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Early Cambrian trace fossils at the northern margin of the Arabian Plate; Telbesmi Formation, Turkey

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ABSTRACT:

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The Telbesmi Formation, at the northern margin of the Arabian Plate, Turkey, is composed of alternating dark-brown, pinky-brown fluvial arkosic sandstone/mudstones with thin-bedded cherty limestones and channel conglomerates. The formation contains rare and poorly diversified trace fossils. The siltstone/sandstone beds of levels 1 and 2 of the formation yielded, however, a moderately diverse assemblage composed of: *Cochlichnus* isp., *Palaeophycus* isp., *Planolites beverleyensis*, *Teichichnus* isp. and ?*Treptichnus rectangularis*. This assemblage, made up of traces left by deposit feeding organisms, represents the *Scoyenia* ichnofacies. *Treptichnus rectangularis* and *Palaeophycus* isp., of the assemblage, can be considered markers for the base of the Cambrian in southeast Turkey.

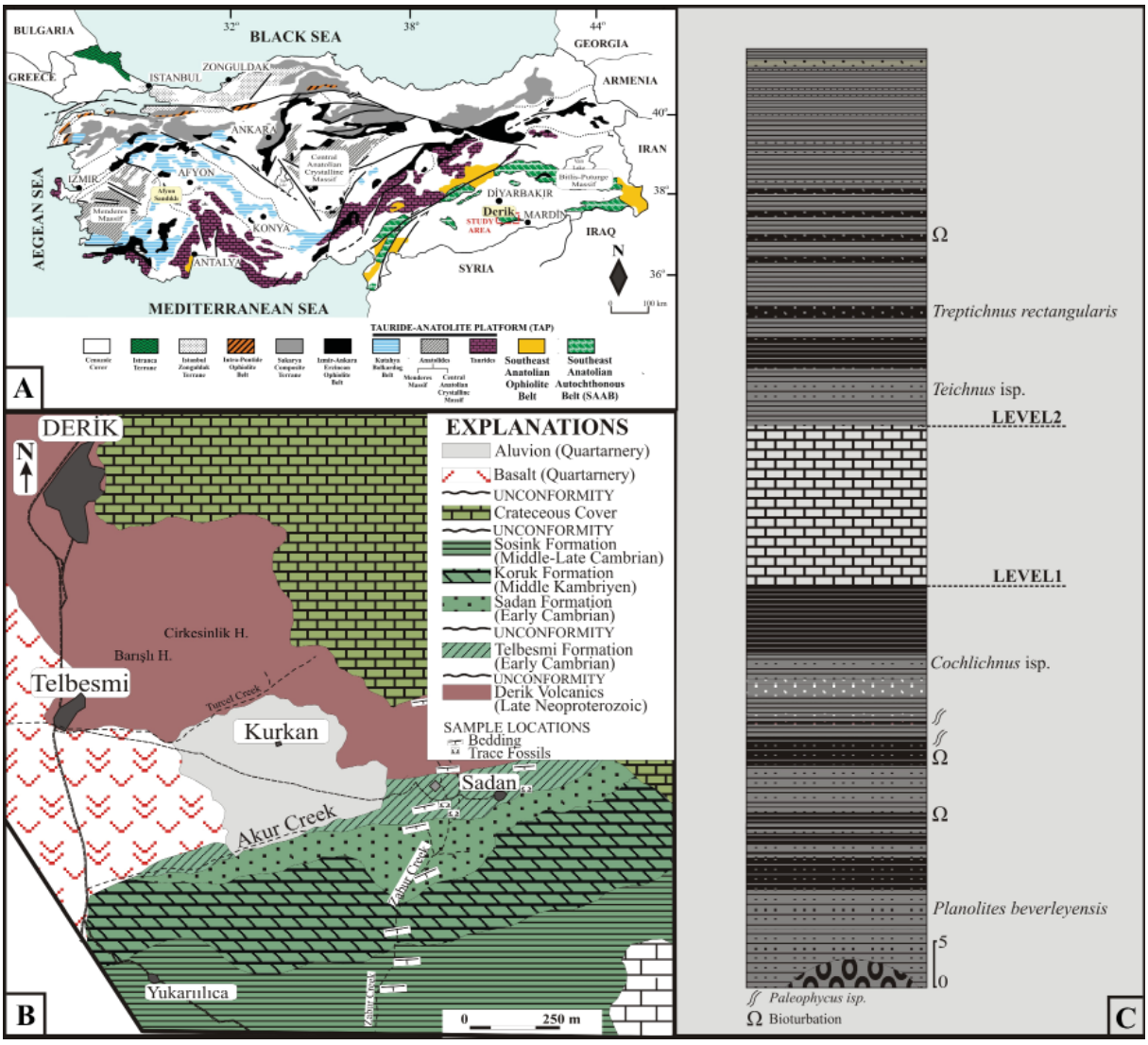
Key words: Ichnnofossils; Telbesmi Formation; Early Cambrian; Derik (SE Turkey).

INTRODUCTION

The diversity and complexity of trace fossils across the Edicaran–Cambrian boundary was described and discussed first by Seilacher (1956). He concluded that trace fossils were rare across the Late Neoproterozoic/Cambrian boundary because the activity of soft bodied benthic life at the earliest Cambrian was limited (cf. subsequent study by Crimes and Harper 1970). Little is still known about trace fossil producers from the Edicaran–Cambrian boundary interval.

The Edicaran–Cambrian boundary, as demonstrated in the stratotypic Fortune Head section (Newfoundland) and elsewhere (e.g., Narbonne *et al*. 1987; Brasier *et al*. 1994; Landing 1994; Jensen 2003; Buatois *et al*. 2013; Peng *et al*. 2012), is defined by the first occurrence of *Phycodes pedum*, being the index taxon of the eponymous zone (Landing 1994). The index taxon is currently referred to *Treptichnus pedum* (Jensen and Grant 1993) or *Trichophycus pedum* (Geyer and Uchman 1995), and characterizes a shallow subtidal setting (Crimes 2001). The stratigraphic range of the *T. pedum* Zone in Gondwanaland, has been discussed recently (e.g., Elicki 2007; Wilson *et al*. 2012, and references therein).

In SE Turkey, the Edicaran–Cambrian boundary succession represents fluvial conditions, including alluvial-fan and lagoonal deposits (e.g., Ghienne *et al*. 2010), which resulted from the erosion, denudation and/or block faulting which produced the features of sediments deposited in extensional basins (Husseini 2000; Amireh *et al*. 2008). The equivalent Ediacaran–Cambrian boundary successions are known widely from the northern margin of Gondwanaland and from peri-Gondwanan terranes that crop out in Spain (Iberia Massif e.g. Fernandez-Suarez *et al*. 2000),



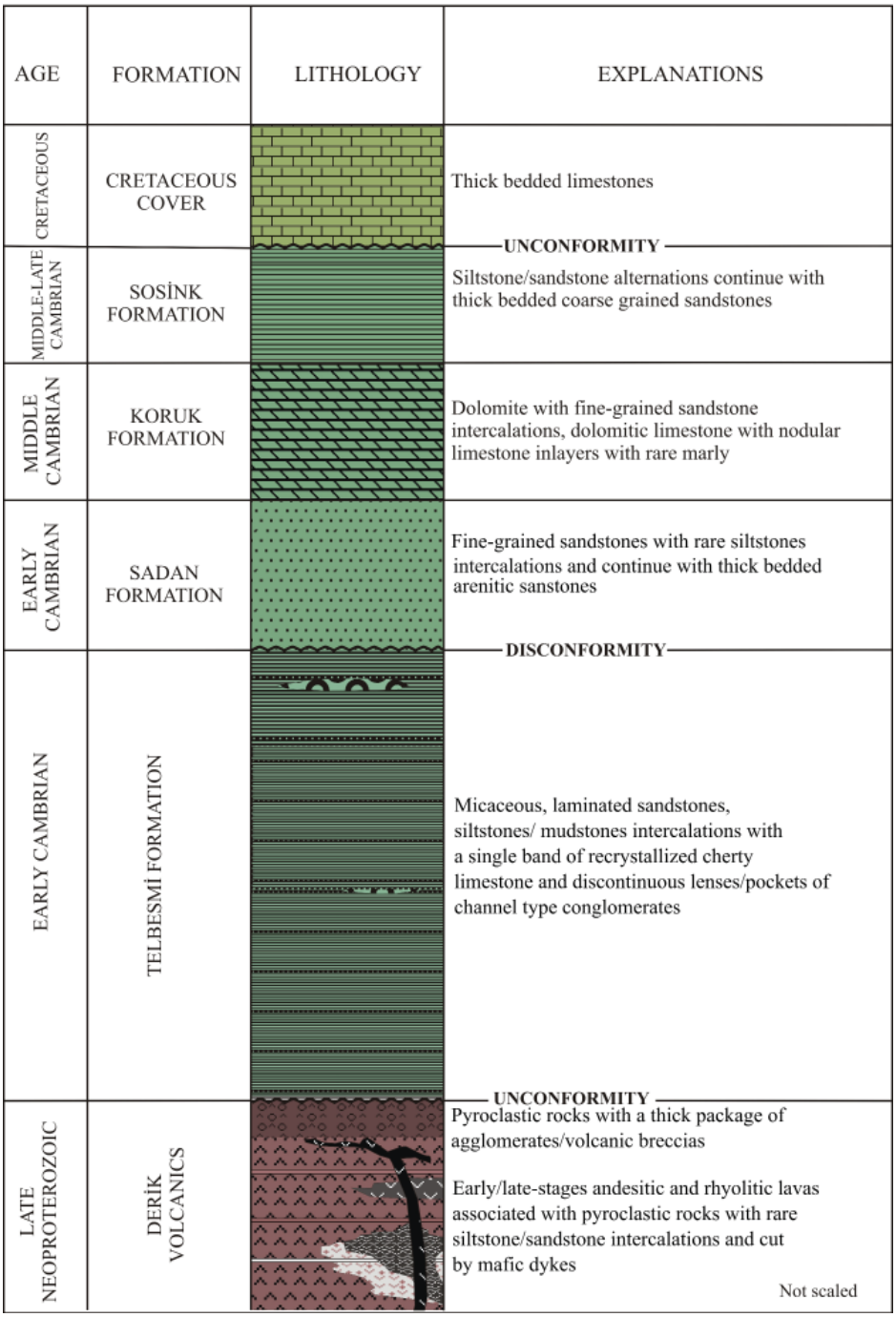
Text-fig. 1. A – Location of the study area (after Göncüoğlu 2010). B – Geological map of the Telbesmi Formation (modified after from Gürsu *et al.* 2015). C – Generalized section of the Telbesmi Formation (own observations)

France (west/east Avalonia and Cadomia, Murphy *et al.* 2004), Germany (Dörr *et al.* 2002), Czech Republic (Bohemian Massif; cf. Chlupáč *et al.* 1998), Algeria (e.g., Lottaroli et al. 2009), Morocco (Pouclet *et al.* 2007), Libya (Abdalselam *et al.* 2002), Egypt (El-Araby *et al.* 1999; Khalifa *et al.* 2006) in northern Turkey (Dean *et al.* 1981, 1986; Kozlu and Göncüoğlu 1997, Gürsu *et al.* 2004; Gürsu and Göncüoğlu 2005); Jordan (Amireh *et al.* 2008; Hofmann *et al.* 2012), Israel (Avigad *et al.* 2003), Saudi Arabia (Dabbagh and Rogers 1983), Iran (Nadimi 2007), and India (Desai *et al.* 2010; Parcha and Pandley 2011). They are also known from Mexico (Oaxaquia Yucatan), Honduras and Guatemala (Chortis Block) in Middle America (Ortega-Gutierrez *et al.* 1995). The Early Cambrian biochronology, based on ichnofossils, in the Central Taurides of the Tauride-Anatolite Platform have recently been reported by Erdoğan *et al.* (2004) and Gürsu and Göncüoğlu (2007).

The aim of this study is to describe and discuss the trace fossil assemblage from the early Cambrian Telbesmi Formation, exposed around Derik-Mardin, south Anatolia, Turkey (Text-fig. 1A, B).

GEOLOGICAL SETTING

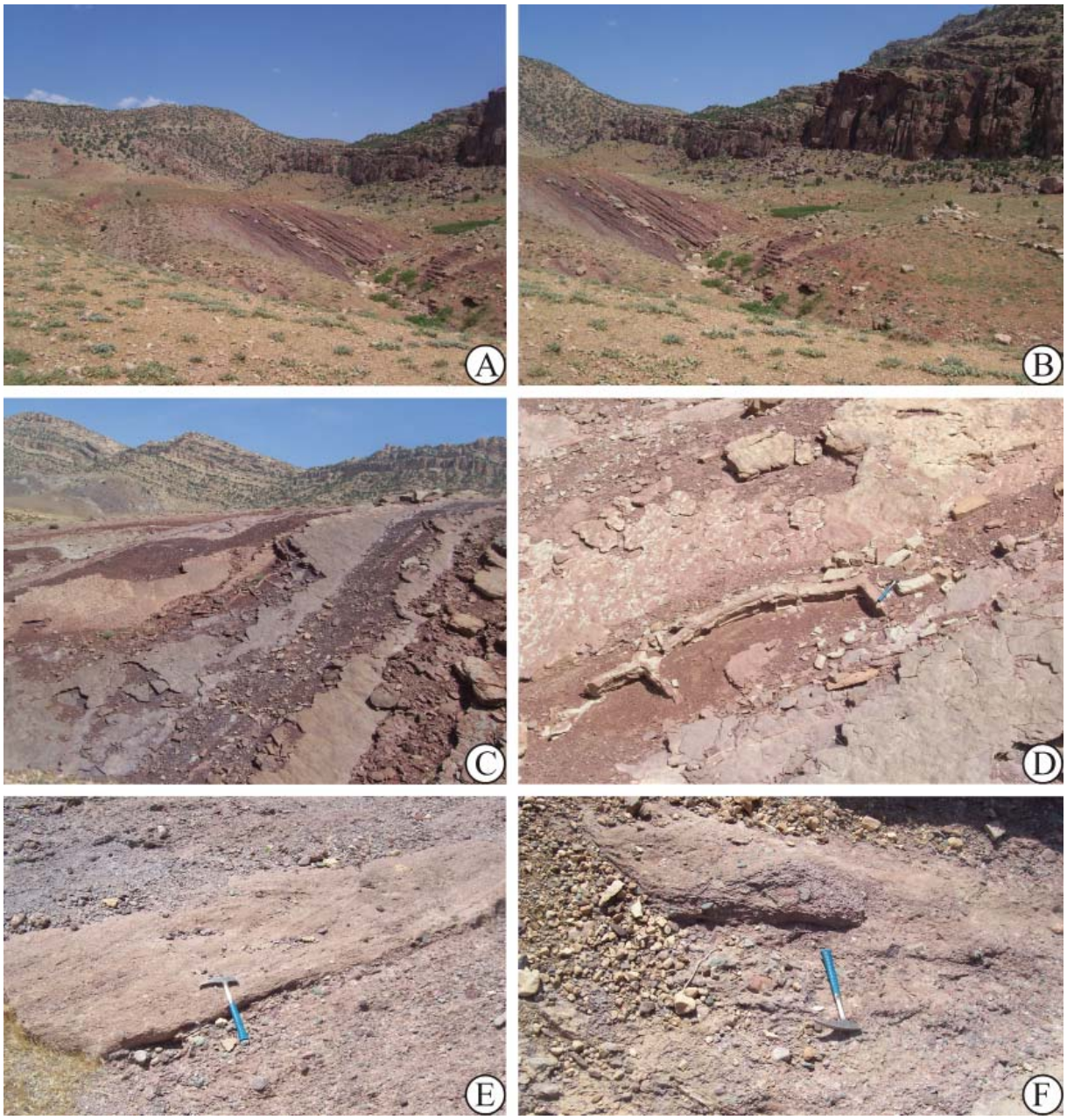
The Ediacaran–Cambrian succession of the Derik-Mardin area represents the Southeast Anatolian Autochthon Belt (Göncüoğlu *et al.* 1997) located



Text-fig. 2. Generalized columnar section of the Derik deposits in the study area (modified after from Gürsu *et al.* 2015)

at the northern margin of the Arabian Plate (Text-fig. 1A). The Early Palaeozoic succession of the area is composed of the Derik volcanics and, in stratigraphic order, of the Telbesmi, Sadan, Koruk and Sosink formations (e.g., Göncüoğlu and Kozlu 2000). The Palaeozoic succession is covered unconformably by Cretaceous sediments (Text-fig. 2).

The 350 m thick Telbesmi Formation is composed of alternating dark- and pinky-brown micaceous, laminated arkosic sandstones, siltstones and mudstones, interlayered with lenses/pockets of channel type conglomerates. A single band of cherty carbonate occurs in the upper part of the formation (Text-figs 3, 4, 5).



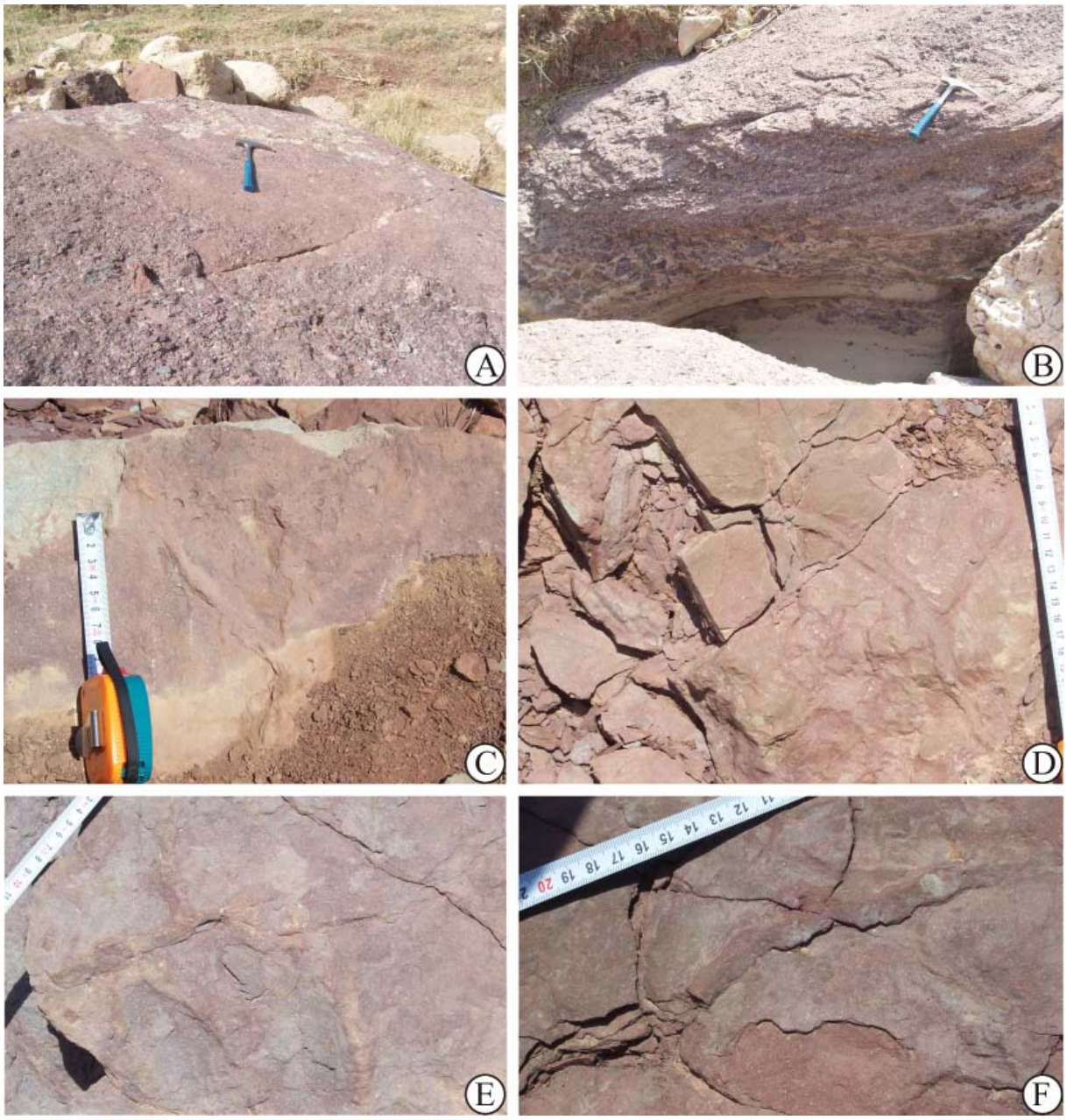
Text-fig. 3. Field occurrence of the facies of the Telbesmi Formation. A – Mudstone intercalated with very fine-grained sandstones and siltstones; B – Dry land facies dominated by reddish sandstone; C – Mudstones intercalated with fine-grained sandstones; D – Sandstones intercalated with mudstones, overlying mudstones; E – Cross-bedded lens of sandstones in mudstones; F – Channel-type sandstone

The Telbesmi Formation overlies unconformably the Derik volcanics, which consists of Late Neoproterozoic andesitic and rhyolitic lavas associated with pyroclastic rocks (Gürsu *et al*. 2015). The latter unit contains rare siltstone/sandstone intercalations and is cut by mafic dykes. Its upper part includes pyroclastic rocks and a thick package of agglomerates/volcanic breccias.

The transition to the overyling middle Cambrian Sadan Formation is transitional.

DESCRIPTION OF THE TRACE FOSSILS

The trace fossils from the Telbesmi Formation described herein come mostly from two horizons

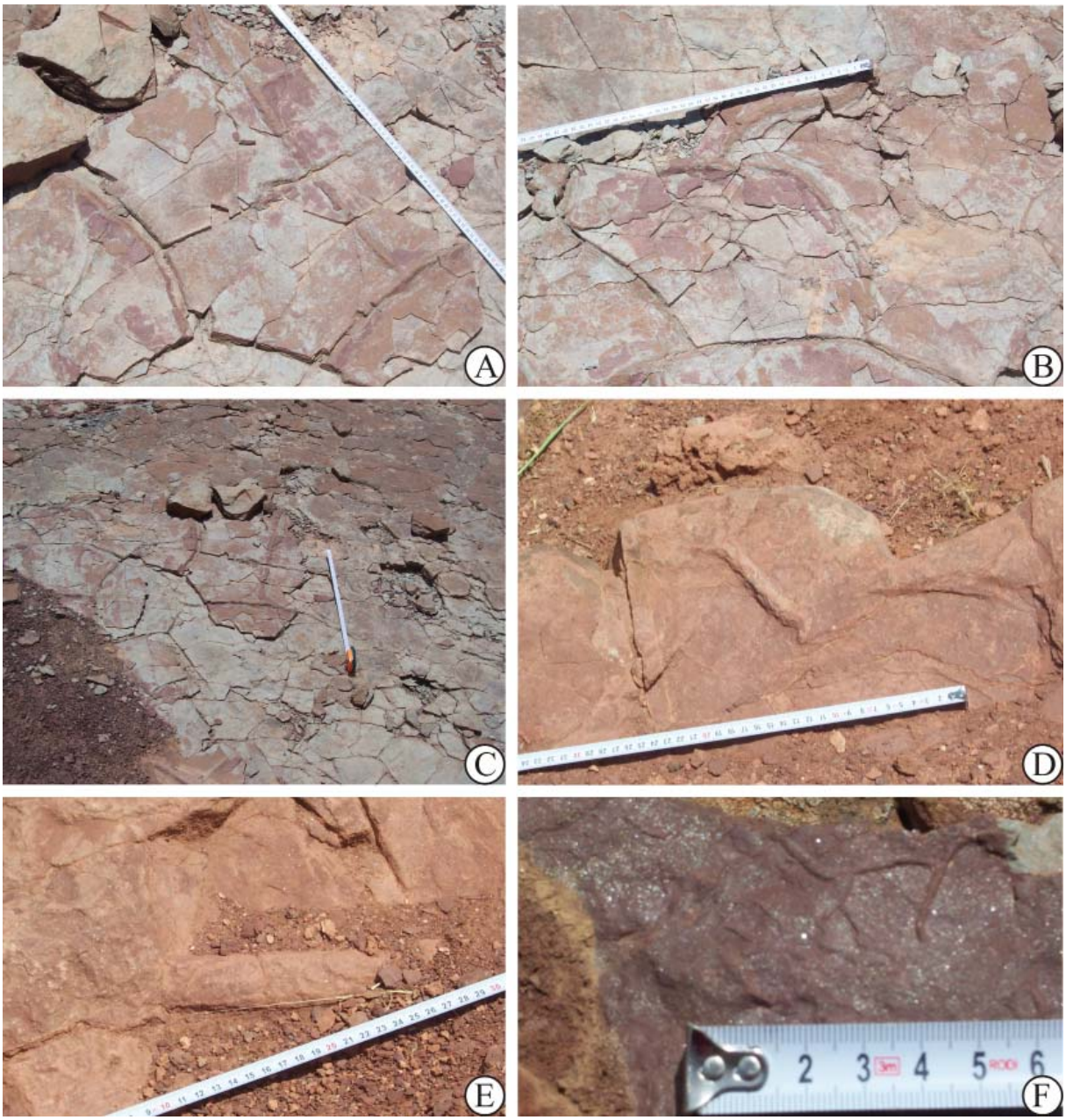


Text-fig. 4. Facies of the Telbesmi Formation and trace fossils; A-B – Channel-type sandstone; C-F – Some trace fossils from the studied area

in the upper part of the formation (UTM coordinates: 0617625, 4131925; 0616425, 4131720; 0616165, 4231875). The horizons are referred to here as Level 1 and Level 2, and are separated by an interval of cherty recrystallized limestones (Text-fig. 1C).

The material studied is housed in the repository of the General Directorate of Mineral Research and Exploration, Department of Geological Research in Ankara. Some of the studied specimens were documented *in situ* and were not collected.

***Cochlichnus* isp.** (Text-fig. 6A). This is an epichnial burrow showing a regularly sinuous trace. The trace is 1–2 mm wide and shows a uniform diameter all along its burrow. The amplitude of the meanders ranges from 12–15 mm. *Cochlichnus* is a facies-crossing trace fossil and occurs in a great variety of marine to nonmarine environments. It is produced by various invertebrates, including annelids and nematodes (Fillion and Pickerill 1990) and is considered to be a grazing and locomotion trace.



Text-fig. 5. Trace fossils of the Telbesmi Formation. A-C – Field view of the some horizontal burrows; D, E – *Planolites beverleyensis*; F – *Cochlichnus* isp.

The studied specimens come from the lower part of Level 1 of the Telbesmi Formation. It is known from the Early Cambrian of Central Australia (Glaessner 1969), Finnmark (Banks 1970), and New South Wales (Webby 1970), Spain (Crimes *et al*. 1977); it is also known from the Cenozoic (Häntzschel 1975).

***Palaeophycus* isp.** (Text-fig. 6B). This is an endichnial, straight to slightly sinious, unbranched, horizontal, lined burrow. In cross section it is circular to eleptical, 7–10 mm long and 5 mm wide. The burrow fill is identical to the host rock. *Palaeophycus* resembles *Planolites* (Osgood 1970; Pickerill and Forbes 1979). Pemberton and Frey (1982) concluded that *Planolites* is an unlined burrow filled with sediment having textural characters unlike that of the host rock, whereas *Palaeophycus* is a lined burrow filled with sediment typically identical to those of

Text-fig. 6. Trace fossils from Telbesmi Formation. A – *Cochlichnus* isp.; B – *Palaeophycus* isp.; C – *Planolites beverleyensis*; D-E – *Teichichnus* isp.; F – ?*Treptichnus rectangularis*

the surrounding matrix. *Palaeophycus* is considered to be a combined and dwelling burrow formed by worm-like animals. The studied specimens are from the middle part of Level 1 and lower part of Level 2 of the Telbesmi Formation. It ranges from the Ediacaran to Recent (Pemberton and Frey 1982).

***Planolites beverleyensis* (Billings, 1862)** (Text-fig. 6C). These traces occur on the bedding surfaces as convex epichnia, or as full relief exichnia and as endichnia. The burrows are cylindrical, straight or slightly bent, with a smooth surface. They are unlined and arranged parallel or slightly oblique to the bedding. The burrow fill is different from the host rock. *Planolites* is a facies-crossing ichnogenus, ranging from the Precambrian to Recent and is so simple in form that many different animal species were probably responsible for it (Crimes and Anderson 1985).

The studied specimens are from the middle part of the Telbesmi Formation. It has been identified in the Lower Cambrian of the Holy Cross Mountains (Orłowski 1989).

***Teichichnus* isp.** (Text-fig. 6D). *Teichichnus* is a wall-like, internally laminated trace produced by vertical migration of horizontal cylindrical burrows. The burrows show internal thin, hemicylindrical, concave-upward laminae which are horizontal or slightly inclined. The sides of these structures are parallel in some cases. Others are irregular or distorted. Structures of this type can be produced as a result of disturbance and redistribution of sediment by displacement of the burrow system, leaving a reworked filling. Some modern arthropods and other organisms backfill their burrows, leaving a cylindrical, plugged tube, (Kennedy and MacDougall 1969). Some burrows are also superficially similar to *Teichichnus*; they are, however, produced by taphonoic effects, i.e. the redistribution of sediment dislodged from the burrow roof (Shinn, 1968). *Teichichnus* isp. comes from lower part of Level 2 of Telbesmi Formation. The ichnogenus is widely known from the Cambrian (Chisholm 1970) to Cenozoic (Frey and Howard 1970).

?*Treptichnus rectangularis* Orłowski and Żylinska 1996 (Text-fig. 6E–F). These are horizontal burrows composed of short, more-or-less straight to slightly curved cylindrical units, oval in cross-section, with a variable angle of branching and, in some forms, with a tendency of right angled branching. Although particular segments of the burrow differ in shape, diameter and length, there is no apparent gradient in their size along the specimen. This is a common representative of the Cambrian ichnofauna. Some of the *T. rectangularis* burrows are similar to burrows identified as *Phycodes pedum* Seilacher (1955) in the early Cambrian of the Holy Cross Mountains (Orłowski 1989). The studied material comes from Level 1 of the Telbesmi Formation. The genus ranges from the early Cambrian (Paczesna, 1989) to the Eocene (Crimes *et al*. 1981).

DISCUSSION AND CONCLUSION

The Telbesmi formation is stratigraphically confined between the Derik Volcanics and the Sadan formation, and the newly determined ichnofossils are of Early Cambrian (Terreneuvian) age following the International Chronostratigraphic Chart of 2012 (Gradstein *et al*. 2012). This determined assemblage, made up of deposit feeding organisms, represents the *Scoyenia* ichnofacies. The depositional age of the upper parts of the formation is interpreted to be Early Cambrian (Terreneuvian, stage 2-Fortunean) rather than Infracambrian as previously suggested by Ketin (1966). Ghienne *et al*. (2010) evaluated the depositional environment of the formation as dry land with alluvial-fan and lagoon deposits. These sedimentary features of the formation clearly indicate that depositional features of the formation are indicative of a fluvial transition. The index zone fossil *Treptichnus pedum* is not present in the formation because of the latter's fluvial depositional character. Buatois *et al.* (2013) declare that the *Treptichnus pedum* ichnotaxon appears in low-energy offshore wave-dominated marine settings, also in the shallow water intertidal and shallow-subtidal zones of tide-dominated systems, whereas the studied rocks were deposited in fluvial environments.

The overlaying Sadan formation mainly consists of arkosic sandstone with rare siltstone/mudstone interlayers and is thought to have been laid down as transgressive, fluvial dominated clastics (meandering channels of fluvial to tidal origin; Ghienne *et al.* 2010). The succession is conformably followed by the Early –Middle Cambrian trilobite bearing Koruk Formation which corresponds to the Sadan Dolomite of Kellog (1960) and is the equivalent of the Koruk Limestone/Dolomite Formation of Schmidt (1966). The succession is composed of thickly bedded dolomite, followed by thinly bedded, grey and pink, nodular limestone beds with minor horizons of sandstone (for details see Dean *et al.* 1981; Dean 1982) and is dated by its trilobite bearing grey limestone members as belonging to the traditional Middle Cambrian (details in Dean *et al.* 1981; Dean 1982), which approximately corresponds to the unnamed "Series 3" proposed by the International Chronostratigraphic Chart of 2012 (Gradstein *et al.* 2012). The formation is conformably overlain by the siliciclastic-dominated rocks of the Sosink Formation, which is assigned to the Late –Middle Cambrian corresponding approximately to the Furongian by means of its trilobite and acritarch content (details in Dean 1982).

The stratigraphic distribution of the ichnofossils is a key to deciphering the Late Neoproterozoic–Cambrian transition. The assemblage of ichnofossils recently found in the Telbesmi Formation in SAAB is stratigraphically important and is useful for the correlation of this section with the neighboring areas. The present assemblage of ichnofossils we recently discovered can also be correlated with the stratotypic Newfoundland section (see Narbonne *et al*. 1987), as

well as other equivalent sections of Tethyan regions (e.g., Brasier *et al.* 1994; Amireh *et al.* 2008; Parcha and Pandey 2011; Hofmann *et al.* 2012).

Another Turkish locality with Terreneuvian ichnofossils is on the Tautide Anatolide Platform (TAP) in the central Taurides (Text-fig. 1), where the Early Cambrian succession disconformably overlies the Late Neoproterozoic basement (Gürsu *et al.* 2004). The succession starts with a basal conglomerate and includes meta-mafic lavas and pyroclastic rocks followed by an alternation of red fluvial conglomerates, sandstones, siltstones and mudstones (e.g., Gürsu and Göncüoglu 2005). Ichnofossils occur in the uppermost part of this succession in the Sandıklı area (Erdoğan *et al.* 2004) where there is present the *Skilothos* ichnofacies, consisting of *Cruziana* ?*fasciculata*, *C.* ?*salomonis,* ?*Cruziana* isp., ?*Diplichnites* isp., *Monomorphichnus* isp., *Petalichnus* isp., *Rusophycus* ?*avalonensis, R.* ?*latus, Arenicolites* isp., cf. *Altichnus foeyni, Planolites* isp., *Skolithos* isp., and ?*Treptichnus* isp indicating Terreneuvian (earliest Cambrian). This succession has been evaluated as being typical of high energy environments with loose, sandy (well sorted to slightly muddy) substrate in intertidal to shallow subtidal zones by Erdoğan *et al*. (2004) and represents the *Rusophycus avalonensis* zone above *Treptichnus pedum* (*Phycodes pedum*). Besides the presence of a basic volcanic unit in Sandıklı, the main difference between these locations concerns the ichnofacies. The trace fossils in the Telbesmi Formation consist of ichnofossils representing the *Scoyenia* ichnofacies that is typically associated with fluvial sedimentary environments representing the *Treptichnus pedum* (*Phycodes pedum*) Zone. The ichnofossil assemblage indicates that the ichnocenosis is deposit feeding organisms.

To conclude, based on their ichnofossil contents, the Early Cambrian siliciclastic rocks in the Derik (SAAB) and Sandıklı (TAP) areas were deposited in different sedimentary environments as alluvial-fluvial (Derik area) and intertidal to shallow subtidal marine environments (Sandıklı area) during the Terreneuvian (Early Cambrian). These distinct depositional environments may indicate that SAAB and TAP were in different paleogeographic positions but close to each other during the Terreneuvian (Early Cambrian).

Acknowledgements

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