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Mid-Ordovician (Late Darriwilian) Conodonts from the Southern-Central Taurides, Turkey: Geological Implications

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Abstract: The Tekmen Member of the Seydişehir Formation of the Silifke-Aydıncık Nappe is exposed between the towns Silifke and Aydıncık, in the central Taurides, southern Turkey. The member is composed of sandy limestones with interbeds of reddish shales. Distinctive depositional features of the carbonates and associated siliciclastics are suggestive of a mixed carbonate-siliciclastic tempestite-type deposition in a shelf environment. The conodont fauna from the Tekmen Member includes taxa that are known from the Baltoscandian region and are referred to the Darriwilian, being the first Middle-Ordovician finding from Turkey. A late Darriwilian (late Lasnamägian to Uhakun) age migth be attributed to the Tekmen Member of the Seydişehir Formation.

This new finding suggests that deposition of the tempestites of the Seydişehir Formation within the Gondwanan Tauride Platform was not terminated during the late Arenig but continued until late Llanvirnian. Additionally, it seems that the erosional event between the Middle and Late Ordovician may have important palaeogeographic implications for the Early Palaeozoic evolution of the Taurides in relation to the opening of the Palaeotethys later in Early Silurian.

Key Words: middle-Ordovician, palaeogeography, Taurides, Turkey, stratigraphy, Conodonts

Orta Torosların Güneyinden (Türkiye) Orta Ordoviziyen (Geç Darriviliyen) Konodontları: Jeolojik Yorumlar

Özet: Silifke-Aydıncık napı içinde yeralan Seydişehir Formasyonunun Tekmen Üyesi, Orta Torosların güneyinde, Silifke ve Ovacık yerleşimlerinin arasında yüzeylenir. Bu üye kırmızı şeyl aratabakalı kumlu kireçtaşlarından oluşur. Karbonat kayaları ve bunlarla birlikteki silisiklastik kayaların çökelim özellikleri, birimin karışık karbonat-silisiklastik tempestit tipli çökeller olup bir şelfde çökeldiklerini gösterir. Tekmen üyesi içinde yer alan konodontlar Baltik-İskandinavya yöresinden tanınan taksayı içerir ve Darriviliyen yaşı verir. Bu, Türkiyedeki ilk Orta Ordovizyen bulgusudur. Yeni bulguya göre, Şeydişehir Formasyonunun Tekmen Üyesi geç Darriviliyen (geç Lasnamagiyen-Uhakun) yaşındadır.

Bu yeni bulgu Gondwana kökenli Toros Platformunda tempestit çökeliminin geç Arenigde sona ermediğini, aksine geç Lanvirniyene kadar sürdüğünü göstermektedir. Buna ek olarak, bu çalışma ile ortaya konan Orta ve Geç Ordovizyen arasındaki aşınma olayının Torosların Erken Paleozoyik evriminde önemli paleocoğrafik sonuçları olduğu ve bu aşınma olayının daha ileride, erken Siluriyende Paleotetis'in açılması ile ilgili olabileceği öne sürülmektedir.

Anahtar Sözcükler: Orta Ordoviziyen, paleocoğrafya, Toroslar, Türkiye, stratigrafi, konodontlar

Introduction

It is generally accepted that the Ordovician rocks in Turkey and surrounding regions are predominantly represented by siliciclastic deposits and formed on the Gondwanan marginal platforms. Therefore, Ordovician bio- and chrono–stratigraphic schemes in Turkey are mainly based on correlations with the Welsh Basin (e.g., Dean *et al.* 1999). Through their detailed work in different parts of southern Turkey, Dean and his co-workers (for the references, see Dean *et al.* 1991) have shown that the British standard scale of the Ordovician period is applicable to this area. In contrast to the siliciclastic-dominated Gondwanan lithologies, the Baltic successions of the same timespan are largely represented by carbonate rocks, and the biozonal successions here are based on conodonts and trilobites. The Taurides in southern Turkey have a peculiar position between these two regions, due to the presence of carbonate-rich intervals within the siliciclastic successions (Stouge 1984; Stouge & Bagnoli 1990). Moreover, in many cases, these carbonate levels are associated with coarse clastic rocks, devoid of fossils, so that the application of the Baltoscandian scale based on conodont zonation is inevitable.

The Tauride Belt, an Alpine unit in southern Turkey, consists of numerous nappes (Brunn *et al.* 1970) or tectono-stratigraphic units (Özgül 1976, 1984). The study area is located within the Geyikdağ Unit of Özgül (1984). This unit is considered "autochthonous" and includes more or less continuous Palaeozoic rock sequences.

The Precambrian basement of the Palaeozoic succession in the Geyikdağ Unit is represented by low-grade metamorphic sediments intruded by mafic and felsic igneous rocks (Kozlu & Göncüoğlu 1997). The earliest sediments that unconformably overlie the basement rocks are Lower Cambrian siliciclastic rocks (Uchmann *et al.* 2000) followed by Middle Cambrian limestones (Çal Tepe Limestone; Dean & Monod 1970). The Cambrian-Ordovician boundary is located within the overlying Seydişehir Formation (Göncüoğlu & Kozur 1999). According to previous works (Dean & Monod 1970, 1990; Dean *et al.* 1999), the Seydişehir Formation is made up mainly of an alternation of quartzitic sandstones and silty shales with a few nodular limestone beds in its lower part (Gedik 1977; Özgül & Gedik 1973).

The Seydişehir Formation is conformably overlain by a carbonate-bearing unit, which is known as the Sobova Formation. The lower part of this formation is made up of 0 to 20-m-thick grey and pink carbonates (Sobova Limestone), succeeded by 20-m-thick grey shales. The limestones include late Arenig trilobites (Dean 1973) and conodonts. The conodont fauna (original determination of Barnes in Dean & Monod 1970: *Distacodus expansus, Drepanodus planus, D. suberectus, Oistodus basiovalis, O. lanceolatus, Paltodus longibasis, Prioniodus alatus, Scolopodus rex*, S. cf. *varicostatus*) was assigned to the upper Arenig. Both the trilobite and conodont faunas exhibit strong Baltic affinities (Dean & Monod 1970). Although limited in thickness, this limestone member was assumed to extend laterally for at least 400 km and was considered an important index horizon, marking the upper limit of the more widespread clastics of the underlying Seydişehir Formation. Similar successions were also reported from the Değirmentaş area of the eastern Taurides and in the Kemer area of the western Taurides (Dean *et al.* 1999).

During field mapping of the Turkish Petroleum Corporation (TPAO) in 1995 between the towns of Aydıncık and Anamur, to the west of Silifke (Figure 1), the fourth author discovered some sandy limestone beds in the uppermost part of the Seydişehir Formation and correlated them with the Sobova Formation (late Arenig) in the Seydişehir area (Gül 1995). A detailed biostratigraphic study of these beds using conodonts, however, has shown that these strata are of Middle Ordovician (Darriwilian) age (Sarmiento *et al.* 1999). The conodont fauna is characterized by species typical of the Baltic Province (*sensu* Bagnoli & Stouge 1991).

Middle Ordovician rocks, formally equivalent to the Llanvirn regional series of Britain, were previously unknown in the Taurides. Their absence had been related to uplift along the so-called "Sardinian-Taurian rise" (Hammann 1992), which caused the isolation of a North African cold-water intra-shelf basin and prevented the faunal exchange between the stable Gondwana shelf and some peri-Gondwanan terranes (e.g., Avalonia, etc.) or those of the present North Atlantic Realm.

On the other hand, the overall palaeogeographic assumption is that the Baltic Terrane arrived in close proximity to the Gondwana-related terranes to exchange benthic shelly faunas only during the Late Ordovician

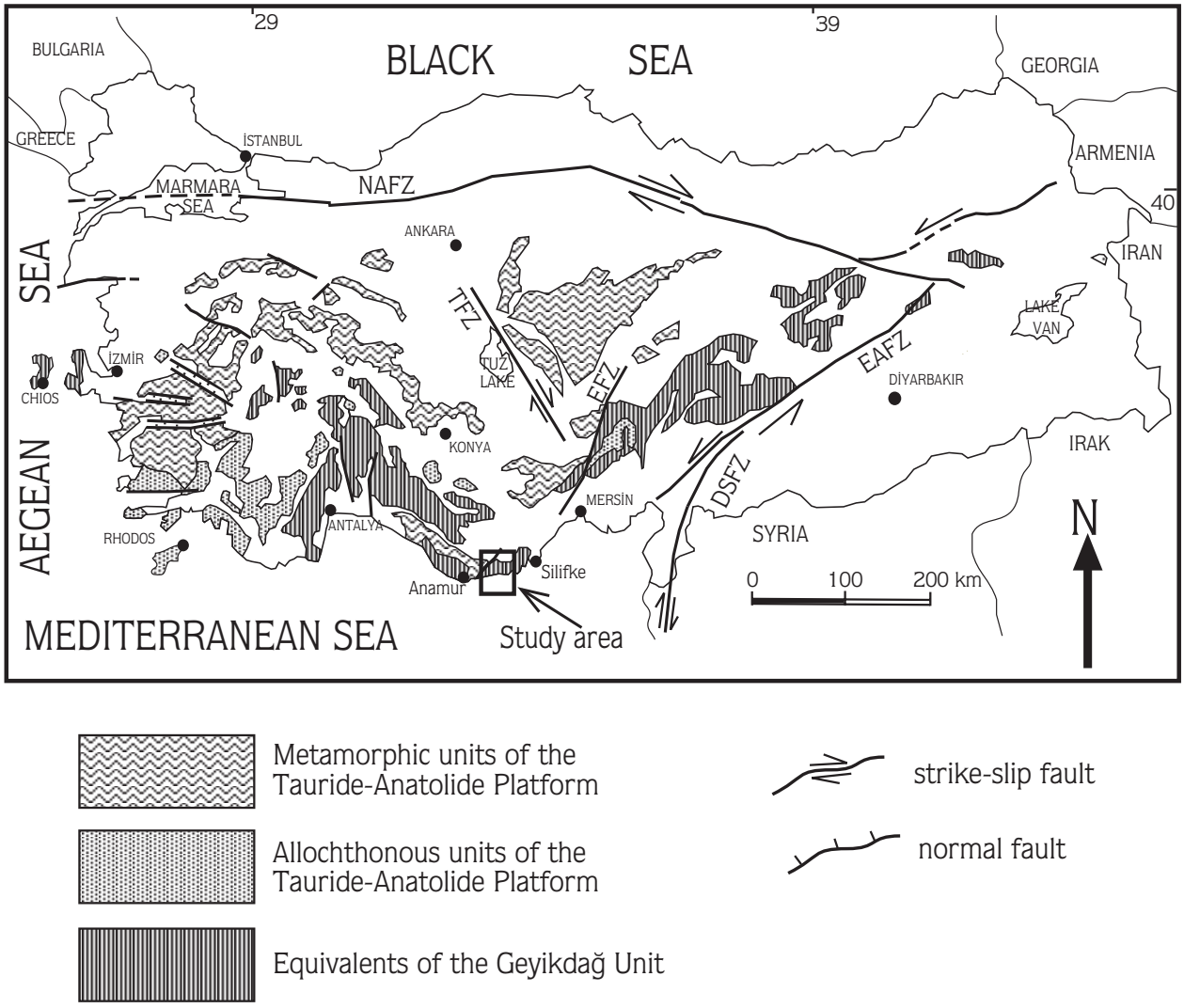

Figure 1. Distribution of the Lower Palaeozoic outcrops in the Taurides (after Göncüoglu & Kozlu 2000) and the location of the study area (NAFZ- North Anatolian Fault Zone, EAFZ- East Anatolian Fault Zone, EFZ- Ecemiş Fault Zone, TFZ- Tuzgölü Fault Zone, DSFZ- Dead Sea Fault Zone).

(Cocks 2001). This idea conflicts with our new finding, which suggests that not only the Ordovician stratigraphy of the Taurides but also the interpretation of its palaeogeographical position need to be revised.

In this study, we present and illustrate our new conodont findings from the central Taurides (Anamur-Aydıncık area) and mainly discuss the geological implications of these findings in regard to the regional geology. A detailed systematic palaeontological study of these findings is in progress.

Geological Setting and Stratigraphy

The studied succession is located in southern Turkey, along the Mediterranean coast, on the Mersin-Antalya highway, between the towns Aydıncık in the east and Anamur in the west, ~ 25 km to the east of the latter (Figure 2). Considering its overall stratigraphic features, it represents one of the southernmost tectonic slivers of the Geyikdağı Unit of Özgül (1976). In his previous study, Demirtaşlı (1984) included the Palaeozoic rocks of this area in his "Northern Zone" - assumed to be a Variscan allochthonous unit, which was emplaced toward the south

(onto the "Intermediate Zone" *sensu* Demirtaşlı) before the Late Permian. This "Northern Zone" corresponds to the Aladağ Unit of Özgül (1976). In a more recent work (Gül 1990), however, it has been shown that there are actually two different nappes: a northern one representing the Aladağ Nappe overthrusting the southerly located Silifke-Aydıncık Nappe - an equivalent of the autochthonous Geyikdağ Unit. This finding does not support the assumption of Demirtaşlı (1984).

The Silifke-Aydıncık nappe includes an almost complete Precambrian-Devonian succession (Figure 3), unconformably overlain by the Akyaka Formation of Cretaceous age, which in turn is overthrust by Triassic-Jurassic rocks of the Aladağ Nappe (Gül 1990). About 5 km to the west of the study area, the lowermost part of the succession is represented by the Precambrian Emirgazi Formation, unconformably overlain by shallow-marine variegated quartzites of the Hüdai Formation. The

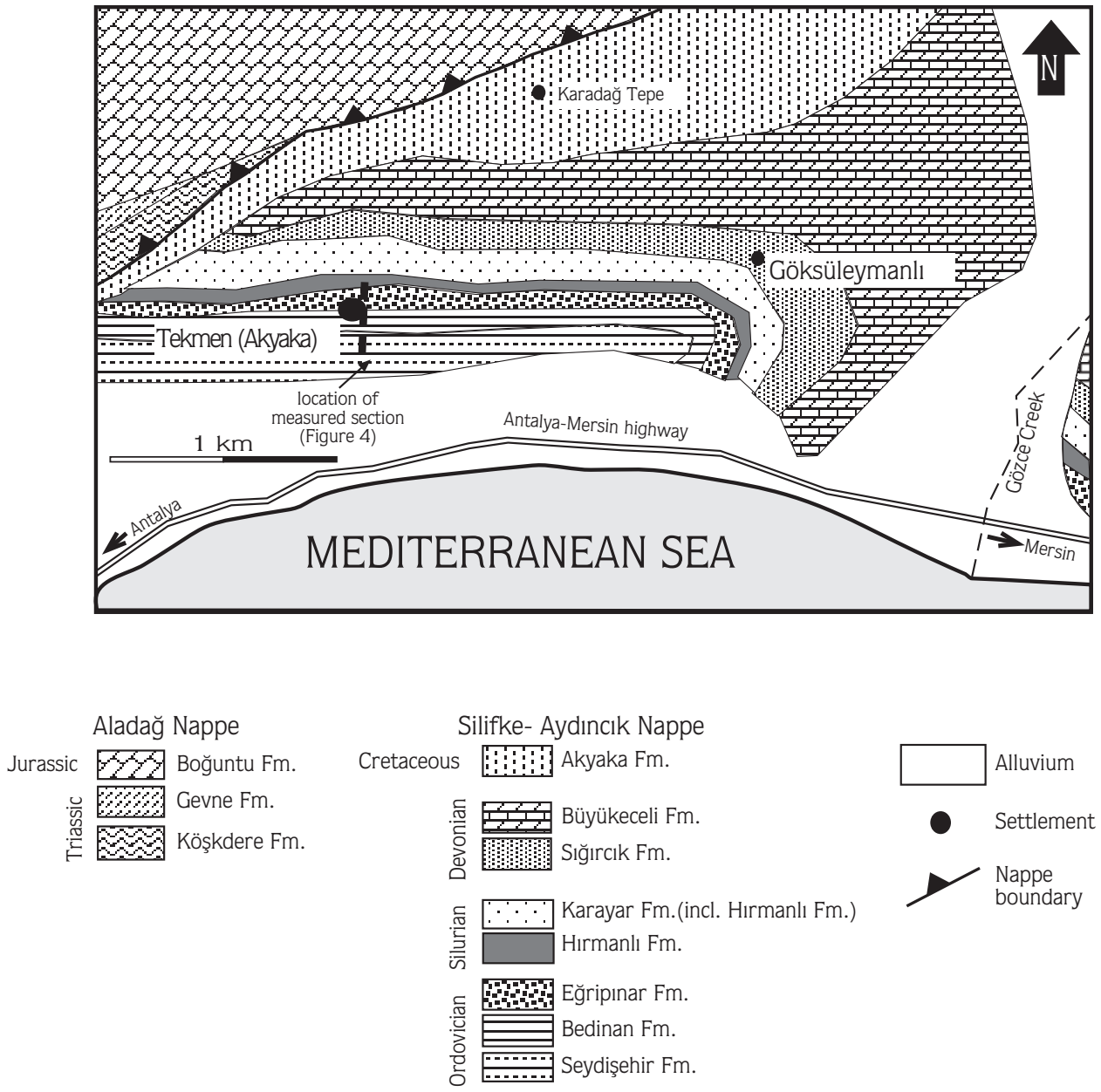

Figure 2. Geological map of the study area (modified after Gül 1990) and the location of the measured section.

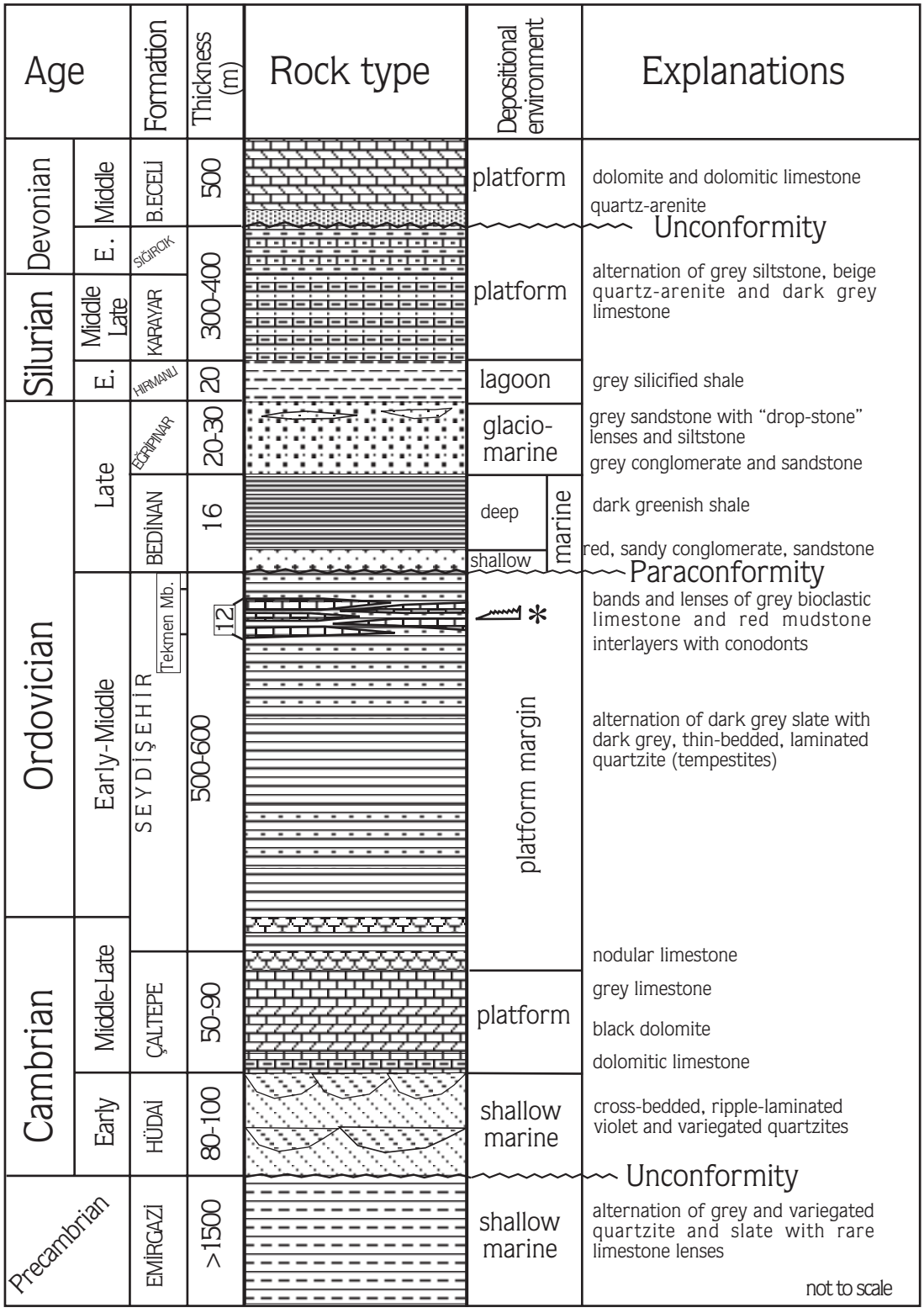

Figure 3. Generalized columnar section of the Lower Palaeozoic rock units of the Silifke-Aydıncık Nappe in the Silifke-Anamur area.

latter is conformably followed upward by carbonate rocks of the Middle-Upper Cambrian Çal Tepe Formation that grades into the Upper Cambrian-Lower to Middle Ordovician Seydişehir Formation. A distinct unconformity separates these units from the Upper Ordovician-Lower Devonian rocks. Along a N-S- trending cross-section to the east of Tekmen (Akyaka) Village (Figure 2), the first author measured a well-exposed succession that includes the Seydişehir, Bedinan, and Eğripınar formations of Ordovician age and the Hırmanlı Formation of Early Silurian age. The Palaeozoic succession crops out in the core of an east-plunging anticline along the Mediterranean Sea coast, between the villages of Tekmen and Göksüleymanlı (Figure 2). In the following paragraphs, the lithological features and stratigraphy of this measured section will be emphasized. The stratigraphic nomenclature of the present study is mainly after Demirtaşlı (1984).

The measured cross-section starts within the upper 124 meters of the Seydişehir Formation, which is represented by an alternation of dark grey silty shales with dark grey, thin bedded and laminated quartz-sandstones. The depositional features of this formation (individual graded beds, planar lamination, hummocky cross-lamination, rapid changes in vertical sequences, etc.) are indicative of its tempestite nature.

Between 54-66 meters of the cross-section, the succession consists of alternating limestone and mudstone. In this study, this unit is named as the Tekmen Member of the Seydişehir Formation. The type section and the type locality of this new member are in Tekmen Village (1/25,000 scaled topographic map of Turkey Nr: P30-d2, coordinates: Starting Point N4.99.850; E12 350, End Point N 4.00 300; E5 12 400). Both the upper and lower boundaries are transitional with silty shales of the Seydişehir Formation. The mudstones are reddish and thinly bedded. The limestones occur as bands and lenses. Individual bands may reach up to 2 meters in thickness. Along the cross-section 5 main limestone horizons were observed and sampled (Figure 4). The limestones are light grey to cream in colour and include graded bioclasts. In general, the limestones are nodular and include fine lamellae of reddish limey mudstone.

Under the microscope, the limestones are bioclastic (crinoid-echinoid)-lithoclastic (quartz-sand) packstones (cf. Dunham 1962). All samples are variably recrystallized and exhibit noticeable grading. The echinoid fragments are elongated and display syntaxial overgrowth. The quartz fragments are angular and make up to 60% of the clasts. The matrix is spary calcite that has well-developed pressure-twinning. Considering their characteristic features, these limestones are interpreted as proximal carbonate tempestites and the alternation of the limestones and siliciclastics as mixed carbonate-siliciclastic tempestites (cf. Einsele 1992).

Each limestone band was sampled and each sample (on average 300 gr. and 1500 gr., respectively) was dissolved and handpicked for conodonts which are variable in relative abundance. The fossil content of the studied samples is noted in the next section.

The uppermost 58 meters of the Seydişehir Formation are dominated by an alternation of sandy shales and medium- to fine-grained sandstones. In general, the observed succession represents a coarsening-up sequence. The uppermost horizon of the Seydişehir Formation consists of red to brown-weathered siltstones and sandstones with hard-ground formation.

The Bedinan Formation starts at 124 meters above the base of the measured section. The lower part of this formation consists of red sandy conglomerates and sandstones. The coarse-grained, clastic-dominated basal part is ~2.5-meters-thick and rests along a parallel unconformity on the silty-sandy lithologies of the Seydişehir Formation. The clasts of the basal part are mainly well-rounded, white, reddish and dark grey quartzites. Upward follow 14 meters of dark-greenish shales. This formation grades into the conformably overlying silty and arkosic sandstones of the Eğripınar Formation. In southeast Anatolia, the Bedinan Formation is dated as Caradoc-early Ashgill (Dean 1967). To date, no fossils have been found in this unit in the study area and its attribution to the Bedinan Formation is mainly due to its lithological characteristics. In the eastern Taurides, the equivalent of this formation is known as the Şort Tepe Formation, dated as ?early Ashgill by Dean & Monod (1990). The shaley middle part of the Bedinan Formation, above the coarse clastic-dominated basal layers, indicate rapid deepening and probably suggests a shallow to deep outer-shelf depositional environment. The overlying silt- and sandstone-dominated part, characteristic of an inner shelf environment at its type locality in southeastern Anatolia (Kellogg 1960), is not represented in the present area, hence the thickness of the formation may be less than envisaged here.

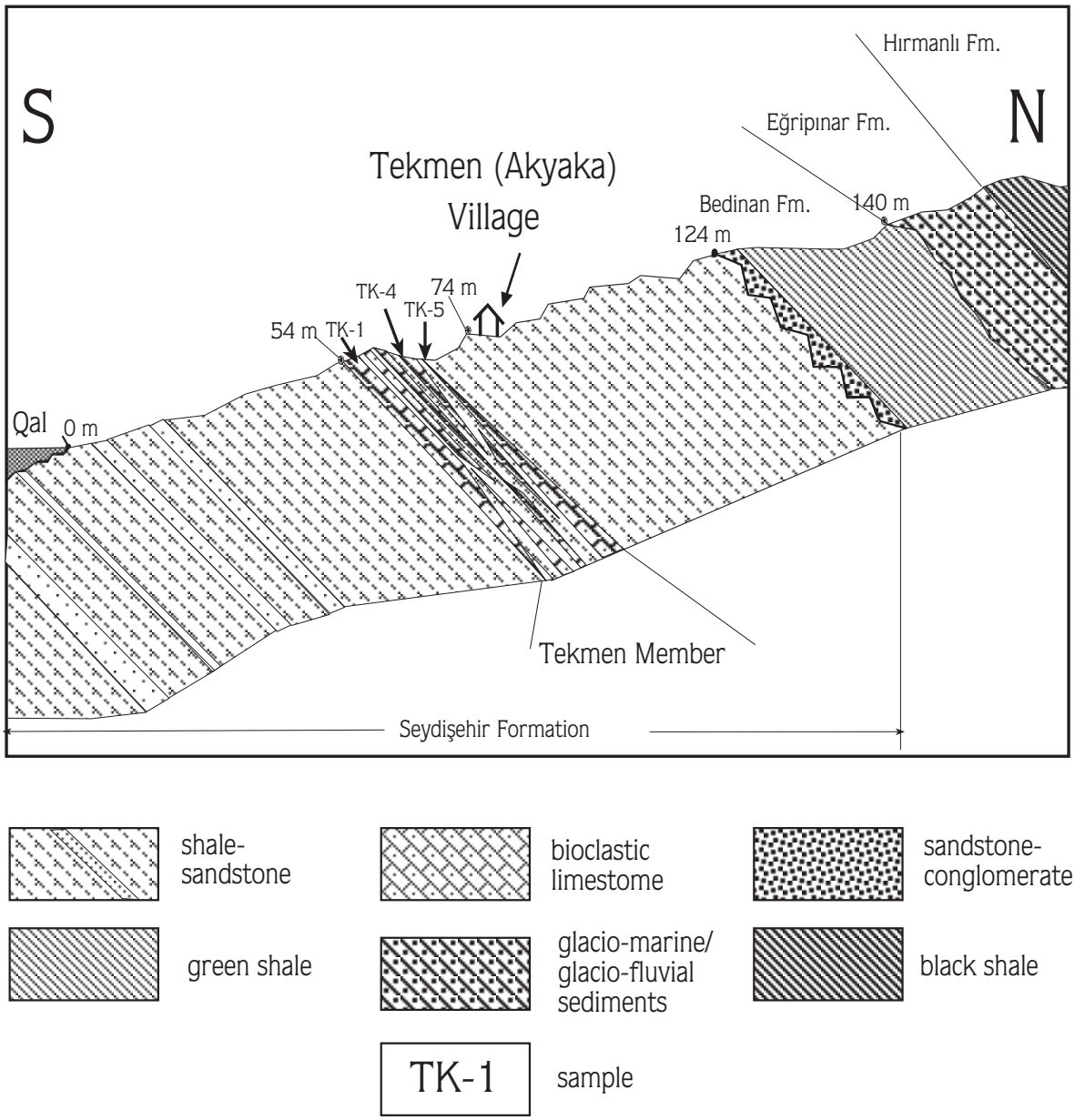

Figure 4. Distribution of the rock-units and the location of the conodont-bearing samples along the measured cross-section around the Tekmen (Akyaka) Village. See Figure 2 for location.

The Bedinan Formation is overlain disconformably by grey conglomerates and sandstones of the Eğripınar Formation (Figure 4). The contact is obviously an erosional surface. In a previous study (Demirtaşlı 1984), this unit was assumed to represent the basal conglomerates of the overlying Hırmanlı Formation. Based on miospores from the dark shales above the conglomerates, Demirtaşlı (1984) assigned an Early Silurian age also for these coarse clastic rocks. However, recent studies (Göncüoğlu 1997; Göncüoğlu & Kozlu 2000; Ghienne *et al.* 2001) suggest that this unit is of glacial/glacio-marine origin and probably of latest Ordovician age. The glacial nature of the unit is accentuated by the presence of heterometric, well- to sub-rounded quartz grains and exotic pebbles of orthogneiss, mylonitic granite, rhyolite and quartzite

within a fine-grained sandstone-siltstone matrix. These sandstones have been interpreted as diamictites (Göncüoğlu & Kozlu 1995) and closely resemble the typical glacio-marine deposits, described from NW Spain and other parts of NW Gondwana (e.g., Vaslet 1989).

The Eğripınar Formation is conformably overlain by grey, partly silicified shales of the Hırmanlı Formation. On the basis of some graptolite findings in the Silifke area, Demirtaşlı (1984) claimed that the age of this latter formation to be Early Silurian. These grey shales are known as the Puşcutepe shale formation in the eastern Taurides and have been dated as Llandovery (Özgül *et al.* 1973). A more precise age (Telychian) is suggested by conodont findings (Göncüoglu & Kozur 2000) for the formation of the earliest "Orthoceras limestone" beds within the lowermost interval of the black shales in the Kemer area. As no diagnostic fossil evidence has been yet reported for the Eğripınar Formation, this finding suggests that the glacial event in the Taurides should be bracketed between early Ashgill and Telychian, which is in accordance with the Hirnantian (highest stage of the Ashgill series) ages obtained from other Gondwanan terranes (e.g., Semtner & Klitzsch 1994).

The Middle-Upper Silurian and Lower Devonian rocks in the study are represented by the Karayar and Sığırcık formations, respectively. These formations consist of alternating grey siltstone, beige quartz-arenite and dark grey limestone. Quartz arenites, thick-bedded reefal limestones and dolomites of Middle Devonian age (Büyükeceli Formation; Demirtaşlı 1984) overlie older rocks along an angular unconformity (Figures 2 & 3).

Conodont Fauna and Age

Limestone levels of the Tekmen Member of the Seydişehir Formation were sampled for conodont studies in 1995 by the last author. The discovery of an interesting conodont assemblage induced a re-sampling of the section in 1999 by the senior author. Five grainstone-packstone levels of the Tekmen Member yielded over 200 conodont elements. The level identified as TK.Sy.4 was found to be the most prolific, with nearly 100 specimens. All the conodont elements are within a range of CAI 4-4.5, indicating burial temperatures of 190-300 ºC (Epstein *et al.* 1977).

Conodont taxa identified in the Tekmen Member do not exhibit significant variation through the section. *Complexodus originalis* Chen and Zhan, *Sagittodontina kielcensis* (Dzik), and *Baltoniodus* spp., are the dominant components of the fauna. In smaller numbers, *Drepanoistodus* sp., *Panderodus* sp., *Semiacontiodus* n. sp. A, New genus A n. sp. A, *Cornuodus longibasis* (Lindström), *Scalpellodus gracilis*? (Sergeeva), *Scalpellodus* sp., *Lenodus* sp., *Ansella*? n. sp., *Microzakodina* cf. *hagetiana* Stouge & Bagnoli (1991) have been identified.

This conodont fauna is characterized by species typical of the cold-water Baltic Province of the North Atlantic Realm (*sensu* Bagnoli & Stouge 1991), which together with new taxa under study (Sarmiento & Göncüoglu, in prep.) could reflect a certain degree of endemism. The affinity of Turkish conodonts with the well-known Baltic faunas was mentioned previously by Barnes (*in* Dean 1973).

Conodont zones for the Lower and Middle Ordovician introduced by Lindström (1971) and Bergström (1971), respectively, together with refinements proposed by Löfgren (1978) are adopted here. Also chronostratigraphic reference to the regional Baltoscandian scale has been used. At present, zonal index conodonts have not been identified in the studied assemblage.

Complexodus originalis Chen and Zhang occurs in China from the *E. reclinatus* Subzone to the *Pygodus anserinus* Zone (Chen & Zhang 1984) involving equivalents of basal Viruan to younger strata. In Poland, the same species was recognized from the *E. lindstroemi* Subzone of the *Pygodus serra* Biozone (Dzik 1994) equivalent to the Lasnamägian. *Sagittodontina kielcensis* (Dzik) is the nominal species of the lower subzone of the *P. anserinus* Zone, equivalent to the Uhakun.

According to the stratigraphic range of the conodont taxa, mainly from the presence of *S. kielcensis*, which defines the lower eponymous subzone of the *P. anserinus* Zone, a late Lasnamägian to Uhakun age, late Darriwilian (Figure 5), is attributed to the Tekmen Member of the Seydişehir Formation.

Discussion and Conclusions

During the fieldwork of TPAO in 1995, a ~12-m-thick package of sandy limestones was discovered in the uppermost part of the Seydişehir Formation. Based on

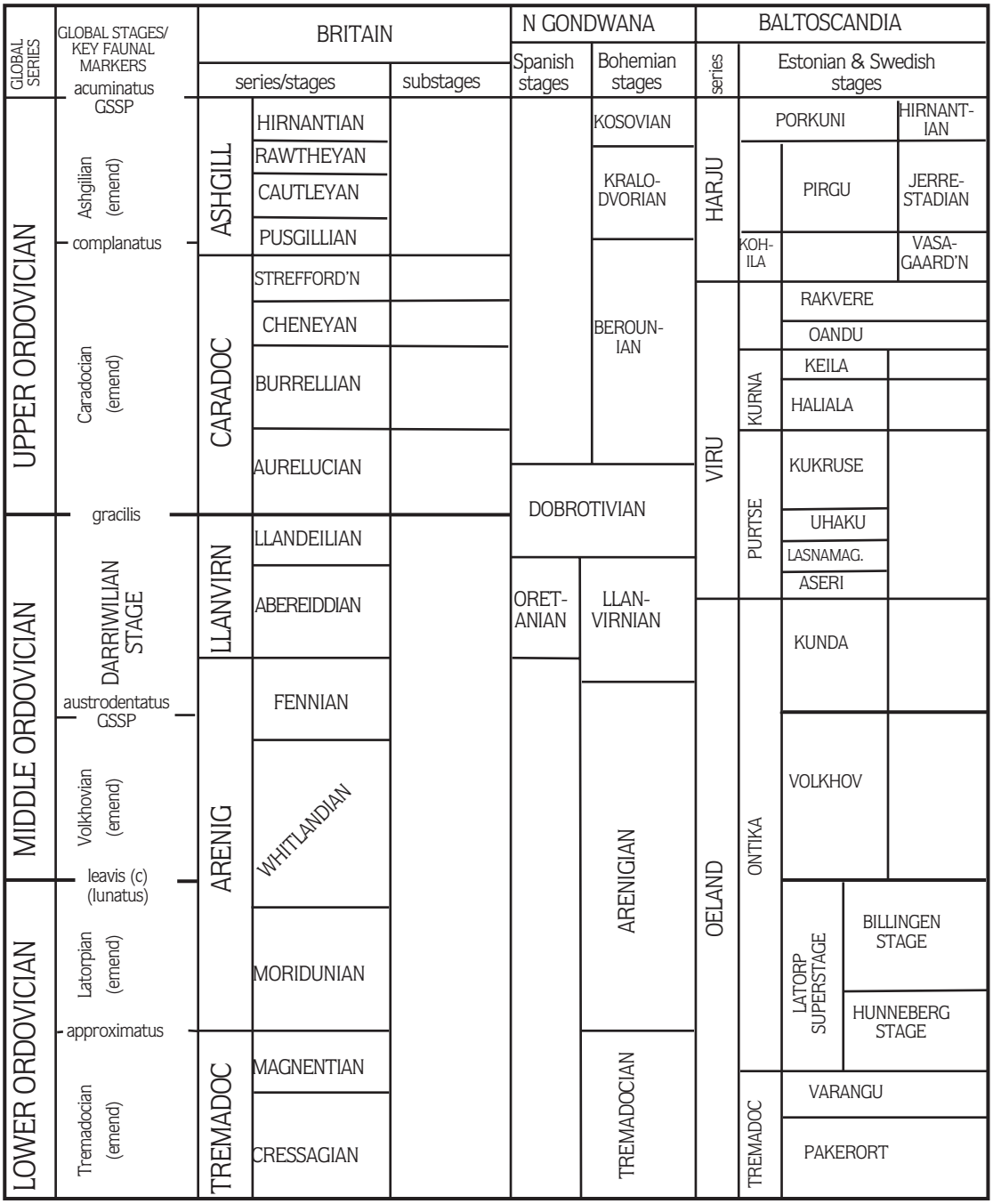

Figure 5. Ordovician chart illustrating the stratigraphic relationships between the Global Series, Stages and key faunal markers, and the main regional series stage and substage divisions used in different parts of the world (after Webby 1988)

previous studies (e.g., Dean & Monod 1990), this unit was correlated with the Sobova Formation of late Arenig age in the Seydişehir area. A preliminary dating (Sarmiento *et al.* 1999) of these beds using conodonts has shown that these strata are of Middle Ordovician (late Darriwilian) age. The fauna is characterized by species typical of the Baltic Province (*sensu* Bagnoli & Stouge 1991).

The Sobova Formation, in its type locality, includes late Arenig shallow-marine limestones and shales. The

depositional environment is also quite different from that of the newly discovered succession. By this, it is suggested that the name "Sobova Formation" be avoided to prevent an inappropriate correlation. Therefore, this unit is herein named the Tekmen Member of the Seydişehir Formation.

The recognition of the Tekmen Member has the following regional implications: (1) Seydişehir-type clastic (tempestites) deposition on the Gondwanan Tauride platform did not terminate during the late Arenig but continued until the Late Llanvirnian; (2) in different parts of the Taurides, the limestone beds in the upper Seydişehir Formation do not necessarily correspond to the late Arenig Sobova Formation. This point is of crucial importance in cases where lithologically similar units, such as Seydişehir, Bedinan and Şort Tepe formations, are being mapped in the field; (3) the erosional event between the Middle and Upper Ordovician is probably more important than previously believed and should be considered in geodynamic models of the Early Palaeozoic evolution of the Taurides. A possible candidate for this event is the rifting of the northern Gondwana margin, which resulted in the separation of some microplates from the main continent (Göncüoğlu 1997; Göncüoğlu & Kozlu 2000). This rifting may have produced the opening of Palaeotethys (*sensu* Stöcklin 1974) later in the Early Silurian; (4) the affinity of the Tekmen conodont fauna to the Baltic Province of the North Atlantic Realm is another issue to be considered in palaeogeographic reconstructions. In previous studies (e.g., Dean & Monod 1970), the predominant Baltoscandian affinities of the Early Ordovician trilobite taxa adjacent to the Mediterranean and South European elements was noticed. Barnes (in Dean 1973) pointed out that the Volkhovian (and slightly older) conodont assemblage of the Sobova Formation s.s. is of Baltic-type. Moreover, a significant affinity between the Tekmen fauna with that of Mojcza (Poland; Dzik 1994), South China (Chen & Zang 1984), and possibly with Kerman (Iran; Hamedi *et al.* 1997) is evident. Our new finding of Baltoscandian-type conodonts of late Darriwilian (late Kunda to Uhaku) age in the Taurides may indicate that these terranes (Bohemia, South China, ?Iran and Turkey) were linked by a series of adjacent shallow seas during Early to Middle Ordovician times.

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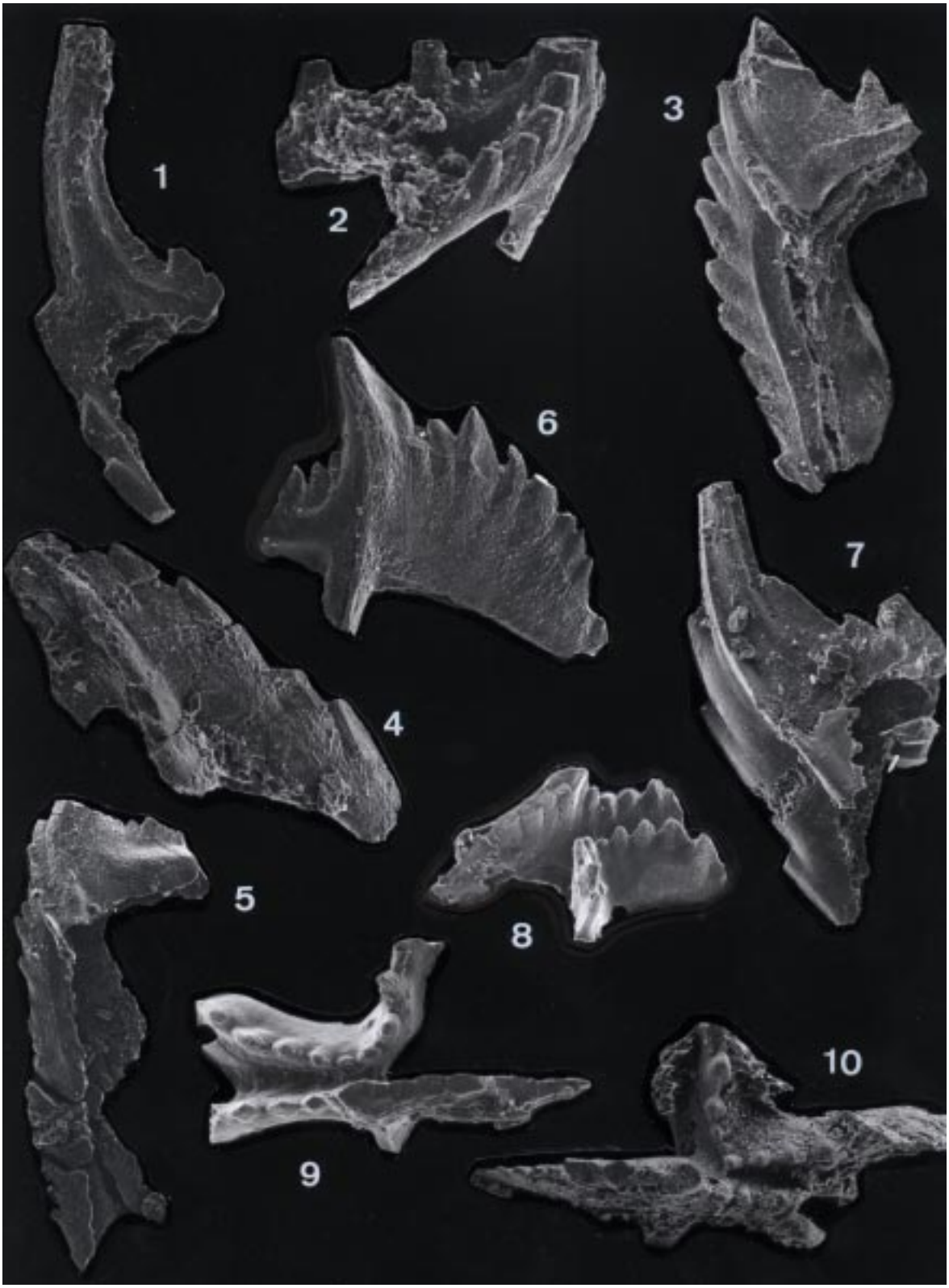
PLATE I. Conodonts of the Tekmen Member.

Figures 1-5. *Sagittodontina kielcensis* (Dzik 1976).
(1) Sc element, lateral view; Tk.Sy.4/7730, X 180.
(2) Sb element, lateral view; Tk.Sy.4/7714, X 280.
(3) Pb element, lateral view; Tk.Sy.4/7859, X 180.
(4) fragment of Pa element; Tk.Sy.4/7869, X 220.
(5) Pb element, lateral view; Tk.Sy.4/7730, X 120.

Figures 6-10. *Complexodus originalis* Chen & Zhang (1984).
(6) fragment of Pa element, lateral oblique view; Tk.Sy.4/7861, X 180.
(7) Pb element, lateral view; Tk.Sy.4/7862, X 220.
(8) Pa element, lateral view; Tk.Sy.4/8101, X 220.
(9) same element, upper view, X 240.
(10) Pa element, upper view; Tk.Sy.1/7849, X 170.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