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LATE DEVONIAN CONODONTS FROM THE HOJEDK SECTION, KERMAN PROVINCE, SOUTHEASTERN IRAN

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Abstract. Conodonts (34 species and subspecies) from the Hojedk section north of Kerman span the late Givetian to early Famennian. The new data suggest that Devonian biostromes in central and eastern Iran were deposited on differing levels, and that the currently accepted ranges of *Icriodus excavatus, Polygnathus subincompletus* and *P. mosquensis* are early Givetian - late Frasnian, early to late Frasnian, and middle to late Frasnian. *Polygnathus ashourii* n. sp. is proposed.

Riassunto. I conodonti (34 specie e sottospecie) ottenuti dalla sezione di Hojedk a nord di Kerman si estendono dal Givetiano superiore al Famenniano inferiore. I nuovi dati suggeriscono che le biostrome devoniane in Iran Centrale e Orientale si deposero a più livelli, e che la distribuzione di *Icriodus excavatus, Polygnathus subincompletus* e *P. mosquensis* si estenda rispettivamente dal Givetiano inferiore al tardo Frasniano, dal Frasniano inferiore a quello superiore e dal Frasniano medio al superiore. Viene proposta la nuova specie *Polygnathus ashourii*.

Introduction

The Hojedk section (Figs. 1, 2), 4 km west of Haruz village and 64 km north of Kerman on the southeastern flank of Kuh-e-Kanseh mountain (Kuh-e-Kanseh section of Wendt et al. 2002, 2005), is noteworthy for abundance of macrofauna. It is located on the western part of Kerman and Horjond sheets of the Geological Survey of Iran (Sahandy 1991; Sahandy & Haj Molla Ali 1992). Its base is at N 30° 43′ 30″ E 57° 0′ 37″, its top at N 30° 43′ 33″, E 57° 0′ 24″ (WGS84 system). Thirty-four out of 41 samples produced conodonts enabling zonation and comparison with the standard Late Devonian conodont zonation of Ziegler & Sandberg (1990).

Noteworthy among previous contributions on the Devonian of the Kerman region are studies of the stratigraphy and palaeoenvironmental analysis based on a modicum of conodont data from spot samples (Wendt et al. 1997, 2002, 2005), brachiopods, rugose corals and stromatoporoids (Rohart 1999; Mistiaen 1999; Brice et al. 1999). An approximate position of the Frasnian-Famennian boundary has been suggested on the basis of brachiopods and chemostratigraphic data (Dastanpour & Aftabi 2002), fish remains (Janvier 1974) and trilobites from the Haruz section (Morzadec et al. 2002). Gholamalian (2006) has undertaken conodont biostratigraphic research on the Late Devonian of the Hutk section.

Stratigraphic setting

The oldest Devonian unit in the area, equivalent to the Padeha Formation elsewhere, consists of arenite, dolomite, and red shale with a few limestone beds. The Padeha Formation is overlain by a unit previously thought to be Devonian to Carboniferous in age, equating with the Bahram and Shishtu formations (Sahandy & Haj Molla Ali 1992). Wendt et al. (2002, 2005) proposed a late Givetian to early Famennian age, a time interval that is confirmed here. The early Famennian Bahram Formation is disconformably overlain by Permian dolomites of the Jamal Formation (Figs 2, 3) and shows a significant hiatus corresponding to the Carboniferous system. The boundary between the Padeha and Bahram formations is quite sharp in the field, whereas that between the Bahram and Shishtu formations is un-

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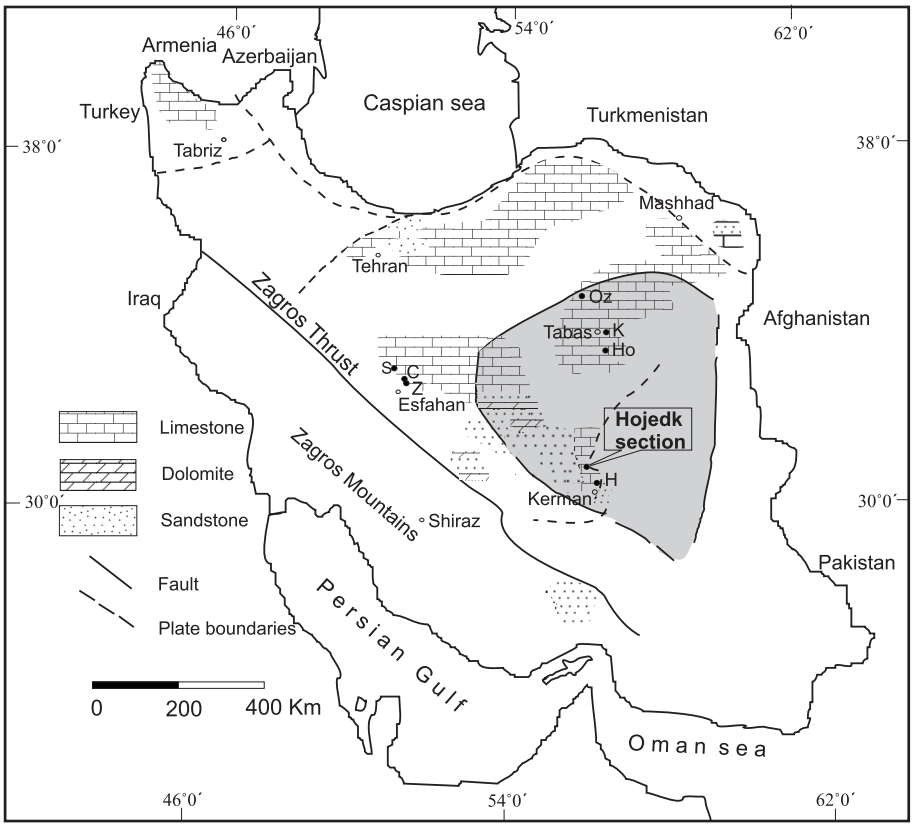


Fig. 1 - Late Devonian palaeogeographic map of Iran and the location of Hojedk section. The map is redrawn from Wendt et al. (2005). The shaded area is east-central Iran microplate. Abbreviations used for localities: C = Chahriseh, Z = Zefreh, S = Soh, H = Hutk, Oz = Ozbak-Kuh, K = Kal-e-Sardar, Ho = Howz-e-Dorah.

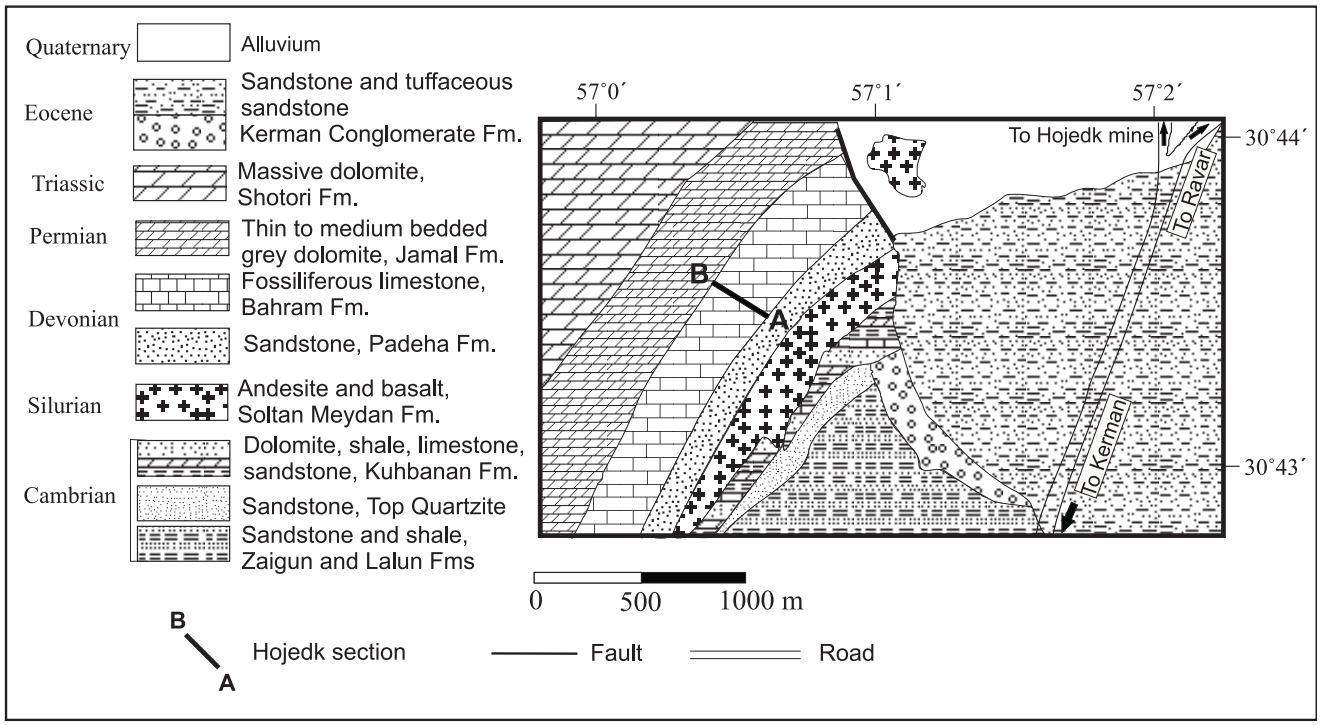


Fig. 2 - Geological map of studied area.

differentiable. Due to lack of a "mapping entity", Wendt et al. (2005, p. 74) suggested ignoring the Shishtu Formation in future stratigraphic work, referring its supposed members to the upper part of the Bahram Formation. This idea seems acceptable for most Iranian Late Devonian sequences including the Hojedk section considered here; it too was previously erroneously regarded as Shishtu Formation ("cephalopod beds"). Its sediments are indicative of shallow-water palaeoenvironments and formed part of a very shallow continental shelf extending over central Iran. The succession in the Tabas region of eastern Iran, typified by the Kal-e-Sar-

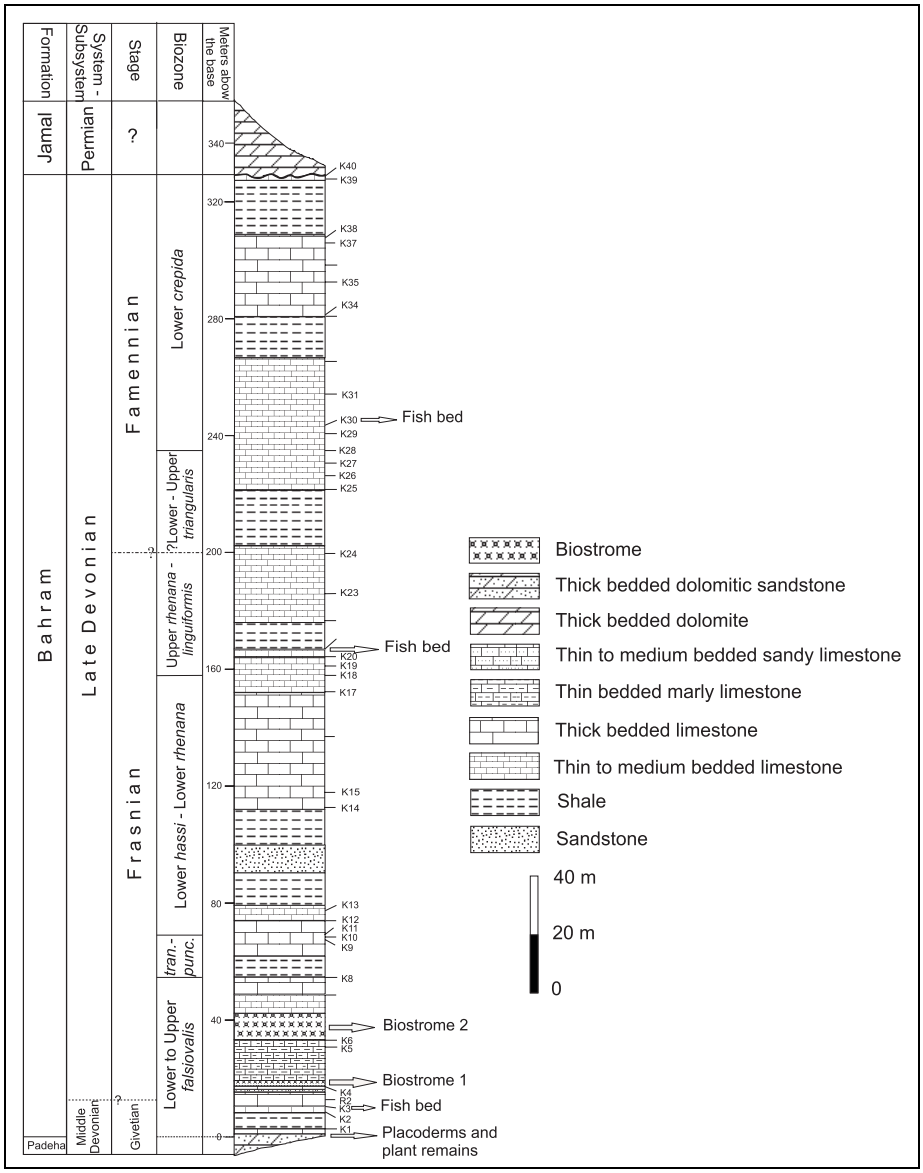


Fig. 3 - Stratrigraphic column of Hojedk section (Kuh-e-Kanseh) with conodont biozonation. Abbreviations used for zones: L. = Lower, U. = Upper, *tran.* = *transitans*, *punc.* = *punctata*.

dar area, differs considerably in lithology, facies, and faunas. It produces numerous ammonoids (Walliser 1966; Becker et al. 2004) and is interpreted as a deeper shelf environment. The conodont faunas of the Kal-e-Sardar area (Yazdi 1999; Ashouri 2002, 2004) represent palmatolepid and palmatolepid – polygnathid biofacies, clearly deeper than the Bahram Formation. Use of the term Shishtu Formation may thus be usefully restricted to deeper shelf facies in that particular region. The conodont faunas of Bahram Formation in the Hojedk section consist mostly of polygnathid – icriodid and icriodid – polygnathid biofacies (Tab. 1), similar to those recently documented from the Howz-e-Dorah and Chahriseh sections (Gholamalian 2007).

The base of the Bahram Formation in the central Iran Basin is diachronous, dated as Eifelian in Zefreh and Howz-e-Dorah (Wendt et al. 2005; Brice et al. 2006), early Givetian in Soh (Adhamian 2003), late Givetian in present area, early Frasnian in Chahriseh (Turner et al. 2002), and middle Frasnian in Hutk (Gholamalian 2006). It shows Eifelian rapid marine transgression and carbonate deposition (Bahram Formation) in the Eifelian in some areas (e.g. Zefreh and Howz-e-Dorah), contrasting with stable terrigenous deposition (Padeha Formation, continuing into the middle Frasnian) in others.

Studied succession

The base of the Bahram Formation in the Hojedk section begins with a one-meter bed with placoderm and plant remains that overlies dolomitic sandstones of the Padeha Formation (Fig. 3). Golshani et al. (1972) studied these fauna and suggested a late Givetian - early Frasnian age. Because it has been reported from many sections, such as Soh and Zefreh (Adhamian 2003; Brice et al. 2006), it can be considered a key horizon in the central Iran basin.

Zones	Lower to Upper *falsiovalis*							*tran.-punc.*			L. *hassi* - L. *rhenana*						U. *rhen.-ling.*				?L. - U. *trian.*				Lower *crepida* Zone									
Species \ Samples	K1	K2	K3	R2	K4	K5	K6	K8	K9	K10	K11	K12	K13	K14	K15	K17	K18	K19	K20	K23	K24	K25	K26	K27	K28	K29	K30	K31	K34	K35	K37	K38	K39	K40
Ancyrodella binodosa				11	1																													
Ad. pristina				4	1																													
Polygnathus webbi	1	2				2		1	1						4			10		6 ◀														
P. xylus	34	39	4	4	23			9																										
P. ovatinodosus	7		7	6	7																													
P. dubius	5	3	4	3	9		2	1						2	1																			
P. alatus	2	3					3			1	3	2	3	3			2	2	1	3 ◀														
Icriodus excavatus				1	2							2	1	3				24	1	11														
I. subterminus				2	2										2																			
I. symmetricus	17	13		3	20		8					1	1	1	3			17		1														
I. vitabilis	11	1			10						1																							
I. sp. A				1	5																													
I. sp. B	2				4											1		2		2														
P. aequalis								▶ 8	1			2	4					14	3	1 ◀														
P. subincompletus								3																										
P. sp.								5										4																
P. zinaidae											▶ 4																							
P. aff. *praepolitus*													9	1	2																			
I. iowaensis iowaensis																	▶ 4	41		8		1					1	1		1				
P. mosquensis																		2																
P. ashourii n. sp.																		10																
P. brevilaminus																		2		1	2				3		1							
I. alternatus alternatus																		7			3	1	3	1	3		11	1	1	2	1	1	1	2
I. cornutus																								1	4		8	4	8	1	2				
P. communis group																							2	2	4	2	11		5	6	2				2
Pel. inclinatus																									▶ 5		1		1	6	6		2		
I. iowaensis ancylus																											5	1	4	2			1		
Pelekysganthus brevis																									1		2								
Pel. planus																											1		3						
P. semicostatus																									1		2				2				
P. aff. *incomptus*																											1			2	10				
P. acutatus																											3								
Pel. serradentatus																													2						
Mehlina sp.																															1	1			
UAE	49	17	18	26	112			9			5	5		7	6		3	43		22	20	9	2	10	29	2	20	8	37	89	37	38	8	5
Total	128	78	33	61	196	2	13	36	2	1	13	12	18	17	18	1	9	180	5	55	25	11	7	14	50	4	67	15	61	109	61	40	12	9
Biofacies	P-I	P-I	P	P-I	I-P			P					P					I-P		P-I					I-P		I-P		I-P	I-P	P-Pel			

Tab. 1 - Range chart of conodont species in the Hojedk section. Abbreviations used: L. = Lower, U. = Upper, *tran. = transitans, punc. = punctata, rhen. = rhenana, ling. = linguiformis, trian. = triangularis.* Biofacies: P = polygnathid, P-I = polygnathid-icriodid, I-P = icriodid-polygnathid.

Two levels of biostromes, consisting mainly of tabulate and rugose corals (Mistiaen 1999; Rohart 1999; Brice et al. 1999) are diachronously exposed at the base of the Bahram Formation in several sections in central and eastern Iran: the late Givetian – early Frasnian in Ozbak-Kuh (Khaksar et al. 2006), the early Frasnian in Hojedk (present work), and the mid-Frasnian in Chahriseh, near Esfahan and at Howz-e-Dorah, in southern Tabas (Mistiaen et al. 2000; Mistiaen & Gholamalian 2000; Yazdi 2000). Conodonts from 12.7 m above the base of the Bahram Formation (4.3 m below the lower biostrome level) in the Hojedk section indicate a late Givetian age.

The middle part of the Hojedk section consists mostly of thin to medium bedded limestones with a few shales and sandstones becoming reddish upward. Though poor in macrofauna, conodonts from this interval are middle to late Frasnian.

The upper part of the section is composed of 146.4 m of red limestone and dark shale. All conodonts from this part of the section are exclusively early Famennian. Contrary to Sahandy (1991), there is no sign of Carboniferous in the Hojedk area. Early Carboniferous intervals have been identified in southern sections such as Hutk and Shams Abad (Wendt et al. 2002; Webster et al. 2003). The occurrences are consistent with the Carboniferous marine regression in the Kerman area having been from north to south, possibly connected with Variscan (sometimes referred to as Hercynian) epeirogenesis.

Conodont materials are hosted in Department of Geology, Hormozgan University.

Biostratigraphy

The 34 species and subspecies of conodonts in the Hojedk section (Tab. 1) are clustered into six biostratigraphic intervals (Fig. 3; Pl. 1).

Lower *falsiovalis* to Upper *falsiovalis* zones

This interval begins with the presence of *Polygnathus dubius, P. xylus, P. alatus, P. webbi, Icriodus vitabilis, I. symmetricus, Ancyrodella pristina* and *Ad. binodosa.* The δ morphotype of *Ad. binodosa* ranges from the Lowermost to Lower *asymmetricus* zones (Bultynck 1983), those correspond to Lower to Upper *falsiovalis* zones. According to Ji & Ziegler (1993), *Ad. pristina* ranges from within the Lower *falsiovalis* into the Middle *falsiovalis* zones corresponding to the Lower *falsiovalis* Zone of Ziegler & Sandberg (1990). The first elements of *Ad. binodosa* and *Ad. pristina* appearing in bed R2 indicate proximity to the Givetian-Frasnian boundary.

P. webbi and *P. alatus* have recently been reported from the base of the Lower *falsiovalis* Zone in some sections in Poland (Narckiewicz & Bultynck 2007).

The upper limit of the interval is defined by appearance of *P. aequalis*.

transitans-punctata zones

The base of this interval, with *Polygnathus alatus, P. webbi, P. subincompletus*, and *P. aequalis* is recognized by entry of *P. aequalis* as its lower limit; entry of *P. zinaidae* defines the base of the next interval. According to Ji & Ziegler (1993, p. 74) and Barskov et al. (1991), *P. aequalis* ranges through the *transitans* to Lower *rhenana* zones, but Gholamalian (2007) has extended the range of this species to the end of the Frasnian (Upper *rhenana - linguiformis* zones). *P. subincompletus* was earlier regarded as confined to the Lower to Upper *rhenana* zones (Ovnatanova & Kononova 2001), but based on our data we regard the *transitans* Zone as its first appearance.

Lower *hassi* - Lower *rhenana* zones

The lower limit of this interval is defined by entry of *Polygnathus zinaidae*, its upper by entry of *Icriodus iowaensis iowaensis.* The former species is restricted to the Lower *hassi* to Upper *rhenana* zones (Ovnatanova & Kononova 2001).

Upper *rhenana - linguiformis* zones

The entry of *Icriodus iowaensis iowaensis*, (sample K18) is a bioevent marker for the upper part of the Upper *rhenana* Zone (Ziegler & Sandberg 1990). The Frasnian-Famennian boundary cannot be identified precisely but is taken to approximate the beds with the last Frasnian index conodonts, notably *Polygnathus webbi,* and *P. aequalis*. *P. mosquensis* was reported by Ovnatanova & Kononova (2001) from the Upper *hassi* to *jamieae* zones. As this species occurs in an assemblage from bed K19, associated with the first appearance of *Icriodus iowaensis iowaensis*, it is the youngest record of this species, extending into the Upper *rhenana* Zone. *Icriodus excavatus* of Weddige (1984) has its last occurrence in the Upper *rhenana* Zone in the Hojedk section.

?Lower to Upper *triangularis* zones

Polygnathus brevilaminus, P. communis group, *Icriodus alternatus, I. cornutus* and *I. iowaensis iowaensis* were found in this interval, but it lacks index conodonts for precise discrimination of the base of the Famennian.

Lower *crepida* Zone

The base of this zone can be identified by entry of *Peleykysgnathus inclinatus*, a form ranging from the Lower *crepida* to Upper *praesulcata* zones (Sandberg

& Dreesen 1984). Co-occurrence of this form with *Icriodus iowaensis ancylus* (otherwise ranging from the Middle *triangularis* to Lower *crepida* zones) defines the interval. *Polygnathus acutatus*, restricted to the Lower to Upper *crepida* zones (Khalymbadzha et al. 1991), is prominent. The latest occurrence of *I. alternatus alternatus* (range: Lower *rhenana* – Upper *crepida* zones) is another prominent species. *Pelekysgnathus serradentatus* ranging from the *triangularis* to *crepida* zones (Capkinoglu 1991; Capkinoglu & Gedik 2000, tab. 4) occurs in this zone.

Systematic Palaeontology

Order **Ozarkodinida** Dzik, 1976

Family Polygnathidae Bassler, 1925

Genus *Polygnathus* Hinde, 1879

Type species: *Polygnathus dubius* Hinde, 1879

Polygnathus ashourii n. sp.

Pl. 2, Figs 15-19

Holotype. HUIC205 sample K19, Hojedk section, Pl. 2, Figs 15-16.

Paratype. HUIC206 sample K19, Hojedk section, Pl. 2, Figs 17-18.

Material. 10 specimens from sample K19, Hojedk section, Kerman area.

Etymology. In honor of Iranian conodont researcher Prof. Ali-Reza Ashouri (Ferdowsi University of Mashhad).

Diagnosis: A species of *Polygnathus* with a much restricted anterior of its platform, a very wide median outer lobe covering two-thirds of the platform, a short posterior tongue, and a low denticulate carina.

Description. Pa elements of this species are asymmetric in outline. The platform is constricted with narrow and deep troughs anteriorly, but becomes very wide and flattened in the middle part. The posterior end is narrower, tongue-like and is slightly bent downward. Ornament of weak, short transverse ridges not reaching the low carina. Carina low, composed of separated coarse denticles, reaching the posterior tip. Basal cavity located beneath the anterior one-fourth of platform. Free blade short, equal to one-fifth of the element.

Remarks. *Polygnathus ashourii* resembles a few species in the *P. dubius* lineage *sensu* Ovnatanova & Kononova (2001). It can be distinguished from *P. seraphimae* by its wider and more flattened platform and restriction of deep troughs to the anterior part. *P. aequalis* and *P. webbi* may be discriminated from this species by having a deeper and narrower platform, a less developed lobe, a wider platform anteriorly, and denticulate carina. *P. krestovnikovi* can be distinguished from *P. ashourii* by its narrower platform with transverse ridges, less developed lobe, and fused carina.

Polygnathus ashourii also differs from *P. squalidus* by having weaker transverse ridges and a lower carina with separated denticles, and from *P. eiflius* by the narrower posterior part of the platform, weaker transverse ridges or its otherwise smooth upper surface, and having its carina composed of more separated denticles, weakened at the posterior end.

PLATE 1

Fig. 1 - *Icriodus* sp. B: upper view of HUIC167, sample K23; 2) upper view of HUIC168, sample K23.

Figs 2, 3, 5-7 - *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947: 1, 3) upper view of HUIC169, sample K23; 5) upper view of HUIC170, sample K25; 6) upper view of HUIC171, sample K19; 7) upper view of HUIC172, sample K19.

Fig. 4 - *Icriodus alternatus alternatus* Branson and Mehl, 1934a: upper view of HUIC173, sample K26.

Figs 8-10 - *Icriodus iowaensis ancylus* Sandberg and Dreesen, 1984: 8) oblique upper view of HUIC174, sample K30; 9, 10) upper and lateral views of HUIC175, sample K30.

Figs 11-12 - *Icriodus cornutus* Sannemann, 1955: 11, 12) upper and lateral views of HUIC176, sample K30.

Fig. 13 - *Icriodus adanaensis* Capkinoglu and Gedik, 2000: upper view of HUIC177, sample K34.

Figs 14-16 - *Icriodus symmetricus* Branson & Mehl, 1934: 14) upper view of HUIC178, sample K2; 15) upper view of HUIC179, sample K4; 16) upper view of HUIC180, sample K4.

Fig. 17 - *Icriodus* sp. A: upper view of HUIC181, sample K4.

Fig. 18 - *Icriodus excavatus* Weddige, 1984: upper view of HUIC182, sample K4.

Fig. 19 - *Icriodus* aff. *excavatus* Weddige, 1984: upper view of HUIC183, sample K4.

Fig. 20 - *Icriodus vitabilis* Nazarova, 1997: upper view of HUIC184, sample K11.

Fig. 21 - *Icriodus subteminus* Youngquist, 1947: upper view of HUIC185, sample K15.

Fig. 22 - *Pelekysgnathus brevis* Sandberg & Dreesen, 1984: Lateral view of HUIC186, sample K30.

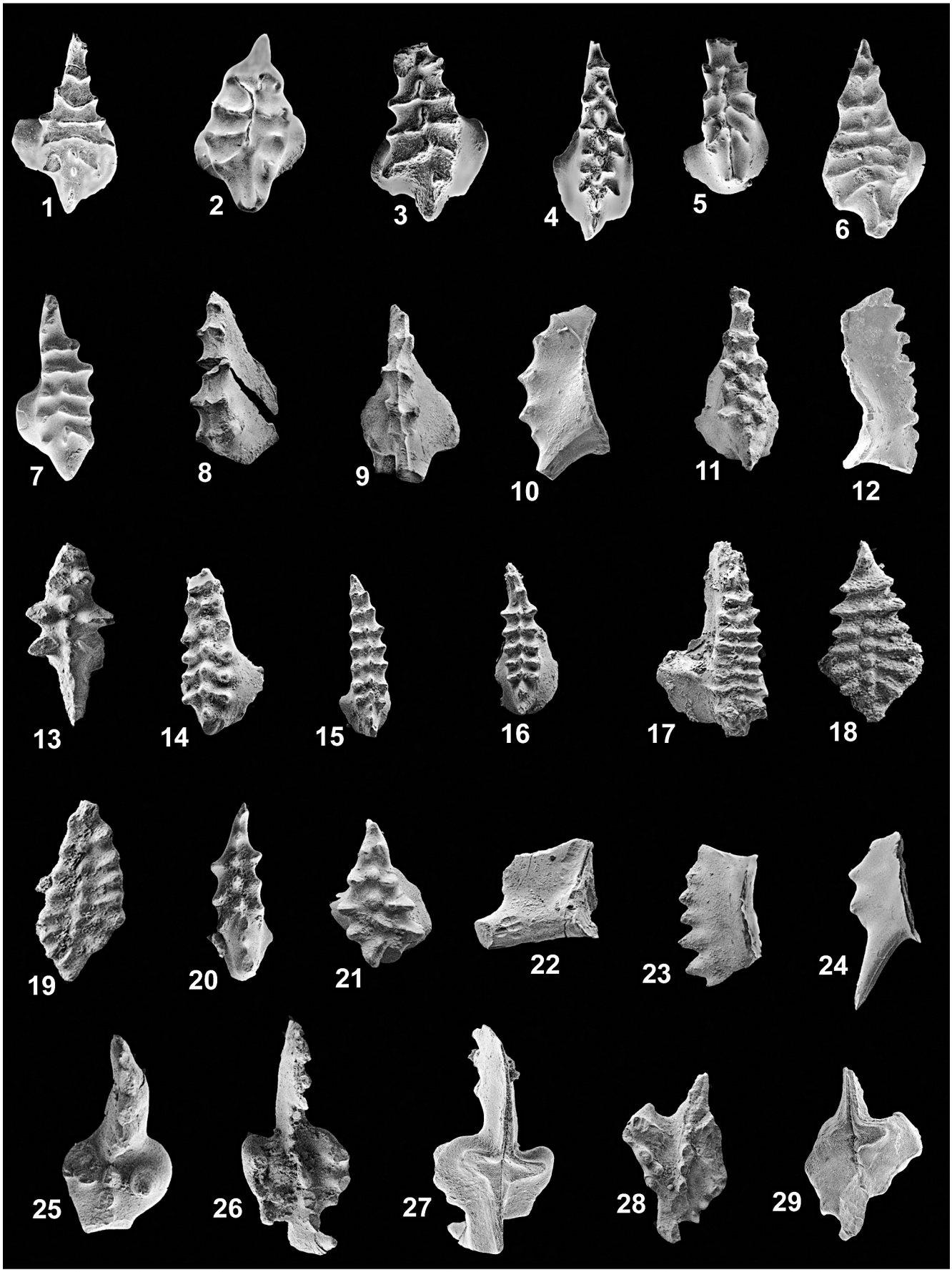
Fig. 23 - *Pelekysgnathus planus* Sannemann, 1955: lateral view of HUIC187, sample K34.

Fig. 24 - *Pelekysgnathus inclinatus* Thomas, 1949: lateral view of HUIC188, sample K37.

Fig. 25 - *Ancyrodella binodosa* d morphotype Uyeno, 1967: upper view of HUIC189, sample R2.

Figs 26-29 - *Ancyrodella pristina* Khalymbadzha and Chernysheva, 1970: 26, 27) upper and lower views of HUIC190, sample R2; 28, 29) upper and lower views of HUIC191, sample R2.

Figs 1-4, 14, 17, 20, 23, x75; figs 6-8, x60; figs 5, 9-13, 15, 16, 18, 19, 21, 22, 24-29, x30.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Range. Upper *rhenana-linguiformis* zones based on associated species in the Hojedk section, sample K19 (Tab. 1).

Conclusions

The base of the Bahram Formation in the Hojedk section is late Givetian - early Frasnian (Lower *falsiovalis* to Upper *falsiovalis* zones). The upper part of the sequence is early Famennian. Permian dolomite disconformably overlies the early Famennian so, contrary to Sahandy (1991) and Sahandy & Haj Molla Ali (1992), a gap in sedimentation during the Carboniferous is demonstrated. *Polygnathus ashourii* n. sp. is introduced; its range is Upper *rhenana - linguiformis* zones. New age ranges are proposed for some species, *varcus* to *linguiformis* zones for *Icriodus excavatus*, and *transitans* to Upper *rhenana* zones for *Polygnathus subincompletus.* The last appearance datum of *P. mosquensis* occurred in the Upper *rhenana* zone.

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PLATE 2

Figs 1, 2 - *Polygnathus xylus* Stauffer, 1938: 1) upper view of HUIC192, sample K2; 2) upper view of HUIC 193, sample K1.

Figs 3, 4 - *Polygnathus alatus* Huddle, 1934: 3) upper view of HUIC194, sample K2; 4) upper view of HUIC195, sample K11.

Fig. 5 - *Polygnathus* sp.: upper view of HUIC196, sample K4.

Figs 6, 7 - *Polygnathus* aff. *praepolitus* Kononova, Alekseev, Barskov and Reimers, 1996: upper and lower views of HUIC197, sample K15.

Fig. 8 - *Polygnathus mosquensis* Litvinova, 1996: upper view of HUIC198, sample K19.

Figs 9-11, 14 - *Polygnathus aequalis* Klapper & Lane, 1985: 9) upper view of HUIC199, sample K8; 10) lower view of HUIC200, sample K8; 11) upper view of HUIC201, sample K19; 14) upper view of HUIC202, sample K19.

Fig. 12 - *Polygnathus subincompletus* Ovnatanova & Kononova, 1996: upper view of HUIC203, sample K8.

Fig. 13 - *Polygnathus zinaidae* Kononova, Alekseev, Barskov & Reimers, 1996: upper view of HUIC204, sample K11.

Figs 15-19 - *Polygnathus ashourii* n. sp.: 15, 16) upper and lower views of HUIC205, sample K8; 17, 18) upper and lower views of HUIC206, sample K19; 19) upper view of HUIC207.

Figs 20-22 - *Polygnathus communis* group Branson & Mehl, 1934: 20, 21) upper and lower views of HUIC208, sample K30; 22) lower view of HUIC209, sample K30.

Figs 23, 24 - *Polygnathus* aff. *P. incomptus* Vorontsova, 1993: 23) oblique upper view of HUIC210, sample K37; 24) lower view of HUIC211, sample K38.

Fig. 25 - *Polygnathus acutatus* Khalymbadzha, Shinkaryov and Gatovsky, 1991: upper view of HUIC212, sample K30.

Fig. 26 - *Polygnathus semicostatus* Branson & Mehl, 1934: upper view of HUIC212, sample K30.

Figs 27, 28 - *Polygnathus dubius* Hinde, 1879: 27) upper view of HUIC213, sample K23; 28) upper view of HUIC214, sample K3.

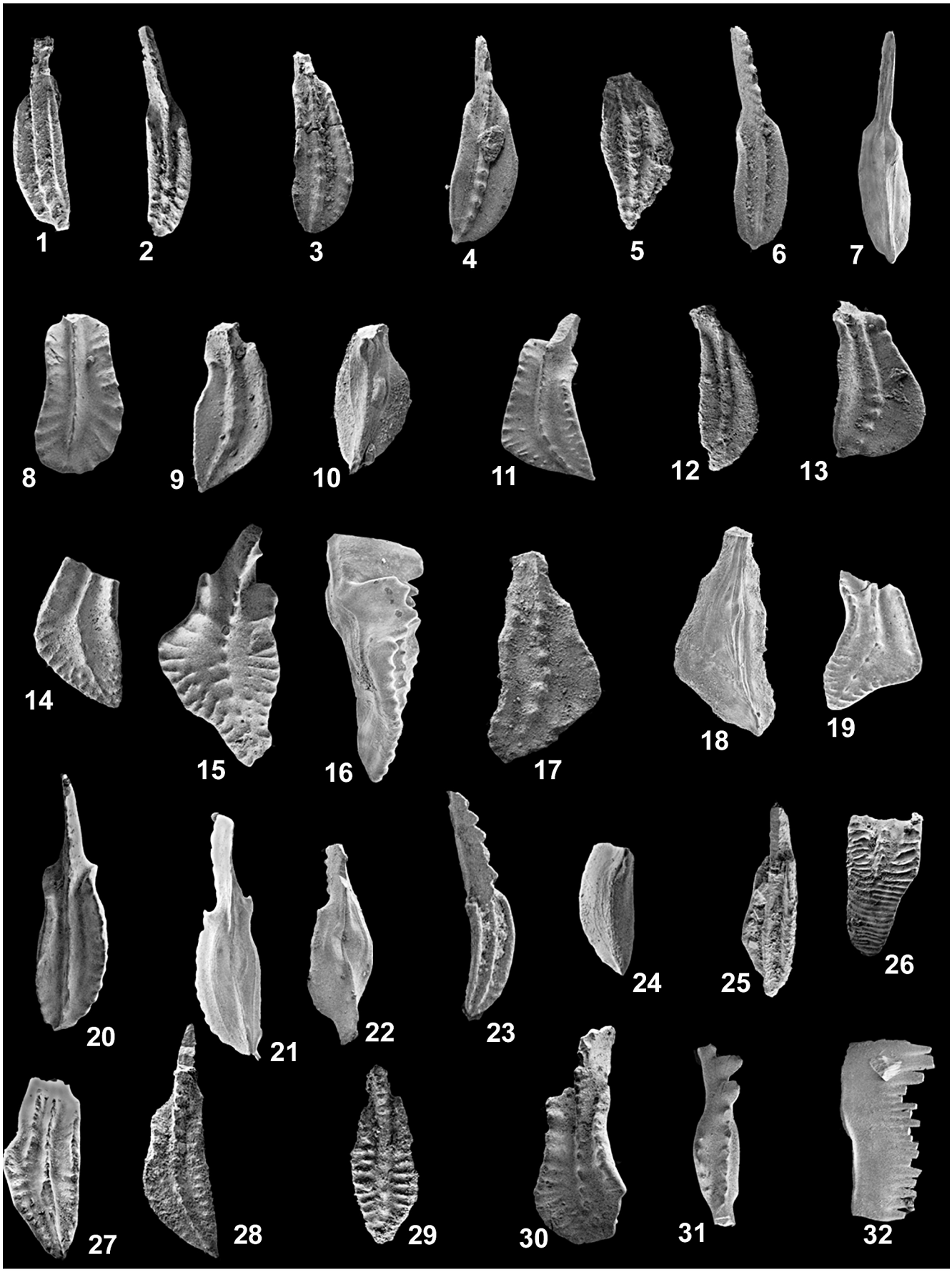
Fig. 29 - *Polygnathus ovatinodosus* Ziegler & Klapper, 1976: upper view of HUIC215, sample K3.

Fig. 30 - *Polygnathus webbi* Stauffer, 1938: upper view of HUIC216, sample K23.

Fig. 31 - *Polygnathus angustidiscus* Youngquist, 1945: upper view of HUIC217, sample K19.

Fig. 32 - *Mehlina* sp. lateral view of HUIC218, sample K37.

Fig.1, x100; fig. 12, x80; figs 13, 23-25 x70; figs 3, 4, 6, 7, 14, x60; figs 2, 9, 10, x55; figs 11, 15-19, 20-22, x50; fig. 26, x35, figs 27-30, x30; figs 31, 32, x35.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