middle Wenlock sequences

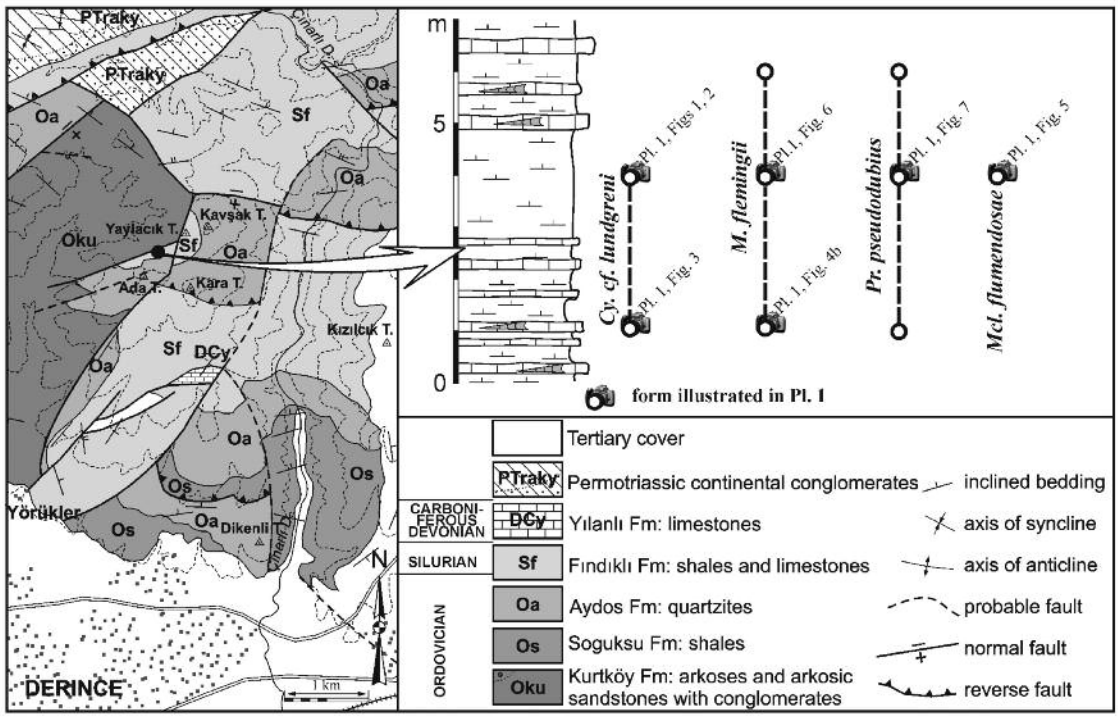

Fig. 2. Geological map (revised after *Gedik* & *al.* 2005) and columnar section of the studied succession and Wenlock Global Zonation (after MELCHIN & *al.* 1998) with the new age data from north-west Turkey. Key to symbols as in Text-fig. 1

served (ALTINLI 1968). The oldest Palaeozoic units in this area are represented by variegated arkoses and arkosic sandstones of the Kurtköy Formation, and the violet to greenish-grey shales and mudstones of the Soguksu Formation. These two formations are always in tectonic contact with each other and both were attributed to the Ordovician (GEDIK & *al*. 2005). Both formations are overlain conformably by white to beige quartzites and quartz-arenites of the Aydos Formation. The latter is overlain by a succession of sandstones, shales and siltstones with rare carbonates, referred to the Late Ordovician–Early Silurian Gozdag Formation (GEDIK & *al*. 2005), which crops out in the Istanbul area. Devonian rocks occur as fault-bounded, thin and discontinuous patches in the study area (Text-fig. 2).

The present study is based on a series of exposures along a newly constructed road from Derince to Mollafenari, about 10 km north of Derince. The exposed succession includes, in addition to greyish-green siltstones, a 7 m thick interval of graptolitic shales with cephalopod-bearing limestones. This lithological assemblage does not resemble the Gozdag Formation in the Istanbul area but is typical of the Findikli Formation known from the Camdag area. Accordingly, the geological map of the area is revised (see Text-fig. 2), and the fossiliferous succession was studied and sampled in detail.

The northern boundary of the studied succession is in a reverse fault-contact against the arkoses of the Kurtköy Formation. The fossiliferous succession represents the uppermost part of the Findikli Formation and is made up of alternating dark grey to black thin-bedded (5-10 cm) limestones and yellowish calcareous shales (Text-fig. 2, columnar section and Text-fig. 3). The limestones yielded cephalopods, tentaculites and brachiopods. The succession is underlain by yellowish shales and siltstones of the Findikli Formation and quartz-arenites of the Aydos Formation. The latter overthrusts another tectonic sliver of the Findikli Formation (Text-fig. 2), composed similarly of dark shales alternating with black limestones.

FOSSIL RECORD AND AGE

The studied limestones of the Findikli Formation yielded three-dimensionally preserved graptolite rhabdosomes and cephalopods; in the shales the graptolites are flattened or in low relief. The graptolites are represented by common *Monograptus flemingii* (Text-fig. 4.4b and 4.6) and *Pristiograptus pseudodubius* (Text-fig. 4.7), as well as rare *Monoclimacis flumendosae* (Text-fig. 4.5) and *Cyrtograptus*.

P. pseudodubius is usually represented by ventrally curved proximal fragments (about 1 cm). Their dorso-ventral width (DVW) is 1.0-1.3 mm; density of thecae – 10 Th/10 mm; thecal angle – 25-30° [these parameters are very close to the type material of PŘIBYL (1943): DVW – 1 (1.2) mm; 11-10 Th/10 mm; thecal angle – 30°]. *P. meneghini* is similar in shape but has a larger DVW (1.5-1.7 mm) and smaller thecal density – 9-7 Th/10 mm (PŘIBYL 1943).

The fragments defined as *Cy*. cf. *lundgreni* (Text-fig. 4.1-4.3) are from the gently dorsally curved procladium. No cladia are preserved. The proximal thecae are axially elongate with short metathecal hooks. The mesial thecae are triangulate. This feature is typical of *Cy*. *lundgreni* and *Cy. ellesae* (WILLIAMS & ZALASIEWICZ 2004). Broad curvature of the procladium through about 360° (Text-fig. 4.1 and 4.2) is found rarely in *Cy*. *lundgreni* only (LENZ 1978). Rapid torsion of the procladium axis through 180° is typical of *Cy. ellesae* (WILLIAMS & ZALASIEWICZ 2004), but is also observed in *Cy*. *lundgreni* (LENZ 1978, ŠTORCH 1994). Consequently, our fragments are closer to *Cy*. *lundgreni* rather than to *Cy. ellesae*. Undoubtedly better material of *Cyrtograptus* is needed to demonstrate

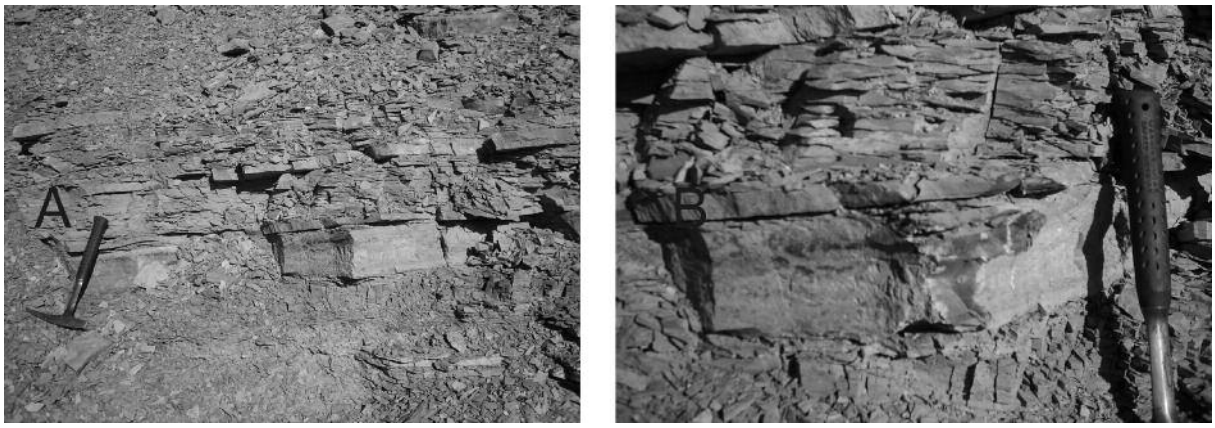

Fig. 3. Field-view of Middle Wenlock dark shales and cephalopod-bearing limestones in Derince area

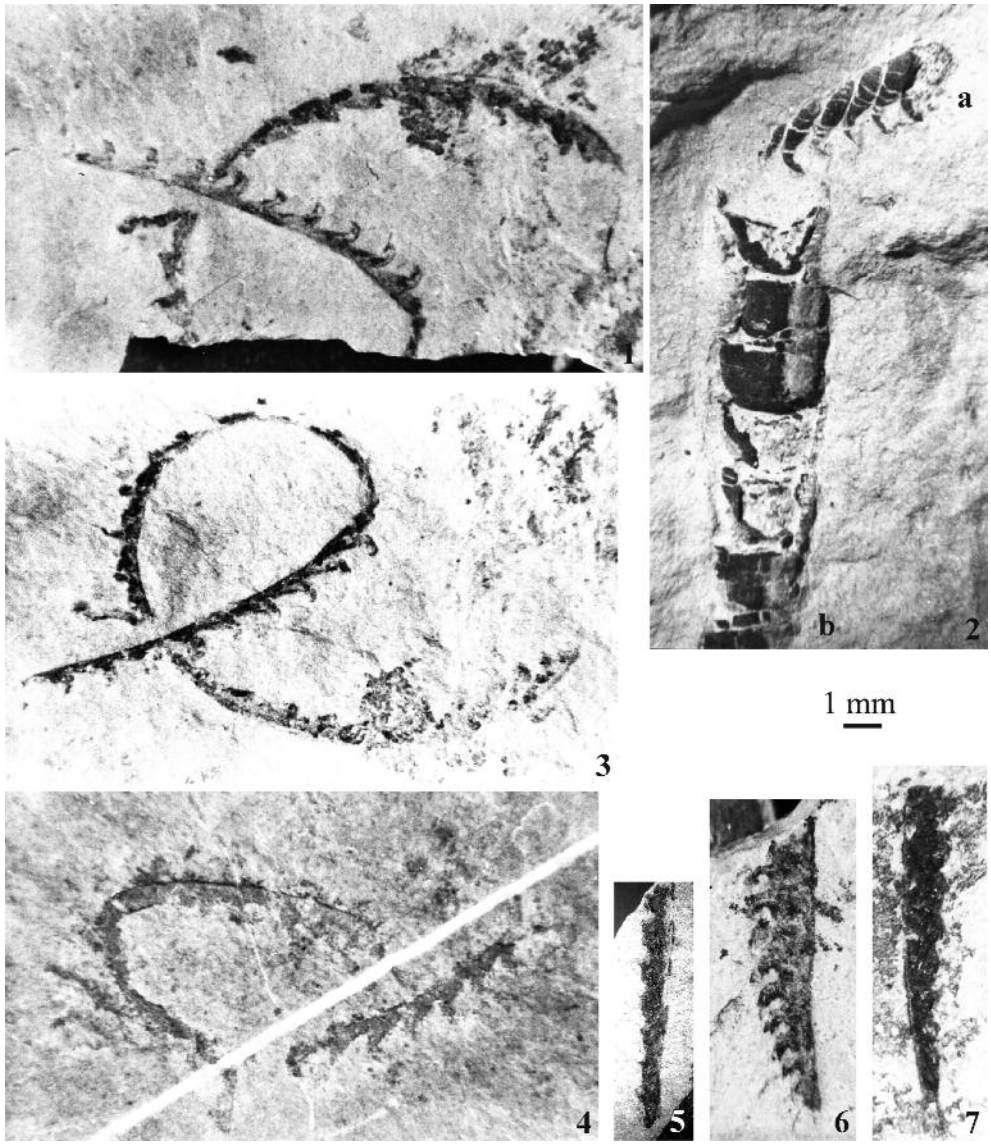

Fig. 4. Graptolites from Derince–Izmit area, NW Turkey. **1-3** – *Cy*. cf. *lundgreni* specimens Der 1-3; **4** – (a) cephalopod and (b) *Monograptus flemingii* (SALTER) specimen Der 11; **5** – *Monoclimacis flumendosae* (GORTANI) specimen Der 12; **6** – *Monograptus flemingii* (SALTER) specimen Der 9; **7** – *Pristiograptus pseudodubius* (BOUČEK) specimen Der 2. The specimens are housed in the Geological Institute, Bulgarian Academy of Sciences

the specific affiliation of the cyrtograptoids from this section.

In the generalized zonation of KOREN & *al* (1996) (see also MELCHIN & *al*. 1998), applied herein, *Cy. lundgreni* characterises its eponymous zone. *Cy. ellesae* is known from the Upper *Cy. rigidus–Cy. perneri* Zone and the *Cy. lundgreni* Zone (WILLIAMS & ZALASIEWICZ 2004). *Mcl. flumendosae* and *M. flemingii* have a similar range: uppermost *M. riccartonensis–M. belophorus* Zone, *Cy. rigidus–Cy. perneri* Zone and *Cy. lundgreni* Zone (ŠTORCH 1994; ZALASIEWICZ & WILLIAMS 1999). According to PŘIBYL (1943) and ŠTORCH (1994), *P. pseudodubius* occurs in the *Cy. rigidus–Cy. perneri* Zone and the *Cy. lundgreni* Zone. RICKARDS & WRIGHT (2003) reported it from the *Cy. lundgreni* and *G. nassa* zones. Summing up, the graptolite assemblage yielded suggests the *Cy. lundgreni* Zone of the middle Wenlock, with a possible downward extension to the Upper *Cy. rigidus–Cy. perneri* Zone (Text-fig. 5).

CORRELATION

In the Istanbul Terrain, on both parts of the Bosporus, the Middle Silurian is characterized by carbonates, named the "Halysites Kalk" by PAECKELMANN

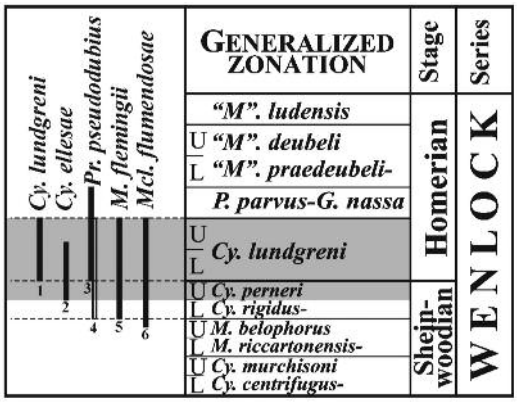

Fig. 5. Graptolite range chart after: ŠTORCH (1994) – 1, 4, 5 and 6; WILLIAMS & ZALASIEWICZ (2004) – 2; RICKARDS & WRIGHT (2003) – 3

(1938). HAAS (1968) subdivided these limestones (Akviran Serie of HAAS 1968) into three formations and dated them as Wenlock and Early Ludlow (part), based on conodonts. The limestones are thick-bedded and include sandy intervals. They are characterized by accumulations of brachiopods and crinoids (detritus).

To the east of Izmit, the Wenlock Series occurs within the Findikli Formation in the Camdag area. It is represented mainly by black shales with light grey quartz-rich siltstone interlayers (Shale-Siltstone Member of the Findikli Formation) and contains palynomorphs of the late Middle Silurian (GÖNCÜOGLU & *al*. 2003; LAKOVA & GÖNCÜOGLU 2006). The upper part of the formation contains dark-grey limestones alternating with shales. As these limestones are rich in cephalopods, they are named the "*Orthoceras* Limestones" (e.g. GEDIK & ÖNALAN 2001). Conodonts found by KOZLU & *al*. (2002) evidence their Late Silurian (Pridoli) age.

Further to the east, the middle Wenlock has been recently discovered in the Gülüc section, to the south of Eregli (SACHANSKI & *al*. *in press*). In this locality, the succession forms a part of the Findikli Formation and consists of three units: (a) greenish-grey calcareous siltstones; (b) alternation of black shales and clayey limestones; and (c) siltstones and sandy limestones (Text-fig. 1). Integrated graptolite, conodont and cryptospore biostratigraphy indicates that the second unit is of late Wenlock–early Ludlow age (Homerian and Gorstian). The Gülüc section is interpreted as a condensed succession with an hiatus in the Sheinwoodian.

Still further to the east, the middle Wenlock, represented by black graptolitic shales with limestone interbeds, crops out in the Safranbolu area (Text-fig. 1). DEAN & *al*. (1997) described from there a detailed succession of the Findikli Formation, comprising a 'Lower Member' and an 'Upper Member'. The Lower Member, 135 m thick, consists of lydites and black argillites, rich in Llandovery graptolites. The Upper Member, composed of 94 m thick grey mudstones, is of Wenlock age. The Gülüc Section differs thus significantly from the stratigraphically coeval successions in the Camdag and Karadere areas of the Zonguldak Terrane.

This data suggest that the late Middle Silurian was represented by deep water graptolitic facies in the Zonguldak Terrane, whereas by shallow marine coral limestones in the Istanbul Terrane. The depositional features of the Zonguldak Terrane correlate well with those at the top of the *lundgreni* Biozone in the Gondwanan part of Europe (e.g. Thuringia, JAEGER 1991 and the Sudetes, POREBSKA 1998), where a strong enrichment of organic matter in black graptolitic shales is observed. In Morocco, however, some black or rusty ferruginous limestones appear in coeval shaly sequences (DESTOMBES & *al*. 1985).

CONCLUSIONS

Graptolitic deep-water facies with *Monograptus flemingii*, *Pristiograptus pseudodubius* and fragments of *Monoclimacis flumendosa* and *Cyrtograptus* cf. *lundgreni* were discovered recently in the Izmit–Derince area, east of the classic "Palaeozoic of Istanbul". The examined section is attributed to the *Cy. lundgreni* Zone of the middle Wenlock, but may possibly extend down to include the Upper *Cy. rigidus–Cy. perneri* Zone.

This new section differs in facies development from the shallow-water limestone-dominated coeval sections of Istanbul area and resembles the Wenlock series in the Camdag, Gülüc and Safranbolu–Karadere sections of the Zonguldak Terrane. Consequently, it is suggested herein that the boundary between the Zonguldak and Istanbul terranes should be located west of the Izmit-Derince area and not west of Camdag, as previously suggested by GÖNCÜOGLU & *al*. (2003).

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