Emsian (Lower Devonian) conodont stratigraphy and correlation of the Anti-Atlas (Southern Morocco)

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Based on revised previous records and many new data from the Tafilalt, Maider, eastern and western Dra Valley, the Emsian litho- and conodont biostratigraphy of the Anti-Atlas is reviewed, with some data on the Pragian below and the basal Eifelian above. More than 14.000 platform and single cone elements are assigned to 62 species/subspecies of 16 genera, partly in open nomenclature. The region is characterized by rather episodic polygnathid occurrences despite a predominant outer shelf biofacies with abundant dacryoconarids and goniatites. The studied Tafilalt polygnathid succession is as follows: rare records of *Eoctenopolygnathus pireneae* (Pragian), *Eolinguipolygnathus excavatus* Morphotype 114 Zone (basal Emsian, with *Eol. radula* sp. nov.), *Eol. catharinae* Subzone (of *Eol. gronbergi* Zone), *Linguipolygnathus inversus* Zone (with dominant *Eol. jacksoni*), *Eol. laticostatus* Zone (at the top of the lower Emsian), a regional basal upper Emsian interregnum (locally with the last *L. inversus*), *L. bultyncki* Zone (with *L. cooperi cooperi* Subzone), *Polygnathus patulus* Zone, *Po. partitus* Zone (basal Eifelian). Abundant icriodids provide an alternative zonation, from base to top with *Latericriodus steinachensis* Zone (lower/middle Pragian), *Caudicriodus celtibericus* Zone (upper Pragian/basal Emsian), *Lat. bilatericrescens gracilis* Zone, *Lat. bilatericrescens bilatericrescens* Zone, *Lat. latus* Zone, *Icriodus fusiformis* Zone (basal upper Emsian, with *Icriodus ovalis* sp. nov. and *I. praerectirostratus* sp. nov.), and *I. corniger corniger* Zone. *Criteriognathus miae* and *Crit. steinhornensis* provide an alternative ozarkodinid zonation in the Pragian to lower Emsian. The conodont sequences are correlated with the regional ammonoid zonations and global event succession. It contributes to the current chronostratigraphic revision of the Emsian. The Zinzilban basal Emsian GSSP level may project into the lower "Pragian Limestone" of the Tafilalt. The proposed revised basal Emsian GSSP level at the first appearance of *Eol. excavatus* Morphotype 114 is correlated in the Tafilalt with the base of the *Devonobactrites* Shale. A significant change of conodont faunas and facies took place at the top of the *Mimagoniatites* Limestone (main Daleje Event). The significant icriodid radiation of the *I. fusiformis* Zone is relevant for the debate on Emsian substage subdivision. *Lenzites gesinae* Klug, 2001 is designated as the type species of the new goniatite genus *Klugites*. • Key words: Emsian, conodonts, ammonoids, lithostratigraphy, biostratigraphy, chronostratigraphy, global events, Morocco.

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Recent geochronological scales suggest that the Emsian was a long to very long time interval, with estimated durations that vary widely between 9.5 (Gradstein *et al*. 2004) and 17.2 Ma (Kaufmann 2006). The most recent revision (Becker *et al*. 2012) assumes a time length of *ca* 14.3 Ma, exceding the Famennian (at *ca* 13.3 Ma). Therefore, the International Subcommission on Devonian Stratigraphy (SDS) has decided to subdivide the stage into two substages (Becker 1997, 2003), at a level close to the Zlíchovian/Dalejan transition or Daleje Event of Bohemia (*e.g.*, Chlupáč 1995, Jansen & Schindler 1997, Walliser 1997, Chlupáč & Lukeš 1999, Bultynck *et al*. 2000, Becker 2007). The base of the Emsian was defined in the Zinzilban section of the Kitab Reserve, Uzbekistan (Yolkin *et al*. 1998). However, this decision has been questioned (*e.g.*, Walliser 1997, Chlupáč & Lukeš 1999) since the chosen GSSP level places more than half of the classical Pragian of Bohemia into the lower Emsian. This was confirmed in subsequent reviews by Carls & Valenzuela-Ríos (2007), Carls *et al*. (2008, 2009), and Jansen (2012). Therefore, SDS decided during its Annual Meeting 2007 in the Kitab Reserve to formally revise the base of the Emsian (Becker 2009). It was decided to search within the Kitab region for a new and higher GSSP level near the entry of *Eolinguipolygnathus excavatus* Carls & Gandl, 1969 (see Kalvoda 1995) or of its advanced "ssp. 114" *sensu* Carls & Valenzuela-Ríos (2002). The first entry of *Eocostapolygnathus kitabicus* Yolkin, Weddige, Izokh & Erina, 1994, the current basal Emsian index conodont, shall define in future a formal Upper Pragian ("Zinzilbanian") substage.

Although the current Emsian revision focuses on the Kitab region (Yolkin *et al*. 2011; Izokh *et al*. 2011a, b; Kim *et al*. 2012), it is clear that a new basal Emsian GSSP must have the potential for wide international correlation. The same applies to the future intra-Emsian substage boundary, which will not necessarily be defined in Bohemia. This requires the detailed documentation of sedimentary and faunal successions from as many other regions as possible (*e.g*., Martínez-Pérez *et al*. 2011; Lu 2013; Martínez-Pérez & Valenzuela-Ríos 2012, 2014; Baranov *et al*. 2014). The correlation between the stratigraphically most important fossil groups of the time, especially between conodonts, ammonoids and dacryoconarids, needs to be improved. New brachiopod and palynomorph data are required to facilitate a better correlation from the pelagic facies realm into the neritic and terrestrial settings (*e.g*., Jansen 2012).

The Anti-Atlas of southern Morocco represents on a global scale one of the most fossiliferous Emsian regions. Building on literature data, the revision of old faunas and new samples (preliminary data in Bultynck & Walliser 2000a, Becker & Aboussalam 2011, Dojen *et al*. 2011, Becker *et al*. 2013b, Aboussalam & Becker 2013), this contribution documents the Emsian litho- and conodont stratigraphy of the Tafilalt/Maider and Dra Valley regions, and discusses implications for chronostratigraphy and the correlation between fossil groups. More than 14.000 platform and single cone elements belong to 16 genera and 62 species/subspecies, including three new taxa, and not counting some Eifelian specimens and species.

Abbreviations. – Conodonts: *Bel*. = *Belodella*, *Caud*. = *Caudicriodus*, *Crit*. = *Criteriognathus*, *Eoc*. = *Eocostapolygnathus*, *Eoct*. = *Eoctenopolygnathus*, *Eol*. = *Eolinguipolygnathus*, *I*. = *Icriodus*, *L*. = *Linguipolygnathus*, *Lat*. = *Latericriodus*, *Neop*. = *Neopanderodus*, *Oz*. = "*Ozarkodina*", *P*. = *Panderodus*, *Pel*. = *Pelekysgnathus*, *Po*. = *Polygnathus*, *Pseud*. = *Pseudooneotodus*.

Ammonoids/goniatites: *An*. = *Anarcestes*, *Anet*. = *Anetoceras*, *Erb*. = *Erbenoceras*, *Lat*. = "*Latanarcestes*" auct., *Sell*. = *Sellanarcestes*.

Figured conodonts collected by ZSA and RTB are housed under the collection number B9.A-5 in the type collection of the Geomuseum of the WWU Münster. Condonts of PB are kept in the micropalaeontology collection of the Muséum des Sciences Naturelles, Brussels, under the numbers b6591 to b6690.

Emsian lithostratigraphy of the Anti-Atlas (Fig. 1)

Informal lithostratigraphy of the Tafilalt

Despite its superb outcrops and international significance, the lithostratigraphy of the Tafilalt is still in an incipient stage. Hollard (1960, 1963a, 1967) subdivided its Devonian succession into lithological units with characteristic faunas but did not suggest formation names. This principle was kept on the explanation of the geological map (sheet Tafilalt-Taouz, Destombes & Hollard 1986). A correlation chart by Hollard (1981b) introduced group names but without explanations and without formally named formations. This system was summarized and updated by Bultynck & Walliser 2000a, b). The Emsian falls in the upper part of the Seheb el Rhassel Group and Amerboh Group. Kröger (2008) improved the distinction of Lower Devonian marker units with nautiloids in the southern Tafilalt. His data, the recognition of two important hypoxic shales below the widespread *Anetoceras* Limestone (Belka *et al*. 1999, Becker & House 2000, Klug 2001, Klug *et al*. 2008), and the preliminary results of Becker & Aboussalam (2011) and Aboussalam & Becker (2013) provide a more refined informal Emsian litho- and event stratigraphy of the Tafilalt. Becker *et al*. (2013a) assigned all of the Tafilalt Devonian to lithological units numbered from A to Y, with Units E to L covering the upper Pragian to basal Eifelian interval. Since a revised smaller-scale (than previously) geological mapping is currently in progress in the region, we cannot establish new formal lithostratigtraphic terms.

Unit E, (regional) "Pragian Limestone" (Bultynck & Walliser 2000a). – ["Calcaires marneux noduleux jaunâtres à trilobites" in Hollard 1963a; Units a1-2 in Hollard 1967; Unit c in Alberti 1980, 1981; Pragian Limestone (Unit B2) in Bultynck & Walliser 2000a, b; De Baets *et al*. 2010; Becker & Aboussalam 2011; Becker *et al*. 2013b.]

This unit of light-grey marly and nodular limestone may reach more than 10 m of thickness and is best characterized by its diverse and locally very rich trilobite fauna. Most characteristic are phacopids (*Reedops*, *Boeckops*), cheirurids (*Crotalocephalina*), scutelluids (*Paralejurus*), dalmanitids (*Odontochile*), and harpids. Orthoconic cephalopods are very common in specific levels (Kröger 2008, Klug *et al*. 2013). Some sections contain thin limestones within the underlying "Pragian Marls and Shales" (Unit D). With respect to the currently unstable position of the formal Pragian/Emsian boundary and a different meaning of the term in the Bohemian type region, this unit should be re-named in a future formal lithostratigraphic subdivision.

Unit F, Devonobactrites Shale (Becker & Aboussalam 2011). – [Shale with Asteropyginae above Unit c in Alberti 1980, 1981; "Niveau ferrugineux" in Hollard 1981b; unit B3 in Bultynck & Walliser 2000a, b; lower haematitic fauna in Becker & House 2000; shale with Faunule 1 in Klug *et al*. 2008.]

This hypoxic shale with locally abundant goethitic fauna, especially from Bou Tchrafine to Ouidane Chebbi and in the Amessoui Syncline, is characterized by the sudden entry of abundant earliest bactritids (*Devonobactrites*), acanthodian spines (*Machaeracanthus*), and small asteropygids (*Metacanthina*, *Pilletina*). They are accompanied by fossil groups that are normally rather rare in cephalopod shales, such as hyolithids, edrioasteroids, phyllocarids (*Ceratiocaris*, *Nahecaris*), and machaeridians (*Lepidocoleus*). The complete fauna has been documented in Klug *et al*. (2008) and De Baets *et al*. (2010).

Unit G, Deiroceras Limestone (Kröger 2008). – [Lower part of Fauna di 3.1 with *Jovellania* in Hollard 1974; "calcaires bleu noir à nautiloides" in Bultynck & Hollard 1980 and Hollard 1981b; calcaires à "*Jovellania*" in Destombes & Hollard 1986; "*Jovellania*" Limestone (Unit C1) in Bultynck & Hollard 2000a, b; Unit A in Klug 2001.]

Kröger (2008) emphasized that the nautiloid *Jovellania* does not occur in this limestone unit that has been informally named after it; instead the large-sized genus *Deiroceras* is characteristic and provided the corrected name. Other macrofauna is rare. Since a true *Jovellania* Limestone succession occurs below in the upper Lochkovian, it is not possible to continue the same name for an Emsian unit.

Unit H, Metabactrites-Erbenoceras Shale (Becker & Aboussalam 2011). – [Middle, marly part of Fauna di 3.1 with *Machaeracanthus* in Hollard 1974; "Argillites grises" in Bultynck & Hollard 1980; "marno-calcaires à *Machaeracanthus*" in Destombes & Hollard 1986; Unit C2 in Bultynck & Walliser 2000a, b; Unit B in Klug 2001; shale with Faunule 2 in Klug *et al*. 2008.]

This second lower Emsian hypoxic shale interval (Becker & House 2000) is characterized by the sudden incoming of a diverse early ammonoid fauna, notably with *Metabactrites*, *Erbenoceras*, *Chebbites*, and *Gyroceratites*. *Machaeracanthus*, hyolithids, various gastropods and bivalves of Faunule 1 re-appear, but not the edrioasteroids, machaeridians, and phyllocarids. The complete assemblage has been described in Klug *et al*. (2008) and De Baets *et al*. (2010).

Unit I, Anetoceras Limestone (adopted from Hollard 1963a in Bultynck & Walliser 2000a). – [Lower part of "calcaires à *Mimagoniatites* et *Anetoceras advolvens*" in Hollard 1963a; Unit a4 in Hollard 1967; upper part of Fauna di 3.1 with *Anetoceras* (*Erbenoceras*) *advolvens* Erben, 1960 *in* Hollard 1974; "calcaires roses à Tentaculites" and "Calcaires gris et marnes" in Bultynck & Hollard 1980, and Hollard 1981b; lower to middle part of Unit d in Alberti 1980, 1981; "niveau supérieur à *Anetoceras advolvens*" in Destombes & Hollard 1986; *Erbenoceras* Beds in Belka *et al*. 1999; *Anetoceras* Limestone (lower part of Unit C3) in Bultynck & Walliser 2000a, b (compare Becker & House 2000 and Becker & Aboussalam 2011); Units C, D in Klug 2001; lower to middle part of the *Erbenoceras* Limestone of Kröger 2008 and Klug *et al*. 2013; lower to middle part of the *Erbenoceras* Beds of De Baets *et al*. 2010.]

Although *Erbenoceras* (= *Kokenia* ex gr. *obliquecostata* in Massa, 1965) is the most common ammonoid in this unit, especially in its lower part, it is the entry of *Anetoceras* s. str., which distinguishes its faunas from the underlying shales. Both genera can be clearly recognized despite significant morphological variability (De Baets *et al*. 2013). Well above the base, *Klugites* gen. nov. is locally common. Relatives of *Erb. solitarium* Barrande, 1865, *Teicherticeras* and *Weyerites* are other, rare marker goniatites.

Unit J, Mimagoniatites Limestone (adopted from Hollard 1963a in Walliser 1991). – [Top part of Fauna di 3.1 in Hollard 1974; upper part of "Calcaires à *Mimagoniatites* et *Anetoceras advolvens*" in Hollard 1963a; Unit a5 in Hollard 1967; "Calcaires bleu gris foncé" in Bultynck & Hollard 1980; upper part of Unit d in Alberti 1980, 1981; *Mimagoniatites* Limestone in Walliser 1991 (compare Becker & Aboussalam 2011); "blue *Mimagoniatites* Limestone" in Bultynck & Walliser 2000a, b; Unit E in Klug 2001; upper part of *Erbenoceras* Limestone in Kröger 2008 and Klug *et al*. 2013; upper part of *Erbenoceras* Beds in De Baets *et al*. 2010.]

Separated from the *Anetoceras* Limestone by some marl or more argillaceous limestone, the medium to dark bluish-grey *Mimagoniatites* Limestone forms a distinctive lithological marker in the upper part of the "*Anetoceras* Ridge" (Becker & House 2000) and at the top of the lower Emsian. The last limestone beds tend to be more nodular and light grey. *Mimagoniatites* is the only common ammonoid, but associated there are many, often large, nautiloids (*e.g.*, *Metarmenoceras*, see Kröger 2008), large bivalves (*Panenka*), and placoderm remains.

Unit K, Daleje Shale Equivalents (Becker & House 2000). – ["Schistes gris ou marnes" and "Marno-calcaires à goniatites pyriteuses" in Hollard 1963a; Unit b6 in Hollard 1967; Unit e in Alberti 1980, 1981; lower and middle formations of Amerboh Group in Hollard 1981b; Unit $di_{3–4}$ in Destombes & Hollard 1986; *Latanarcestes* Shale in Bultynck & Walliser 2000a, b; "Late Emsian marls" in Klug 2002.]

In basinal settings this distinctive shale-siltstone interval is more than 100 m thick. Becker & House (2000) and Klug (2002) correlated its base with the Daleje Event of Bohemia (= Mid-Emsian Event in Bultynck & Walliser 2000a, b). In the lower part faunas with *Gyroceratites* and mimagoniatitids are very characteristic (Alberti 1980; Becker & House 1994, 2000). New collections show that the latter belong to *Rherisites* Klug, 2002. In the *ca* upper half first anarcestids enter, including forms that have commonly been assigned to *Latanarcestes* (Hollard *et al.* 1967, Becker & House 1994, Klug 2002). The type of this genus, however, is most likely from the Eifelian and the basal upper Emsian group needs to be re-named. Consequently, the name *Latanarcestes* Shale (Bultynck & Walliser 2000a) is not appropriate. Klug (2002) showed that the first *Sellanarcestes* (*Sell. eos* Klug, 2002) also appear in the thick shale unit, probably in its upper part (Becker *in* Webster *et al.* 2005). This means that the Daleje Shale Equivalents of the Tafilalt includes some younger strata than the type Daleje Shale of Bohemia. Therefore, a new, neutral term should be established in a future formal lithostratigraphic scheme for the Tafilalt.

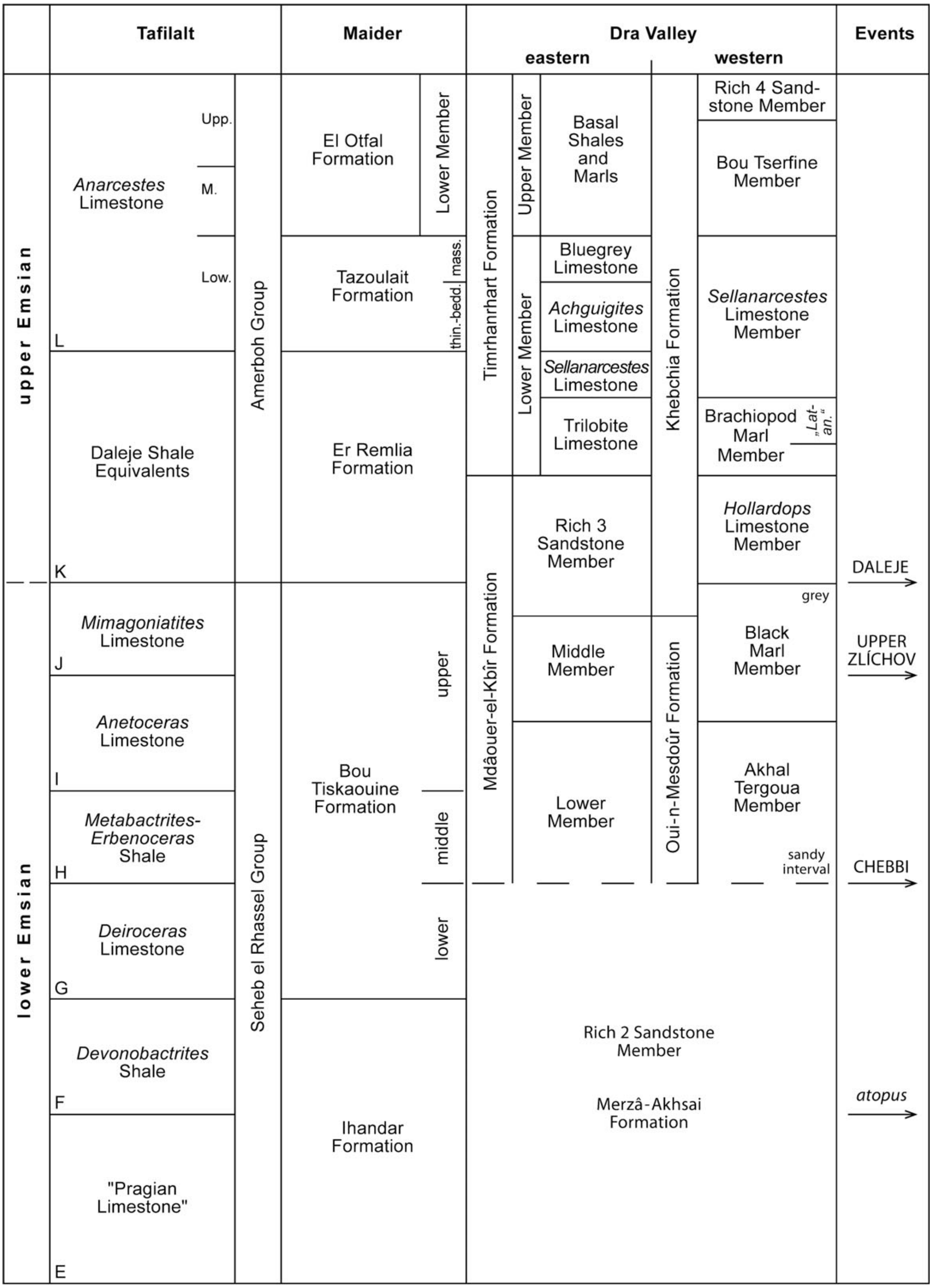
Unit L, Anarcestes Limestone (adopted from Hollard 1963a). – ["Calcaires et marno-calcaires à polypiers, trilobites et *Anarcestes lateseptatus*" in Hollard 1963a, "schistes argileux gris et calcaires argileux" (Units b7–9) in Hollard 1967; upper formation of Amerboh Group in Hollard 1981b; "calcaire argileux à *Favosites*, *Anarcestes lateseptatus*" (dm_{1-1}) in Destombes & Hollard, 1986; Unit D in Walliser 1991; *Sellanarcestes* Limestone/Marl in Bultynck & Walliser 2000a, b and Lubeseder *et al.* 2010; "Late Emsian nodular limestones" in Klug 2002.]

The main goniatite genus that ranges from the very base of this unit (Becker *in* Webster *et al.* 2005) to the top (Klug 2002, section Gara Mdouara) is *Anarcestes*. Therefore, it is best to name the unit after this marker genus. *Sellanarcestes* is restricted to its lower part (Becker & House 1994). *Achguigites* and *Sell. neglectus* (Barrande, 1865) enter slightly above the base in *Sellanarcestes-Anarcestes* assemblages. The extinction of *Sellanarcestes* defines a middle part (Becker & House 1994, Klug 2002) of the *Anarcestes* Limestone. The upper part is rather unfossiliferous, with *An. lateseptatus* (Beyrich, 1837) as the main index species. This subdivision was already known to Hollard (1967), who distinguished a level with *Sellanarcestes* (b7) and two levels with *Anarcestes* (b8–9). The change from pelagic and hypoxic ammonoid shales of the Daleje Shale equivalents to condensed, hemipelagic cephalopod limestone suggests a shallowing at the base of the *Anarcestes* Limestone. This contradicts the interpretation of Lubeseder *et al.* (2010), who interpreted his corresponding *Sellanarcestes* Limestone as a transgressive unit. The Emsian–Eifelian boundary lies within the top part of Unit L (Bultynck & Walliser 2000a).

Formal formation terminology of the Maider (Fig. 1)

Hollard (1974) subdivided the upper Emsian to Frasnian of the Maider (and southern Tafilalt) into a succession of numbered ammonoid zones and named formations. He included his Faunas di 3 and di 4, the interval from the *Deiroceras* Limestone to the nodular limestones with *Sell. wenkenbachi* (Kayser, 1884), in a "Formation du Talus d'Issemour". The upper Emsian Fauna with "*Anarcestes*" *neglectus* was thought to represent the basal Middle Devonian and called Fauna dm 1.1. Within his El Otfal Formation it was aligned with a poorly fossiliferous interval (Fauna dm 1.2) and with the top Emsian/lower Eifelian Fauna dm 1.3. Hollard (1981b) altered this scheme and distinguished in the Emsian of the Maider at the base an Ihandar Formation, then a Bou Tiskaouine Formation (correlating with the *Deiroceras* to *Mimagoniatites* Limestones, Units G–J), an Er Remlia Formation (correlating with the Tafilalt Unit K), and subsequent Tazoulait and El Otfal formations. The basal upper Emsian Er Remlia Formation includes many argillaceous limestones or even limestone cliffs in comparison with the contemporaneous Daleje Shale Equivalents of the Tafilalt. The higher upper Emsian Tazoulait Formation correlates with the *Sellanarcestes*-rich, more condensed lower *Anarcestes* Limestone of the Tafilalt. Solid limestones serve as a lithostratigraphical marker at the top. The Lower Member of the El Otfal Formation straddles the Emsian/Eifelian boundary. It is unfortunate that the subsequent sequence stratigraphic approach of Döring (2002) made no attempt to use or correlate Hollard's terminology. However, Döring used the goniatite limestones of the Bou Tiskaouine Formation, the argillaceous interval of the Er Remlia Formation (Daleje Shale Equivalent), the *Sellanarcestes*-rich limestones of the Tazoulait Formation, and the subsequent more nodular limestones to recognize regional Depophases Oa, Ob, 1a, 1b, and 2.

Figure 1. Comparison of the Emsian lithostratigraphy of the Tafilalt, Maider, eastern and western Dra Valley regions and the position of recognized global events. Numbers E to L refer to the Tafilalt lithological units of Becker *et al.* (2013a).


Tafilalt
Maider
Dra Valley
eastern
western
Events
upper Emsian
lower Emsian
Anarcestes Limestone
Upp.
M.
Low.
L
Daleje Shale Equivalents
K
Mimagoniatites Limestone
J
Anetoceras Limestone
I
Metabactrites-Erbenoceras Shale
H
Deiroceras Limestone
G
Devonobactrites Shale
F
"Pragian Limestone"
E
Amerboh Group
Seheb el Rhassel Group
El Otfal Formation
Lower Member
Tazoulait Formation
thin.-bedd.
mass.
Er Remlia Formation
Bou Tiskaouine Formation
upper
middle
lower
Ihandar Formation
Timrhanrhart Formation
Upper Member
Lower Member
Basal Shales and Marls
Bluegrey Limestone
Achguigites Limestone
Sellanarcestes Limestone
Trilobite Limestone
Mdâouer-el-Kbîr Formation
Rich 3 Sandstone Member
Middle Member
Lower Member
Khebchia Formation
Oui-n-Mesdoûr Formation
Rich 4 Sandstone Member
Bou Tserfine Member
Sellanarcestes Limestone Member
Brachiopod Marl Member
„Lat-an."
Hollardops Limestone Member
grey
Black Marl Member
Akhal Tergoua Member
sandy interval
Rich 2 Sandstone Member
Merzâ-Akhsai Formation
DALEJE
UPPER ZLÍCHOV
CHEBBI
atopus

Emsian lithostratigraphy of the Dra Valley (Fig. 1)

The litho- and biostratigraphy of the Dra Valley Devonian has been summarized by Becker *et al*. (2004a) and Jansen *et al*. (2007). Subsequently, Ouanaimi & Lazreq (2008) and Lubeseder *et al*. (2009) investigated the sedimentology, sequence stratigraphy and synsedimentary tectonics of the Lower Devonian of the region. The formation terminology was introduced by Hollard (1978), replacing informal names used in Hollard (1967). The concept of cyclic sedimentation within the regional Rich Group was further outlined by Hollard (1981a). The eastern (*ca* Foum Zguid to Tata) and western Dra Valley (*ca* Akka to Ain-n'Delouine = Ain Deliouine) regions display different Emsian successions (*e.g.*, Hollard 1967, 1978; Bultynck & Hollard 1980).

In all of the Dra Valley the base of the Emsian (of any definition) lies within the Rich 2 Sandstone Member of the upper Merzâ-Akhsai Formation, which contains no conodonts. In the eastern succession the following Mdâouer-el-Kbîr Formation can be subdivided into three members, a Lower Member with limestones, marls, *Erbenoceras* and other goniatites (details in De Baets *et al.* 2010), a fine siliciclastic Middle Member ("Grès d'El Mdâouer Srhir" in Hollard 1978), and the (upper) Rich 3 Sandstone Member ("Grès et lumachelles du Mdâouer-el-Kbîr" in Hollard 1978) with some sandy limestones in its upper part. The subsequent Timrhanrhart Formation consists of two members. The Lower Member clearly falls in the upper Emsian. In ascending order, it consists at Oufrane of a Trilobite Limestone at the base, a massive *Sellanarcestes* Limestone (without *Anarcestes*), the nodular *Achguigites* Limestone (with *Anarcestes*), and a Bluegrey Limestone dominated by *Anarcestes* faunas (Ebbighausen *et al*. 2011). The Emsian–Eifelian boundary lies in overlying shales and marls of the Upper Member (compare Jansen *et al*. 2004a).

In the western succession, the Merzâ-Akhsai Formation is overlain by the Oui-n-Mesdoûr Formation, which consists of dark limestones in the lower part (Akhal Tergoua Member), partly with large trilobites (*Odontochile*), and an upper Black Marl Member with rare *Erbenoceras* (Becker *et al.* 2008) and very restricted benthos. The subsequent Khebchia Formation begins with the trilobite-rich *Hollardops* Limestone Member (details in Brett *et al*. 2012), followed by the Brachiopod Marl Member, with a "*Latanarcestes*" level in its upper half, the *Sellanarcestes* Limestone Member (with frequent *Anarcestes*, Becker *et al*. 2004c), and by a thick package of shale and siltstones, the Bou Tserfine Member. The Emsian–Eifelian boundary lies within the rather unfossiliferous Rich 4 Sandstone Member at the top of the formation.

Previous work on Emsian conodonts from the Anti-Atlas

The first Emsian conodont data from the Tafilalt were provided by Massa (1965), based on identifications by M. Lys and M. Mauvier (see repetition in Hollard 1974). The faunal lists include first regional records of species, such as *Lat. bilatericrescens* (Ziegler 1956), *Crit. steinhornensis* (Ziegler, 1956), and *Pseud. beckmanni* (Bischoff & Sannemann, 1958). Other forms, however, especially the polygnathids, were given post-Emsian species names. Due to the lack of illustrations, these identifications cannot be revised without re-examination of the material. The more detailed conodont biostratigraphy of the region begun with Bultynck & Hollard (1980, 1982), who introduced a succession of numbered regional faunas, based on different successions either from the Tafilalt (sections Bou Tchrafine West, Bou Tchrafine North, Hamar Laghdad, Fig. 2), SW Maider (Ou Driss), or from numerous localities of the eastern and western Dra Valley. Their regional zonation, which is revised here, can be summarized as follows:

Fauna VIII – *Po. costatus patulus* – Maider – [now *Po. patulus*]
Fauna VII – *Po. serotinus* – Maider – [now *L. serotinus*]
Fauna VIc – *Po. linguiformis cooperi* – Tafilalt – [now *L. cooperi cooperi*]
Fauna VIb – *Po. linguiformis* α – Maider, eastern and western Dra Valley – [now *L. bultyncki*]
Fauna VIa – *I. rectirostratus* – eastern and western Dra Valley – *I. corniger*
Fauna Vb – *I. fusiformis* – western Dra Valley
Fauna Va – *Po. laticostatus* – Tafilalt – [now *Eol. laticostatus*]
Fauna IV – *Oz. steinhornensis steinhornensis* – Tafilalt – [now *Crit. steinhornensis*]
Fauna III – *Po. gronbergi* – Tafilalt – [now *Eol. gronbergi*]
Fauna II – *Lat. bilatericrescens* – Maider, eastern and western Dra Valley
Fauna Ib – *Oz. steinhornensis miae* – Tafilalt – [now *Crit. miae*]
Fauna Ia – *Po. dehiscens* – Tafilalt – [now *Eol. excavatus*] – *Caud. sigmoidalis*

The succession combines intervals defined by representatives of three different conodont groups, which have a partly different biofacies distribution: polygnathids, icriodids, and spathognathodids ("ozarkodinids"). It is possible to separate regional zonations for the three groups and to correlate them internationally. Their vertical combination reflects distinctive palaeoecological trends of the region, further complicated by intervals (ecozones) dominated in certain sections or in the whole region by long-ranging, supposed shallow-water single cone genera, such as *Belodella* (compare first data of Massa 1965), *Coelocerodontus*, *Panderodus*, or *Neopanderodus*.

Bultynck (1985) added new data for the Ou Driss section (SW Maider), with further evidence for Faunas Ia, Ib, IV, Va, VIa/b, VIc, VII, and VIII. In the northern Maider, at the Jebel Issimour (section Tizi n'Ikouâch) and in the Ouihlane (= Ouahlane) Syncline, Faunas VIa to VIII were recognized. Based on the comparison with Bohemia (Klapper *et al*. 1978), he considered that the appearance of *L. bultyncki* indicates the base of the *serotinus* Zone. Emsian conodont data for Ou Driss were also briefly discussed in Bultynck (1991). Belka *et al*. (1999) provided some new data for the lower Emsian of the Ouidane Chebbi at the eastern margin of the Tafilalt, with very few conodonts from the upper Emsian. Subsequently, Z. Belka identified in Klug *et al*. (2000) and Klug (2002) a few samples from the *Anarcestes* Limestone of the Jebel Ouaoufilal (Amessoui Syncline, southern Tafilalt). In a more general review of the Tafilalt, Bultynck & Walliser (2000a) included updated lower Emsian conodont ranges at section Bou Tchrafine West, which are further revised here. In the same volume, Plodowski *et al*. (2000) listed some new lower Emsian conodont faunas from the Jebel Issimour. Bultynck & Walliser (2000b) added data from Achguig, which is the western prolongation of the Ouidane Chebbi outcrop belt. Fröhlich (2004) assigned some strata of the Jebel Rheris (see JRW in Fig. 2) to the lower Emsian *dehiscens* Zone but provided no further details. Becker & Aboussalam (2011) and Aboussalam & Becker (2013) published preliminary data on the lower Emsian conodont succession at Jebel Ihrs, near the western margin of the Tafilalt. Becker *et al*. (2013b) provided preliminary data for El Khraouia in the southern Tafilalt, Becker & Aboussalam (2013) for the Emsian–Eifelian boundary at Jebel Amelane (western Tafilalt). The position of all mentioned Tafilalt localities is shown in Fig. 2.

New Emsian conodont data for the eastern Dra Valley were published in the last decade by P. Bultynck (*in* Ebbighausen *et al*. 2004) and K. Weddige (*in* Jansen *et al*. 2007). For the western succession there are recent records from the Oui-n-Mesdoûr Formation and the *Hollardops* Limestone Member (Weddige *in* Becker *et al*. 2003 and Jansen *et al*. 2004b, 2007; preliminary data of Aboussalam *in* Becker *et al*. 2008 and Dojen *et al*. 2010).

Investigated localities and their conodont successions (Fig. 2)

Lower Emsian at Jebel Ihrs (Figs 3A, B, 4–10, Table 1)

The Jebel Ihrs is in the western Tafilalt the continuation of the *ca* W-E running Jebel Amelane west of the pass formed by the main road from Rissani to Mississi (sheet Erfoud, NH-30-XX-2). Its Pragian/Emsian litho- and biostratigraphy was first outlined by Alberti (1980, 1981). Because of its dacryoconarid succession, revised in Alberti (1998), we chose it as one of the regional reference sections for Emsian conodonts. Klug (2001) noted it as a minor locality for lower Emsian ammonoids; they are locally very rare. The published upper Emsian goniatite record refers to the Jebel Amelane succession (Becker & House 1994, Klug 2002). Becker & Aboussalam (2011) and Aboussalam & Becker (2013) provided a summary of the lower Emsian litho- and conodont stratigraphy, which is updated in Fig. 4 and Table 1, including additional faunas. The GPS position for the section base is W N 31°16´ 11.4˝, W 4°24´ 8.8˝.

The "Pragian Limestone" crops out at *ca* 75 m south of the main road to Msissi, opposite to a small hut right at the road (Fig. 3A). Bed 2, a solid nodular limestone, contains only a few *Belodella* (Fig. 5A, B). Subsequent light-grey limestones (Beds 3, 4) are even more solid and yielded more belodellids at the top, in association with a single *Caud. celtibericus* (Carls & Gandl, 1969). The upper part of this low limestone ridge is partly nodular, partly solid, and has no conodonts at all (Samples 6b and 8c). An interval with thin-bedded alternations of marls and nodular limestones (Beds 9–14) forms a gradual transition to the mostly covered *Devonobactrites* Shale (Fig. 4). Despite this gradual deepening, a shallow-water belodellid biofacies prevails in Beds 10b (Fig. 5E) and 14b.

Three thin limestones beds (Beds 15b–16a) underlie the main, more massive and condensed (only 38 cm thick) *Deiroceras* Limestone (Beds 16b–d, Fig. 3A, D), which is rich in orthocones up to 2.5 cm in diameter. The base (Bed 15b) yielded a monospecific *Caud. celtibericus* fauna. The nodular Bed 16a differs radically in its *Caud. sigmoidalis* (Carls & Gandl, 1969) fauna (Fig. 5F) and the sudden appearance of the regionally oldest and morphologically rather diverse polygnathids (*ca* 12.5% of Pa elements), of *Crit. miae* (Bultynck, 1971; 1.2%, Fig. 5I), and of the first representatives of *Lat. bilatericrescens* (only 1.75%; Fig. 5G, H). The sudden change of conodont biofacies is not evident in the lithofacies. The upper part of the unit (Beds 16c, d) belongs to a yet different *Criteriognathus-Latericriodus*-polygnathid biofacies. The sudden exclusion of *Caudicriodus*, especially of *Caud. sigmoidalis*, is remarkable and underlines the distinction of the two lower Emsian icriodid genera in terms of a different palaeoecology (facies distribution). *Criteriognathus miae* has become the dominant species in the lower sample (almost 40% of the fauna), *Lat. bilatericrescens* in the upper bed (78% of the assemblage). *Caudicriodus celtibericus* re-appears as a rare form in Bed 16d.

The *Anetoceras* Limestone (Fig. 3B) begins with three thin limestones (Beds 18a–c), which belong (Sample 18b) to a *Latericriodus* biofacies with *ca* 30% *Caudicriodus* and rare *Criteriognathus* but without any polygnathids. Overlying more solid limestones (Bed 19) contain some crinoid debris. Subsequent thin, nodular beds are very conodont-rich (more than 800 specimens in *ca* 2.5 kg of Sample 20b), which enables to record the inception of initially rare taxa, such as *Lat. beckmanni beckmannni* (Ziegler, 1956) and *Lat. latus* (Al-Rawi, 1977). *Latericriodus bilatericrescens* is by far dominant (almost 90% of the fauna), followed by *Crit. miae*. There are only very rare *Eol. excavatus*. The lower part of the solid Bed 21a yielded yet another distinctive conodont biofacies, dominated jointly by *Lat. bilatericrescens* (*ca* 65%) and *Lat. beckmanni* (*ca* 29%). *Eolinguipolygnathus* and the first *Crit. steinhornensis* are extremely rare (one specimen each). The *Latericriodus-Criteriognathus* biofacies of Bed 20b returns in the nodular Bed 22b and includes the inception of two more rare taxa, *Eol. catharinae* (Bultynck, 1989) and *Lat. beckmanni sinuatus* (Klapper, Ziegler & Mashkova, 1978).

The middle part of the *Anetoceras* Limestone consists of solid to massive, light-grey limestones (Beds 23b–24d, Figs 3B, 4), partly with strongly bioturbated upper surfaces. These indicate brief episodes of non-deposition (*e.g.*, at the top of Bed 24d). In the upper part beds become thinner. In Beds 23b and 25a *Crit. steinhornensis* replaces *Crit. miae*, which is last seen in Bed 25a. Bed 23b is especially conodont-rich (more than 1200 Pa elements in a normal-sized, *ca* 2.5 kg sample). Despite this, there is not a single polygnathid and the diversity drops. There are placoderm bones in Bed 26d, but only three conodont taxa, including the last, rare *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969) and *Caud. celtibericus*. This worsening of living conditions for conodonts continues at the top of the *Anetoceras* Limestone (Sample 27b), where the setting changes to a conodont-poor *Belodella* biofacies, resembling the "Pragian Limestone".

The main *Mimagoniatites* Limestone consists locally of massive, up to 30 cm thick, bluish, middle-grey limestones (Fig. 4, see also Aboussalam & Becker 2013, fig. 6A, C). Large orthocones, including actinoceratids, are very common in the upper part (Beds 29, 30) and there are some big placoderm remains (*e.g.*, a 30 cm long arm plate at the top of Bed 30). The upper surface of Bed 29 displays several *Mimagoniatites* cf. *fecundus* (Barrande, 1865). Despite the distinctive goniatite influx, which suggests a more pelagic biofacies, there are no conodonts at all. This proves an ecological independence of both fossil groups. The thin three beds above the main *Mimagoniatites* Limestone (Beds 31a_1, a_2, and 31b) are fossil-rich (many orthocones, large *Panenka*, more large placoderm plates) and lighter grey. Strong bioturbation and hematite incrustations testify a condensed and partly interrupted deposition, an indicator for increased bottom turbulance. The pure polygnathid biofacies of Samples 31a_1 and 31b, however, suggests a deepening trend. It is remarkable that the two sampled beds contain different polygnathids, with a higher diversity in the lower sample, including both *Eolinguipolygnathus*, with dominant *Eol. jacksoni* (Bardashev, Weddige & Ziegler, 2002), and *Linguipolygnathus* (two species) in association with some *Pseudooneotodus*. The top sample only contains the first genus. A stepwise deepening from Zlíchovian into Dalejan strata is also typical for the Barrandian (Ferrová *et al*. 2012).

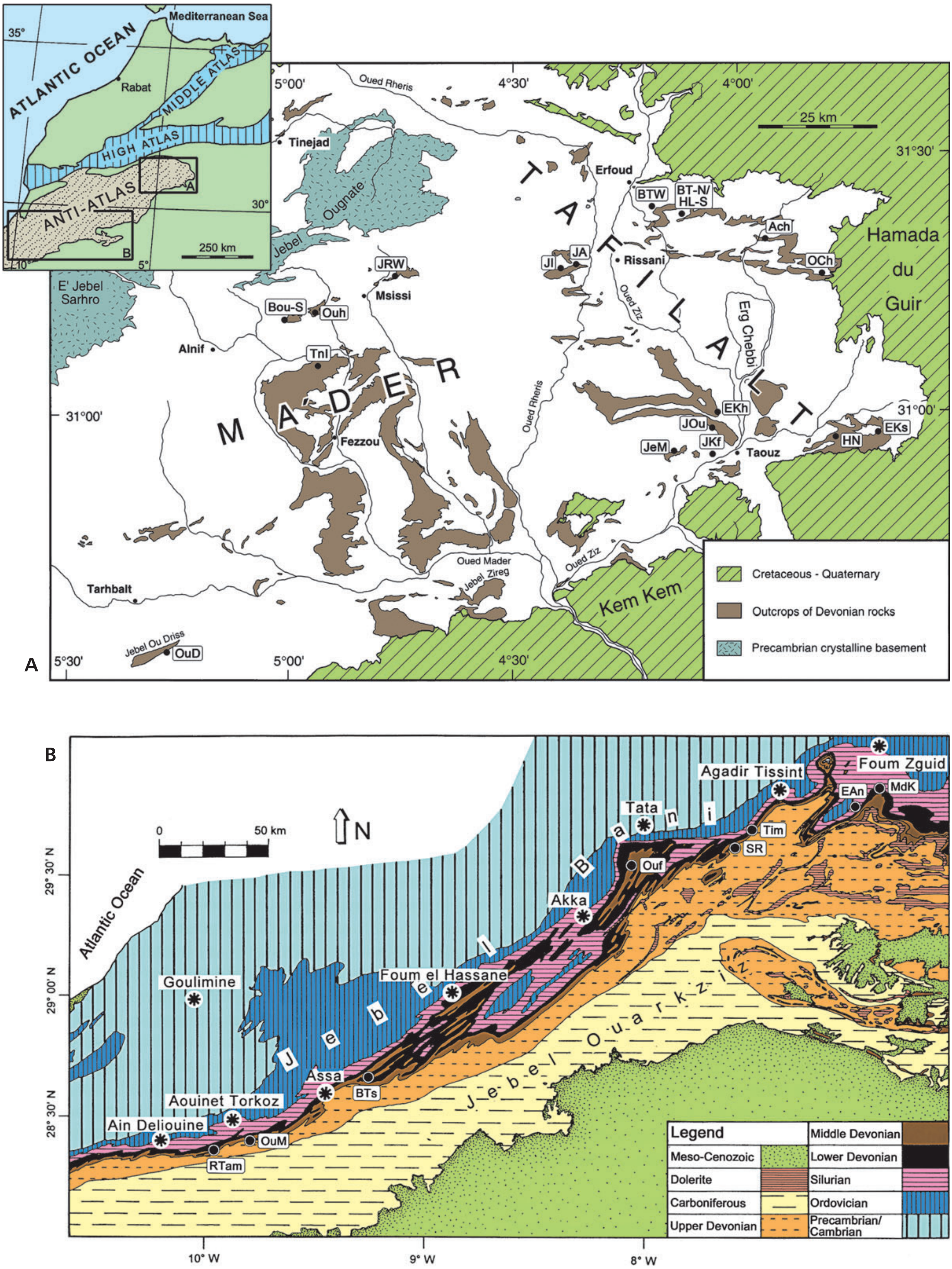
The Daleje Shale Equivalents are *ca* 100 m thick and unfossiliferous. The *Anarcestes* Limestone is locally relatively poor in goniatites and has not been sampled for conodonts.

Bou Tchrafine West (Figs 11A, 12)

Section Bou Tchrafine West belongs to the central Tafilalt Platform. It is located in the plain SW of the Bou Tchrafine ridge about 500 m south of the most western point of that ridge (Figs 2, 11A), *ca* 8 km SE of Erfoud (*ca* x = 616.6, y = 87.6; see detailed map in Bultynck & Walliser 2000a, fig. 4). The outcrop is relatively low. Following a rather general compilation in Hollard (1968), the Emsian stratigraphy at the Bou Tchrafine ridge was first studied in detail by Bultynck & Hollard (1980) for conodonts and by Alberti (1980, 1981) for dacryoconarids. An updated lithological column with new conodont records was published by Bultynck & Walliser (2000a). The new sampling comprises new, larger samples from the 1980 samples 1 to 5 and the new samples 0, 0/1, 1b, 2b, 4b, 4t and 6. The sampling density is about one sample at every 0.5 m.

Early ammonoids have been described by Becker & House (2000) from a lateral section to the southwest, just adjacent to the road pass through the ridge. Another good lower Emsian outcrop, with rich fauna of the *Devonobactrites* Shale and many goniatites in the *Anetoceras* Limestone, lies just beneath the little bridge of the road to Erfoud, at the NW corner of Bou Tchrafine.

Figure 2. Geographic position of Emsian conodont localities in the Tafilalt and Maider (A) and Dra Valley (B). Abbreviations: OuD = Ou Driss, TnI = Tizi n'Ikouâch/Jebel Issimour, Bou-S = Boultan South, Ouh = Ouahlane (= Ouihlane), JRW = Jebel Rheris West, JI = Jebel Ihrs, JA = Jebel Amelane, BT-W = Bou Tchrafine West, BT-N/HLS = Bou Tchrafine North/Hamar Laghdad South, Ach = Achguig, OCh = Ouidane Chebbi, EKh = El Khraouia, JOu = Jebel Ouaoufilal, JKf = Jebel Kfiroun South, JeM = Jebel el-Mrier, HN = Hassi Nebech, EKs = Erg Kseir, MdK = Mdâouer-el-Kbîr, EAn = El Anhsour, Tim = Timrhanrhart, SR = Sidi Rezzoug, Ouf = Oufrane, BTs = Bou Tserfine, OuM = Oui-n-Mesdoûr, RTam = Rich Tamelougou.


Mediterranean Sea
35°
ATLANTIC OCEAN
Rabat
MIDDLE ATLAS
HIGH ATLAS
ANTI-ATLAS
30°
A
B
250 km
10°
5°
5°00'
4°30'
4°00'
Oued Rheris
25 km
31°30'
Tinejad
Ougnate
Jebel
Erfoud
T
A
F
I
L
A
L
T
BTW
BT-N/
HL-S
Ach
Hamada
du
Guir
OCh
JRW
JI
JA
Rissani
Msissi
Oued Ziz
Erg Chebbi
E' Jebel
Sarhro
Bou-S
Ouh
Alnif
Tnl
M
A
D
E
R
31°00'
EKh
JOu
Fezzou
Oued Rheris
JeM
JKf
Taouz
HN
EKs
Oued Mader
Jebel Zireg
Oued Ziz
Kem Kem
Tarhbalt
Cretaceous - Quaternary
Outcrops of Devonian rocks
Precambrian crystalline basement
Jebel Ou Driss
OuD
A
5°30'
5°00'
4°30'
B
Agadir Tissint
Foum Zguid
EAn
MdK
Tata
0
50 km
N
Tim
SR
Ouf
29° 30' N
Atlantic Ocean
Akka
Foum el Hassane
Goulimine
29° 00' N
J
e
b
e
l
B
a
n
i
J e b e l O u a r k z i z
Assa
BTs
28° 30' N
Aouinet Torkoz
Ain Deliouine
OuM
RTam
Legend
Meso-Cenozoic
Dolerite
Carboniferous
Upper Devonian
Middle Devonian
Lower Devonian
Silurian
Ordovician
Precambrian/
Cambrian
10° W
9° W
8° W

The illustrated BTW section starts with the *Deiroceras* Limestone (previous named as "*Jovellania* Beds", Fig. 12). At the base *Caud. celtibericus* occur together with *Caud. sigmoidalis* and *Crit. miae*. The two latter species range higher up, but *Caud. celtibericus* occurs only in Sample BTW0. The depositional environment is considered as a hemipelagic platform but icriodids (especially *C. sigmoidalis*) are dominating and polygnathids are rare.

Latericriodus bilatericrescens enters as a rare form in Sample BTW0/1 and becomes more common at the top (Sample BTW1), where there are also some *Eol. excavatus* but *Caudicriodus* remains far dominant (see *Caud. sigmoidalis* of Bultynck & Hollard 1980, pl. I, figs 1–4).

The base of the *Anetoceras* Limestone has many, partly very diagnostic *Latericriodus* in association with common *Crit. miae* and rare *Belodella*. Higher, still in the lower part, there is a more diverse conodont fauna (Sample BTW2) with various polygnathids (including *Eol.* aff. *gronbergi* Klapper & Johnson, 1975, Fig. 15H), four species of *Latericriodus*, a few *Belodella*, *Crit. miae* (Bultynck & Hollard 1980, pl. II, figs 3, 4), and the first *Crit. steinhornensis*. The latter becomes dominant and replaces more and more *Crit. miae* (Samples BTW2b and 3), which then disappears completely (Sample BTW4). Polygnathids have disappeared in this interval, apart from a single *Eol.* ?*gronbergi* of BTW4 (figured in Bultynck & Hollard 1980, pl. II, fig. 7). *Lat. bilatericrescens* becomes the only remaining but not abundant species of the genus (Samples BTW3 and 4) in this *Criteriognathus* biofacies.

The basal *Mimagoniatites* Limestone (Sample BTW 4b) is characterized by a poor, monospecific *Latericriodus* assemblage. The crinoidal main part of the latter (Sample BTW4t) belongs to a conodont-poor *Belodella* ecozone, as at Jebel Ihrs. At the top (Sample BTW6), polygnathids suddenly re-appear and are dominant at the very top (Sample BTW5), which suggests a gradual deepening towards the (main) Daleje Event. But this contrasts with thin brachiopod coquinas that are locally developed on strike towards the east.

The local conodont biofacies patterns and faunal successions strongly resemble Jebel Ihrs, with some minor differences in the *Deiroceras* Limestone (locally no polygnathids in the lower and fewer in the upper part) and lower *Anetoceras* Limestone (locally no *Caudicriodus* but with a few more polygnathids and *Lat. armoricanus*).

Bou Tchrafine North (Figs 11B, 13)

The section Bou Tchrafine North was also introduced by Bultynck & Hollard (1980). It is located in the plain north of the Bou Tchrafine ridge, approximately 2.4 km northeast of the most western point of the ridge or east of the Wadi Ar Rocfa (topographic sheet, 1:50,000, Arfoud, *ca* at x = 624.4, y = 87.5, Fig. 11B). The strike of the beds is more or less parallel with the orientation of the Bou Tchrafine ridge.

In this section there is an exposure of coarse bluish crinoidal limestones, about 10 m below the *Deiroceras* Limestone. Sample BTN P/E1 provided regionally the so far only record of *Pelekysgnathus serratus serratus* Jentzsch, 1962 in association with *Lat. steinachensis* (Al-Rawi, 1977; Fig. 17C), both morphotypes, and dominant single cone genera (*Belodella*, *Panderodus*, and *Coelocerodontus*). Sample BTN P/E2 yielded more *Lat. steinachensis*, the regionally oldest *Crit. miae*, and a unique, possibly new *Latericriodus* that is left in open nomenclature (Fig. 18S–U).

The *Deiroceras* Limestone changes its thickness towards the Hamar Laghdad to the east, which is noted in the lateral section in Fig. 13. *Caudicriodus sigmoidalis* dominates Sample BTN1. In the middle to upper parts of the unit it is joined by all three subspecies of *Lat. bilatericrescens* (Samples BTN BK496, BTN2-3), in association with *Crit. miae*, which becomes more common towards the top. Unlike the sections to the west, there are almost no polygnathids but some *Lat. steinachensis* with rather straight spindle, which are the youngest known globally. This faunal difference probably reflects the proximity to the elevated Hamar Laghdad mudmounds. There is a single *Eol. excavatus* from Sample BTN BK496, figured as *Po. dehiscens* Philip & Jackson, 1967 in Bultynck & Hollard (1980, pl. II, fig. 5a, b).

As in the previous sections, *Lat. bilatericrescens* also dominates the lower *Anetoceras* Limestone (Sample BTN4). The rather diverse assemblage, with eight species, includes some *Caudicriodus*, *Belodella*, two species of *Eolinguipolygnathus* (*catharinae* and aff. *gronbergi*, Fig. 15I, J), *Lat. beckmanni*, *Lat. armoricanus* Bultynck, 1989, and *Crit. miae*. A flood of *Crit. steinhornensis* enters above a very conodont-poor interval (Sample BTN BK495) in the solid middle *Anetoceras* Limestone, especially in Samples BTN 31-1 (Bultynck & Hollard 1980, pl. II, figs 1, 2) and 31-3, which bracket a *Favosites* marker unit. A similar, contemporaneous *Favosites* Biostrome was noted at Ouidane Chebbi further to the east (Belka *et al.* 1999). The rare polygnathids, *Caudicriodus* and *Crit. miae* have disappeared in this interval, whilst single cone genera become more frequent, but locally not so much *Belodella*. There is a last *Eol. gronbergi* in Sample BTN 31-4 from the upper *Anetoceras* Limestone (Bultynck & Hollard 1980, pl. II, fig. 6a, b).

In the conodont-poor assemblage of Sample BTN 31-5 from the lower *Mimagoniatites* Limestone single cone genera remain dominant and there is a remarkably early *Oz. carinthiaca*. Higher, the unit yielded, as at Jebel Ihrs and Bou Tchrafine West, *Eol. laticostatus* (Klapper & Johnson, 1975), but the top Samples BTN 31-6 and BTN5 had no Pa elements.

Table 1. Upper Pragian (Beds 2–14) to lower Emsian (Beds 15b–31b) conodont record from Jebel Ihrs (western Tafilalt). Abbreviations: *Mimag.* = *Mimagoniatites*, *inv.* = *inversus*, *latic.* = *laticostatus*, U. *Bel.* Ez. = (local) Upper *Belodella* Ecozone; entry of index taxa marked in bold, * = local record interruption.

Conodont zones	Lower *Belodella* Ecozone								*miae*				*steinhornensis*						U. *Bel.* Ez.			
								excavatus					*catharinae*								*inv.*	*latic.*
		celtibericus						*gracilis*	*bilatericrescens*		*latus*											
Lithological unit	Pragian Limestone						*Deiroceras* Limestone				*Anetoceras* Limestone									*Mimag*. Lst.		
Bed and sample No.	2	4b	6b	8c	10	14	15b	16a	16c	16d	18b	20b	21a	22b	23b	24b	25a	26b	27b	29	31a1	31b
Bel. resima	1	12	*	*	1	21	*	7	*	*	*	*	*	*	1	*	1	*	2	*	*	*
Bel. triangularis	**4**	*	*	*	2	*	*	*	*	*	*	*	*	*	*	*	*	*	2	*	*	*
Caud. celtibericus		**1**	*	*	*	*	**33**	*	*	6	36	*	3	*	14	*	39	2				
Crit. miae								**7**	87	49	3	67	20	156	131	*	53					
Caud. sigmoidalis								**476**	*	*	*	2										
Eol. excavatus MJI16a								**7**														
Eol. excavatus M114								**27**	38	20	*	2										
Eol. excavatus s. str.								**26**	2	21												
Eol. radula sp. nov.								**10**	15	**9**												
Eol. pannonicus								**2**														
Lat. bilat. gracilis								**8**	*	*	*	4	*	4								
Lat. bilat. gracilis/multicostatus								**2**														
Lat. bilat. multicostatus									**58**	368	21	7	*	*	26	*	5	2				
Lat. bilat. bilatericrescens									**21**	*	65	725	259	348	*	*	2	*	1			
Lat. latus												**10**	*	3								
Lat. beckmanni beckmanni												**1**	116	34								
Lat. armoricanus													2									
Crit. steinhornensis													**1**	21	1071	*	480	136				
Eoc. juferevi													**1**									
Lat. beckmanni sinuatus														**2**								
Eol. catharinae														**1**								
Eol. jacksoni																					**8**	
Linguipolygnathus sp. nov.																					1	
Eol. annamariae																					1	
L. inversus juv.																					**1**	
Coelocerodontus sp.																					1	
Pseudooneotodus sp.																					3	
Eol. laticostatus																						**9**
Eol. vigieri																						1
Total Pa elements	5	13	0	0	3	14	33	572	219	473	125	818	402	569	1243	0	580	140	5	0	15	7
(Sub)species diversity	2	2	0	0	2	1	1	9	5	6	4	8	7	8	5	0	6	3	3	0	6	3

Hamar Laghdad (= Hamar el Khdad) South II (Figs 11B, 14)

This section was also first introduced by Bultynck & Hollard (1980) and subsequently briefly discussed in Bultynck (1985). It is exposed along the northern flank of an E-W orientated ridge, about 2 km south-west of the Hamar Laghdad massif and forms the upwards continuation of the BTN section (Fig. 11B, see precise position in Bultynck & Walliser 2000a, fig. 3, x = 624.55, y = 89.23 on sheet Arfoud). The outcrop shows the uppermost part of the Emsian and the lower part of the Eifelian up to the *costatus* conodont Zone.

The lowest part of the section consists of dark fissile shales (Unit D of Bultynck & Walliser 2000a = Unit K, Daleje Shale Equivalents), overlain by marly nodular shales. This part did not produce conodonts but there is a succession of goethitic goniatite faunas with *Gyroceratites*, *Rherisites* and the oldest anarcestids. The overlying Unit E *sensu* Bultynck & Walliser consists of shaly marls alternating with nodular limestone beds becoming progressively thicker (now Unit L, *Anarcestes* Limestone). In the upper half of the unit the nodular limestone beds become more important than the shales. The basal nodular beds of the *Anarcestes* Limestone (Samples HLS II-1 and II-2) yielded some *L. bultyncki* (Weddige, 1977) from an *Icriodus-Belodella* biofacies that also has common panderodontids. Polygnathids become more common upwards (Sample HLS II-4) but disappear again, leaving an *I. rectirostratus* Bultynck, 1970-*Panderodus* assemblage. A more solid limestone with *An. lateseptatus* (Sample HLS II-6) produced *Po. patulus* Klapper, 1971, "*Oz.*" *carinthiaca* (Schulze, 1968), and others. The Emsian–Eifelian boundary can be precisely pinpointed by the earliest occurrence of *Po. partitus* Klapper, Ziegler & Mashkova, 1978 in Sample HLS II-7. The top part of the *Anarcestes* Limestone has not been sampled.

In Unit M (= Unit F *sensu* Bultynck & Walliser 2000a) the limestone beds become well stratified. Sample HL II-8 contains more *Linguipolygnathus* [with three species, including the first *L. zieglerianus* (Weddige, 1977)], than *Polygnathus* (*costatus* Group). *Belodella* re-appears. *L. pinguis* (Weddige, 1977) dominates over *L. bultyncki* in the following Sample HL II-9. A complete new set of Eifelian icriodids (*I. amabilis* Bultynck & Hollard, 1980, *I. introlevatus* Bultynck, 1970, *I. struvei* Weddige, 1977) enters together with *Po. costatus* Klapper, 1971, *Po. angusticostatus* Wittekindt, 1966, and early *Pinacites* in Sample HL II-11. Bed 13 is a 35 cm thick marker limestone with *Pinacites* and *Subanarcestes*, which corresponds with Bed BT7 of the main Bou Tchrafine seetion of Bultynck (1985). It can be traced throughout the Tafilalt (Klug 2002, Becker & Aboussalam 2013). *Linguipolygnathus*, *Polygnathus*, and *Icriodus* are *ca* equally common at this lower Eifelian level.

El Khraouia (Figs 19–21; Table 2)

El Khraouia is the locality name marked on sheet Taouz-Ouest (NH-30-XIV-4) for the sharp northern bend at the eastern end of the northern limb of the Amessoui Syncline in the southern Tafilalt, *ca* 11 km NNW of Taouz and 4 km E of the abandoned El Atrous settlement (Fig. 2). It is named after a small settlement just to the SE. The succession *ca* 2–3 km to the N has been named in Klug (2002) as Rich Tamirant. The high amount of shales and marls proves a palaeogeographical position at the locally short transition from the southern Tafilalt Platform to the eastern Tafilalt Basin. A corresponding small Emsian depocenter embayment has previously been noted in the isopach map of Kaufmann (1998).

The Devonian sequence dips with *ca* 40–50° to the NE. The Lower/Middle Devonian has recently been summarized by Becker *et al*. (2013b). The middle part of the "Pragian Marls and Shales" (Unit D) consists of nodular marls and limestone (top of Bed 8, just below the log shown in Fig. 19), which carry abundant *Lat. steinachensis*, rare *Lat.* cf. *claudiae* Klapper, 1980 (*in* Johnson *et al.* 1980), and early relatives of *Caud. celtibericus*. Higher, there are two poorly fossiliferous limestones within Bed 9, which are separated by 3.5 m deeply weathered shale (Bed 10) from the "Pragian Limestone". Bed 9b (GPS position W 4° 4′ 20″, N 31° 0′ 24″, Sample MA RTB2a) is characterized by a flood occurrence of *Belodella* (Fig. 20E, G) accompanied by a few (<1%) *Caud.* cf. *curvicauda* (Carls & Gandl, 1969; Fig. 20F). The base of the overall massive "Pragian Limestone" (Bed 11a, Sample MA RTB2b) is still in *Belodella* biofacies, but with a higher *Caudicriodus* percentage (*ca* 12%; this time *Caud. celtibericus*) and with some *Pseudooneotodus*. A sample from the top of this widely visible low cliff (Bed 11g) was barren. Above, a thin light-grey limestone from near the top of the predominantly marly Bed 13b continues the *Belodella-Caud. celtibericus* assemblage.

The almost 10 m thick *Devonobactrites* Shale (Bed 14) begins locally with nodular marls with a rich neritic fauna, including trilobites (phacopids, scutelluids), small brachiopods, and branching tabulate corals (*Thamnopora*). The typical goethitic "Faunule 1" with early bactritids occurs in the upper part. The overlying *ca* 2 m thick *Deiroceras* Limestone consists of mostly massive, grey limestones with orthocones. At the base, Bed 15a (Sample MA RTB3) yielded a single polygnathid among hundreds of belodellids and icriodids. *Neopanderodus* specimens amount to *ca* 6% (Fig. 21A) of this *Belodella-Caudicriodus* assemblage, *Criteriognathus* and *Latericriodus* each only to less than 2%. In other words, the stratigraphically important index conodonts are rare. A thin-bedded limestone from the middle *Deiroceras* Limestone (Bed 15c) contains an equally diverse association with fewer belodellids (only *ca* 15%), more dominant *Caud. sigmoidalis* (70%), and three more *Eol. excavatus*. The conodont biofacies changes markedly at the top of the *Deiroceras* Limestone (Bed 15f) to a relatively diverse (ten taxa) *Latericriodus* Assemblage with more than 10% polygnathids, *Panderodus*, and *Crit. miae*. The decline of belodellids and *Caudicriodus* suggests a deepening trend, which culminates in the locally not very fossiliferous *Metabactrites-Erbenoceras* Shale (Bed 16).

The *Anetoceras* Limestone begins with *ca* 50 cm solid limestone (Bed 17), followed by a shale and solid limestone (Bed 18), and ends with *ca* 85 cm of thin-bedded limestones with some phacopids and *Erb. advolvens* (Bed 19). Despite the pelagic platform facies, there were no conodonts at all in a sample from Bed 17c. The biofacies appears to be strongly oligotrophic. A mostly covered shale unit (Bed 20) separates the 4.7 m thick, darker-grey, mostly nodular and crinoidal *Mimagoniatites* Limestone. Again, there are hardly any conodonts (base of the nodular Bed 21a). The light-grey top bed (top Bed 22) yielded a shallow-water *Belodella-Neopanderodus* assemblage with subordinate (*ca* 20%) polygnathids and *Caudicriodus*. As in the western and central Tafilalt, this new influx of polygnathids indicates a deepening at the end of the lower Emsian.

The Daleje Shale Equivalents are more than 100 m thick. Exposures are restricted to small ravines in the western steep slope of the ridge formed by Eifelian limestones. Still in the lower part of the slope there is a peculiar, thin trilobite bed and marly limestone, which did not produce any conodonts. In the middle of the cliff, the yellowish weathering, nodular, goniatite-rich *Anarcestes* Limestone is poorly exposed. Therefore, it is locally difficult to measure a detailed upper Emsian section.

Hassi Nebech (Figs 19, 22; Table 3)

The extensive Devonian outcrops at Hassi Nebech, *ca* 20 km ENE of Taouz (sheet Taouz-Est, NH-30-XV-3), belong to the Tafilalt Basin. The Givetian to Famennian interval has become famous for its ammonoid faunas (Bensaid 1974; Becker *et al*. 2002; Bockwinkel *et al*. 2002, 2013) but there is hardly any literature on the upper Silurian, Lower Devonian and Eifelian strata, which are also well exposed. Klug (2002) mentioned a few *Achguigites* specimens, as evidence for the lower *Anarcestes* Limestone.

Above 15–16 m Lochkovian to Pragian thin limestones and predominant marls, which indicate condensed marginal platform, not basinal conditions at that time, there is a superb sequence of very trilobite-rich, nodular "Pragian Limestone" (Fig. 19). A 55 cm unit of solid limestone (Bed 11) forms the base; it yielded no conodonts (Sample TA RTB 2, GPS position W 3° 45´ 34˝, N 30° 56´ 59˝). Fluctuating abundances of different trilobite and other faunal groups provide an ecostratigraphical subdivision into marker beds with *Crotalocephalina* (Bed 12), corals and *Lamellorthoceras* (Bed 13), *Reedops* (1^{st} and 2^{nd} trilobite coquina of Beds 14/15), large orthocones (Bed 16), and scutelluids (Bed 17b). The upper part of the *ca* 12 m thick succession is less fossiliferous. A lenticular coral limestone with many orthocones and Tabulata forms a distinctive low mound in the transition to the poorly exposed *Devonobactrites* Shale. Conodont samples from the lower (Bed 11c) and middle parts (Bed 19b) were barren. Sample TA RTB 4 from Bed 22c produced a rich shallow-water conodont assemblage dominated by *Belodella* (Fig. 22L, M), but with *ca* 17% diagnostic *Caud. celtibericus* (Fig. 22N) that are partly transitional from *Caud. curvicauda*. The thin limestone (Bed 24b, Sample TA RTB 5) below the low coral mound produced just one *Belodella*. At the top of the slope, above a sand field, a neritic lower Emsian platform setting re-appears as thick, massive, bluish-grey *Deiroceras* Limestone with planispiral, involute gastropods and orthocones. As in the Tafilalt Platform sections, it is dominated by *Caud. sigmoidalis* (72%), followed by *Belodella* (*ca* 23%; Sample TA RTB 6). A single *Eol. excavatus* M114 conforms with the other *Deiroceras* Limestone localities.

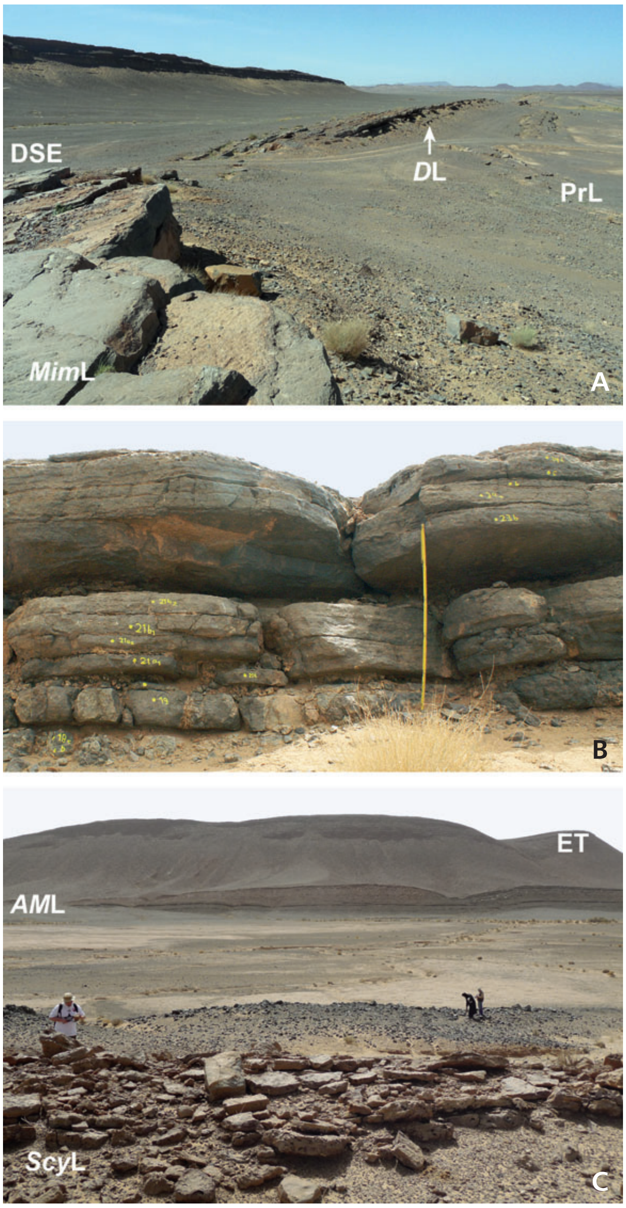


Figure 3. Lower Devonian strata at Jebel Ihrs and Jebel el-Mrier. • A – succession at Jebel Ihrs from the "Pragian Limestone" (PrL – right), *Deiroceras* Limestone (*D*L – arrow) to the massive *Mimagoniatites* (*Mim*L – left foreground), Daleje Shale Equivalents (DSE), to the upper Emsian/Eifelian cliff (background). • B – details of the *Anetoceras* Limestone at Jebel Ihrs, showing bed numbers and the incision below Bed 23b. • C – overview of the Lower Devonian at Jebel el-Mrier, with the lower Lochkovian *Scyphocrinites* Limestone (*Scy*L) in the foreground, the low cliff of the *Anetoceras* and *Mimagoniatites* Limestone (*AM*L) in the middle ground, including the *Deiroceras* Limestone as a continuous solid interval in the lower third of the slope, and the high cliff of Daleje Shale Equivalents to Eifelian turbidites (ET) in the background.

In a wide depression towards the S, the Daleje Shale Equivalents are locally very thick and poorly fossiliferous. The yellowish weathering, nodular *Anarcestes* Limestone is exposed in the lower part of the next ridge, which top is formed by Eifelian turbiditic limestones. At the base *Sell. wenkenbachi* is common in nodules (Bed 28), followed by somewhat more solid light-grey limestone with *Sell. wenkenbachi*, *Sell. ebbighauseni* Klug, 2002, *An. simulans* (Barrande, 1865), and phacopids (Bed 29), a peculiar, goniatite-rich *Achguigites* Marl (Bed 30, also with *Sell. neglectus*), and grey limestones with dominant *Anarcestes* (Bed 31). Loose anarcestids found around Bed 29 were dissolved as a conodont sample. It is surprising that assumed shallow-water genera (*Neopanderodus* and *Belodella*) are more common in such a hemipelagic lithofacies and macrofauna assemblage than polygnathids and icriodids. This affects the ammonoid-conodont correlation (see "Ammonoid-conodont correlation in the Tafilalt") and indicates a shift or restriction of the main habitat of these genera in time, especially from the Lower to Middle Devonian.

Jebel el-Mrier (Figs 3C, 22; Table 3)

The Jebel el-Mrier forms a southwards opening syncline *ca* 13.5 km W of Taouz, *ca* 9 km S of the Amessoui Syncline, and *ca* 6 km NNE of Jdaid. Lochkovian to Pragian limestones and shales lie at the base of the section. The "Pragian Limestone" is locally a condensed, only *ca* 60 cm thick marker unit with poor macrofauna. Sample AL RTB 5 (GPS position 4°9´ 47˝, N 30°54´ 40˝) from the top of the unit was barren. The *ca* 4.5 m thick *Devonobactrites* Shale is interrupted in its lower part by two thin layers of crinoidal nodular limestone. The *Deiroceras* Limestone forms a marked ridge of massive, light-grey limestones with crinoidal debris (Fig. 3C) within a lower Emsian slope. Beds are between 25 and 35 cm thick and dip in the measured section with 24° to the SE. The top (Sample AL RTB 6) is in *Caudicriodus* biofacies, with *ca* 20% *Lat. bilatericrescens* and 15% *Belodella*. The *Metabactrites-Erbenoceras* Shale is locally also rather unfossiliferous; it contains only a few orthocones. The *Anetoceras* Limestone consists of medium-bedded, light-grey limestone with orthocones, especially in the lower part and in a 20 cm thick massive bed at the top. There are only a few goniatites. *Teicherticeras*, which elsewhere in the Tafilalt is extremely rare, is locally the most obvious goniatite. Conodont faunas from the middle and upper part of the unit (Samples AL RTB 7a and 7b) are dominated by *Criteriognathus* (up to 67% of the faunas), followed by *Latericriodus* or *Belodella*. Polygnathids are absent. The overlying *Mimagoniatites* Limestone is separated by a recessive 1 m interval of thin-bedded limestones. Conodont samples from the base (AL RTB 8) and top (AL RTB 9a and 9b) are in shallow-water biofacies, with dominant *Neopanderodus* (Fig. 22E, H), accompanied by a few or abundant (AL RTB 9b) *Belodella*. For all of the Tafilalt, there is an exceptional (single) polygnathid from the lower *Mimagoniatites* Limestone and a single *Crit. steinhornensis* (Fig. 22J) from the top. The differences of goniatite and conodont faunas suggest a somewhat shallower setting then in the Tafilalt sections to the north and east. The upper Emsian strata have not been studied in detail since they are widely covered by debris from the overhanging Eifelian limestone cliff.

Jebel Kfiroun South

The Jebel Kfiroun is a *ca* W-E running ridge SW and S of Taouz (sheet Taouz-Ouest, NH-30-XIV-4; Fig. 2). A small hill between the main ridge and the piste from Taouz to Jdaid, *ca* 3.5 km SW of Taouz, exposes a vertical Lower Devonian sequence capped unconformably by the upper Famennian *Gonioclymenia* Limestone. The "Pragian Limestone" is locally *ca* 3 m thick, followed by the deeply weathered and mostly covered *Devonobactrites* Shale. The *Deiroceras* Limestone is massive and *ca* 1 m thick, the locally unfossiliferous *Metabactrites-Erbenoceras* Shale deeply weathered and *ca* 2 m thick. The light-grey *Anetoceras* Limestone consists of *ca* 65 cm solid limestones in the lower part, with an orthocone-rich 20 cm limestone at the top, and *ca* 1 m of nodular, more thin-bedded limestone. The *ca* 50 cm thick *Mimagoniatites* Limestone is darker grey, it contains abundant *Mimagoniatites* sp., bivalves (*Panenka*), phacopids, and orthocones at the top. Sample AL RTB 11 (GPS position W 4° 2´ 19˝, N 30° 53´ 8˝) from the lower part yielded almost only *Neopanderodus*. Sample AL RTB 12 from the upper massive marker limestone was barren, as at Jebel Ihrs but in contrast with the presence of goniatites. The rarity of conodonts suggests a further shallowing of the palaeoenvironment, extending from the Jebel el-Mrier towards the east. The Daleje Shale Equivalents are more than 50 m thick below the mentioned unconformity. Intercalated thin limestones near the top carry no conodonts (Sample AL RTB 13).

Jebel Ouaoufilal

The Jebel Ouaoufilal (= Jebel Aoufilal) is the elongated southeastern extension of the Amessoui Syncline, from *ca* 4.5 km NW of Taouz on. Following first detailed studies by Klug (2001, 2008), Kröger (2008) investigated the local Lower Devonian succession and its nautiloid faunas. Recently, Klug *et al.* (2013) provided a summary of the Lochkovian to Eifelian of the ridge. Two conodont samples were taken during the spring 2013 field trip day led by

Table 2. Conodont record of lower Emsian samples from El Khraouia. Abbreviations: Prag. = Pragian, *Anet*. Lst. = *Anetoceras* Limestone, *gracilis* = *bilatericrescens gracilis*, *bilat*. = *bilatericrescens bilatericrescens*. Entry of index taxa marked in bold.

Conodont zones		Lower *Belodella* Ecozone				*miae*					
						excavatus M114					*laticostatus*
	steinachensis		*celtibericus*			*gracilis*		*bilat.*			
Lithological unit	Prag. Marl/Shale		Pragian Lst.			*Deiroceras* Lst.			*Anet.* Lst.	*Mimagoniatites* Lst.	
Sample No.		MA 2a	MA 2b			MA 3					
Bed No.	top 8	9b	11a	11g	13 Top	15a	15c	15f	17c	21a1	22 Top
Lat. steinachensis	**63**										
Lat. claudiae	**2**										
Caud. ?celtibericus	**18**										
Bel. resima		530	76	*	57	304	38	1	*	*	44
Bel. triangularis		6	2								
Caud. curvicauda		**4 cf.**	*	*	*	*	4				
Caud. celtibericus			**11**	*	5	16	21	2			
Pseudo. beckmanni			5								
Crit. miae						**7**	1	27			
Eol. excavatus M114						**1**	3	8			
Neop. perlineatus						33	*	*	*	1	21
Lat. bilat. gracilis						**10**	2	13			
Caud. sigmoidalis						168	177	4			
Panderodus sp.						1					
Eol. excavatus s. str.							6	16			
Lat. bilat. multicostatus								**55**			
Lat. bilat. bilatericrescens								**95**			
Eol. radula sp. nov.								1			
Caud. ultimus											2
Eol. laticostatus											**3**
Eol. gilberti											1
L. inversus											9
Eoc. cf. *juferevi*											2
Eol. vigieri											**1**
Eol. cf. *vigierei*											1
Total conodonts	83	540	89	0	59	540	252	222	0	1	82
(Sub)species diversity	3	3	4	0	2	8	8	10	0	1	6

C. Klug (Klug *et al*. 2013). The top of the "Pragian Limestone" yielded, as in other sections, mostly *Belodella* (thirty-one *Bel. resima*, six *Bel. triangularis*). In addition there are nine *Caud. curvicauda* as the only icriodid. The top of the *Mimagoniatites* Limestone produced just a single *Neop. perlineatus* Ziegler & Lindström, 1971, which suggests a northward extension of the shallow pelagic lower Emsian platform of the southern Tafilalt.

Eastern Dra Valley

Bultynck & Hollard (1980) studied conodont samples from four sections of the eastern Dra Valley, from east to west (Fig. 2) Mdâouer-el-Kbîr, El Annsa, Foum Timrhanrhart, and Targa Kheniga. We present updates for two sections. The Mdâouer-el-Kbîr ridge, *ca* 22 km south of Foum Zguid, has a beautiful erosional landscape (Fig. 23A) and is the type locality for the Mdâouer-el-Kbîr Formation. At the bottom of Fig. 24 the results of a sample from about 60 m above the base of the formation are shown. In that sample *L.* aff. *inversus* (Klapper & Johnson, 1975) occurs together with *Caud. celtibericus* ("subsp. A" in Bultynck & Hollard, 1980, pl. I, fig. 25) and *Lat. bilatericrescens*, indicating a lower Emsian age.

The part of the El Anhsour section (El Annsa) studied herein is exposed in a cliff face about 30 km SSW of Foum Zguid (Figs 23B, 24). The lowest part belongs to the uppermost part of the Upper Member of the Mdâouer-el-Kbîr Formation (Hollard 1978). The overlying part belongs to the Lower Member of the Timrhanrhart Formation (Hollard 1978). Brachiopod coquinas at the top of the Rich

Table 3. Lower Emsian conodont record of samples from Hassi Nebech, Jebel el-Mrier, and Jebel Kfiroun. Abbreviations: Prag. Lst. = "Pragian Limestone", *Deiro*. = *Deiroceras* Limestone, *Anet*. Lst. = *Anetoceras* Limestone, *excav*. = *excavatus* Morphotype 114, *bilat*. = *bilatericrescens bilatericrescens*, J. Kfir. = Jebel Kfiroun South, U. *Bel*. Ez. = Upper *Belodella* Ecozone. Entry of index taxa marked in bold.

Conodont zones			*excav.*		*excav.*	*gronbergi*					
	celtibericus		*bilat.*		*bilat.*	*steinhornensis*				/ U. *Bel*. Ez.	
Locality	Hassi Nebech			Jbel El Mrier							J. Kfir.
Lithostratigraphy	Prag. Lst.		*Deiro.*	Prag. Lst.	*Deiro.*	*Anet*. Lst.		*Mimagoniatites* Limestone			
Bed No.	22c	24b									
Sample No.	TA4	TA5	TA6	AL5	AL6	AL7a	AL7b	AL8	AL9a	AL9b	AL11
Caud. celtibericus	**31**	*	3			28					
Bel. resima	124	1	22		2	48	1	3	7	30	1
Bel. triangularis	15									3	
Neopand. perlineatus	14	*	1			19	*	18	47	70	24
Caud. sigmoidalis			70		9						
Eol. excavatus M114			**1**								
Lat. bilat. bilatericrescens					**3**	1					
Crit. steinhornensis						**218**	16	*	*	1	
Lat. bilat. multicostatus						41	7				
Eol. cf. *gronbergi*								**1**			
(Sub)species diversity	4	1	5	0	3	6	3	3	2	4	2
Total conodonts	184	1	97	0	14	355	24	22	54	104	25

3 Member of the Mdâouer-el-Kbîr Formation are in icriodid biofacies. Sample I is dominated by *I. fusiformis* Carls & Gandl, 1969 (Fig. 25A–D) and *Caud. culicellus culicellus* Bultynck, 1976, with some *I. corniger ancestralis* Weddige, 1977, and with rare *I. ovalis* sp. nov. (Fig. 25E–G). Sample II belongs to a shallower biofacies with many *Panderodus* and dominant *Caud. culicellus culicellus* (Fig. 25J–L). *Latericriodus beckmanni sinuatus* occurs throughout the section. The Lower Member of the Timrhanrhart Formation is locally developed as an alternation of shales and thin limestones, which are rich in phacopids in higher parts. This Trilobite Limestone can be followed westwards to the Tata region (*e.g.*, Ebbighausen *et al*. 2004, 2011). Sample 2 from at El Anhsour yielded a relatively diverse *Caudicriodus-Panderodus* assemblage with subordinate *Latericriodus* (*ca* 5%) and *Icriodus* (18.5%), including *I. ovalis* sp. nov. and *I. praerectirostratus* sp. nov. (Fig. 25R–X). A higher thin limestone (Sample 8) differs by its *Panderodus-I. rectirostratus* association, with subordinate *Belodella* and *Caud. culicellus culicellus* (both *ca* 5%). This conodont biofacies is maintained at the top of the Trilobite Limestone (Sample 14) and at the base of the overlying *Sellanarcestes* Limestone (Sample 16) but *I. rectirostratus* becomes more abundant than *Panderodus*. *Linguipolygnathus inversus* (Fig. 25AB, AC) and *L.* aff. *inversus* (Fig. 25Z, AA) re-appear just below and in the first massive *Sellanarcestes* Limestone (Samples 14 and 16) whilst there are still no typical upper Emsian polygnathids. The top of the massive goniatite limestone (Sample 19b) is very poor in conodonts, with just two *Lat. beckmanni sinuatus* (Fig. 25Y) and two *I. rectirostratus*.

The conodont fauna from the El Anhsour section (Fig. 25) is very similar to the conodont fauna of the Scheidt Formation described by Weddige & Requadt (1985) from the Rhenish Massive. The Scheidt Formation occurs between Koblenz and Limburg an der Lahn. It belongs to the lower part of the Upper Emsian in its original sense. *Icriodus homorectus* Weddige, 2003 was originally described from that area and is recognized for the first time in the Anti-Atlas (Samples II and 2). The conodont fauna from El Anhsour is not found in the Tafilalt because it corresponds to the Daleje Shale Equivalents, for example between sections BTN and HLS II.

Western Dra Valley (Figs 26, 27; Table 4)

The western Dra Valley includes, from east to west, over more than 200 km distance (Fig. 1) an extensive series of sections exposed in Lower Devonian folds (Hollard & Jaquemont 1956, Lubeseder *et al*. 2008, Ouanaimi & Lazreq 2008). Bultynck & Hollard (1980) included conodont samples, from east to west, from Tjafane, Oui-n-Mesdoûr, and Hassi Talha. Our detailed biostratigraphic work has concentrated on sections near Assa and to the SW of Torkoz.

The succession at Bou Tserfine (sheet Assa, NH-29-III-4, Figs 26, 27) was described by Becker *et al*. (2004c). Our numbering adopts the letters used in the published section log, which is updated here. Subsequent conodont data were mentioned in preliminary notes of Becker *et al*. (2008) and Dojen *et al*. (2010). Brett *et al*. (2012) illustrated and interpreted the strongly cyclic lime-

Table 4. Emsian conodonts from samples of the western Dra Valley. Abbreviations: Akh. T. Mbr. = Akhal Tergoua Member, Bl. Marl = Black Marl Member, Brach. Marl Mbr. = Brachiopod Marl Member, *Sell*. Lst. = *Sellanarcestes* Limestone, *bilatericr*. Ecoz. = local *bilatericrescens bilatericrescens* Ecozone. Entry of index taxa marked in bold.

Locality	Bou Tserfine						Rich Tamelougou											
Zones	*latus*	*bilatericr.* Ecoz.		*fusiformis*			*latus*	*fusiformis*										
Lithostratigraphy	Akh. T.	Bl. Marl	*Hollardops* Limestone				Akh. T.	*Hollardops* Limestone							Brach. Marl Mbr.			Sell. Lst.
Bed or sample No.	A10b	A18b	D1	D38	D91b	top D	base	base	3	main	9	35	61	105	161	161 + 1m	*"Latan."*	**X**
Lat. beckmanni beckmanni	**6**						**2**											
Lat. bilat. bilatericrescens	12	**11**	5				12	*	*	12								
Bel. resima	1						4	*	1	26	*	*	*	1	5	4		
Caud. sigmoidalis	8						11											
Caud. cf. *ultimus*	15						12	2										
I. corniger leptus				**1**	2	1?				9	*	1?						
Caud. culicellus altus					1?													
Neop. perlineatus					1		2	*	3	3	2	4	*	4	1			
Caud. celtibericus							2											
Lat. beckmanni sinuatus							**4**											
Bel. triangularis							3											
Eol. excavatus M114							1											
I. rectirostratus								**1 cf.**	*	1								
Panderodus sp.								1	*	*	*	*	*	*	*	*	*	2
Caud. ultimus									1	22	*	*	4	3	2			
I. cf. *werneri*										1								
Caud. aff. *sigmoidalis*										3								
Caud. culicellus culicellus										**5**								
I. corniger ancestralis											**1?**							
Icriodus sp.																1		
Caud. aff. *celtibericus*																	1	
Total conodonts	43	11	5	1	4	1	53	4	5	82	3	5	1	3	3	5	1	2
(Sub)species diversity	5	1	1	1	3	1	9	3	3	9	2	2	4	8	8	2	1	1

stone-marl alternation of the *Hollardops* Limestone Member. The Emsian section starts at GPS N 28°39´ 19.6˝, W 9° 16´ 9.3˝ with the last, thick- and cross-bedded Rich 2 sandstones (Fig. 26, Beds A_0–A_5). Calcareous siltstones form a gradual transition and lower subunit of the Akhal Tergoua Member (Beds A_6, A_7). The slightly calcareous top of Bed A_2 was unsuccessfully sampled for conodonts. A thin phosphatic lag deposit at the top of the marly Bed A_6 contains ostracodes, bryozoans, dacryoconarids, and trilobite debris, but no conodonts. The middle subunit (Beds A_8–A_{12}) consists of solid dark-grey limestones with many *Zoophycus* and intercalated dark marls with abundant *Odontochile* sp. in specific layers (*e.g.*, Bed A_{11}), which provided the name "Calcaire noir à *Odontochile*" on the geological map. Bed A_{10b}, a rather massive marker limestone, is in moderately rich icriodid biofacies, with almost equal representation of *Latericriodus* and *Caudicriodus* (two species each). The upper unit of the Akhal Tergoua Member consists of predominant dark-grey marls, with black, more calcareous and dacryoconarid-rich beds at the top of four cycles (A_{14}, A_{15}, A_{17b}, A_{18b}). Bed A_{18b} at the boundary to the overlying Black Marl Member (Unit B) yielded a small, monospecific *Latericriodus* fauna. The subsequent black marls are not calcareous enough for conodont sampling but contain abundant dacryoconarids and some small brachiopods. The poorly exposed upper part of the member includes packages of lighter-grey marls (Unit C).

The basal *Hollardops* Limestone Member (Unit D, section log in Becker *et al*. 2004c) consists of alternating dark-grey marls and argillaceous nodular limestone with some phacopids and large, up to 20 cm long orthocones. Becker *et al*. (2008) correlated this hypoxic interval with the initial Daleje Event. The first limestone (Bed D_1) continues the monospecific *Latericriodus* fauna from below. Further conodont samples through the member were taken from the base of the interval with increasingly abundant trilobites (Bed D_{38}: only one *Icriodus corniger leptus* Weddige, 1977), from a more solid limestone (Bed D_{54}: barren), and from the concretionary Bed D_{91b} that includes solitary rugose corals, acrotetrid brachiopods, *Neopanderodus*, rare icriodids, and fenestrate bryozoans. The last solid nodular limestone of the member yielded a single *Mimagoniatites tabuliformis* Group, *Oligophyllum* sp., phacopids, and just one *Icriodus* in more than 2.5 kg of dissolved limestone. The brachiopod-rich main part of the neritic Brachiopod Marl Member (Beds E_1–E_3) is too argillaceous for conodont sampling. Above, the nodular Bed E_4 with its abundant "*Latanarcestes*" and *Lamellorthoceras* documents a return to hemipelagic deposition, which correlates with the peak of the Daleje Transgression still low in the upper Emsian (LD IV-B of the ammonoid succession). The sudden goniatite incursion is not associated with a re-appearance of conodonts; Sample E4 was barren. The overlying *Sellanarcestes* Limestone Member has locally not yet been sampled for conodonts.

The succession at Rich Tamelougou (sheet Fask, NH-29-III-3, conodonts in Table 4 and Fig. 27) is more condensed but very similar to Bou Tserfine, with about the same number of cycles in the *Hollardops* Limestone Member despite reduced sedimentation (Brett *et al*. 2012). The sections described by Jansen *et al*. (2004b, 2007) and Becker *et al*. (2004b) lie very close to each other along strike on the same ridge. The top of the Rich 2 Sandstone includes cross-bedded and iron-rich calcareous sandstones, which indicate a very shallow deposition, mostly by tempestites. The upper boundary to the 9 m thick, rather unfossiliferous Akhal Tergoua Member is locally sharp. This suggests a drowning unconformity at the base of a transgressive system tract (TST). A sample from the first dark bluish-grey limestone produced a rather diverse conodont assemblage (10 taxa) with a slight dominance of *Caudicriodus* (47.2%) over *Latericriodus* (34%), and with 13.2% *Belodella*, 3.8% *Neopanderodus* (Fig. 27N), and a single, broken polygnathid. Despite the hypoxic and calm lithofacies, the conodonts are typical for a shallow marine setting. Conodonts reported by Jansen *et al*. (2004b, 2007: Fauna C10) from the basal 30 cm of the Oui-n-Mesdoûr Formation of section Torkoz IIa have a similar composition but *Belodella* and *Neopanderodus* were not listed. The same authors describe a different fauna with *Latericriodus*, *Criteriognathus* and very rare polygnathids from the upper part of the Akhal Tergoua Member (Fauna C13), which becomes increasingly marly upsection. A thin, Fe-rich red layer indicates a peak of oxygene deficiency at the top, followed by light grey marls with some limestone concretions. This better oxygenated interval correlates with the light-grey Unit C of Bou Tserfine and with the onset of the Rich 3 Sandstone of the eastern Dra Valley.

Weathering of the *Hollardops* Limestone Member forms distinctive, rounded hills separate from the main, southern slope of the Rich Tamelougou. From the distance, these hills look like a long series of dumps from excavations. The basal nodular beds are very argillaceous; samples were taken from the base, Bed 3 and Bed 9. Their icriodid faunas with some belodellids and panderodids are very sparse. The main, more solid and trilobite-rich limestones commence with Bed 19 (barren sample). A sample from the middle of the member taken in 2003 contained a diverse assemblage with *ca* 35% *Caudicriodus* (mostly *Caud. ultimus* Weddige, 1985 *in* Requadt & Weddige 1985), 28% *Icriodus* s. str., *ca* 5.5% *Latericriodus*, 29% *Belodella* (Fig. 27Q) and a few *Neopanderodus* (Fig. 27O); no polygnathids or "ozarkodinids" were found. Fauna C14 from Torkoz of Jansen *et al*. (2004b, 2007) is rather similar. But such faunas are an exception; normally (*e.g.*, Bed 35) there are very few conodonts in normal-sized samples and single cone genera (*Neopanderodus*) are rather dominant. Higher up in the member (Beds 61 and 105), *Caud. ultimus* remains as the only icriodid in association with *Belodella* and *Neopanderodus*.

The Brachiopod Marl Member is very inconspicuous at Rich Tamelougou. A change from trilobite limestones to nodular levels with "*Latanarcestes*" was recognized by Brett *et al*. (2012) in Bed 153. Dissolved "*Latanarcestes*" specimens yielded only a single *Caudicriodus*. Samples from Bed 161 and 1 m above continue the sparse assemblage of the upper *Hollardops* Limestone and are not diagnostic. As at Bou Tserfine, the pelagic faunal influx is not mirrorred in the composition of the conodont faunas.

The *Sellanarcestes* Limestone Member is locally very rich in anarcestids (three genera), trilobites, solitary rugose corals, nautiloids, crinoid ossicles, bivalves (*Panenka*), gastropods, and placoderms. A conodont sample taken from just above the first (loose) *Sellanarcestes* was almost barren (two small single cones). The complete lack of polygnathids and icriodids in goniatite limestones does not fit the expectations from current conodont biofacies models.

Goniatite samples (Figs 28, 29; Table 5)

In order to improve the regional ammonoid-conodont correlation, goniatites from additional localities and levels have been dissolved. These are in stratigraphic order from old to young (see Table 5):

RT-Erb: Loose block with *Erbenoceras* sp. from the syncline W of Rich Tamelougou, SW of Torkoz (sheet Fask, NH-29-III-3), illustrated in Becker *et al*. (2008).

OCh-*Anet*: Block with the negative imprint of an *Anetoceras* cf. *obliquecostatum* Ruan & He, 1974 from the lower part of the *Anetoceras* Limestone of Ouidane Chebbi (see section log in Belka *et al*. 1999 and Klug 2001), sheet Hassi Beraber (NH-30-XXI-1).

BT-*Kl*: Several fragments of *Klugites gesinae* (Klug, 2001) gen. nov., sampled in situ from a nodular interval *ca* in the middle of the *Anetoceras* Limestone at Bou Tchrafine NW (sheet 1:50,000 Arfoud, x = 616.2, y = 88.6).

Ouf-*Sell*: Several specimens of *Sellanarcestes*, collected in situ from the *Sellanarcestes* Limestone at Oufrane-West (Bed 11 of Ebbighausen *et al*. 2011; sheet Tata, NH-29-XI-3).

EKs-B: Several specimens of *Sellanarcestes* and *Anarcestes*, collected at Erg Kseir (*ca* 6.5 km E of Hassi Nebech) in situ from the 2nd bed (Bed B) of the locally very goniatite-rich lower *Anarcestes* Limestone.

HN-TA29: Several specimens of *Sellanarcestes* and *Anarcestes* collected loose from the lower *Anarcestes* Limestone at Hassi Nebech (sheet Taouz-Est, NH-30-XV-3, near Bed 29).

EKs-D: Several specimens of *Sellanarcestes* and *Anarcestes*, collected at Erg Kseir in situ from the 4th bed (Bed D) of the locally very goniatite-rich *Anarcestes* Limestone, which contains rare specimens of *Achguigites tafilaltensis*.

OCh-*An*: Several specimens of *Anarcestes*, collected loose from the *Anarcestes* Limestone at Ouidane Chebbi.

Emsian conodont zonations (Fig. 30)

Previous Emsian conodont zonations

There are previous approaches to distinguish Lower Devonian biozones based on different, co-occuring conodont groups (*e.g.*, Mashkova 1979). Their correlation offers the best regional time resolution but separate polygnathid and icriodid zonations can be used internationally, too.

Polygnathids. – Based on faunas from Nevada, Klapper & Johnson (1975) established the fundaments of the lower Emsian polygnathid succession, which combines the first appearances of species of two phylogenetic branches. Original zonal markers were *Po. dehiscens* s.l., which then included both *Eol. excavatus* and *Eoct. lenzi* (Klapper, 1969), *Po. gronbergi*, *Po. nothoperbonus* Mawson, 1987, *Po. inversus*, and *Po. laticostatus* (*e.g.*, Klapper 1977, Weddige & Ziegler 1977, Yolkin & Izokh 1988). Yolkin *et al*. (1994) added at the assumed base of the Emsian a new *kitabicus* Zone and introduced an *exvacatus* Zone, which was subdivided into three subzones based on the first entries of *Po. excavatus excavatus*, *Po. excavatus gronbergi*, and *Po. perbonus* (Philip, 1966). Their Lower *excavatus* Zone replaced the controversial *dehiscens* (s.l.) Zone. According to Carls *et al*. (2002, 2009), the Middle *excavatus* Zone of the Zinzilban section begins in fact with the level of *Eol. excavatus* Morphotype 114, not with the entry of *Eol. gronbergi*.

Yolkin *et al*. (1994) did not accept the *laticostatus* Zone, which was partly justified by the re-identification of a morphologically transitional specimen between *Eol. gronbergi* and *Eol. laticostatus* figured by Klapper & Johnson (1975, pl. 1, figs 25, 26). This specimen comes from a level below *Eol. nothoperbonus* but it is more similar to *Eol. gilberti* (Bardashev, 1986) than to typical *laticostatus* (see synonymy list in Bardashev *et al*. 2002). Mawson (1995) criticized the *kitabicus*, *excavatus* and *nothoperbonus* zones but defended the *laticostatus* Zone. The distinction of *perbonus* and *nothoperbonus* zones/subzones was doubted because their defining species enter almost at the same level in Victoria (Mawson 1987a). The separation of successive *inversus* and *laticostatus* zones is obviously restricted to some regions whilst in others *L. inversus* and *Eol. laticostatus*, which belong to separate phylogenetic lineages, enter together in the *laticostatus* Zone (*e.g.*, Klapper *et al*. 1978, Bardashev & Ziegler 1992). Such a pattern may reflect regionally delayed first occurrences of *L. inversus*.

Bultynck (1989) did not separate *gronbergi* and *nothoperbonus* zones at the base of the La Grange Limestone of the Armorican Massif. He used the entry of *Po. catharinae* to define an Upper *gronbergi* Zone. At La Grange, there is only a short interval for a *nothoperbonus* Zone/Subzone below the Upper *gronbergi* Zone. More recently, Martínez-Pérez *et al*. (2011) recognized an Upper *nothoperbonus* Zone based on the entry of *Po. mashkovae* Bardashev, 1986. However, they synonymized *Po. catharinae* with *Po. mashkovae*, which is not followed here. As emphasized in the original distinction of Bultynck (1989), the holotype of *Eol. mashkovae* is characterized by a deeper and rimmed basal cavity, followed posteriorly, due to strong cavity inversion, by a very distinctive carina whilst in *Eol. catharinae* only the posterior tip is inverted. It seems that the Upper *nothoperbonus* and Upper *gronbergi* zones represent more or less identical intervals. In order to allow an easier understanding, the latter is re-named here after its marker species as *catharinae* Subzone.

Baranov *et al*. (2014) established a different regional zonation for NE Siberia, which is characterized by several endemic species and, therefore, difficult to compare. This applies especially for their tripartite *ivanovskyii* Zone, with a *gronbergi* Subzone at the base (without typical *Eol. gronbergi* but with *Eol. perbonus*), sandwiched between *excavatus* and *nothoperbonus* zones. For the upper Emsian polygnathids, Weddige (1977) introduced the *serotinus* and *costatus patulus* zones, the latter with two informal divisions. Klapper *et al*. (1978) proposed in Bohemia a subdivision of the *serotinus* Zone, based on the entry of *Po. cooperi cooperi* Klapper, 1971, and recognized the Upper *patulus* Zone (now *partitus* Zone), which subsequently defined the Emsian–Eifelian boundary. Vodrážková *et al*. (2011) granted *Po. patulus* and *Po. partitus* full species status.

The alternative polygnathid zonations of Bardashev *et al*. (2002), based on supposed parallel polygnathid lineages, are not used here.

Icriodids. – Wittekindt (1966) established an *I. corniger* Zone, which included strata that now fall in the upper Emsian to lower Eifelian. Subsequently, Carls & Gandl (1969) investigated the Lower Devonian succession of the eastern Iberian Chains (Celtiberia, NE Spain), which is rich in icriodids. They recognized in the lower Emsian an assemblage with two subspecies of *Lat. bilatericrescens* and others and in the upper Emsian a fauna with *I. fusiformis* and *I.* aff. *corniger* Wittekindt, 1966 (now *I. corniger ancestralis*), followed higher by the fauna with typical *I. corniger*. The distinction of the *I. fusiformis* fauna was subsequently recognized by Ziegler (1971, level of oldest "nonlatericrescide" icriodids) and Carls *et al*. (1972). The succession of the Sierra de Guadarrama of central Spain yielded Bultynck (1976) a more detailed Emsian icriodid sequence: Fauna IV with *Caud. celtibericus*, Fauna V with *Caud. sigmoidalis*, Fauna VI with *Lat. bilatericrescens*, Fauna VII with *I. fusiformis*, *I.* aff. *corniger*, *I. rectirostratus*, and *Caud.*? *culicellus*, and Fauna VIII with *I.* aff. *fusiformis*, *I. corniger* and others. Klapper *et al*. (1978) added data from Bohemia, which suggest that subspecies of *Lat. beckmanni* can be used as markers in the higher part of the lower Emsian. Further support comes from data in Bultynck (1989), who also specified the lower Emsian range of *Lat. latus* in the Armorican Massif.

The Celtiberian conodont succession was reviewed by Carls (1999) and Carls & Valenzuela-Ríos (2002) and summarized in "conodont steps", which can be used as regional zones, but with high international correlation potential (*e.g.*, Jansen *et al*. 2007, Becker & Aboussalam 2011). *Caudicriodus curvicauda* seems to straddle the Pragian/Emsian boundary of current GSSP definition and is abundant in the "basal Emsian" Step 16 of Celtiberia (level of the oldest *Eol. excavatu*s in supposedly equivalent strata of the GSSP, at 92 m). *Caudicriodus celtibericus* and *Caud. sigmoidalis* enter in Step 17, together with *Eol. excavatus* Morphotype 114. A succession of both index icriodids, as in Faunas IV and V of Bultynck (1976), was not observed but forerunners of *Lat. bilatericrescens* were noted. Step 18 is defined by the entry of *Lat. bilatericrescens gracilis* Bultynck, 1985, which Carls & Valenzuela-Ríos (2002) regarded as a distinctive species. *Lat. bilatericrescens bilatericrescens* and *Lat. bilatericrescens multicostatus* enter slightly higher and give Step 19. Step 20 is defined by the entry of *Lat. latus* and also includes *Eol. gronbergi*, and, slightly higher, *Eol. catharinae*. There is no icriodid innovation in Step 21. *Caudicriodus culicellus* is used to define Step 21, followed slightly later by *I. fusiformis*. The scheme does not extend to the higher part of the upper Emsian.

Similar successions from the Cantabrian Mountains were used by García-López & Sanz-López (2002) to establish regional *celtibericus*, *bilatericrescens*, *culicellus*, *corniger ancestralis*, and *corniger corniger* zones. Alleged *Caud. culicellus* from the lower Emsian, from levels before and together with *Crit. steinhornensi*s, are probably based on mixing the species with *Caud. ultimus* (as in García-López & Alonso-Menendez 1994, pl. 2, figs 5–7). Slavík (2004) explored the potential of *Lat. bilatericrescens gracilis* as a basal Emsian index species and zonal marker in Bohemia. He confirmed that it enters slightly lower than the other subspecies, near an important event interval with the last *Neomonograptus* faunas.

The European icriodid succession cannot be easily transferred to different continents (see Klapper & Johnson 1980, Bultynck 2003). Some taxa range into Asian regions, which partly belonged to Gondwana and partly formed distinctive crustal blocks. For example, Bardashev & Ziegler (1992) noted four European species in Tadzhikistan and a few were variably noted in different regions of China. Such occurrences are given below in the correlation of the individual zones. But the rarity of icriodids in the lower Emsian of SE Asia is remarkable. It is especially strange that there are practically no icriodid faunas from the Emsian of Australia (*e.g.*, Philip 1966; Mawson *et al*. 1985, 1987a; Mawson & Talent 1989; Furey-Greig 1995; Sloan *et al*. 1995) since European Pragian and Middle Devonian icriodid species are wide spread on that continent (*e.g.*, Mawson & Talent 1994, Dongal 1995). In North America, especially in Nevada (*e.g.*, Johnson *et al*. 1980, Johnson & Klapper 1981), there are different lower Emsian taxa. They are followed by a widespread, endemic fauna with *Lat. latericrescens robustus* (Orr, 1971), whose base is commonly correlated with the *serotinus* Zone (*e.g.*, Weddige & Ziegler 1977, Klapper & Johnson 1980). Baranov (2012) summarized the very different Lower Devonian icriodid zonation of Russian arctic regions, which is based on the evolution of *Gagievodus* and *Vjaloviodus*. But there are a few subordinate European taxa (*e.g.*, *Caud. sigmoidalis*) and more of these can be found in the Russian Far East (see Eikhvald 2008, Baranov *et al*. 2014). Typical Arctic Russian taxa, such as *Vj. taimyricus* (Kuz'min, 1967), range from the Taimyr and Omolon regions (NE Russia; *e.g.*, Sobolev *et al*. 1988) into Alaska (Lane & Ormiston 1979) and western Yukon (Savage *et al*. 1985). The Salair region of South Siberia is characterized by yet a different lower Emsian icriodid lineage (*Caud. amplus – vicinus – longicavatus*; Izokh 1990, 1998), which partly extends into the Tuva region to the east (Izokh 2005). The Altai region to the south hosted the endemic *Lat. altaicus* (Aksenova,

Table 5. Conodont record from dissolved Emsian goniatites of the Anti-Atlas. For explanation of sample numbers see text. Abbreviations: Bl. Marl = Black Marl Member, *Sell*. Lst. = *Sellanarcestes* Limestone, *bilat*. Ez. = local *bilatericrescens bilatericrescens* Ecozone. Entry of index taxa marked in bold.

Conodont zones		*steinhornensis*					*cooperi*	*patulus*
	bilat. Ez.	*latus [beckmanni]*		*fusiformis*	*corniger corniger*			
Lithostratigraphy	Bl. Marl	*Anetoceras* Lst.		Sell. Lst.	*Anarcestes* Limestone			
Bed or sample No.	RT-*Erb*	OCh-*Anet*	BT-*Kl*	Ouf-*Sell*	EKs-B	EKs-D	HN-TA29	Och-*An*
Lat. bilat. bilatericrescens	**24**	4	1					
Bel. resima		22		3	9	11	2	
Bel. triangularis		3	1					
Crit. miae		2	5					
Crit. steinhornensis		**29**	28					
Caud. sigmoidalis		2						
Lat. bilatericrescens (towards *beckmanni*)		9						
Lat. beckmanni beckmanni		**1**	4					
Caud. celtibericus			3					
Neop. perlineatus				8	10	19	7	2
Caud. culicellus culicellus				**2**	4	5	2	
L. aff. *cooperi*							**2**	
Po. patulus								**1**
(Sub)species diversity	1	7	6	3	3	3	4	2
Total conodonts	24	72	41	13	23	35	13	3

1987). An alleged *I. trojani* Johnson & Klapper, 1981 from the lower Emsian of Yunnan (Jin *et al*. 2005) is not very similar to that endemic form of Nevada but closer to the Siberian icriodids.

Spathognathodids. – In the lower Emsian, Bultynck (1976) noted the significance of *Crit. miae* as an alternative index species for his Fauna V with *Caud. sigmoidalis*, followed above the first *Eol. gronbergi* by *Crit. steinhornensis* (Bultynck *et al*. 1979). This was subsequently confirmed in the Armorican Massif (Bultynck 1989), where *Crit. steinhornensis* enters as a marker species in the Upper *gronbergi* Zone, slightly above the entry of *Eol. catharinae*. The same range defines conodont Step 21 in Celtiberia (Carls & Valenzuela-Ríos 2002). Both *Crit. miae* and *Crit. steinhornensis* had a very wide pantropical distribution (Klapper & Johnson 1980) but the first has a longer range than observed by Bultynck (1976), down into the Pragian (see details below). In the upper Emsian no ozarkodinid zone has been proposed so far. However, Klapper *et al*. (1978) and Klapper & Johnson (1980) noted that *Oz. carinthiaca* is a good index for the *serotinus* to *patulus* zones in Bohemia and several other regions.

Regional Anti-Atlas polygnathid zonation

The Emsian polygnathid record of the Anti-Atlas is partly very sparse and episodic, despite a predominant outer shelf setting, as indicated by frequent to very abundant dacryoconarids and ammonoids. The peculiar regional aspects of Emsian conodont biofacies have first been outlined by Bultynck (1998). Rich polygnathid assemblages are confined in the Tafilalt and Maider to specific deepening phases. The complete regional ranges of all conodont taxa are summarized in Fig. 31.

Pragian. – The "Pragian Marls and Shales" (Unit D) and "Pragian Limestone" (Unit E) of the Tafilalt and corresponding strata of the Dra Valley (near the base of the Merzâ-Akhsai Formation, Faunas C6-9 of Jansen *et al*. 2007) almost lack polygnathids. This prevents a regional recognition of the *kitabicus* Zone. *Eoct. pireneae* (Boersma, 1974) has recently been found together with *Caud. celtibericus* in an allochthonous upper Pragian clast at the northern margin of the Anti-Atlas (Rytina *et al*. 2013). A single fragmentary specimen of the *pireneae* Group was found together with *Lat. steinachensis* in Sample BTN P/E2 at Bou Tchrafine North (Fig. 18V–X). It shows some similarities with specimens assigned to Morphotype α of *Eoct. savagei* Bardashev, Weddige & Ziegler, 2002, which is a taxon that requires further investigation. Even more similar is the figured paratype of *Eoct. ivanowskyii* (Baranov, Slavík & Blodgett, 2014). With respect to the limited knowledge of variability within the *pireneae* Group we do not wish to specify the species identification of our form. Both records of the group are so far the very limited evidence for a regional, long-ranging *pireneae* Zone in the Pragian of the Anti-Atlas (see further discussion of Valenzuela-Ríos 1997).

(Regional) Eolinguipolygnathus excavatus Morphotype 114 Zone. – The oldest rich Tafilalt polygnathid assemblages can be morphologically diverse. The index form enters in the basal part of the *Deiroceras* Limestone at El Khraouia (Bed 15a, Fig. 20I, J) and it is associated at Jebel Ihrs (Bed 16a, Fig. 5N–Q) with typical *excavatus* morphotypes (Figs 5L, M, 6K, L), Morphotype beta *sensu* Bardashev *et al*. (2002; Fig. 5J, K), rare *Eol. pannonicus* Mashkova & Apekina, 1980 (Fig. 6G, H), a few transitional forms towards *Eocostapolygnathus*, here named Morphotype JI16a (Fig. 6C, D; possibly the contemporaneous *kitabicus* in Belka *et al*. 1999), and early morphotypes of *Eol. radula* sp. nov. The latter are slightly transitional towards *Eol. excavatus* (Fig. 6A, B, I, J) and include forms with very wide basal cavity (Fig. 6E, F).

Eolinguipolygnathus excavatus s. str. was illustrated by Bultynck & Hollard (1980) as *Po. dehiscens* from a slightly higher level in the same unit (Sample BTN BK 496); it provided the oldest evidence for their Fauna Ia. Belka *et al*. (1999) illustrated a supposed *Po. gronbergi* from their 2nd sample of the *Deiroceras* Limestone of Ouidane Chebbi, Section I. This specimen, however, is a transitional form between *excavatus* and *gronbergi* (see Klapper & Johnson 1975). *Eolinguipolygnathus excavatus* Morphotype 114 occurs throughout the middle and upper *Deiroceras* Limestone, based on samples from Hassi Nebech (Sample 6), Jebel Ihrs (Beds 16c, d, Fig. 7C, D, G, H, N, O), and El Khraouia (Bed 15f, Fig. 21D–F). Typical morphotypes of the species are associated (Fig. 7E, F). At Jebel Ihrs and El Khraouia, typical *Eol. radula* sp. nov. (Figs 6M–R, 21C) are diagnostic for the upper part of the zone. This new form does not occur at Bou Tchrafine West (Sample BTW1), which, however, has *Eol. excavatus* s. str. (Fig. 15A–D, G). There are rare *Eol. excavatus*, which show a trend towards *Eol. perbonus* (Fig. 7P, Q) but an inversion of the posterior basal cavity has not been observed in any specimen. The top of the *Deiroceras* Limestone is polygnathid-free at Ouidane Chebbi (Sample 22 of Belka *et al*. 1999), Jebel el-Mrier (Bed 26e), and in the SW Maider (Samples 3–5 from Ou Driss, Bultynck 1985).

Jansen *et al*. (2007) described from the poorly known section Sidi Rezzoug I in the eastern Dra Valley a Fauna C11 with *Eol. excavatus*, *Caud. celtibericus*, and *Caud. sigmoidalis*, which resembles faunas from the lower *Deiroceras* Limestone but it could be slightly older (conodont Step 17). Just slightly higher at Sidi Rezzoug, there is an icriodid assemblage that is typical for the middle *Deiroceras* Limestone (Fauna C12, see below).

The oldest polygnathids of the Tafilalt co-occur with icriodids of the upper part of Step 18 *sensu* Carls & Valenzuela-Ríos (2002; see below). In the Zinzilban (Uzbekistan) lower Emsian, *Eol. excavatus* Morphotype 114 enters earlier, at the base of conodont Step 17, *Eol. excavatus* s. str. even earlier, at the base of Step 16. The same succession was used by Sanz-López (2002) to recognize in the eastern Pyrenees the Lower and Middle *excavatus* zones *sensu* Yolkin *et al*. (1994), which is supported by the recent data from the Central Pyrenees (Martínez-Pérez & Valenzuela-Ríos 2014). Baranov *et al*. (2014) distinguished in NE Siberia an *excavatus/sobolevi* Zone. Since no *Eol. excavatus* Morphotype 114 has been figured, the base of this regional interval should be correlated with conodont Step 16.

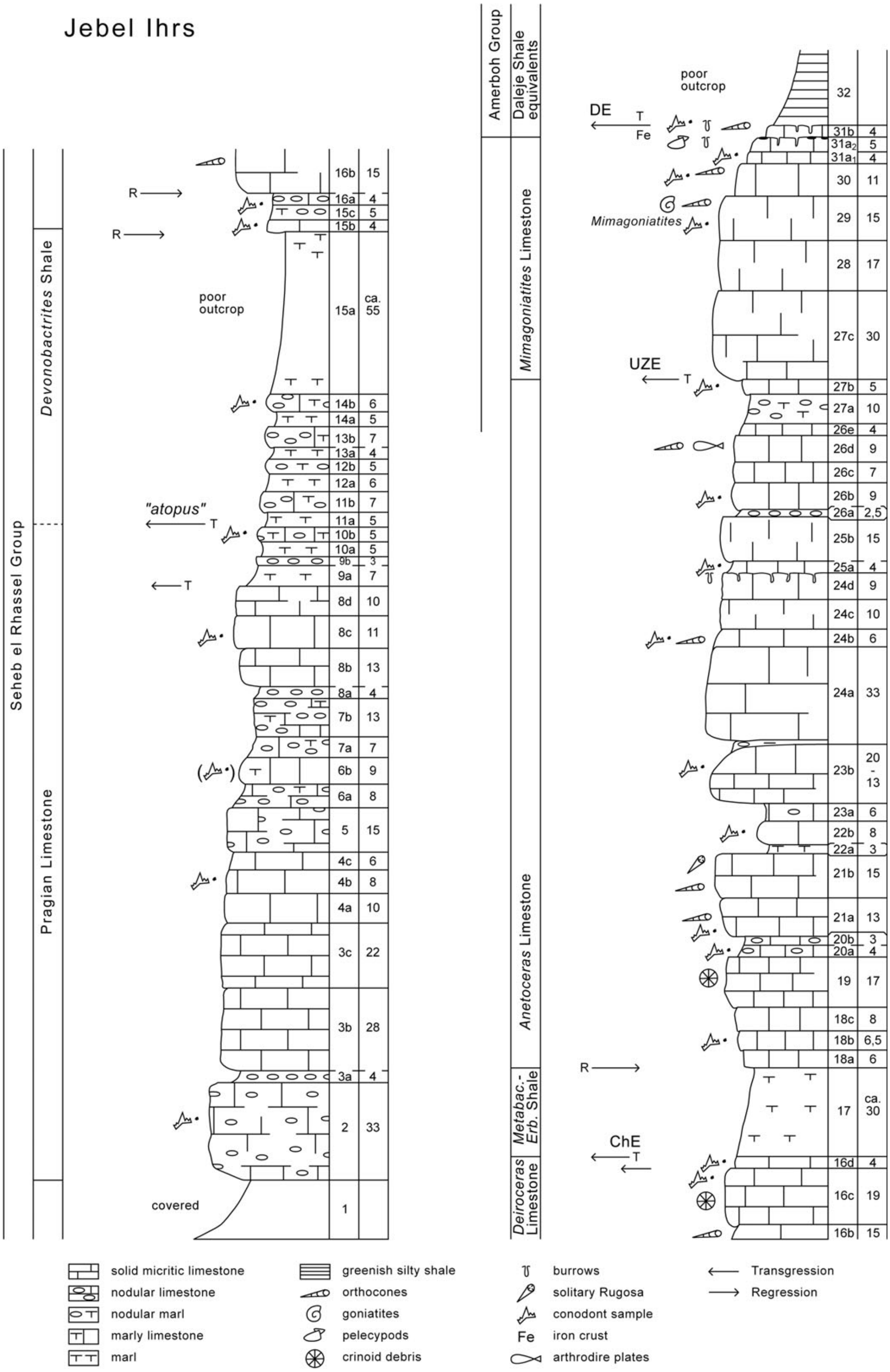
It is assumed that sampling (*Devonobactrites* Shale) and biofacies (polygnathid-free "Pragian Limestone") aspects caused a regional delay of the first occurrence of both *excavatus* morphotypes. *Eolinguipolygnathus pannonicus* overlaps in the Kitab Reserve of Uzbekistan with the oldest *Eol. excavatus* but has not been reported from the levels of Morphotype 114 (Middle *excavatus* Zone *sensu* Yolkin *et al*. 1994). However, Martínez-Pérez & Valenzuela-Ríos (2014) noted such an overlap from the Pyrenees.

[Regional Eol. excavatus-catharinae Interregnum]. – The *Metabactrites-Erbenoceras* Shale furnished so far no conodonts, which creates a regional polygnathid interregnum between the last rich fauna with *Eol. excavatus* and the oldest *Eol. catharinae*. There is also no conodont record from the corresponding shaly middle part of the Bou Tiskaouine Formation of the Maider. The limestones at the top of the Rich 2 Sandstone Member of the Dra Valley yielded icriodids but no polygnathids.

So far there are no polygnathids from the very base of the *Anetoceras* Limestone (*e.g*., at Jebel Ihrs, Bou Tchrafine West, and Ouidane Chebbi, Samples 25, 26 of Belka *et al*. 1999), which could narrow the interregnum. The *Eol. gronbergi* record plotted in Bultynck & Walliser (2000a) with Sample BTW1b refers in fact to specimens from Sample BTW2 (see Bultynck & Hollard 1980, p. 26).

It is likely that the *gronbergi* Subzone time interval begins in the conodont-barren *Metabactrites-Erbenoceras* Shale. This idea is supported by the presence of transitional forms between *Eol. excavatus* and both *Eol. gronbergi* and *Eol. perbonus* in the upper *Deiroceras* Limestone (as noted above). The Anti-Atlas faunas have no record of a *nothoperbonus* (Sub)Zone below the level of the first *Eol. catharinae*.

Figure 4. Lithological succession and the position of conodont samples, sea level changes, and named events at Jebel Ihrs (western Tafilalt). Abbreviations: T = transgression, R = regression, ChE = Chebbi Event, UZE = Upper Zlíchov Event, DE = Daleje Event. For conodont ranges and zonation see Table 1.



Jebel Ihrs
Seheb el Rhassel Group
Pragian Limestone
Devonobactrites Shale
Amerboh Group
Daleje Shale equivalents
Mimagoniatites Limestone
Anetoceras Limestone
Metabac.-Erb. Shale
Deiroceras Limestone
poor outcrop
covered
"atopus"
DE
UZE
ChE
Mimagoniatites
Fe
R
T
solid micritic limestone
nodular limestone
nodular marl
marly limestone
marl
greenish silty shale
orthocones
goniatites
pelecypods
crinoid debris
burrows
solitary Rugosa
conodont sample
iron crust
arthrodire plates
Transgression
Regression

Eolinguipolygnathus catharinae Subzone. – The index species enters at Bou Tchrafine West (Sample BTW2, Fig. 15N, O, S), Bou Tchrafine North (Sample BTN4), and Jebel Ihrs (Bed 22b, Fig. 9B, C, Table 1) in the lower part of the *Anetoceras* Limestone. Since it is rare, and in accord with Bultynck (1989), its entry is only recognized as the base of a subzone of the *gronbergi* Zone. *Eolinguipolygnathus* aff. *gronbergi* co-occurs in both Bou Tchrafine sections (Fig. 15H–J). Sample BTW2 yielded also some *Eol. nothoperbonus* (Fig. 15E, F), but by comparison with the La Grange polygnathid succession (Bultynck 1989), the underlying polygnathid-barren interval of the Anti-Atlas caused a regionally delayed entry of the latter taxon. The lower part of Bed 21a of Jebel Ihrs contains rare *Eol. juferevi* (Aksenova, 1987; Fig. 8L, M). As noted by Bardashev *et al*. (2002, synonymy list), a contemporaneous specimen, illustrated by Bultynck (1985, pl. 5, fig. 16) as *Po. gronbergi* from the basal upper Bou Tiskaouine Formation of Ou Driss (SW Maider, Sample OD6), also shows the platform outline of *Eol. juferevi.* Its precise range has not yet been established in the Russian type-region. Bultynck (1985) recorded associated *Po*. aff. *perbonus* (= *Eol. nothoperbonus*) and *Crit. steinhornensis* from Ou Driss. The latter species gives a correlation with a level above the first *Eol. catharinae* of the Tafilalt. The limestones overlying the Merzâ-Akhsai Formation of the Dra Valley yielded no polygnathids, with the exception of the possibly older Fauna C11 of Jansen *et al*. (2007), as discussed above. In the western Dra Valley there is a fragmentary *Eol. excavatus* M114 (Fig. 27L) from the basal Akhal Tergoua Member of Rich Tamelougou. Its correlation with the *catharinae* Subzone is based on the associated marker icriodids.

In the Tafilalt *Eol. catharinae* and polygnathids disappear in general in the middle *Anetoceras* Limestone, with the exception of rare last *Eol.* aff. *gronbergi* at Bou Tchrafine West (Sample BTW2b).

The *catharinae* Subzone correlates with the Upper *gronbergi* Zone of Bultynck (1989), the upper part of conodont Step 20 of Carls & Valenzuela-Ríos (2002), and the Upper *nothoperbonus* Zone of Martínez-Pérez *et al*. (2011). In the Kitab Reserve of Uzbekistan, *Eol. catharinae* enters delayed, jointly with *L. inversus* (Yolkin *et al*. 2008). This interpretation is based on the La Grange Limestone, where *L. inversus* begins significantly higher than *catharinae* but overlaps it. Due to large faunal differences, it is difficult to correlate the *catharinae* Subzone with the polygnathid succession of NE Siberia (Baranov *et al*. 2014) but it may postdate most of the described faunas.

Linguipolygnathus inversus Zone. – Polygnathids are almost absent from the upper *Anetoceras* Limestone to main part of the *Mimagoniatites* Limestone. They are also lacking in the corresponding levels of the Maider and Dra Valley. There is just a single *Eol*. cf. *gronbergi* from the lower *Mimagoniatites* Limestone of Jebel el-Mrier (Sample AL RTB8, Fig. 22F, G). The first thin-bedded, light grey limestone at the top of the *Mimagoniatites* Limestone yielded at Jebel Ihrs (Bed $31a_1$) a single, small and incomplete *L. inversus* (Fig. 9I, J). It resembles the small paratype of Klapper & Johnson (1975, pl. 3, fig. 23). We do not follow the re-assignment of the latter in Bardashev *et al*. (2002) to Morphotype α of their *Ctenopolygnathus senckenbergi*, because this ignores ontogenetic changes in *L. inversus* and the very different morphology of the selected *senckenbergi* holotype (*Po. inversus* of Uyeno & Klapper 1980, pl. 8-1, figs 9, 10). At Jebel Ihrs *L. inversus* is associated with dominant *Eol. jacksoni* (Fig. 9K–P), which could justify a different local zone name. There are also a probably new *Linguipolygnathus* species and a single *L. annamariae* (Bultynck, 1989), which also occurs in the *inversus* Zone of the Armorican Massif (Bultynck 1989). Jansen *et al*. (2007, fig. 3.15) figured a juvenile/questionable *inversus* specimen from the Oui-n-Mesdoûr Formation (Fauna C13) of the western Dra Valley. It co-occurs with *Crit. miae*, may represent a juvenile *Eolinguipolygnathus* and, therefore, an older level than the *inversus* Zone.

The very thin Tafilalt record of the *inversus* Zone (Jebel Ihrs) represents only the upper part of the zone, which is well known from Nevada, Canada, Germany (Schönau Limestone), and France (*e.g*., Klapper & Johnson 1975, Bultynck 1989). Its global recognition is further based on a wide distribution in the Arctic regions of Eurasia (Baranov 2012), eastern Urals (Snigireva & Nasedkina 1995), the Fergana Valley (Klishevich *et al*. 1985), Tadzhikistan (Bardashev & Ziegler 1992), South China (*e.g*., Wang & Ziegler 1983, Kuang & Zhou 1992, Jin *et al*. 2005), Australia (*e.g*., Mawson *et al*. 1985), and the Russian Far East (Gagiev 2000).

Linguipolygnathus laticostatus Zone. – The *laticostatus* Zone is well developed at the top of *Mimagoniatites* Limestone of Jebel Ihrs (Bed 31b, Fig. 10C, D, G–L), El Khraouia (top Bed 22, Fig. 21K), and Bou Tchrafine (Fauna Va of Bultynck & Hollard 1980, pl. II, figs 9–11; Bultynck & Walliser 2000a; Samples BTW6, Fig. 15K, BTW5, and BTN BK494). There are two morphotypes of *Eol. laticostatus* (alpha and beta) and forms identified as *Eol*. cf. *laticostatus* (Sample BTW5, Fig. 15L, M, T, U). The *laticostatus* Zone is also developed at the top of the Bou Tiskaouine Formation of the SW Maider (Ou Driss, Bultynck 1985). Polygnathids are, however, absent from the top *Mimagoniatites* Limestone of the southern Tafilalt (Jebel Ouaoufilal, Jebel el-Mrier) and from the contemporaneous, more argillaceous strata of the Dra Valley. *Eol. vigierei* (Bultynck, 1989) is regionally an important associated marker (Figs 10E, F, 15P, Q) but not all specimens are typical (Fig. 21I, P, Q). This explains our cf. identifications. *L. inversus* is only associated at El Khraouia, but locally common. *Eol. gilberti* is rare in the Anti-Atlas and only known from the latter locality (Fig. 21J), together with a form here identified as *Eoc.* cf. *juferevi* (Fig. 21N, O).

The eastern Anti-Atlas *laticostatus* Zone correlates straight forward with the top lower Emsian *laticostatus* Zone of Alaska (Lane & Ormiston 1979), British Columbia (Pyle *et al.* 2002), Nevada (Klapper & Johnson 1975), Armorican Massif (NW France, Bultynck 1989), Montagne Noire (southern France, Feist *et al.* 1985), the Central Pyrenees (Martínez-Pérez *et al.* 2011), central Spain (Bultynck *et al.* 1979), Moroccan Meseta (Benfrika *et al.* 2007), the Rhenish Massif (*e.g.*, Weddige & Ziegler 1977), Harz Mountains (Germany, Luppold 1984), Bohemia (Klapper *et al.* 1978), Bulgaria (Boncheva 1991), eastern Urals (Snigireva & Nasedkina 1995, Yurtische section), Uzbekistan (Yolkin *et al.* 1994, Mawson 1995), Tadzhikistan (Bardashev & Ziegler 1992), Guangxi, South China (Ziegler & Wang 1985), and Russian Far East (Gagiev 2000).

[Regional laticostatus-bultyncki Interregnum]. – There are no conodonts at all in the few marly limestone beds intercalated within the Daleje Shale Equivalents of the Tafilalt and no polygnathids in the correlative limestones of the Er Remlia Formation of the Maider or in the *Hollardops* Limestone Member and Brachiopod Marl Member (nodules with "*Latanarcestes*") of the western Dra Valley. In these three regions, the polygnathid gap between the *Eol. laticostatus* and *L. bultyncki* faunas forms regionally a distinctive, facies-controlled interregnum.

Linguipolygnathus bultyncki Zone and Subzone. – The index species enters in the Tafilalt in the lower *Anarcestes* Limestone of Hamar Laghdad South (Samples HLS II1-2, Figs 15V, 16A) but elsewhere it is uncommon or absent in the same unit (samples from Erg Kseir and El Khraouia). Belka *et al.* (1999) reported *L. bultyncki* at Ouidane Chebbi from Sample 37 from above *Sell. neglectus* (full goniatite record in Klug 2002), which is an index species of the *An. simulans* Zone (Ebbighausen *et al.* 2011). In the SW Maider (Ou Driss, Sample 12), the first *L. bultyncki* is from the top of the Er Remlia Formation and probably slightly older than the first Tafilalt specimens (Bultynck 1985). In the northern Maider it appears in the overlying lower Tazoulait Formation (Sample 4 of Ouahlane, Fauna VIb in Bultynck 1985), which correlates with the lower *Anarcestes* Limestone. The middle, *Sellanarcestes* bearing part of the Lower Member of the Timrhanrhart Formation of the eastern Dra Valley yielded the zonal index (identified as *linguiformis* Morphotype α) at El Annsa (Sample 27-3) and Foum Timrhanrhart (Sample 25-1). These two records provided the original definition for Fauna VIb in Bultynck & Hollard (1980) but may have come from above the solid *Sellanarcestes* Limestone, where *Sellanarcestes* and *Anarcestes* co-occur (LD IV-D1). The *Sellanarcestes* Limestone itself has dominating *Belodella* (Fig. 29K) and *Neopanderodus* but no polygnathids in a new sample from Oufrane (Sample Ouf-*Sell*, Bed 11 of Ebbighausen *et al.* 2011) and no *L. bultyncki* at El Anhsour (Samples 16 and 19b). However, there are still some *L. inversus* (Fig. 25AB, AC) and *L.* aff. *inversus* (Fig. 25Z, AA), which apparently belong to the upper Emsian top of the extended *laticostatus* Zone. In the western Dra Valley, *L.* cf. *bultyncki* occurs rarely in the *Sellanarcestes* Limestone Member of the Khebchia Formation at Hassi Targa (Bultynck & Hollard 1980).

As discussed by Bultynck (1985), the *bultyncki* Zone correlates with the lower part of the *serotinus* Zone of Bohemia, where the two zonal markers enter together (Klapper *et al.* 1978, Klapper & Vodrážková 2013). This applies also to the Fergana Valley of central Asia (Kim *et al.* 1988), South China (Ziegler & Wang 1985, Bai & Bai 1988), and Queensland (Mawson & Talent 1989). In Nevada (Johnson *et al.* 1980, table 15), British Columbia (Pyle *et al.* 2002), and New South Wales (Talent & Mawson 1994), *L. serotinus* enters slightly before *L. bultyncki*. The "Tafilalt pattern", with *L. bultyncki* as the only polygnathid at the base of the *serotinus* Zone, was also observed in the Istanbul region (Saydam-Demiray & Capkinoglu 2012). The general rarity of polygnathids in the pelagic basal upper Emsian of all of the Anti-Atlas, confirmed by our re-sampling of various goniatites, is striking. The strong biofacies influence caused a delayed regional entry of *L. serotinus*.

Linguipolygnathus cooperi cooperi Subzone. – The index species occurs in the Tafilalt together with *L. bultyncki* in higher parts of the *Anarcestes* Limestones of Hamar Laghdad (Samples HLS-6 to HLS-3, Fauna VIc of Bultynck & Hollard 1980). Sample HLS II-4 proves that *L. serotinus* may enter at *ca* the same level (Fig. 15W), which eliminates the distinction of a subsequent regional Fauna VII with *L. serotinus*. A loose *Sellanarcestes-Anarcestes* goniatite sample from Hassi Nebech yielded very narrow forms resembling to some extent the Australian *L. pugiunculus* (Mawson, 1997); they are here identified as *L.* aff. *cooperi*.

In the Maider the *cooperi cooperi* Subzone is present in the middle to higher parts of the Tazoulait Formation, where it partly overlaps *Sellanarcestes*. Records are from Ou Driss (Samples 13, 14 and 16), Ouahlane (Sample 6), and Tizi n'Ikouâch (Samples 5 and 7, Bultynck 1985, pl. 7, figs 5, 6, 14). *L. cracens* has only been found at Ou Driss (Sample 16, Bultynck 1985, pl. 7, fig. 1). *L. serotinus* enters slightly above *L. cooperi cooperi* at Ou Driss (Sample 30-5, Bultynck & Hollard 1980, pl. II, figs 12, 13) and Tizi n'Ikouâch (Sample 7; Bultynck, 1985, pl. 5, fig. 7) in the lower El Otfal Formation. In the second locality, *L. quadratus* (Klapper, Ziegler & Mashkova, 1978) or *L. foliformis* (Snigireva, 1975) were noted, too (Bultynck

1985, pl. 6, figs 1, 2), but both are now regarded as *serotinus* synonyms (Klapper & Vodrážková 2013).

An overlap of *Sellanarcestes* and *L. cooperi cooperi* was also reported from the lower part of the Timrhanrhart Formation of the eastern Dra Valley, based on a sample from El Annsa (Bultynck & Hollard 1980, pl. II, fig. 18a, b). *Linguipolygnathus serotinus* (Telford, 1975) co-occurs with *Anarcestes* in Sample 25-3 at Foum Timrhanrhart. This record provided the original base for the regional Fauna VII (Bultynck & Hollard 1980). Polygnathids are very rare in the *Sellanarcestes* Limestone Member of the Khebchia Formation of the western Dra Valley. Only section Hassi Targa yielded a single *L.* cf. *bultyncki* (Bultynck & Hollard 1980). A new sample from the Rich Tamelougou hardly had any conodonts (Table 4).

The regional *cooperi cooperi* Subzone correlates with the higher part of the *serotinus* Zone of Bohemia (Klapper *et al.* 1978) and the Carnic Alps (*e.g.*, Schönlaub 1985), the Upper *serotinus* Zone of South China (Ziegler & Wang 1985), of the Istanbul region (Saydam-Demiray & Capkinoglu 2012), eastern slope of the Urals (Snigireva & Nasedkina 1995), Uzbekistan (Apekina & Mashkova 1978, Kim *et al.* 1988), Tadzhikistan (Bardashev & Ziegler 1992), and New South Wales (Talent & Mawson 1994). Obviously it can also be recognized in peninsular Malaysia (record of Lane *et al.* 1979) and in the Armorican Massif (Lardeux & Weyant 1993).

Polygnathus patulus Zone. – The index species dominates at Hamar Laghdad South (Sample HLS II-6) in the higher part of the *Anarcestes* Limestone. *Linguipolygnathus cooperi*, *L. serotinus* (Fig. 15X), and *L. bultyncki* are associated. Klug (2002) showed that the upper part of the *Anarcestes* Limestone at Jebel Ouaoufilal contains *Po. patulus* (Fig. 29A) together with *L. serotinus*. A new sample of anarcestids from Ouidane Chebbi yielded only a juvenile *Po. patulus* in association with two *Neopanderodus*.

Fauna VIII with *Po. costatus patulus* was originally based on Samples 22, 23 at Ou Driss from the Maider (Bultyck & Hollard 1980). Bultynck (1985, pl. 8, fig. 1) lowered the local zonal base to Sample 19, less than 2 m above the base of the El Otfal Formation. Not much higher transitional forms towards lower Eifelian members of the *Po. costatus* Group were noted (Sample 20), also at Ouahlane and Tizi n'Ikouâch in the northern Maider. There are no conodonts from the corresponding clastics of the Dra Valley, both in the east (upper Timrhanrhart Formation) and the west (Bou Tserfine Member). But *Po. patulus* does occur in the basal Eifelian of the latter region (Bultynck & Hollard 1980).

The Anti-Atlas *patulus* Zone can be correlated straight forward with the same Zone of Nevada (Johnson *et al.* 1985), the Rhenish Massif (*e.g.*, Weddige 1977, Weddige & Requadt 1985) and Harz Mountains of Germany (Luppold 1984), Austria (Schönlaub 1985), Bohemia (Klapper *et al.* 1978), Bulgaria (Boncheva 1991), Yunnan (Carls & Gong 1992), Guangxi (*e.g.*, Wang & Ziegler 1983, Bai & Bai 1988), and eastern Australia (*e.g.*, Mawson 1987b).

Lower Eifelian. – All top-Emsian polygnathids continue into the basal Eifelian *Po. partitus* Zone, which can be precisely located at Hamar Laghdad South (Sample HLS II-7) and in the Maider (Bultynck 1985). Associated polygnathids are *Po. patulus*, *L. zieglerianus*, and *L. cooperi cooperi*. *L. bultyncki* includes forms with well-rounded outer posterior margin (Fig. 16B, J), which defines Morphotype beta *sensu* Wang & Ziegler (1983). Such forms are intermediate between forms named as *Po. obovatus* Xiong (*in* Xian *et al.* 1980) and *Po. labiosus mawsonae* Long & Burrett, 1989, which Klapper & Vodrážková (2013) treated as intraspecific variants of *L. bultyncki*. *L. pinguis* enters in the upper part of the *partitus* Zone (Sample HLS II-9) and includes an aberrant specimen (Fig. 16M).

The *costatus* Zone enters in Sample HLS II-11, based on the index species (Fig. 16N) and *Po. angusticostatus* (Fig. 16O, P). *L. zieglerianus*, *L. bultyncki* Morphotype beta (Fig. 16H, I), and *L. pinguis* (Fig. 16K, L) are associated. A comparable lower Eifelian polygnathid succession of the Tafilalt has recently been published by Becker & Aboussalam (2013).

Regional Anti-Atlas icriodid zonation (Fig. 30)

Pragian. – A crinoidal limestone at Bou Tchrafine North (Samples BTN P/E1-2) and thin limestones within the "Pragian Marls and Shales" at El Khraouia (top Bed 8) yielded small or rich faunas with *Lat. steinachensis* Morphotypes eta (Fig. 17C) and beta (Fig. 20D). The first locality yielded a single and unique *Latericriodus* sp. nov. (Fig. 18S–U). The second locality also has some incomplete *Lat.* cf. *claudiae* (Figs 20B, C) and slender, early relatives of *Caud. celtibericus* (Fig. 20A). Bultynck & Walliser (2000b) recorded from Achguig *Caud.* sp. ex gr. *angustoides* (Carls & Gandl, 1969) from the local basal layer of the "Pragian Limestone". *Lat. steinachensis* is also known from the northern Maider, where it is associated with various *Pelekysgnathus* (Plodowski *et al.* 2000). Morphotype eta is in the Barrandian a lower/middle Pragian index species (*sensu* the type region, Slavík 2004b) that probably does not reach the level of the current (Zinzilban) basal Emsian GSSP (Slavík *et al.* 2007). A similar range applies to the central Pyrenees (Valenzuela-Ríos 2002), Carnic Alps (Schönlaub 1985, Suttner 2007, also with an upper overlap with *celtibericus* relatives), and Urals (Mavrinskaya & Slavík 2013). Therefore, it is possible to recognize in the Tafilalt an undoubted Pragian *Lat. steinachensis*

Zone (of any stage definition). It includes in the eastern Dra Valley Fauna C7 from the top of the Assa Formation (Jansen *et al*. 2007), which consists of *Caud. steinachensis* (no morphotype specified) and questionable *Caud. angustoides castilianus* (Carls, 1969). In the western Dra Valley, Fauna C8 from the base of the Merzâ-Akhsai Formation is similar but there are also the regionally oldest *Caud. curvicauda* (Jansen *et al*. 2007). Fauna C9 from 75 cm higher adds *Lat*. aff. *beckmanni* and the regionally youngest *Wurmiella excavata* (Branson & Mehl, 1933). The co-occurrence of *Lat. steinachensis* with *Pelekysgnathus serratus serratus* (Fig. 16T, U) at Bou Tchrafine North (Sample BTN P/E1) gives a position in the short, early middle Pragian overlap interval of both taxa (see Al-Rawi 1977 for Franconia and the Carnic Alps record of Schönlaub 1985). The *steinachensis* Zone can be easily correlated around the globe, from the Moroccan Meseta (Benfrika *et al*. 2007) to western North America (*e.g*., Murphy & Cebecioglu 1984), Franconia (Al-Rawi 1977), central Asia (Bardashev & Ziegler 1992), and southern and eastern parts of Australia (Mawson & Talent 1994).

Bed 9b (Sample MA RTB 2a) from the top of the "Pragian Marls and Shales" at El Khraouia contains only *Caud*. cf. *curvicauda*. It may represent a slightly younger level than the mentioned Dra Valley Fauna C9 with *Lat. steinachensis* and *Caud.* ?*curvicauda*. Typical *curvicauda* specimens range in the Barrandian into the classical upper Pragian, together with *Caud. celtibericus* (Slavík 2004b). The species occurs also in the higher Pragian of the Moroccan Meseta (Lazreq 1990). The Zinzilban GSSP level is tentatively projected to a position low in the main "Pragian Limestone" of the Tafilalt, which agrees with the regional dacryoconarid record. Bultynck & Walliser (2000b) came to a similar conclusion. Such a correlation has a significant impact for trilobite stratigraphy, because there are many Pragian marker trilobites in the "Pragian Limestone" of the Tafilalt.

Caudicriodus celtibericus Zone. – The index species enters in the basal "Pragian Limestone" of El Khraouia (mostly small specimens, Bed 11a, Fig. 20H). It also occurs in the middle part of the unit at Jebel Ihrs (Bed 4b, rarely, Fig. 5C, D) and in the upper part at Hassi Nebech (Bed 22c, Sample TA RTB4, Fig. 22N) and Jebel Ihrs (Bed 13). *Bel. resima* (Philip, 1965), *Bel. triangularis* (Stauffer, 1940), *P. unicostatus* Branson & Mehl, 1933 (record of Belka *et al*. 1999 from Ouidane Chebbi), and *Pseud. beckmanni* are associated shallow-water taxa and often more dominant. This led Becker & Aboussalam (2011) to propose a Lower *Belodella* Ecozone for the "Pragian Limestone" at Jebel Ihrs. *Caud. curvicauda*, another icriodid of the Barrandian upper Pragian, was only found in the southern Tafilalt, where it excludes *Caud. celtibericus* (Jebel Ouaoufilal, top "Pragian Limestone"). But it co-occurs with *Eoct. pireneae* and *Caud. celtibericus* in an allochthonous block of the Tinerhir region (northernmost Anti-Atlas, Rytina *et al*. 2013). Bultynck & Walliser (2000b) recorded from the "Pragian Limestone" of Achguig first transitional forms between *Caud. curvicauda* and *celtibericus*, followed by typical *Caud. celtibericus*. There are no contemporaneous conodonts from the Maider and Dra Valley.

The *celtibericus* Zone equals Fauna IV of Bultynck (1976) and the upper Pragian *celtibericus* Zone of the Barrandian (Kalvoda 1995, Slavík 2004b), if defined by the entry of the index species, not by the extinction of the *Pelekysgnathus serratus* Group. The latter ranged much higher in the Moroccan Meseta (Benfrika *et al*. 2007). In Celtiberia, *Caud. celtibericus* enters delayed, together with *Caud. sigmoidalis* and the oldest *Eol. excavatus* Morphotype 114 in conodont Step 17 (Carls & Valenzuela-Ríos 2002). In the Moroccan Meseta, the *celtibericus* Zone can be recognized in the Oued Cherrat region (Benfrika & Bultynck 2003) and Rabat-Tiflet Zone (Benfrika *et al*. 2007).

Lower Devonian icriodid faunas are generally characterized by a high level of endemism. Therefore, it is interesting that the *celtibericus* Zone can be recognized in the distant Amur region of the Russian Far East (Eikhvald 2008, regional level of *I. huddlei* Klapper & Ziegler, 1967). Preliminary data (Valenzuela-Ríos *in* Senglaub & Ebert 2002) also indicate a spread into eastern New York State.

At least the main/upper part of the polygnathid-free "Pragian Limestone" (*celtibericus* Zone) of the Tafilalt correlates with conodont Step 16 and with the basal Emsian in its current GSSP definition (see discussion in Kalvoda 1995). Most likely, it will not fall in a future Emsian defined by the entry of *Eol. excavatus* Morphotype 114.

[Regional celtibericus-gracilis Interregnum]. – There are no conodonts from the *Devonobactrites* Shale or from correlative beds of the Maider and Dra Valley. Therefore, it is regionally not possible to recognize conodont Step 17 of Carls & Valenzuela-Ríos (2002), which is best characterized by the oldest *Caud. sigmoidalis*. Support for this correlation comes from the main range of the dacryoconarid *Guerichina* both in Step 17 of Celtiberia and in the lower part of the *Devonobactrites* Shale (Alberti 1980, 1981).

Lat. bilatericrescens gracilis Zone. – At Jebel Ihrs, the basal part of the *Deiroceras* Limestone (Bed 15b) still has a monospecific *Caud. celtibericus* assemblage but the same level is dominated at Bou Tchrafine West and North (Samples BTW0 and BTN1), Hassi Nebech (Sample TA 6), and El Khraouia (Bed 15a, Fig. 20L) by *Caud. sigmoidalis*. The zonal index *Lat. bilatericrescens gracilis* (Fig. 5G) and transitional forms towards *multicostatus* (Fig. 5H) enter as subordinate faunal elements at Jebel Ihrs in Bed 16a (there associated with *Caud. sigmoidalis*, Fig. 5F) and at El Khraouia in Bed 15a. *Caudicriodus celtibericus* may be associated (Sample BTW0, Fig. 16V–X, El Khraouia, Bed 15a, Fig. 20M) and include specimens, which are still somewhat transitional from *Caud. curvicauda*. The last good *Caud. curvicauda* were observed at El Khraouia in Bed 15c but elsewhere the species may range higher (into the Barrandian *bilatericrescens* Zone, see Kalvoda 1995). An unexpected range extension applies to *Lat. steinachensis*, which occurs in the *Deiroceras* Limestone of Bou Tchrafine North (Samples BTN1 and BTN2, Fig. 17E, as well as in the lateral Sample BK496, Fig. 17A). Normally this taxon disappears in the middle Pragian. The lower Emsian representatives are less curved than typical specimens and could be assigned to a new, late morphotype.

Caud. sigmoidalis is also dominant in the basal Bou Tiskaouine Formation of the Maider (Ou Driss, Samples 1–4, Bultynck 1985, pl. 5, figs 3, 4), which lead to the recognition of Fauna Ia (Bultynck & Hollard 1980) in that unit.

The *bilatericrescens gracilis* Zone correlates probably only with the upper part of Fauna V of Bultynck (1976) with *Caud. sigmoidalis*. Based on rare morphotypes close to *Lat. bilatericrescens multicostatus*, it equals the transition from conodont Step 18 to 19 *sensu* Carls & Valenzuela-Ríos (2002). Regionally, its base coincides with the base of the *Eol. excavatus* Morphotype 114 Zone. Slavík (2004a) emphasized the significance of the entry of *Lat. bilatericrescens gracilis* as an alternative basal Emsian marker. Sanz-López (2002) listed *I. gracilis* from a much lower level (*kitabicus* Zone) of the eastern Pyrenees, which cannot be evaluated since there are no illustrations of specimens. Benfrika & Bultynck (2003) documented an earlier range of *Lat. bilatericrescens gracilis* than *Lat. bilatericrescens bilatericrescens* in the Al Attamna region of the Moroccan Meseta.

Latericriodus bilatericrescens bilatericrescens Zone. – The zonal index enters in the upper half of the *Deiroceras* Limestone at Bou Tchrafine West (Sample BTW0-1) and North (Sample BTN BK496). At the top of the unit the nominate subspecies (El Khraouia, Bed 15f; Jebel Ihrs, Bed 16c, Fig. 7A, B) and *Lat. bilatericrescens multicostatus* (El Khraouia, Bed 15f, Fig. 20N–Q; Jebel Ihrs, Bed 16c, d, Fig. 7I, M), which is an alternative marker form, can be dominant. In Samples BTW1 (see Bultynck & Hollard 1980, pl. I, figs 1, 2) and BTN 2–3 *Caud. sigmoidalis* is still the most common icriodid. *Caudicriodus celtibericus* (at Jebel Ihrs, El Khraouia, and Hassi Nebech) and *Lat. bilatericrescens gracilis* (Sample BTN 2–3 and Bed 15f at El Khraouia) continue from the previous zone. A *Caud*. cf. *ultimus* was recorded together with *Lat. bilatericrescens bilatericrescens* by Belka *et al*. (1999) from the upper *Deiroceras* Limestone of Ouidane Chebbi but not illustrated. The Jebel el-Mrier (Bed 26e, Sample AL RTB 6) in the southern Tafilalt has the most restricted icriodid fauna of the *bilatericrescens* Zone, with only *Lat. bilatericrescens bilatericrescens* (Fig. 22B) and *Caud. sigmoidalis* (Fig. 22A).

The *bilatericrescens bilatericrescens* Zone has not yet been recognized in the lower Bou Tiskaouine Formation of the Maider. Bultynck (1985) reported at Ou Driss *Lat. bilatericrescens gracilis* only from higher parts of that member (Samples 3–5, pl. 5, figs 1, 2), a level that correlates with the upper *Deiroceras* Limestone of the Tafilalt. The three subspecies of *Lat. bilatericrescens* continue in the Tafilalt into the basal *Anetoceras* Limestone (Jebel Ihrs, Bed 18b, Fig. 8A–C, and Ouidane Chebbi, Sample 25, Belka *et al*. 1999), locally accompanied by *Caud. celtibericus* (Jebel Ihrs).

Fauna II with *Lat. bilatericrescens* of Bultynck & Hollard (1980) was based on the limestones above the Rich 2 Sandstone Member of the eastern Dra Valley (Mdâour-el-Kbîr Ravine, with early *Erb. advolvens*). In the western Dra Valley, specimens illustrated from the basal Oui-n-Mesdoûr Formation of Tjafane by Bultynck & Hollard (1980, pl. I, figs 22–24) belong to *Lat. bilatericrescens gracilis* and include the holotype. An ontogenetic series from Oui-n-Mesdoûr (Bultynck & Hollard 1980, pl. I, figs 15–19) falls in *Lat. bilatericrescens multicostatus*. Fauna C12 of Jansen *et al*. (2007) from Sidi Rezzoug I (eastern Dra Valley) with *Lat. bilatericrescens bilatericrescens*, *Lat. bilatericrescens multicostatus*, and *Caud. celtibericus* represents the same interval. *Caud. sigmoidalis* is still more frequent than the *Lat. bilatericrescens* Group at Tjafane (Sample 20-1, Bultynck & Hollard 1980, pl. I, figs 5, 6). In terms of sequence stratigraphy, it is likely that the Dra Valley assemblages correlate partly with the *Metabactrites-Erbenoceras* Shale of the Tafilalt, as suggested by De Baets *et al*. (2010) and confirmed by the dacryoconarid record in Hollard (1978) and Alberti (1998).

The Moroccan *bilatericrescens bilatericrescens* Zone equals Fauna VI of Bultynck (1976) and conodont Step 19 of Carls & Valenzuela-Ríos (2002). Its lower part correlates with the higher parts of the *excavatus* Morphotype 114 Zone. This is supported by rare *Eol. excavatus* in the lower Bou Tiskaouine Formation of the Maider. The *bilatericrescens bilatericrescens* Zone is obviously also recognizable in the Moroccan Meseta (Benfrika & Bultynck 2003, Benfrika *et al*. 2007) and Bulgaria (data in Boncheva *et al*. 2007).

Latericriodus latus Zone. – The index species enters at the base of the *Anetoceras* Limestone at Bou Tchrafine West (Sample BTW1b, Figs 17K–M) and low in the same unit at Jebel Ihrs (Bed 20b, Fig. 8I). In both localities, as well as at

Ouidane Chebbi (Sample 26 of Belka *et al*. 1999), it is accompanied by the oldest *Lat. beckmanni beckmanni* (*e.g*., Fig. 9A), which is an alternative zonal marker. *Latericriodus bilatericrescens bilatericrescens* is often the dominant icriodid (Jebel Ihrs, Bed 20b, Figs 8D, E, and Bed 22B; Sample BTW2; Sample BTN4, Fig. 17F, G, Sample OCh-*Anet*, Fig. 28G) and it may be associated with *bilatericrescens multicostatus* (Figs 8F–H, 22C). *Latericriodus bilatericrescens gracilis* is generally rather rare and currently only known from Jebel Ihrs and Section BTN (Fig. 17H). *Caudicriodus celtibericus*, which is sometimes frequent (*e.g*., at Jebel el-Mrier, Sample AL RTB 7a), and *Caud. sigmoidalis* (Sample BTN4) continue as well. *Latericriodus armoricanus* appears slightly later than *Lat. latus*, still within the lower *Anetoceras* Limestone (Sample BTW2, Fig. 17N, O, *Lat*. aff. *beckmanni* of Bultynck & Hollard 1980, pl. I, fig. 7; Jebel Ihrs, Bed 21a, Fig. 8J). This matches closely the La Grange Limestone (Bultynck, 1989). However, the first *Lat. beckmanni sinuatus* were found in the Tafilalt (Jebel Ihrs, Bed 22b, Fig. 8N) lower than in the Armorican Massif. They represent the globally earliest record of the subspecies.

Latericriodus latus disappears in the Tafilalt in the middle *Anetoceras* Limestone, which mostly contains *Lat. bilatericrescens bilatericrescens* (*e.g*., Fig. 28B). At this level, *Lat. bilatericrescens gracilis* occurs only in Sample BTN 31-1. Regionally, the last lower Emsian *Lat. beckmanni beckmanni* were observed in Samples Och-*Anet* (Fig. 28H), BT-*Kl* (Fig. 28C), and BTN 31-2, the last *Lat. armoricanus* in Sample BTW2b. *Caudicriodus celtibericus* is locally still present (Jebel Ihrs, Bed 25a; Sample BT-*Kl*, Fig. 28A) and reaches the upper *Anetoceras* Limestone (Jebel Ihrs, Bed 26b). Even higher, *Lat. bilatericrescens* is the only remaining icriodid in more and more sparse assemblages (*e.g*., Jebel Ihrs, Bed 27b, Fig. 9F), with a last record of *bilatericrescens multicostatus* from Jebel el-Mrier (Sample 7b).

Finally, there are almost no icriodids left in the *Mimagoniatites* Limestone. Increasing shallowing led both in the Tafilalt and Maider to a complete lack of conodonts or restriction to *Belodella-Neopanderodus* assemblages (Jebel Ihrs, Bou Tchrafine West, Jebel el-Mrier, Jebel Kfiroun, Ou Driss). Rare exceptions are a few *Lat. bilatericrescens bilatericrescens* from Bou Tchrafine West (Sample BTW4b) and the Jebel Issimour (Plodowski *et al*. 2000). As pointed out by Becker & Aboussalam (2011), an Upper *Belodella* Ecozone developed in the eastern Anti-Atlas before the end of the lower Emsian.

The knowledge of terminal lower Emsian icriodids is generally very poor, not only in the Anti-Atlas, but also in Spain (García-López & Sanz-López 2002, Garcia-López *et al*. 2002, Carls & Valenzuela-Ríos 2002), in the Armorican Massif (Bultynck 1989), and Bohemia. The sudden re-appearance of rich polygnathid faunas at the top of the *Mimagoniatites* Limestone is not paralleled by a revival of icriodids. They are lacking at Jebel Ihrs, Bou Tchrafine, Jebel el-Mrier, and Ou Driss. Only El Khraouia yielded two specimens of *Caud. ultimus* (Fig. 21L, M), which resemble to some extent *Caud. celtibericus.* The precise lower range of *Caud. ultimus* needs further elaboration.

In the eastern Dra Valley, the *latus* Zone cannot be recognized within *bilatericrescens-celtibericus* assemblages of the Lower Member of the Mdâouer-el-Kbîr Formation (*e.g*., at Mdâouer-el-Kbîr, Fig. 18). In the *ca* middle part of the Akhal Tergoua Member of the western Dra Valley succession (Bed A10b at Bou Tserfine), the alternative markers *Lat. beckmanni beckmanni* (Fig. 27A) and *Lat. beckmanni sinuatus* were found in association with *Lat. bilatericrescens bilatericrescens*, *Caud. sigmoidalis* (Fig. 27C) and *Caud*. cf. *ultimus* (Fig. 27B). A similar, diverse association, including *Lat. beckmanni ?sinuatus* (Fig. 27G), occurs at the base of the member south of Torkoz (Rich Tamelougou) and in Fauna C10 of Jansen *et al*. (2007). In the SW (Ou Driss, Bultynck 1985, Sample 8) and northern Maider (Jebel Issimour, Plodowski *et al*. 2000), as well as at the top of the Akhal Tergoua Member of the Oui-n-Mesdoûr Formation (western Dra Valley, Becker *et al*. 2008), *Lat. bilatericrescens bilatericrescens* is the only icriodid (Bou Tserfine, Sample A18) in the top lower Emsian. This gave the regional "*bilatericrescens* Ecozone" of Becker *et al*. (2008).

The entries of *Lat. latus* and *Lat. beckmanni beckmanni* coincide both in the Tafilalt and in Celtiberia and define conodont Step 20 of Carls & Valenzuela-Ríos (2002). In the La Grange Limestone (Bultynck 1989), the *latus* Zone precedes slightly the first appearance of *Eol. nothoperbonus*. This enables us to project the base of the *nothoperbonus* (Sub)Zone into the basal *Anetoceras* Limestone. The *latus* Zone is further developed in Franconia (the type-region, Al-Rawi 1977) and in the Carnic Alps (Schönlaub 1985). The stratigraphic significance of the oldest *Lat. beckmanni* is clouded by alleged much earlier occurrences in Bohemia (*e.g*., Chlupáč & Lukeš 1999). These were marked as questionable in Slavík (2004a) and their relationships with *Lat. simulator* (Carls, 1969) have to be clarified. In the Kitab Reserve area of Uzbekistan, *Lat. beckmanni beckmanni* was first observed slightly above the oldest *Eol. nothoperbonus* (Yolkin *et al*. 2008). In Tadzhikistan, *Lat. beckmanni beckmanni* is very rare and was found within the higher *gronbergi* Zone below the first *Lat. latus* (Bardashev & Ziegler 1992). Locally, the latter reaches beds with *L. inversus*, which enables a projection of its upper range into the conodont-poor *Mimagoniatites* Limestone of the Tafilalt. *Lat. beckmanni* also enables a correlation into lower Emsian sections of the Moroccan Meseta (Benfrika *et al*. 2007), southern Siberia (Rudny Altai, Yolkin *et al*. 2005), and South China (Wang & Ziegler 1983, Ziegler & Wang 1985).

Icriodus fusiformis Zone. – At the base of the upper Emsian, the icriodid record is interrupted in the Tafilalt to eastern Dra Valley by the Daleje Shale Equivalents and corresponding clastics of the lower Er Remlia Formation and Rich 3 Sandstone Member. The oldest *fusiformis* Zone, Fauna Vb of Bultynck & Hollard (1980), was based on samples from the *Hollardops* Limestone Member of the western Dra Valley, which equals Fauna C14 in Jansen *et al*. (2007). The oldest *I. fusiformis* record is from Sample 7-1 at Hassi Talha (Bultynck & Hollard 1980, pl. IV, fig. 1a, b). Apart from the index species, *I. corniger ancestralis*, *I. corniger leptus*, *I. rectirostratus*, *I.* cf. *rectirostratus* (Fig. 27P), *I.* cf. *werneri* Weddige, 1977 (Fig. 27E), and the oldest *Caud. culicellus culicellus* (Bultynck & Hollard 1980, pl. IV, fig. 15a–c) form a very characteristic association. But most of our new samples from Bou Tserfine and Rich Tamelougou (Table 4) were surprisingly conodont-poor. The marker species is absent at both localities and *Caud. ultimus* (Fig. 27F) and *I. corniger leptus* (Fig. 27M) tend to be more common than other icriodids. In general, many icriodids are small and at early stages it is difficult to separate some taxa (*e.g.*, *Caud. ultimus* and *Caud. culicellus culicellus*, Fig. 27H–K). Some juvenile forms identified as *Caud*. aff. *sigmoidalis* may represent a new taxon (Fig. 27R). Sample D91 at Bou Tserfine yielded a questionable (poorly preserved) *Caud. culicellus altus*, whilst the typical subspecies occurs only in one richer sample at Rich Tamelougou. *Lat. bilatericrescens bilatericrescens* continues from the lower Emsian and may be the only taxon at the base of the *Hollardops* Limestone (Fig. 27D). Only one questionable *I. corniger ancestralis* and one undoubted *I. rectirostratus* were found at Rich Tamelougou.

The subsequent nodules with "*Latanarcestes*" auct. in the upper part of the Brachiopod Marl Member have hardly any diagnostic conodonts. There are a few more *Caud. ultimus* at Rich Tamelougou (Bed 161 of Brett *et al*. 2012), poorly preserved *Icriodus* sp. (1 m higher), and a youngest relative of *Caud. celtibericus*, here identified as *Caud*. aff. *celtibericus* (Fig. 29M). The regionally very restricted conodont record of the pelagic "*Latanarcestes*" level is remarkable.

Very typical assemblages of the *fusiformis* Zone enter also in the sandy limestones at the top of the Rich 3 Sandstone Member of the eastern Dra Valley succession (El Anhsour, Samples I, II). *Icriodus fusiformis* (Fig. 25A–D), *I. corniger ancestralis* (Fig. 25H, I), and *Caud. culicellus culicellus* (Fig. 25J–L) are accompanied by *I. ovalis* sp. nov. (Fig. 25E–G). *Icriodus homorectus* follows in the second sample (Fig. 25M–P), which is also characterized by the rare re-appearance of *Lat. beckmanni sinuatus* and by a drastic abundance reduction of *I. fusiformis*.

The *fusiformis* Zone continues in the basal Timrhanrhart Formation of the eastern Dra Valley (Bultynck & Hollard 1980, Bultynck *in* Ebbighausen *et al*. 2004). At El Anhsour, *I. praerectirostratus* sp. nov. enters in Sample 2 (Fig. 25Q–W), followed by *I. rectirostratus* in Sample 8. This succession documents the potential for a future zone subdivision.

Bultynck (1985) recorded icriodid assemblages of Fauna Vb, but with restricted diversity, from the higher Er Remlia Formation of the SW (Ou Driss, Sample 11 with *Caud. culicellus*, pl. 5, fig. 6) and northern Maider (Tizi n'Ikouâch, Samples 1, 2 with *I. rectirostratus*).

The *fusiformis* Zone correlates with a fauna of the Hierge Formation of the Ardennes (Bultynck & Godefroid 1974), with Fauna VII of Bultynck (1976) from the Sierra Guadarrama of Spain, faunas from the upper Schönau Limestone and below the Rupbach Slate of the Rhenish Massif (Weddige & Ziegler 1977, Requadt & Weddige 1978), a typical assemblage from Reun ar C'Hrank in the Armorican Massif (Bultynck & Morzadec 1979), Fauna I from the Lahn area of the Rhenish Massif (Weddige & Requadt 1985), the upper Oued Akresch Formation of the Moroccan Meseta (Benfrika *et al*. 2007), conodont Step 22 of Carls *et al*. (2002, based on the entry of *Caud. culicellus*), and the Cantabrian *corniger ancestralis* Zone of García-López (1987) and García-López & Sanz-López (2002). An alleged occurrence together with lower Emsian polygnathids in the Kabylei (northern Algeria, Gélard *et al*. 1978), is based on a different *Caudicriodus*. Beyond Europe, the *fusiformis* Zone can be recognized as the oldest Devonian unit in the Saradzhlin Suite of Transcaucasia (Nakhichevan autonomous region, Mamedov & Rzhonsnitskaya 1985). The index species is even known from Tibet (Rao & Yu 1985), *I. corniger ancestralis* from South China (Bai *et al*. 1982), and *I. rectirostratus* from the *patulus* Zone of Western Yunnan (Baoshan Block, a Gondwana-derived terrane, Carls & Gong 1992). Such isolated occurrences improve the potential to use the base of the *fusiformis* Zone for chronostratigraphic definition.

Icriodus corniger corniger Zone. – Fauna VIa with *I. corniger corniger* of Bultynck & Hollard (1980) was based on limited evidence from the *Sellanarcestes* Limestone of the lower Timrhanrhart Formation of the eastern Dra Valley. The best representation was from Targa Kheniga (Sample 22-3), where the index species was found together with *Caud. culicellus culicellus*, *I. fusiformis*, and *I. rectirostratus*. A re-sampling at Oufrane (Bed 11 of Ebbighausen *et al*. 2011) was unsuccessful; dissolved goniatites contained only *Caud. culicellus culicellus* (Fig. 29L), *Neopanderodus* and *Belodella*. Sample 14 at El Anhsour, from just below the *Sellanarcestes* Limestone, and Sample 16 from the lower subunit of the latter, yielded common *I. rectirostratus* and *I.* aff. *corniger*. The latter lacks the asymmetric posterior outer extension of the cavity but is provisionally taken as an indicator of the *corniger corniger* Zone. *Latericriodus beckmanni sinuatus* re-appears in this interval (Fig. 25Y). Specimens of *Caud. culicellus culicellus* are not typical (see aff. determination in Fig. 24).

Assemblages with *I. corniger corniger* and *I. rectirostratus* continue as part of Faunas VIb to VII through the higher part of the Lower Member of the Timrhanrhart Formation, sometimes accompanied by juvenile *Caud. culicellus culicellus* and *I.* aff. *fusiformis* (at Foum Timrhanrhart, Bultynck & Hollard 1980).

The *Sellanarcestes* Limestone Member of the western Dra Valley yielded Fauna VIa, the lower part of the *corniger corniger* Zone, at three localities, Tjafane, Oui-n-Mesdoûr, and Hassi Talha (Bultynck & Hollard 1980). There are *I. corniger*, *I. rectirostratus*, and *Caud. culicellus culicellus*. A new sample from Rich Tamelougou was extremely conodont-poor and lacked icriodids. The overlying siliciclastics (Bou Tserfine and Rich 4 Members) have not been sampled for conodonts.

In general, conodont faunas from the basal *Anarcestes* Limestone of the Tafilalt are also poor. The second bed with very abundant *Sellanarcestes* and *Anarcestes* yielded at Erg Kseir two *I. corniger corniger*? in association with *Caud. culicellus culicellus* (Fig. 29H, I), *Neopanderodus*, and *Belodella*. The fourth goniatite bed, with rare *Achguigites*, produced only *Caud. culicellus culicellus* (Fig. 29C, D) and the named shallow-water genera. Klug (2002) noted *I. corniger* from the *Sellanarcestes* beds at Jebel Ouaoufilal West. At Hamar Laghdad South (Samples HLS II-1 and II-2), *I. rectirostratus* is the only icriodid (Fig. 17P–U). There are none at Ouidane Chebbi further to the east (Belka *et al*. 1999). This illustrates some faunal difference between localities of the Tafilalt Basin and Platform. *Icriodus corniger corniger* has also been found at the top of the *Anarcestes* Limestone, in a sample of the *patulus* Zone of Jebel Ouaoufilal West (Klug 2002). It continues at Hamar Laghdad South, above the last *I. rectirostratus* of the Tafilalt (Sample HLS II6), into the basal Eifelian (Sample HLS II-7), where it is accompanied by a single *Caud. culicellus altus* Weddige, 1985 (*in* Requadt & Weddige 1985).

A better development of the *corniger corniger* Zone can be found in the Maider. At Ou Driss (Sample 12) and Tizi n'Ikouâch (Sample 3), *I. corniger corniger* enters at the top of the Er Remlia Formation (Bultynck 1985, Fauna VIa/VIb). *I. rectirostratus* and *Lat. beckmanni* ssp. are associated. Above, in the Tazoulait Formation (Faunas VIb–c), *Caud. culicellus culicellus* re-appears (Ou Driss, Sample 17, Ouhlane, Samples 5, 6, Bultynck 1985). The Emsian part of the El Otfal Formation yielded *I. corniger corniger*, *I. corniger leptus* (only at Ouahlane), *I.* aff. *fusiformis* (only at Tizi n'Ikouâch), and *I. rectirostratus* but, as in the Tafilalt, only the first taxon survives into the basal Eifelian (Bultynck 1985).

The regional *corniger corniger* Zone correlates with the *corniger corniger* Zone of the Cantabrian Mountains (García-López 1987, García-López & Sanz-López 2002). It also can be recognized in the eastern part of the central Meseta (see Moulay Hassane data in Lazreq 1990). The precise correlation between the first appearances of *I. corniger corniger* and *L. bultyncki* is regionally masked by facies influences. Currently it seems that *I. corniger corniger* appears somewhat earlier, in LD IV-C, before the entry of *Anarcestes* (Fig. 31).

Lower Eifelian. – The Anti-Atlas *corniger corniger* Zone includes early upper Emsian to basal Eifelian strata. *Caud. culicellus altus* (Fig. 18A, B), *I. corniger corniger* (Fig. 18D–F), and *I.* aff. *corniger* (Fig. 18C) reach the basal Eifelian (Sample HLS II-7). The subsequent lower Eifelian is characterized by the radiation of new, zonally diagnostic icriodids, such as *I. amabilis* (Fig. 18J–L), *I. struvei*, *I. introlevatus* (Fig. 18G–I, Sample HLS II-11), and others (Bultynck & Hollard 1980, Belka *et al*. 1997, Gouwy & Bultynck 2002, Becker & Aboussalam 2013). Since *I. struvei* enters first at Bou Tchrafine and Jebel Amelane, it can be used as the marker for a regional *struvei* Zone that begins high in the *partitus* Zone.

Regional Anti-Atlas spathognathodid zonation (Fig. 30)

(Regional) Criteriognathus miae Zone. – The new, oldest evidence for the zonal marker comes in the Tafilalt from a Pragian sample (P/E2) *ca* 10 m below the *Deiroceras* Limestone at section BTN, which belongs to the *steinachensis* Zone. This lowers the entry of the marker of Fauna Ib *sensu* Bultynck & Hollard (1980) to a position much below their Fauna Ia. Therefore, Ia and Ib faunas cannot be distinguished. The index species is then widespread in the basal *Deiroceras* Limestone of El Khraouia (Bed 15a, Fig. 21B), at Jebel Ihrs (Bed 16a, Fig. 5I), and Bou Tchrafine West (Sample BTW0). It continues in the middle (El Khraouia, Bed 15c, and Sample BTN BK596) and upper *Deiroceras* Limestone (Jebel Ihrs, Bed 16c, Fig. 7J, K; Ouidane Chebbi, Belka *et al*. 1999, Bou Tchrafine North, Sample BTW1, Fig. 18M, N, and Jebel el-Mrier). It occurs also in the lower Bou Tiskaouine Formation of Ou Driss (Bultynck 1985). "*Pandorinellina*" *exigua* (Philip, 1966) is so far only known from the basal *Deiroceras* Limestone of Ouidane Chebbi (Section I, Sample 20, Belka *et al*. 1999).

The regional *miae* Zone ranges into the lower *Anetoceras* Limestone, *e.g.*, at Jebel Ihrs and Bou Tchrafine West (Fig. 18O, P), but the last records of the index species are from the middle part of the unit (Jebel Ihrs, Bed 25a; Bou Tchrafine West, Sample BTW3). At corresponding levels of the Maider it has been found together with *Erb. advolvens* in the higher Bou Tiskaouine Formation of the Jebel Issimour (Plodowski *et al*. 2000). In the eastern Dra

Valley it occurs in the Lower Member of the Mdâouer-el-Kbîr Formation (Bultynck & Hollard 1980, Sample 26-1).

The Pragian entry of the *miae* Zone in the Tafilalt correlates roughly with records of the index species from the middle Pragian *serratus* Zone of Bohemia (Slavík 2004b). In the eastern Pyrenees *Crit. miae* was found in association with polygnathids of the *kitabicus* Zone (Sanz-López 2002), in Australia (Mawson & Talent 1994, Colquhoun 1995), the Western Karakorum, Pakistan (Gaetani *et al*. 2008), and in the eastern Urals (Snigireva & Nasedkina 1995) in the *ca* middle Pragian. There is an upper Pragian occurrence in the *celtibericus* Zone of the Moroccan Meseta (Benfrika *et al*. 2007). In Uzbekistan there is a long overlap with *Monograptus* faunas (*e.g*., Mashkova 1979, Yolkin *et al*. 2008). But the *miae* Zone of Tadzhikistan (Bardashev & Ziegler 1992) was placed in the lower Pragian. Alleged much earlier, middle Lochkovian records of *Crit. miae* from Spain (García-López *et al*. 1990) and Sardinia (Corradini & Corriga 2012) require further investigation. Just recently, Mavrinskaya & Slavík (2013, fig. 6F) assigned very close upper Lochkovian relatives to "*Pandorinellina* cf. *miae*".

Because *Crit. miae* has such a wide distribution, *e.g*., in the Russian Arctic with very different and endemic conodonts (Baranov & Al'khovik 2003, Baranov 2012), it could be of high value for international correlation. However, the facies-controlled, strong regional range differences and rather generalized morphology much reduce its significance.

Criteriognathus steinhornensis Zone. – The globally wide-spread (*e.g*., Klapper & Johnson 1980) zonal index occurs commonly or in masses well above the base of the *Anetoceras* Limestone of the Tafilalt, for example at Jebel Ihrs (Beds 21a–26b, Figs 8K, 9D, E), Bou Tchrafine West (Sample BTW2-4, Fig. 18Q), North (Samples BTN 31-1 to 31-4), and Northwest (Sample BT-*Kl*, Fig. 28D–F), Jebel el-Mrier (Samples AL RTB 7a, Fig. 22D, and AL RTB 7b), and Ouidane Chebbi (Samples 27/28 of Belka *et al*. 1999; new Sample OCh-*Anet*, Fig. 28F, associated with common *Belodella*, Fig. 28I, J). The *steinhornensis* Zone is also developed in the upper Bou Tiskaouine Formation of the SW (Ou Driss, Bultynck 1985) and northern Maider (Jebel Issimour, Plodowski *et al*. 2000). There is a first record of the index species for the eastern Dra Valley (auxiliary locality Rich el M'Bidia, Fig. 18R, lower Mdâouer-el-Kbîr Formation).

Criteriognathus steinhornensis ranges more rarely in the Tafilalt into the lower (Bou Tchrafine West, Sample BTW4b, see also Bultynck 1985) and top of the *Mimagoniatites* Limestone (Jebel el-Mrier, Bed 20a), with a facies-controlled record gap in the middle part of that unit. It is absent from the polygnathid faunas of the *laticostatus* Zone and *Anarcestes* Limestone.

Criteriognathus steinhornensis, excluding all previous "subspecies", defines the "zone of *Spathognathodus steinhornensis*" in Carls *et al*. (1972), Fauna IV in Bultynck & Hollard (1980), and conodont Step 21 of Carls & Valenzuela-Ríos (2002). At Jebel Ihrs, its base correlates *ca* with the base of the *Eol. catharinae* Subzone, which is supported by the La Grange data of Bultynck (1989), and with an epibole of *Lat. beckmanni beckmanni.* Carls & Valenzuela-Ríos (2002) suggested that there is no range overlap of *Crit. miae* and *Crit. steinhornensis* in Celtiberia but that both overlap with a smaller-sized new species, which was informally named "*Ozarkodina*" sp. M. Currently we cannot follow that distinction but observe in the *Anetoceras* Limestone of the Tafilalt a rather gradual replacement of *Crit. miae* by *steinhornensis*, with an overlap high in the lower part of the unit. The index species is widespread in the higher lower Emsian of different blocks of the western Prototethys, such as the Moroccan Meseta (Benfrika *et al*. 2007), Kabylia of northern Algeria (Gélard *et al*. 1978), Peloritanian Mountains of southern Italy (Somma *et al*. 2013), Pyrenees (Buchroithner 1978), and Central Carinthia (Austria, Buchroithner 1979). The significance of the *steinhornensis* Zone for international correlation is underlined by far distant records reaching Central Iran (Nasehi 1997), Tadzhikistan (Bardashev & Ziegler 1992), SW Mongolia (Ruzhentsev 2001), the Baoshan block of Yunnan (Carls & Gong 1992), the Amur region of the Russian Far East (Eikhvald 2008, Baranov *et al*. 2014), and Nevada (*e.g*., Klapper & Johnson 1980). The short overlap interval of *Crit. miae* and *steinhornensis* was met by a single sample from the Karakorum (northern Pakistan, Talent *et al*. 1999).

Criteriognathus steinhornensis has been reported to range into the lower part of the *serotinus* Zone in Bohemia (Klapper *et al*. 1978), Uzbekistan (Apekina & Mashkova 1978), Thailand (Long & Burrett 1989), and on Sardinia (Barca *et al*. 1986). But it disappears near the end of the lower Emsian in the eastern Anti-Atlas. The revised *steinhornensis* Zone should not be confused with the much more extensive (upper Silurian to Emsian) *steinhornensis* biozone *sensu* Maskkova (1972), which includes older representatives of various genera.

"Ozarkodina" carinthiaca Zone. – The index species enters in its Austrian type region in the *serotinus* Zone (*e.g*., Schönlaub 1985). In the Barrandian it ranges from the basal *serotinus* Zone to the lower part of the *partitus* Zone (*e.g*., Klapper *et al*. 1978). A similar range has recently been reported from the Istanbul region of NW Turkey (Saydam-Demiray & Capkinoglu 2012) and, previously, from the Harz Mountains of Germany (*e.g*., Luppold 1984), the Armorican Massif (Lardeux & Weyant 1993), Malaysia (Lane *et al*. 1979), and Uzbekistan (last update in Yolkin *et al*. 2008). Gagiev & Rodygin (1988) claim a

slightly longer range (lower *costatus* Zone) in Siberia. At Hamar Laghdad South it has only been found right around the Lower/Middle Devonian boundary (Samples HLS II-6, Fig. 16Q–S, and HLS II-7). However, there is a significantly older, top lower Emsian specimen from the lower *Mimagoniatites* Limestone of Bou Tchrafine North (Sample BTN 31-5), which overlaps with *Crit. steinhornensis*. So far, the species is lacking in the Maider and Dra Valley.

The generic position of "*Oz.*" *carinthiaca* is unresolved. The Pa element has similarities with some upper Emsian species of *Amydrotaxis*, for example *Am. maxillaris* Baranov, 1991. Consequently, Bardashev *et al.* (2002, p. 392) included *carinthiaca* in that genus.

Anti-Atlas Emsian conodont – ammonoid correlation (Fig. 32)

Previous work on Emsian ammonoid stratigraphy of the Anti-Atlas

Data on lower Emsian ammonoid stratigraphy of the Tafilalt were published by Hollard (1963b, 1967), Massa (1965), Becker & House (1994), and Belka *et al*. (1999). The regional zonation was erected by Klug (2001), with some additions in Becker & House (2000), Klug *et al*. (2008), Kröger (2008), De Baets *et al*. (2010), Becker & Aboussalam (2011), and De Baets *et al*. (2013). Following a first outline in Hollard (1974) and Bultynck & Hollard (1980), Becker & House (1994) established the upper Emsian zonation, with more detailed data in Klug *et al*. (2000), Klug (2002), and by Becker *in* Webster *et al*. (2005).

Emsian ammonoid data for the Maider are more limited (*e.g.*, Hollard 1974, Bultynck 1985, Plodowski *et al*. 2000). New collections were made at the northern margin, including a new record of *Erbenoceras* from the upper Bou Tiskaouine Formation, abundant "*Latanarcestes*" auct. from the Er Remlia Formation, and *Sellanarcestes wenkenbachi*, other species of the genus, and still abundant "*Latanarcestes*" auct. from the Tazoulait Formation (Stichling 2013). There are only a few localities with lower Emsian ammonoids in the Dra Valley (Hollard 1963b, 1978; Bultynck & Hollard 1980; Becker *et al*. 2008; De Baets *et al*. 2010). The upper Emsian zonal succession of the Maider and Dra Valley has recently been summarized by Ebbighausen *et al*. (2011).

Ammonoid-conodont correlation in the Tafilalt

The oldest ammonoid zone recognized here (Lower Devonian III-A, Becker & House 1994) is the *Devonobactrites obliqueseptatus* Zone. It is sandwiched between the *celtibericus* Zone of the "Pragian Limestone" below and the *bilatericrescens gracilis* Zone (= regional *excavatus* Morphotype 114) of the basal *Deiroceras* Limestone above. It seems to correlate at least partly with the level of the first *Lat. bilatericrescens gracilis* and the *Neomonograptus atopus* Zone of Bohemia (*e.g.*, Slavík 2004a). This is supported by an overlap with the last *Guerichina* and *Nowakia* (*Turkestanella*) *anteacuaria* Alberti, 1993 (see Alberti 1998). Specimens from the "Pragian Limestone" of Filon Douze (southern Tafilalt) identified by Kröger (2008) as ?*Bactrites* sp. did not show a ventral siphuncle. These alleged oldest bactritids of the Anti-Atlas are here excluded from the group. Kröger (2008) also mentioned *Devonobactrites* from the *Deiroceras* Limestone but did not describe or illustrate these specimens.

As discussed by Becker & Aboussalam (2011) an alleged oldest *Chebbites* from the top *Deiroceras* Limestone, which defined Zone A of Klug (2001), is not accepted until further confirmation (compare the query in De Baets *et al*. 2010).

The highly diverse faunas of the *Erbenoceras advolvens* Zone, with *Metabactrites formosus* Bogoslovskiy, 1972 and *Chebbites reisdorfi* Klug, 2001 as alternative regional markers, fall in LD III-B *sensu* Becker & House (1994) and define Zone B of Klug (2001). Due to the dominance of loose collections, *Gyroceratites laevis* Eichenberg, 1931 is not used here for a subdivision. The *advolvens* Zone is sandwiched between the upper part of the regional *excavatus* Morphotype 114 Zone (top of *Deiroceras* Limestone) and the *catharinae* Subzone (upper *gronbergi* Zone) or *latus* Zone of the lower *Anetoceras* Limestone. Therefore, it can be correlated with the main *gronbergi* Subzone. It overlaps with *Nowakia* (*Now.*) *zlichovensis* Bouček, 1964 and *Now.* (*Now.*) *praesulcata* Alberti, 1982 in its lower part (Alberti 1998).

The *Anetoceras obliquecostatum* Zone (lower LD III-C, Fauna C of Klug 2001) can be directly correlated with the *steinhornensis* Zone, based on Sample OCh-*Anet*. However, since the zonal marker occurs near the base of the *Anetoceras* Limestone at Jebel Mech Irdane and Ras el Kebber (Klug 2001), the base of the *obliquecostatum* zone is also correlated with the base of the *catharinae* Subzone and with the basal *latus* Zone of the icriodid succession. Alberti (1998) reported *Nowakia* cf. *praecursor* at this position.

The *Klugites gesinae* Zone (upper LD III-C, Fauna D in Klug 2001) falls in the higher part of the *steinhornensis* Zone, based on Sample BT-*Kl* from middle parts of the *Anetoceras* Limestone. *Anet.* aff. *solitarium* from Ouidane Chebbi and a new *Teicherticeras* from Jebel el-Mrier belong to the same zone. Alberti (1998) shows *Nowakia* (*Now.*) *barrandei* Bouček & Prantl, 1959 *ca* in the same interval. Due to the lack of illustration it is possible that a rather early *Mimagoniatites* from Jebel Amelane noted in Alberti (1998) in fact belongs to *Klugites* gen. nov. Both genera share rectiradiate growth lirae with deep flank sinus and a concave whorl zone.

The *Mimagoniatites fecundus* Zone of the *Mimagoniatites* Limestone falls in LD III-D (*sensu* Becker & House, 1994) and Zone E of Klug (2001). The directly associated conodonts are too poor for a comparison with the polygnathid zonation. As discussed in Becker & Aboussalam (2011), a tentative correlation with the *inversus* Zone is based on Spain (García-López *et al*. 2002) and the Khodzha-Khurgan Gorge of the Kitab Reserve (review in Becker *et al*. 2010). Hollard (1974) documented that the *Mimagoniatites* Zone extends to the northern Maider.

The light-grey limestones at the top of the *Mimagoniatites* Limestone have no goniatites. The alleged occurrence of a *Mimosphinctes* at Jebel Amelane (Massa 1965, p. 66), the index genus of LD III-E *sensu* Becker & House (2000), has never been substantiated by subsequent findings. Currently there are no Tafilalt goniatite faunas, which fall in the *laticostatus* Zone.

As shown by Alberti (1980, 1981) and briefly noted by Becker & House (2000), the basal Daleje Shale Equivalents contain a distinctive, goethitic/limonitic *Gyroceratites*-rich fauna, still without anarcestids. New rich collections from the plain between the sections Bou Tchrafine North and Hamar Laghdad South provide sufficient evidence to establish a *Rherisites tuba* Zone (UD IV-A *sensu* Becker & House 1994) below the onset of "*Latanarcestes*" auct., "*Praewerneroceras*" *hollardi* Becker & House, 1994 and other early anarcestids ("*noeggerathi* Zone", LD IV-B). *Sellanarcestes eos* (LD IV-C) follows probably higher in the middle to upper parts of the Daleje Shale Equivalents. This interval cannot be correlated with conodonts in the Tafilalt and falls in the long regional *laticostatus-bultyncki* Interregnum.

The lower *Anarcestes simulans* Zone (LD IV-D1) begins at the base of the *Anarcestes* Limestone. The limited evidence from Samples EKs-B and HLS II1 place the first beds with *Sell. wenkenbachi*, but still without *Achguigites* or *Sell. neglectus*, in the lower part of the *corniger corniger* and *bultyncki* zones. But the dissolved goniatites mostly yielded specimens of *Neopanderodus* (Fig. 29F, G, J, N) and *Belodella* (Fig. 29B, E), which is not in accord with current biofacies models. Data from Ouidane Chebbi (Belka *et al*. 1999, in combination with Klug 2002) and Hamar Laghdad South (Bultynck & Hollard 1980) enable us to recognize the *bultyncki* (Sub)Zone also slightly higher, above the first *Sell. neglectus*. *Sellanarcestes* seems to range into the *cooperi cooperi* Subzone (Sample HN-TA29). There are no good conodont data for the upper *simulans* Zone (lower LD IV-D2 *sensu* Becker & House 1994), without *Sellanarcestes*. Klug (2002, Jebel Ouaoufilal) provided a correlation of the *Anarcestes lateseptatus* Zone (upper LD IV-D2) with the *patulus* Zone, which is supported by the new Sample OCh-*An* and Sample HLS II6.

Ammonoid-conodont correlation in the Dra Valley

In the eastern Dra Valley (Mdâouer-el-Kbîr Ravine, Sample 26-1), *Erb. advolvens* is directly associated with icriodids of the *bilatericrescens* Zone s.l. (Fauna II of Bultynck & Hollard 1980) and *Crit. miae*. This enables a correlation with the *Erb. advolvens* Zone (LD III-B) of the Tafilalt (*Metabactrites-Erbenoceras* Shale), which is supported by associated *Nowakia* (*Dmitriella*) cf. *praecursor* Bouček, 1964 and *Now*. cf. *zlichovensis* (see Hollard 1978), as in the *Metabactrites-Erbenoceras* Shale. De Baets *et al*. (2010) came to a similar conclusion. Their higher fauna from Mdâouer-el-Kbîr with *Anetoceras* and *Lenzites* (= *Klugites* gen. nov., LD III-C), as in the *steinhornensis* Zone of the *Anetoceras* Limestone of the Tafilalt, was not sampled for conodonts. Our sample with *L.* aff. *inversus* (*inversus* Zone) is from *ca* five meters higher, if we accept the measurements in the section log of De Baets *et al*. (2010, fig. 2B, not 2A, as claimed in the figure caption).

A record of *Mimagoniatites fecundus* from the upper part of the Rich 3 Sandstone Member at Foum Zguid (Jansen *et al*. 2004, 2007) indicates LD III-D but it comes from clastics without conodonts. Hollard (1978) listed *Latanarcestes* from the top of the Mdâouer-el-Kbîr Formation. Based on conodonts from El Anhsour (Samples I, II, see Bultynck & Hollard 1980) this local record of the "*noeggerathi* Zone" (LD IV-B) can be correlated with the *fusiformis* Zone.

The *Sellanarcestes* Limestone (*Sell. wenkenbachi* Zone, LD IV-C) of the subsequent lower Timrhanrhart Formation falls in the basal *corniger corniger* Zone, based on limited data from Targa Kheniga (Bultynck & Hollard 1980, Fauna VIa, Sample 22-3). However, this could not be substantiated by a new sample from Oufrane, which also lacks polygnathids. Sample 16 from El Anhsour yielded only abundant *I.* aff. *corniger*, *L. inversus*, and *L.* aff. *inversus*. The two latter records indicate that *Sellanarcestes* enters in the regional *laticostatus-bultyncki* Interregnum. Above, the *Anarcestes simulans* Subzone, with *Achguigites tafilaltensis* Klug, 2002 and *Sell. neglectus*, falls in the *bultyncki* Zone, based on data in Bultynck & Hollard (1980, Fauna VIb from El Annsa and Foum Timrhanrhart). It is still open whether the following *An. crassus* Subzone of Ebbighausen *et al*. (2011), which includes the youngest *Sellanarcestes*, belongs in the *L. cooperi cooperi* Subzone.

In the western Dra Valley, a single loose *Erbenoceras* from the upper Oui-n-Mesdoûr Formation falls in the local monospecific *Lat. bilatericrescens bilatericrescens* assemblage high in the lower Emsian (Becker *et al*. 2008). Higher, a single *Mimagoniatites tabuliformis* Kullmann, 1960 Group from the top of the *Hollardops* Limestone Member of Bou Tserfine (Becker *et al*. 2008) is younger than the *fusiformis* Zone faunas described by Bultynck & Hollard (1980) and Jansen *et al*. (2007) from the main part of the unit. The "*noeggerathi* Zone" (LD IV-B) of the overlying upper part of the Brachiopod Marl Member (Khebchia Formation) is associated at Rich Tamelougou with zonally non-diagnostic *Caud. ultimus* and *Caud*. aff. *celtibericus*. The base of the *Sellanarcestes* Limestone Member, which may belong to the *Sell. wenkenbachi* Zone (LD IV-C), produced at Hassi Talha the *corniger corniger* Zone (Fauna VIa of Bultynck & Hollard 1980, Sample 5-2). The main part of the unit falls in the lower *An. simulans* Zone (LD IV-D1) and in the *bultyncki* Zone (Hassi Talha, Sample 5-1, Fauna VIb) but the polygnathid evidence is very poor. The *cooperi cooperi* Subzone has not yet been verified within the higher *Sellanarcestes–Anarcestes* faunas. The overlying assemblage of the upper *An. simulans* Zone (lower LD IV-D2, without *Sellanarcestes*), found by Becker *et al*. (2008) at the base of the Bou Tserfine Member, has not yet been correlated with the conodont succession.

Emsian event stratigraphy of the Anti-Atlas (Fig. 1)

Tafilalt

The marked transgression at the base of the *Devonobactrites* Shale has been correlated by Becker & Aboussalam (2011) with the Bohemian Basal Zlíchov Event. In the definition of Chlupáč & Kukal (1986, 1988), however, this is a regional and slightly younger facies change at the base of the Zlíchov Limestone. It coincided with the disappearance of the dacryoconarid *Guerichina*, which ranges into the upper part of the *Devonobactrites* Shale (Alberti 1998). Due to its position well above the base of the *Caud. celtibericus* Zone and in the upper range of the *Nowakia (Turkestanella) acuaria* (Richter, 1854) Group, the first deepening pulse of the Tafilalt Emsian is more likely correlated with the significant short-termed transgression that enabled within the Dvorce-Prokop Limestone of Bohemia ("upper Pragian" in a classical sense) the sudden influx of a last graptolite fauna with *Neomonograptus atopus* (Bouček, 1966) (*atopus* Event of Becker *et al*. 2012; see Chlupáč & Lukeš 1999 and Slavík 2004a).

The significant deepening of the Chebbi Event (Becker & Aboussalam 2011), at the base of the *Metabactrites-Erbenoceras* Shale, led to one of the most significant marine evolutionary innovations of the Middle Palaeozoic, the sudden and very fast appearance, spread and radiation of early ammonoids. Similarly early ammonoid faunas occur in the deepening pulse of the Taravale Limestone of Victoria (Mawson 1987a). The Chebbi Event needs further documentation in other regions, in an interval slightly above the first *Nowakia* (*Now.*) *zlichovensis* and near the base of the *gronbergi* Zone (below the *nothoperbonus* Zone) or between the successive entries of *Lat. bilatericrescens bilatericrescens* and *Lat. latus*, within conodont Step 19.

The Upper Zlíchov Event (UZE) of García-Alcalde (1997) was placed at the base of the Vañes Beds of the Palentine Domain of the Cantabrian Mountains and just above the base of Member d4bα of the Mariposas Formation of the Eastern Iberian Chains. The first level lies slightly below the base of the *inversus* Zone and well above *Lat. latus* (García-López *et al*. 2002), near the boundary of the *barrandei* and *elegans* zones of the dacryoconarid succession (García-Alcalde 1998, Truyols-Massoni 1998). In the second region, the UZE occurs within conodont Step 21 (*steinhornensis* Zone) of Carls & Valenzuela-Ríos (2002). This enables us to correlate the minor deepening and the change to the more bituminous *Mimagoniatites* Limestone with the Upper Zlichov Event, as suggested by Becker & Aboussalam (2011). Only a few goniatite species of the *Anetoceras* faunas continue regionally into the upper part of the lower Emsian. The wide spread of *Nowakia* (*Now.*) *elegans* (Barrande, 1867) in the *Mimagoniatites* Limestone (Alberti 1980, 1981, 1998) confirms the dacryoconarid correlation of the Palentine Domaine. It proves that the first Daleje Transgression of the Barrandian *sensu* Ferrová *et al*. (2012; not *sensu* Chlupáč & Kukal 1988), with co-occuring *Now. barrandei* and *Now. elegans*, correlates with the Upper Zlíchov Event.

The Daleje Event (*sensu* Chlupáč & Kukal 1988) is marked in the Tafilalt by a very sudden change from condensed limestone to thick silty shales with goethitic fauna. It correlates with the main Daleje Transgression of Bohemia, which flooded, for example, the upper Chynice Limestone (Ferrová *et al*. 2012). The last Tafilalt limestones below the Daleje Shale Equivalent tend to be lighter grey than the true *Mimagoniatites* Limestone. *Now. cancellata* may enter in these last beds (Alberti 1980, 1981). The study of neritic faunas of the *Mimagoniatites* Limestone will be important to document which taxa survived into the final Zlíchovian and which co-existed at the very top with the first *Now.* (*Now.*) *cancellata* (Richter, 1854). The (main) Daleje Event falls in the Tafilalt clearly in the lower part of the *laticostatus* Zone.

Maider

The Chebbi Event can be recognized in the Maider as the base of a shaly interval in the middle of the Bou Tiskaouine Formation. A manifestation of the Upper Zlíchov Event is not yet evident, but Bultynck (1999) noted *Mimagoniatites* from the top of the Bou Tiskaouine Formation at Ou Driss. The Daleje Event (s. str.) is very pronounced at the base of the Er Remlia Formation. Some sections, for example at the western end of the Ouahlane Syncline, contain a distinctive basal siltstone. In others (*e.g.*, Boultan South, Stichling 2013) the change from thick limestone to shale is as sharp as in the Tafilalt.

Dra Valley

The Rich 2 Sandstone Member masks possible influences of earliest Emsian events. The base of the Mdâouer-el-Kbîr and Oui-n-Mesdoûr formations can tentatively be correlated with the Chebbi Event. This is more likely than the correlation with the Basal Zlíchov Event, as proposed by Ouanaimi & Lazreq (2008). It has been noted as a Transgressive System Tract by these authors and Lubeseder *et al*. (2009). The limestone with Fauna C11 of Jansen *et al*. (2007) forms an exception and deserves further studies.

In the eastern Dra Valley the Daleje Event is not prominent within the Rich 3 Sandstone Member. It may be expressed by the change from quartzites to sandy brachiopod coquina limestones. A later transgressive pulse, which correlates with *ca* the middle part of the Daleje Shale Equivalents, is represented by the Trilobite Limestone at the base of the Timrhanrhart Formation. In the western succession, the Daleje Event is perceptible as a minor hypoxic interval with black shales and dark limestone at the base of the *Hollardops* Limestone Member, above a light-grey marl package at the top of the Oui-n-Mesdoûr Formation (for example, at Bou Tserfine, Becker *et al*. 2004c). This TST is recognized in Ouanaimi & Lazreq (2008, R4a) and, with a query, in Lubeseder *et al*. (2009). There is no evidence for an unconformity in the western Dra Valley, which correlates with the lowstand of the Rich 3 Sandstone. A first upper Emsian maximum flooding occurred in the upper part of the Brachiopod Marl Member ("*Latanarcestes*" Beds, upper *fusiformis* Zone). Based on a maximum of (primarily) pyritic faunas with "*Latanarcestes*" and others, it seems to correlate with a deepening peak within the middle Daleje Shale Equivalents of the Tafilalt. A second sudden deepening is evident at the base of the Bou Tserfine Member, which contains goethitic *Anarcestes*, *Mimagoniatites* and other fauna in the syncline W of the Rich Tamelougou, SW of Torkoz (Becker *et al*. 2008). It is correlated with the extinction of *Sellanarcestes* but not with a sedimentological event in the Tafilalt and Maider.

Chronostratigrapic implications

The current basal Emsian GSSP at the base of the *kitabicus* Zone cannot be traced with the help of conodonts in the Anti-Atlas, mostly since there are no critical polygnathids. Based on the disappearance of *Lat. steinachensis* Morphotype eta near the base and the onset of the *celtibericus* Zone in the lower part of the regional "Pragian Limestone", it may become possible to approximate the current GSSP level (planned upper Pragian substage level) but the polygnathid-icriodid correlation is currently not precise. It is also difficult to recognize regionally a future basal Emsian defined by the onset of *Eol. excavatus* Morphotype 114, which appears with a facies/sampling-controlled delay at the base of the *Deiroceras* Limestone. It is well possible that the first appearance of the index taxon falls in the Tafilalt and Maider in the interval of the underlying, deeply weathered *Devonobactrites* Shale or corresponding lower member of the Bou Tiskaouine Formation, which are difficult to sample for conodonts. An alternative definition based on the entry of *Lat. bilatericrescens gracilis* (Slavík, 2004a) faces the same problem. The contemporaneous Rich 2 Sandstone Member of the Dra Valley is also unsuitable for conodont search but offers a relevant brachiopod record.

The Daleje Event (s. str.) should remain the primary marker for a lower/upper Emsian substage boundary, not much lower levels, such as the base of the *nothoperbonus* Zone or the level of the Upper Zlíchov Event, including the base of the *Nowakia* (*Now.*) *elegans* Zone. The first can be projected to the basal *Anetoceras* Limestone, just below the onset of *Anetoceras*. The second level lies outside the Anti-Atlas well within the range of typical and partly rich lower Emsian/Zlíchovian *Anetoceras* faunas, which always have been regarded as typical for the lower Emsian. These also extend into the *laticostatus* Zone (*e.g.*, Becker *et al*. 2010). Regionally, there is no evidence for a sudden and simultaneous extinction of many goniatite taxa at a sharp boundary but this does not alter their reception as typical lower Emsian faunal elements. A too low placing of the future intra-Emsian substage boundary would seriously alter the classical meaning of marker taxa and create confusion because a wealth of old literature would have to be re-interpreted. As shown in the case of other chronostratigraphic boundaries (*e.g.*, base of the Emsian), a significant deviation from classical definitions finds little or no acceptance in the wider geoscience community.

Because of the absence of suitable marker polygnathids, the *I. fusiformis*-*I. corniger ancestralis*-*Caud. culicellus* faunas provide a very distinctive evolutionary innovation episode just above the Daleje Event. Unfortunately, the group had a restricted palaeogeographic distribution (Klapper & Johnson 1980, Bultynck 2003, Becker 2007). However, the range of some marker species, such as *I. fusiformis*, *I. corniger ancestralis* and *I. rectirostratus*, into various Asian crustal blocks increases the correlation potential of the level.

The intra-Emsian substage debate would benefit from more detailed dacryoconarid data from southern Morocco.

Especially the precise range of *Now.* (*Now.*) *cancellata*, of transitional forms from *Now.* (*Now.*) *elegans*, and of possible homoemorphic taxa and subspecies should be established.

Systematic palaeontology

Genus *Criteriognathus* Walliser, 1972

Discussion. – *Ozarkodina steinhornensis* Ziegler, 1956 was designated by Walliser (1972) as type species of his new multi-element genus *Criteriognathus*. The restricted definition of the genus *Ozarkodina*, for example in Murphy *et al*. (2004), adds to the justification of the genus. It differs from Lower Devonian forms assigned to *Pandorinellina* by its wide basal cavity and more or less equidentate Pa elements, without prominent anterior teeth. It is unlikely that the latter group is the same phylogenetic lineage as the latest Givetian/Frasnian type group of *Pandorinellina*.

Crit. steinhornensis was clearly derived from *Crit. miae*, supported both by morphology and faunal successions in several sections (see Fåhraeus 1974). Although there is not yet a multi-element reconstruction for *miae*, it is currently best placed in the same ozarkodinid genus as its descendent.

Eolinguipolygnathus Bardashev, Weddige & Ziegler, 2002

Type species. – *Polygnathus dehiscens* Philip & Jackson, 1967.

Discussion. – As emphasized by Becker & Aboussalam (2011), *Polygnathus* in the sense of its type species (*Po. dubius* Hinde, 1879) and related forms from the Givetian/Frasnian is characterized by a small basal pit under the anterior platform of the Pa element. Contemporaneous species with a large pit or with a wide basal cavity fall in different genera, such as *Schmidtognathus* and *Klapperina*. The Pa elements of early siphonodellids and related taxa (*e.g.*, Becker *et al*. 2013c) can be especially similar to those of ancestral polygnathids. In a consistent taxonomy with clear differential diagnoses, it is not possible to include any polygnathids with wide basal cavity in *Polygnathus* (Becker 2012, 2013). Therefore, Bardashev *et al*. (2002) introduced three different genera for such forms.

The main difference between *Eocostapolygnathus*, with the type species *Po. kitabicus*, and *Eolinguipolygnathus* is the presence or absence of a "lingua", a posterior part of the platform ornamented mostly by transverse ridges. Forms with a "semicrossed" lingua (*sensu* Yolkin *et al*. 1994), with carina nodes superimposed on a lingua, were noted in the diagnosis of *Eolinguipolygnathus*. The lingua may be slightly interrupted by weak furrows, or it may be secondarily reduced (shortened or narrowed). This leaves transitional and secondarily changed forms that are difficult to assign. For example, the holotypes of *Po. excavatus* (re-illustrated in Klapper & Johnson 1975) and *Po. gronbergi* posses a "semicrossed lingua". Both taxa, however, were assigned by Bardashev *et al*. (2002) to *Eocostapolygnathus*, which is not followed here. *Costapolygnathus telfordi* Bardashev, Weddige & Ziegler, 2002 is a lower Emsian example in which a well developed lingua may have been secondarily fully interrupted by shallow adcarinal troughs, leaving a posterior carina that consists of very fine nodes. This species is more likely a relative of *Eol. vigierei* from the same locality (see the atypical *vigierei* paratype of Bultynck 1985, pl. 5, fig. 1a, b) than a late descendent of the *Eoc. kitabicus* lineage. Here we restrict *Eocostapolygnathus* to forms close to the type species (*kitabicus*, *alkhovikovae* Baranov, Slavík & Blodgett, 2014, *aragonensis* Martínez-Pérez & Valenzuela-Ríos, 2014, *bardashevi* Baranov, Slavík & Blodgett, 2014, *erinae* Bardashev, Weddige & Ziegler, 2002, *hindei* Mashkova & Apekina, 1980, *lezhoevi* Baranov, Slavík & Blodgett, 2014, *rosae* Martínez-Pérez, Valenzuela-Ríos & Botella, 2010, *sobolevi* Bardashev, Weddige & Ziegler, 2002, *sokolovi* Yolkin, Weddige, Izokh & Erina, 1994, *tamarae* Apekina, 1989) and, with some reservation, the *lenzi* group (*lenzi*, *juferevi* = *pierrei* Bardashev, Weddige & Ziegler, 2002, *richi* Bardashev, Weddige & Ziegler, 2002).

Eoctenopolygnathus Bardashev, Weddige & Ziegler (2002), with the type species *Po. pireneae*, is defined by a carina that extends posteriorly beyond a small, narrow platform. The genus should also be restricted to probable close relatives and descendents of the type species (*pireneae*, *boersmai* Bardashev, Weddige & Ziegler, 2002, *boucoti* Savage, 1977, ?*debaoensis* Xiong, 1980 *in* Xiang *et al.* 1980, *ivanovskyii* Baranov, Slavík & Blodgett, 2014, *mawsonae* Bardashev, Weddige & Ziegler, 2000 (non *mawsonae* Long & Burrett, 1989), *savagei* Bardashev, Weddige & Ziegler, 2002). A posteriorly extended carina occurs also in juveniles of Emsian polygnathids with an adult lingua (*e.g*., Long & Burret 1975, Klapper & Vodrážková 2013, our population of *L. inversus* from El Khraouia). Baranov *et al*. (2014) suggest that the feature is also present in juvenile *Eoc. lezhoevi*, which is related to the type species, *Eoc. kitabicus*. A similar morphology may result from a secondary extreme narrowing of the lingua, for example in *Eol. senckenbergi*, or in the Givetian *L. mucronatus* (Wittekindt, 1966). It is possible that the *lenzi* Group was derived from *Eoctenopolygnathus*.

The acceptance of just one (*Eocostapolygnathus*, *e.g*., Becker *et al*. 2012) or of several genera for early polygnathids with large basal cavity remains a question of subjective taxonomic preference. But only, as far as ontogenetic developments, intraspecific variability, homoemorphy, and monophyly are strictly respected (compare the discussions in Mawson & Talent 2003 or Klapper & Vodrážková 2013). Subgenera are a taxonomic option but this creates very long names.

Linguipolygnathus Bardashev *et al*. (2002) differs from its ancestor, *Eolinguipolygnathus*, by the completed inversion of most of the basal cavity, creating a basal pit that becomes smaller during ontogeny (*e.g*., Klapper & Vodrážková 2013), often with some asymmetric lateral extension (protuberances). In the Givetian, the genus is very distinctive from *Polygnathus* and shows partly a different facies distribution. In the Emsian, however, there are strong indications that the inversion of the basal cavity occurred iteratively in several lineages (*e.g*., phylogenetic models in Klapper & Johnson 1975 and Bultynck 1989). There are species, such as *Po. laticostatus* or *Po. cooperi*, with only a very short or "semicrossed" lingua. The probable polyphyletic origin of *Linguipolygnathus* in its current scope and a subdivision of the genus into monophyletic taxa require further studies that lie beyond this contribution. *Eucostapolygnathus* Bardashev & Weddige, 2003, based on the type species *Po. costatus*, is treated as a junior synonym of *Polygnathus*.

Eolinguipolygnathus excavatus **(Carls & Gandl, 1969)**
Figures 5J–Q, 6C, D, 6K, L, 7C–H, 7N–Q, 15A–D, 15G, 21D–F, 27L

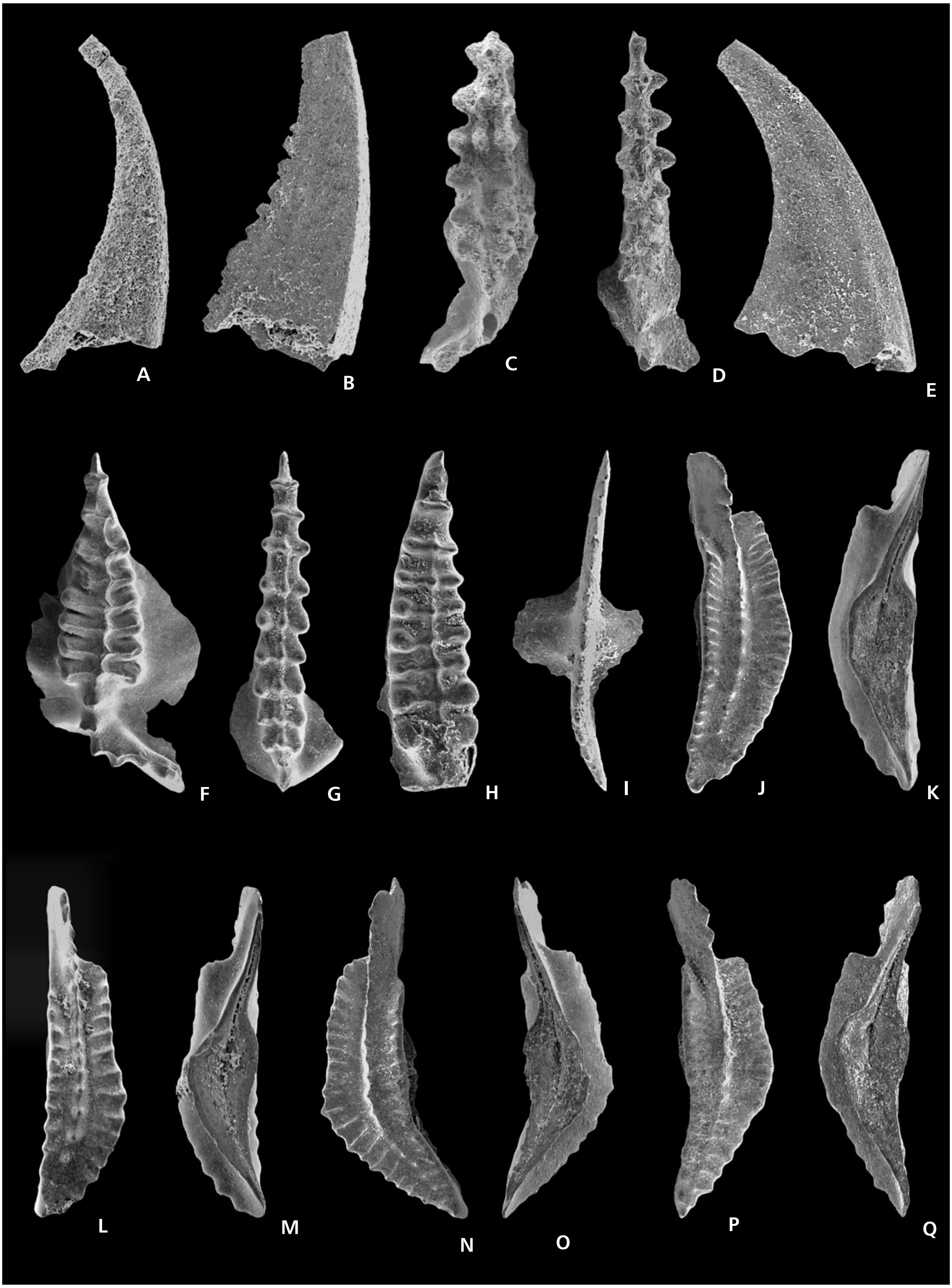
*e.p. 1969 *Polygnathus webbi excavata* n. ssp.; Carls & Gandl, pp. 193–195, pl. 18, figs 9–12 (only).
e.p. 1975 *Polygnathus dehiscens* Philip & Jackson. – Klapper & Johnson, pp. 72–73, pl. 1, figs 1–3, 7–12, 15, 16 (only) [figs 5, 6 and 13, 14 = *Eoct. lenzi*].
1980 *Polygnathus dehiscens* Philip & Jackson. – Bultynck & Hollard, p. 25, fig. 10, pl. II, fig. 5a, b.
e.p. 1987a *Polygnathus perbonus* (Philip). – Mawson, pp. 276–277, pl. 34, figs 10, 11 (only).
1999 *Polygnathus gronbergi* Klapper & Johnson. – Belka *et al*., fig. 4, table 1, pl. 2, fig. 7.
? 1999 *Polygnathus kitabicus* Yolkin, Weddige, Izokh & Erina. – Belka *et al*., fig. 4, table 1.
*? 2014 *Polyganthus settedabanicus* sp. nov.; Baranov, Slavík & Blodgett, p. 672, fig. 14h–j.
e.p. 2014 *Polygnathus excavatus* Carls & Gandl. – Baranov, Slavík & Blodgett, p. 662, figs 9d, e, 11e–j, m–q, 15a (only) [figs k, l resemble *Eoc. juferevi*].

Discussion. – Yolkin *et al*. (1994, pp. 150–151) established an extended list of figured specimens of *excavatus* in conodont papers. Although we do not always agree with the view of these authors we will not include here another long synonymy list. Bardashev *et al*. (2002) published two synonymy lists for *Eo. excavatus* because they recognized alpha and beta morphotypes, which is not followed here.

In order to improve the lower Emsian conodont stratigraphy, it is best to restrict the use of polygnathid taxa to forms close to their type populations and/or to recognize the distribution of clearly defined morphotypes in time and space. *Eol. gronbergi* and *excavatus* share in a restricted sense a short free blade, a narrow anterior platform with regular transverse costae, upturned margins, distinctive adcarinal furrows, an asymmetric curvature with slightly wider outer than inner platform, and a subtriangular posterior platform with partly interrupted or semi-crossed lingua. The basal cavity is large and anteriorly constricted. As emphasized by Klapper & Johnson (1975), its posterior end is inverted in *gronbergi*, not in *excavatus*, but there are transitional forms. *Eol. excavatus* has been synonymized by many authors with *Eol. dehiscens* (Philip & Jackson, 1967), which, however, is distinguished by a reduced ornament, forming wide and smooth adcarinal furrows, and a well-developed lingua (see re-illustrations in Mawson 1995). Bultynck (1989) used slight differences of the basal pit for a distinction only at subspecies level. The NE Asian *Eol. michaelmurphyi* (Baranov, Slavík & Blodgett, 2014) is morphologically intermediate between *Eol. excavatus* and *Eol. dehiscens*, because it combines the ornamented anterior platform of the first with the long lingua and short carina of the second species.

Yolkin *et al*. (1994) separated *excavatus* and *gronbergi* only at subspecies level and, without comment on the aboral morphology, used for the Zinzilban material the interruption of the lingua (*excavatus excavatus*) or the presence of a "semicrossed lingua" (in supposed *excavatus gronbergi*) to separate both. Carls & Valenzuela-Ríos

Figure 5. Conodonts from the "Pragian Limestone" and lower *Deiroceras* Limestone of Jebel Ihrs; A–E – upper Pragian *celtibericus* Zone or local lower *Belodella* Ecozone; F–Q – Bed 16a, lower *excavatus* M114 Zone or *bilatericrescens gracilis* Zone. • A – *Bel. resima* (Philip, 1965). B9.A-5.1, × 85, Bed 2, denticulation not preserved (compare Telford 1975, fig. 14). • B – *Bel. triangularis* (Stauffer, 1940). B9.A-5.2, × 90, Bed 2. • C, D – *Caud. celtibericus* (Carls & Gandl, 1969). Two specimens showing the intraspecific variability; C – B9.A-5.3, × 95, Bed 4; D – B9.A-5.4, × 100, Bed 4. • E – *Bel. triangularis* (Stauffer, 1940). B9.A-5.5, × 65, Bed 10, denticulation not preserved (compare Sorentino 1989, pl. 8, fig. 8). • F – *Caud. sigmoidalis* (Carls & Gandl, 1969). B9.A-5.118, × 50. • G – *Lat. bilatericrescens gracilis* Bultynck, 1985. Outer process broken off, B9.A-5.119, × 75. • H – *Lat. bilatericrescens gracilis* Bultynck, 1985. Transitional to *multicostatus*, denticles not isolated, posterior end broken off, B9.A-5.120, × 75. • I – *Crit. miae* (Bultynck, 1971). B9.A-5.121, × 100. • J–M – *Eol. excavatus* (Carls & Gandl, 1969) s. str.; J, K – "Morphotype beta", B9.A-5.122, × 60; L, M – B9.A-5.123, × 65. • N–Q – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114; N, O – B9.A-5.124; P, Q – B9.A-5.125; both × 60.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(2002) and Carls *et al*. (2009) regarded forms with *excavatus*-type (non-inverted) basal cavity and a "semi-crossed lingua" as a distinctive morphotype or subspecies, *excavatus* 114 or *excavatus* ssp. 114. They advocated to use this form in future to define the base of the Emsian. This requires a look at the types of *Eol. excavatus*. The original illustrations by Carls & Gandl (1969) and the slightly different photos in Klapper & Johnson (1975) clearly show that in the holotype of *Po. excavatus* the posterior transverse ridges are interrupted only on the outer platform, leaving an inner platform with the habitus of a "semi-crossed" lingua. In one of the paratypes (Carls & Gandl 1969, pl. 18, fig. 10), the posterior transverse ridges are interrupted only on the inner platform, whilst a well-developed, slightly "semi-crossed lingua" characterizes the specimen of pl. 18, fig. 12. The identification of *excavatus* specimens as Morphotype 114 requires that the lingua is not interrupted at all. The differences to the holotype are very subtle and forms with partly interrupted (*excavatus* s. str.) or "semi-crossed" lingua occur together within well-preserved *excavatus* population from Jebel Ihrs (Bed 16a, Fig. 5J–Q, Bed 16c, Fig. 7C–H) and El Khraouia (Bed 15f). This speaks against a formal taxonomic separation of Morphotype 114. Some justification for a subspecies distinction could come from the different distributions in time and space, which may indicate that Morphotype 114 represents a later, minor genpool expansion, a chronosubspecies.

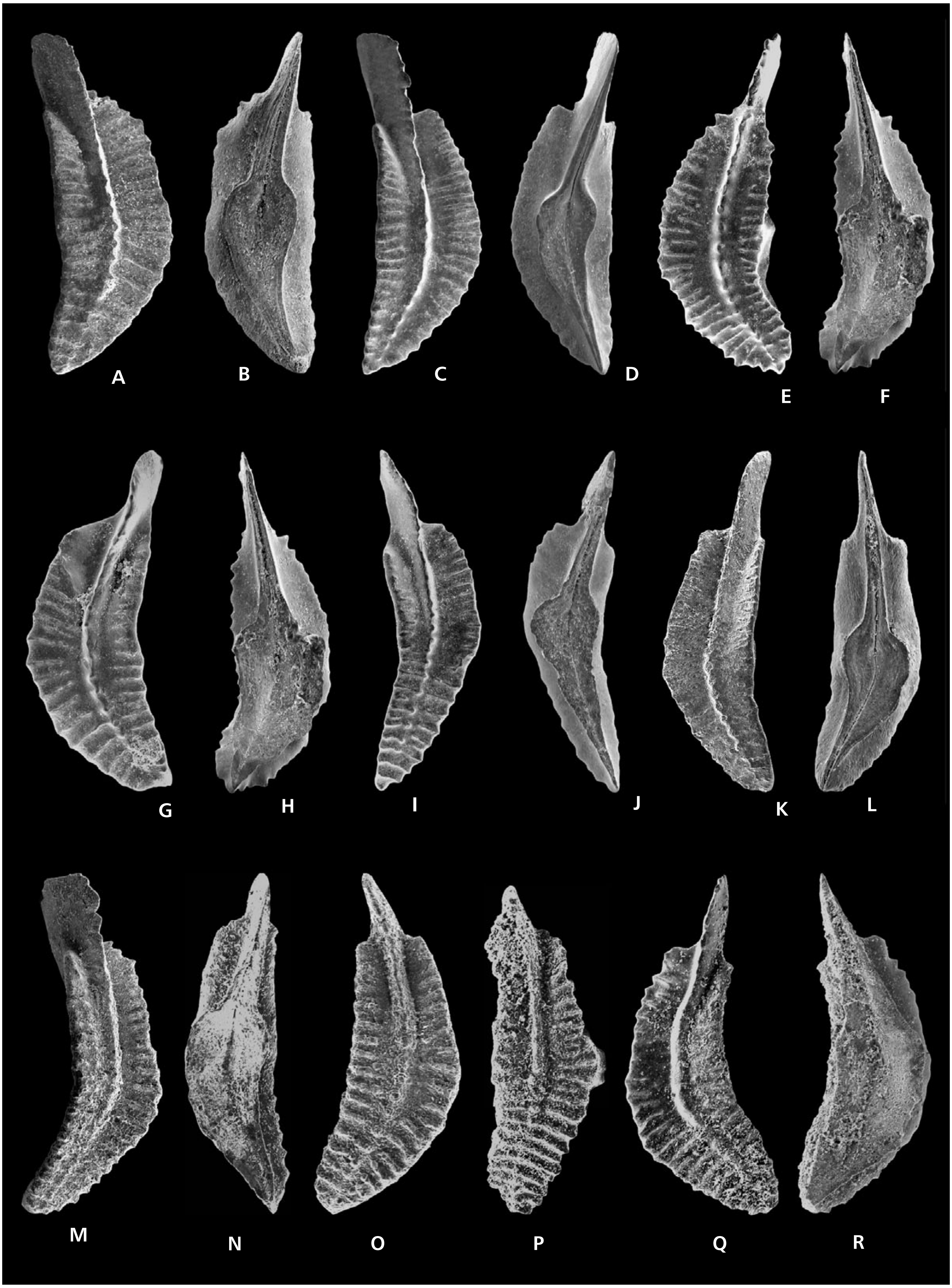
Another *excavatus* paratype figured by Carls & Gandl (1969, pl. 18, fig. 13) has a shortened carina that is terminated by continuing, deep adcarinal furrows, which also fully interrupt the transverse ridges. This specimen has been separated in Bardashev *et al*. (2002) as "Morphotype β" and conforms to their definition of *Eocostapolygnathus*. One of our specimens from the lower *Deiroceras* Limestone of Jebel Ihrs (Fig. 5J, K) approaches the same morphology, also with respect to a slight narrowing of the anterior inner platform. Currently we do not separate such specimens beyond the morphotype level.

Lower Emsian polygnathids with a strong carina that extends slightly beyond the posterior platform end (*e.g.*, Klapper & Johnson 1975, pl. 1, figs 5, 6, 13, 14) fall in *Eoc. lenzi* Klapper, 1969 in the strict sense of its holotype (see synonymy in Bardashev *et al*. 2002). As noted by Murphy (2002), but contrary to the proposal in Klapper & Johnson (1975), *Eoc. lenzi* is not identical with *Eol. excavatus* or *Eol. dehiscens*. In the system of Bardashev *et al*. (2002) it is not even congeneric with both. The absence of *lenzi*- and *dehiscens*-type polygnathids from our *excavatus* populations from several localities supports the view that they represent distinctive taxa with a different distribution.

Eol. perbonus (= *foveolatus* Philip & Jackson, 1967, name of Pa element) is based on the type specimens of Philip (1966) and Philip & Jackson (1967). It differs from *Eol. excavatus* in its shortened carina, complete lingua, and a stronger curvature of the platform. The posterior tip of the basal cavity may be slightly inverted but the lower surface of the *foveolatus* holotype was never figured. *Eolinguipolygnathus perbonus* s. str. is morphologically closer to *Eol. dehiscens* than to *Eol. excavatus* or *Eol. gronbergi*. It should include the Victoria form illustrated by Mawson (1987a, pl. 32, figs 6–10) as transitional between *Eol. dehiscens* and *Eol. nothoperbonus*, but not her polygnathids with less (pl. 34, figs 10, 11 = *excavatus* Morphotype 114) or more advanced basal cavity (pl. 34, figs 12, 13; close to her *Eol. labiosus*). In Victoria there is a complete transition from *perbonus* to *nothoperbonus* (see specimens of Klapper & Johnson 1975 and Mawson 1987a). Typical representatives of *Eol. perbonus* were documented by Mawson & Talent (2003) also from Queensland. But the species is apparently absent from North Africa. *Polygnathus yakutensis* Baranov, Slavík & Blodgett, 2014 is here regarded as a subjective synonym of *Eol. perbonus*.

In the *excavatus* material from Bed 16a of Jebel Ihrs there are a few specimens with an only very weak interruption of the posterior carina. They are intermediate to Morphotype 114 representatives from the same bed (Fig. 5N–Q). The latter show some transition to early, narrow morphotypes of *Eol. radula* sp. nov. (Fig. 6I–L). In addition, there are specimens that combine regular transverse ribs and a moderately curved platform with a rather well defined row of posterior carina nodes (Fig. 6C, D). This "Morphotype JI16a" is somewhat intermediate to *Eocostapolygnathus*. It may include the *kitabicus* record from the *Deiroceras* Limestone of Belka *et al*. (1999), which has not been illustrated. A specimen with a similar, fine carina but more posterior bending of the platform was illustrated as *Po. excavatus* by Baranov *et al*. (2014, figs 9D, E).

Figure 6. Conodonts from the *Deiroceras* Limestone of Jebel Ihrs (western Tafilalt); A–L – Bed 16a; M–R – Bed 16c; all lower Emsian, *excavatus* M114 Zone. • A, B – *Eol. radula* sp. nov. Early wide form, B9.A-5.126, × 60. • C, D – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype JI16a. With fine but distinctive posterior carina, B9.A-5.127, × 60. • E, F – *Eol. radula* sp. nov. Early form with basal cavity that is wider than the upper platform, paratype B9.A-5.128, × 40. • G, H – *Eol. pannonicus* (Mashkova & Apekina, 1980). With typical oblique ridge of left anterior platform, B9.A-5.129, × 60. • I, J – *Eol. radula* sp. nov. Early narrow form, slightly transitional to *Eol. excavatus* Morphotype 114, B9.A-5.130, × 60. • K, L – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. Slightly transitional to *Eol. radula* sp. nov., B9.A-5.131, 40. • M – *Eol. radula* sp. nov. Slightly transitional to *Eol. excavatus* Morphotype 114, B9.A-5.6, × 60. • N–P – *Eol. radula* sp. nov.; N – paratype B9.A-5.7, × 60; O – paratype B9.A-5.8, × 75; P – paratype B9.A.5-9, × 50. • Q, R – *Eol. radula* sp. nov. Holotype B9.A-5.10, × 60.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Four specimens from Sample BTW1, at the top of the *Deiroceras* Limestone, are illustrated in Fig. 15. They show a large basal cavity, covering the major part of the lower side of the platform. In the posterior part the cavity becomes very narrow, but showing still a deep slit. In specimen b6594 (Fig. 15C, D) this slit is flattened. In the four specimens the ornamentation of the oral side consists of short ribs on the major part of the platform while ribs on the tongue are interrupted by small nodes. The only difference to the type material of *Eol. excavatus* is that the inward bowing of the tongue is situated more posteriorly and that it is more angular. This feature applies to the majority of our specimens, including representatives of Morphotype 114 (for exceptions see Fig. 5J, P, Q). In this way, there are transitions towards *Po. ramoni* Martínez-Pérez & Valenzuela-Ríos, 2014, which type series includes specimens with semi-crossed (the holotype) or interrupted lingua (all figured paratypes). Our *excavatus* specimen of Fig. 5L, M resembles the *ramoni* paratype MGUV 21.027 (their fig. 8k), the specimen of Fig. 15C, D the *ramoni* paratype 21.024 (their fig. 8i), and our specimen from Fig. 7E, F is another intermediate form. We propose to restrict *Eol. ramoni*, perhaps as a subspecies, to forms with both a slightly widened, well-rounded outer posterior platform and reduced anterior platform ornament. The latter feature resembles *Eol. dehiscens*. There are also intermediates towards *ramoni* in the *excavatus* populations of Far East Russia illustrated by Baranov *et al*. (2014).

Eol. carlsi (Martínez-Pérez & Valenzuela-Ríos, 2014) is closely related to *Eol. excavatus* but characterized by a narrow and concave outer posterior platform margin. Such forms do not occur in our populations, which supports their distinction. The holotype of *Eol. settedabanicus* (Baranov, Slavík & Blodgett, 2014) resembles *excavatus* Morphotype 114 but it has a slightly extended outer platform and the basal cavity is narrower than in the Spanish forms, than in typical NE Siberian *excavatus*, or than in our specimens, producing a spine-like, slitted posterior ridge without inversion. This form, which was based on two specimens, may be regarded as a subspecies or morphotype within *Eol. excavatus* but we would hesitate to use the name for our M114 specimens.

A specimen from Jebel Ihrs identified by Becker & Aboussalam (2011, figs 6.6 and 6.11) as *Eoc*. aff. *gronbergi* displays an elongated, shallow basal cavity that tapers rather gradually under the anterior platform. Its posterior tip is intermediate between *Eol. excavatus* and *gronbergi* (compare intermediate specimens illustrated in Klapper & Johnson 1975). This form, included here as a variant in *Eol*. *excavatus* Morphotype 114, resembles to some extent *Eol. abyssus* (Mawson, 1987a), which has a deeper basal cavity with V-shaped cross-section.

Geographic range. – Pan(sub)tropical, from Nevada and northern Gondwana to Australia.

Stratigraphic range. – The species defines the *excavatus* Zone and is mostly restricted to it. A single fragmentary specimen from the basal Akhal Tergoua Member of the western Dra Valley is associated with *Lat. beckmanni*, which suggests a rare upper range into equivalents of the higher *gronbergi* Zone (lower *catharinae* Subzone). This is supported by an overlap of the typical morphotype in NE Siberia with *Eol. perbonus* (Baranov *et al*. 2014).

Eolinguipolygnathus radula
Aboussalam & Becker sp. nov.
Figures 6A, B, E, F, I, J, M–R, 21C

2011 *Eocostapolygnathus* aff. *pannonicus* Mashkova & Apekina. – Becker & Aboussalam, p. 38, figs 5.11–5.16, 6.1.

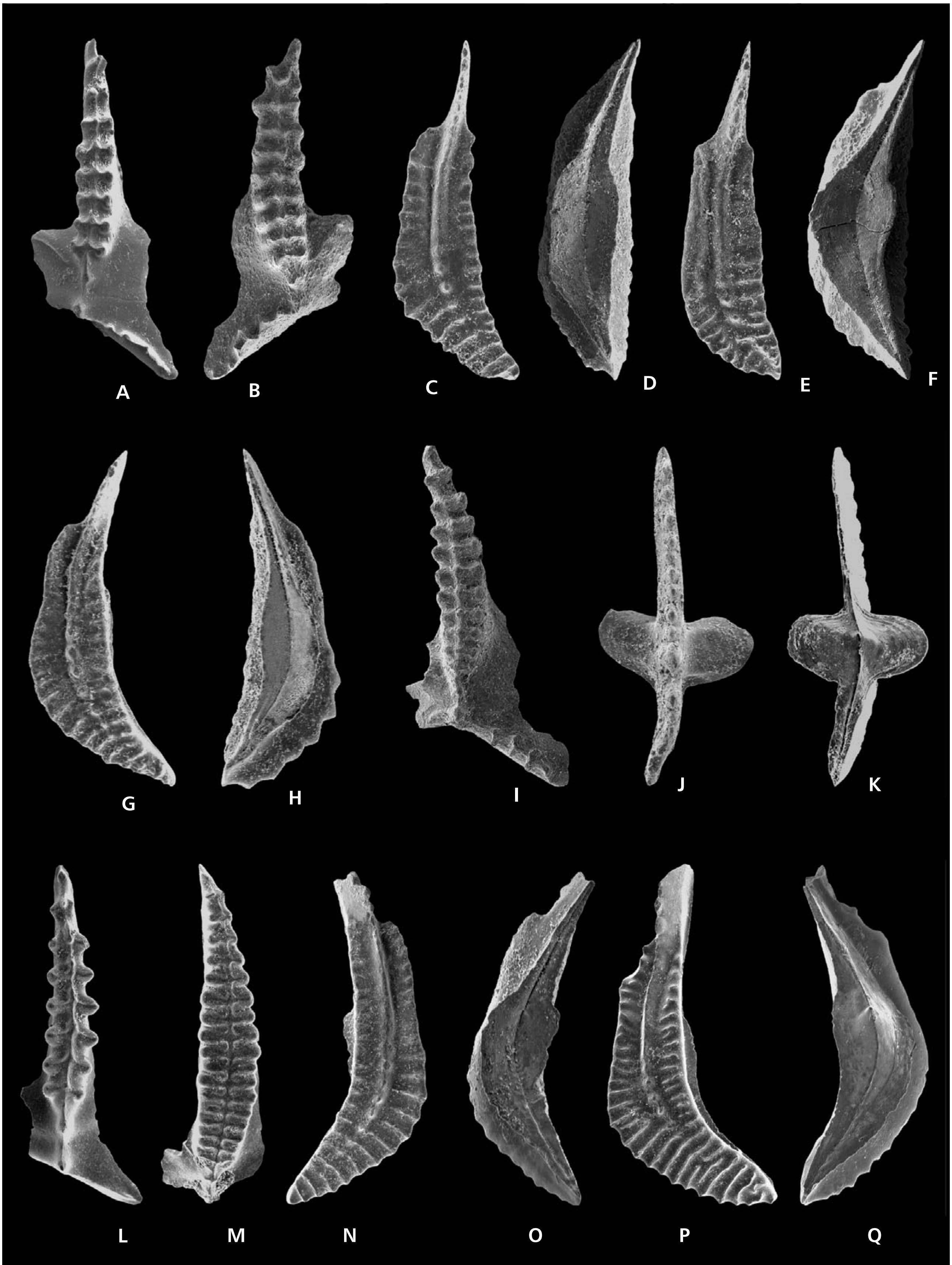
2013 *Eolinguipolygnathus* sp. nov. aff. *pannonicus* Mashkova & Apekina. – Aboussalam & Becker, p. 138, figs 7.9–11.

Derivation of name. – From the Latin *radula* = rasp, because of the strongly and regularly ribbed ornament.

Types. – Holotype B9.A-5.10, Becker & Aboussalam (2011), fig. 5.15, 5.16, here re-illustrated in Fig. 6Q, R; paratypes B9.A-5.6-9, 56, 128.

Type level and locality. – Upper part of *Deiroceras*

Figure 7. Conodonts from the upper *Deiroceras* Limestone of Jebel Ihrs, lower Emsian; A–K – Bed 16c, *excavatus* Morphotype 114 Zone; L–Q – Bed 16d, *bilatericrescens bilatericrescens* Zone. • A, B – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Intermediate from *bilatericrescens gracilis* Bultynck, 1985, B9.A-5.11-12, × 60. • C, D – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114; C – upper view of B9.A-5.13; D – lower view of B9.A-5.14; both × 75. • E, F – *Eol. excavatus* (Carls & Gandl, 1969) s. str.; E – upper view of a specimen with strongly upturned outer anterior platform margin, B9.A-5.15, × 45; F – lower view of specimens with wide basal cavity that flattens at the posterior tip, B9.A-5.16, × 75. • G, H – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. With rather gradually tapering anterior basal cavity, slightly resembling *Eol. abyssus* (Mawson, 1987a), B9.A-5.17, × 85. • I – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). B9.A-5.24, × 50. • J, K – *Crit. miae* (Bultynck, 1971); J – upper view of B9.A-5.27, – 60; K – lower view of B9.A-5.28, × 60. • L – *Caud. celtibericus* (Carls & Gandl, 1969). B9.A-5.132, × 85. • M – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). B9.A-5.133, × 60. • N, O – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. B9.A-5.134, × 65. • P, Q – *Eol. excavatus* (Carls & Gandl, 1969). Specimen with very short carina; therefore, transitional to *Eol. perbonus*, B9.A-5.135, × 60.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Limestone (Bed 16c), upper part of *excavatus* Morphotype 114 Zone, lower Emsian, Jebel Ihrs.

Diagnosis. – Free blade very short (less than 20% of total length), platform markedly curved, moderately narrow, flat, with weak adcarinal furrows in the anterior third, and regular, straight to radial transverse ridges that form a long "semicrossed lingua" with rounded posterior end. Basal cavity large, occupying most of the aboral platform area, very shallow to flat but not inverted at the posterior end.

Description. – Early morphotypes from the lower *Deiroceras* Limestone (Jebel Ihrs, Bed 16a) partly still resemble *Eol. excavatus* M114 because they have relatively narrow platforms (Fig. 6I, J) or their anterior margins are not yet flat but slightly bent outwards (Fig. 6A, B). The basal cavities are large and sometimes wider than the platform, occasionally with secondary small marginal constrictions, which gives a "labiose pattern" (Fig. 6F). The posterior end is narrow, not yet wide tongue-shaped.

In the type material from Bed 16c of Jebel Ihrs there is some intraspecific variability of *Eol. radula* sp. nov. concerning platform width and curvature. The basal cavities are large (Fig. 6N) or very large (holotype, Fig. 6R), the name-giving, rib-like ornament is very regular, and the semi-crossed lingua is weakly (Fig. 6P) or well (Fig. 6O) developed. B9.A-5.6 (Fig. 6M) is a narrow form that is still slightly transitional from *Eol. excavatus* M114.

Discussion. – As noted above, the main difference from *Eol. excavatus* is the flat platform, lack of deep adcarinal grooves, especially in the anterior half, and the very regular ribbing. The early morphotypes differ from associated *Eol. pannonicus* by the lack of the characteristic, oblique anterior ridge (see Fig. 6G, H) of the latter, which forms a distinctive, smooth anterior platform corner. *Eol. pannonicus*, including *Eoc. yolkini* Bardashev, Weddige & Ziegler, 2002, is generally a variable species. A few of the Siberian specimens figured by Izokh *et al*. (2011, especially pl. III, fig. 15a, b) show a similar platform shape and ribbing as in *Eol. radula* sp. nov. The supposed youngest representative of *Eol. pannonicus* from the basal *nothoperbonus* Zone of the Central Pyrenees (Martínez-Pérez & Valenzuela-Ríos 2014, fig. 9i), resembles *Eol. radula* sp. nov. but has a wider platform with rounded posterior outer extension, and a shorter carina. Specimens illustrated by Yolkin *et al.* (2008) as *Po*. "*postpannocus*" nom. nud. and as *Po. foveolatus* in Izokh *et al.* (2011a) all differ in their narrow und upturned anterior platforms and semi-crossed linguae. Half of them lack a posterior cavity inversion and fall in *excavatus* M114, the others with an inverted tip should be placed in *Eol. gronbergi*.

Eol. karsteni (Baranov, Slavík & Blodgett, 2014) from younger strata (*gronbergi* Zone) of the Russian Far East differs from our new form by the regular presence of nodes and small spines on the transverse costae. The Spanish *Eol. ramoni* lacks regular anterior platform ornament; *Eol. carlsi* is much narrower with a concave outer posterior margin. The platform outline is very different, with a reduced lingua, in the group of *Eol. arthuri* (Baranov, Slavík & Blodgett, 2014) and *Eol. rarus* (Aksenova, 1987). *Eol. perbonus* (=*foveolatus*) has deep adcarinal furrows and upturned platform margins, especially in the anterior third, a less extensive basal cavity, and a fully developed (not semi-crossed) lingua. *Eol. abyssus* (Mawson, 1987a) is additionally characterized by a deeper, V-shaped (in cross-section) basal cavity. Typical *Eol. gronbergi* combine the *excavatus*-type platform with an inversion of the posterior part of the basal cavity. All other, younger species of *Eolinguipolygnathus* share the latter feature.

In a more conservative approach our new form may be recognized at subspecies level. Its distinction is emphasized by the fact that it has not been illustrated from the many other regions with *Eol. excavatus*.

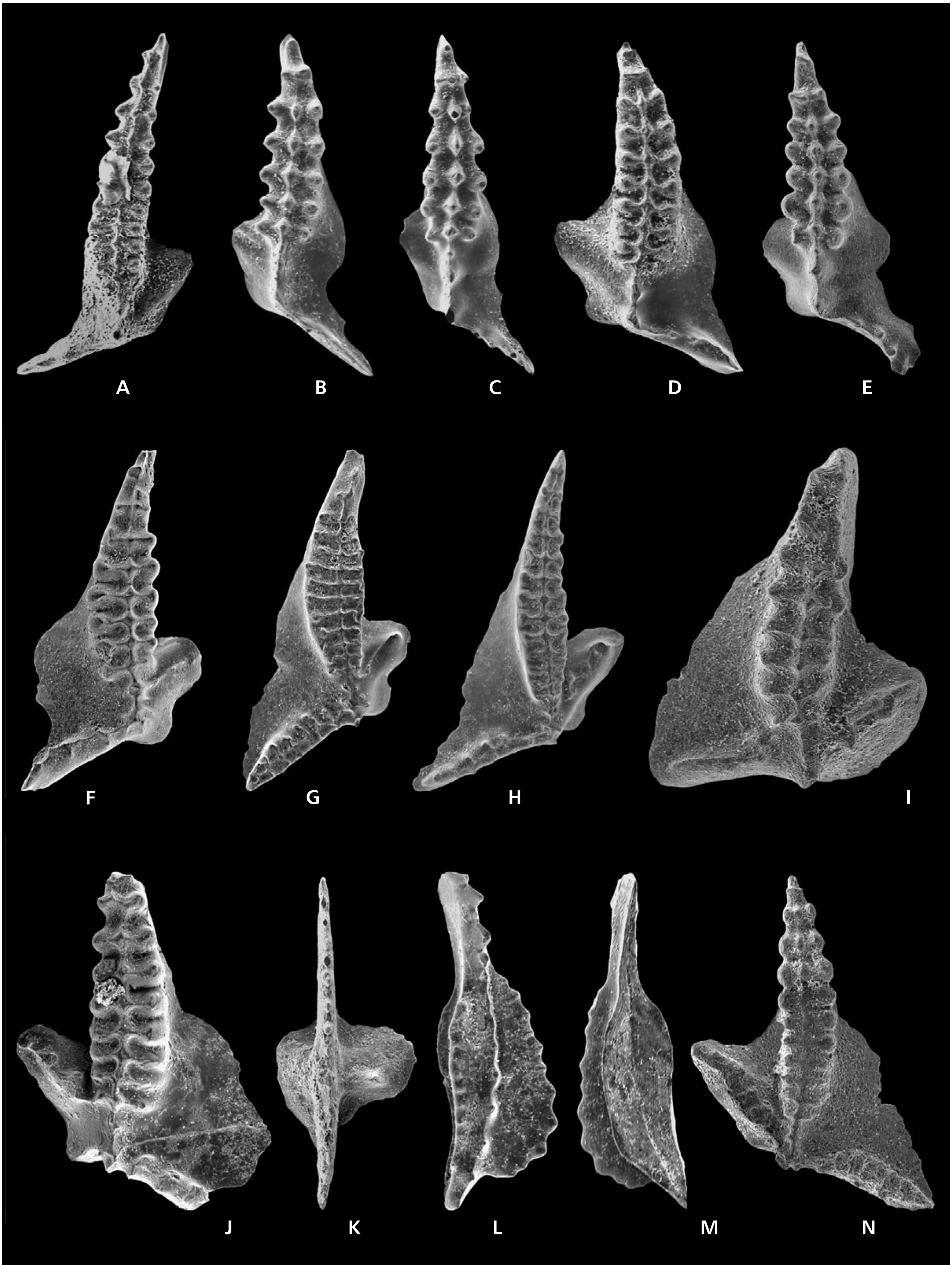
Geographic distribution. – Only known from the Tafilalt (Jebel Ihrs, El Khraouia).

Stratigraphic range. – Restricted to the *Deiroceras* Limestone (*excavatus* M114 Zone).

Eolinguipolygnathus gronbergi
(Klapper & Johnson, 1975)
cf. Figure 22F, G

*e.p. 1975 *Polygnathus gronbergi* sp. nov.; Klapper & Johnson, p. 73, pl. 1, figs 17–24, 27–28 [figs 25, 26 transitional to *L. gilberti*].

Figure 8. Conodonts from the *Anetoceras* Limestone of Jebel Ihrs; A–C – Bed 18b, *bilatericrescens bilatericrescens* Zone; D–I – Bed 20b, *latus* Zone; J–M – Bed 21a, *latus* or basal *steinhornensis* Zone; N – Bed 22b, higher *latus* or *catharinae* Subzone. • A – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). Small specimen, B9.A-5.23, × 120. • B–E – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Showing the intraspecific variability; B – B9.A-5.25, × 85; C – B9.A-5.26, × 75; D – form with widened basal cavity, B9.A.5-29, × 65; E – B9.A5-30, × 65. • F–H – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). Three different morphotypes; F – transitional specimen towards the nominate subspecies, with long posterior end of the spindle, B9.A-5.31, × 55; G – advanced morphotype with almost double-rowed outer posterior process, B9.A-5.32, × 45; H – typical specimen, B9.A-5.33, × 55. • I – *Lat. latus* (Al-Rawi, 1977). B9.A-5.35, × 75. • J – *Lat. armoricanus* Bultynck, 1989. B9.A-5.136, × 65. • K – *Crit. steinhornensis* (Ziegler, 1956). B9.A-5.137, × 85. • L, M – *Eoc. juferevi* (Aksenova, 1987). Specimen closely resembling one of the paratypes, B9.A-5.138, × 85. • N – *Lat. beckmanni sinuatus* (Klapper, Ziegler & Mashkova, 1978). B9.A-5.37, × 45.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1980 *Polygnathus gronbergi* Klapper & Johnson. – Bultynck & Hollard, p. 26, pl. II, fig. 6a, b, ?fig. 7a–c.

non 1985 *Polygnathus gronbergi* Klapper & Johnson. – Bultynck, fig. 4, pl. 5, fig. 16 [= *Eol. juferevi*; see Bardashev *et al.* 2002].

non 1999 *Polygnathus gronbergi* Klapper & Johnson. – Belka *et al*., fig. 4, table 1, pl. 2, fig. 7 [= *Eol. excavatus*].

*e.p. 2002 *Eocostapolygnathus philipi* sp. nov.; Bardashev, Weddige & Ziegler, p. 405 (only the holotype).

*e.p. 2002 *Eocostapolygnathus polinae* sp. nov.; Bardashev, Weddige & Ziegler, pp. 405–406 (only the holotype).

*e.p. 2008 *Polygnathus* "*postpannonicus*"; Yolkin, Weddige, Izokh & Erina *in* Yolkin *et al*. (eds), pp. 92–94, pl. 3, figs 11, 12 (only).

*e.p. 2011 *Polygnathus luciae* sp. nov.; Martínez-Pérez & Valenzuela-Ríos, figs 7a–b2 (only).

e.p. 2011a *Polygnathus foveolatus* Philip & Jackson. – Izokh, Yolkin, Weddige, Erina & Valenzuela-Ríos, pp. 54–55, pl. III, figs 23, 23 (only).

Discussion. – The type material of *Eol. gronbergi* shows a "semi-crossed lingua" and large basal cavity with a marked constriction under the anterior platform. Based on the amount of posterior basal cavity inversion, Bultynck (1989) introduced α and β morphotypes, which are both present among the Nevada originals (see Klapper & Johnson 1975, pl. 1). Bardashev *et al*. (2002) adopted Bultynck's distinction. *Eocostapolygnathus philipi* Bardashev, Weddige & Ziegler, 2002 and *Eoc. polinae* Bardashev, Weddige & Ziegler, 2002 are regarded as variants of *Eol. gronbergi*. The second shows a stronger basal cavity inversion than the first. *Eolinguipolygnathus gagievi* Bardashev, Weddige & Ziegler, 2002 differs in an extended outer posterior platform and better-developed lingua, similar as in *Eol. perbonus*. Baranov *et al*. (2014) introduced a new Morphotype gamma based on specimens with rather strong inversion, long semi-crossed lingua, and peculiar additional nodes and spines on the oral surface; this distinctive form could well represent a new taxon.

The *gronbergi* specimen from Sample BTW4 (upper *Anetoceras* Limestone, figured in Bultynck & Hollard (1980, pl. II, fig. 7a, b), resembles *Eoc. lenzi* and a *Po. gronbergi* figured by Apekina & Mashkova (1978, pl. 75, fig. 6, 6a), which Bardashev *et al*. (2002) placed in their *Eoct. richi*.

The *gronbergi* specimen illustrated by Belka *et al*. (1999) from the lower *Deiroceras* Limestone of Ouidane Chebbi does not really show an inverted posterior basal cavity and is regarded as an *Eol. excavatus* with a slight trend towards *Eol. gronbergi*. A specimen identified as *Eol*. cf. *gronbergi* from the lower *Mimagoniatites* Limestone of Jebel el-Mrier has an unusually smooth upper surface but it appears to have been abraded (Fig. 19F, G). The absence of deep adcarinal furrows is also remarkable. The posterior basal cavity is markedly inverted, the lingua slightly "semi-crossed". The upper surface resembles a specimen assigned to the Morphotype β of *Eol. gronbergi* by Bultynck (1989, pl. 3, fig. 3a, b). But the flat basal cavity is somewhat larger.

Geographic distribution. – Pan(sub)tropical, from Nevada to Australia.

Stratigraphic range. – *Gronbergi* Subzone (Lower *gronbergi* Zone) to *inversus* Zone.

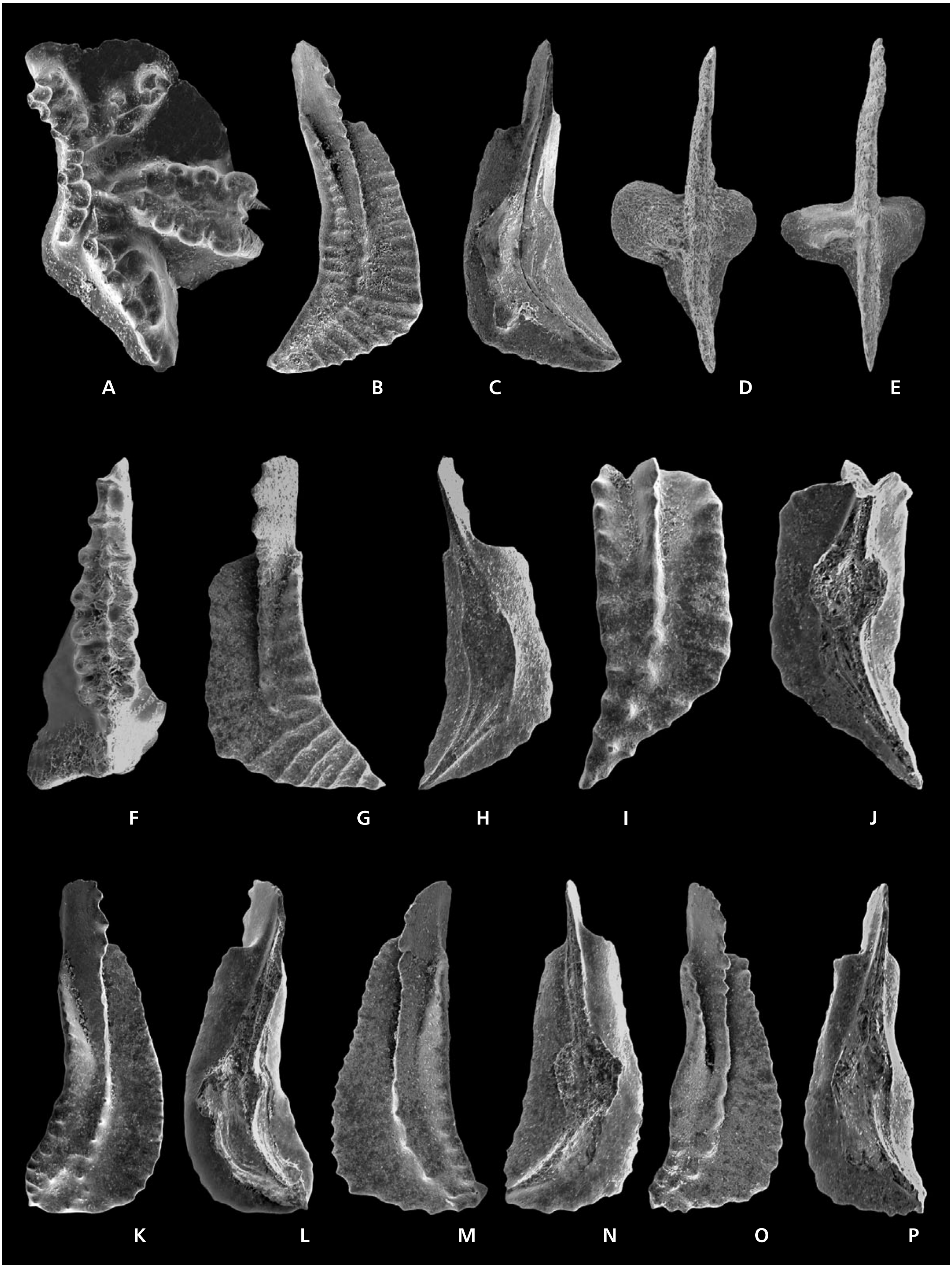
Eolinguipolygnathus aff. *gronbergi* (Klapper & Johnson, 1975)

Figure 15H–J

Description. – Several specimens from the lower *Anetoceras* Limestone of sections BTW and BTN are characterized by wide and flat, somewhat labiose basal cavities with an inverted posterior tip (Fig. 15I), relatively broad, flat, variably costate platforms, shallow adcarinal furrows, an extension of the outer posterior platform, and a poorly developed, broad tongue (Fig. 15H).

Discussion. – The posterior inversion of the basal cavity conforms to *Eol. gronbergi*, but the platform is wider and flatter than in that species, especially in the outer corner, which is wider than the inner platform. Similar specimens have been figured by Bultynck (1989, pl. 3, figs 3, 4) as "*gronbergi* ß morphotype". *Eolinguipolygnathus rarus* is

Figure 9. Conodonts from the upper part of the lower Emsian at Jebel Ihrs; A–E – middle *Anetoceras* Limestone, Bed 22b, *catharinae* Subzone or lower *steinhornensis* Zone; F – Bed 27b, upper *Mimagoniatites* Limestone, local Upper *Belodella* Ecozone; G–P – Bed 31a$_1$, *inversus* Zone. • A – *Lat. beckmanni beckmanni* (Ziegler, 1956). Fragmentary, advanced specimen with third, nodose, posterior process, B9.A-5.36, × 60. • B, C – *Eol. catharinae* (Bultynck, 1989); B – upper view; C – lower view showing the typical extensions of the flat basal cavity, very unlike as in the holotype of *Eol. mashkovae* (Bardashev, 1986), B9.A-5.34, × 60. • D, E – *Crit. steinhornensis* (Ziegler, 1956). Two differently asymmetric specimens; D – B9.A-5.38, × 60; E – B9.A-5.39, × 65. • F – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Rare, unfortunately incomplete specimen from the top *Anetoceras* Limestone, B9.A-5.40, × 85. • G, H – *Eol. annamariae* (Bultynck, 1989) Morphotype alpha. Somewhat transitional to *Eol. nothoperbonus*, B9.A-5.139, × 75. • I, J – *L. inversus* (Klapper & Johnson, 1975). Small form, B9.A-5.140, × 85. • K–P – *Eol. jacksoni* (Bardashev, Weddige & Ziegler, 2002). Three specimens illustrating the ontogenetic and intraspecific variation; K, L – B9.A-5.141, × 60; M, N – B9.A-5.142, × 75; O, P – B9.A-5.143, × 85.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somewhat similar but there is no clear evidence for a posterior cavity inversion in its type material. The new specimens show trends towards *Eol. jacksoni*, especially some specimens with relatively small basal cavity. They may represent a new species between *Eol. rarus* and *Eol. jacksoni*, which we leave currently in open nomenclature. In the related "*Polygnathus* sp. 1" of Luppold (1987), the platform is smoother, narrower, and less curved in the posterior part.

Stratigraphic range. – *Anetoceras* Limestone, *catharinae* Subzone.

Eolinguipolygnathus jacksoni **(Bardashev, Weddige & Ziegler, 2002)**
Figure 9K–P

e.p. 1989 *Polygnathus laticostatus* Klapper & Johnson. – Bultynck, p. 185, pl. 3, figs 9–11 (only).
e.p. 1989 *Polygnathus gronbergi-laticostatus*. – Bultynck, pl. 3, figs 5, 8 (only).
* 2002 *Costapolygnathus jacksoni* sp. nov.; Bardashev, Weddige & Ziegler, pp. 415–416.

Description. – A population from Bed $31a_1$ at Jebel Ihrs gives insights into the ontogeny and variability of the species. Most characteristic is the asymmetric drop-shape. The largest representative (Fig. 9K) is more elongate than the smaller specimens, which display somewhat narrower and deeper anterior adcarinal troughs. The inner platform margin is slightly convex to straight at small to median size (Fig. 9M) but strongly concave in the largest specimen or undulose in a third specimen (Fig. 9O). Since all specimens come from one population it is clear that there is considerable variability in the shape and size of the basal cavity. The central basal pit is moderately large and flat (Fig. 9N, P) but does not become relatively smaller with growth. Curved, shelf-like extensions characterize especially the posterior outer part and can be pronounced at large size (Fig. 9L). The posterior cavity inversion is always pronounced. The proportions of the free blade decreases from >1/3 of total length in small specimens to less than 1/5 in the adult. It is moderately prominent, with three larger denticles. The carina is lower than the free blade, with fused denticles in the anterior part and small, low, isolated denticles (Fig. 9O) or wide and unclearly defined denticles (Fig. 9K) near the end. It does not reach the posterior tip. In the posterior half there are adjacent, smooth, wide adcarinal depressions. There are either transverse costae or the posterior margin, especially its widened outer part, is markedly serrate. There is no clear lingua.

Discussion. – The new Tafilalt population lacks any characteristics of *Eol. laticostatus* and provides support that *Eol. jacksoni* is a valid species, which can be well defined despite some intraspecific variability. It was originally based on specimens from the La Grange Limestone assigned by Bultynck (1989) to *Eol. laticostatus* but should also include some of Bultynck's transitional specimens from *gronbergi*. *Eol. jacksoni* obviously belongs to a so far neglected lineage with characteristic suboval platform shape and feeble ornament that probably evolved in parallel to the other lower Emsian polygnathids. Most ancestral, with a still non-inverted basal cavity, are a specimen from the German Harz Mountains assigned to *Po. gronbergi* in Luppold (1987, fig. 8.1a, b) and the Russian *Eol. rarus*. *Eolinguipolygnathus arthuri* provides a morphological transition from the *excavatus* Group, which is supported by its stratigraphic position. In the narrow *Polygnathus* sp. 1 *sensu* Luppold (1987) and in our *Eol.* aff. *gronbergi*, the posterior cavity has started to invert. Progressing inversion led to *Eol. jacksoni*. Its shelf-like extensions under the outer platform resemble those in *Eol. catharinae* and *Eol. vigierei* and served the attachment of the basal body. *Eolinguipolygnathus* cf. *laticostatus* (see below) with a basal pit represents the end member of the morphological and assumed phylogenetic series.

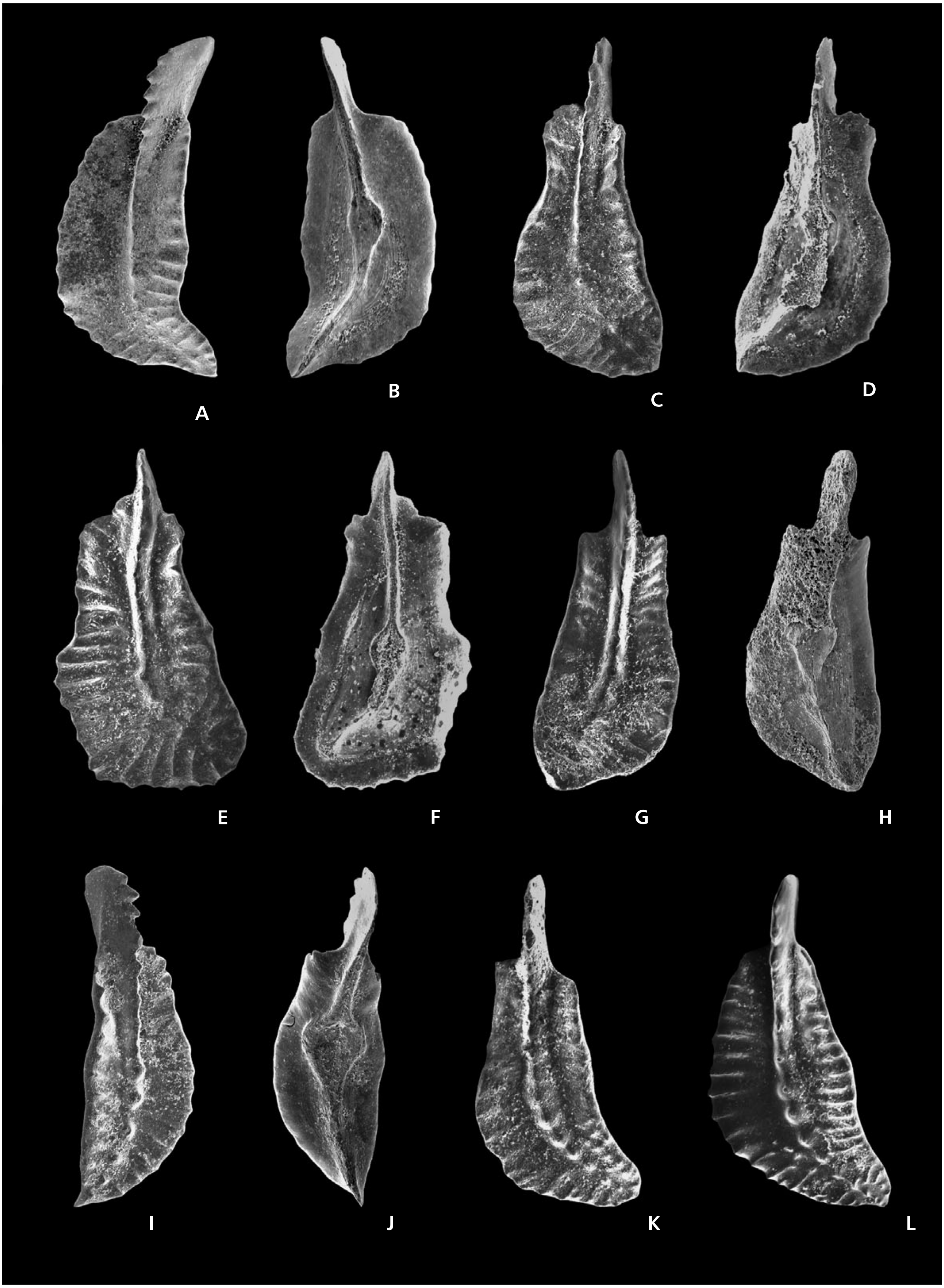
Geographic distribution. – Armorican Massif, Anti-Atlas (new record).

Stratigraphic range. – Upper part of *inversus* Zone.

Eolinguipolygnathus laticostatus **(Klapper & Johnson, 1975)**
Figures 10C, D, G–L, 15K, *cf.* 15L, M, T–U, 21K

*e.p. 1975 *Polygnathus laticostatus* sp. nov.; Klapper & Johnson, p. 74, pl. 2, figs 20, 21, 28, 29 (only).
1980 *Polygnathus laticostatus* Klapper & Johnson. – Bultynck & Hollard, p. 43, pl. 2, figs 9–11.

Figure 10. Conodonts from the upper *Mimagoniatites* Limestone at Jebel Ihrs; A, B – Bed $31a_1$, *inversus* Zone; C–L – Bed 31b, *laticostatus* Zone. • A, B – *Linguipolygnathus* sp. nov., B9.A-5.144, × 60. • C, D – *Eol. laticostatus* (Klapper & Johnson, 1975) Morphotype beta. With strongly concave outer anterior platform margin, B9.A-5.18, × 60. • E, F – *Eol. vigierei* (Bultynck, 1989). B9.A-5.19, × 50. • G–K – *Eol. laticostatus* (Klapper & Johnson, 1975) Morphotype beta. Three specimens showing the variation of the anterior platform margin; G, H – with only weakly concave outer anterior platform margin and relatively large basal pit, B9.A-5.21, × 60; I, J – smaller specimen with large and shallow basal pit, B9.A-5.41, × 75; K – B9.A-5.20, × 65. • L – *Eol. laticostatus* (Klapper & Johnson, 1975) Morphotype alpha. With convex outer anterior platform margin, B9.A-5.22, × 65.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1985 *Polygnathus laticostatus* Klapper & Johnson. – Bultynck, pl. 5, figs 19, ?20.

e.p. 1987 *Polygnathus laticostatus* Klapper & Johnson. – Luppold, p. 311, fig. 8.2a, b [figs 7.2a, b and 8.2a, b = sp. nov.].

e.p. 1989 *Polygnathus laticostatus* Klapper & Johnson. – Bultynck, p. 185, pl. 3, fig. 12a, b (only) [figs 9–11 = *Eol. jacksoni*].

non 1990 *Polygnathus* cf. *laticostatus* Klapper & Johnson. – García-López *et al*., pl. II, figs 26, 27 [= *gilberti*].

non 2013 *Polygnathus laticostatus* Klapper & Johnson. – Lu, p. 316, pl. 2, fig. 1.

non 2013 *Polygnathus* cf. *laticostatus* Klapper & Johnson. – Lu, p. 316, pl. 1, fig. 10.

Desription. – Four of the representatives from the top of the *Mimagoniatites* Limestone of Jebel Ihrs differ from typical *laticostatus* in a gentle (Fig. 10G–K) to marked (Fig. 10C, D) concave anterior, outer platform margin and angular to pointed anterior platform shoulders. The outer posterior margin is always markedly convex, without any angularity. The inner platform margin is straight (Fig. 10G) or slightly undulose. The basal pit is very shallow but relatively wide in small specimens (Fig. 10J) and relatively smaller in larger ones (Fig. 10D, H).

Several specimens from equivalent strata of Section BTW (Fig. 15L, M, T, U) differ by an extended posterior outer platform with reduced ornament, which is much wider than the inner platform. The platform shape is asymmetrically drop-shaped, with an almost straight, blunt, posterior platform front.

Discussion. – Bardashev (1986), Bultynck (1989), Bardashev & Ziegler (1992), and Bardashev *et al*. (2002) removed forms with a large, well-developed, broadly rounded or triangular lingua from the Nevada type series of *Po. laticostatus* as *Po. gilberti* and added similar forms from France and Tadzhikistan. The absence of specimens with "*gilberti* morphology" from the *laticostatus* faunas of Jebel Ihrs and Bou Tchrafine supports the distinction. The remaining *laticostatus* types (s. str.) from Nevada and many other representatives show a convex outer platform and small platform angles at the anterior end. This typical form is here defined as Morphotype alpha, whilst our form from Jebel Ihrs with outer platform concavity and marked anterior shoulders is placed in a new Morphotype beta. It has previously been illustrated from the Tafilalt (Bultynck & Hollard 1980, pl. II, fig. 10a, b) and Maider (Bultynck 1985, pl. 5, fig. 19). Bardashev *et al*. (2002) placed the latter specimen in their *Costapolygnathus telfordi*, the holotype of which, however, has a very different platform shape and basal cavity. The restriction of Morphotype beta to the eastern Anti-Atlas may justify the introduction of a new taxon (*e.g*., a new subspecies). However, there are intermediates within one bed that connect Morphotype alpha (Fig. 10L, close to the holotype) and beta (Fig. 10C, D) end members. A better documentation of the intraspecific variability in successive beds of other regions would be helpful to clarify the taxonomy of the species.

Apart from the two morphotypes of the typical *laticostatus* there are specimens from the Harz Mountains (Luppold 1987; see above) and BTW with extended outer posterior platform, which are here called cf. *laticostatus*. They possess platforms similar as in *Eol. jacksoni* and may represent a distinctive (sub)species or a third morphotype. Bardashev *et al*. (2002) suggested that typical *Eol. laticostatus* evolved from *Eol. gronbergi*, via forms assigned to *Eoc. philipi* (a species based on Rzhonsnitskaya *et al*. 1990, pl. 9, figs 9, 10). The transitional specimen figured by Klapper & Johnson (1975, pl. 1, figs 25, 26) fits a direct *gronbergi-laticostatus* transition. It combines a strong basal cavity inversion with the anterior platform shoulders of our Morphotype beta and an incipient outer platform concavity. The *gronbergi-laticostatus* intermediate of García-López *et al*. (1990) is poorly preserved but similar. It is well possible that our *Eol*. cf. *laticostatus* derived independently from *Eol. jacksoni*.

The moderate size of the basal pit, the short semicrossed lingua, and the supposed independent origin (*e.g*., Klapper & Johnson 1975, Bultynck, 1989) justifies our placing of *laticostatus* in *Eolinguipolygnathus* rather than in *Polygnathus* (= *Eucostapolygnathus*) or *Linguipolygnathus*.

Geographic distribution. – Pan(sub)tropical, from Alaska and northern Gondwana to South China and the Russian Far East.

Stratigraphic range. – Both morphotypes and *Eol*. cf. *laticostatus* are restricted to the *laticostatus* Zone.

***Eolinguipolygnathus annamariae* (Bultynck, 1989)**
Figure 9G, H

* 1989 *Polygnathus annamariae* sp. nov.; Bultynck, p. 184, pl. 6, figs 4, 5.

Figure 11. Emsian to Eifelian outcrops at Bou Tchrafine West, Bou Tchrafine North, and Hamar Laghdad South. • A – position of section Bou Tchrafine West (arrow) in the plain to the west of the main (Eifelian–Givetian) cliff. • B – position of section Bou Tchrafine North in the plain below the western extension of the Hamar Laghdad ridge, with section HLS II at the foot of the low northern cliff. The western margin of the Pragian Hamar Laghdad Mudmounds forms the foreground in the lower right corner.


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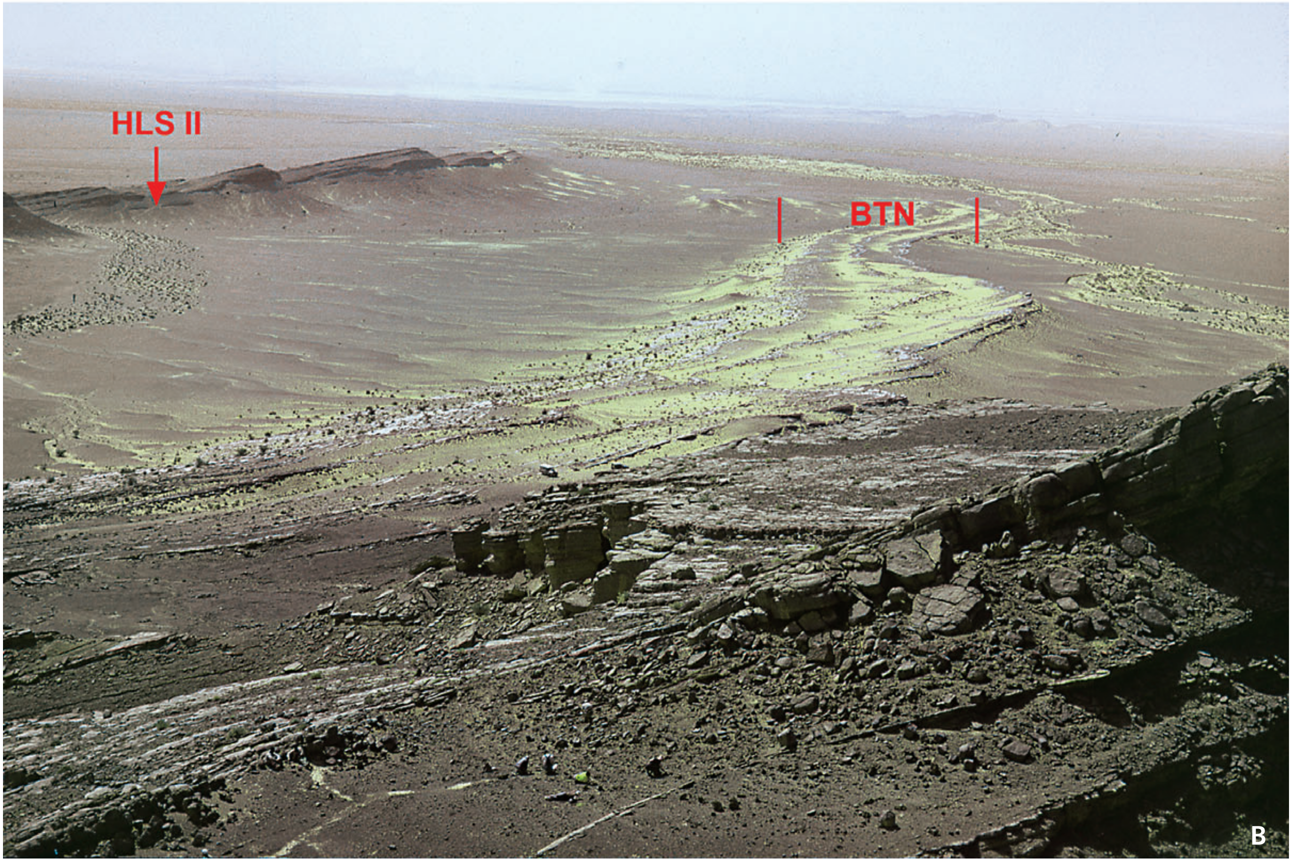

HLS II
BTN
B

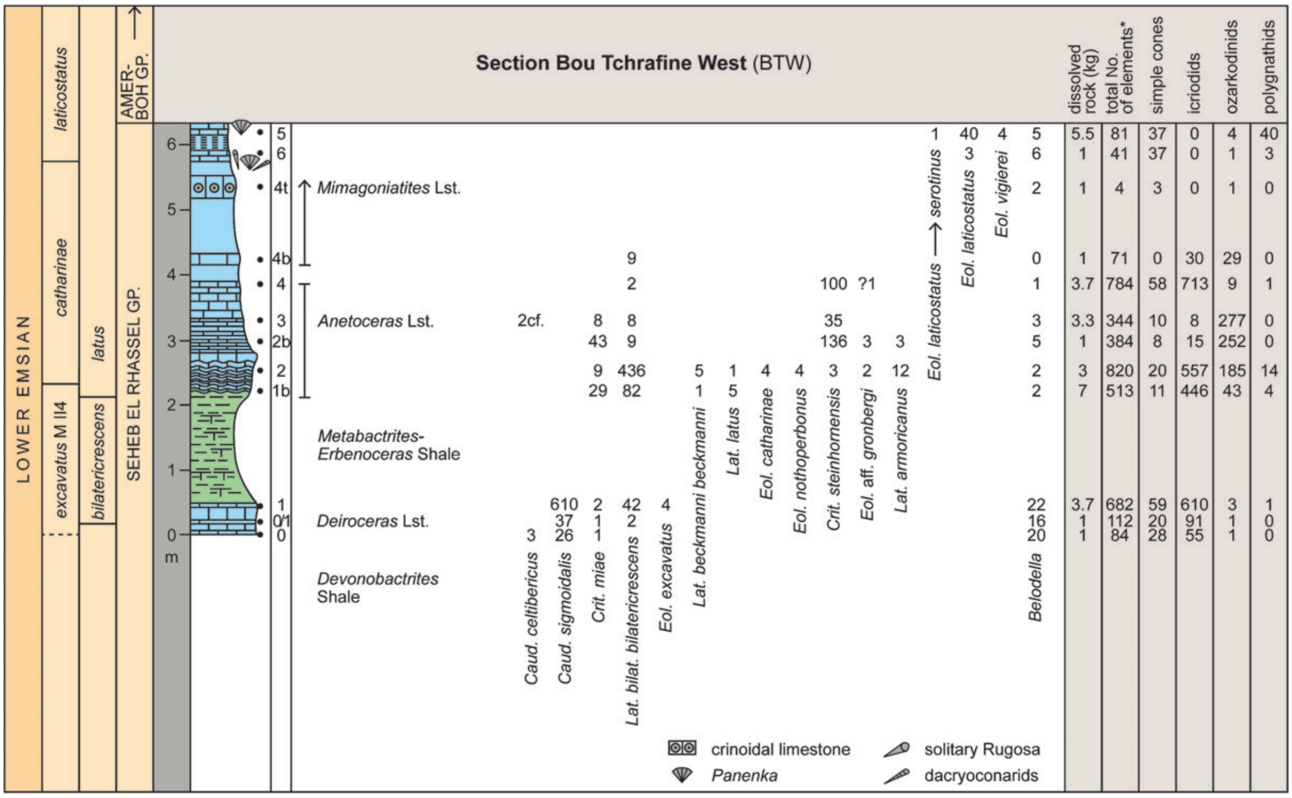


Figure 12. Lower Emsian lithological succession, sample positions, conodont ranges and abundances at Bou Tchrafine West (central Tafilalt). For additional symbols see Fig. 4. *The total number of elements partly includes ramiforms, which are not assigned to any of the four listed groups.

2002 *Eolinguipolygnathus annamariae* (Bultynck). – Bardashev, Weddige & Ziegler, pp. 407–408.

Discussion. – A single specimen from Jebel Ihrs (Bed 31a$_1$) resembles the paratype of *Eol. annamariae* figured by Bultynck (1989, pl. 6, fig. 5a, b), which Bardashev *et al.* (2002) placed in their Morphotype beta. It is also very close to the holotype of *Po. mashkovae latus* Aksenova, 1987, which, however, is an invalid junior homonym of *Po. latus* Wittekindt, 1966. *Eol. mashkovae* Bardashev, 1986 differs mostly in the narrower anterior platform with deep adcarinal furrows and in a much more inverted basal cavity. *Eol. perbonus* and *Eol. labiosus* are more slender, with deeper anterior adcarinal troughs.

Geographic distribution. – ?Tadzhikistan, Armorican Massif, Anti-Atlas (new record).

Stratigraphic range. – Restricted to the *inversus* Zone.

***Eolinguipolygnathus gilberti* (Bardashev, 1986)**
Figure 21J

*e.p. 1975 *Polygnathus laticostatus* sp. nov.; Klapper & Johnson, p. 74, pl. 1, figs 29–32, pl. 2, figs 22–26, 30, 32, 33 (only).
* 1986 *Polygnathus gilberti* sp. nov.; Bardashev, pp. 63–64, pl. V, figs 17, 18.
1990 *Polygnathus* cf. *laticostatus* Klapper & Johnson. – García-López *et al.*, pl. II, figs 26, 27.
1992 *Polygnathus laticostatus* Klapper & Johnson. – Bardashev & Ziegler, pl. 5, figs 1–6.
1992 *Polygnathus gilberti* Klapper & Johnson. – Bardashev & Ziegler, pl. 6, figs 1–4, 6–11, 22.
2002 *Polygnathus gilberti* Bardashev. – Bardashev, Weddige & Ziegler, p. 422.
* 2002 *Linguipolygnathus talenti* Bardashev, Weddige & Ziegler, pp. 422–423.
non 2013 *Polygnathus gilberti* Bardashev. – Lu, p. 315, pl. 1, figs 6, 7 [a new species].
non 2013 *Polygnathus* cf. *gilberti* Bardashev. – Lu, p. 316, pl. 1, figs 8, 9 [variants of the new species].

Discussion. – Bardashev (1986) first separated only two originals of *Po. laticostatus* Klapper & Johnson, 1975 with broadly rounded long lingua as *Po. gilberti*. But his types from Tadzhikistan possess a large, triangular lingua. Therefore, it is consequent that Bardashev *et al.* (2002) added similar Nevada types to their *gilberti* syno-

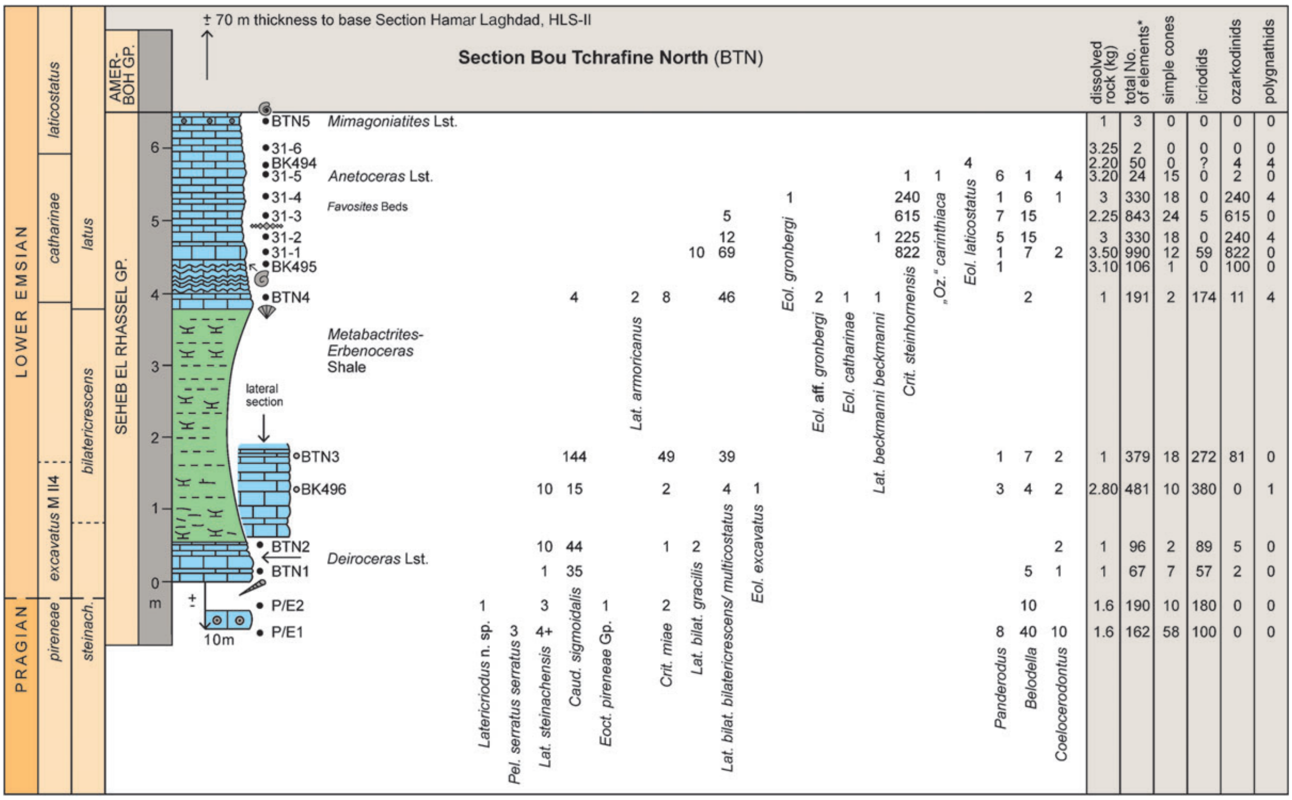


Figure 13. Upper Pragian to lower Emsian lithological succession, sample positions, conodont ranges and abundances at Bou Tchrafine North (east-central Tafilalt). For symbols see Figs 4 and 12. *The total number of elements includes variable amounts ramiforms, which are not assigned to any of the four listed groups.

nymy. Both morphotypes were illustrated by Bultynck (1989) from La Grange but his Pa elements are very wide, with semicircular outer platform margin. Two additional French specimens, identified by Bultynck (1989) as *Po.* ?*gilberti*, have somewhat narrower platforms. They resemble some of the Nevada paratypes. We do not support the separation of such variants (morphotypes) as a different species (*L. talenti* Bardashev, Weddige & Ziegler, 2002).

Our specimen from the top of Bed 22 at El Khraouia is a relatively narrow morphotype with triangular lingua. It closely resembles specimens from the type region figured by Bardashev & Ziegler (1992, especially pl. 6, fig. 10). Specimens illustrated from South China by Lu (2013), including cf. forms, posses a very different platform ornament, with diverging anterior ridges and adcarinal furrows; they do not resemble any named Emsian taxon.

Geographic distribution. – Alaska, Nevada, Armorican Massif, Pyrenees, Catalonia (NE Spain), Anti-Atlas (new record), Uzbekistan, Tadzhikistan, South China.

Stratigraphic range. – Restricted to the *laticostatus* Zone.

Eocostapolygnathus juferevi **(Aksenova, 1987)**
Figures 8L, M, *cf.* 21N, O

cf. 1985 *Polygnathus gronbergi* Klapper & Johnson. – Bultynck, fig. 4, pl. 5, fig. 16.
cf. 1986 *Polygnathus dehiscens* Philip & Jackson. – Barca *et al.*, pl. 29, figs 3–5.
* 1987 *Polygnathus juferevi* sp. nov.; Aksenova, pp. 91–92, pl. 26, figs 8, 10, pl. 27, figs 4–6.
cf. 1989 *Polygnathus dehiscens dehiscens* Philip & Jackson. – Bultynck, pl. 3, fig. 1a–c [= *pierrei* holotype].
*cf. 2002 *Eocostapolygnathus pierrei* sp. nov.; Bardashev, Weddige & Ziegler, p. 405 (holotype only).
e.p. 2002 *Eocostapolygnathus juferevi* (Aksenova) alpha morphotype. – Bardashev, Weddige & Ziegler, pp. 403–404 [Aksenova types only].

Description. – A single specimen (B9.A-5.13, Fig. 8L, M) from the lower part of Bed 21a at Jebel Ihrs differs from all other lower Emsian polygnathids of the region. It displays a well-rounded, curved and ribbed outer posterior platform, which is shorter than the strong, moderately curved carina that reaches the posterior end. The inner platform is reduced and mostly has a row of nodes that

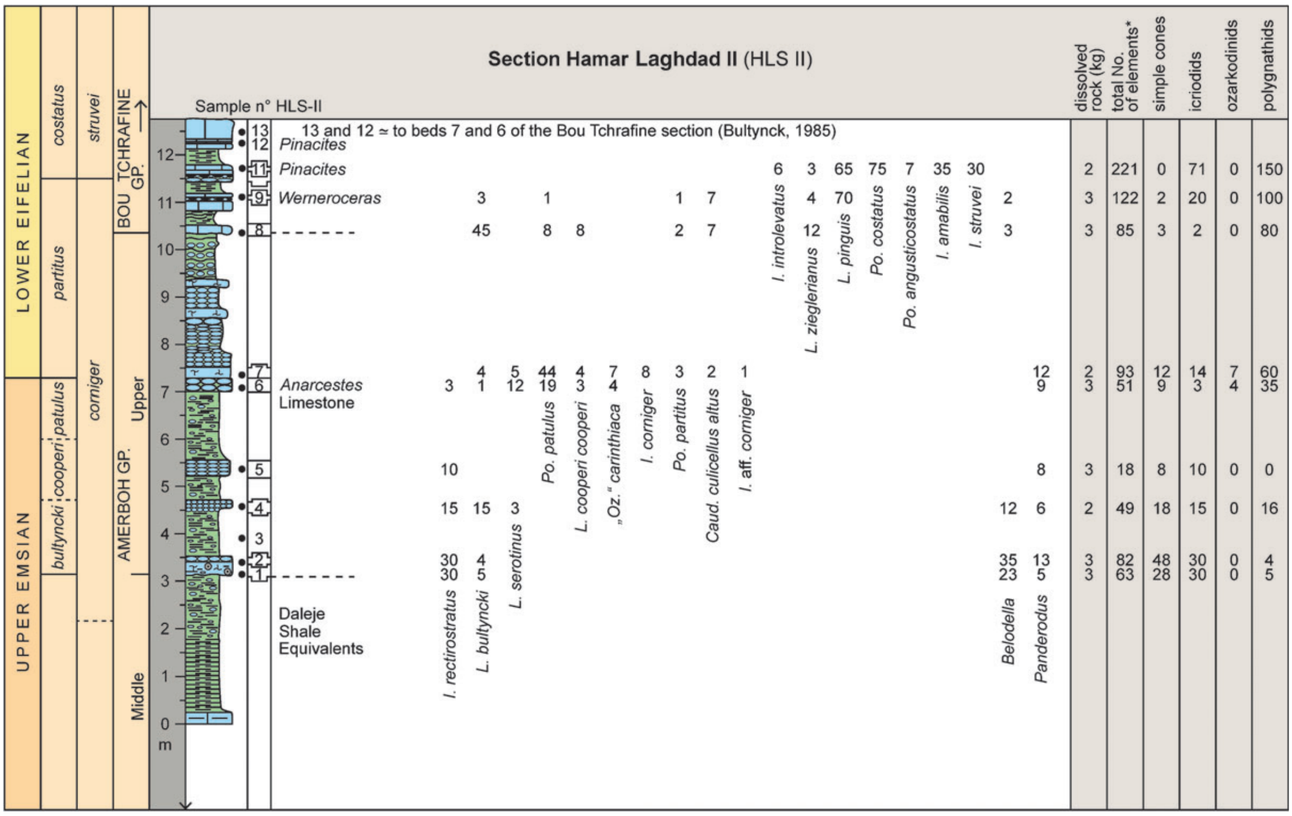
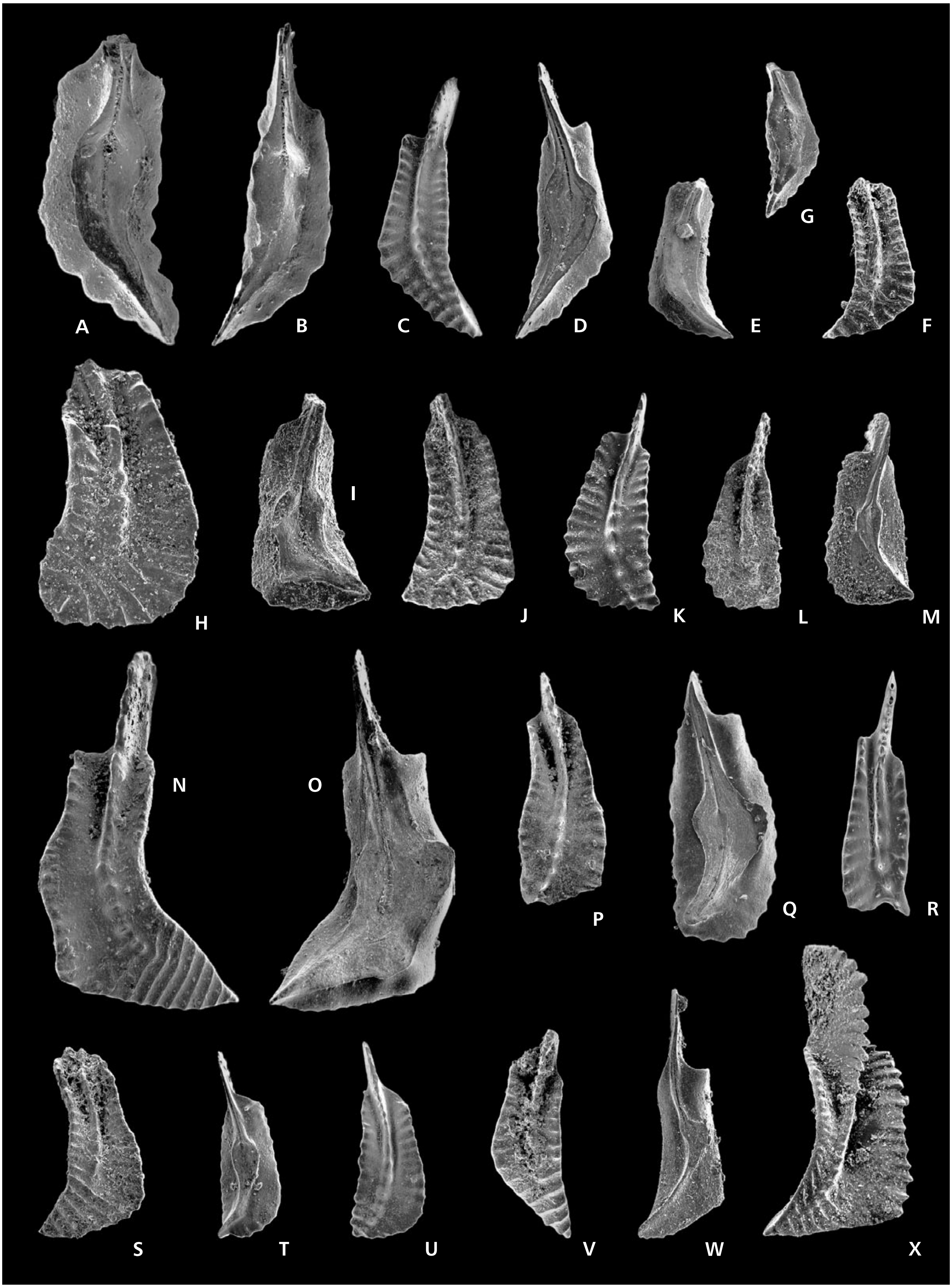


Figure 14. Lithological succession, sample positions, and conodont record at Hamar Laghdad SW (HLS II, east-central Tafilalt).

joines smoothly the gently curved anterior platform end and the carina at the posterior platform tip. The basal cavity is wide and shallow, without posterior inversion. Adcarinal troughs are well developed, especially on the outer side, and smooth.

In two specimens from the top of Bed 22 at El Khraouia (Fig. 21N, O) a wide, flat and rather poorly demarcated basal cavity flexes upwards at the posterior tip but it is not really inverted. The somewhat subrectangular platform has high, upturned margins with only weak transverse costae and wide and smooth adcarinal troughs along a low, ridge-like carina that dissolves into small denticles towards the posterior end. The outer platform margin forms a distinctive, slightly costate corner. The inner platform has been reduced to a narrow ridge, which becomes lower near the posterior end.

Figure 15. Polygnathid conodonts from the Emsian of Bou Tchrafine and Hamar Laghdad SW (HLS II, east-central Tafilalt), all × 47. • A–D, G – *Eol. excavatus* (Carls & Gandl, 1969) typical morphotype. Sample BTW1, upper *Deiroceras* Limestone, upper *excavatus* M114 Zone; A – lower view with basal cavity, b6591; B – lower view, b6592; C, D – upper and lower views, b6593; G – lower view of small specimen, b6594. • E, F – *Eol. nothoperbonus* (Mawson, 1987). Upper and lower views of incomplete specimen b6595, Sample BTW2, lower part of *Anetoceras* Limestone, *catharinae* Subzone. • H–J – *Eol.* aff. *gronbergi* (Klapper & Johnson, 1975). Specimens with marked transverse costae and extended outer posterior platform, lower *Anetoceras* Limestone, *catharinae* Subzone, probably ancestral to *Eol. jacksoni*; H – Sample BTW2, b6596; I, J – Sample BTN4, b6597. • K – *Eol. laticostatus* (Klapper & Johnson, 1975). Upper view of typical specimen, b6598, Sample BTW6, middle *Mimagoniatites* Limestone, *laticostatus* Zone. • L, M – *Eol.* cf. *laticostatus* (Klapper & Johnson, 1975). Specimens with outer posterior platform extension and reduced ornament as in *Eol. jacksoni* but with more strongly inverted basal cavity, Sample BTW5, top of *Mimagoniatites* Limestone, *laticostatus* Zone; L – upper view of b6599; M – lower view of b6600. • N, O, S – *Eol. catharinae* (Bultynck, 1989). Sample BTW2, lower *Anetoceras* Limestone, *catharinae* Subzone; N, O – upper and lower views of b6605; S – upper view of b6606. • P, Q – *Eol. vigierei* (Bultynck, 1989). Sample BTW5, top *Mimagoniatites* Limestone, *laticostatus* Zone; P – upper view of b6607; Q – lower view of b6608. • R – *Eol. laticostatus* (Klapper & Johnson, 1975) towards *L. serotinus* (Telford, 1975). Small specimen with bilobate posterior platform as in the *serotinus* juvenile of Telford (1975, pl. 7, fig. 9) and as in some *serotinus* Morphotype 3 *sensu* Klapper & Vodrážková (2013), b6604, top *Mimagoniatites* Limestone, *laticostatus* Zone. • T, U – *Eol.* cf. *laticostatus* (Klapper & Johnson, 1975). Specimens resembling *Eol. jacksoni* but without shelf extensions of basal cavity; T – lower view of b6601; U – upper view of b6602. • V – *L. bultyncki* (Weddige, 1977). Upper view of b6609, Sample HLS II-2, lower *Anarcestes* Limestone, *bultyncki* Zone. • W – *L. serotinus* (Telford, 1975) Morphotype 2 *sensu* Klapper & Vodrážková (2013). Lower view of b6610, Sample HLS II-4, middle *Anarcestes* Limestone, *cooperi* Subzone. • X – *L. serotinus* (Telford, 1975). Upper view of b6611, Sample HLS II-6, top *Anarcestes* Limestone, *patulus* Zone.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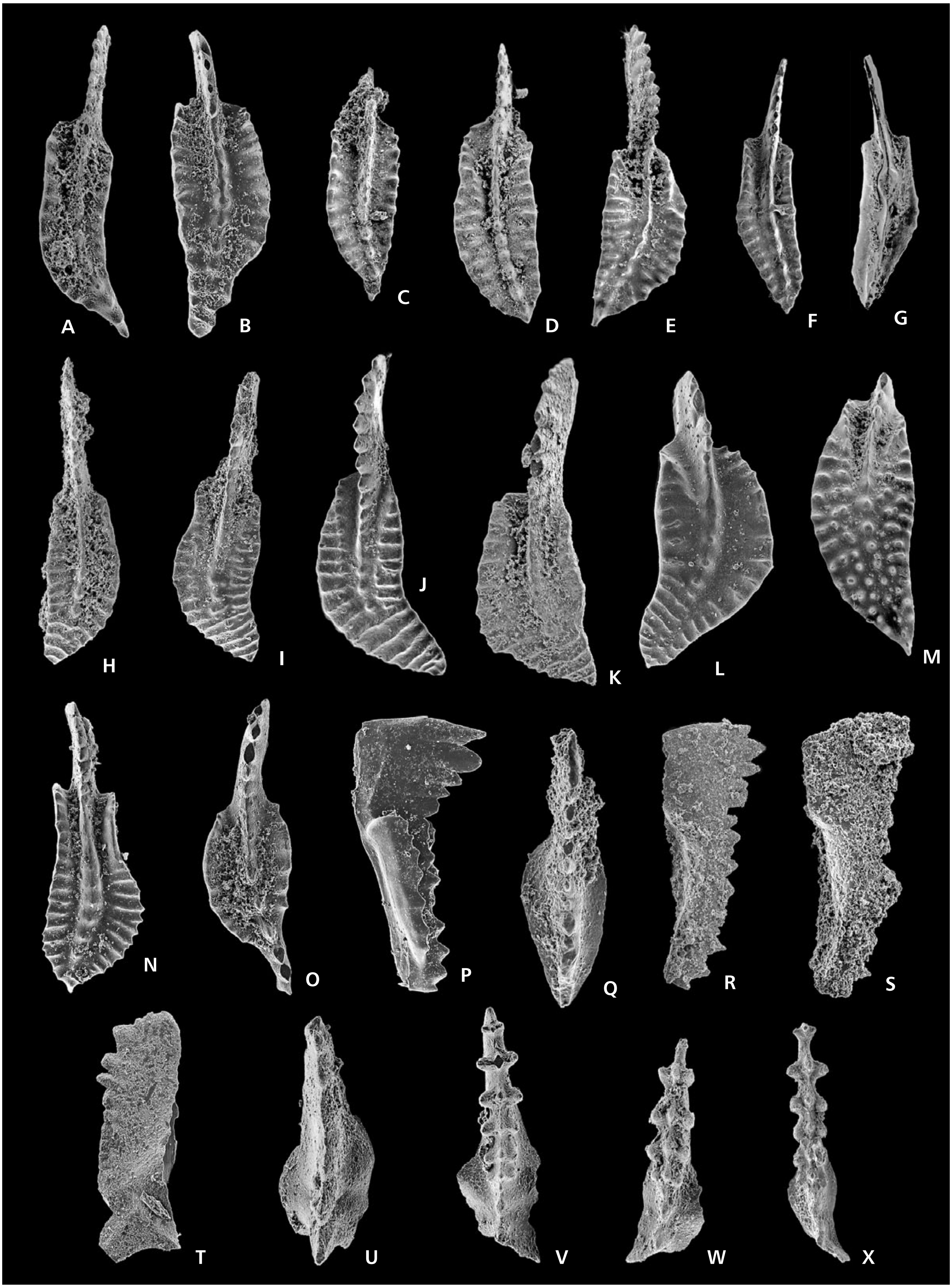
Discussion. – The Jebel Ihrs specimen strongly resembles paratype 1652/26 of *Eoc. juferevi*, illustrated by Aksenova (1987, pl. 27, fig. 6). Specimen B9.A-5.64 from El Khraouia closely resembles the holotype of *Eoc. pierrei* Bardashev, Weddige & Ziegler, 2002, which was based on a supposed *dehiscens* specimen from the *gronbergi* Zone of the La Grange Limestone (Bultynck 1989, pl. 3, fig. 1a–c). But there are also similarities with the holotype of *Eoc. juferevi*, in which the outer platform is less convex and less costate than in the paratypes. Since the holotypes and paratypes of *Eoc. juferevi* indicate some intraspecific variability in the species, the holotype of *Eoc. pierrei* and our El Khraouia specimens may only represent end members of the spectrum. Until more details become known, we assign *pierrei*-like forms with a cf. to *juferevi*.

We do not apply the intraspecific morphotype separation of Bardashev *et al*. (2002). The *juferevi* type material has a bowed, upward flexed posterior lower platform without a clear cavity inversion at the pointed tip. Most of the other polygnathids quoted under *juferevi* in Bardashev *et*

Figure 16. Conodonts from the Pragian to Eifelian of the Tafilalt; A–S – upper Emsian to lower Eifelian of Hamar Laghdad SW (HLS II); T, U – Pragian of Bou Tchrafine North; V–X – basal Emsian of BTW, all × 47. • A – *L. bultyncki* (Weddige, 1977). Upper view of specimen that is transitional towards *L. zieglerianus* (Weddige, 1977), b6612, Sample HLS II-1, lower *Anarcestes* Limestone, *bultyncki* Zone. • B – *L. bultyncki* (Weddige, 1977), Morphotype beta *sensu* Wang & Ziegler (1983). With concave outer posterior platform margin, b6613, Sample HLS II-8, basal Eifelian Limestone, higher *partitus* Zone. • C–E – *Po. patulus* Klapper, 1971. Upper views of three specimens; C – b6614, Sample HLS II-6, top *Anarcestes* Limestone, *patulus* Zone; D – b6615, Sample HLS II-7, basal *partitus* Zone; E – b6616, Sample HLS II-8 (age as 2). • F, G – *Po. partitus* Klapper, Ziegler & Mashkova, 1978. Upper and lower views, b6617, Sample HLS II-8 (age as B). • H–J – *L. bultyncki* (Weddige, 1977), Morphotype beta *sensu* Ziegler & Wang (1983). Upper views of three specimens; H – b6618, Sample HLS II-11, lower Eifelian Limestone, basal *costatus* Zone; I – b6619, Sample HLS II-8 (age as B); J – b6620, lower Eifelian Limestone, top *partitus* Zone. • K, L – *L. pinguis* (Weddige, 1977). Upper views of two specimens, Sample HLS II-11, basal *costatus* Zone; K – b6621; L – b6622. • M – *L. pinguis*? (Weddige, 1977). Aberrant form (or new taxon) with unusual, nodose platform, b6623, Sample HLS II-9, higher *partitus* Zone. • N – *Po. costatus* Klapper, 1971. B6624, Sample HLS II-11, basal *costatus* Zone. • O, P – *Po. angusticostatus* Wittekindt, 1966. Upper and outer lateral views of two specimens, Sample HLS II-11, basal *costatus* Zone; O – b6625; P – 6626. • Q–S – "*Oz.*" *carinthiaca* Schulze, 1968. Upper and outer lateral views of three specimens, Sample HLS II-7, basal *partitus* Zone; Q – b6627; R – b6628; S – b6629. • T, U – *Pel. serratus serratus* Jentzsch, 1962. Inner lateral and upper views, b6603, Sample BTN P/E1, Pragian, *steinachensis* Zone. V–X – *Caud. celtibericus* (Carls & Gandl, 1969). Upper views of three specimens, Sample BTW0, basal *Deiroceras* Limestone, lower Emsian (by correlation *bilatericrescens gracilis* Zone); V – b6630; W – b6631, transitional from *Caud. curvicauda* (Carls & Gandl, 1969); X – b6632.

Figure 17 (page 950). Conodonts from the Pragian to upper Emsian of Bou Tchrafine and Hamar Laghdad SW (HLS II), all × 47 unless stated otherwise. • A, B, E – *Lat. steinachensis* (Al-Rawi, 1977). Late morphotype with straight spindle; A, B – lower and upper views of b6633, Sample BTN Bk496, middle *Deiroceras* Limestone, lower Emsian, *bilatericrescens bilatericrescens* Zone; E – upper view of b6635, Sample BTN2, upper *Deiroceras* Limestone, lower Emsian, *bilatericrescens bilatericrescens* Zone. • C – *Lat. steinachensis* (Al-Rawi, 1977) Morphotype eta. Typical form, upper view, Sample BTN P/E2, *steinachensis* Zone, Pragian. • D – *Caud. sigmoidalis* (Carls & Gandl, 1969). Upper view, b6636, Sample BTW1, upper *Deiroceras* Limestone, *bilatericrescens bilatericrescens* Zone. • F – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Upper view, b6637, Sample BTN4, basal *Anetoceras* Limestone, *latus* Zone (locally with *Lat. armoricanus*). • G – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Transitional from *bilatericrescens gracilis* Bultynck, 1985, upper view, b6638, Sample BTN4 (age as F). • H–J – *Lat. bilatericrescens gracilis* Bultynck, 1985. Upper views of three specimens; H – b6639, Sample BTN4 (age as F, G); I – b6639, Sample BTN4 (age as F, G); J – b6640, 6641, Sample BTN2 (age as E). • K–M – *Lat. latus* (Al-Rawi, 1977). Upper views of three specimens, Sample BTW1b, basal *Anetoceras* Limestone, basal *latus* Zone; K – b6643; L – b6644; M – b6645, × 80. • N, O – *Lat. armoricanus* Bultynck, 1989. Upper and lower views, b6642, Sample BTW2, lower *Anetoceras* Limestone, *latus* Zone. • P–U – *I. rectirostratus* Bultynck, 1970. Upper and lower views of three specimens, Sample HLS II-1, lower *Anarcestes* Limestone, *bultyncki* Zone; P, Q – b6646; R, S – b6647; T, U – b6648.

Figure 18 (page 951). Conodonts from the Pragian to lower Eifelian of Bou Tchrafine, Hamar Laghdad SW (HLS II), and Rich el M'Bidia, an auxiliary locality of the eastern Dra Valley, all × 47, unless stated otherwise. • A, B – *Caudicriodus culicellus altus* (Weddige *in* Weddige & Requadt, 1985). Upper and outer lateral views of two specimens, Sample HLS II-7, basal Eifelian Limestone, basal *partitus* Zone; A – b6649; B – 6650. • C – *I.* aff. *corniger* Wittekindt, 1966. Upper view of specimen with symmetric posterior end of cavity, b6651, Sample HLS II-7 (age as A, B). • D–F – *I. corniger corniger* Wittekindt, 1966. Sample HLS II-9, lower Eifelian Limestone, higher *partitus* Zone; D – lower view of b6652; E – upper view of b6653; F – upper view of juvenile b6654. • G–I – *I. introlevatus* Bultynck, 1970. Upper and lower views of three specimens, Sample HLS II-11, basal *costatus* Zone; G – b6655; H – b6656; I – 6657. • J–L – *I. amabilis* Bultynck & Hollard, 1980. Lower and upper views of three specimens, Sample HLS II-11 (age as G–I); J – b6658; K – b6659; L – b6660. • M–P – *Crit. miae* (Bultynck, 1971); M, N – upper and inner lateral views of b6661, Sample BTW1, upper *Deiroceras* Limestone, upper *excavatus* M114 or *miae* Zone; O, P – upper and outer lateral views of b6662, Sample BTW2, lower *Anetoceras* Limestone, basal *steinhornensis* Zone. • Q, R – *Crit. steinhornensis* (Ziegler, 1956); Q – upper view of b6663, Sample BTW2, basal *steinhornensis* Zone; R – upper view of b6664, Rich el M'Bidia, Sample 7, lower Mdâouer-el-Kbîr Formation, *steinhornensis* Zone. • S–U – *Latericriodus* sp. nov. Upper, lower and side views, b6665, Sample BTN P/E2, Pragian, *steinachensis* Zone. • V–X – *Eoct. pireneae* (Boersma, 1974) Group. Incomplete specimen, upper, lower and oblique lateral views, b6666, Sample BTN P/E2 (age as S–U), × 80.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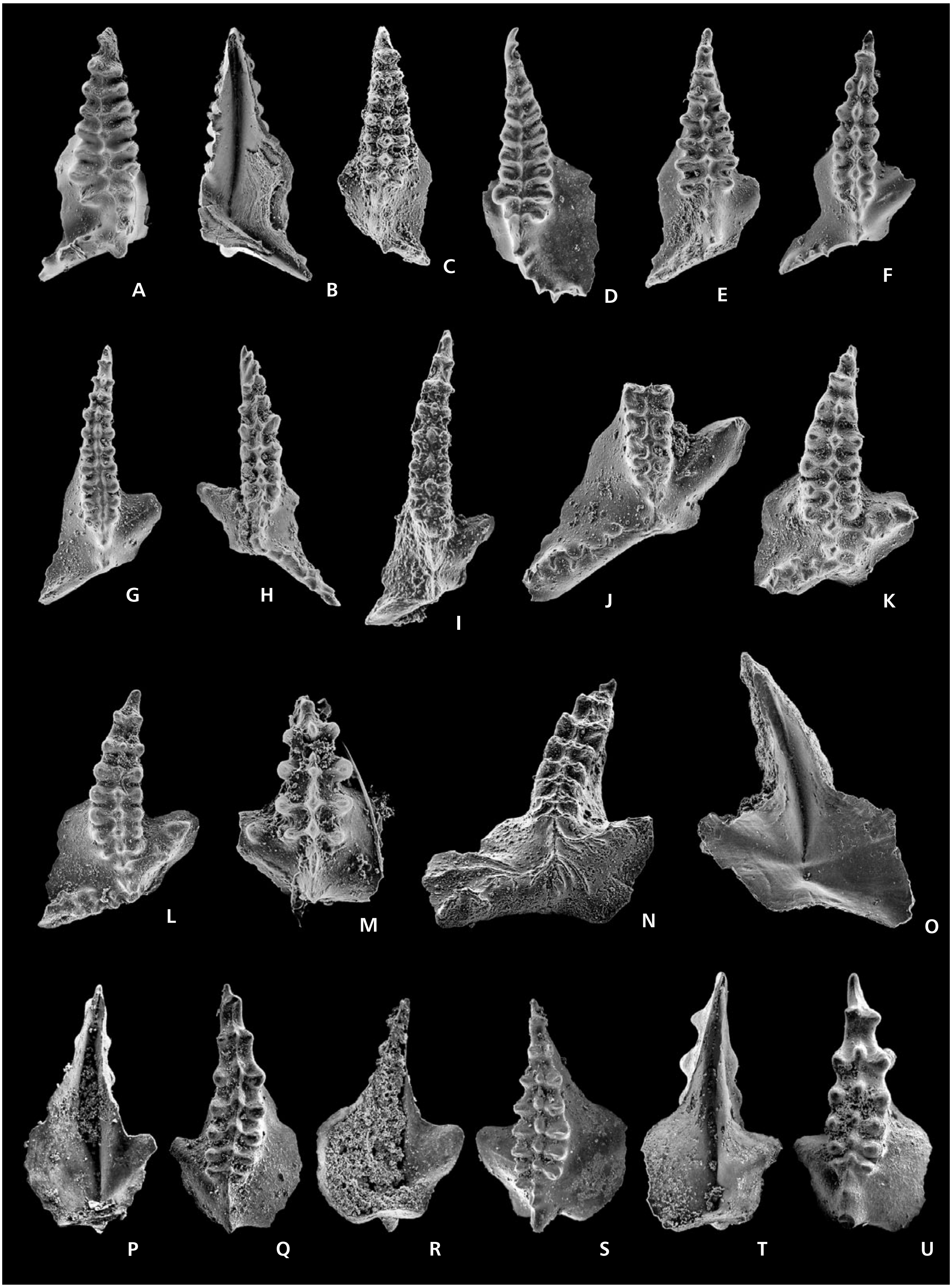
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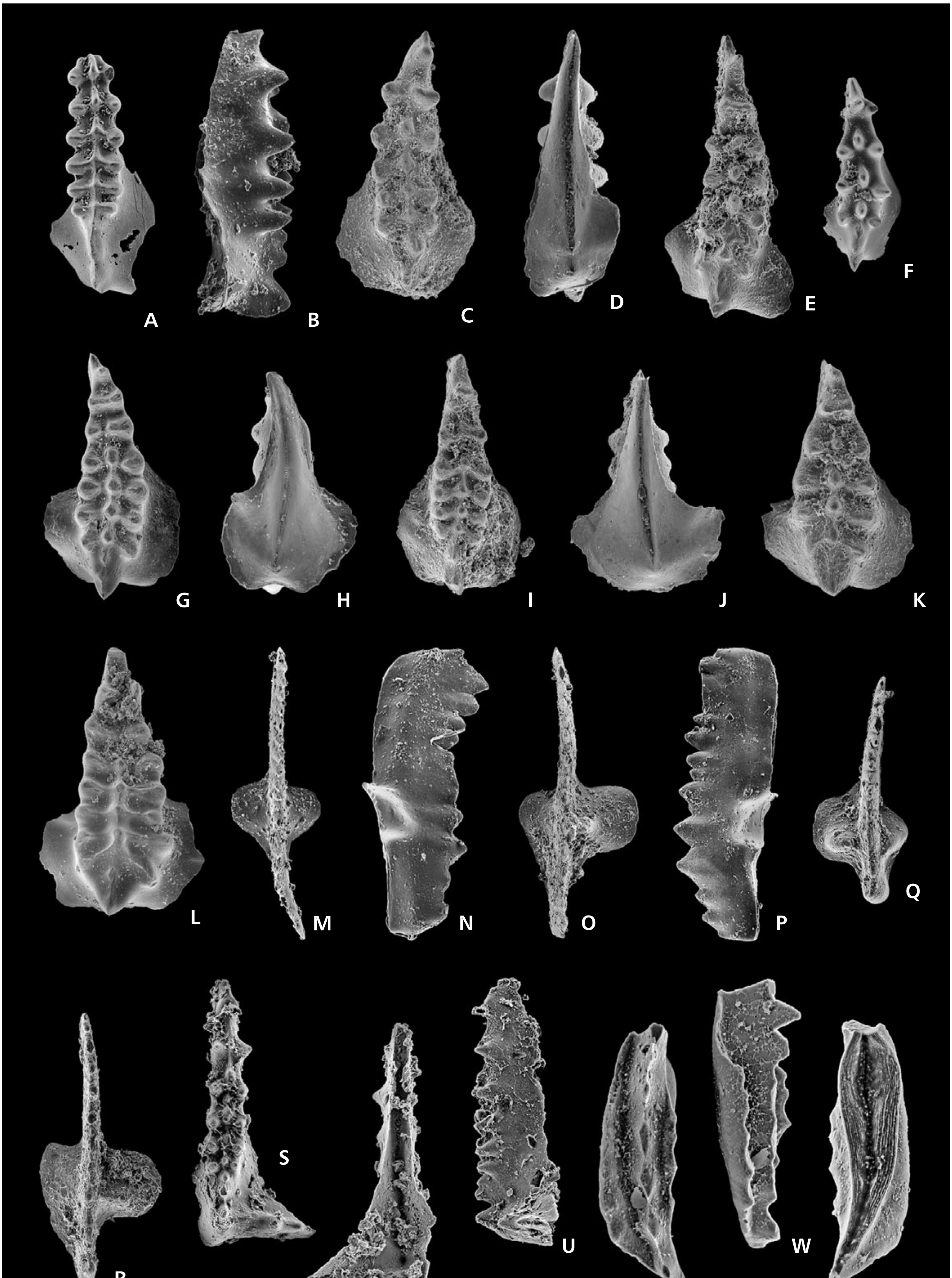
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al. (2002) do not conform to the types. They lack the posterior carina, which leaves no lingua. But we agree with Bardashev *et al*. (2002) that the extended outer posterior platform of a *gronbergi* specimen from Ou Driss, figured in Bultynck (1985), resembles *Eol. juferevi*. A rather smooth specimen with fine posterior carina, figured in Bultynck (1989, pl. 3, fig. 7a, b) as transitional form between *Eol. gronbergi* and *Eol. laticostatus*, is also similar but the inner platform is wider. *Polygnathus* sp. 3 of Luppold (1987) is possibly an extreme variant of this group with especially wide platform; its basal cavity is not known. This form was questionably assigned to *Eoc. juferevi* in Bardashev *et al*. (2002).

Eoc. lenzi (*sensu* its holotype) lacks the widening of the outer posterior platform and shows a different transverse platform ornament. In the holotype of the related *Eoc. richi*, originally figured by Lane & Ormiston (1979, pl. 6, figs 21, 22) as *Po*. cf. *gronbergi*, there are two to three rows of nodes on the central platform.

Geographic distribution. – Central Asia (Gorny Altai), Armorican Massif, *cf.* Sardinia, and Anti-Atlas.

Stratigraphic range. – *Gronbergi* and (*cf.* specimens) *laticostatus* zones.

***Linguipolygnathus* sp. nov.**
Figure 10A, B

Description. – A single specimen from Bed $31a_1$ at Jebel Ihrs does not resemble any named lower Emsian polygnathid. It has a very short free blade with four denticles plus an incipient denticle at the front. The subrectangular platform has upturned margins, the outer of which is higher than the inner. The margins bear regular transverse costae but there are wide, smooth adcarinal troughs. The outer margin curves sharply inwards near the posterior end, followed by a small, asymmetric lingua that is demarcated by constrictions. The inner platform margin is slightly convex. The tranverse ridges of the lingua weaken in the middle. The central basal pit is small, as in a typical *Linguipolygnathus*, with a very incipient outer protuberance.

Discussion. – There is a slight resemblance to *Eol. tomi* Bardashev, Weddige & Ziegler, 2002 and *Eol. senckenbergi* Bardashev, Weedige & Ziegler, 2002, which both have a narrower platform and a less inverted basal cavity.

The constricted lingua distinguishes the Jebel Ihrs specimen from *L. khalymbadzhai* Bardashev, Weddige & Ziegler, 2002 (perhaps better a subspecies of *L. johnsoni* Bardashev, Weddige & Ziegler, 2002), and the younger *L. bultyncki* [which includes *L. mawsonae* (Long & Burret, 1989), see Klapper & Vodrážková 2013]. Since only one specimen is currently available, open nomenclature is preferred for this possibly new species, which lies close to the rootstock of upper Emsian linguipolygnathids.

Geographic distribution. – Only known from the Anti-Atlas.

Stratigraphic range. – Upper part of *inversus* Zone.

Linguipolygnathus* aff. *inversus
Klapper & Johnson, 1975
Figure 25Z, AA

Description. – Specimens from the Mdâouer-el-Kbîr and lower Timrhanrhart formations of the eastern Dra Valley are characterized by a basal, subsymmetric pit without outer lip, which is situated under the anterior third of the platform. The straight anterior part of the platform and the incurved, well-developed tongue are about of the same length. The carina fades as a series of minor, superimposed nodes on the anterior half of the tongue, just behind the platform inflexion.

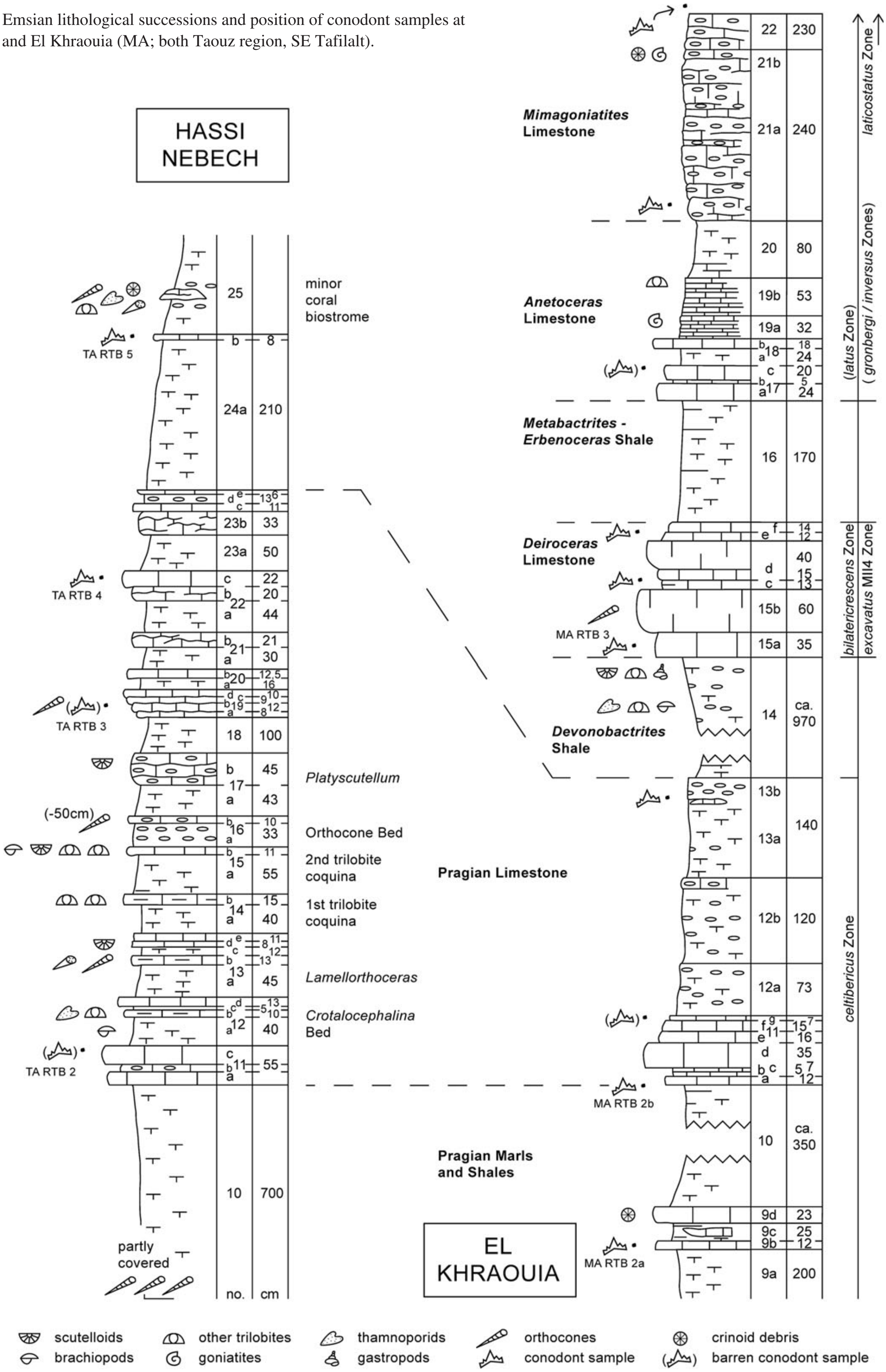
Discussion. – Typical *L. inversus*, in the sense of the holotype and of a specimen illustrated in Fig. 25AB, AC, lack a well-developed tongue. Forms assigned to *L. khalymbadzhai* in Bardashev *et al.* (2002) differ in deeper adcarinal furrows of the anterior platform and in an elevated, angular outer platform corner. There are similarities with *L. johnsoni*, which, however, is characterized by an outer lip of the basal pit, as in *L. serotinus*, and the inner platform is markedly narrower than the outer.

Stratigraphic range. – In the Anti-Atlas, this form is so far known from the lower Emsian *inversus* Zone to the upper Emsian *Sellanarcestes* Limestone of the eastern Dra Valley (level of *I.* aff. *corniger*, *ca* basal *corniger* Zone).

***Caudicriodus celtibericus* (Carls & Gandl, 1969)**
Figures 5C, D, 16V–X, ?20A, H, M, 22N, 28A, aff. 29M

* 1969 *Icriodus huddlei celtibericus* n. ssp.; Carls & Gandl, pp. 182–183, pl. 16, figs 18–20.
1976 *Caudicriodus celtibericus* (Carls & Gandl). – Bultynck, pp. 29–31, pl. 6, figs 7–19, pl. 7, figs 27–29.
1979 *Caudicriodus celtibericus* (Carls & Gandl). – Bultynck, pl. 2, fig. 18.
1990 *Icriodus celtibericus* Carls & Gandl. – Olivieri & Serpagli, p. 62, pl. 1, figs 1–5, 19.
1995 *Caudicriodus celtibericus* (Carls & Gandl). – Kalvoda, pp. 35–36, pl. 1, figs 5–9, 11, pl. 2, figs 1, 4.

Figure 19. Lower Emsian lithological successions and position of conodont samples at Hassi Nebech (TA) and El Khraouia (MA; both Taouz region, SE Tafilalt).



2001 *Caudicriodus celtibericus* (Carls & Gandl). – Slavík, p. 261, pl. 2, fig. 7.

2003 *Caudicriodus celtibericus* (Carls & Gandl). – Bultynck, fig. 1, line 4, pl. 1, fig. 27.

2004a *Caudicriodus celtibericus* (Carls & Gandl). – Slavík, pl. 1, figs 7, 8.

2004b *Caudicriodus celtibericus* (Carls & Gandl). – Slavík, fig. 11.1–3.

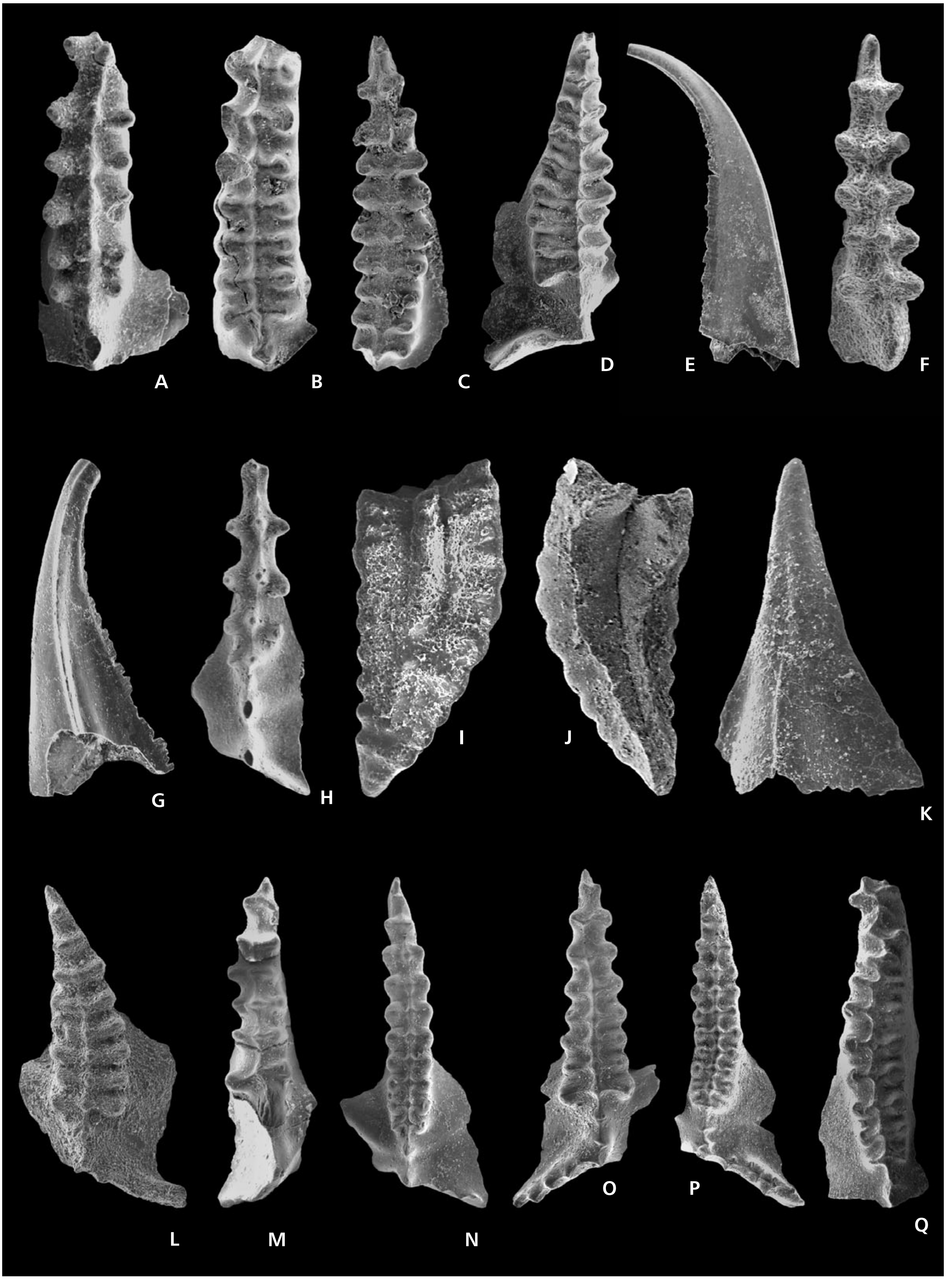
Description. – The spindle of *Caud. celtibericus* is narrow and slightly concavo-convex. The tip of the denticles on the spindle are rounded; the two to three middle row denticles behind the spindle are higher than those on the spindle. The middle-and lateral row denticles are not connected. The length of the outer posterior lateral process is about 1/3 of the length of the spindle and is not denticulated. The angle between the axis of the spindle and posterior lateral process is between 130° and 110°. There is no development of a spur on the inner posterior side of the element. In the posteriormost part of the spindle the distance between the transversal denticle rows is smaller than on the main part of the spindle.

Discussion. – Specimens from the "Pragian Limestone" are variably very narrow (Fig. 5D) or wider (Fig. 5C). Juveniles have in general only few transverse rows of nodes (five in Fig. 20H, six in Fig. 20M, only three in Fig. 22N, four in Fig. 28A). Questionable specimens from the oldest sample (*steinachensis* Zone) at El Khraouia (top Bed 8, Fig. 20A) are incomplete. In these, the presence of a second main denticle behind the platform and of a lateral process cannot be verified. But the posterior extension of the basal cavity speaks against *Caud. curvicauda* and there is no narrowing of the posterior row interspaces as in the associated *Lat. steinachensis* or *Lat.* cf. *claudiae*. Small-sized specimens from the basal "Pragian Limestone" of Hassi Nebech (Sample TA4, *e.g.*, Fig. 22N) are somewhat intermediate from *Caud. curvicauda*.

Figure 20. Conodonts from El Khraouia; A–D – top Bed 8, top "Pragian Marls and Shales", *steinachensis* Zone; E–G – Bed 9b, top "Pragian Marls and Shales", *steinachensis* Zone; H – "Pragian Limestone", Bed 11a, *celtibericus* Zone; I–M – *Deiroceras* Limestone, Bed 15a, *bilatericrescens gracilis* and *excavatus* Morphotype 114 zones; N–Q – *Deiroceras* Limestone, Bed 15f, *bilatericrescens bilatericrescens* Zone. • A – *Caud.* ?*celtibericus* (Carls & Gandl, 1969). B9.A-5.144, juvenile specimen, × 150. • B, C – *Lat.* cf. *claudiae* (Klapper, 1980 *in* Johnson *et al.* 1980). Two specimens, posterior end incomplete, × 85; B – B9.A-5.145; C – B9.A-5.146. • D – *Lat. steinachensis* (Al-Rawi, 1977) Morphotype beta. With straight median axis, B9.A-5.147, × 60. • E – *Bel. triangularis* (Stauffer, 1940). B9.A-5.43, × 50. • F – *Caud.* cf. *curvicauda sensu* Carls & Gandl (1969, pl. 16, fig. 17), B9.A-5.44, juvenile, × 120. • G – *Bel. resima* (Philip, 1965). B9.A-5.42, × 65. • H – *Caud. celtibericus* (Carls & Gandl, 1969). Small specimen, transitional from *Caud. curvicauda* (Carls & Gandl, 1969), B9.A-5.45, × 115. • I, J – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. B9.A-5.53, juvenile, × 120. • K – "*Acodina* sp." (coniform icriodid). B9.A-5.52, × 120. • L – *Caud. sigmoidalis* (Carls & Gandl, 1969). B9.A-5.46, × 55. • M – *Caud. celtibericus* (Carls & Gandl, 1969). Median-sized specimen, B9.A-5.48, × 75. • N–Q – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). Four specimens illustrating the variability; N – B9.A-5.50, × 50; O – B9.A-5.51, × 50; P – B9.A-5.148, × 40; Q – B9.A-5.149, × 65.

Figure 21 (page 956). Conodonts from the *Deiroceras* and upper *Mimagoniatites* Limestone of El Khraouia; A, B – Bed 15a; C–H – Bed 15f; both *excavatus* Morphotype 114 Zone; I–Q – top Bed 22, *laticostatus* Zone. • A – *Neop. perlineatus* Ziegler & Lindström, 1971. B9.A-5.47, × 120. • B – *Crit. miae* (Bultynck, 1971). B9.A-5.49, × 75. • C – *Eol. radula* sp. nov. Strongly curved paratype with constricted tongue, B9.A-5.56, × 60. • D–F – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. Typical specimens with narrow platform and upturned anterior platform margins; D – B9.A-5.57, × 100; E – B9.A-5.58, × 75; F – B9.A-5.59, × 60. • G, H – *Lat. bilatericrescens gracilis* Bultynck, 1985. G- B9.A-5.54, × 75; H – B9.A-5.55, × 60. • I – *Eol.* cf. *vigierei* (Bultynck, 1989). Incomplete specimen with serrate, strongly extended outer platform corner, B9.A-5.60, × 70. • J – *L. gilberti* (Bardashev, 1986). Morphotype with triangular lingua, B9.A-5.62, × 75. • K – *Eol. laticostatus* (Klapper & Johnson, 1975). B9.A-5.63, × 100. • L, M – *Caud. ultimus* Weddige *in* Weddige & Requadt, 1985. Upper and oblique view, B9.A-5.61, × 100. • N, O – *Eoc.* cf. *juferevi* (Aksenova, 1987). Specimen resembling the French holotype of *Eoc. pierrei* Bardashev, Weddige & Ziegler, 2002, B9.A-5.64, × 55. • P, Q – *Eol. vigierei* (Bultynck, 1989). Slightly transitional to *Eol. gilberti*, B9.A-5.150, × 60.

Figure 22 (page 957). Lower Emsian conodonts from the southern Tafilalt; A–K – Jebel el-Mrier; L–N – Hassi Nebech. • A – *Caud. sigmoidalis* (Carls & Gandl, 1969). B9.A-5.65, Sample AL RTB 6, *Deiroceras* Limestone, *bilatericrescens* Zone, × 60. • B – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). B9.A-5.66, Sample AL RTB 6 (level as 1) × 65. • C – *Lat. bilatericrescens multicostatus* (Carls & Gandl, 1969). Morphotype with double-rowed processes, B9.A-5.67, Sample AL RTB 7a, *Anetoceras* Limestone, *steinhornensis* Zone, × 50. • D – *Crit. steinhornensis* (Ziegler, 1956). B9.A-5.68, Sample AL RTB 7a (level as 3), × 60. • E, H – *Neop. perlineatus* Ziegler & Lindström, 1971; E – specimen from Sample AL RTB 8, B9.A-5.69, × 65; H – specimen from Sample AL RTB 9a, B9.A-5.70, × 60; both *Mimagoniatites* Limestone, *steinhornensis* Zone. • F, G – *Eol.* cf. *gronbergi* (Klapper & Johnson, 1975). Abraded specimen, B9.A-5.71, Sample AL RTB 8 (level as E) × 75. • I, K – *Bel. triangularis* (Stauffer, 1940). Both upper *Mimagoniatites* Limestone, upper *steinhornensis* Zone/Upper *Belodella* Ecozone; I – specimen from Sample AL RTB 9a, B9.A-5.72, × 80; K – specimen from Sample AL RTB 9b (11, B9.A-5.73, × 75. • J – *Crit. steinhornensis* (Ziegler, 1956), B9.A-5.74, × 85, AL RTB 9b (level as I). • L, M – *Bel. resima* (Philip, 1965). Two specimens from the higher part of the "Pragian Limestone", *celtibericus* Zone, Sample TA RTB 4; L – B9.A-5.75, juvenile, × 150; M – B9.A-5.76, × 45. • N – *Caud. celtibericus* (Carls & Gandl, 1969). Small specimen, somewhat similar to *Caud. curvicauda*, B9.A-5.77, Sample TA RTB 4 (level as 11), × 120.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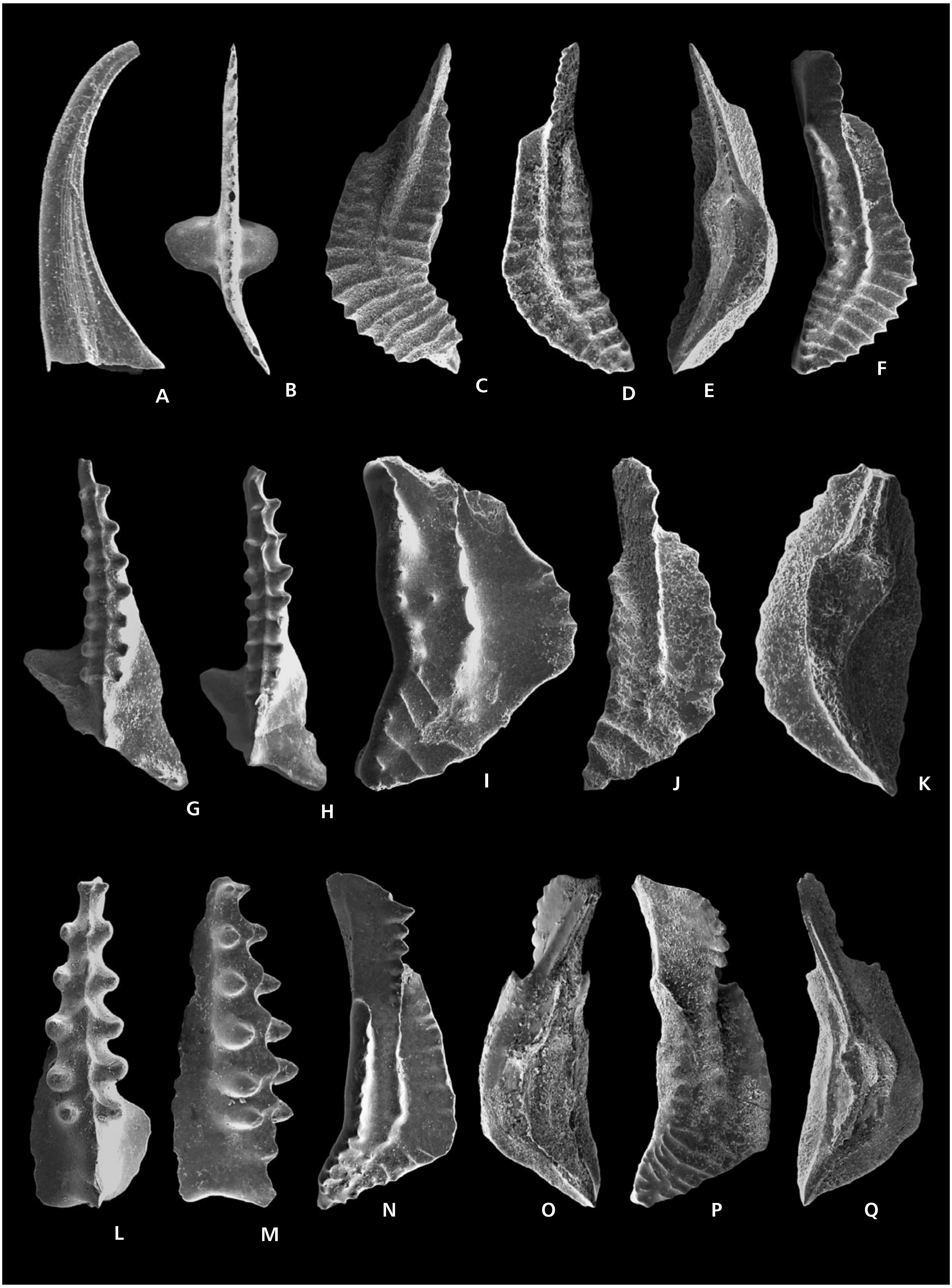
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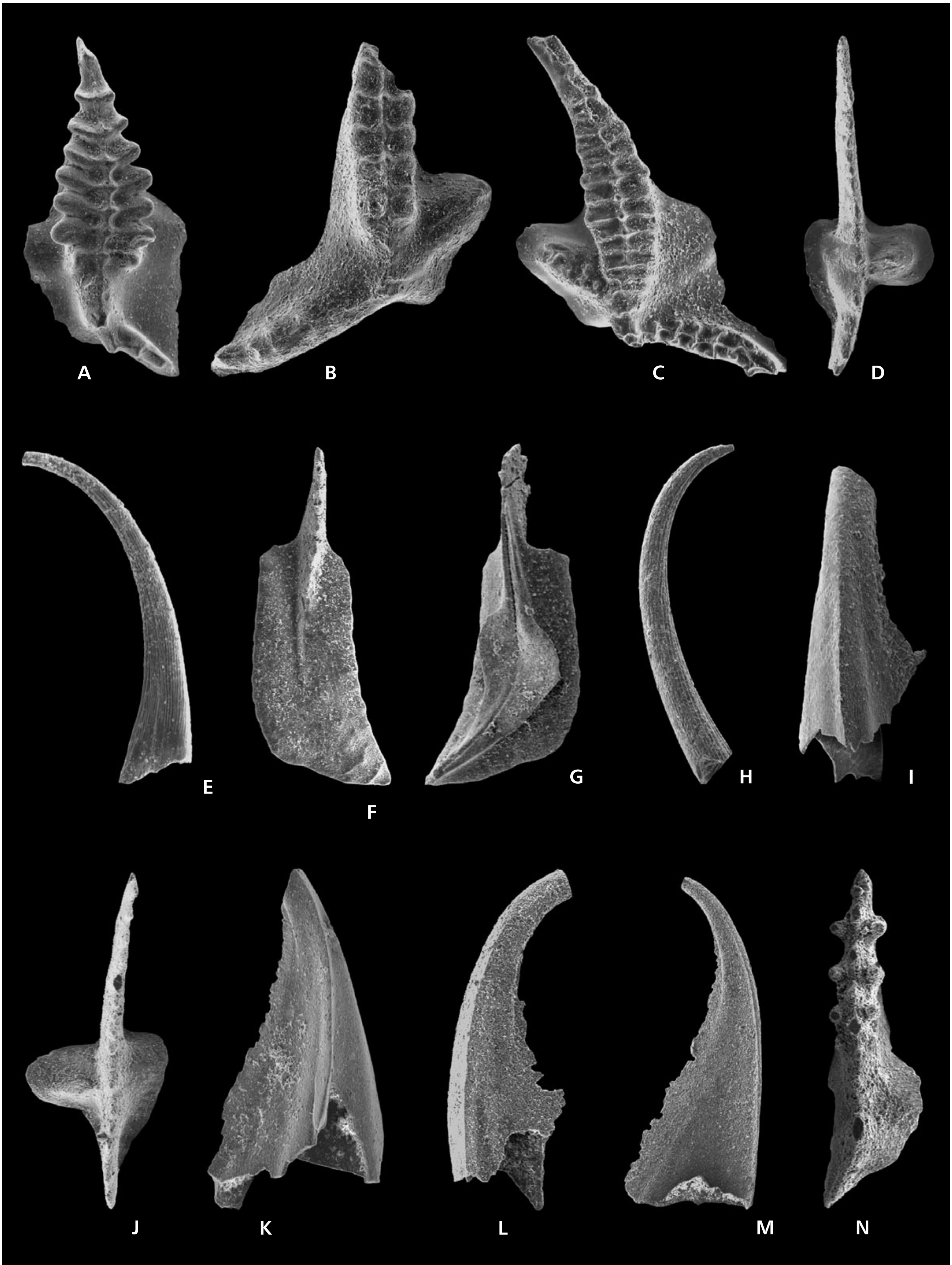
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The specimen of Fig. 16X (b6632) is closest to the figured type specimens of Carls & Gandl (1969). In all three specimens of Fig. 16V–X the distance between the transversal denticle rows on the major part of the spindle is larger than in the type material; this suggests a different ontogeny. Specimen b6631 (Fig. 16W) resembles to some extend the mostly older *Caud. curvicauda*.

A small *Caudicriodus* from the "*Latanarcestes*" nodules of Rich Tamelougou has a very short terminal side lobe of the cavity platform, but not any more of the median node row. Therefore, it appears to be transitional to *Icriodus* s. str. and has been preliminarily identified as *Caud*. aff. *celtibericus*.

Ziegler (1975, pp. 117–119) considered *Caud. celtibericus* as a junior synonym of *I. huddlei* Klapper & Ziegler, 1967. However, the preservation of the holotype of *I. huddlei* is not good enough to be used currently in precise taxonomy. The margin of the posterior part of the basal cavity is too corroded (see Ziegler 1956, pl. 6, fig. 17). Until a revision based on type material, *I. huddlei* is treated as a nom. dub.

Geographic distribution. – ?Alaska, New York State, Germany (Harz Mountains), Pyrenees, Cantabrian Mountains, Celtiberia, Ossa-Morena Zone (SW Spain), Sardinia, Moroccan Meseta, Anti-Atlas, Carnic Alps, Bohemia, Pakistan, Russian Far East.

Stratigraphic range. – Upper Pragian *celtibericus* Zone to high in the lower Emsian (*latus* Zone). Its oldest occurrence is from the upper part of the Dvorce-Prokop Limestone in the Barrandian area, below the first occurrence of *Eol. excavatus* (Slavík 2004a, pp. 63–66, 2004b, p. 459). The youngest records are our specimens from the upper *Anetoceras* Limestone of the Tafilalt.

Caudicriodus aff. *sigmoidalis* (Carls & Gandl, 1969)

Figure 27R

Description. – Three small icriodids from the *Hollardops* Limestone of Rich Tamelougou are characterized by a short, nodose outer process, which curves into a rather long posterior extension of the median row of the spindle. It is almost as long as the spindle but bears just one denticle. The spindle has only few rows, with rounded and isolated denticles.

Discussion. – The three specimens do not fit the other icriodid taxa of the same unit. They are somewhat similar to juveniles of the stratigraphically older *Caud. sigmoidalis*, in which, however, the side denticles are tranversally elongate and the outer process is more distinctive. The latter is more reduced in *Caud. culicellus*, *Caud. ultimus*, and *Caud. trojani*, and in these three species the spindle is much longer than the posterior middle row extension. The juvenile nature of the material suggests to use open nomenclature for our form.

Stratigraphical range. – So far only known from the basal upper Emsian *fusiformis* Zone.

Latericriodus Müller, 1962

Type species. – *Icriodus latericrescens* Branson & Mehl, 1938.

Discussion. – We use the genus *Latericriodus* in a wide sense, although we are aware that Lower Devonian lineages could be separated at the genus level. Such revision is beyond the scope of this paper. The type group of the genus ranges in North America from the upper Emsian to the upper Givetian (see review of icriodid ranges in Bultynck 2003).

Latericriodus steinachensis (Al-Rawi, 1977)

Figures 17A–C, E, 20D

1967 *Icriodus latericrescens bilatericrescens* Ziegler. – Van Adrichem Boogaert, pp. 181–182, pl. 3, figs 18–20 [Morphotype eta].

1971 *Icriodus latericrescens* group. – Klapper & Philip, p. 438, fig. 8 [Morphotype eta].

*e.p. 1977 *Icriodus steinachensis* sp. nov.; Al-Rawi, pp. 55–56, pl. 5, fig. 42 (holotype = Morphotype eta), 43 (paratype = Morphotype beta).

1979 *Icriodus steinachensis* Al-Rawi. – Lane & Ormiston, p. 54, pl. 4, figs 28, 29 [transitional between holotype and paratype].

1980 *Icriodus steinachensis* Al-Rawi eta morphotype. – Klapper & Johnson, p. 448, pl. 2, figs 25–27 [fig. 25 = broad submorphotype, additional synonymy].

1980 *Icriodus steinachensis* Al-Rawi beta morphotype. – Klapper & Johnson, p. 448, pl. 2, figs 20–22 [fig. 19 is transitional to a broad Morphotype eta; additional synonymy].

1981 *Icriodus steinachensis* Al-Rawi eta morphotype. – Johnson & Klapper, pl. 1, figs 15, 16 [figs 18, 19 = Klapper & Johnson 1980, pl. 1, fig. 25, is a broad submorphotype].

1983 *Icriodus steinachensis* Al-Rawi. – Murphy & Matti, p. 58, pl. 5, fig. 31 (Morphotype beta), fig. 36 (Morphotype eta).

1984 *Icriodus steinachensis* Al-Rawi. – Murphy & Cebecioglu, figs 2a–r, z–hh, 5g–q [typical Morphotype beta = 2h, z–cc, ff, hh, 5g, h, j, n, slender beta submorphotype = 2a, c–e, gg, 5o, p, typical Morpho-

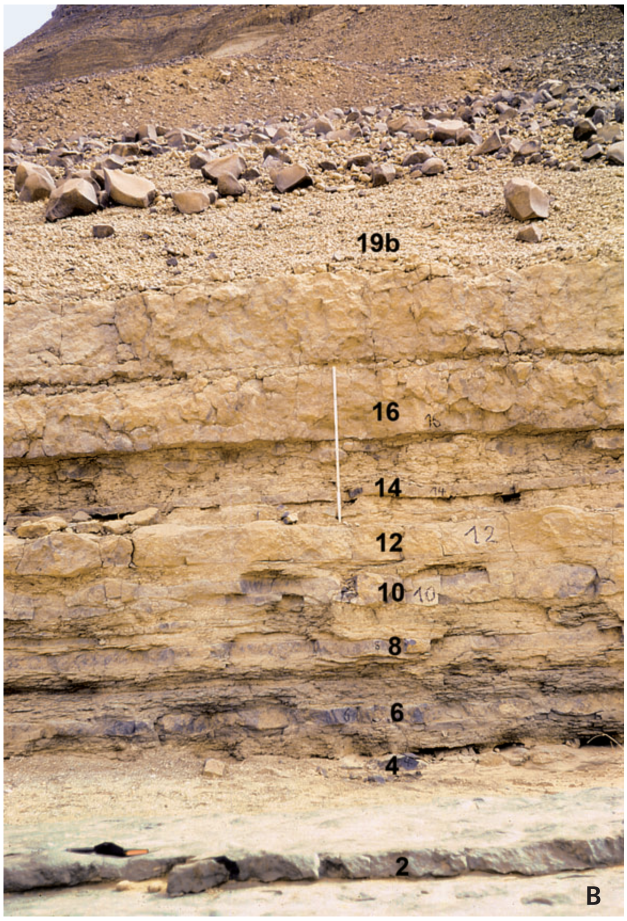


Figure 23. Emsian outcrops at Mdâouer-el-Kbîr (A) and El Anhsour (B) in the eastern Dra Valley.

type eta = 2b, f, k–r, ee, 5q, broad eta submorphotype = 2g, i, j, dd, 5i, k].

e.p. 1985 *Icriodus steinachensis* Al-Rawi beta morphotype. – Chlupáč, Lukeš, Paris & Schönlaub, pl. 2, fig. 4 (only).

1994 *Icriodus steinachensis* Al-Rawi. – Valenzuela-Ríos, pl. 8, figs 5, 7, 8, 11.

1994 *Icriodus steinachensis* Al-Rawi eta morph. – Mawson & Talent, pp. 47, 49, figs 9k–n.

1995 *Icriodus steinachensis* Al-Rawi eta morph. – Dongal, p. 137, figs 5a, b [transitional to Morphotype beta].

? 1999 *Icriodus steinachensis* Al-Rawi eta morph. – Talent & Mawson, p. 73, pl. 4, fig. 6, pl. 7, figs 5, 6, pl. 12, fig. 17 [all fragmentary].

2001 *Latericriodus steinachensis* Al-Rawi eta morph. – Slavík, pl. 2, fig. 4.

2002 *Icriodus steinachensis* Al-Rawi beta. – Valenzuela-Ríos, pp. 416–417, pl. 2, fig. 2 [slender submorphotype, transitional to Morphotype eta].

2004a *Latericriodus steinachensis* Al-Rawi beta. – Slavík, figs 3.1, 3.14 (slender submorphotypes), fig. 3.13 (here re-assigned as Morphotype eta).

2004a *Latericriodus steinachensis* Al-Rawi eta. – Slavík, figs 3.2–3.4.

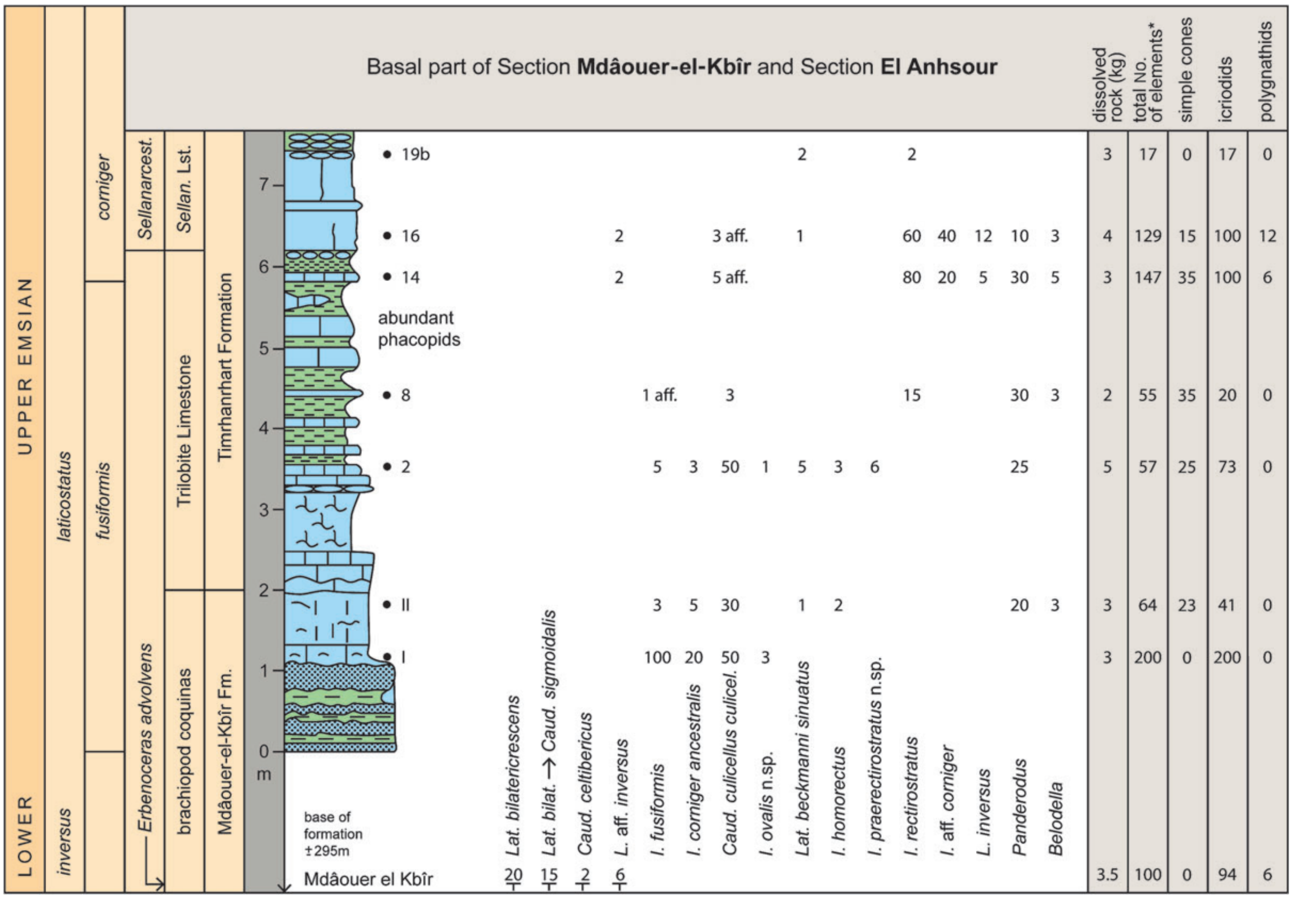


Figure 24. Lithological succession, sample positions, and conodont ranges at El Anhsour (eastern Dra Valley).

2004b *Latericriodus steinachensis* Al-Rawi beta. – Slavík, pl. 1, fig. 4 [here re-considered as Morphotype eta].

2004b *Latericriodus steinachensis* Al-Rawi eta. – Slavík, pl. 1, fig. 5.

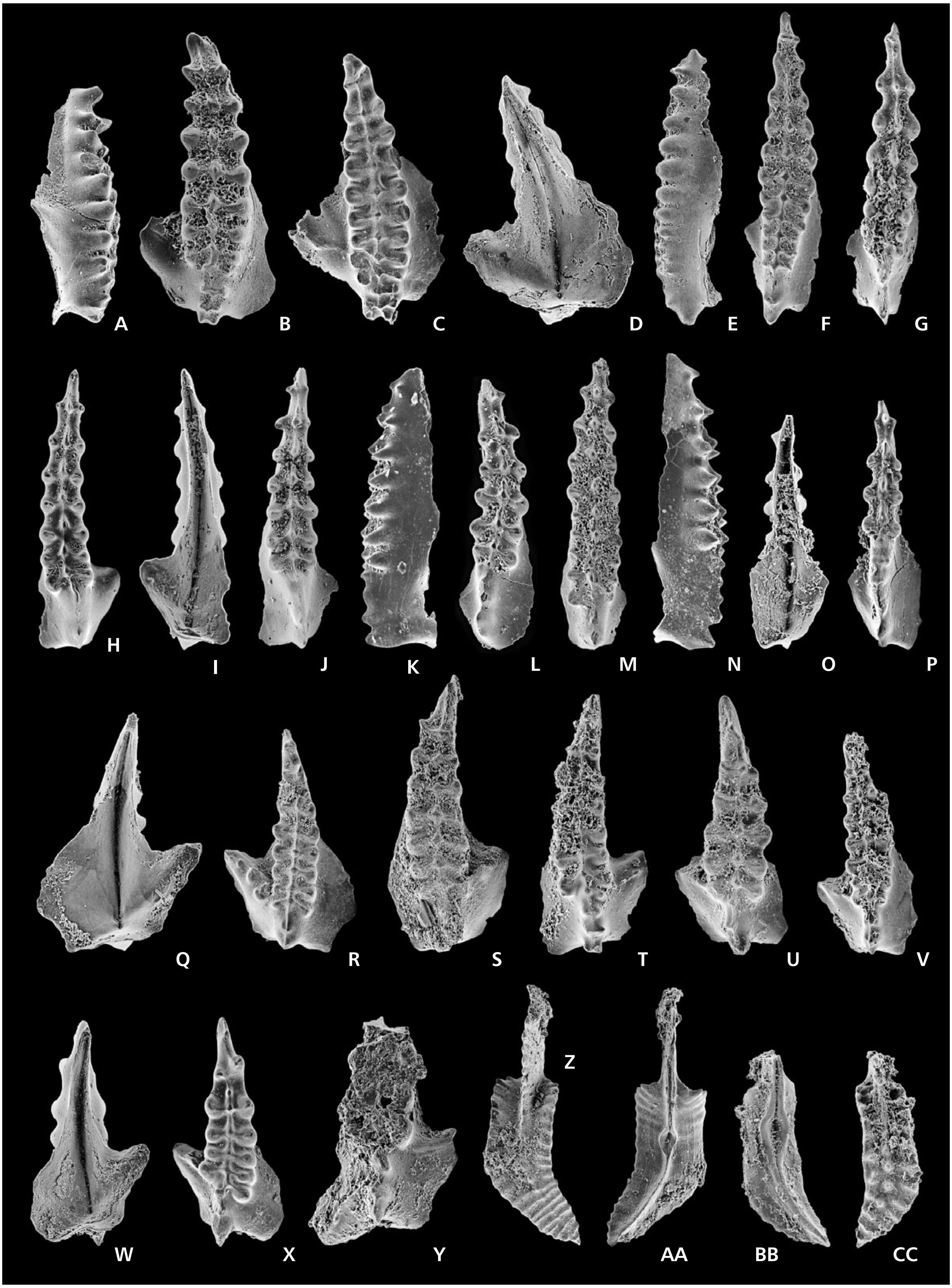
2004 *Latericriodus steinachensis* Al-Rawi eta morph. – Slavík & Hladil, pp. 144–145, pl. 1, figs 2–4 [wide and narrow submorphotypes but fig. 4 is a juvenile].

2004 *Latericriodus steinachensis* Al-Rawi beta morph. – Slavík & Hladil, p. 145, pl. 1, figs 2–4 [spindle not very curved].

2012 *Caudicriodus*? *steinachensis* Al-Rawi eta morphotype of Klapper & Johnson, 1980. – Drygant & Szaniawski, pp. 850, 852, fig. 11m [with additional and partly different synonymy].

Discussion. – In the holotype of *Lat. steinachensis* the spindle is rather slender and the posterior part of the basal cavity is not much expanded. In the paratype the spindle is shorter and broader and the posterior part of the basal cavity is expanded. However, many characteristics are the

Figure 25. Conodonts from the upper Emsian of El Anhsour of the eastern Dra Valley; A–V – the *fusiformis* Zone; W–AC – beds with *I.* aff. *corniger*, *ca corniger* Zone, all × 47. • A–D – *I. fusiformis* Carls & Gandl, 1969. Sample I, upper Mdâouer-el-Kbîr Formation; A – outer lateral view of b6667; B – upper view of b6668; C – upper view of b6669; D – lower view of b6670. • E–G – *I. ovalis* sp. nov. Sample I, upper Mdâouer-el-Kbîr Formation; E – outer lateral view of paratype b6671; F – upper view of holotype b6672; G – upper view of paratype 6673. • H, I – *I. corniger ancestralis* Weddige, 1977. Sample II, top Mdâouer-el-Kbîr Formation; H – upper view of b6674; I – lower views of b6675. • J–L – *Caud. culicellus culicellus* Bultynck, 1976. Sample II, top Mdâouer-el-Kbîr Formation; J – upper view of b6676; K – outer lateral view of b6677; L – outer lateral view of b6678. • M–P – *I. homorectus* Weddige, 2003. Sample II (as 8–12); M – upper view of b6679; N – outer lateral view of b6680; O, P – lower and upper views of b6681. • Q, R – *I. praerectirostratus* sp. nov. Sample 2, basal Timrhanrhart Formation, lower and upper views of holotype b6682. • S–X – *I. praerectirostratus* sp. nov. Type level (Sample 2); S – upper view of paratype b6683; T – upper view of paratype b6684; U – upper view of paratype 6685; V – upper view of paratype b6686; W, X – lower and upper views of paratype b6687. • Y – *Latericriodus beckmanni sinuatus* (Klapper, Ziegler & Mashkova, 1978). Upper view of fragmentary b6688, Sample 19b, *Sellanarcestes* Limestone Member. • Z, AA – *L.* aff. *inversus* (Klapper & Johnson, 1975). Specimen with extensive lingua and subsymmetric basal pit, b6689, Sample 14, top of Trilobite Limestone. • AB, AC – *L. inversus* (Klapper & Johnson, 1975). Typical specimen with short, semi-crossed lingua, b6690, Sample 14, top of Trilobite Limestone.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same in both type specimens: the outline of the spindle is clearly concavo-convex; the axis of the element is distinctly curved, the cross-sections of the denticles on the spindie are rounded, the middle and lateral rows denticles are not fused, and the outer lateral, posterior process joins the extension of the middle row denticles just before its end. Klapper & Johnson (1980) distinguished beta and eta morphotypes corresponding mostly to the paratype and the holotype as originally established by Al-Rawi (1977). However, they defined both morphotypes on the position of the maximum spindle width, not on the distinction between slender and broad forms. Consequently, there are wide and narrow forms (submorphotypes) within both named morphotypes (see our new synonymy list above). The morphometric study of Murphy & Cebecioglu (1984) suggests a large intraspecific variability, but with morphological trends through time. Biostatistics from other regions should test the possibility that the morphotypes represent different subspecies, with different distributions in time and space.

In the material from Bou Tchrafine North (Fig. 17C) *Lat. steinachensis sensu* the holotype (eta morphotype) occurs in the upper Pragian. The Pragian specimens from El Khraouia include rather elongate forms of Morphotype beta with hardly curved spindle (Fig. 20D). Murphy & Cebecioglu (1984) illustrated a similar specimen in their fig. 5P, Dongal (1995) in his fig. 5B. In lower Emsian specimens from BTN the longitudinal axis of the element is also less curved than in the holotype (Fig. 17A, B, E). We regard such straight forms currently as intraspecific variants although they could be assigned to a late third morphotype, which is close to the narrow forms transitional between Morphotypes eta and beta. The taxonomic position of this form should be re-evaluated when more material becomes available.

Stratigraphic range. – The entry of *Lat. steinachensis*, especially of Morphotype eta, is used to approximate the base of the Pragian in its type region (Slavík & Hladil 2004), where both morphotypes range into the *serratus* Zone. Here we extend the upper range into the basal Emsian *Eol. excavatus* M114 Zone or *bilatericrescens bilatericrescens* Zone (upper *Deiroceras* Limestone) but this is based on atypically straight specimens.

***Latericriodus* sp. nov.**
Figure 18S–U

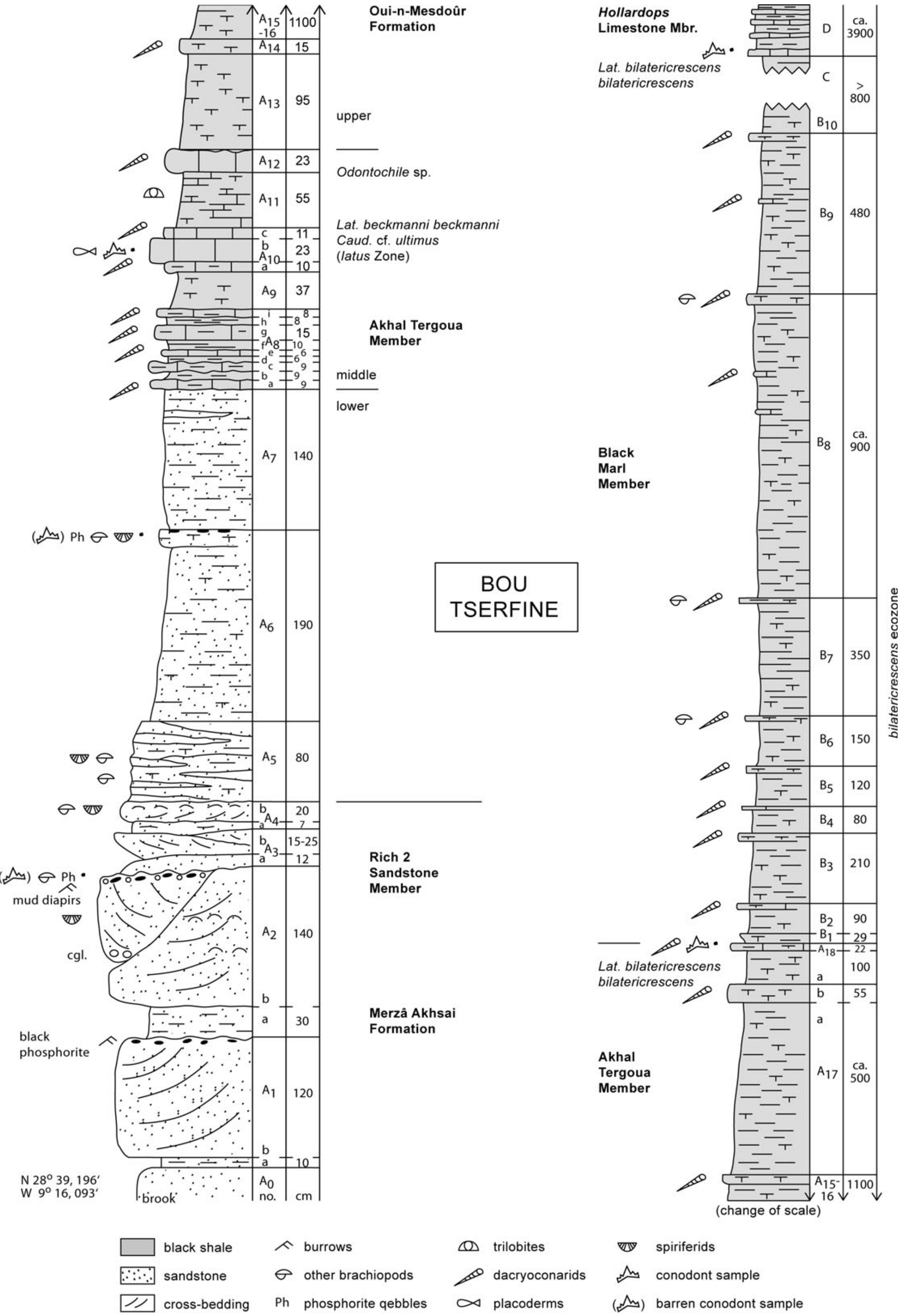
Description. – A single slender *Latericriodus* from Sample BTN P/E2 has a narrow spindle with six rows that are more closely spaced posteriorly. The denticles are coarse in the anterior part and small in the last three rows. The denticles of the posterior middle row are smaller and there are three nodes on the median extension of the spindle. The outer lateral process joins the last denticle of the median row at a right angle and possesses two nodes. The cavity extension has a triangular outline and is restricted to the area between the posterior third of the platform and the pointed tip of the outer process.

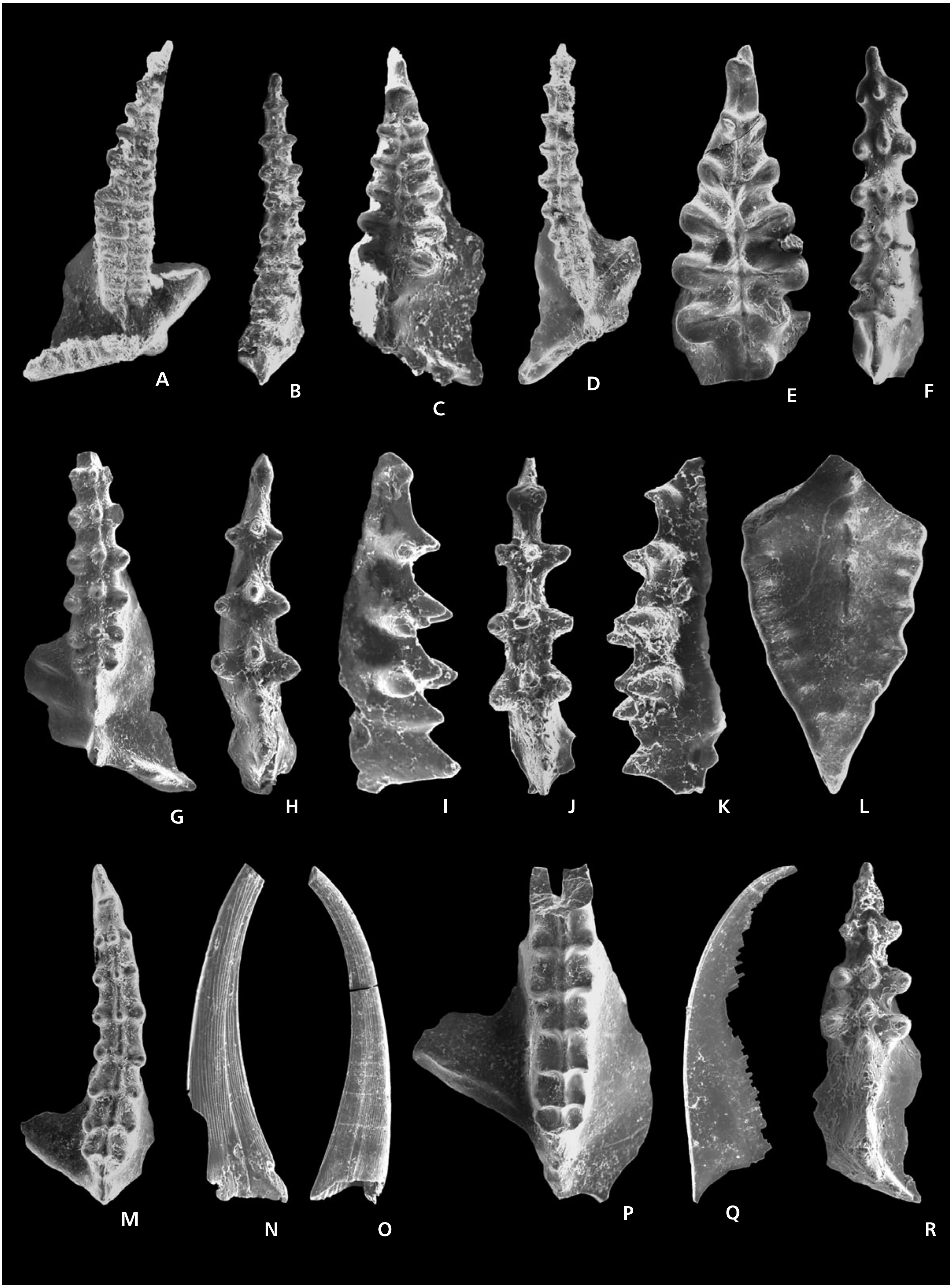
Discussion. – The morphology differs from that in all named Pragian *Latericriodus* species but since there is only one available specimen open nomenclature is used.

Stratigraphic range. – Regional *Lat. steinachensis* Zone, Pragian.

Figure 26. Lithology and position of conodont samples in the lower Emsian of Bou Tserfine (western Dra Valley). For additional symbols see Fig. 4.

Figure 27 (page 964). Conodonts from the Emsian of the western Dra Valley; A–C – Bou Tserfine, Bed A10b, Akhal Tergoua Member, *Lat. latus* Zone with *Lat. beckmanni*; D – Bou Tserfine, Sample D1, basal *Hollardops* Limestone, local *bilatericrescens* Ecozone; E, F, H–K, M, O–R – Rich Tamelougou, main sample of *Hollardops* Limestone, *fusiformis* Zone with *I.* cf. *rectirostratus* and *Caud. culicellus culicellus*; G, L, N – Rich Tamelougou, basal Akhal Tergoua Member, *latus* Zone with *Lat. beckmanni*. • A – *Lat. beckmanni beckmanni* (Ziegler, 1956). B9.A-5.78, × 65. • B – *Caud.* cf. *ultimus* Weddige *in* Weddige & Requadt, 1985. Specimen without curvature of the posterior middle row of denticles, transitional to *Icriodus* s. str., B9.A-5.79, × 70. • C – *Caud. sigmoidalis* (Carls & Gandl, 1969). B9.A-5.80, × 85. • D – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956). Intermediate to *bilatericrescens multicostatus* (Carls & Gandl, 1969), B9.A-5.81, × 50. • E – *I.* cf. *werneri* Weddige, 1977. With fewer denticle rows and thicker denticles of side rows that are connected with the middle row than in typical representatives, B9.A-5.82, × 85. • F – *Caud. ultimus* Weddige *in* Weddige & Requadt, 1985. More typical small specimen with slightly sinuose posterior extension of the middle denticle row, B9.A-5.83, × 120. • G – *Lat. beckmanni ?sinuatus* (Klapper, Ziegler & Mashkova, 1978). B9.A-5.84, × 85. • H–K – *Caud. culicellus culicellus* Bultynck, 1976. Two juvenile specimens with still few denticle rows; H, I – upper and outer oblique views of B9.A-5.85, × 200; J, K – upper and inner oblique view of B9.A-5.86, × 150. • L – *Eol. excavatus* (Carls & Gandl, 1969) Morphotype 114. Fragmentary specimen, B9.A-5.87, × 130. • M – *I. corniger leptus* Weddige, 1977, B9.A-5.88, × 75. • N, O – *Neop. perlineatus* Ziegler & Lindström, 1971; N – Akhal Tergoua Member, B9.A-5.89, × 100; O – *Hollardops* Limestone Member, B9.A-5.-90, × 70. • P – *I.* cf. *rectirostratus* Weddige, 1977. B9.A-5.91, × 85. • Q – *Bel. resima* (Philip, 1965). B9.A-5.92, × 85. • R – *Caud.* aff. *sigmoidalis* (Carls & Gandl, 1969). Small specimen with long straight ridge between median row and its curved posterior extension, B9.A-5.93, × 120.


BOU TSERFINE
Oui-n-Mesdoûr Formation
upper
Odontochile sp.
Lat. beckmanni beckmanni
Caud. cf. ultimus
(latus Zone)
Akhal Tergoua Member
middle
lower
Rich 2 Sandstone Member
Merzâ Akhsai Formation
mud diapirs
cgl.
black phosphorite
N 28° 39, 196′
W 9° 16, 093′
brook
no.
cm
Hollardops Limestone Mbr.
Lat. bilatericrescens bilatericrescens
Black Marl Member
Lat. bilatericrescens bilatericrescens
Akhal Tergoua Member
bilatericrescens ecozone
(change of scale)
black shale
sandstone
cross-bedding
burrows
other brachiopods
Ph phosphorite qebbles
trilobites
dacryoconarids
placoderms
spiriferids
conodont sample
barren conodont sample


A
B
C
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Q
R

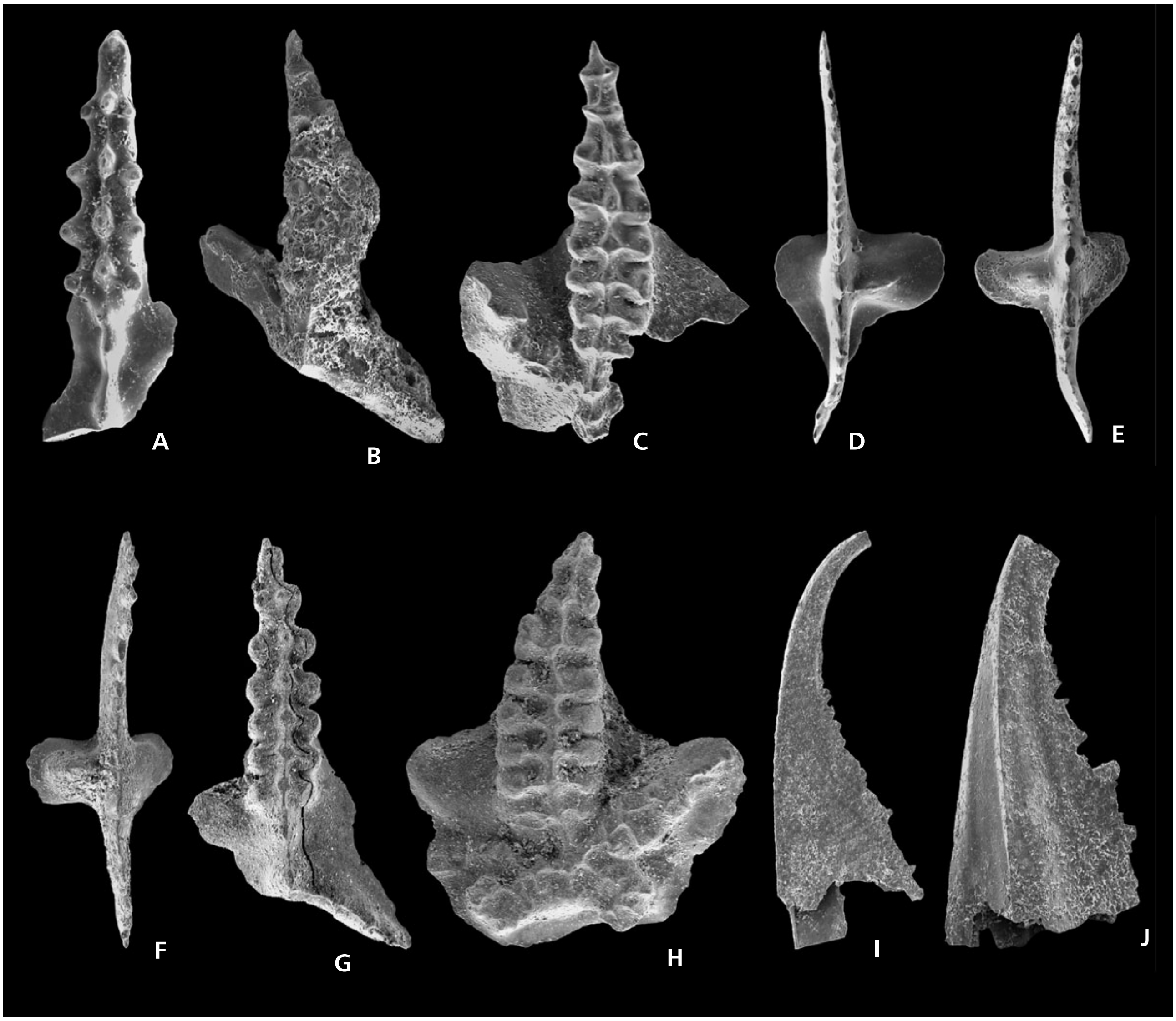


Figure 28. Lower Emsian conodonts from dissolved goniatites of the *Anetoceras* Limestone, *latus* Zone (with *Lat. beckmanni*) or *steinhornensis* Zone; A–F – Bou Tchrafine, Sample BT-*Kl*, several dissolved *Klugites gesinae* gen. nov.; G–J – Ouidane Chebbi, Sample OCh-*Anet*, block with *Anet*. cf. *obliquicostatum*. • A – juvenile *Caud. celtibericus* (Carls & Gandl, 1969). B9.A-5.94, posterior end broken, × 100. • B, G – *Lat. bilatericrescens bilatericrescens* (Ziegler, 1956); B – poorly preserved, B9.A-5.95, × 60; G – B9.A-5.96, × 65. • C, H – *Lat. beckmanni beckmanni* (Ziegler, 1956); C – incomplete, B9.A-5.97, × 65; H – typical specimen, B9.A-5.98, × 60. • D–F – *Crit. steinhornensis* (Ziegler, 1956); D – specimen with thin ridge on the outer lobe and triangular posterior platform extension, B9.A-5.99, × 75; E – specimen with small node on the outer lobe, B9.A-5.100, × 85; F – B9.A-5.101, × 60. • I – *Bel. resima* (Philip, 1965). B9.A-5.102, × 60. • J – *Bel. triangularis* (Stauffer, 1940). B9.A-5.103, × 60.

***Latericriodus bilatericrescens bilatericrescens* (Ziegler, 1956)**

Figures 7A, B, 8B–E, 9F, 17F, G, 22B, 27D, 28B, G

* 1956 *Icriodus latericrescens bilatericrescens* sp. nov.; Ziegler, pp. 101–102, pl. 6, figs 6–11.

1979 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Bultynck, pl. 2, figs 10, 11.

1979 *Latericriodus* subsp. B; Bultynck, pl. 2, fig. 12.

1980 *Icriodus bilatericrescens* Ziegler. – Klapper & Johnson, pl. 2, figs 13–16.

e.p. 1980 *Latericriodus bilatericrescens* (Ziegler) subsp. A. – Bultynck & Hollard, pl. 1, fig. 13 (only).

e.p. 1980 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Bultynck & Hollard, pl. 1, fig. 14 [figs 15–21 = *multicostatus*, figs 22–24 = *gracilis*].

1981 *Icriodus bilatericrescens* Ziegler. – Johnson & Klapper, p. 1241, pl. 1, fig. 7.

1985 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Bultynck, pl. 5, figs 9, 10 (only).

1989 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Bultynck, pl. 7, figs 13–15.

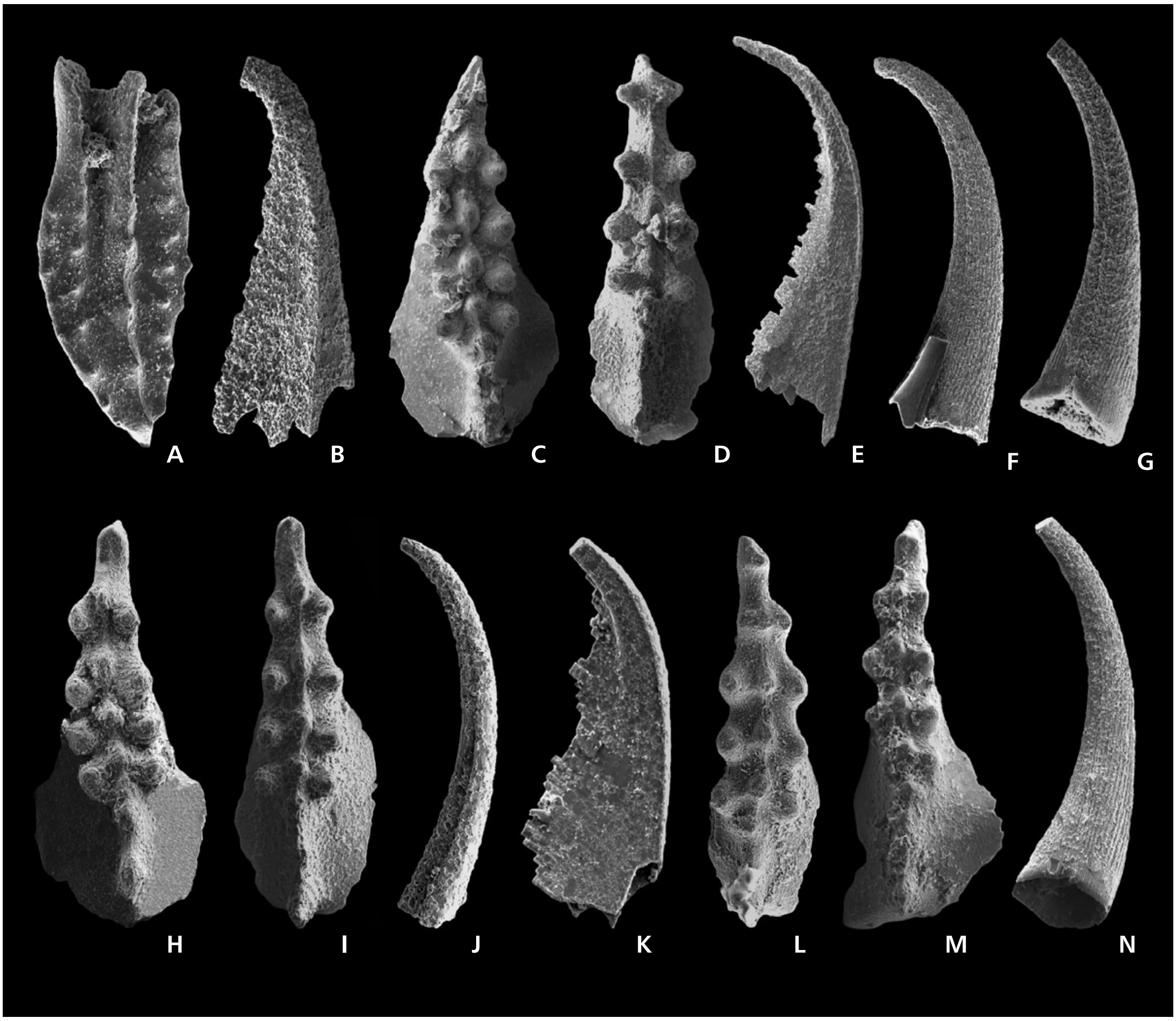
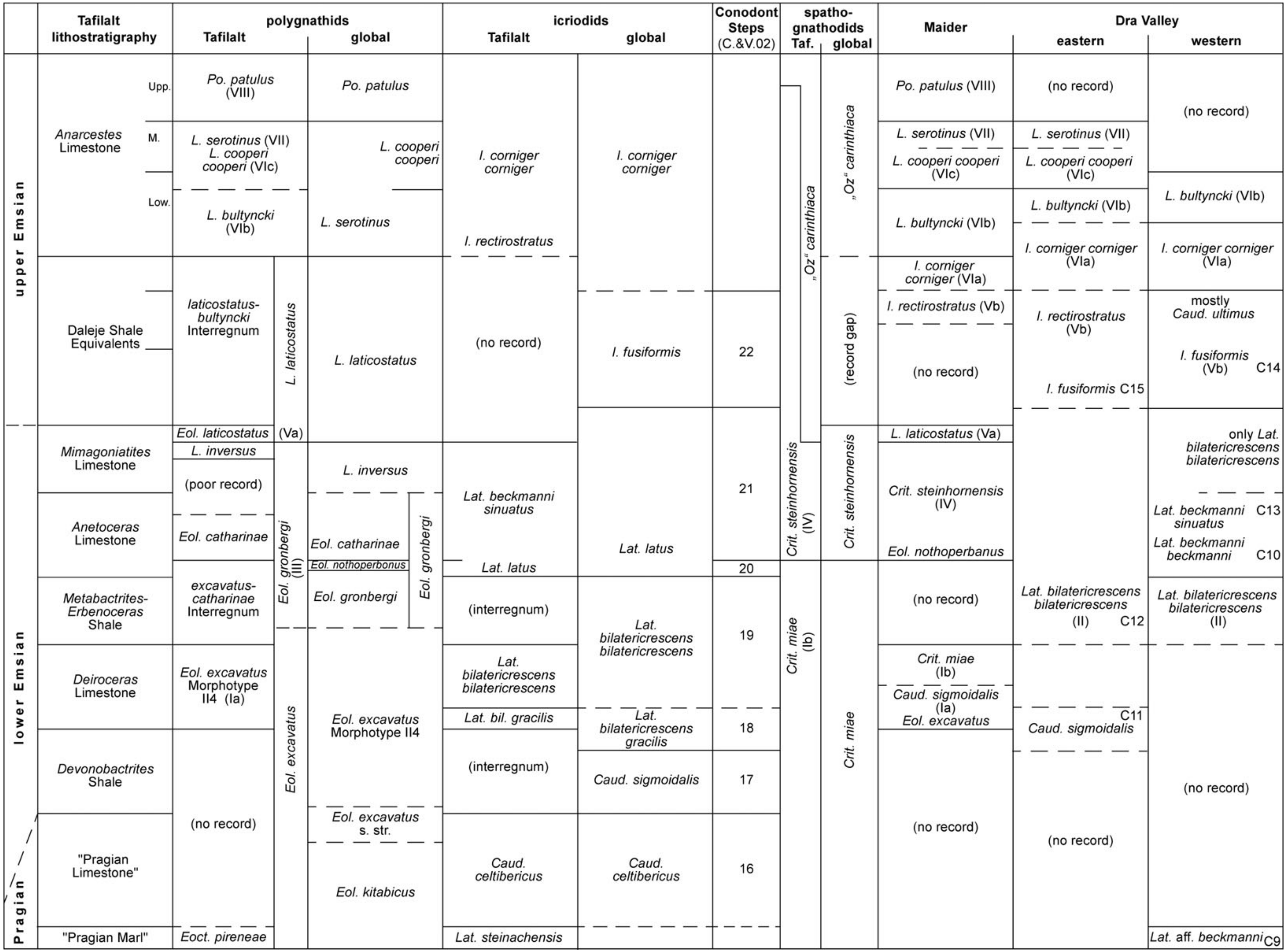


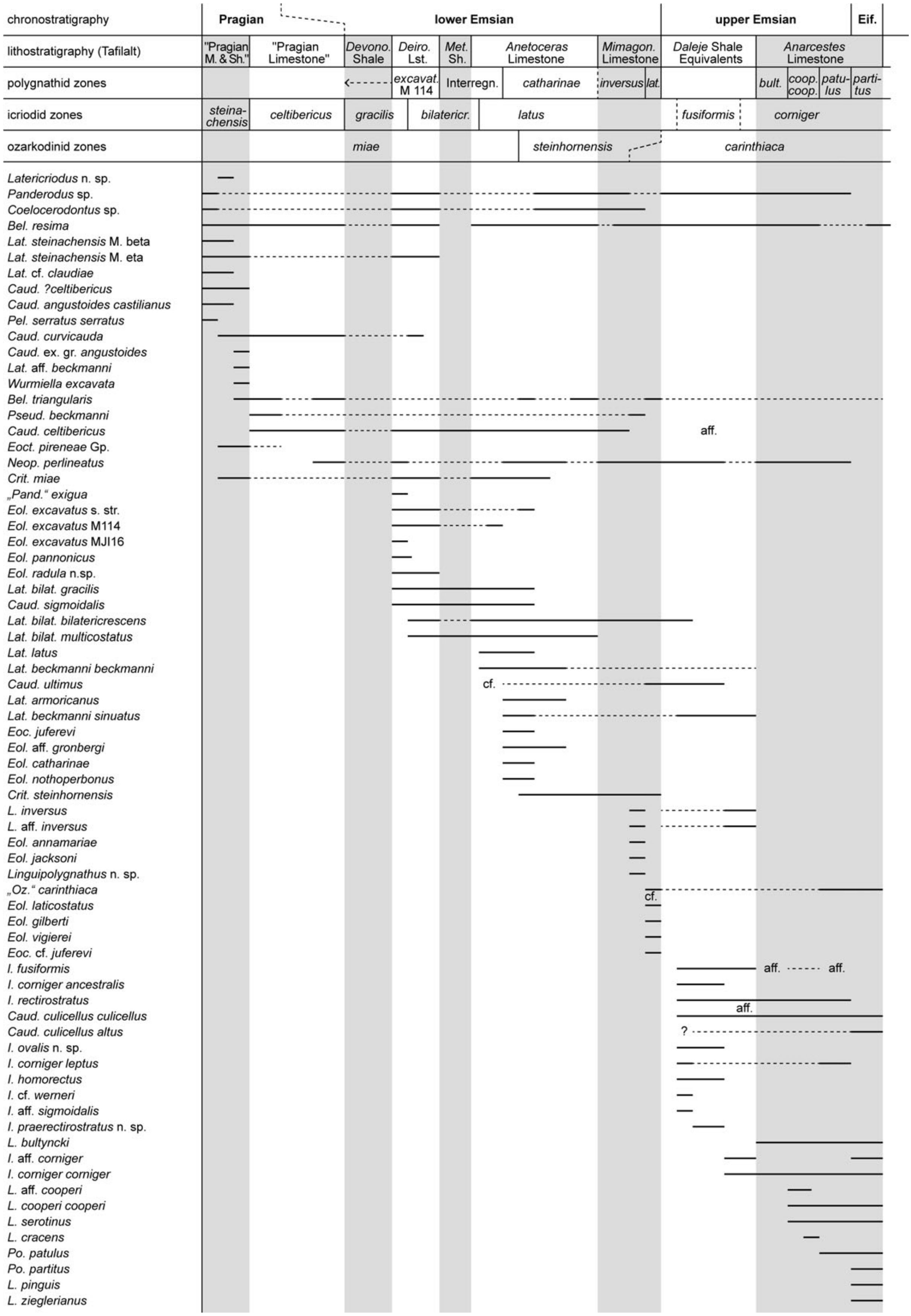
Figure 29. Upper Emsian conodonts from dissolved anarcestids of the Anti-Atlas; A–J, N – Tafilalt, *Anarcestes* Limestone; K, L – eastern Dra Valley, *Sellanarcestes* Limestone, Oufrane West, Bed 11, *fusiformis* Zone with *Caud. culicellus culicellus*; M – western Dra Valley, Rich Tamelougou, "*Latanarcestes*" nodules of the Brachiopod Marl Member, upper *fusiformis* Zone. • A – *Po. costatus patulus* Klapper, 1971. Fragmentary, small specimen, B9.A-5.104, Sample OCh-*An*, *patulus* Zone, × 140. • B, E, K – *Bel. resima* (Philip, 1965); B – B9.A-5.105, Sample EKs-D, ?*corniger* Zone (locally without diagnostic icriodids), × 80; E – B9.A-5.106, EKs-B, ?*corniger* Zone, × 75; K – B9.A-5.107, Sample Ouf-*Sell*, × 115. • C, D, H, I, L – *Caud. culicellus culicellus* (Bultynck, 1976); C – B9.A-5.108, Sample EKs-D, × 95; D – juvenile, B9.A-5.109, Sample EKs-D, × 115; H – wide morphotype, B9.A-5.110, Sample EKs-B, × 100; I – narrow morphotype, B9.A-5.111, Sample EKs-B, × 120; L – B9.A-5.112, Sample Ouf-*Sell*, × 80. • F, G, J, N – *Neop. perlineatus* Ziegler & Lindström, 1971; F – B9.A-5.113, Sample EKs-D, × 60; G – B9.A-5.114, Sample EKs-B, × 75; J – B9.A-5.115, Sample EKs-B, × 60; N – B9.A-5.116, Sample EKs-B, × 75. • M – *Caud.* aff. *celtibericus* (Carls & Gandl, 1969). Transitional to *Icriodus* s. str., B9.A-5.117, × 100.

Figure 30. Comparison of Emsian conodont zonations for different faunal groups (polygnathids, icriodids, spathognathodids) and different regions (Tafilalt, Maider, western and eastern Dra Valley) of the Anti-Atlas, correlated with the Conodont Steps *sensu* Carls 1999 and Carls & Valenzuela-Ríos (2002). Roman numbers in () refer to the previously numbered zones of Bultynck & Hollard (1980) and Bultynck (1985), showing the successions where they have been recognized originally. C-numbers refer to the Dra Valley conodont faunas of Jansen *et al*. (2007).

Figure 31 (page 968). Stratigraphic ranges of conodont taxa and morphotypes in the upper Pragian to basal Eifelian of the Anti-Atlas, based on literature data and the new record. Ranges are plotted against the Tafilalt lithostratigraphy.



Tafilalt lithostratigraphy
polygnathids
Tafilalt
global
icriodids
Tafilalt
global
Conodont Steps (C.&V.02)
spatho-gnathodids
Taf.
global
Maider
Dra Valley
eastern
western
upper Emsian
lower Emsian
Pragian
Upp.
M.
Low.
Anarcestes Limestone
Daleje Shale Equivalents
Mimagoniatites Limestone
Anetoceras Limestone
Metabactrites-Erbenoceras Shale
Deiroceras Limestone
Devonobactrites Shale
"Pragian Limestone"
"Pragian Marl"
Po. patulus (VIII)
L. serotinus (VII)
L. cooperi cooperi (VIc)
L. bultyncki (VIb)
laticostatus-bultyncki Interregnum
L. laticostatus
Eol. laticostatus
(Va)
L. inversus
(poor record)
Eol. catharinae
Eol. gronbergi (III)
excavatus-catharinae Interregnum
Eol. excavatus Morphotype II4 (Ia)
Eol. excavatus
(no record)
Eoct. pireneae
Po. patulus
L. cooperi cooperi
L. serotinus
L. laticostatus
L. inversus
Eol. catharinae
Eol. nothoperbonus
Eol. gronbergi
Eol. excavatus Morphotype II4
Eol. excavatus s. str.
Eol. kitabicus
I. corniger corniger
I. rectirostratus
(no record)
Lat. beckmanni sinuatus
Lat. latus
(interregnum)
Lat. bilatericrescens bilatericrescens
Lat. bil. gracilis
(interregnum)
Caud. celtibericus
Lat. steinachensis
I. corniger corniger
I. fusiformis
Lat. latus
Lat. bilatericrescens bilatericrescens
Lat. bilatericrescens gracilis
Caud. sigmoidalis
Caud. celtibericus
22
21
20
19
18
17
16
„Oz" carinthiaca
Crit. steinhornensis (IV)
Crit. miae (Ib)
„Oz" carinthiaca
(record gap)
Crit. steinhornensis
Crit. miae
Po. patulus (VIII)
L. serotinus (VII)
L. cooperi cooperi (VIc)
L. bultyncki (VIb)
I. corniger corniger (VIa)
I. rectirostratus (Vb)
(no record)
L. laticostatus (Va)
Crit. steinhornensis (IV)
Eol. nothoperbanus
(no record)
Crit. miae (Ib)
Caud. sigmoidalis (Ia)
Eol. excavatus
(no record)
(no record)
L. serotinus (VII)
L. cooperi cooperi (VIc)
L. bultyncki (VIb)
I. corniger corniger (VIa)
I. rectirostratus (Vb)
I. fusiformis C15
Lat. bilatericrescens bilatericrescens (II) C12
C11
Caud. sigmoidalis
(no record)
(no record)
L. bultyncki (VIb)
I. corniger corniger (VIa)
mostly Caud. ultimus
I. fusiformis (Vb) C14
only Lat. bilatericrescens bilatericrescens
Lat. beckmanni sinuatus C13
Lat. beckmanni beckmanni C10
Lat. bilatericrescens bilatericrescens (II)
(no record)
Lat. aff. beckmanni C9


chronostratigraphy
Pragian
lower Emsian
upper Emsian
Eif.
lithostratigraphy (Tafilalt)
"Pragian M. & Sh."
"Pragian Limestone"
Devono. Shale
Deiro. Lst.
Met. Sh.
Anetoceras Limestone
Mimagon. Limestone
Daleje Shale Equivalents
Anarcestes Limestone
polygnathid zones
excavat. M 114
Interregn.
catharinae
inversus
lat.
bult.
coop. coop.
patu- lus
parti- tus
icriodid zones
steina- chensis
celtibericus
gracilis
bilatericr.
latus
fusiformis
corniger
ozarkodinid zones
miae
steinhornensis
carinthiaca
Latericriodus n. sp.
Panderodus sp.
Coelocerodontus sp.
Bel. resima
Lat. steinachensis M. beta
Lat. steinachensis M. eta
Lat. cf. claudiae
Caud. ?celtibericus
Caud. angustoides castilianus
Pel. serratus serratus
Caud. curvicauda
Caud. ex. gr. angustoides
Lat. aff. beckmanni
Wurmiella excavata
Bel. triangularis
Pseud. beckmanni
Caud. celtibericus
aff.
Eoct. pireneae Gp.
Neop. perlineatus
Crit. miae
„Pand.“ exigua
Eol. excavatus s. str.
Eol. excavatus M114
Eol. excavatus MJI16
Eol. pannonicus
Eol. radula n.sp.
Lat. bilat. gracilis
Caud. sigmoidalis
Lat. bilat. bilatericrescens
Lat. bilat. multicostatus
Lat. latus
Lat. beckmanni beckmanni
Caud. ultimus
cf.
Lat. armoricanus
Lat. beckmanni sinuatus
Eoc. juferevi
Eol. aff. gronbergi
Eol. catharinae
Eol. nothoperbonus
Crit. steinhornensis
L. inversus
L. aff. inversus
Eol. annamariae
Eol. jacksoni
Linguipolygnathus n. sp.
„Oz.“ carinthiaca
cf.
Eol. laticostatus
Eol. gilberti
Eol. vigierei
Eoc. cf. juferevi
I. fusiformis
aff.
aff.
I. corniger ancestralis
I. rectirostratus
aff.
Caud. culicellus culicellus
Caud. culicellus altus
?
I. ovalis n. sp.
I. corniger leptus
I. homorectus
I. cf. werneri
I. aff. sigmoidalis
I. praerectirostratus n. sp.
L. bultyncki
I. aff. corniger
I. corniger corniger
L. aff. cooperi
L. cooperi cooperi
L. serotinus
L. cracens
Po. patulus
Po. partitus
L. pinguis
L. zieglerianus

	Tafilalt lithostratigraphy	regional conodont zonations: polygnathids	regional conodont zonations: icriodids	amm. zonal key		regional ammonoid successions: Tafilalt	Maider	eastern Dra Valley	western Dra Valley
upper Emsian	Anarcestes Limestone	Po. patulus	I. corniger corniger	LD IV	D2b	Anarcestes lateseptatus	"Anarcestes cf. praecursor" dm 1.3	(no record)	(no record)
upper Emsian	Anarcestes Limestone	L. cooperi cooperi	I. corniger corniger	LD IV	D2a	Anarcestes (without Sellanarcestes)	dm 1.2	(no record)	Mimagoniatites sp. Anarcestes sp.
upper Emsian	Anarcestes Limestone	L. bultyncki	I. corniger corniger	LD IV	D1	Sellan. neglectus; Anarcestes simulans	Sellanarcestes neglectus dm 1.1	Anarcestes crassus; Sell. neglectus An. simulans	Anarcestes crassus; Sell. neglectus; An. simulans
upper Emsian	Daleje Shale Equivalents	laticostatus-bultyncki Interregnum	I. corniger corniger / I. fusiformis	LD IV	C	Sellanarcestes eos	Sellanarcestes wenkenbachi di 4	Sellanarcestes wenkenbachi	Sellanarcestes wenkenbachi
upper Emsian	Daleje Shale Equivalents	laticostatus-bultyncki Interregnum	I. fusiformis	LD IV	B	"Latanarcestes noeggerathi"	"Latanarcestes noeggerathi"	„Latanarcestes noeggerathi"	„Latanarcestes noeggerathi"
upper Emsian	Daleje Shale Equivalents	laticostatus-bultyncki Interregnum	I. fusiformis	LD IV	A	Rherisites tuba	(no record)	(no record)	Mimagoniatites sp.; (no record)
lower Emsian	Mimagoniatites Limestone	Eol. laticostatus	Lat. latus	Crit. steinhornensis / LD III	E	(no record)	(no record)	(no record)	(no record)
lower Emsian	Mimagoniatites Limestone	L. inversus; (poor record)	Lat. latus	Crit. steinhornensis / LD III	D	Mimagoniatites fecundus	Mimagoniatites sp.	Mimagoniatites fecundus	Erbenoceras sp.
lower Emsian	Anetoceras Limestone	(poor record); Eol. catharinae	Lat. latus	Crit. steinhornensis / LD III	C2	Klugites gesinae	Erbenoceras advolvens	Klugites gesinae	Erbenoceras sp.
lower Emsian	Anetoceras Limestone	Eol. catharinae	Lat. latus	Crit. miae / LD III	C1	Anetoceras obliquecostatum	Erbenoceras advolvens	Erbenoceras advolvens	(no record)
lower Emsian	Metabactrites-Erbenoceras Shale	excavatus-catharinae Interregnum	Lat. b. bilatericrescens	Crit. miae / LD III	B	Erbenoceras advolvens	Erbenoceras advolvens	Erbenoceras advolvens	(no record)
lower Emsian	Deiroceras Limestone	Eol. excavatus MII4	Lat. b. bilatericrescens; Lat. b. gracilis	Crit. miae / LD III	A	Devonobactrites obliqueseptatus	(no record)	(no record)	(no record)
lower Emsian	Devonobactrites Shale	(no record)	(no record)		A	Devonobactrites obliqueseptatus	(no record)	(no record)	(no record)
	"Pragian Lst."	(no record)	Caud. celtibericus			(no record)	(no record)	(no record)	(no record)

Figure 32. Correlation of the Tafilalt conodont and ammonoid zonation and alignment with goniatite levels of the Maider and Dra Valley. Ammonoid zonal key updated from Becker & House (1994) and Becker *et al*. (2012). Zonal numbers di 4 to dm 1.3 refer to the numbering in Hollard (1974).

1990 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Olivieri & Serpagli, p. 60, pl. 1, fig. 11 [fig. 17 = supposed Pb element].

1994 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – García-López & Alonso-Menendez, pl. 3, figs 2, 3, 6.

e.p. 1995 *Latericriodus bilatericrescens* (Ziegler). – Kalvoda, pp. 36–37, pl. 1, figs 2, 6, pl. 2, figs 5, 7 [including transitional forms towards *multicostatus*; synonymy for all subspecies].

2001 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Slavík, p. 262, pl. 3, fig. 6, pl. 4, fig. 2.

2002 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – García-López, Jahnke & Sanz-López, p. 252, pl. 3, figs 21, 22.

2003 *Latericriodus*? *bilatericrescens bilatericrescens* (Ziegler). – Bultynck, pl. 2, figs 9–12 [re-illustration of specimen from Bultynck 1979].

2004a *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Slavík, pp. 465–466, figs 11.13, 11.14.

2004a *Latericriodus bilatericrescens* cf. *bilatericrescens* (Ziegler). – Slavík, pp. 465–466, fig. 11.15 [fig. 11.16 is very fragmentary].

Discussion. – The holotype of *Icriodus latericrescens bilatericrescens* (Ziegler 1956, pl. 6, figs 8, 9) differs somewhat from the other figured specimens, which are not from the type region. In the holotype the lateral row denticles are slightly elongate transversally and slightly connected with the middle row denticles. In the two other original specimens the lateral row denticles are clearly round and less connected with the middle row denticles, which are also larger than in the holotype. The most diagnostic features are given in Johnson & Klapper (1981, p. 1241): "Specimens of *Icriodus bilatericrescens* are characterized by a longer inner spur, which is characteristically ornamented by a ridge that may be denticulated. The spur is on line with the outer lateral process. The longitudinal spacing of lateral-row denticles is essentially uniform as opposed to the spacing in I elements of *I. nevadensis*."

Apart from typical forms there are intermediates towards the other subspecies, which have more denticle rows and which are more slender. Specimens B9.A-5.11–12 (Fig. 7A, B) and b6638 (Fig. 17F) are transitional from *gracilis*, specimen B9.A-5.81 (Fig. 27D) shows a trend towards *multicostatus*. As noted in Kalvoda (1995) there are specimens, which do not fall clearly in any of the three recognized subspecies. The numerous transitions speak against a full species separation of these.

Stratigraphic range. – Lower Emsian *bilatericrescens bilatericrescens* Zone to basal upper Emsian *fusiformis* Zone (*e.g.*, at Rich Tamelougou).

***Latericriodus bilatericrescens gracilis* Bultynck, 1985**
Figures 5G, H, 17H–J, 21G, H

e.p. 1980 *Latericriodus bilatericrescens bilatericrescens* (Ziegler). – Bultynck & Hollard, pl. 1, fig. 22 (only fig. 23 = holotype).
* 1985 *Latericriodus bilatericrescens gracilis* n. subsp.; Bultynck, p. 269, pl. 5, figs 1, 2.
1990 *Icriodus bilatericrescens gracilis* (Bultynck). – Olivieri & Serpagli, p. 62, pl. 1, fig. 10a, b.
2004a *Latericriodus bilatericrescens gracilis* Bultynck. – Slavík, pl. 1, fig. 9.
2004b *Latericriodus bilatericrescens gracilis* Bultynck. – Slavík, p. 467, figs 11.19–11.21.

Type level. – The holotype is from sample 20-1 of the Tjafane section, about 25 km east of Akka, western Dra Valley. The sample is from the base of the Oui-n-Mesdoûr Formation, which is of lower Emsian age (Becker 2004a, Jansen *et al*. 2007). The precise level seems to predate the *latus* Zone (locally with *Lat. beckmanni beckmanni*) of the main part of the Akhal Tergoua Member further to the west (*e.g*., of Bou Tserfine).

Discussion. – The specimen of Fig. 17H is very similar to the holoype. The subspecies can be distinguished from typical *Lat. bilatericrescens* by the concavo-convex outline of the spindle, which is slightly biconvex in the latter (especially in its holotype). Moreover, in *bilatericrescens bilatericrescens* the middle row denticles are smaller and in adult specimens they are connected with the transversal lateral row denticles, which is not the case in *bilatericrescens gracilis.* In the latter the middle and lateral row denticles are rounded and do not fuse laterally. Another characteristic of *bilatericrescens gracilis* is the irregular pattern of the denticles on the outer lateral process. The inner process meets the spindle extension one denticle before the outer process. In *Lat. claudiae* the posterior outer lateral process is clearly shorter than in *L. bilatericrescens gracilis.*

Stratigraphic range. – Lower Emsian (of proposed future definition), *bilatericrescens gracilis* to middle *latus* Zone (middle *Anetoceras* Limestone of the Tafilalt, Sample BTN 31-1). Its oldest record in the Barrandian is from the higher Dvorce-Prokop Limestone, from just below the monograptid marker interval ("*atopus* Event", Slavík 2004b: section Na Branzovech, Sample 26B).

***Icriodus praerectirostratus* Bultynck sp. nov.**
Figure 25Q–X

Derivation of name. – Because the morphology and stratigraphic range suggest that it is the direct ancestor of *I. rectirostratus* Bultynck, 1970.

Types. – Holotype b6682, illustrated in Fig. 25Q, R; five paratypes b6683–6687 (Fig. 25S–X).

Type level and locality. – Lower part of Lower Member of Timrhanrhart Formation, upper Emsian, El Anhsour, Sample 2, *fusiformis* Zone.

Diagnosis. – P1 element characterized by a strong spur, pointed in an oblique angle to the anterior, showing obvious nodes or a marked costa, and a posterior extension of the middle denticle row with transversally developed ridges.

Description. – The spindle is slightly concavo-convex, slightly curved, and the anterior end is pointed. There are six to seven transversal denticle rows on the spindle. The denticles of the middle row are much smaller than the rounded or oval denticles of the lateral rows and they are mostly connected by a longitudinal thin ridge. The basal cavity is well expanded. On the outer side the border of the cavity is rounded and on the inner side there is a prominent triangular spur with nodes or a costa. In smaller specimens (Fig. 25V) all these characteristics are only weakly developed. In specimen b6684 (Fig. 25T) the posterior denticles show an especially distinctive transverse widening.

Discussion. – In *I. rectirostratus* there is only a thin ridge on the surface of the spur (Bultynck 1970, pl. 30, figs 7, 8) and the denticles of the posterior extension of the middle row are not transversally developed.

Stratigraphic range. – At present only known from the basal upper Emsian *fusiformis* Zone.

***Icriodus ovalis* Bultynck sp. nov.**
Figure 25E–G

Derivation of name. – From the Latin *ovalis*, according to the oval outline of the spindle.

Types. – Holotype b6672, upper view illustrated in Fig. 25F; Paratypes b6671 (lateral view in Fig. 25E) and b6673 (upper view in Fig. 25G).

Type level and locality. – Uppermost part of Mdâouer-el-Kbîr Formation, upper Emsian, El Anhsour, Sample I, *fusiformis* Zone.

Diagnosis. – P1 element characterized by a slender, biconvex spindle with a large number of slightly oval lateral row denticles and smaller middle row denticles. In the posterior part of the spindle the denticles are smaller and the last middle row denticle is clearly inclined.

Description. – In the holotype the number of lateral row denticles is ten. In upper view they are slightly oval, larger than the middle row denticles and not fused. There are two to three middle row denticles behind the spindle and they are strongly inclined. In lateral view the upper margin of the spindle is slightly convex. The outline of the border of the basal cavity is not much laterally expanded in the posterior part of the P1 element.

Discussion. – In the *ca* contemporaneous *Icriodus homorectus* the margins of the spindle are straight and there are more denticles in the posterior extension of the middle denticle row.

Stratigraphic range. – *Icriodus ovalis* sp. nov. occurs together with *L. inversus*, *I. fusiformis*, *I. corniger ancestralis*, and *Caud. culicellus culicellus* in the basal part of the upper Emsian.

Order Agoniatitida Ruzhentsev, 1957
Family Mimoceratidae Steinmann *in* Steinmann & Döderlein, 1890

Genus *Klugites* Becker gen. nov.

Derivation of name. – In honor of Christian Klug (Zürich), for his significant contributions to the knowledge of early ammonoids from the Tafilalt.

Type species. – *Lenzites gesinae* Klug, 2001 (currently monospecific).

Diagnosis. – Mature shell strongly compressed (ww/dm *ca* 0.25, ww/wh < 0.5), subevolute (uw/dm *ca* 0.35), with small imprint zone, and very high whorl expansion rate (WER 2.7 to 3.0). Growth lirae rectiradiate, concavo-convex, with deep and wide flank sinus and narrow, moderately high ventrolateral salient bordered by a fine spiral ridge. Sutures with small ventral lobe, asymmetrically rounded, narrow ventral saddle, deeply rounded lateral lobe occupying the flanks, and small internal lobe. Suture formula: ELI.

Discussion. – Klug (2001) assigned his new species to *Lenzites* Becker & House, 1994 and agreed that the genus occupies an intermediate position between the Teicherticeratidae and Mimoceratidae. The Tafilalt species, however, differs significantly from *Lenzites*, whose type species, *L. lenzi* (House & Pedder, 1963), is from the lower Emsian of Yukon, NW Canada. These differences justify the introduction of a new genus. The true *Lenzites* has much lower WER rates, rursiradiate (not rectiradiate), slightly biconvex (not fully concavo-convex) growth lines, with a shallow (not deep) flank sinus, and impressions on the venter as in *Chebbites*. There is no evidence for an imprint zone or dorsal (internal) lobe. *Klugites* gen. nov. combines the distinctive and advanced *Gyroceratites*-type ornament with the introduction of an imprint zone. Therefore, it is regarded as a descendent of *Gyroceratites*, not as an ancestor. *Lenzites* remains at its transitional position between the Teicherticeratidae and *Gyroceratites*.

Mimagoniatites and other genera of the Mimagoniatitidae differ by their well-rounded, much less compressed shells.

Stratigraphic and geographic range. – Restricted to the *gesinae* Zone of the Tafilalt (higher *Anetoceras* Limestone) and eastern Dra Valley (lower member of the Mdâouer-el-Kbîr Formation, De Baets *et al*. 2010).

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