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CARBONIFEROUS CONODONT BIOSTRATIGRAPHY AND LATE PALAEOZOIC DEPOSITIONAL EVOLUTION IN SOUTH CENTRAL IRAN (ASADABAD SECTION - SE ISFAHAN)

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Abstract. Asadabad section in Central Iran is one of the most complete sequences so far described across the Carboniferous of Iran. The stratigraphic and biostratigraphic data on the sediments overlying the Devonian carbonate platform give evidence about the duration of shallow water depositional evolution. There are thirty productive levels with conodonts in the Carbonifeous section ranging in age from early Tournaisian to the top of Bashkirian (Lower *expansa* – *sulcata* to *sinuosus* zones). There is scarce evidence about the *elongatus* Zone presence – Late Pennsylvanian. *Sulcata* to *anchoralis-latus* conodont zones in Shishtu Formation and *muricatus* to *sinuosus* Zone and a possible *elongatus* Zone in Sardar Formation have been indentified. These conodont zones are reported for the first time in that area. A crinoidal limestone – key bed horizon, is traceable in the studied area as well as in other parts of Iran. It is Early Pennsylvanian – Bashkirian in age and is correlated to *sinuatus-minutus* Zone. The studied Shishtu and Sardar Formations (Carboniferous) as well as Vazhnan and Surmaq Formation (Permian) in the section belong to marine near shore sedimentation with many macrofaunal remains.

Riassunto. La sezione di Asadabad in Iran Centrale é una delle sezioni più complete sinora descritte nel Carbonifero dell'Iran. I dati sulla lito- e biostratigrafia dei sedimenti che ricoprono la piattaforma carbonatica del Devoniano forniscono elementi per comprendere l'evoluzione della durata della sedimentazione carbonatica in acque poco profonde. Sono stati individuati trenta livelli produttivi a conodonti nella successione carbonifera, con età che vanno dal Tournesiano inferiore alla sommità del Bashkiriano (zone da Lower *expansa* – *sulcata* a *sinuosus*). L'evidenza per la presenza della Zona a *elongatus* del tardo Pennsylvaniano è debole. Nella Formazione Shishtu sono state identificate le zone a conodonti da *sulcata* a *anchoralis-latus*, mentre nella Formazione Sardar sono stati riconosciuti conodonti delle zone da *muricatus* a *sinuosus* e forse anche della Zona a *elongatus.* Queste zone a conodonti sono riconosciute per la prima volta nella regione. Un orizzonte-guida di calcare a crinoidi è tracciabile in tutta l'area studiata ed è presente anche in altre parti dell'Iran. Ha un'età Bashkiriana (Pennsylvaniano inferiore) ed è riferito alla Zona *sinuatus-minutus*. Le formazioni studiate, Shishtu e Sardar del Carbonifero, così come le soprastanti formazioni Vazhnan e Surmaq del Permiano, sono state deposte in ambiente marino poco profondo e contengono molti resti macrofaunistici.

Introduction

Iran was situated at the northern margin of Gondwana during the Palaeozoic (Scotese 2004; Berberian & King 1981). The main Palaeozoic sequences in Iran occur in the eastern and central parts of the country. Devonian and Carboniferous deposits in Iran are mostly widespread in Central and Eastern Alborz Range and in the western, central and eastern part of the Central Iran. They almost exclusively formed in a shallow neritic environment (Wendt et al. 2002, 2005) (Fig. 1).

Tracing back the shallow water depositional conditions from the Middle Devonian it can be found out a continue sequence, predominantly consisting of dolostones, reaching 500 m in thickness, which formed a large carbonate platform (about 800 km in north-south direction and 500 km in east-west direction). The lithostratigraphic subdivision of the Upper Devonian and Carboniferous concerning Central and Eastern Iran includes three major units: Bahram Formation, Shishtu Formation and Sardar Formation. The older Devonian sequences are covered and laterally replaced by sediments of the Bahram Formation, which was considered mainly as Frasnian by Yazdi (1999). Wendt et al. (2002, 2005) extended the age of Bahram Formation to the top of

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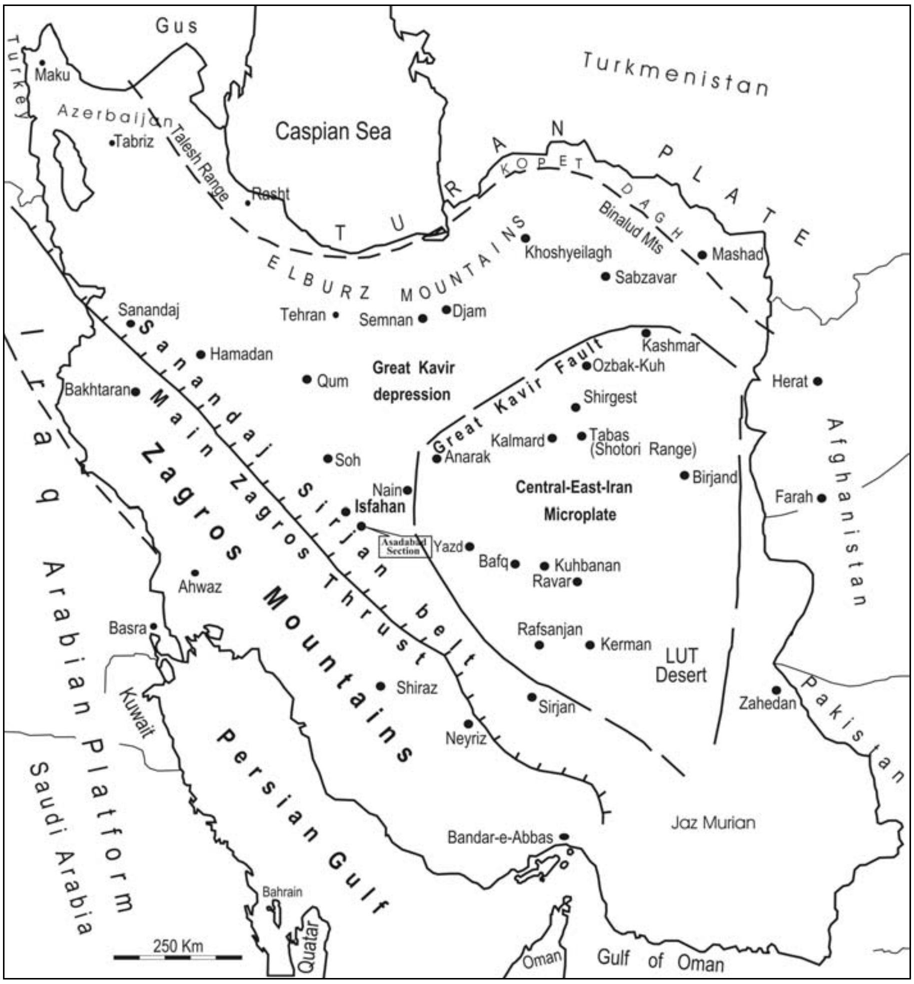

Fig. 1 - Structural zones of Iran (after Wendt et al. 2005).

Famennian. The Asadabad section includes Shishtu Formation and Sardar Formation in the Carboniferous and the Vazhnan and Surmaq Formations in the Permian. The purpose of this paper is to provide evidence of the stratigraphic and biostratigraphic position of the sediments covering the Devonian carbonate platform. These data elucidate the carbonate platform evolution in the studied area.

Previous works

Eastern and Central Iran

Carboniferous and Lower Prermian deposits were firstly obtained in the 1960's during the geological mapping of the Tabas area, in Shirgesht and Ozbak-Kuh mountains (Stöcklin et al. 1965; Ruttner et al. 1966, 1968) establishing the Shishtu and Sardar formations. Stepanov (1971) and Stöcklin (1971) later published more detailed stratigraphic and palaeontologic data on the Carboniferous sequences for these areas.

The Shishtu Formation starts in the Upper Devonian but its upper part is assigned to Lower Carboniferous (Yazdi 1999). The type section of this formation is located in the Ozbak-Kuh Mountain, north of Tabas, and is 543 m-thick in the type locality (Howz-e- Dorah section). The Shishtu Formation includes limestone, oolitic ironstone beds, "Cephalopod beds" and grey to dark intercalation of thin bedded limestone with corals as well as chert layers, which were assigned to Late Devonian and Early Carboniferous by Yazdi (1996b, 1999). The Shishtu Formation unconformably overlies the dolostones of Bahram Formation.

The Sardar Formation unconformably overlies the top of Shishtu Formation and consists of green shale, sandy limestone and oolitic limestone (Stöcklin et al. 1965, 1991). Its type section at Kuh-e-Shotori is located in Shotori region to the East of Tabas (Stöcklin et al. 1965) and is 660 m-thick. The Sardar Formation is subdivided in Sardar 1 and Sardar 2 units (Ruttner & Stöcklin 1966). The lower unit (Sardar 1) consists of interbedded shale, sandstone and limestone, and the upper unit (Sardar 2) includes shale with sandstone (Stöcklin et al. 1965). The age of their mutual boundary was not defined in detail. According to Stepanov (1971), the boundary between Sardar 1 and Sardar 2 could be placed between Lower and Middle Carboniferous, but no evidence for this statement have been given.

Carboniferous "Crinoidal bed" in the Shotori region in Eastern Iran has been studied by Webster et al.

(1999, 2000) and Yazdi (1999) and has been traced till to the Ramsheh area (Fig. 1). A conglomerate layer, 20 m thick, was described by Yazdi (1999) in the Tabas area within the Sardar Formation. There are some conglomerate levels in other outcrops but with different thickness and characteristics and they are related to Sardar formation according to Yazdi (1996a, 1999).

Leven et al. (2006) described two more complete Carboniferous sequences with new palaeontologic and lithostratigraphic data in Central and Eastern Iran (Anarak and Zaladu sections). According to Leven et al. (2006), the Sardar Group (Sardar 1 and Sardar 2) in Anarak and Zaladu sections are different in comparison to the type section and they renamed them as Galeh Formation (formerly Sardar 1) and Absheni Formation (formerly Sardar 2). They referred the Galeh Formation to the early Bashkirian and the Absheni Formation to late early Moscovian and reported a hiatus between the two formations.

Pennsylvanian foraminifers were published from the Eastern Alborz Mountains, south to Gorgan city, Northern Iran (Bozorgnia 1973; Lys 1986; Lys et al. 1987; Jenny et al. 1987).

A disconformity is present between Lower Permian and older sediments in Iran in several sections (Vaziri 1993; Partoazar 1995; Yazdi et al. 2000; Wendt et al. 2002, 2005; Leven & Taheri 2003; Sohrabi et al. 2006; Leven et al. 2006).

Partoazar (1995) distinguished the lowermost part of Jamal Formation as separate unit, named Bagh-e-Vang, between Sardar and Jamal Formation and assigned it to Asselian-Sakmarian. Leven & Taheri (2003) documented the fusulinid occurrences in the upper part of the Sardar Formation (Zaladu Member) of the Ozbak Kuh region (Eastern Iran), and demonstrated that these deposits cannot be referred to the Bagh-e-Vang Formation, which contains Bolorian fusulinids of Early Permian and lies at the base of a transgressive carbonate sequence.

Southwestern Central Iran (Abadeh-Shahreza-Hambast Belt)

Carboniferous sediments of that area were also referred to Shishtu and Sardar Formations (Stöcklin et al. 1965, 1991). However, no biostratigraphic studies have been published on the Lower Carboniferous.

The Permian sequence was divided by the Iranian-Japanese Research Group (1981) into three formations in the Abadeh region: Surmaq Formation (units 1-3), Abadeh Formation (units 4, 5) and Hambast Formation (units 6, 7).

Baghbani (1993) described the most complete sequences of Permian strata in Abadeh and adjacent area (Tang-e-Darchaleh, located 25 km to the north of Asadabad section) and suggested that Carboniferous deposits of Moscovian age, due to the presence of *Ozawainella mosquensis* Zone, underlie the Vazhnan Formation (Asselian and Sakmarian). The Vazhnan Formation consists of a basal conglomerate overlaid by alternating sandstone, limestone, and shale.

Fasihi (1999) described the Permian sequence in the Asadabad section as consisting of red sandstone, sandy limestone, and siliceous sandstone overlaying the Upper Carboniferous. This author assigned the Permian sequence to Vazhnan Formation on the base of foraminifera (*Pseudoschwagerina-Pseudofusulina* Zone). According to Fasihi (1999), the presence of *Pseudoschwagerina* and *Robustoschwagerina* in the middle and in the upper parts of the Vazhnan Formation indicates the Asselian-Sakmarian age.

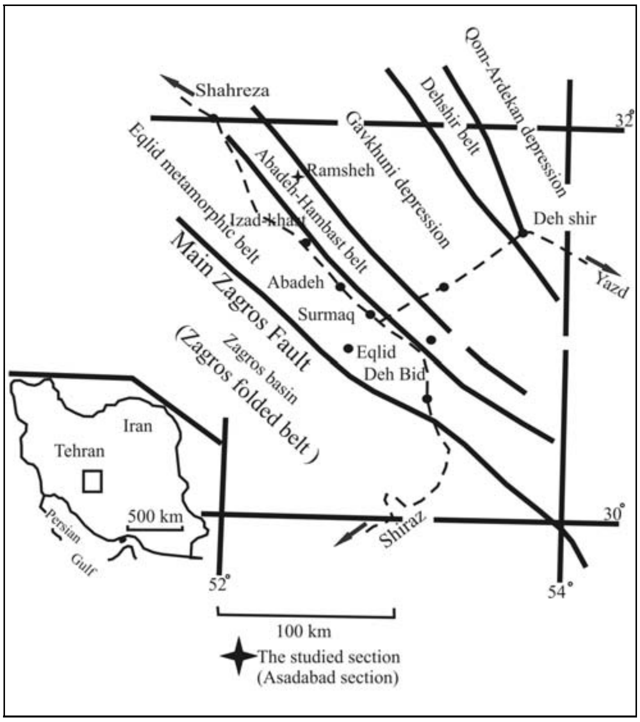

Fig. 2 - Structural zonation of the Abadeh-Deh Bid area (after Iranian-Japanese Research Group 1981).

Geological setting

The studied section is located in Central Iran, 135 km southeast of Isfahan in Ramsheh area (latitude N 31° 46' 65 , longitude E 52° 8' 63 GPS-WGS84 coordinates). The Ramsheh area structurally belongs to the South-west-Central Iran and includes the Shahreza-Abadeh-Hambast belt, which is separated by faults from the Gavkhoni-Abarqu depression to the northeast, and from the Yazdehkhast-Dehbid metamorphic belt to the southwest (Iranian-Japanese Research Group 1981) (Fig. 2). This belt covers an area about 25 Km wide and 200 km long. The main body of Shahreza-Abadeh-Hambast belt consists of Permian-Triassic rocks, with

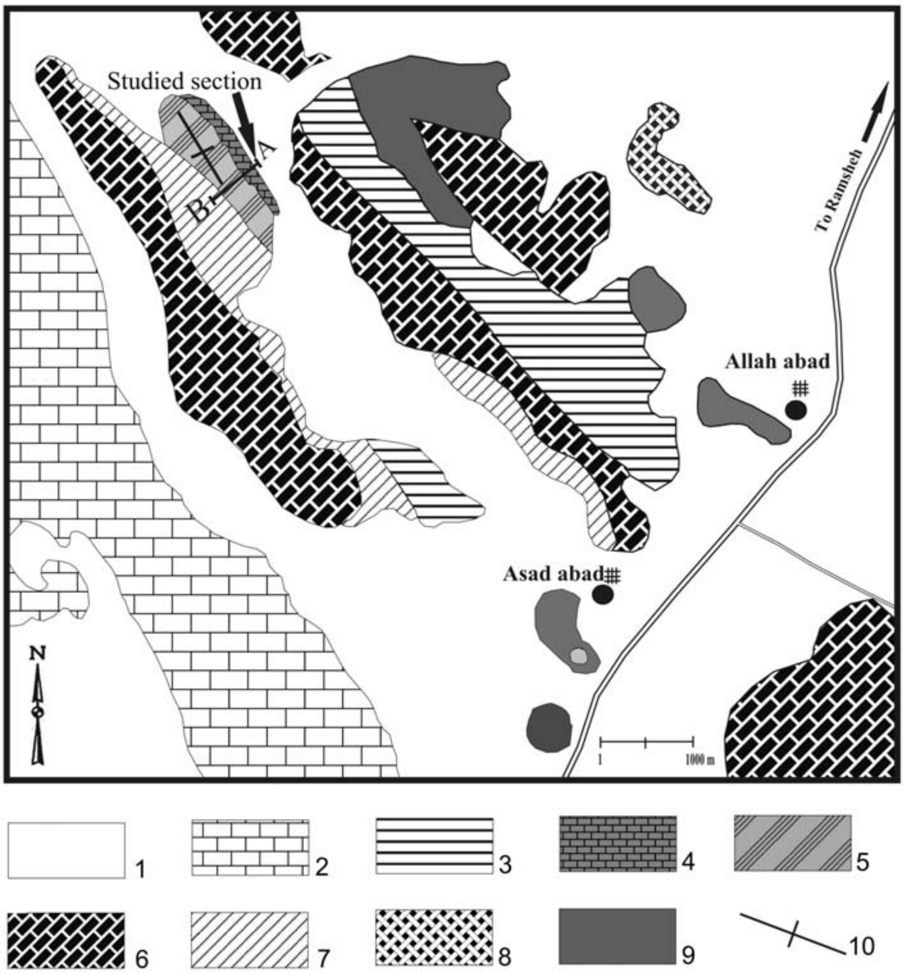

Fig. 3 - Geological map of the studied section. (after Iranian-Japanese Research Group in 1981). Legend: 1 - Unconsolidated texturally variable recent clastic deposits; 2 - Grey massive to thick bedded *Orbitolina*-bearing limestone with dolostone in lower part (Aptian to Cenomanian); 3 - Light grey and brown thick bedded dolostone (Early - Middle Triassic); 4 - Dark grey micritic, thin bedded limestone with conodonts, gastropods and bryozoans (Late Devonian-Early Carboniferous); 5 - Dark, thin to medium bedded partly reefal limestone and argillaceous limestone with shale (Carboniferous); 6 - Grey to dark thin bedded to massive limestone and shaly limestone (Permian); 7 - Red and light grey quartzite and calcareous sandstone (Early Permian); 8 - Red thin bedded limestone (Permian); 9 - Thin to medium bedded, partly vermiculated and oolitic, spar inter layer of argillaceous limestone (Late Triassic); 10 - Anticline.

NW-SE strike (Baghbani 1993). The Carboniferous sequence (614 m total thickness) is situated in the core of an asymmetric anticline (Fig. 3).

Lithostratigraphy of Asadabad section

Top to bottom the succession is as follows:

Surmaq Formation (528 m thickness)

2) Grey thin bedded to thick bedded limestone with thiny chert layers. In the uppermost part chert decreases, whilst thick bedded cliff-forming grey limestones are increasing, with abundant oncoliths (the alga *Girvanella permica* surrounding long fusulinids). Thickness 70 m. The presence of *Clarkina altudaenses* Kozur, 1992 and *Clarkina changxingensis* Wang & Wang, 1981 assignes it to the Permian, having ranges from Guadalupian to Lopingian.

1) Dark micritic thick-bedded limestone, intercalated to dolostones and chert nodules, increasing upward, rich in crinoids, gastropods (*Bellerophon*), bryozoans, and foraminifers (*Paleotextularia* sp., *Minojapanella* cf. *alongae*, *Parafusulina* sp., *Verbeekina* sp., *Neoschwagerina* cf. *margaritae*, *Pachyphloia* cf. *cukukoyi*). Thickness 458 m. Permian.

Vazhnan Formation (118 m thickness)

7) Thin bedded limestone with grey sandstone, 10 m-thick, in some parts containing *Schwagerina*, *Langella*, *Pseudoschwagerina*, *Triticites, Geinitzina*, *Tetrataxis*, *Planulata*. Asselian and Sakmarian (Early Permian).

6) Brown marly limestone, 11 m-thick, with *Toriyamaia laxiseptata* and abundant brachiopod fragments.

5) Micritic sandstone, 9 m-thick, with *Langella* sp. and brachiopods.

4) Bedded massive sandy limestone, 7.6 m-thick, containing *Globivalvulina* sp, *Hemigordius* sp., *Geinitzina postcarbonica, Nankinella orbicularia.*

4) Grey siltstone, 24 m-thick, rich in crinoids and brachiopods.

2) Bedded grey limestone, 54.5 m-thick, with sparite matrix and fractures containing crinoids, brachiopods and foraminifers (*Nankinella orbicularia*, *Pseudufusulina* sp, *Paleotextularia* sp.).

1) Basal conglomerate with red sandstone and grey sandy limestone, 1.9 m-thick.

Sardar Formation (total thickness 295 m)

18) 15 m thick an alternation of yellow limestone with dolostone; disconformably overlaid by the basal conglomerate of the Vazhnan Formation.

17) Oolitic limestone; 7 m-thick.

16) Alternation of grey sandy limestone and dolostone; 27 m-thick.

15) Oolitic limestone; 6 m-thick.

14) limestone, rich of corals; 2 m thick.

13) Alternation of sandstone and shale; 12 m-thick.

12) Medium to thick bedded grey limestone intercalated with sandy limestone containing fish remains and shell fragments; 26 m-thick.

11) Yellow limestone with abundant crinoid stems (Crinoidal bed), fish remains, gastropod and brachiopod shells; 8 m-thick.

10) Conglomerate; 14 m-thick.

9) Thin to medium bedded brown limestone alternating with sandstone; 20 m-thick.

8) Grey sandy limestone alternating with shale and dolostone; 34 m-thick.

7) *4 m thick volcanic rocks- dyke.*

6) Red limestone alternating with shale and dolostone; 23 m-thick.

5) Medium to thick bedded intercalated with massive yellow limestone, with corals in abundance and few trilobites; 20 m-thick.

4) Yellow thin bedded sandstone intercalated with light shale; 24 m-thick.

3) Red thin bedded siltstone with goniatitids, brachiopods and crinoid stems; 10 m-thick.

2) Light sandy limestone with shell fragments; 20 m-thick.

1) Yellow to green thick bedded sandy limestone with small crinoid stems brachiopods, conodonts and shell fragments; 27 m-thick.

Shishtu Formation (thickness 315 m)

10) Brown to red shale with iron nodules; 18 m-thick.

9) Black limestone medium to thick bedded, containing shell fragments, brachiopods, and sponge spicules; 12 m- thick.

8) Green shale, thin to medium bedded, alternating with limestone containing brachiopods, small crinoid stems and holoturian remains; 58 m-thick.

7) Sandy limestone intercalated with shale, containing brachiopods, crinoid stems, bryozoans, conodonts and shell fragments; 30 m-thick.

6) Grey massive limestone alternating with thin bedded dolostone; 29 m-thick.

5) Grey thin bedded micritic limestone with shell fragments, gastropods and conodonts; 50 m-thick.

4) Dark grey limestone, medium bedded, with intercalation of dolostone; 25 m-thick.

3) Dark micritic limestone medium to thick bedded with conodonts and brachiopods; 40 m-thick.

2) Dark grey limestone with intercalation of thin to medium bedded dolostone; 33 m-thick.

1) Dark grey thin bedded micritic limestone, with conodonts, gastropods and bryozoans; 20 m-thick (Fig. 4).

The base of the section is covered by recent deposits.

In this paper we apply the name Sardar Formation for Upper Carboniferous succession, because we focused our study on the general depositional evolution in the studied area basing on our faunal data and their biostratigraphic interpretation. To clarify the relations with the Galeh Formation (formerly Sardar 1) and Absheni Formation (formerly Sardar 2) (Leven et al. 2006), was not the aim of this study.

The Permian part of Asadabad section is assigned to the Vazhnan and to the Surmaq Formation. Above an erosional surface, the transgressive sediments of Vazhnan Formation start with basal conglomerate, followed by red sandstones, sandy limestones, and siliceous sandstones. The conodont fauna is missing in Vazhnan Formation. The Vazhnan Formation (118 m) is conformably overlaid by the Surmaq Formation (528 m). According to Baghbani (1993) it spans from the Bolorian stage (*Pseudofusulina-Parafusulina* Zone) to the Upper Murgabian stage (*Neoschwagerina simplex* zone, *Eopolydiexodina douglasi* zone, *Neoschwagerina margaritae* zone). According to Fasihi (1999) in Asadabad section and Baghbani (1993) in Tang-e-Darchaleh section a gap can be traced between Vazhnan and Surmaq Formation.

Permian deposits crop out at the base with a basal conglomerate overlaying the Sardar Formation. The boundary between Sardar and Vazhnan formations is a disconformity.

Conodont biostratigraphy

Thirty productive levels allowed for identification of conodont zones, ranging from the early Tournaisian to near the top of Bashkirian (Lower *expansa-sulcata* to *sinuosus-delicatus* Zones and possibly *elongatus* Zone) (Fig. 5).

Early Tournaisian conodont standard zonation (Sandberg et al. 1978) is based on the distribution of siphonodellids, which characterize the pelagic facies and deep water habitats. Because no siphonodellids were found, we could correlate Iranian conodonts to

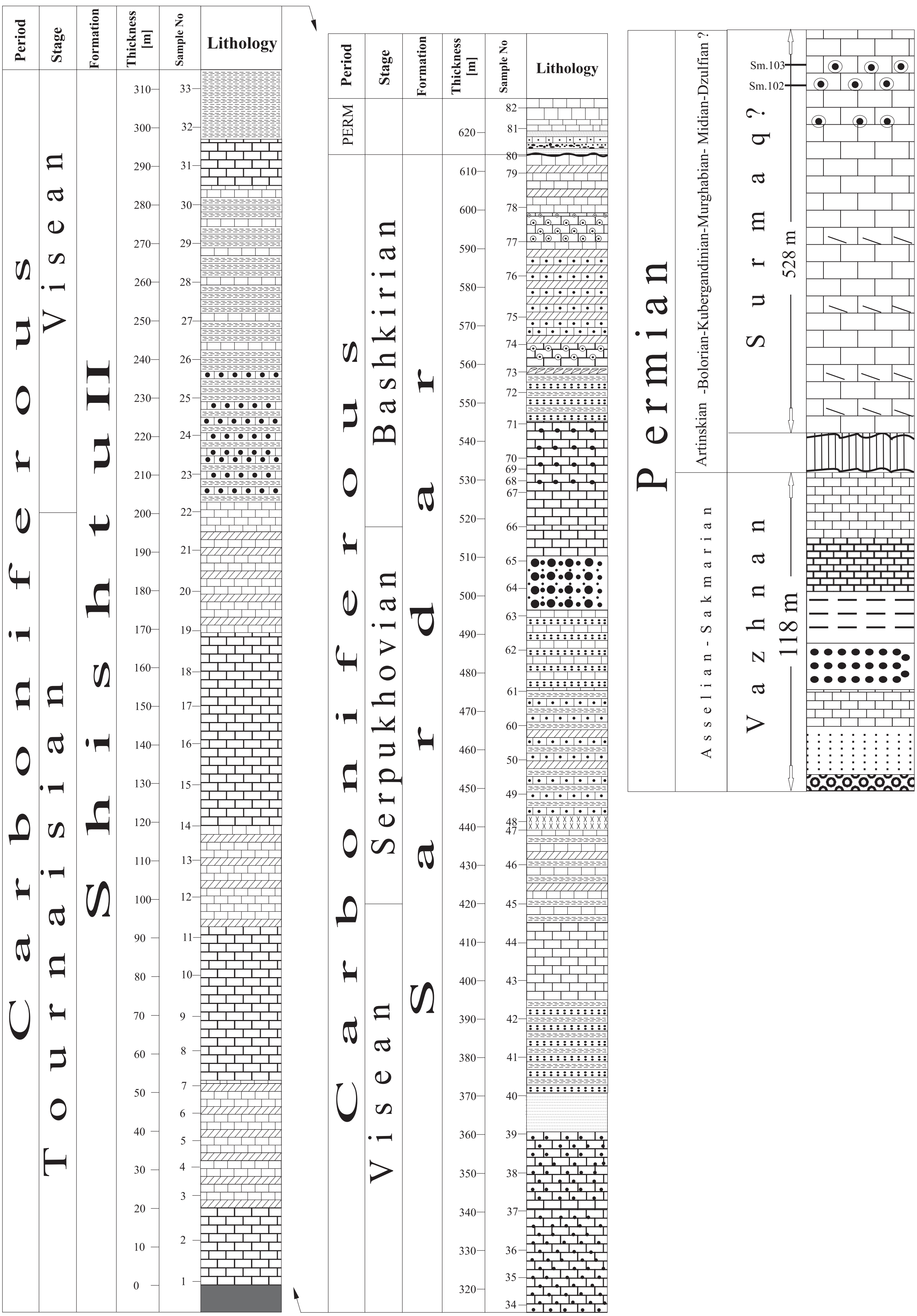

Fig. 4 - Stratigraphic log of the Asadabad section.

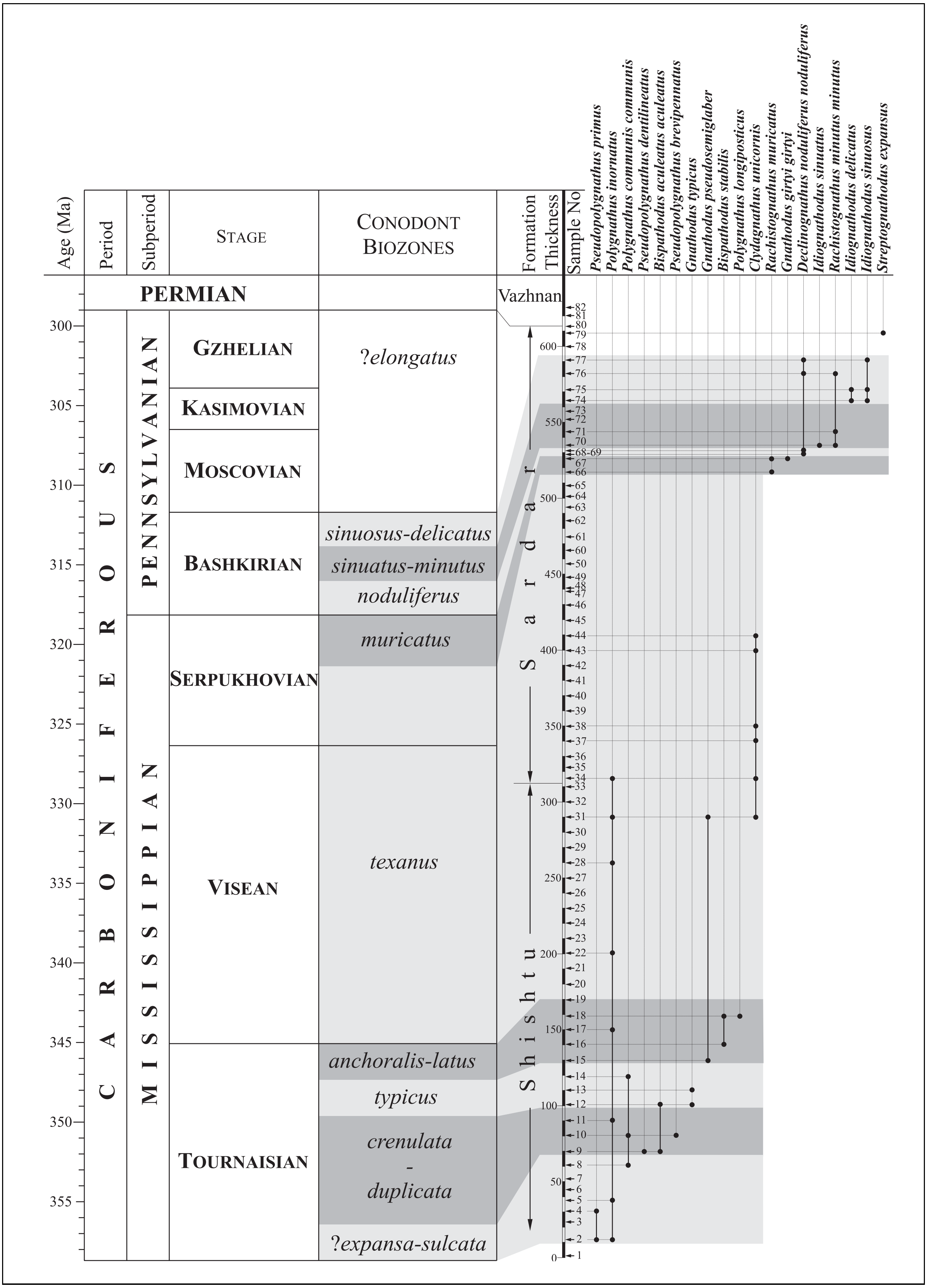

Fig. 5 - Conodont biozones of the studied section.

the standard zonation, by the presence of coeval *Polygnathus*, *Pseudopolygnathus*, *Bispathodus* and *Gnathodus* species.

?*expansa-sulcata* Zones

At 10 m above the base of the section from (sample 2) dark micritic limestone with gastropods and bryozoans, the following conodonts have been collected: *Pseudopolygnathus primus* Branson & Mehl, 1934, *Polygnathus communis communis* Branson & Mehl, 1934 and *Polygnathus inornatus* Branson, 1934. *Pseudopolygnathus primus* ranges from Lower *expansa* Zone, late Famennian (e.g., Klapper in Ziegler 1981) to Lower *crenulata* Zone and indicates *expansa-sulcata* zones for the basal 70 m of the Shishtu Formation. Lack of age-diagnostic conodonts precludes definite assignment to *expansa* or *sulcata* Zone. The late Famennian and earliest Tournaisian *expansa-sulcata* zones are recognized at the very base of the studied section comprising packets of micritic limestone and a packet with intercalations of thin bedded dolostone. The basal beds of the section are not cropping out, being under the recent clastic deposits.

Lower *duplicata* – Lower *crenulata* Zones

At 70 m above the base of the section in samples 9 and 10 from layers of limestone intercalated with thin bedded dolostone, have been obtained: *Polygnathus communis communis* Branson & Mehl, 1934, *Polygnathus inornatus* Branson, 1934, *Pseudopolygnathus dentilineatus* Branson, 1934 and *Bispathodus aculeatus aculeatus* (Branson & Mehl, 1934). *Bispathodus aculeatus aculeatus* ranges from Middle *expansa* to Lower *crenulata* Zones, *Pseudopolygnathus dentilineatus* ranges from Early *duplicata* to *typicus* Zones. The co-occurrent ranges of these taxa during the Lower *duplicata* – Lower *crenulata* Zones perhaps indicate the age of the interval between 70 m and 100 m in the Shishtu Formation.

typicus Zone

At 100 m above the base of the section in sample 12, and 10-20 m above in samples 13 and 14, the presence of *Gnathodus typicus* Hass, 1953 allows for the identification of the late Tournasian *typicus* Zone. The upper boundary of the zone could be placed by the first occurrence of *Gnathodus pseudosemiglaber* Thompson & Fellows, 1970. The *typicus* Zone comprises 30 m of dark to grey limestone with intercalations of dolostone.

anchoralis-latus Zone

Conodonts are collected from samples between 130 m and 170 m (samples 15-18) above the base of section in micritic limestone rich in shell fragments of brachiopods and gastropods and including numerous specimens of *Polygnathus inornatus* Branson, 1934, *Polygnathus communis communis* Branson & Mehl, 1934, *Bispathodus stabilis* (Branson & Mehl, 1934) and *Gnathodus pseudosemiglaber* Thompson & Fellows, 1970. The fauna do not include the zonal indexes *Scaliognathus anchoralis* Branson & Mehl and *Doliognathus latus* Branson & Mehl. The oldest occurrence of *Gnathodus pseudosemiglaber* is within the *anchoralis-latus* Zone just below the middle *anchoralis-latus* Zone and ranges through the *texanus* Zone. *Bispathodus stabilis* and *Polygnathus communis communis* complete their ranges at the end of the *anchoralis-latus* Zone. Considering the above, it appears that the age of the 40 m conodont-bearing interval is the latest Tournaisian *anchoralis-latus* Zone. Conodonts from between 290 m and 410 m (samples 31- 44) dramatically decreased in diversity, only a few specimens of *Clydagnathus* and *Polygnathus* occur. Due to the lack of index conodonts, Viséan and probably most of Serpukhovian can not be indentified in details, on the conodont base. The rare ammonoids including *Neoglyphioceras yazdii* and *Dombarites* sp. from a siltstone bed from 362 m to 372 m above the base of section indicate latest Viséan age (Hairapetian et al. 2006).

muricatus Zone

The presence of *Rhachistognathus muricatus* (Dunn, 1965) at 520 m from the base of the section and *Gnathodus girtyi girtyi* Hass, 1953 from sample 67 at 525 m indicate *muricatus* Zone assigned to the Serpukhovian, just below the Pennsylvanian. This zone is about 7 m thick.

noduliferus Zone

Conodonts from between 527 m and 538 m above the base of the section are *Declinognathus noduliferus noduliferus* (Ellison & Graves, 1941). The first occurrence of *Declinognathus noduliferus noduliferus* at 527 m above the base defines the lower boundary of *noduliferus* Zone. The upper boundary coincides with the lower boundary of the overlying *sinuatus-minutus* Zone. *Noduliferus* Zone consists of fossiliferous limestone and sandy limestone yielding fish micro-remains, gastropods, brachiopod shells. It coincides with a change of the environment and a sea level rise. This interval is thin in thickness, only about 10 m.

sinuatus-minutus Zone

At 538 m from the base of the section sample 70 produced: *Rhachistognathus minutus minutus* (Higgins & Bouckaert, 1968), *Idiognathoides sinuatus* Harris and Hollingsworth, 1933, suggesting the *sinuatus-minutus* Zone. Stratigraphic occurrences of *Rhachistognathus minutus minutus* and *Idiognathoides sinuatus* are from the base of *sinuatus-minutus* into *sinuosus* zones (Bashkirian). This zone comprises a packet of 30 m thick, between 538 m and 565 m from the base of the section, with thick bedded grey limestone, intercalated sandy limestone, yielding fish remains and shell fragments.

A crinoidal limestone horizon is easily traceable in the area. This key bed, at 511-519 m from the base of the studied section, is well known in other parts of Iran such as: central of Iran - Kerman Province (Webster et al. 2003); Anarak (Korn et al. 1999), Tabas or Shotori range (east Iran), (Webster et al. 2000), and a section close to Ramsheh or Darchaleh area (Rabie 2003). This horizon is referred to the *sinuatus-minutus* Zone - late Bashkirian.

sinuosus-delicatus Zone

Idiognathodus sinuosus Ellison & Graves, 1941 ranges from 565 m (sample 74) to 590 m (sample 77) from the base of the section. *Idiognathodus delicatus* Gunnell, 1931 co-occurs in samples 74 and 75. This zone is defined on the base of the both species ranges and comprises a packet of alternating sandy limestone with dolostone and a thin packet of oolitic limestone.

elongatus Zone

Streptognathodus expansus Igo & Koike, 1964 is the youngest Carboniferous species found in the section from sample 79 at 610 m from the base of the section. Because of lack of more conodonts below the Permian cover in the studied section, we tentatively assign the interval comprising the sediments between 565 m and 610 m from the base, to the *elongatus* Zone (Late Pennsylvanian).

Biofacies and environment

The Asadabad section was deposited in shallow-marine environments, rich in marine macrofauna, belonging to a goniatites/brachiopods biofacies and accompanied by crinoids, corals, rare trilobites and fish or microvertebrate remains. These fossil associations are assigned to the upper slope and outer shelf environment.

Most of the Tournaisian conodont faunas (Fig. 6) ranging in *expansa-sulcata, duplicata-crenulata, typicus and anchoralis-latus* Zones, are dominated by species of *Polygnathus* and *Bispathodus*. No *Siphonodella* elements have been found. According to Sandberg & Ziegler (1979) and Ziegler et al. (1990) the conodont biofacies are not applied to mixed faunas, in which two platform genera do not constitute at least 70% of the population. By the presence of more than 57% of specimens of *Polygnathus* (*P. longiposticus, P. communis, P. inornatus*) and specimens of *Bispathodus (Bi. stabilis, Bi. aculeatus)* in less percentages – 15%, as well as the concomitant specimens of *Pseudopolygnathus* 21% and *Gnathodus* 7% we could recognize polygnathid-bispathodid biofacies. Ziegler & Sandberg (1984) associated *Bispathodus* group with a habitat in euphotic zone in the highest part of the water column but nevertheless they are common in the nearshore, restricted biofacies as well as *P. communis communis* and *P. inornatus* are considered as ubiquitous. *Bispathodus stabilis* is the only species of any platform genus that is apparently ubiquitous (Sandberg 1976). The number of conodont elements per sample is however low in contrast to the macrofauna. This part of the section is dominated by several fossil groups, inhabiting shallow waters and moderate energy environments in normal salinity conditions.

Concerning the Late Carboniferous conodont fauna, Pennsylvanian associations are relatively well represented and reflect a shallow, near-shore, moderate energy environments similar to those during Early Carboniferous. *Declinognathus noduliferus* is presenting in possible conditions of moderate to high energy environments with water of normal salinity in Pennsylvanian. Idiognathodids dominate in the uppermost part of the section, suggesting higher salinity environment, documented in the interval from 540 to 600 m. They co-occur with idiognathodids and streptognathodids assigned to ubiquitous *Idiognathodus-Streptognathodus* biofacies and considered by Sweet (1988) as ubiquitous of environments intermediate between the shallow, well oxygenated near shore waters and the much deeper water. Co-occurrence of gnathodids with rachistognathids and declinognathids in the upper part of the section (from 520 m) could suggest deepening in the marine environment. Statistically, the conodonts from the upper part of Sardar Formation show low abundance and are not informative for conodont biofacies analysis.

The better markers are observed in the oolitic limestones in Sardar Formation from this interval, suggesting high-energy environments of oolitic shoals and not deeper than the outer ramp.

Discussion and conclusions

Comparing the conodont biofacies and fusulinids microfacies from the same section could reveal aspects of the paleoenvironment during the Carboniferous and Early Permian in the studied area (Baghbani 1993). According to Flügel (2004) the fusulinids were adapted to shallow warm and warm-temperate waters, platforms and reefs. They lived in normal marine, well-oxygenated environments on subtidal open shelves, in depths between a few meters to a few tens of meters. Carboniferous and early Permian fusulinids are particularly common in bedded medium to light grey grainstones,

Meters above base of section	12	30	37	60	70	80	90	100	110	120	130	140	150	160	200	260	290	315	340	350	400	410	518	525	530	532	535	545	565	570	583	592	610
Sample number	2	4	5	8	9	10	11	12	13	14	15	16	17	18	22	28	31	34	37	38	43	44	66	67	68	69	70	71	74	75	76	77	79
Sample Wt. (kg)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Conodont taxa																																	
Pseudopolygnathus primus	5	7																															
Polygnathus inornatus	9		7				7						7		6	3	4	1															
Polygnathus communis communis				6		5				8																							
Pseudopolygnathus dentilineatus					3																												
Bispathodus aculeatus aculeatus					6			4																									
Pseudopolygnathus brevipennatus						4																											
Gnathodus pseudosemiglaber											2						1																
Bispathodus stabilis												2		2																			
Gnathodus typicus								2	2																								
Plygnathus longiposticus														3																			
Clydagnathus unicornis																	2	2	1	1	2	2											
Rachistognathus muricatus																							4	3									
Declinognathus noduliferous noduliferous																									2	2					3	4	
Gnathodus girtyi girtyi																								2									
Idiognathodus delicatus																													1	2			
Idiognathodus sinuosus																													1	2		1	
Idiognathodus sinuatus																											2						
Rachistognathus minutus minutus																											2	1			2		
Straptognathodus expansus																																	1
Total	**14**	**7**	**7**	**6**	**9**	**9**	**7**	**6**	**2**	**8**	**2**	**2**	**7**	**5**	**6**	**3**	**7**	**3**	**1**	**1**	**2**	**2**	**4**	**5**	**2**	**2**	**4**	**1**	**2**	**4**	**5**	**5**	**1**

Fig. 6 - Number of conodont specimens from each sample in the Asadabad section.

packstones and wackestones deposited on shallow carbonate shelves, banks and platforms. They mark specific levels in cyclic sucessions but are rare to absent in oolitic limestones.

The percentage of siliciclastic sediments (high percentage in siliceous sand or grains) is increasing across the Carboniferous/Permian boundary in the area. Predominately high energy is characteristic of near shore sediments such as oolitic and oncolitic, or oncolitic sandy limestone beds. A shoal complex was configured during the latest Carboniferous in the inner zone of a platform not deeper than outer ramp and marked the beginning of the regression stage of the platform. An eroded surface or disconformity is present between the Upper Carboniferous and Permian sediments in the area. This event may be related to the epirogenetic movement and uplifting phenomena close to the Carboniferous - Permian boundary in the studied area.

The presence of oolitic limestones in Sardar Formation at two levels: 7 m thick layer (592-599 m) and 6 m thick layer (559-565 m) give evidence for more specific conditions. There are concentric ooids accumulated in marine shoal near an outer platform conditions, as well as radial ooids cortices which have been accumulated in restricted near-coast marginal-marine parts of a carbonate platform. Allochthonous accumulations occur in turbidites and debris flows deposited on slopes and in basin. The studied ooids exhibit distinct structures and probably have different places of accumulation. Ooid-rich limestones like these were originally regarded as formed in high-energy environments of oolitic shoals, tidal bars and not deeper than the outer ramp (Flügel 2004). We consider this part of Iranian platform as formed in the subtidal flat zone of the basin in shoals, characterized by high energy, near-shore conditions. The Devonian carbonate platform persisted with shallow marine sedimentation during Carboniferous and Permian times, continuing its broad depositional environment.

The presence of Carboniferous and Permian sequence in shallow marine depositional environment gives evidences of a formerly widespread marine not only in Lower, but in Upper Carboniferous sedimentary wedge. The gradual transition and the lithologic similarity between the Upper Devonian and the Lower Carboniferous show that the depositional regime remained virtually unchanged. Evidences for the carbonate flat can be found over bigger part of Central Iran and also in Pakistan and Afghanistan (Khan et al. 2004). Asadabad section was deposited in high energy shallow-marine conditions rich in macrofauna. Conodont faunas are of low diversity, but very well preserved. Upper Carboniferous sediments produced conodonts with CAI (Color Alteration Index) between CAI 2 and 4.5. In Central and Eastern Iran, CAI of Devonian-Permian conodonts fall into the oil and gas window. As a result of examination of the depositional history of the Shishtu and Sardar Formations of Iran it became apparent that the Carboniferous succession in Asadabad section is fairly complete, in spite of the emergences during Serpukhovian as well as in late Bashkirian and in the Kasimovian. This could be the reason of the gaps in Bashkirian and Gzhelian.

Systematic palaeontology

All specimens figured in this paper are housed in the collections of University of Isfahan - Iran. Their museum codes EUIC are mentioned in the plate as well as the magnification.

Phylum **Conodonta** Pander, 1856
Order **Conodontophorida** Eichenberg, 1930
Genus *Bispathodus* Müller, 1962
Type species: *Spathodus spinulicosatus* E. R. Branson, 1934

Bispathodus aculeatus aculeatus
(Branson & Mehl, 1934)
Pl. 3, figs 7, 8

1934 *Spathodus aculeatus* Branson & Mehl, p. 186, pl. 7, figs 11, 14.
1962 *Spathodus aculeatus* – Ziegler, p. 105, pl. 13, figs 27, 31-36.
1969 *Spathognathodus* cf. *S. aculeatus* – Druce, p. 124, pl. 27, fig. 5.
1970 *Spathognathodus tridentatus* – Austin, Conil, Rhodes & Streel, pl. 1, fig. 3.
1974 *Bispathodus aculeatus aculeatus* – Ziegler, Sandberg & Austin, p. 101, pl. 3, fig. 18.
1979 *Bispathodus aculeatus aculeatus* – Nicoll & Druce, p. 21, pl. 22, figs 6,7.
1983 *Bispathodus aculeatus aculeatus* – Wang & Ziegler, pl. 7, fig. 3.
1997 *Bispathodus aculeatus aculeatus* – Molloy et al., pl. 1, fig. 7.
2000 *Bispathodus aculeatus aculeatus* – Capkinoglu, p. 98, pl. 3, fig. 5.

Remarks. A subspecies of *Bispathodus aculeatus* having three accessory denticles above the basal cavity on the right side of the blade.

Stratigraphic range. This subspecies is worldwide and is long ranging from the Middle *expansa* (late Famennian) to the *duplicata* Zone (middle Tournaisian) and to *crenulata* Zone according to Ziegler et al. (1974).

Regional occurrence. Shishtu Formation, samples 9, 12.

Bispathodus stabilis (Branson & Mehl, 1934)
Pl. 5, figs 5a-b, 6, 7

1934 *Spathodus stabilis* Branson & Mehl, p. 188-189, pl. 17, fig. 20.

1969 *Spathognathodus stabilis* – Schönlaub, p. 349, pl. 3, figs 14, 15.
1974 *Bispathodus stabilis* – Ziegler et al., p. 103-104, pl. 3, figs 2, 3.
1985 *Bispathodus stabilis* – Hou et al. p. 144, pl. 40, figs 11-13.
1992 *Bispathodus stabilis* – Over, pl. 6, figs 1, 16, 21, 26, 28.
1997 *Bispathodus stabilis* – Mawson & Talent, pl. 1, figs 6a, b, pl. 10, figs 6, 7, 8, 9a, b, 10.
1999 *Bispathodus stabilis* – Mawson & Talent, p. 412, pl. 1, figs 1-6.
2000 *Bispathodus stabilis* – Capkinoglu, pl. 4, figs 12, 13, 16.

Remarks. The illustrated specimens of *Bispathodus stabilis* haven't got accessory denticles on the right side of the blade and display differences between the shapes of their basal cavities belonging to Morphotype 1 or 2 (sensu Ziegler et al. 1974). The Iranian specimens are very similar to the type exemplars described in the original diagnosis and are ssigned to Morphotype 1 having a large basal cavity, with small extensions on each side of the blade (pl. 5, fig. 6; 7). *Bispathodus stabilis* Morphotype 2 (pl. 5, fig. 5 a, b) is with extensions of basal cavity reaching the posterior tip of the blade.

Stratigraphic range. In Ziegler & Sandberg (1984, fig. 4) *Bi. stabilis* Morphotype 1 ranges from the base of the Upper *marginifera* Zone of Famennian to the Upper *crenulata* Zone of Tournaisian; *Bi. stabilis* Morphotype 2 ranges from the base of Lower *expansa* Zone within late Famennian through the *crenulata* Zone in middle Tournaisian and in the *texanus* Zone (Early Viséan). Iranian specimens are only from *anchoralis-latus* Zone.

Regional occurrence. Shishtu Formation, samples 16, 18.

Genus *Declinognathus* Dunn, 1970

Type-species: *Cavusgnathus nodulifera* Ellison & Graves, 1941

Declinognathus noduliferus noduliferus

(Ellison & Graves, 1941)

Pl. 1, figs 2, 3, 5, 8, 10, 11; Pl. 2, figs 1, 2, 5, 11, 14

1941 *Cavusgnathus nodulifera* Ellison & Graves, p. 4, pl. 3. fig. 4 [non fig. 6].
See Lane & Straka, 1974, p. 85 synonymy until 1970.
1970 *Idiognathoides noduliferus* – Thompson, p. 1046, pl. 139, figs 2, 3, 5, 6, 8, 16, 20.
1974 *Idiognathoides noduliferus* – Lane & Straka, p. 85-87, fig. 35: 1-15; fig. 41: 15-17.
1975 *Declinognathus noduliferus* – Ziegler, p. 63, pl. 1, fig. 6.
1980 *Idiognathoides noduliferus* – Bender, p. 12, pl. 1, figs 3, 8-16.
1985 *Idiognathoides noduliferus* – Savage & Barkley, p. 1466. figs 9, 1-8.
1985 *Declinognathus noduliferus* – Weyant, pl. 6, figs 8-11.
1985 *Declinognathus noduliferus* – Higgins, p. 216, pl. 6. 3. fig. 7.
1990 *Declinognathus noduliferus* – Grayson et al., pl. 1, figs 21, 22.
1990 *Declinognathus noduliferus noduliferus* – Gibshman & Akhmetshina, pl. 5, figs 7, 8.
1992 *Declinognathus praenoduliferus* Nigmadganov & Nemirovskaya - p. 262, pl. 2, figs 10-13, pl. 3, figs 1, 2.
1993 *Declinognathus noduliferus noduliferus* – Ji & Ziegler, p. 182, pl. 45, figs 1-4.
1996 *Declinognathus noduliferus noduliferus* – Krumhardt, Harris & Watts, p. 37-38, pl. 3, figs 10-14.

Remarks. For more detailed synonymy see in Krumhardt et al. (1996). The Iranian specimens resemble the figured type specimens of *Declinognathus praenoduliferus* Nigmadganov & Nemirovskaya, but they differ in having very short parapets, weakly developed at the anterior part of the platform. The outer platform is more strongly impressive, ornamented by transverse ridges whereas the inner platform is reduced to the 1-3 large separate nodes at the anterior part. The carina does not reach the posterior end, discontinuing after fusing with the inner platform and replaced by weak trough mediating between the transverse ridges to the very end of the platform.

Stratigraphic range. According to Krumhardt, Harris & Watts (1996) the known stratigraphic range is from earliest Morrowan (base of *noduliferus-primus* Zone) to early Desmoinesian (?). In Nigmadganov & Nemirovskaya (1992) it ranges in Bashkirian (early *Homoceras* Zone). Bed by bed sampling method for conodonts from the boundary stratotype section at Stonehead Beck (Cowling, North Yorkshire, England) confirms that the middle Carboniferous boundary should be placed at the first appearance of the *Declinognathus noduliferus* at the base of the *Declinognathus noduliferus* conodont Zone, which is correlated with *Eumorphoceras* and *Homoceras* ammonoid zones and miospore zone in Varker et al. (1990). Iranian specimens have occurrences within *noduliferus-primus* Zone, early Bashkirian.

Regional occurrence. Sardar Formation, samples 68, 69, 76 and 77.

Genus *Gnathodus* Pander, 1856

Type species: *Gnathodus mosquensis* Pander, 1856

Gnathodus girtyi girtyi Hass, 1953

Pl. 1, fig. 6; Pl. 2, fig. 6

1969 *Gnathodus girtyi girtyi* – Rhodes, Austin & Druce, p. 98, pl. 17, figs 9-12
1996 *Gnathodus girtyi girtyi* – Krumhardt, Harris & Watts, p. 40, pl. 2, figs 20-22.
1999 *Gnathodus girtyi girtyi* – Yazdi, p. 194, pl. 12, figs 9, 11, 12.

Remarks. For detailed synonymy see in Krumhardt et al. (1996). The Iranian exemplars have well-developed transversely ridged anterior inner parapet continuing close to the posterior end of the platform. The carina is straight to slightly deflected, central, and continues to the posterior end of the platform forming a tip.

Stratigraphic range. Iranian specimens are only from *muricatus* Zone.

Regional occurrence. Sardar Formation, samples 67.

Gnathodus pseudosemiglaber
Thompson & Fellows, 1970

Pl. 2, fig. 3, 13; Pl. 3, fig. 9

1980 *Gnathodus pseudosemiglaber* – Lane, Sandberg & Ziegler, p. 132, pl. 4, figs 15-17, 19, pl. 5, figs. 8-15.

1990 *Gnathodus pseudosemiglaber* – Ramovš, p. 93, pl. 1, figs. 1, 3, 7-9, 12, 15; pl. 2, figs 7, 9; pl. 4, figs 13, 14.

1999 *Gnathodus pseudosemiglaber* – Yazdi, p. 192, pl. 11, figs. 11, 13, 15, 16.

2004 *Gnathodus pseudosemiglaber* – Bermudes-Rochas, Sarmiento & Rodriguez, p. 56, pl. 5, figs 12, 13.

Remarks. For a detailed synonymy and discussion see Lane, Sandberg & Ziegler (1980) and Bermudes-Rochas et al. (2004). The characteristic elongated triangular cup reaching the posterior tip and the presence in the anterior part of a strong parapet parallel to the blade consisting of cross ridges very close to the elements described by Lane et al. (1980).

Stratigraphic range. The oldest occurrence of *Gnathodus pseudosemiglaber* is within the *anchoralis-latus* Zone just below the middle *anchoralis-latus* Zone and ranges trough the *texanus* Zone.

Regional occurrence. Shishtu Formation, samples 15, 31.

Genus *Idiognathodus* Gunnell, 1931
Type species: *Idiognathodus claviformis* Gunnell, 1931

Idiognathodus delicatus Gunnell, 1931
Pl. 6, figs 2a-b

1932 *Idiognathodus delicates* – Stauffer & Plummer, pl. 4, figs 4, 21, 24-26.

1941 *Idiognathodus delicatus* – Ellison, p. 134. pl. 22, figs 31-36.

1941 *Idiognathodus delicatus* – Ellison & Grave, pl. 3, figs 20-23.

1956 *Idiognathodus* cf. *delicatus* – Gabert, Stoppel & Vinken, pl. 47, fig. 9.

1967 *Idiognathodus delicatus* - Koike, pl. 2, figs 18-23.

1975 *Idiognathodus delicates* – Higgins, pl. 17, fig. 7; pl. 18, figs 1-3, 7.

1975 *Idiognathodus delicatus* – Ziegler, p. 169, figs 1 g, h.

1980 *Idiognathodus delicatus* - Bender, pl. 3, figs 4-8, 10, 11, 16, 28-31, 33, 38.

1985 *Idiognathodus delicatus* – Weyant & Massa, pl. II, figs 17-25.

1985 *Idiognathodus delicatus* - Savage & Barkley, pl. 8, figs 1-8, 4.

Remarks. For a detailed synonymy and discussion see in Ziegler (1975). Iranian specimens are close to revised description of Baesemann (1973): "Platform in upper view is long, lanceolate, and tapers posteriorly. Upper surface is ornamented by parallel transverse ridges, which may or may not be transected by a shallow trough. Accessory nodes and lobes may be present. Free blade is long and widest at base of the denticles; it bears 10 or more laterally compressed fused denticles, which are free at the tips. Carina extends only a short distance onto platform. Large flaring basal cavity extends anteriorly as groove along the lower surface of the free blade".

Stratigraphic range. According to Ziegler (1975) this species has its stratigraphic occurrence from the base of *sinuatus-minutus* Zone into *sinuosus* Zone (late Bashkirian). Iranian specimens are from *sinuosus-delicatus* Zone.

Regional occurrence. Sardar Formation, samples 74, 75.

Idiognathoides sinuatus Harris & Hollingsworth, 1933
Pl. 6, figs 3a-b

1967 *Idiognathoides sinuatus* – Lane, pl. 119, figs 1, 9, 12-15; pl. 123, figs 7, 8, 12.

1968 *Idiognathoides sinuatus* - Higgins & Bouckaert, pl.2, fig, 14, pl. 4, figs 5, 8, 9, pl. 5, fig. 11.

1970 *Idiognathoides sinuatus* - Dunn, p. 335, pl. 63, figs 14, 15, 21-23.

1974 *Idiognathoides sinuatus* - Lane & Straka, fig. 37: 14, 15, 18, 20, 23, 26; fig. 41: 1-4, 20-27.

1975 *Idiognathoides sinuatus* - Higgins, pl. 16, figs 1-7, 9-14; pl. 15, figs 11, 16; pl. 14, figs 4, 5, 6; pl. 13, fig.15.

1980 *Idiognathoides sinuatus* - Bender, pl. 1, figs 17-33.

1985 *Idiognathoides sinuatus* – Rexroad & Merrill, pl. 4, figs 1-10.

1990 *Idiognathoides sinuatus* - Grayson et al., pl. 1, figs 26-27, pl. 2, fig.1.

1992 *Idiognathoides sinuatus* - Nigmadganov & Nemirovsskaya, pl. 5, figs 4, 5.

1996 *Idiognathoides sinuatus* - Krumhardt, Harris & Watts, pl.5, figs 22.

1999 *Idiognathoides sinuatus* – Yazdi, pl. 12, figs 5-7.

Remarks. Illustrated specimen has a platform with two ridged parapets separated by a shallow groove reaching the posterior end of the platform. The margin of outer side of the platform is slightly convex near to the posterior end and is widest near the anterior end. The platform surface is gently convex and bears transverse ridges which may be fused to those of the inner side or they may terminate abruptly at the median groove. The outer and inner sides of the platform continue to the blade end, forming 1-2 narrow sharp and joined ridges at the end. Outer platform is higher than the inner one.

Stratigraphic range. According to Grayson et al. (1990, p. 335, fig. Z) *Idiognathoides sinuatus* ranges from the Morrowan (Namurian) to Early Desmoinesian. Stratigraphic occurrence is from the base of *sinuatus-minutus* Zone into *sinuosus* Zone (late Bashkirian). Iranian specimens are only from *sinuatus-minutus* Zone.

Regional occurrence. Sardar Formation, sample 70.

Idiognathodus sinuosus Ellison & Graves, 1941

Pl. 6, figs 1a-b, 4a-b, 5a-b

1941 *Idiognathodus sinuosus* Ellison & Graves, pl. 3, 22.
1970 *Idiognathodus sinuosus* – Dunn, p. 333, pl. 63, figs 3, 4.
1974 *Idiognathodus sinuosus* – Lane & Straka, fig. 37: 10-13, 21; fig. 42: 1-11; fig. 43: 1-8, 10-15, 19, 20.
1980 *Idiognathodus sinuosus* – Bender, pl. 3, figs 17-19.
1990 *Idiognathodus sinuosus* – Grayson et al., pl. 4, figs 36-39.
1996 *Idiognathodus sinuosus* – Krumhardt et al., p. 44, pl. 3, figs 15-18, 23-25.

Remarks. Iranian specimens are referred to *Idiognathodus sinuosus* Ellison & Graves following the concept about the species – long platform, slender, curved inward and posteriorly pointed in aboral view; accessory lobe only on the inner margin and positioned anteriorly to the junction of the blade and platform. Transverse ridges on the aboral surface of the platform are tilted downward towards inner margin. Oral surface ornamented with 8-10 parallel transverse ridges complete from one margin to the other, normal or slightly oblique to axis. Blade of average length ending abruptly against the first continuous transverse ridge; set off from the platform on either side by deep, laterally constricted sulci, so that lateral margins of the anterior portion of the platform extend as free edges.

According to Krumhardt et al. (1996) and Grayson et al. (1990, p. 335, fig. Z) *Idiognathoides sinuosus* ranges from the Morrowan (Namurian) to the Lower Atokan. Stratigraphic occurrence is from the base of *sinuatus-minutus* Zone to at least Late Pennsylvanian in Asadabad section.

Regional occurrence. Sardar Formation, samples 74, 75, 77.

Genus *Polygnathus* Hinde, 1879

Type species: *Polygnathus dubius* Hinde, 1879

Polygnathus communis communis Branson & Mehl, 1934

Pl. 5, figs 1a-b, 2, 3, 4

1934 *Polygnathus communis* Branson & Mehl, p. 293, pl. 24, figs 1-4.
1979 *Polygnathus communis communis* – Sandberg & Ziegler, p. 188, pl. 2, figs 1-9.
1981 *Polygnathus communis communis* – Metcalfe, pl. 9, figs a,b.
1985 *Polygnathus communis communis* – Higgins, pl. 5. 1, figs 12, 16, 17.
1986 *Polygnathus communis communis* – Belka & Groessens, pl. 3, figs 3-4.
1991 *Polygnathus communis communis* – Johnston & Chatterton, p. 171, pl. 2, figs 11-12.
1993 *Polygnathus communis communis* – Nemirovskaya et al., pl. 3, figs 12, 15, 19-21.
1993 *Polygnathus communis communis* – Wang, p. 231, pl. 40, fig. 13, pl. 41, figs 11a, b, 12a, b.
1993 *Polygnathus communis communis* – Ji & Zeigler, p. 76, pl. 35, figs 7-12.
1994 *Polygnathus communis communis* – Pickett, p. 54, fig. 2.2.
1999 *Polygnathus communis communis* – Yazdi, pl. 7, figs 7, 13, 15.

Remarks. Typical representatives of *Polygnathus communis communis* with simple unornamented platform and a basal cavity commonly located at the upper anterior end of the platform.

Stratigraphic range. From within the Middle *crepida* Zone into the *anchoralis-latus* Zone (late Tournaisian).

Regional occurrence. Shishtu Formation, samples 8, 10, 14.

Polygnathus inornatus Branson, 1934

Pl. 4, figs 1, 2 a-b; 3, 4, 5 a-b; 6, 7, 9 a-b, 10 a-b.

1934 *Polygnathus inornata* Branson - Branson & Mehl, p. 293, pl. 24, figs 5, 6, 7.
1971 *Polygnathus inornata sensu* Branson & Mehl - Klapper, p. 7, pl. 1, figs 11, 12.
1974 *Polygnathus* cf. *inornatus* – Gedik, p. 19, pl. 4, figs 16, 17.
1975 *Polygnathus inornatus* – Ziegler, p. 293, pl. 4, figs 1, 2, 4.
1982 *Polygnathus inornatus* – Wang & Ziegler, pl. 1, fig 21.
1984 *Polygnathus inornatus* – Austin & Davies, pl. 1, figs 25-28.
1985 *Polygnathus inornatus* – Weyant, p. 365, tab 5.
1985 *Polygnathus inornatus* – Hou et al., p. 114, pl. 32, figs 15-18.
1986 *Polygnathus inornatus* – Belka & Groessens, pl. 3, figs 8-10.
1993 *Polygnathus inornatus* – Wang, p. 232, pl. 41, figs 3a, b.
1995 *Polygnathus inornatus* – Zhuravlev & Tolmacheva, p. 320-321, Tab 6, Text- fig. 6.
1996 *Polygnathus inornatus* – Yazdi, p. 137-138, pl. 8, figs 1-5.
1999 *Polygnathus inornatus* – Mawson & Talent, pl. 5, figs 1-2, 7-8, 11, 14.
2000 *Polygnathus inornatus* – Capkinoglu & Gedik, pl. 2, figs 1-2.

Remarks. For a detailed synonymy and discussion see Ziegler (1975). For discussion about the species see Klapper (1971).

Stratigraphic range. According to Ziegler & Sandberg (1984) the stratigraphic range is in the Early Carboniferous from the top of the Upper *expansa* Zone.

Regional occurrence. Shishtu Formation, samples 2, 5, 11, 17, 22, 28 and 31. Sardar Formation, sample 34.

Polygnathus longiposticus Branson & Mehl, 1934

Pl. 4, figs 8 a-b, 11 a-b

1934 *Polygnathus longipostica* Branson & Mehl, p. 294, pl. 24, figs 8-11.
See Ziegler, 1975, p. 304 for synonymy to 1973.
1975 *Polygnathus longiposticus* – Ziegler, p. 303, pl. 6, fig. 1.
1986 *Polygnathus longiposticus* – Belka & Groessens, pl. 3, figs 11-15.
1987 *Polygnathus longiposticus* – Wang, pl. 3, fig. 4.
1991 *Polygnathus longiposticus* – Barskov et al., p. 27, pl. 7, figs 12-15.
1999 *Polygnathus longiposticus* – Yazdi, p.189, pl. 8, fig. 18.

Remarks. Illustrated exemplars are very close to original description of Branson & Mehl (1934). For a detailed synonymy and discussion see in Ziegler (1975).

Stratigraphic range. Early Carboniferous, Lower *crenulata* to *anchoralis-latus* zones. Iranian specimens are only from *anchoralis-latus* zones.

Regional occurrence. Shishtu Formation, sample 18.

Genus *Pseudopolygnathus* Branson & Mehl, 1934

Type species: *Pseudopolygnathus primus* Branson & Mehl, 1934

Pseudopolygnathus dentilineatus E. R. Branson, 1934

Pl. 3, fig. 6

1934 *Polygnathus dentilineata* Branson - Branson & Mehl, p. 317, pl. 26, fig. 22.
1963 *Pseudopolygnathus dentilineata* – Ziegler, pl. 2, figs 10, 11.
1973 *Pseudopolygnathus dentilineatus* – Szulczewski, p. 44, pl. 5, figs 5, 6.
1992 *Pseudopolygnathus denticulineatus* – Carls & Gong, p. 220, pl. 6, fig. 11.
1993 *Pseudopolygnathus dentilineatus* – Ji & Ziegler, p. 178, pl. 43, fig. 18.
2000 *Pseudopolygnathus dentilineatus* – Capkinoglu, p. 99, pl. 3, fig. 6.

Remarks. A psudopolygnathid species with asymmetric platform and ornamented by irregular nodes 1-2 more on the right platform than on the left one. The carina extends beyond the posterior extremity of the platform bearing 5- 6 fused denticles.

Stratigraphic range. Lower *duplicata* Zone.

Regional occurrence. Shishtu Formation, sample 9.

Pseudopolygnathus primus Branson & Mehl, 1934

Pl. 3, figs 11a-b, 12, 13

1934 *Pseudopolygnathus prima* Branson & Mehl, p. 298, pl. 24, figs 24, 25.
1959 *Pseudopolygnathus prima* – Hass, pl. 49, fig 14.
1966 *Pseudopolygnathus prima* – Klapper, p. 14, pl. 4, fig 8.
1969 *Pseudopolygnathus primus* – Rhodes, Austin & Druce, p. 214, pl. 6, figs 4, 5, 7, 10-12.
1993 *Pseudopolygnathus primus* – Ji & Ziegler, p. 178, pl. 43, fig. 19.
1997 *Pseudopolygnathus primus* -Molloy et al., pl. 9, figs 4a, b, c, 5a, b, c, 6a, b, c, 7a, b, 8a, b.
2004 *Pseudopolygnathus primus* – Piecha, p. 259, pl. 2, figs 1-8.

Remarks. For a detailed synonymy list see Ziegler (1981). This species is extremely variable, but regarded as intraspecific variations, having an asymmetric platform, ornamented by nodes or ridges on the outer and inner platform and with the shape of the basal cavity. Ziegler (1981) defined two morphotypes of *Pseudopolygnathus primus*: based on their pits - the Late Devonian specimens have a large pit, whereas the Early Carboniferous specimens have a small pit. In Iranian specimens the small pit is surrounded by widely opened basal extensions.

Stratigraphic range. Lower *expansa* Zone (Klapper in Ziegler 1981) to Lower *crenulata* Zone (Sandberg et al. 1978).

Regional occurrence. Shishtu Formation, samples 2, 4.

Genus *Rhachistognathus* Dunn, 1966

Type species: *Rhachistognathus prima* Dunn, 1966

Rhachistognathus minutus minutus (Higgins & Bouckaert, 1968)

Pl. 1, figs 1, 7; Pl. 2, fig. 4

1996 *Rhachistognathus minutus minutus* – Krumhardt, Harris & Watts, p. 48, pl. 4, figs 13-15.

Remarks. Iranian specimens correspond to the description and figures given in Krumhardt et al. (1996).

Stratigraphic range. From the base of *sinuatus-minutus* Zone, but below the mid-Carboniferous boundary to *sinuosus* Zone (late Serpukhovian).

Regional occurrence. Sardar Formation, samples 70, 71, 76.

Rhachistognathus muricatus (Dunn, 1965)

Pl. 2, figs 8, 10, 12

1965 *Cavusgnathus muricatus* Dunn, p. 1147-1148, pl. 140, figs 1, 4.
See Tyan, 1980, pp. 1303-1304, for synonymy to 1980.
1980 *Rhachistognathus muricatus* - Metcallfe, p. 308, pl. 38, figs 24, 25.
1985 *Rhachistognathus muricatus* - Weyant, Tab. 5, pl. 6, figs 16-20.

1985 *Rhachistognathus muricatus* - Weyant & Massa, pl. 1, figs 10-13.

1999 *Rhachistognathus muricatus* - Yazdi, p. 186, pl. 6, figs 8-11.

Remarks. This species is assigned to *Rhachistognathus* because its morphologic characteristics conform more closely to those of *R. primus*, the type of the genus, than to those of either *Adetognathus* or *Gnathodus* (Dunn, 1970).

Stratigraphic range. At the base of *muricatus* Zone in late Serpukhovian to the base of Pennsylvanian.

Regional occurrence. Sardar Formation, samples 66 and 67.

Genus *Streptognathodus* Stauffer and Paummer, 1932

Type species: *Streptognathodus excelsus* Stauffer and Paummer, 1932

Streptognathodus expansus Igo & Koike, 1964

Pl. 1, figs 4 a-b

1964 *Streptognathodus expansus* Igo & Koike, pl. 6, figs 3a, b.

1964 *Idiognathodus togashii* Igo & Koike, pl. 28, figs 1-4.

1967 *Streptognathodus expansus* – Koike, pl. 3, figs 6, 8, 16, 17.

1970 *Streptognathodus expansus* – Dunn, p. 339, pl. 62, figs 18-20.

1974 *Streptognathodus expansus* – Lane & Straka, figs 34: 9, 16-18, 21-26.

1996 *Streptognathodus expansus* – Webster, pl. 6, figs 1-5.

Remarks. A slitlike median trough generally from the posterior end of the carina to near the posterior tip of the platform. In some cases this slitlike trough is present only in the posterior one – third of platform. Koike (1967, Pl. 3, figs 7, 17) figured several right – side specimens and referred to *Streptognathodus expansus*. One figured specimen (7a, b) has a V-shaped upper outline in lateral view, and another (17a, b) processes as a very narrow platform. These two figured specimens are excluded from *S. expansus* (Lane & Straka 1974). *Idiognathodus togashii* reported by Igo & Koike from Omi limestone is synonym of *Strepthognathdus expansus* Igo & Koike.

Stratigraphic range. Early Pennsylvanian to Permian.

Regional occurrence. Sardar Formation, sample 79.

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PLATE 1

All magnifications are X 80

Figs 1, 7 - *Rhachistognathus minutus minutus* (Higgins & Bouckaert, 1968). Sardar Formation, samples 70, 71. Fig. 1 - sample 70 - EUIC 9463; fig. 7 - sample 71 - EUIC 9469.

Figs 2, 3, 5, 8, 10, 11 - *Declinognathus noduliferus noduliferus* (Ellison & Graves, 1941). Sardar Formation, samples 68, 69, 76, 77. Fig. 2 - sample 76 - EUIC - 9464; fig. 3 - sample 76 - EUIC 9465; fig. 5 - sample 76 - EUIC 9467; fig. 8 - sample 77 - EUIC 9470; fig.10 - sample 77 - EUIC 9472; fig. 11 - sample 76 - EUIC 9473.

Figs 4 a, b - *Streptognathodus expansus* Igo & Koike, 1964. Sardar Formation, sample 79 - EUIC 9466.

Fig. 6 - *Gnathodus girtyi girtyi* Hass, 1953. Sardar Formation, sample 67 - EUIC 9468

Figs 9, 12, 13, 14 - *Clydagnathus* sp. Shishtu Formation, sample 31 and Sardar Formation, sample 34. Fig. 9 - sample 34, - EUIC - 9471; fig. 12 - sample 31 - EUIC - 9474; fig. 13 - sample 34 - EUIC - 9475; fig. 14 - sample 31 - EUIC - 9476.

PLATE 2

All magnifications are X 80

Figs 1, 2, 5, 11, 14 - *Declinognathus noduliferus noduliferus* (Ellison & Graves, 1941). Sardar Formation, samples 68, 69, 76, 77. Fig. 1 - sample 76 - EUIC 9449; fig. 2 - sample 76 - EUIC 9450; fig. 5 - sample 77 - EUIC 9453; fig. 11 sample 69 - EUIC 9459; fig. 14 - sample 68 - EUIC 9461.

Fig. 3, 13 - *Gnathodus pseudosemiglaber* Thompson & Fellows, 1970. Shishtu Formation, sample 31 - EUIC 9451, EUIC 9452.

Fig. 4 - *Rhachistognathus minutus minutus* (Higgins & Bouckaert, 1968). Sardar Formation, sample 76 - EUIC 9452.

Fig. 6 - *Gnathodus girtyi girtyi* Hass, 1953. Sardar Formation, sample 70 - EUIC 9454.

Fig. 7 - *Gnathodus* sp. Sardar Formation, sample 71 - EUIC 9455.

Fig. 8, 10, 12 - *Rhachistognathus muricatus* (Dunn, 1965). Sardar Formation, samples 66, 67. Fig. 8 - sample 66 - EUIC 9456; fig. 10 - sample 66 - EUIC 9458; fig. 12 - sample 67 - EUIC 9460.

Fig. 9 - *Gnathodus typicus* Hass, 1953 - Shishtu Formation, sample 12 - EUIC 9457.

Fig. 15 - *Clydagnathus* sp. Sardar Formation, sample 34 - EUIC 9477.

PLATE 3

All magnifications are x 80

Figs 1, 2, 3, 4, 5, 14 - *Clydagnathus unicornis* Rhodes, Austin & Druce, 1969. Shishtu Formation, sample 31, Sardar Formation, samples 37, 38, 43, 44. Fig. 1 - sample 44 - EUIC 9435; fig. 2 -sample 44 - EUIC 9436; fig. 3 - sample 43 - EUIC 9437; fig. 4 - sample 37 - EUIC 9438; fig. 5 - sample 38 - EUIC9439; fig. 14 - sample 31 - EUIC 9448.

Fig. 6 - *Pseudopolygnathus dentilineatus* Branson, 1934. Shishtu Formation, sample 9 - EUIC 9440.

Figs 7, 8 - *Bispathodus aculeatus aculeatus* (Branson & Mehl, 1934). Shishtu Formation, samples 9, 12. Fig. 7 - sample 9 - EUIC 9441; fig. 8 - sample 12 - EUIC 9442.

Fig. 9 - *Gnathodus pseudosemiglaber* Thompson & Fellows, 1970. Shishtu Formation, sample 15 - EUIC 9443.

Fig. 10 - *Gnathodus* sp. juv. Shishtu Formation, sample 10 - EUIC 9444.

Figs 11 a, b; 12, 13 - *Pseudopolygnathus primus* Branson & Mehl, 1934. Shishtu Formation, sample 2, 4. Fig. 11 - sample 2 - EUIC 9445; fig. 12 - sample 4 - EUIC 9446; fig. 13 - sample 4 - EUIC 9447.

PLATE 4

All magnifications are X 80

Figs 1-7, 9 a, b, 10 a, b - *Polygnathus inornatus* Branson, 1934. Shishtu Formation, samples 2, 5, 11, 17, 22, 28, 31; Sardar Formation, sample 34. Fig. 1 - sample 2 - EUIC 9413; fig. 2 - sample 5 - EUIC 9414; fig. 3 - sample 11 - EUIC 9415; fig. 4 - sample 28 - EUIC 9416; fig. 5 - sample 17 - EUIC 9417; fig. 6 - sample 28 - EUIC 9418; fig. 7 - sample 22 - EUIC 9419; fig. 9 - sample 31 - EUIC 9421; fig. 10 - sample 34 - EUIC 9422.

Figs 8 a, b, 11 a, b - *Polygnathus longiposticus* Branson & Mehl, 1934. Shishtu Formation, sample 18. Fig. 8 - EUIC 9420, fig. 11 - EUIC 9423.

PLATE 5

All magnifications are X 80

Figs 1a, b, 2, 3, 4 - *Polygnathus communis communis* Branson & Mehl, 1934. Shishtu, samples 8, 10, 14. Fig. 1 - sample 14 - EUIC 9424; fig. 2 - sample 10 - EUIC 9425; fig. 3 - sample 8 - EUIC 9426; fig. 4 - sample 8 - EUIC 9427.

Figs 5 a, b; 6, 7 - *Bispathodus stabilis* (Branson & Mehl, 1934). Shishtu Formation, samples 16, 18. Fig. 5 - sample 18 - EUIC 9428; fig. 6 - sample 16 - EUIC 9429; fig. 7 - sample 16 - EUIC 9430.

Figs 8, 9 - *Mehlina*? sp., Shishtu Formation, samples 9, 12. Fig. 8 - sample 12 - EUIC 9431; fig. 9 - sample 9 - EUIC 9432.

Figs 10 a, b - *Polygnathus* cf. *inornatus* Branson & Mehl, 1934. Shishtu Formation, sample 28 - EUIC 9434.

PLATE 6

All magnifications are X 80

Figs. 1a, b, 4 a, b, 5 a, b - *Idiognathodus sinuosus* Ellison & Graves, 1941. Sardar Formation, samples 74, 75, 77. Fig. 1 - sample 74 - EUIC 9477; fig. 4 - sample 74 - EUIC 9480; fig. 5 - sample 75 - EUIC 9481; sample 77 - EUIC 9482.

Figs 2 a, b - *Idiognathodus delicatus* Gunnell, 1931. Sardar Formation, samples 75 - EUIC 9478

Figs 3 a, b - *Idiognathoides sinuatus* Harris and Hollinsworth, 1933. Sardar Formation, sample 70 - EUIC 9479.

Figs 6 a, b - *Idiognathodus* aff. *delicatus* Gunnell, 1931. Sardar Formation, sample 74 - EUIC 9483.

Figs 7 a, b - *Clarkina changxingensis* Wang & Wang, 1981. Surmaq Formation, sample 102, Permian - EUIC 9484.

Figs 8 a, b - *Clarkina altudaensis* Kozur, 1992. Surmaq Formation, sample 103, Permian - EUIC 9485.

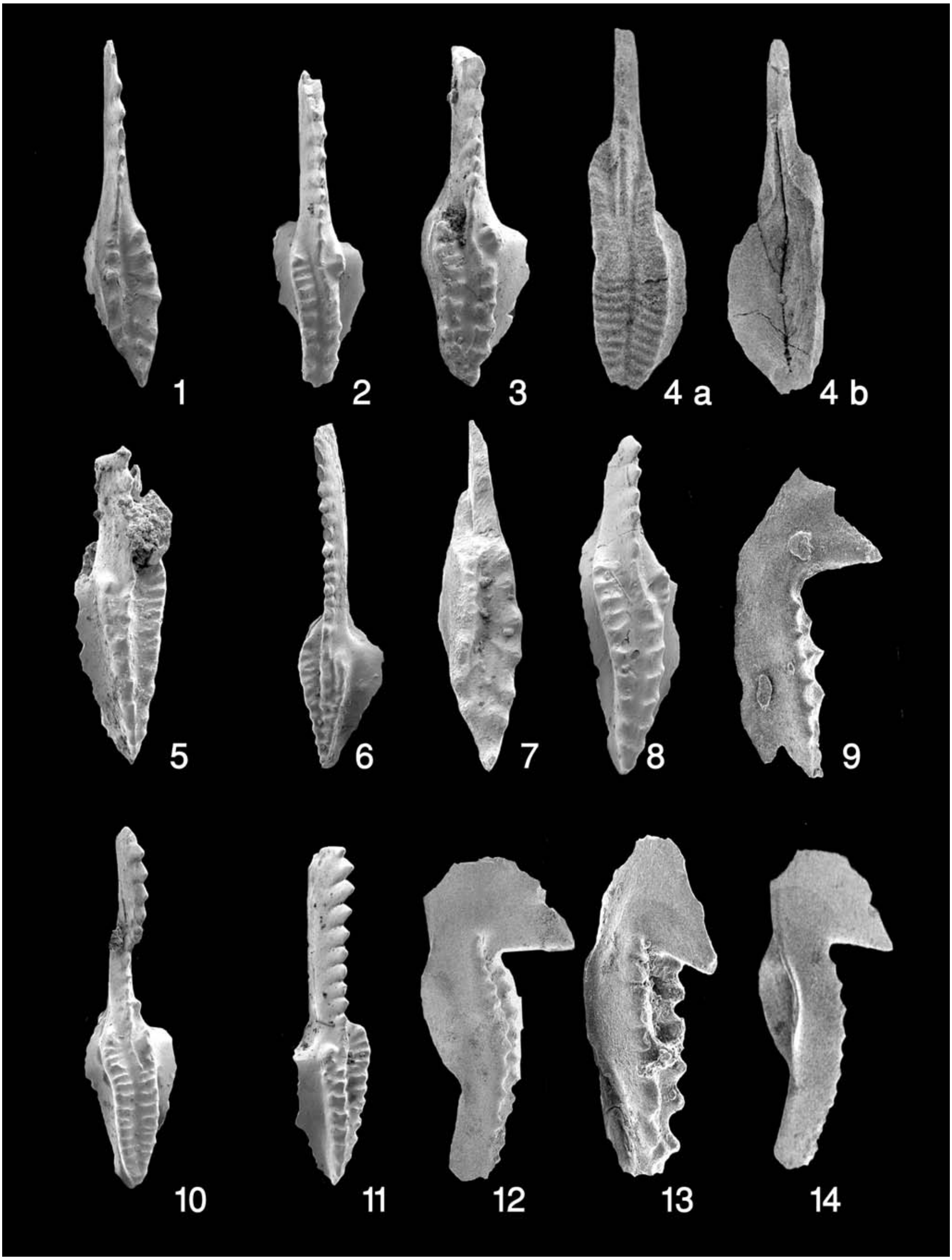

PLATE 1

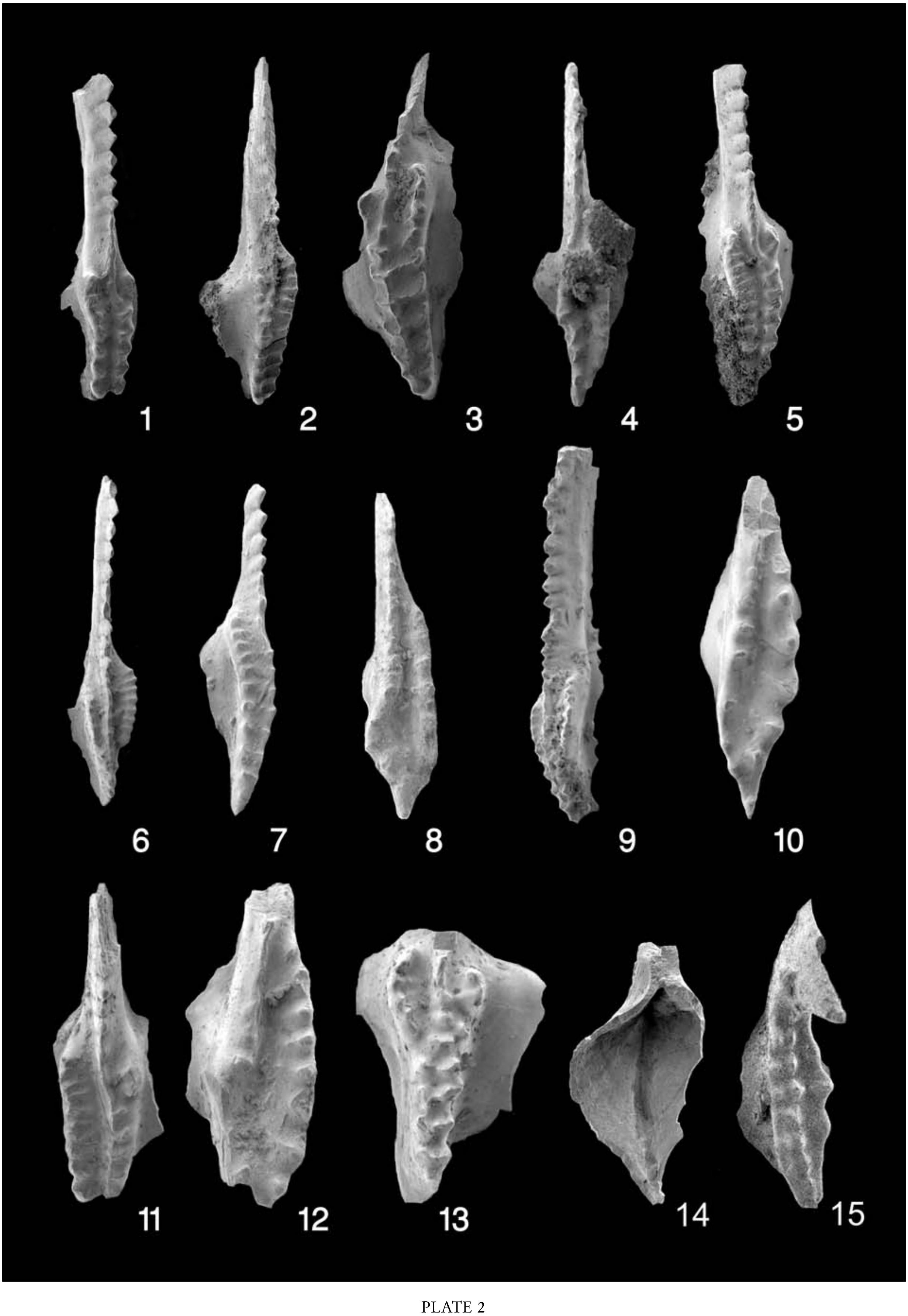

PLATE 2

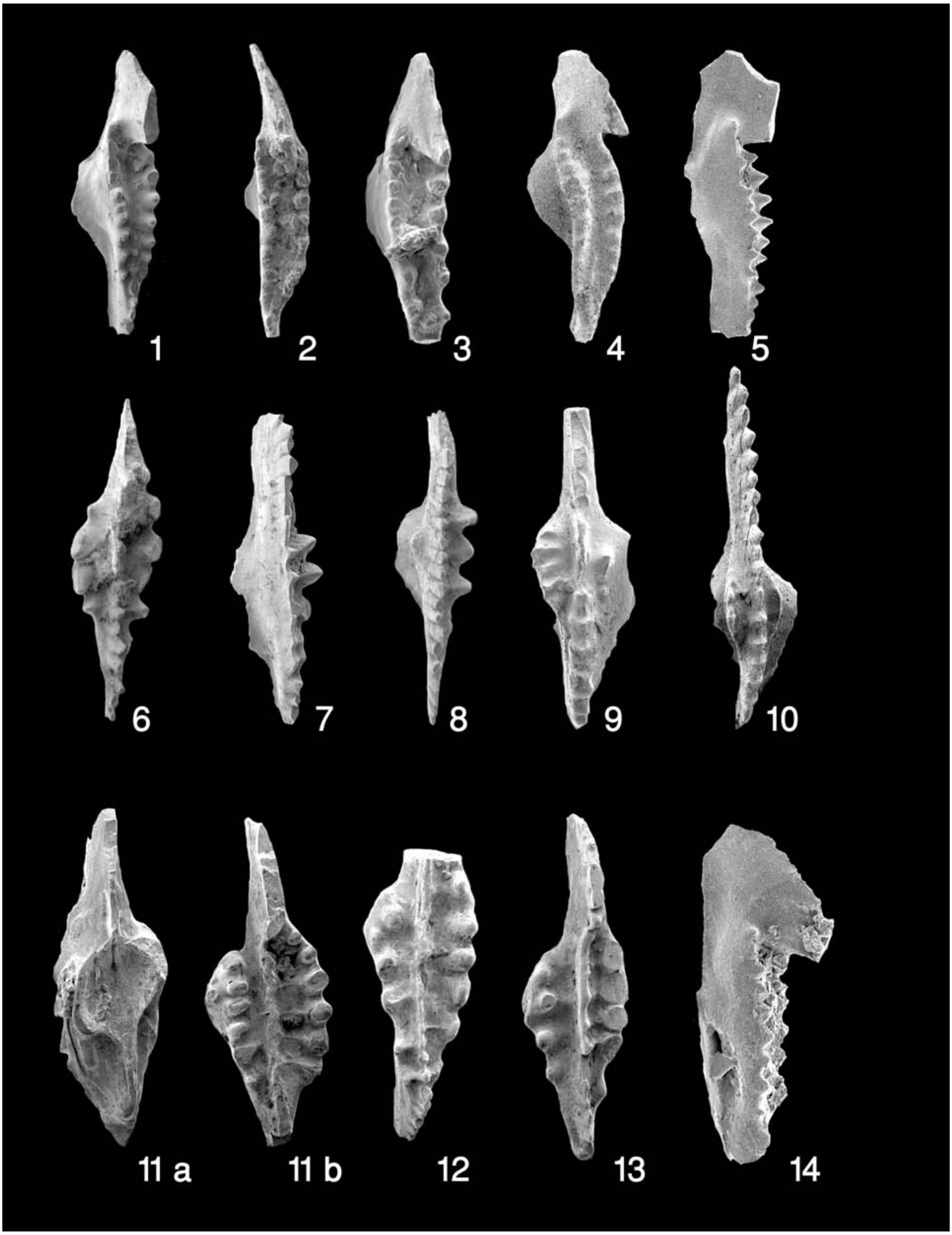

PLATE 3

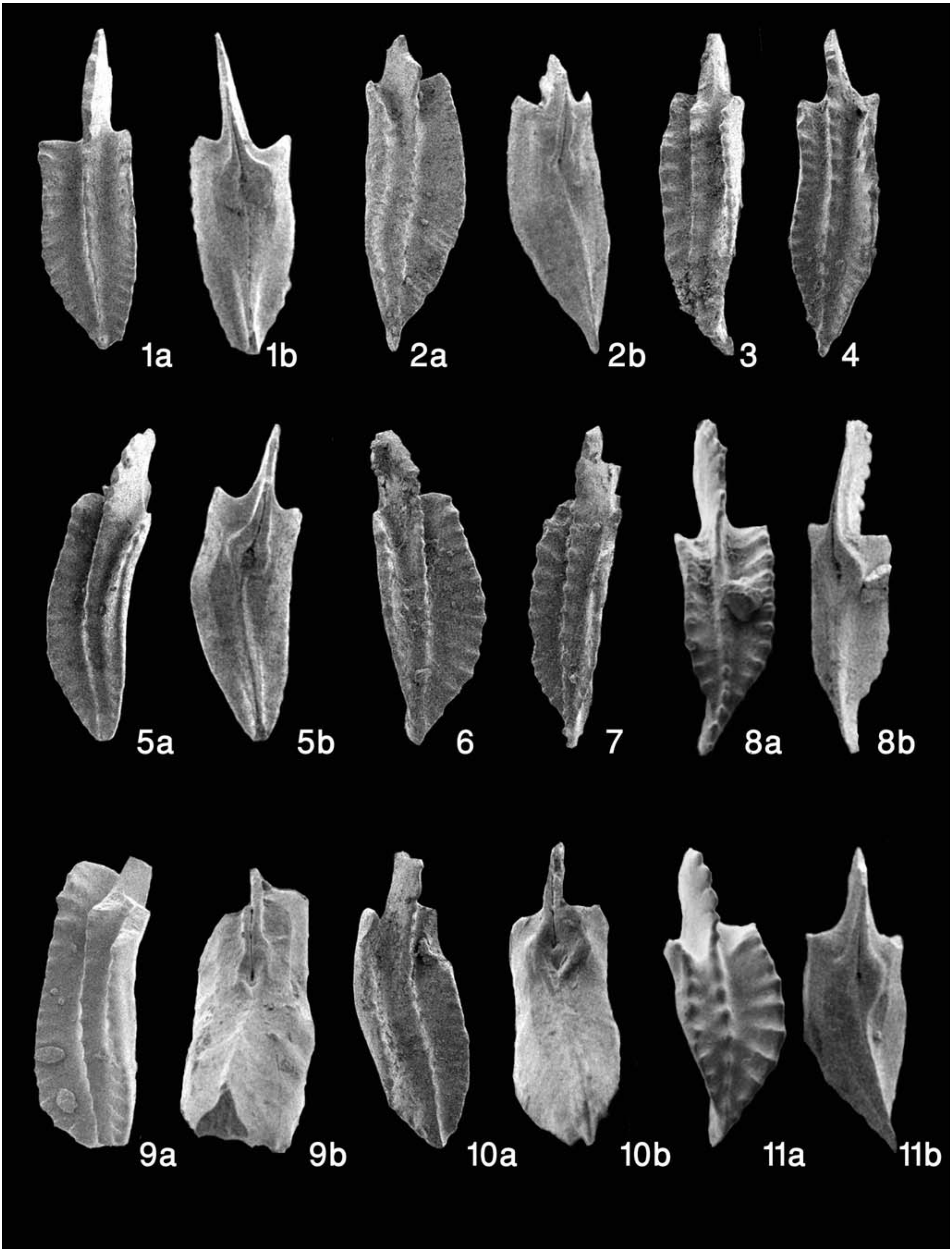

PLATE 4

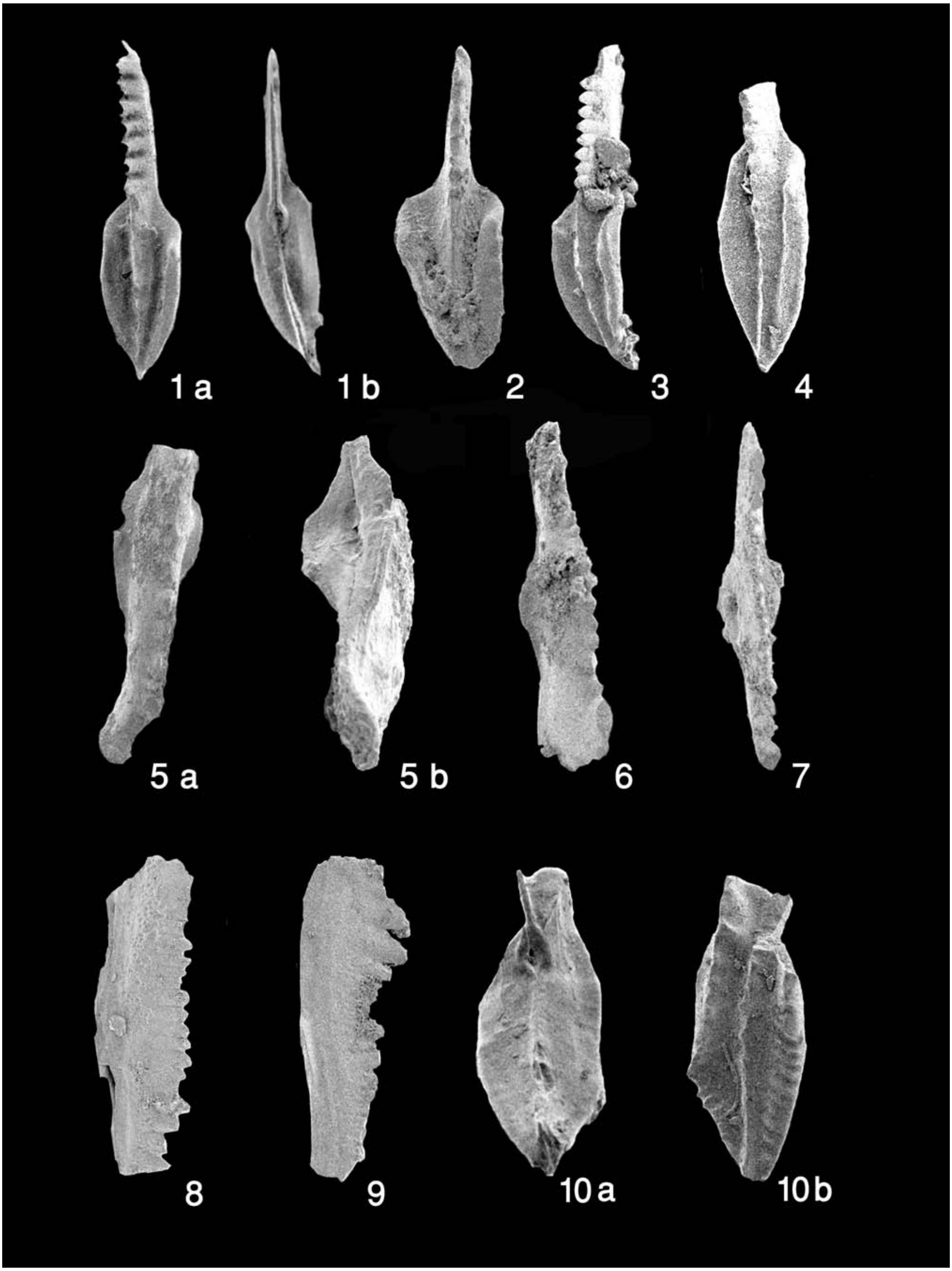

PLATE 5

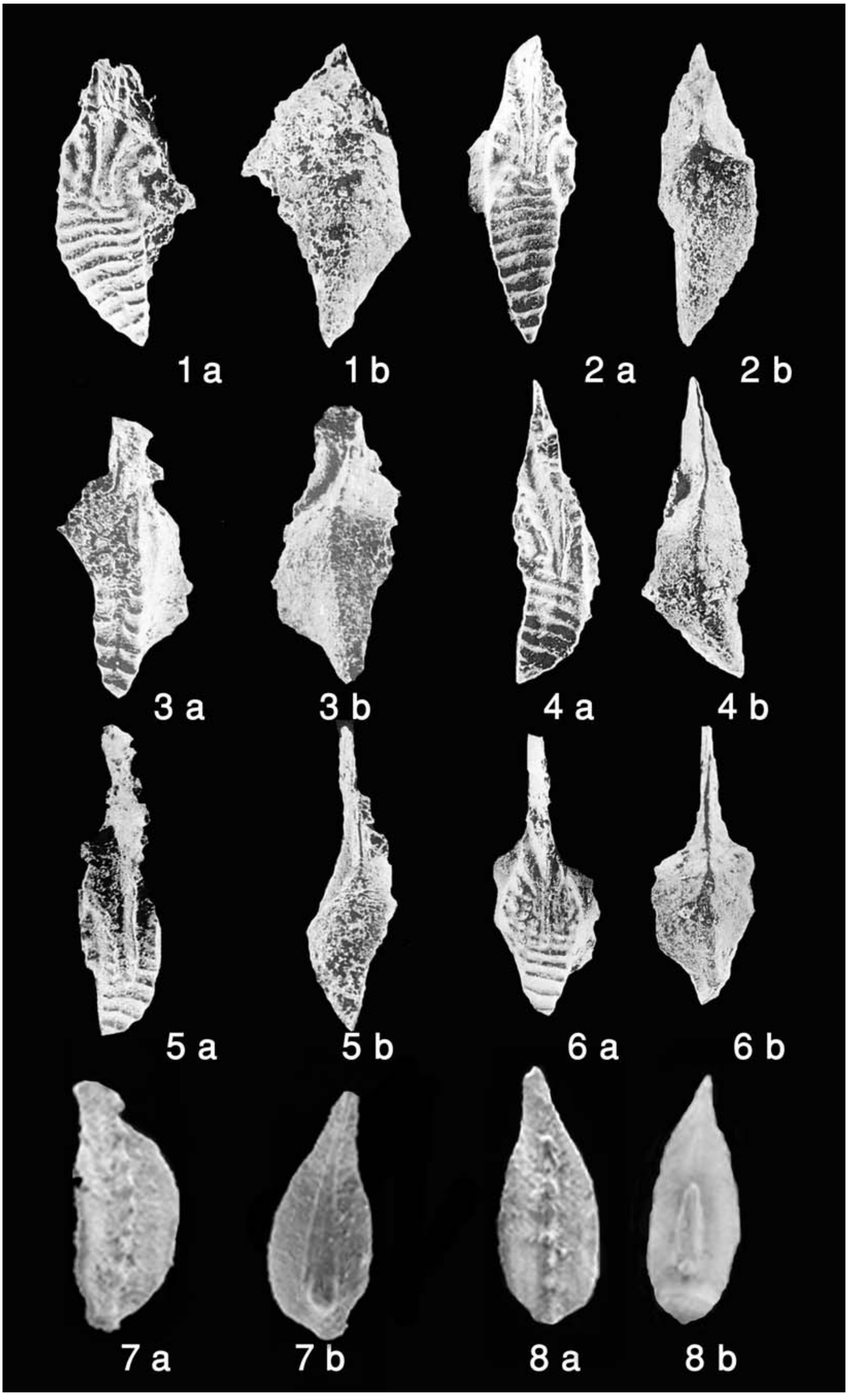

PLATE 6

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