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Neritic–pelagic correlation in the Lower and basal Middle Devonian of the Dra Valley (Southern Anti-Atlas, Moroccan Pre-Sahara)

U. JANSEN[1], N. LAZREQ[2], G. PLODOWSKI[1], M. SCHEMM-GREGORY[1], E. SCHINDLER[1] & K. WEDDIGE[1]

[1]*Forschungsinstitut Senckenberg, Senckenberganlage 25, D-60325 Frankfurt am Main, Germany (e-mail: Ulrich.Jansen@senckenberg.de)*

[2]*Université Cadi Ayadd, Faculté des Sciences Semlalia, Département de Géologie, BP 2390, Marrakech, Morocco*

Abstract: Marine Lower Devonian successions are widely exposed in the Dra Valley (Southern Anti-Atlas, Moroccan Pre-Sahara). Resulting from new studies, especially on brachiopods, conodonts, and dacryoconarid tentaculitids, the chronostratigraphic assignments of the Lower Devonian formations are revised. Thanks to lateral and vertical facies variations, it is possible to correlate pelagic and neritic successions and corresponding biostratigraphies. Pelagic conodont, dacryoconarid and goniatite faunas allow correlations and dating in the sense of the Bohemian and global chronostratigraphies, whereas units of the traditional Rhenish subdivision can be identified by means of neritic brachiopods.

Devonian strata are almost continuously exposed over 400 km in a SW–NE direction on strike in the Dra Valley along the southeastern flank of the Anti-Atlas Anticlinorium (Fig. 1). The Lower Devonian to Eifelian strata bear a complex variety of marine facies and faunas described by Hollard in a number of pioneer stratigraphic works (Hollard 1963*a*–*c*, 1965, 1967, 1977, 1978, 1981*a*, *b*). Palaeontological research is still ongoing. Previous faunal studies focused on trilobites (e.g. Alberti & Hollard 1963; Hollard 1963*b*; Morzadec 1988, 2001; Schraut 1998*a*, *b*, 2000), brachiopods (e.g. Drot 1964, 1971, 1975; Jansen 1999, 2001; Aït Malek *et al.* 2000), ammonoids (Hollard 1960, 1963*c*), conodonts (Bultynck & Hollard 1980), and ostracodes (G. Becker *et al.* 2003, 2004 *in* Jansen, G. Becker *et al.* 2004*a*, p. 24). Bultynck & Walliser (2000) summarized stratigraphic assignments in their comprehensive survey of the Devonian in the Moroccan Anti-Atlas.

The Lower Devonian to Eifelian successions in the Dra Valley offer outstanding possibilities for correlation mainly due to the fact that neritic and pelagic units follow one above the other in four main cycles called 'riches' (Choubert 1956). A 'rich' generally consists of a thin (few metres) basal limestone, 100 to 150 m of silty and sandy shales in the middle part and a 50 to 120 m thick sandstone unit at the top (Hollard 1981*a*). In essence, this succession is repeated four times and, accordingly, the whole complex may be subdivided into four formations, 'Rich 1' to 'Rich 4' (Hollard 1963*a*, 1967, 1981*a*). Single units may be traced and correlated over tens of kilometres (Fig. 2). However, significant lateral facies changes are present within these cycles, and new names have been proposed for special regional facies developments (Hollard 1978, 1981*b*; R. T. Becker, Jansen *et al.* 2004). Essentially, the facies in the studied area changes from the SW, i.e. from Aouinet Torkoz to about Foum el Hassane, to the NE, i.e. from about Foum el Hassane to Foum Zguid (Figs 1 & 2). The calcareous and shaly parts of the 'riches' correspond to the 'Hercynian' resp. (hemi-)pelagic facies and the sandy parts to the 'Rhenish' resp. neritic facies. The neritic sandstones contain diverse and abundant brachiopod faunas allowing precise assignments to the regional Rhenish subdivision as defined in the Rheinisches Schiefergebirge (Germany) and in the Ardennes (Belgium) (Jansen 1999, 2000, 2001). On the other hand, conodonts, dacryoconarid tentaculitids and goniatites are present in the intercalated limestones which can be attributed to global pelagic biozones, the classical Bohemian subdivision, and the global chronostratigraphy (Bultynck & Hollard 1980; Lazreq & Ouanaimi 1998).

Unfortunately, the use of different subdivisions has caused much confusion. There is a Pragian in the original sense of Bohemia and a shorter Pragian in the GSSP sense according to the decisions of the international *Subcommission on Devonian Stratigraphy* (SDS). Similarly, there is an Emsian in the traditional German (Rhenish) sense and an Emsian in the Belgian (Ardennan) sense slightly differing in the age of their bases; both concepts are used in the Rhenish facies of Central and Western Europe and North Africa.

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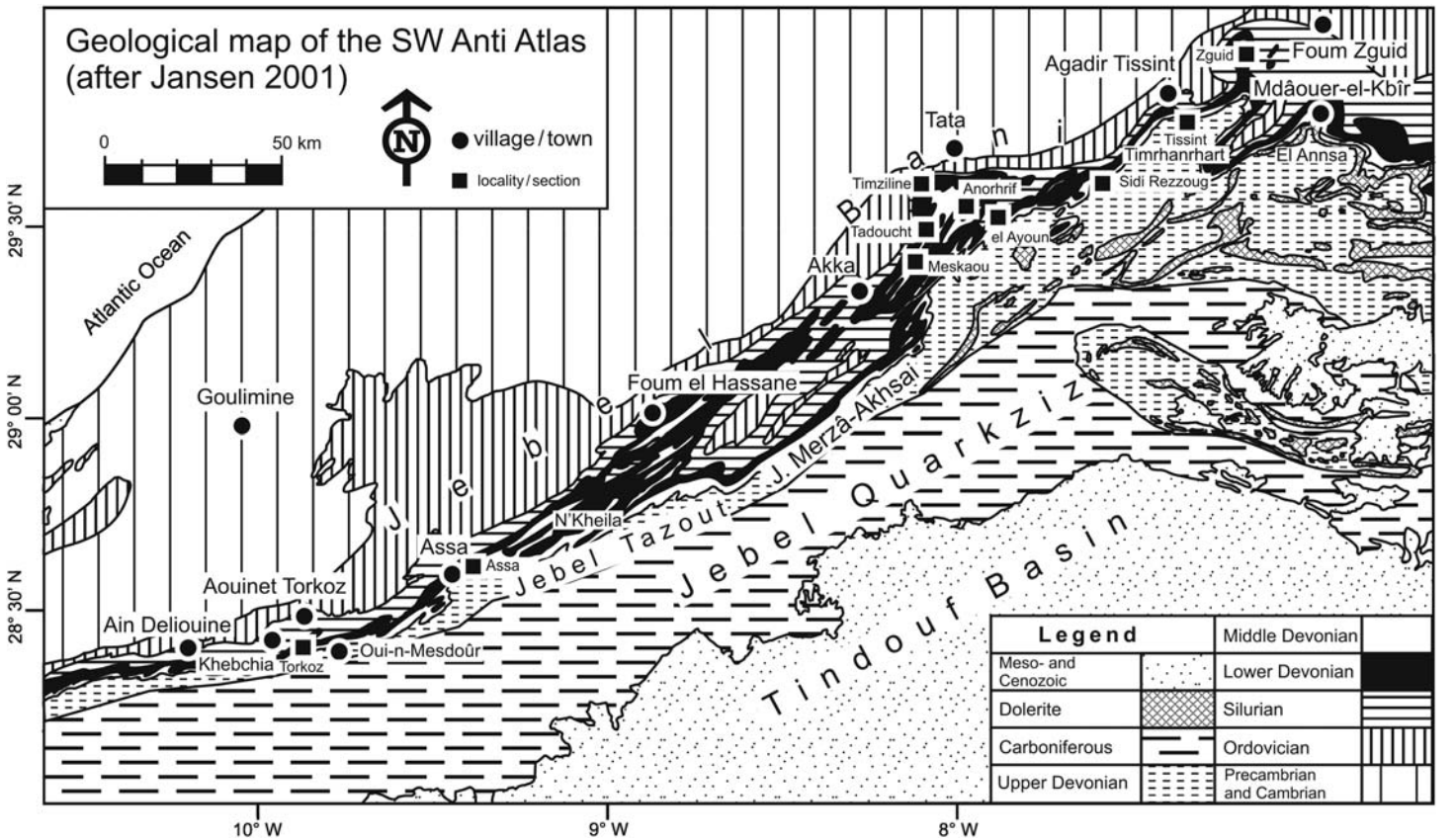


Fig. 1. Geological map of the Southern Anti-Atlas, after Jansen (2001), based on Hollard & Jacquemont (1956). The location of the main sections is indicated.

Finally, there is a third Emsian in the GSSP sense as defined in the Zinzilban section in Uzbekistan (Yolkin *et al.* 1997). Therefore, it is always necessary to explain in which sense one of these chronostratigraphic units is meant. The Rhenish stages Gedinnian and Siegenian are still used, because they are regionally important. Unfortunately, some authors use the terms Lochkovian and Pragian just as synonyms of Gedinnian and Siegenian—and by doing so increase the confusion.

The Lower Devonian strata in the Ardenno-Rhenish Mountains are not continuously marine. Fortunately, the resulting gaps in the documentation of marine faunas, which have proved to be substantial, could at least partly be closed by correlations with sections in the Armorican Massif (NW France), the Cantabrian Mountains (North Spain), the Celtiberian Chains (NE Spain), and in North Africa where the marine documentation is more continuous (e.g. Plusquellec 1980; Morzadec *et al.* 1981; Carls 1987; Gourvennec 1989; García-Alcalde *et al.* 1990; Carls *et al.* 1993; García-Alcalde 1996; Jansen 2001). As a result, the biostratigraphical content of the regional stages Gedinnian, Siegenian and Emsian is now much better known. The regional chronostratigraphic boundaries Lower/Upper Gedinnian, Gedinnian/Siegenian and Lower/Middle Siegenian could be redefined in marine successions in W and SW Europe (Carls 1987). When discussing the stratigraphic position of the Rhenish faunas, this subdivision is followed herein. Thanks to detailed sampling in many sections and palaeontological studies, evolutionary lineages of brachiopods could be reconstructed (orthids, strophomenids: Renouf 1972; Carls 1974; chonetids: Racheboeuf 1981; Carls 1985; spiriferids: Gourvennec 1989; Carls *et al.* 1993; Jansen 2001; Schemm-Gregory & Jansen 2004, 2005; athyridids: Alvarez 1990).

Based on brachiopod comparisons Jansen (2000, 2001) was able to show that the Lower Devonian 'riches' in the Dra Valley are generally older with regard to the Rhenish stages than formerly considered, e.g. by Hollard (1963*a*, 1981*a*).

The Forschungsinstitut Senckenberg (Frankfurt am Main) and Moroccan Institutions (Université Cadi Ayyad, Marrakech; Institut Scientifique, Rabat) cooperate in a successful research project focusing on the Devonian of the Anti-Atlas. The project benefited from its integration into the UNESCO-IGCP Project 421 '*North Gondwanan mid-Palaeozoic bioevent/biogeography patterns in relation to crustal dynamics*' from 1997 to 2003. The most recent activities are embedded in the follow-up IGCP Project 499 '*Devonian land–sea interaction: evolution of ecosystems and climate*' (DEVEC), to which this article is a contribution.

New results of these investigations have recently been presented during a joint meeting of SDS and IGCP 499 in Rabat (Morocco) and a subsequent field trip (Jansen, Plodowski *et al.* 2004*a*, *b*; Jansen, G. Becker *et al.* 2004*a*, *b*; R. T. Becker, Jansen *et al.* 2004).

The present work summarizes these results based on brachiopods, conodonts, and dacryoconarid tentaculitids from the Lower and basal Middle Devonian in the Dra Valley, drawing special attention to interfacial correlations. Stratigraphic data from other faunal groups are taken from the literature, especially information on the trilobites and goniatites. All mentioned localities and sections are described in detail in Jansen (2001), Jansen, Plodowski *et al.* (2004*b*), and Jansen, G. Becker *et al.* (2004*a*, *b*). The Rhenish stratigraphic terminology used below follows Weddige (1996*c*) and Weddige *et al.* (2002). The global Pragian defined by GSSPs is informally subdivided into lower, middle and upper Pragian following the three conodont zones in Carls & Weddige (1996). The position of litho-, bio- and chronostratigraphic units is often given in terms of the Devonian Correlation Table (DCT) edited by K. Weddige as a series in the past 10 years (Weddige 1996*a*, 1998*a*, *b*, 2000*a*, *b*, 2001, 2003, 2004, 2005*a*, *b*); it is indicated by values on a scale from 0 to 20 cm (for introduction, see Weddige 2000*a*) for both the Lower Devonian (di) and the Middle Devonian (dm). The material referred to is stored in the Senckenberg Museum, Frankfurt am Main ('SMF' numbers).

Lmhaïfid Formation

Distribution, thickness and facies

The Lmhaïfid Formation (Hollard 1981*a*, *b*; = 'Série de Passage' *sensu* Hollard 1963*a*) consists of up to more than 600 m of sandy shales, sandy limestones and limestones which are further subdivided into five subunits (Hollard 1963*a*, *b*, 1981*b*). The facies is predominantly of the 'Hercynian' resp. 'Bohemian' type. The formation is known to us only from the section el Ayoun S of Tata in the NE Dra Valley. Because of the considerable variation in facies and strong diachrony from SW to NE, the concept of the formation apparently needs revision; a division into separate formations has to be considered.

Conodont faunas C 1 to C 4

Conodonts of the Lmhaïfid Formation (Fig. 3) were collected from the Section el Ayoun by N. Lazreq and K. Weddige and determined with the kind assistance of Mike Murphy (Davis, California) during a stay at Senckenberg. The section and sample numbers are illustrated in Lazreq &

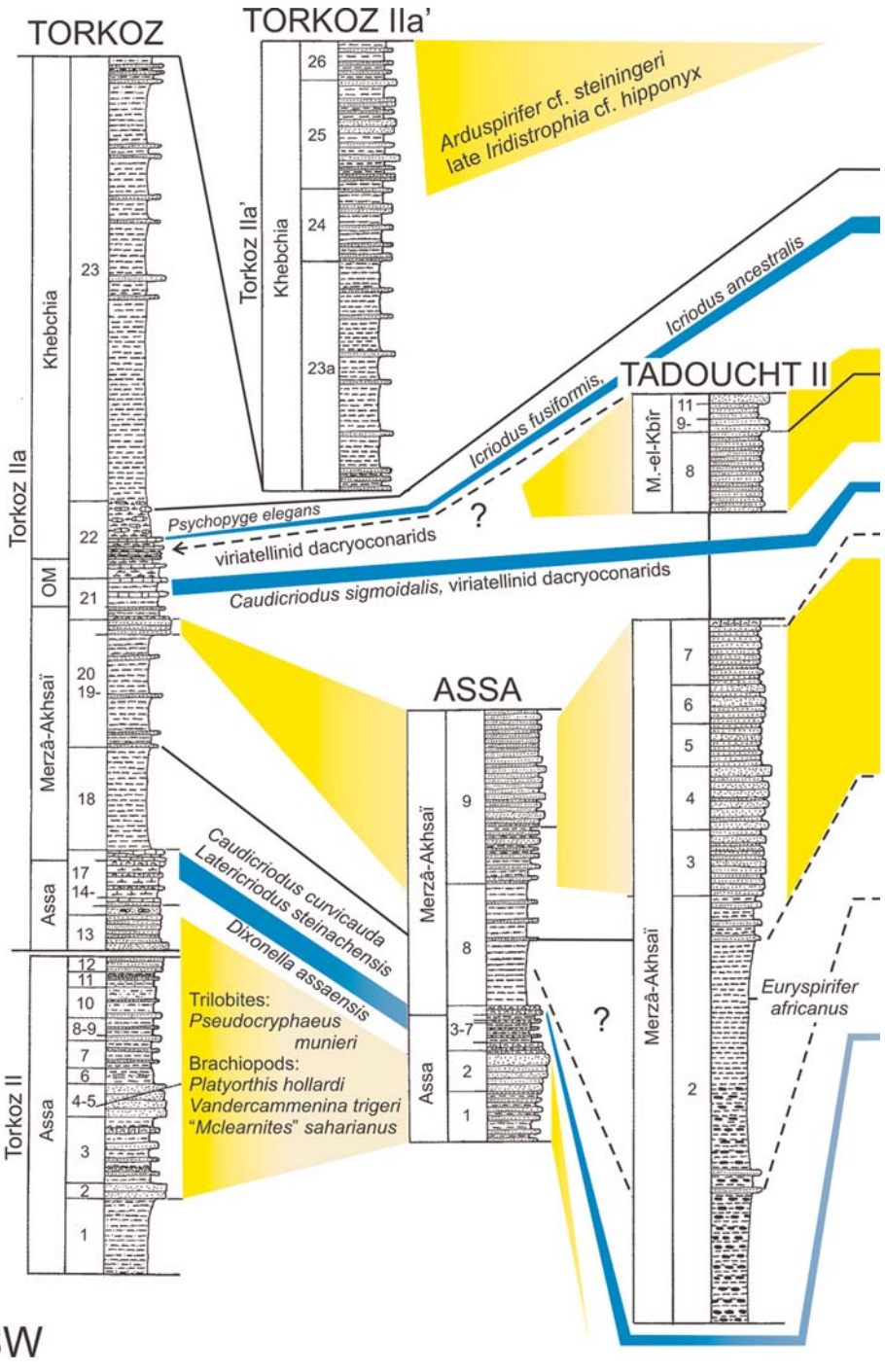


Fig. 2. Correlation of sections (mainly Lower Devonian) in the Dra Valley based on litho- and biostratigraphical criteria (after Jansen 2001, R. T. Becker, Jansen *et al.* 2004). For location of the sections, see Figure 1. OM, Oui-n'-Mesdoûr; O-el-M, Oued-el-Mdâouer; M.-el-Kbîr, Mdâouer-el-Kbîr.

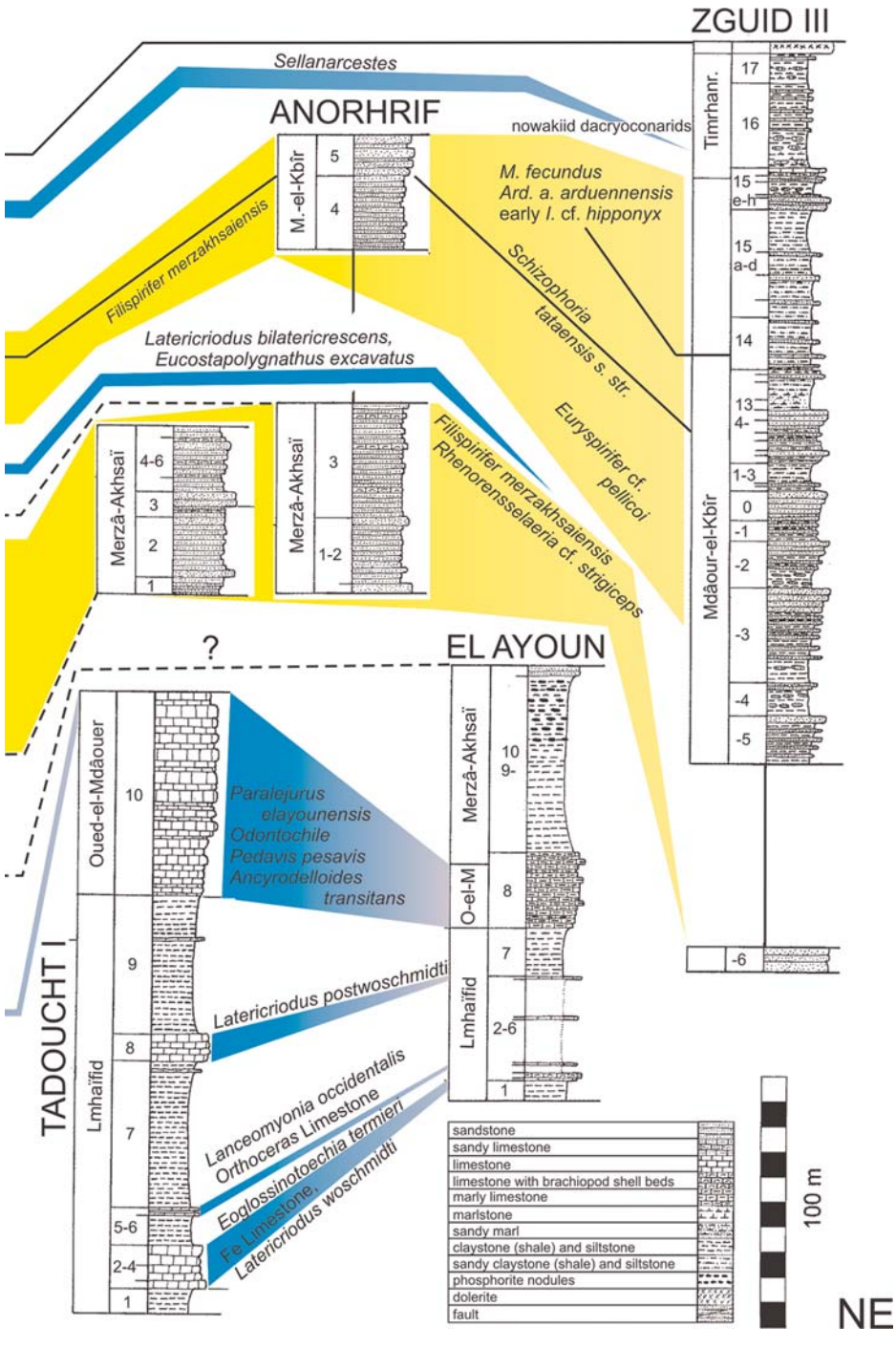
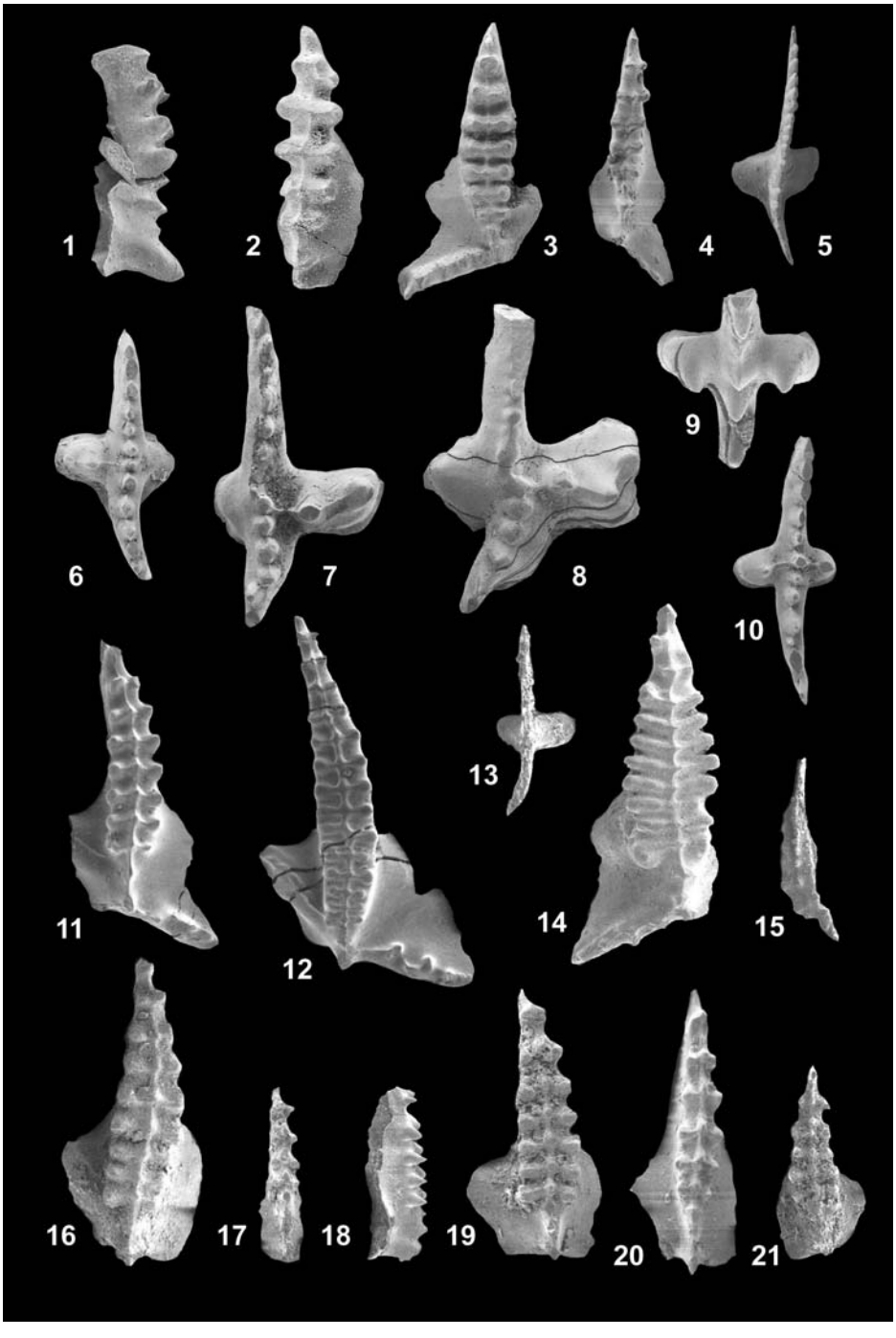


Fig. 2. *Continued.*

Ouanaimi (1998, pp. 224–227, text-fig. 2). Herein (cf. Fig. 5, Table 1), Lazreq's and Ouanaimi's samples CH1, CH5, L1 represent conodont fauna C 1, sample L2 is C 2, L5 is C 3, L8 is C 4, L15 is C 5, and L16 is C 6.

The basal limestones with the conodont fauna C 1 are poor in conodonts, but single fragments of ?'*Ozarkodina*' *eosteinhornensis* (Walliser 1964) [*Remark*: The genus assignment is still under revision, e.g. it was assigned to a 'New Genus W' by



Murphy *et al.* (2004). According to Peter Carls (pers. comm. 2006), the true '*eosteinhornensis*' does not occur during the Lochkovian, and thus the present Moroccan specimens identified as '*eosteinhornensis*' may represent forms of the '*remscheidensis* group'] and ?*Caudicriodus angustoides* (Carls & Gandl 1969) have been found. They questionably suggest a chronostratigraphic position within the Lower Lochkovian, about DCT interval from di 0.0 to 2.6 cm, i.e. *woschmidti-postwoschmidti-*, and *eurekaensis* zones (see Carls & Weddige 1996) resp. *hesperius-*, *eurekaensis-* and *sexidentata* zones *sensu* Murphy (2000).

The following conodont fauna C 2 with *Caudicriodus angustoides* (Carls & Gandl 1969), *Latericriodus postwoschmidti* (Mashkova 1968), *Lanea omoalpha* Murphy & Valenzuela-Ríos 1999, and ?'*Ozarkodina*' *eosteinhornensis* (Walliser 1964) documents the *omoalpha* Zone *sensu* Murphy (2000, DCT interval di 2.7 to 3.1 cm) which after Murphy & Valenzuela-Ríos (1999, p. 322, text-fig. 1) is rather similar with the range of the zone index.

The *omoalpha* Zone is also represented by the conodont fauna C 3 because of the occurrence of *Ancyrodelloides asymmetricus* (Bischoff & Sannemann 1958), *A. carlsi* (Boersma 1974), ?'*Ozarkodina*' *steinhornensis* (Ziegler 1956), *Lanea omoalpha* (Murphy & Valenzuela-Ríos 1999), and *Ozarkodina repetitor* (Carls & Gandl 1969). Since Murphy & Valenzuela-Ríos (1999, p. 322, table 1, text-fig. 1) regard *A. asymmetricus* as a possible variant of *A. transitans* (Bischoff & Sannemann 1958), the entry of which is later than that of *A. omoalpha*, the fauna C 3 may document a high level within the *omoalpha* Zone (DCT interval di 2.9 to 3.1 cm).

The succeeding conodont fauna C 4 contains *Ancyrodelloides transitans* (Bischoff & Sannemann 1958) represented by its early morphotype which is characterized by an open basal cavity. Therefore, C 4 represents the lower half of the *A. transitans* range *sensu* Murphy & Valenzuela-Ríos (1999, p. 322, text-fig. 1) or the upper *omoalpha* Zone *sensu* Murphy (2000, DCT interval di 2.9 to 3.1 cm).

Conodont faunas C 2 to C 4 as a whole distinctly indicate the *omoalpha* Zone resp. the lower part of the (traditional) *delta* Zone, i.e. the lower Middle Lochkovian [*Remark*: Valenzuela-Ríos & Murphy (1997, p. 133, fig. 3) and Murphy & Valenzuela-Ríos (1999, p. 322, text-fig. 1) indicate the range of the conodont genus *Ancyrodelloides* as 'Middle Lochkovian'. It starts with the *omoalpha* Zone and ends with the base of the *pandora* beta Zone of the global conodont zonation, and it is rather coincident with the *delta* Zone of the Cordilleran conodont zonation.] according to Murphy & Valenzuela-Ríos (1999) and Murphy (2000). Thus, the Lmhaïfid Formation of the el Ayoun section corresponds well with the '*Orthoceras*' Limestone horizons in the Achguig area of the Tafilalt region (SE Morocco) which are approximately of the same age (Bultynck & Walliser 2000, Unit A).

Fig. 3. All magnifications of specimens about×60. **1–8**, conodonts from the Lmhaïfid Formation (Lochkovian). **1–2**, *Caudicriodus angustoides* (Carls & Gandl 1969). **1**, SMF 69627, lateral view—Section el Ayoun (Tata), bed CH5. **2**, SMF 69625, upper view—Section el Ayoun (Tata), bed L2. **3**, *Caudicriodus postwoschmidti* (Mashkova 1968); SMF 69624 upper view—Section el Ayoun (Tata), bed L2. **4**, *Icriodus eolatericrescens* (Mashkova 1968); SMF 69652 upper view—Section el Ayoun (Tata), bed L2. **5**, '*Ozarkordina*' *steinhornensis* (Ziegler 1956); SMF 69650 upper view—Section el Ayoun (Tata), bed L5. **6**, *Lanea omoalpha* Murphy & Valenzuela-Rios 1999; SMF 69631 upper view—Section el Ayoun (Tata), bed L5. **7**, *Ancyrodelloides asymmetricus* (Bischoff & Sannemann 1958); SMF 69629 upper view—Section el Ayoun (Tata), bed L5. **8**, *Ancyrodelloides carlsi* (Boersma 1974); SMF 69638 upper view—Section el Ayoun (Tata), bed L5. **9–10**, conodonts from the Oued-el-Mdâouer Formation (Lochkovian to Pragian). **9**, *Ancyrodelloides transitans* (Bischoff & Sannemann 1958); SMF 69635 upper view—Section el Ayoun (Tata), bed L15. **10**, *Ancyrodelloides transitans* (Bischoff & Sannemann 1958); SMF 69634 upper view—Section el Ayoun (Tata), bed L15. **11–15**, Conodonts from the Oui-n-Mesdoûr Formation (Zlichovian to Lower Dalejian resp. Lower to lower Upper Emsian). **11**, *Latericriodus beckmanni sinuatus* (Klapper, Ziegler & Mashkova 1978); SMF 69961 upper view—Section Torkoz IIa (Dra Valley), bed 21 g. **12**, *Latericriodus multicostatus* (Carls & Gandl 1969); SMF 69962 upper view—Section Torkoz IIa (Dra Valley), bed 21 g. **13**, '*Ozarkordina*' *steinhornensis miae* (Bultynck 1971); SMF 69963 upper view—Section Torkoz IIa (Dra Valley), bed 21e. **14**, *Caudicriodus sigmoidalis* (Carls & Gandl 1969); SMF 69964 upper view—Section Torkoz IIa (Dra Valley), bed 21d. **15**, *Polygnathus inversus* Klapper & Johnson 1975 (juvenile form); SMF 69965 upper view—Section Torkoz IIa (Dra Valley), bed 21e. **11–21**, Conodonts from the Khebchia Formation (Dalejian resp. Upper Emsian). **16**, *Icriodus corniger ancestralis* Weddige 1977; SMF 69966 upper view—Section Torkoz IIa (Dra Valley), bed 22c. **17**, *Icriodus culicellus* Bultynck 1976; SMF 69967 upper view—Section Torkoz IIa (Dra Valley), bed 22d. **18**, *Icriodus culicellus* Bultynck 1976; SMF 69968 lateral view—Section Torkoz IIa (Dra Valley), bed 22e. **19**, *Icriodus corniger rectirostratus* Bultynck 1970; SMF 69969 upper view—Section Torkoz IIb (Dra Valley), 54.4 m. **20**, *Icriodus corniger leptus* Weddige 1977; SMF 69970 upper view—Section Torkoz IIa (Dra Valley), bed 22 g. **21**, *Icriodus* sp., aff. *I. werneri* Weddige 1977; SMF 69971 upper view—Section Torkoz IIa (Dra Valley), bed 22d.

Hollard (1977) reported '*I. woschmidti woschmidti* Ziegler 1960' from limestones in the lower Lmhaïfid Formation in the SW Dra Valley at Aïn-Deliouine; if this determination is correct (if it is actually not *Icriodus postwoschmidti*), then the formation would have an early *woschmidti-postwoschmidti* age there, corresponding to the DCT interval di 0.0 to 0.85 cm (see Carls 1996*a*). According to Hollard (1977), a limestone layer near the top of the Lmhaïfid Formation in the SW Dra Valley has yielded *Pedavis pesavis* (Bischoff & Sannemann 1958), the range of which would indicate an age within the interval upper Middle Lochkovian to Upper Lochkovian or lowermost Pragian (DCT interval about di 3.5 to 6.55 cm).

Brachiopod faunas B 1 to B 2

In the lower brachiopod limestones of the el Ayoun section, i.e. in the level of conodont fauna C 1 mentioned above, *Eoglossinotoechia termieri* (Drot 1964) has been found in association with other rhynchonellids and atrypids (brachiopod fauna B 1: Table 1 and Fig. 5); *E. termieri* has been reported from strata attributed to the Lower Gedinnian [*Remark*: Carls (1987) has proposed a formal definition of Lower and Upper Gedinnian] in Morocco (Drot 1964; Hollard 1977). Higher in the section, corresponding to the fauna C 2, *Lanceomyonia occidentalis* (Drot 1964) occurs in masses (brachiopod fauna B 2: Table 1 and Fig. 5). According to Carls (1987), *L. occidentalis* occurs in the upper part of the Lower Gedinnian (Carls 1996*d*, DCT interval di $<$2.7 to 3.5 cm) in the Celtiberian Chains and the Sierra de Guadarrama (Spain). A faunal element showing a typical Gedinnian aspect from the SW Dra Valley is *Howellella* ex gr. *mercurii* (Gosselet 1880) as described by Drot (1964) from the 'zone à *Acastella tiro*'.

Trilobites and graptolites

Hollard (1963*b*) described a succession of typical Gedinnian *Acastella* species from the Lmhaïfid Formation at Aïn-Deliouine in the SW Dra Valley including, e.g. *A. heberti* (Gosselet 1888), *A. tiro* (Rud. & E. Richter 1954) and *A. tanzidensis* Hollard 1963 (Carls 1996*b*, DCT interval di 0.0 to 1.8 cm, di 2.7 to 3.5 cm, and di 4.5 to 6.0 cm). Apparently, the Lmhaïfid Formation here ends later than at the el Ayoun section, confirmed by the occurrence of Pragian fossils in the basal Assa Formation following above (see below). Hollard (1977) reported *Monograptus uniformis* Přibyl 1940, the zonal index fossil of the first graptolite zone in the Lochkovian.

Correlation and age

Due to the conodont data, the Lmhaïfid Formation as it was identified in the el Ayoun section ranges from the Lower to the lower Middle Lochkovian. Brachiopods from the same section in the NE Dra Valley indicate lower to upper parts of the Lower Gedinnian.

According to Hollard (1977) the SW succession of the Lmhaïfid Formation at Aïn-Deliouine begins above the *Scyphocrinites* Beds near the Silurian–Devonian boundary which can be recognized mainly by graptolites and conodonts. Trilobites point to the Lower Gedinnian and lower part of the Upper Gedinnian in terms of the Rhenish subdivision. The top of the formation is younger and could reach there even into the lowermost Pragian. Accordingly, Pragian index fossils have been reported from the basal limestone of the overlying Assa Formation.

Oued-el-Mdâouer Formation

Distribution, thickness and facies

In the NE Dra Valley, crinoidal limestones yielding corals and bryozoans and marly limestones of the Oued-el-Mdâouer Formation overlie the Lmhaïfid Formation. The thickness of this formation reaches about 30 to 80 m near Tata (Jansen 2001). The facies is of 'Hercynian' resp. 'Bohemian' type.

Conodont faunas C 5 to C 6

Although the Oued-el-Mdâouer Formation in the el Ayoun section is dominated by limestones conodonts are restricted to the samples L15 and L16 (see sample numbers in Lazreq & Ouanaimi 1998, pp. 224–227, text-fig. 2).

In sample L15, the conodont fauna C 5 occurs with *Icriodus eolatericrescens* (Mashkova 1968) and, as a distinct guide fossil, *Ancyrodelloides transitans* (Bischoff & Sannemann 1958) represented by a morph which possesses a basal cavity constricted in large individuals; thus it is obviously more advanced than individuals with open basal cavities from fauna C 4 of the Lmhaïfid Formation (see above). According to Murphy & Valenzuela-Ríos (1999, text-fig. 1) this late *transitans* morph, however, suggests an age still within the Middle Lochkovian, i.e. still within the (traditional) *delta* Zone resp. below the *pesavis* Zone (see Carls & Weddige 1996, DCT interval about di 3.1 to 3.8 cm).

On the contrary, sample L16 resp. conodont fauna C 6 from the overlying bed yielded *Caudicriodus curvicauda* (Carls & Gandl 1969), according to Lazreq & Ouanaimi (1998, p. 225, text-fig. 2). Due to Bultynck (2003, fig. 1), this would indicate an age not earlier than the upper *kindlei* Zone of the middle Pragian resp. DCT height di 8.4 cm. As a consequence, the whole *pesavis* Zone, the Lochkovian/Pragian boundary and even the lower Pragian would be represented

by the interval between samples L15 and L16. Such a long time interval, however, is rather contrary to the limited thickness of the interval in the section, and therefore the C 6 datation should be affirmed by further samples. Moreover, a correlation of the upper Oued-el-Mdâouer Formation with the Assa Formation towards the SW because of a Pragian datation should be affirmed, too. Towards the NE, in any case, the el Ayoun limestone sequence of both the upper Lmhaïfid Formation and the lower Oued-el-Mdâouer Formation corresponds obviously well with the '*Orthoceras*' Limestone in the Achguig region with regard to carbonate facies development and presumably to the datation mainly as *delta* Zone (Bultynck & Walliser 2000, Unit A). It is not clear whether the uppermost limestone beds may already represent the basal Merzâ-Akhsaï Formation.

Trilobites

Uppermost parts of the limestone succession in the el Ayoun section have yielded a Pragian trilobite fauna including the genera *Odontochile* and *Paralejurus* (see Schraut 2000). It is, however, not clear whether these beds already correlate with the basal Merzâ-Akhsaï Formation.

Correlation and age

According to conodont faunas, the Oued-el-Mdâouer Formation in the el Ayoun section starts in the *delta* Zone resp. the Middle Lochkovian and reaches into the Pragian. The formation represents an equivalent of upper parts of the Lmhaïfid Formation and at least partly of the Assa Formation in the SW Dra Valley. Upper beds of the Oued-el-Mdâouer Formation may correlate with the limestone beds of the uppermost Assa Formation; uppermost limestone beds in the section el Ayoun with Pragian trilobites possibly represent already the basal Merzâ-Akhsaï Formation. Towards the NE, the Oued-el-Mdâouer Formation is most probably an equivalent of the '*Orthoceras*' Limestone in the Achguig region.

Assa Formation ('Rich 1')

Distribution, thickness and facies

The Assa Formation (Hollard 1963*a*, content modified by Hollard 1981*a*) or 'Rich 1' is typically developed as a 'rich' including basal limestones, middle shales and upper sandstones in the SW Dra Valley, between Aïn Deliouine in the SW and Foum el Hassane in the NE. In the type area near the town of Assa, the formation reaches a thickness of approximately 300 m (Hollard 1981*a*).

Conodont fauna C 7

In the limestones just below the top of the Assa Formation in the Assa I section (samples 3 and 5, Unit 5; Fig. 5, Table 1: conodont fauna C 7), questionably determinable fragments of ?*Caudicriodus angustoides castilianus* (Carls 1969) were found but particularly specimens of *Latericriodus steinachensis* (Al-Rawi 1977). The latter is a distinct index for the uppermost Lochkovian and lower to middle Pragian (Schönlaub *in* Chlupáč *et al.* 1985 pp. 24–27; Murphy 1989; Weddige 1987; Slavik 2004; Slavik & Hladil 2004, fig. 3). Because no overlap of *L. steinachensis* and *Eoctenopolygnathus pireneae* (Boersma 1974) is known world-wide up to now, it can be concluded that the middle Pragian resp. the Assa Formation is older than the *pireneae* Zone and ranges within the interval of the *sulcatus* and *kindlei* zones (see Carls & Weddige 1996, DCT interval di ~6.0 to 9.0 cm).

Brachiopod faunas B 3 and B 4

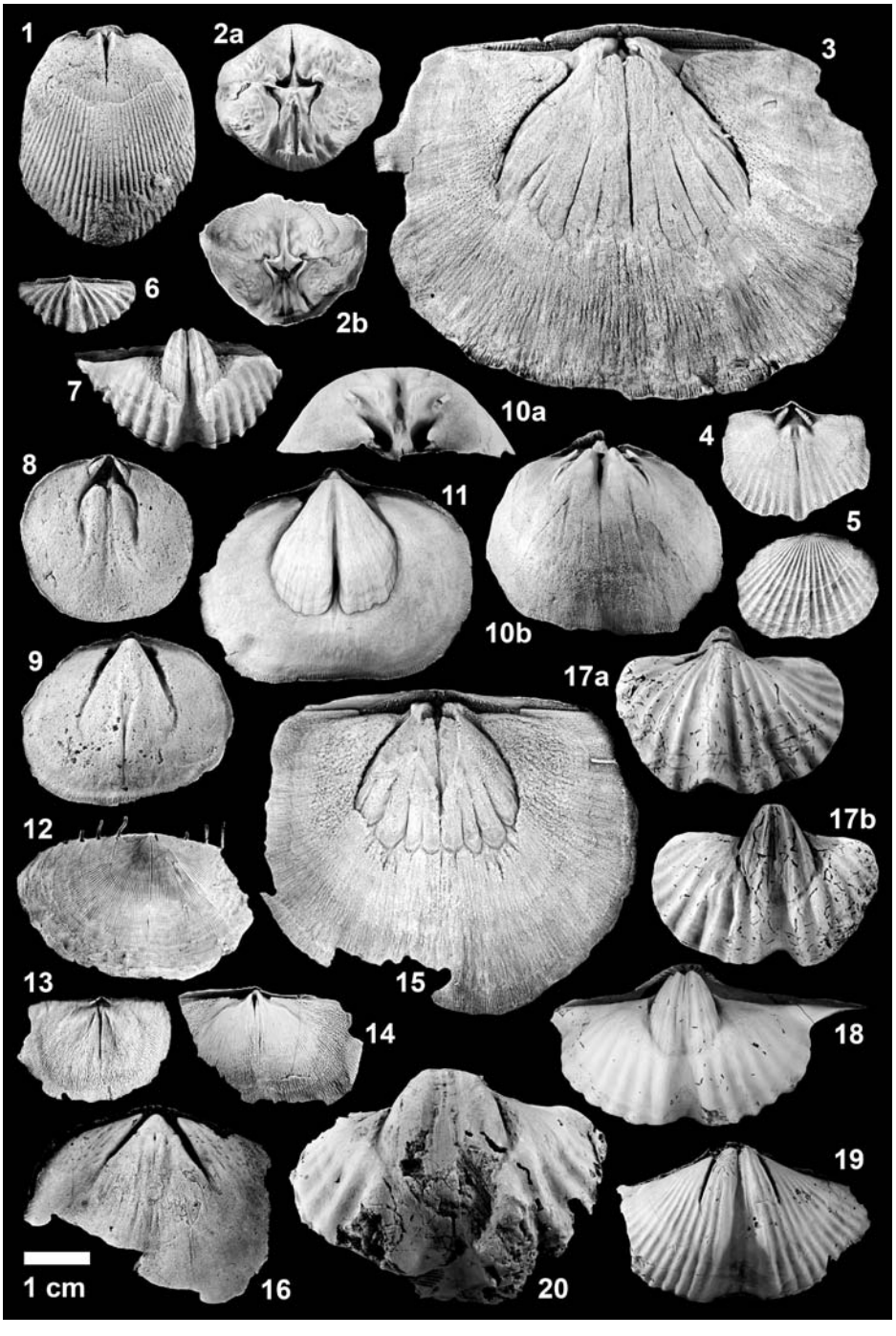
Hollard (1977) reported *Eucharitina oehlerti* (Bayle 1878) already from the basal limestones of the Assa Formation; the genus supports a latest Lochkovian to Pragian age (Brice *et al.* 2000). *Platyorthis* sp. described by Drot (1975) from the same level represents an ancestral form still close to the Gedinnian *P. monnieri* (Rouault 1851).

The brachiopod fauna B 3 (Table 1 and Fig. 5) from the upper sandstones of the Assa Formation in the sections Assa I and Torkoz II includes a number of stratigraphically significant brachiopod taxa (Fig. 4) allowing stratigraphic alignments in the sense of the regional Rhenish subdivision as improved and modified by Carls (1987) and Jansen (2001): *Iridistrophia* sp. X *sensu* Jansen (2001) represents a primitive evolutionary stage because of its short dental lamellae; it is certainly more primitive than *I. maior* (Fuchs 1915) of the Rhenish Lower Emsian and more evolved than the Gedinnian *I. euzona* (Fuchs 1919).

Ctenochonetes ex gr. *aremoricensis* Racheboeuf 1976 is an advanced taxon which is similar to congeneric forms from the Siegenian of Western Europe (comp. Racheboeuf 1981). *Mclearnites saharianus* Jansen 2001 is more primitive than *M. cherguiensis* Jansen 2001 from the overlying Merzâ-Akhsaï Formation which supports a Middle Siegenian age (see below). *Platyorthis hollardi* Jansen 1999 is phylogenetically intermediate between the Gedinnian *P. monnieri* (Rouault 1851) and the Middle Siegenian *P. circularis taunica* (Fuchs 1915), being more similar to *P. c. taunica* than to *P. monnieri*. Very similar forms of *Platyorthis* occur in upper parts of the Nogueras Formation of the Celtiberian Chains, i.e. the d2c beta (material studied by U. Jansen, see also

Jansen 2001), representing upper parts of the Lower Siegenian according to Carls (1987). Accordingly, in the sense of the DCT (Carls 1996*d*), the upper Assa Formation falls into the interval di 8.4 to 9.1 cm.

Rhenoschizophoria torkozensis (Jansen 2001) is much more developed than *R. runegatensis* (Renouf 1972) from the Gedinnian of the Armorican Massif in NW France and slightly less developed than



R. provulvaria (Maurer 1886) from the Middle Siegenian of the Rheinisches Schiefergebirge in Germany.

Filispirifer cf. *merzakhsaiensis* Jansen 2001 is a large, plicate spiriferid of 'Siegenian aspect', with strong apical callosities and lacking free crural plates. Forms determined as *Vandercammenia trigeri* (de Verneuil 1850) from the Rhenish Middle Siegenian (Dahmer 1940, material re-studied by U. Jansen) are more advanced than the specimens from the upper Assa Formation as indicated by a trend towards a greater shell-size and more plications. The latter are comparable to Lower Siegenian forms from the Néhou Formation in Brittany described by Gourvennec (1989) and contemperaneous ones from the upper Nogueras Formation in the Celtiberian Chains (Carls 1996*c*), whereas forms from the Middle or Upper Siegenian Faou Formation in Brittany (Gourvennec 1989, Pl. 7, text-figs 3–5) and the top of the Santa Cruz Formation (coll. Carls) are again representing a higher phylogenetic development.

The genus *Dixonella* is transitional between *Hysterolites* and *Euryspirifer*, the first being regarded as the ancestor of the latter. *Euryspirifer* appears first in the Middle Siegenian (Carls 1987). *Dixonella assaensis* Jansen 2001 from the shales near the top and above the terminal sandstones of the Assa Formation (Assa I section, Unit 4b, brachiopod fauna B 4: Table 1 and Fig. 5) is similar to 'Acrospiriferinae n. gen. N, n. sp. N' *sensu* Carls & Heddebaut (1980) from high in the Nogueras Formation in the Celtiberian Chains, unit d2c beta 8 (Carls & Heddebaut 1980, p. 22; Carls 1987, p. 101, text-fig. 7) corresponding to DCT di 8.9 to 9.1 cm (Carls 1996*d*). *Dixonella rouaulti* (Gourvennec 1988) from the upper Céneré Formation of the Armorican Massif may be more primitive and somewhat older. In the same unit, again *Ctenochonetes* ex gr. *aremoricensis* Racheboeuf 1976 and *Oligoptycherhynchus* cf. *daleidensis* (C. F. Roemer 1844) occur.

In the lowermost Siegenian of the Armorican Massif and the Celtiberian Chains, species of *Platyorthis*, *Schizophoria*, *Mclearnites*, *Ctenochonetes* and *Vandercammenina* occur, which are more primitive than their congeneric relatives from the upper Assa Formation (Carls 1987 and observations by U. Jansen). Finally, the absence of *Euryspirifer* and *Arduspirifer* in spite of suitable facies suggests that the Assa Formation is older than the Middle Siegenian. From the total brachiopod fauna, it is concluded that the upper Assa Formation has a rather late Early Siegenian age.

Tentaculitids and trilobites

Nowakia acuaria (Rh. Richter 1854) has been described from the Assa Formation (Lardeux 1969, p. 96) having its entry in the basal limestones (Hollard 1977, pp. 191). Therefore, this level indicates already the Pragian.

Schraut (2000) described several trilobite taxa of Rhenish aspect from the upper Assa Formation which he considered to be of late Pragian age. However, *Pseudocryphaeus munieri* (Oehlert 1877) is known from the d2c alpha and beta in the Celtiberian Chains (Gandl 1972, pp. 100–101), which is well consistent with the brachiopod-based correlation. In general, Siegenian trilobites are still little known and require revision.

Fig. 4. **1–7**, Brachiopods from the upper Merzâ-Akhsaï Formation ('Rich 2' sandstones, Middle to Upper Siegenian). **1–2**, *Rhenorensselaeria* cf. *strigiceps* (Roemer 1843). **1**, Internal mould of conjoined specimen; SMF 65040—Section Anorhrif I. **2** Internal mould of conjoined specimen and latex replica; SMF 65044—Section Anorhrif I. **2a**, Internal mould, posterior view. **2b**, latex replica of apical region. **3**, '*Mclearnites*' *cherguiensis* Jansen 2001; Internal mould of ventral valve; holotype SMF 59295—Section Anorhrif II, Unit 3. **4–5**, *Tropidoleptus carinatus* ssp. A *sensu* Jansen 2001. **4**, Internal mould of dorsal valve; SMF 59058—Loc. Meskaou I. **5**, External mould of dorsal valve; SMF 59046—Loc. Meskaou I. **6**, *Hysterolites* sp.: Internal mould of dorsal valve; SMF 65029—Loc. Tiguisselt. **7**, *Arduspirifer maroccanicus* Jansen 2001: Internal mould of ventral valve; holotype SMF 65064/24—Loc. Anorhrif III. **8–20**, Brachiopods from the upper Assa Formation (Rich 1 sandstones, upper Lower Siegenian, lower or middle Pragian). **8–9**, *Platyorthis hollardi* Jansen 1999. **8**, Internal mould of dorsal valve; SMF 59208—Section Assa I, Unit 2. **9**, Internal mould of ventral valve; SMF 59203—Section Assa I, Unit 2. **10–11**, *Rhenoschizophoria torkozensis* (Jansen 1999). **10**, Internal mould of dorsal valve; SMF 59228—Section Torkoz II, Unit 9. **10a**, posterior view; **10b**, dorsal view. **11**, Internal mould of ventral valve; SMF 59234a—Section Torkoz II, Unit 6. **12–14**, *Ctenochonetes* ex gr. *aremoricensis* Racheboeuf 1976. **12**, External mould of ventral valve; SMF 59021—Section Assa I. **13**, Internal mould of dorsal valve; SMF 59231—Section Torkoz II, Unit 6. **14**, Internal mould of ventral valve; SMF 59321—Section Assa I. **15**, '*Mclearnites*' *saharianus* Jansen 2001: Internal mould of ventral valve; holotype, SMF 59275—Section Timziline, Unit 1. **16**, *Iridistrophia* sp. X *sensu* Jansen 2001: Internal mould of ventral valve; SMF 65833—Loc. Assa II. **17–18**, *Dixonella assaensis* Jansen 2001. **17**, Internal mould of conjoined specimen; SMF 59338—Section Assa I, Unit 4b. **17a**, dorsal view. **17b**, ventral view. **18**, Internal mould of ventral valve; SMF 65241—Section Assa I, Unit 4b. **19**, *Vandercammenina trigeri* (de Verneuil 1850): Internal mould of ventral valve; SMF 59181—Section Assa I, Unit 3. **20**, *Filispirifer* cf. *merzakhsaiensis* Jansen 2001: Internal mould of ventral valve; SMF 65022—Section Assa I, Unit 3.

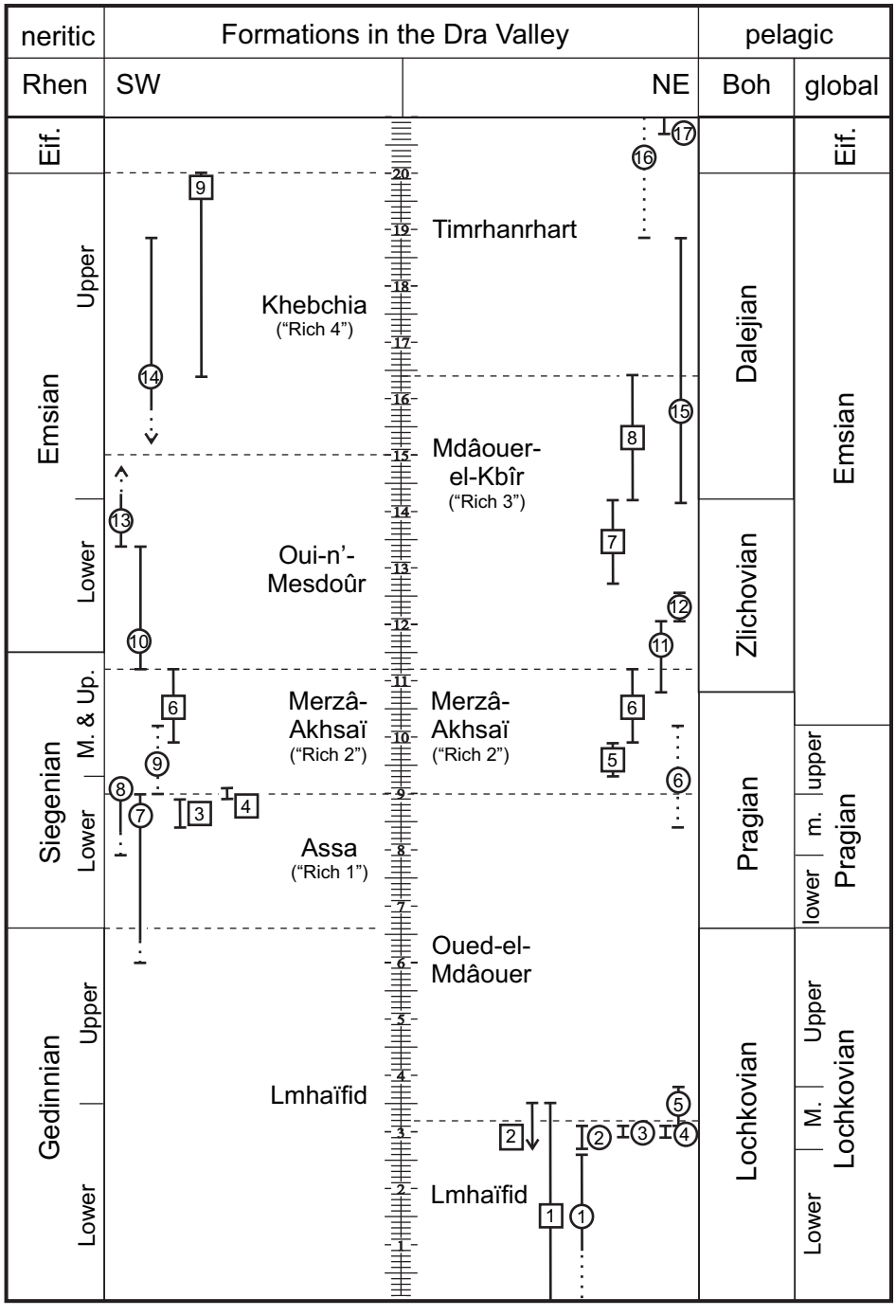


Fig. 5. Ranges of Lower Devonian brachiopod and conodont faunas of the Dra Valley. Numbers of brachiopod (in square frames) and conodont faunas (in circles) are positioned with respect to their lithostratigraphic occurrences within the sequence of Dra Valley formations. The vertical range line, adjacent to each number, demonstrates the uncertainty interval of the biostratigraphic dating with respect to the DCT time ruler (=median cm scale). 'Rhen', Rhenish chronostratigraphy; 'Boh', Bohemian chronostratigraphy; 'global', global chronostratigraphy with stage boundaries defined by GSSPs. For detailed lithostratigraphy, see R. T. Becker, Jansen *et al.* (2004).

Correlation and age

Due to the age of the underlying Lmhaïfid Formation, the Assa Formation probably starts in the uppermost Lochkovian. However, the occurrence of *Nowakia acuaria* in the basal Assa Formation—as mentioned above—pleads already for a Pragian age; a diachronous onset of the formation has also to be taken into consideration. The Assa Formation has no age equivalents documented by marine faunas in the Lower Devonian of the Rhenish Mountains. Phylogenetically, the brachiopod fauna of the upper Assa Formation contains forms which are intermediate between the classical Gedinnian and Middle Siegenian faunas. In the Celtiberian Chains, the Cantabrian Mountains and the Armorican Massif, similar faunas occur in units regarded as upper Lower Siegenian by Carls (1987). In terms of the DCT (Carls 1996*d*), a level from 8.4 to 9.1 cm is most probable. The icriodid conodont fauna from the upper Assa Formation shows an early to middle Pragian age in the GSSP sense, older than the *pireneae* Zone resp. lower than 9.0 cm in the DCT.

Merzâ-Akhsaï Formation ('Rich 2')

Distribution, thickness and facies

The Merzâ-Akhsaï Formation or 'Rich 2' (Hollard 1963*a*, 1981*a*) is typically developed between Aouinet Torkoz in the SW and Tata in the NE. It is a typical 'rich' with 10 to 20 m basal limestone beds, followed by approximately 100 m shales, siltstones and single sandstone beds and about 50 m of 'Rich 2' sandstone beds at the top.

Conodont faunas C 8 to C 9

The basal limestones of the Merzâ-Akhsaï Formation have yielded single conodont elements in a rather poor preservation.

In the section Torkoz IIa, only one conodont fragment could be determined as *Latericriodus* sp., aff. *L. beckmanni* (Ziegler 1956).

In the section Assa I, however, in its 2.7 m basal limestone beds (Unit 7) conodont fragments are more diverse, at 0.3–0.35 m (Fig. 5, Table 1: conodont fauna C 8) with individuals of *Latericriodus steinachensis* (Al-Rawi 1977), ?*Caudicriodus angustoides castilianus* (Carls & Gandl 1969), ?*C. curvicauda* (Carls & Gandl 1969), and at 0.75 m (Fig. 5, Table 1: conodont fauna C 9) with ?*L. claudiae* (Klapper 1980), *Latericriodus* sp., aff. *L. beckmanni* (Ziegler 1956), and *Wurmiella excavata* (Branson & Mehl 1933). The association of *L. steinachensis* and ?*C. curvicauda* in C 8 points to a middle Pragian age of about the *kindlei* Zone in the sense of the Czech regional stages (Schönlaub *in* Chlupáč *et al.* 1985, pp. 24–27; Weddige 1987; Slavik 2004), i.e. DCT interval di ~7.9 to 9.0 cm. Because of the icriodid form aff. *L. beckmanni*, Fauna C 9, however, this possibly represents a later Pragian age above the *L. steinachensis* range, e.g. the *pireneae* Zone resp. the DCT interval di 9.0 to 10.2 cm.

Brachiopod faunas B 5 and B 6

The Merzâ-Akhsaï Formation contains diverse brachiopod faunas (see Figures 4 and 6). *Euryspirifer africanus* Jansen 2001 from middle shales (brachiopod fauna B 5: Table 1 and Fig. 5) of the formation is an early representative of the genus that is well comparable with forms from the Middle and Upper Siegenian of the Rheinisches Schiefergebirge and the Ardennes (Godefroid 1994; Siegenian forms determined as *dunensis;=Euryspirifer* sp. 3 *sensu* Jansen 2001). In the same level, an ancestral *Arduspirifer* sp. occurs.

The brachiopod fauna B 6 (Table 1 and Fig. 5) from the upper sandstones includes a number of biostratigraphically indicative taxa. *Arduspirifer maroccanicus* Jansen 2001 from the upper sandstones is more primitive than the Lower Emsian *A. arduennensis prolatestriatus* Mittmeyer 1973. *Hysterolites* sp. is a typical Siegenian form. *Filizpirifer merzakhsaiensis* Jansen 2001 (='*Acrospirifer*' in older literature) shows close similarities to congeneric Middle or Upper Siegenian forms of the upper Santa-Cruz Formation in the Celtiberian Chains (Carls & Valenzuela-Ríos 1998) and the Montguyon Formation in the Armorican Massif (Gourvennec 1989).

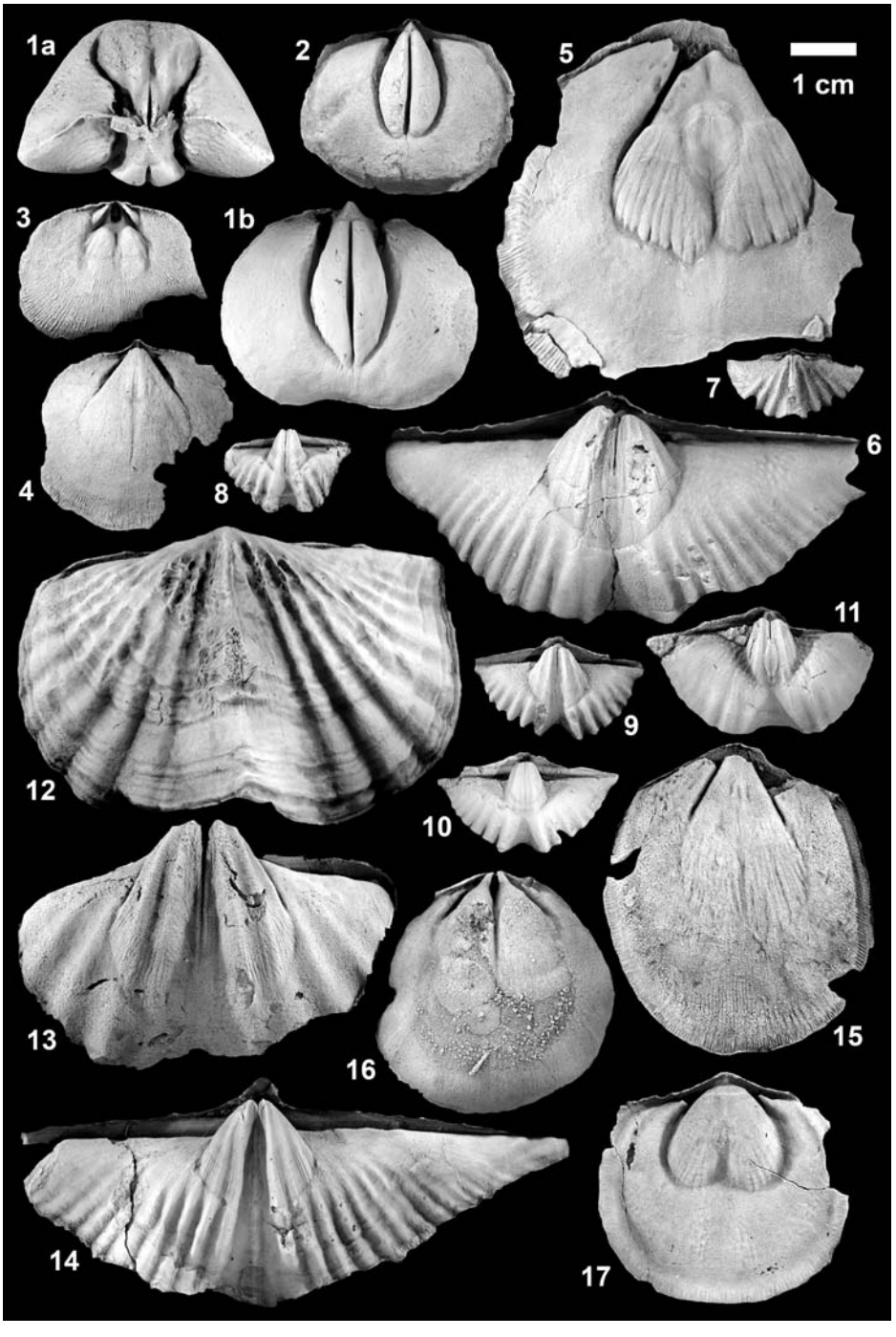
The large strophomenid '*Mclearnites*' *cherguiensis* Jansen 2001 which occurs in many sections of the Dra Valley is similar to *Boucotstrophia herculea* (Drevermann 1904) from the Middle Siegenian of the Rheinisches Schiefergebirge. The differences between the two genera, mainly in the shell profile, are regarded as rather ecomorphotypic than phylogenetic, so that a comparable evolutionary level is assumed (Jansen 2001). *Iridistrophia anorhrifensis* Jansen 2001 is especially closely related to a congeneric form occurring in the Augustenthal Beds of the Rhenish Middle Siegenian (Dahmer 1932); it is also close to the Lower Emsian *I. maior* (Fuchs 1915) (see discussion in Jansen 2001).

Tropidoleptus carinatus ssp. A *sensu* Jansen (2001) is very similar to Upper Siegenian to Lower Emsian *T. c. rhenanus* Frech 1897 from the Rheinisches Schiefergebirge. *Proschizophoria* sp. F *sensu* Jansen (2001) is—as indicated by its large shell and diffuse ventral muscle-bounding ridges—an advanced form within the genus and closely related to the Rhenish *P. personata* (Zeiler 1857) from the Middle to Upper Siegenian.

Table 1. *Succession of studied Dra Valley brachiopod and conodont faunas. For numbers of faunas and DCT interval values compare with Figure 5 and text*

Brachiopod faunas		Conodont faunas	
		C 17 *Eucostapolygnathus costatus costatus* ?*Linguipolygnathus cooperi cooperi* ?*Linguipolygnathus linguiformis pinguis* ?*Polygnathus benderi* ?*Polygnathus trigonicus*	dm 0.7–2.3
		C 16 *Eucostapolygnathus costatus* ssp.	di ?18.85–dm ?3.4
B 9 *Arduspirifer* cf. *steiningeri* *Alatiformia* sp. *Iridistrophia* cf. *hipponyx* late morph	di 16.4–≥20.0	C 15 *Caudicriodus* ?*culicellus* *Icriodus fusiformis* *Icriodus corniger rectirostratus*	di 14.15–18.85
B 8 *Arduspirifer ard. arduennensis* *Euryspirifer* cf. *robustiformis* *Iridistrophia* cf. *hipponyx* early morph *Platyorthis circularis* cf. *circularis* *Pachyschizophoria tataensis* late morph	di 14.2–16.4	C 14 *Caudicriodus culicellus culicellus* *Iciodus corniger ancestralis* *Iciodus corniger leptus* *Iciodus corniger rectirostratus* *Icriodus fusiformis* *Icriodus* sp., aff. *I. werneri*	di ~14.15–18.85
B 7 *Arduspirifer ard.* cf. *arduennensis* *Euryspirifer* cf. *pellicoi* *Iridistrophia* cf. *maior* *Pachyschizophoria tataensis* early morph	di 12.7–14.2	C 13 '*Ozarkordina*' *steinhornensis miae* ?*Eucostapolygnathus inversus* *Latericriodus bilatericrescens* *Latericriodus beckmanni sinuatus*	di 13.35–~14.2
		C 12 '*Ozarkordina*' *steinhornensis miae* *Latericriodus multicostatus* *Lat. bilatericrescens bilatericrescens* *Latericriodus celtibericus*	di 12.05–2.55
		C 11 *Caudicriodus sigmoidalis* *Eucostapolygnathus excavatus* *Latericriodus celtibericus*	di 11.2–12.05
		C 10 *Caudicriodus sigmoidalis* *Caudicriodus* cf. *ultimus* *Latericriodus beckmanni* *Latericriodus bilatericrescens*	di 11.2–13.35
B 6 '*Mclearnites*' *cherguiensis* *Iridistrophia anorhrifensis* *Tropidoleptus carinatus* ssp. A *Proschizophoria* sp. F *Hysterolites* sp. *Arduspirifer maroccanicus* *Rhenorensselaeria* cf. *strigiceps*	di 9.1–11.5	C 9 ?*Latericriodus claudiae* *Latericriodus* sp., aff. *L. beckmanni* *Wurmiella excavata*	di ?9.0–?10.2
B 5 *Euryspirifer africanus*			

Arduspirifer sp. (ancestral form)			
B 4 *Dixonella assaensis*	di 8.4–9.1	C 8 ?*Caudicriodus angustoides castilianus*	di ~7.9–9.0
Ctenochonetes ex gr. *aremoricensis*		?*Caudicriodus curvicauda*	
Oligoptycherhynchus cf. *daleidensis*		*Latericriodus steinachensis*	
B 3 *Iridistrophia* sp. X		C 7 *Latericriodus steinachensis*	di ~6.0–9.0
Ctenochonetes ex gr. *aremoricensis*		?*Caudicriodus angustoides castilianus*	
Mclearnites saharianus			
Platyorthis hollardi			
Rhenoschizophoria torkozensis			
Vandercammenina trigeri			
		C 6 ?*Caudicriodus curvicauda*	di ?8.4–?10.2
		C 5 *Ancyrodelloides transitans* late morph	di 3.1–3.8
		Latericriodus eolatericrescens	
		C 4 *Ancyrodelloides transitans* early morph	di 2.9–3.1
		C 3 *Ancyrodelloides asymmetricus*	di 2.9–3.1
		Ancyrodelloides carlsi	
		?'*Ozarkordina*' *steinhornensis*	
		Lanea omoalpha	
		Ozarkodina repetitor	
B 2 *Lanceomyonia occidentalis*	di 2.9–3.5	C 2 *Caudicriodus angustoides*	di 2.7–3.1
		?'*Ozarkordina*' *eosteinhornensis*	
		Lanea omoalpha	
		Latericriodus postwoschmidti	
B 1 *Eoglossinotoechia termieri*	di 0.0–2.6	C 1 *Caudicriodus angustoides*	di <0.0–2.6
		?'*Ozarkordina*' *eosteinhornensis*	


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The genus *Proschizophoria* has generally been considered to have gone extinct before the classical Siegenian/Emsian boundary in the German sense (Carls 1974); however, at least one specimen has recently been found in the Lower Emsian of the Celtiberian Chains (Mariposas Formation, top of the d4a beta; Carls, pers. comm. 2005), but this seems to be a very rare exception.

Finally, the occurrence of the terebratulid *Rhenorensselaeria* cf. *strigiceps* (C. F. Roemer 1844) is a strong argument in favour of the Middle to Upper Siegenian, because *R. strigiceps* is confined to this interval in the Rheinisches Schiefergebirge (Mittmeyer 1982). From the brachiopod fauna it is concluded that middle to high parts of the Merzâ-Akhsaï Formation have a Middle to Late Siegenian age corresponding to the DCT interval di 9.3 to 11.5 cm (Carls 1996*c*).

Trilobites

The basal limestone of the Merzâ-Akhsaï Formation at section Assa I contains specimens of the genus *Odontochile* indicating the Pragian stage. Schraut (2000) considered the trilobite faunas from the middle and upper Merzâ-Akhsaï Formation as 'uppermost Pragian' in the GSSP sense.

Correlation and age

Basal limestone beds of the Merzâ-Akhsaï Formation point to a middle to upper Pragian age (in the GSSP sense) according to the icriodid conodonts, whereas middle and upper parts of the formation can be dated as Middle to Late Siegenian in the sense of the Rhenish subdivision. Since the overlying formations start within the *excavatus* Zone resp. within the regional Zlichovian stage, it is concluded that the Merzâ-Akhsaï Formation ranges into the upper parts of the Pragian (in the sense of the Czech regional stages) resp. into the lowermost Emsian (in the GSSP sense). In comparison with the Achguig region, there is a coeval equivalent recognizable in the 'Pragian' Limestone (cf. Bultynck & Walliser 2000).

Mdâouer-el-Kbîr Formation ('Rich 3')

Distribution, thickness and facies

The Mdâouer-el-Kbîr Formation (Hollard 1978; =most of the former 'Rich d'El Annsar' or 'Rich 3' *sensu* Hollard, 1963*a*, 1965, 1967) is typically developed as a 'rich' in the NE Dra Valley between Akka and Foum Zguid. Maximal thickness of the formation (295 m) is reached near Foum Zguid at its type locality (Hollard 1978). The formation was studied mainly in the Foum Zguid section.

Conodont faunas C 11, C 12 and C 15

In the section Sidi Rezzoug I, which could not be investigated in detail, two limestone beds at the base of the Mdâouer-el-Kbîr Formation ('Rich 3') have yielded distinct conodont faunas. In the lowermost part (Fig. 5, Table 1: conodont fauna C 11), *Eucostapolygnathus excavatus* (Carls & Gandl

Fig. 6. **1–11**, Brachiopods from the upper Mdâouer-el-Kbîr Formation ('Rich 3' sandstones, upper Lower Emsian to lower Upper Emsian). **1–2**, *Pachyschizophoria tataensis* (Jansen 2001). **1**, Internal mould of conjoined specimen; holotype SMF 59138a—Section Anorhrif II, Unit 5. 1**a**, posterior view **1b**, ventral view, boundary interval Lower/Upper Emsian. **2**, Internal mould of dorsal valve; SMF 65528—Section Foum Zguid, Unit 9, boundary interval Lower/Upper Emsian. **3–4**, *Platyorthis circularis* ssp. **3**, Internal mould of dorsal valve; SMF 66094—Section Foum Zguid, Unit 14c-d, basal Upper Emsian. **4**, Internal mould of ventral valve; SMF 66093—Section Foum Zguid, Unit 14c-d, basal Upper Emsian. **5**, *Iridistrophia* cf. *hipponyx* (Schnur 1851): Internal mould of ventral valve; SMF 65835—Section Foum Zguid, Unit 14, basal Upper Emsian. **6**, *Euryspirifer* cf. *pellicoi* (de Verneuil & d'Archiac 1845): Internal mould of ventral valve, SMF 65706—Section Tissint I, boundary interval Lower/Upper Emsian. **7–10**, *Arduspirifer arduennensis* cf. *arduennensis* (Schnur 1853). **7**, Internal mould of dorsal valve; SMF 66102—Section Foum Zguid, Unit 5, boundary interval Lower/Upper Emsian, more probably upper Lower Emsian. **8**, Internal mould of ventral valve; SMF 65583—Section Foum Zguid, top Unit 12, boundary interval Lower/Upper Emsian. **9**, Internal mould of ventral valve; SMF 66101—Section Foum Zguid, Unit 5, upper Lower Emsian. **10**, Internal mould of ventral valve; SMF 65587—Section Foum Zguid, top Unit 12, boundary interval Lower/Upper Emsian. **11**, *Arduspirifer arduennensis arduennensis* (Schnur 1853). Internal mould of ventral valve; SMF 66105—Section Foum Zguid, Unit 14a–b, basal Upper Emsian. **12–17**, Brachiopods from the Merzâ-Akhsaï Formation ('Rich 2' sandstones, Middle to Upper Siegenian). **12–13**, *Filispirifer merzakhsaiensis* Jansen 2001. **12**, Internal mould of dorsal valve; holotype SMF 59103a—Section Tadoucht II. **13**, Internal mould of ventral valve; SMF 59121—Loc. Meskaou I. **14**, *Euryspirifer africanus* Jansen 2001: Internal mould of ventral valve; holotype SMF 59061—Section Tadoucht II, Unit 3. **15**, *Iridistrophia anorhrifensis* Jansen 2001: Internal mould of ventral valve; holotype SMF 59837—Section Anorhrif II. **16–17**, *Proschizophoria* sp. F *sensu* Jansen (2001). **16**, Internal mould of ventral valve; SMF 59393—Section Torkoz IIa, base of Unit 21a. **17**, Internal mould of dorsal valve; SMF 59288—Section Torkoz IIa, base of Unit 21a.

1969), *Caudicriodus sigmoidalis* (Carls & Gandl 1969), and *Latericriodus celtibericus* (Carls & Gandl 1969) indicate the *excavatus* Zone—most probably its lower part, because this conodont association defines 'conodont step 17' *sensu* Carls (1996*a*, DCT interval di 11.2 to 12.05 cm). In black limestones a little above (Fig. 5, Table 1: conodont fauna C 12), *L. multicostatus* (Carls & Gandl 1969), *L. bilatericrescens bilatericrescens* (Ziegler 1956), *L. celtibericus*, and ?'*Ozarkodina*' *steinhornensis miae* (Bultynck 1971) are present; this association represents the 'conodont step 18' *sensu* Carls (1996*a*, DCT interval di 12.05 to 12.55 cm). The base of the Mdâouer-el-Kbîr Formation thus appears to be distinctly correlative with the lower Zlichovian stage in Bohemia.

Bultynck & Hollard (1980, pp. 26, 33, samples 27-1 and 27-2) identified *Caudicriodus* ?*culicellus* (Bultynck 1976), *Icriodus fusiformis* Carls & Gandl 1969, and *I. corniger rectirostratus* Bultynck 1970 from shell beds intercalated in the upper sandstones of the formation (Fig. 5, Table 1: conodont fauna C 15). The fauna correlates with Upper Emsian faunas from the 'Grauwacke de Hierges' in the Ardenne Mountains (Bultynck & Hollard 1980, p. 26, Faune Vb) attributed to the *laticostatus* to *serotinus* zones (after Bultynck *et al*. 2000, cf. Weddige & Requadt 1985) resp. DCT interval di 14.15 to 18.85 cm (Bultynck *et al*. 2004). Moreover, Becker, Bockwinkel *et al.* (2004) suggested that such icriodid faunas are of high correlative value in the basal Upper Emsian below the onset of polygnathid faunas of the *serotinus* Zone.

Tentaculitids

Bultynck & Hollard (1980, p. 22) reported *Viriatellina pseudogeinitziana* Bouček 1964 and *V. hercynica* Bouček 1964 from the base of the Mdâouer-el-Kbîr Formation and noted the absence of *Nowakia acuaria* (Rh. Richter 1854). They attributed these limestones to the Lower Emsian. Lardeux (1969, pp. 106–108, text-fig. 77) described *N. praecursor* Bouček 1964 from the basal limestone of the Mdâouer-el-Kbîr Formation. The species characterizes the middle Zlichovian in Bohemia (e.g. Chlupáč 1982, p. 362; Lukeš & Chlupáč 1998) resp. DCT interval di 10.75 to 12.4 cm (Alberti 1996); it is also present in the Lower Emsian Hunsrück-Schiefer of the Rheinisches Schiefergebirge (Alberti 1982). This is in good agreement with the datation by conodont faunas C 11 and C 12 from the basal limestones.

Brachiopod faunas B 7 and B 8

Brachiopods from sandstones of the upper Mdâouer-el-Kbîr Formation (see Fig. 6) are of outstanding biostratigraphic potential. Most informative in this respect is the Foum Zguid section in the NE Dra Valley (see Fig. 1 and Jansen, G. Becker *et al.* 2004*a*) bearing highly diverse and abundant faunas.

In previous works (Drot 1964; Hollard 1978; Bultynck & Hollard 1980), all specimens of *Arduspirifer* from the Mdâouer-el-Kbîr Formation have been determined as *A. arduennensis arduennensis* (Schnur 1853). According to the range of this subspecies in the Ardenno-Rhenish Mountains, the productive beds as a whole were attributed to the Upper Emsian. However, more recent studies (Jansen 2001) have shown that several taxa are present. Some specimens from the Foum Zguid section, units 5 and 12 (Fig. 6, specimens 7–10), which are provisionally determined as *A. a.* cf. *arduennensis* herein, are also rather similar to *A. adradensis* García-Alcalde 2004 from the upper Lower Emsian La Pedrosa Formation in the Province of Leon, North Spain (see García-Alcalde 2004). Starting with Unit 14 of the section Foum Zguid, some specimens (e.g. Fig. 6, specimen 11) are hardly distinguishable from Upper Emsian *A. a. arduennensis* as known from the Rheinisches Schiefergebirge.

Euryspirifer cf. *pellicoi* (de Verneuil & d'Archiac 1845) occurs very abundantly in the section; it is typical of the interval around the Lower/Upper Emsian boundary (Truyóls-Massoni & García-Alcalde 1994). Specimens of *Euryspirifer* from units 9 to 14 are very similar to *E. robustiformis* Mittmeyer 1972 from the basal Upper Emsian of the Rheinisches Schiefergebirge (Emsquarzit and Wiltz formations).

Representatives of *Iridistrophia* from the Foum Zguid section, Unit 7, are close to *I. maior* (Fuchs 1915) known from the Rhenish Lower Emsian whereas forms from Unit 14 resemble early morphs of *I.* cf. *hipponyx* (Schnur 1851) *sensu* Jansen (2001) from the Lahnstein substage (lower Upper Emsian) in the Rhein/Mosel/Lahn area of the Rheinisches Schiefergebirge (Weddige 1996*c*, DCT interval di 14.2 to 16.35 cm).

Stropheodontids of the *gigas* group ('*Boucotstrophia*' pro parte) range from the Middle Siegenian to the lower Upper Emsian in the Rheinisches Schiefergebirge (Lahnstein substage). In the sandstones of the upper Mdâouer-el-Kbîr Formation, the group is represented by '*Stropheodonta*' *jahnkei* (Aït Malek *et al.* 2000).

Platyorthis circularis ssp. from units 14c–d resembles *Pl. c. circularis* (Sowerby 1842) from the Stadtfeld Formation (upper Lower Emsian) of the Eifel region, but seems to be even more similar to *Pl. c. transfuga* (Walther 1903) from the lower Upper Emsian Hohenrhein Formation of the Middle Rhein/Mosel/Lahn region; however, both taxa still need to be revised. The latter occur

especially in units 14c–d. *Pachyschizophoria tataensis* (Jansen 2001) from Unit 9 of the Foum Zguid section represents a less advanced evolutionary level than *Pachyschizophoria* sp. C *sensu* Jansen (2001) from the lower Upper Emsian (Emsquarzit Formation) of the Rheinisches Schiefergebirge. A very similar form is '*Schizophoria vulvaria*' *sensu* Mélou (1981) (non von Schlotheim 1820) from the Marettes Formation of the Armorican Massif (Mélou 1981, Pl. 16 text-figs 5–10). The accompanying tentaculitids *Nowakia* cf. *praecursor* Bouček 1964 and *N.* cf. *zlichovensis* Bouček 1964 indicate a Zlichovian age (Morzadec *et al.* 1981). Closer to the Rhenish species is a late morph of the same species from Unit 14 which already supports a lower Upper Emsian position.

It is concluded from the brachiopod faunas B 7 and B 8 (Table 1 and Fig. 5) that the upper Mdâouer-el-Kbîr Formation reaches from the upper Lower Emsian to the lower Upper Emsian in the Rhenish sense, resp. from about the Vallendar to the Lahnstein substages (DCT interval di 12.7 to 16.4 cm). The Lower/Upper Emsian boundary may be drawn in the Foum Zguid section a little below Unit 14. According to the observed changes, the brachiopod fauna B 7 from units 2 to 13 shows a less advanced phylogenetic development than the fauna B 8 from units 14 and 15.

The conodont fauna C 15 (Table 1 and Fig. 5) from shell beds high in the sandstones (see above) attributed to the *laticostatus* to *serotinus* zones correlates well with Upper Emsian faunas in the Rheinisches Schiefergebirge, where accompanying brachiopod faunas with *Arduspirifer arduennensis arduennensis* (Schnur 1853) allow an assignment to the lower and middle Upper Emsian (Weddige & Requadt 1985).

Current studies show that the upper boundary of the Mdâouer-el-Kbîr Formation is slightly older in the SW, e.g. in the section Oufrane near Tata (Ebbighausen *et al.* 2004).

Goniatites

The report of the primitive goniatite *Erbenoceras advolvens* (Erben 1960) in the basal limestones of the Mdâouer-el-Kbîr Formation (see Hollard 1963*c*, 1978; Bultynck & Hollard 1980, p. 22) indicates a Zlichovian age (R. T. Becker 1996*b*, DCT interval di 11.3 to 12.1 cm).

In Unit 14b of the Foum Zguid section, two goniatite fragments have been found which have been determined by O. H. Walliser as *Mimagoniatites fecundus* (Barrande 1865) indicating an interval from the upper Zlichovian to the lower Dalejian in the sense of the Bohemian subdivision (Chlupáč & Turek 1983; Chlupáč 1998*b*, DCT interval di 13.5 to 16.1 cm). Hollard (1978, Table 2) reported ('niveau 2') *Latanarcestes* cf. *noeggerathi* (von Buch 1832) from the upper Mdâouer-el-Kbîr Formation and *Latanarcestes* spp. (R. T. Becker 1996*a*, *b*, DCT interval di 15.1 to 16.4 cm). Chlupáč & Turek (1983, p. 136) attributed this level to the lower Dalejian. The Mdâouer-el-Kbîr Formation is overlain by trilobite limestones and the *Sellanarcestes* Limestone of the Timrhanrhart Formation which are clearly within the Upper Emsian (R. T. Becker 1996*a*, *b*, DCT interval di 16.4 to 17.5 cm; approx. *serotinus* Zone).

Correlation and age

The abrupt change from sandstones of the Merzâ-Akhsaï Formation to basal limestones of the Mdâouer-el-Kbîr Formation resp. the Oui-n'-Mesdoûr Formation (see below) has been referred to the Basal Zlíchov Event (*sensu* Chlupáč & Kukal 1988) which is visible in many sections of Western and Central Europe (e.g. García-Alcalde 1997). However, more research is required to prove the synchronicity of this event. The basal limestone of the Mdâouer-el-Kbîr Formation starts within the *excavatus* Zone and contains dacryoconarid tentaculitids, conodonts, and goniatites of the Zlichovian stage in Bohemia resp. the middle Lower Emsian (in the GSSP sense). Hollard (1978) assumed a break in sedimentation or a very condensed interval in the lowermost Emsian (in the Rhenish sense). It is to be stressed that it is not yet clear how long is the time span between the Middle/Late Siegenian brachiopod faunas below and the first anetoceratids above, so that our observations do not necessarily suggest that the first anetoceratids occur low in the Lower Emsian in the German sense as appears to be consistent with the probable Ulmen age of the Hunsrück-Schiefer. On the other hand, observations in the Tafilalt region by Klug (2001) suggest that anetoceratids appear earlier than thought before.

The basal limestones correlate well with Klug's Unit A, yielding a similar conodont fauna associated with the mimosphinctid goniatite *Chebbites* Klug 2001 and the Unit B 1 with *Erbenoceras advolvens* above. With respect to the Achguig area, the lower parts of the basal limestone well correspond with the '*Jovellania*' Limestone, because that limestone is also assigned to the *excavatus* Zone; above, shales with very diverse early goniatites (Klug 2001) and the *Anetoceras* Limestone follow (Bultynck & Walliser 2000).

The upper sandstones of the Mdâouer-el-Kbîr Formation contain diverse brachiopod faunas showing an evolutionary development from the late Early Emsian to the early Late Emsian (both in the Rhenish sense). The boundary between the Lower and the Upper Emsian (in the Rhenish

sense) can be approximately recognized by brachiopods and roughly corresponds to the Zlichovian/Dalejian boundary in Bohemia according to the goniatites. The top of the formation is obviously positioned within the Upper Emsian resp. Dalejian demonstrated by all fossil groups. According to conodonts and particularly to ammonoids, a position from the *laticostatus* to *serotinus* zones is most probable.

Oui-n'-Mesdoûr Formation

Distribution, thickness and facies

The Oui-n'-Mesdoûr Formation (Hollard 1978) is developed in Hercynian facies; it consists of limestones and marly limestones reaching a thickness of up to 45 m. It is confined to the SW Dra Valley. Its type locality is situated near Aouinet Torkoz. The formation has been subdivided into Akhal Tergoua and Black Marl members (R. T. Becker, Jansen *et al.* 2004).

Conodont faunas C 10 and C 13

The limestone beds become more distinct towards the top of the bed 21b in the section Torkoz IIa. Although the conodont elements belong to the shallow water facies, are fragmentary, and stratigraphically less significant, the Oui-n'-Mesdoûr Formation in its basal 0.3 m (with the sample horizons 21b-1 to 21b-4; Fig. 5, Table 1: conodont fauna C 10) include particularly *Caudicriodus sigmoidalis* (Carls & Gandl 1969), but also *Latericriodus beckmanni* (Ziegler 1956), *L. bilatericrescens* (Ziegler 1956) and *C.* cf. *ultimus* Weddige 1985. This conodont fauna can be assigned more or less to the *excavatus* Zone of the Lower Emsian (see Carls & Weddige 1996, DCT interval di 11.2 to 13.35 cm). In the Barrandian area, this conodont zone indicates the Zlíchov Formation resp. the 'Zlichovian' as a Czech regional stage (see Chlupáč 1998*a*, DCT interval di 10.5 to 13.8 cm).

In the beds 21b-5 to 21b-7 (Fig. 5, Table 1: conodont fauna C 13), which lie 6.5 to 8.2 m above the base of the formation, a recognizably younger Emsian conodont fauna occurs because of ?*Eucostapolygnathus inversus* (Klapper & Johnson 1975), ?'*Ozarkodina*' *steinhornensis miae* (Bultynck 1971), *Latericriodus bilatericrescens* (Ziegler 1956) and *L. beckmanni sinuatus* (Klapper *et al.* 1978). This assemblage pleads for the *nothoperbonus* Zone (see Carls & Weddige 1996, DCT interval di 13.35 to 14.2 cm). The *inversus* Zone, however, cannot be excluded, because of a questionably determinable ?*E. inversus* fragment; that would indicate already the stratigraphic transition to the Dalejian as a Barrandian regional stage (see Chlupáč 1998*a*, DCT $\geq$ di 14.2 cm).

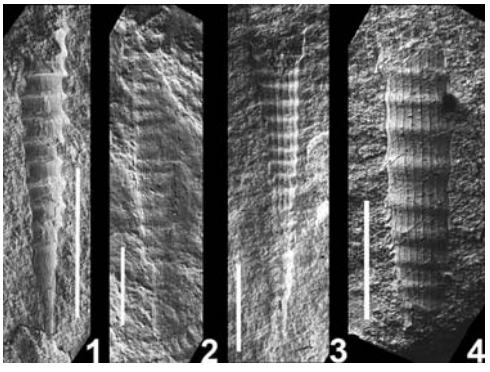


Fig. 7. Selected tentaculitids. **1**, *Nowakia* (*Dmitriella*) *sulcata sulcata* (F. A. Roemer 1843). Partly preserved shell; SMF 37798, Timrhanrhart Formation, section Foum Zguid 16-k-1. Scale 1 mm. **2**, *Viriatellina* cf. *pseudogeinitziana* Bouček 1964. Poorly preserved specimen; SMF 37799, Oui-n'-Mesdoûr Formation, section Torkoz IIa, middle part of unit 21. Scale 1 mm. **3**, *Viriatellina* cf. *hercynica* Bouček 1964. Partly preserved shell; SMF 37800, lower Khebchia Formation, section Torkoz IIa $22b_3$. Scale 1 mm. **4**, *Viriatellina* cf. *hercynica* Bouček 1964. Detail of partly preserved shell; SMF 37801, lower Khebchia Formation, section Torkoz IIa $22b_{Top}$. Scale 1 mm.

Tentaculitids

In the Torkoz IIa section, dacryoconarid tentaculitids occur in the middle part of the formation (Unit 21). Besides stratigraphically insignificant taxa (e.g. of the styliolinids), *Viriatellina* cf. *pseudogeinitziana* Bouček 1964 is present (Fig. 7). Similar forms have also been found in the Mdâouer-el-Kbîr section near Foum Zguid by Bultynck & Hollard (1980, p. 22).

Brachiopods and goniatites

Small and smooth-shelled brachiopods occur but are without any biostratigraphic value. In upper parts of the Oui-n'-Mesdoûr Formation, *Mimagoniatites* has been found which has its onset in the upper Zlichovian and ranges up into the Dalejian (Chlupáč & Turek 1983).

Correlation and age

According to conodont, dacryoconarid and goniatite data, the Oui-n'-Mesdoûr Formation approximately represents the Zlichovian, also confirmed by the ages of the under- and overlying strata. In comparison with the Achguig region, the formation at its base, just like the base of the Mdâouer-el-Kbîr Formation, is correlative with the '*Jovellania*' Limestone, in its upper parts with the *Anetoceras* Limestone and

blue *Mimagoniatites* Limestone (comp. Bultynck & Walliser 2000).

Khebchia Formation (including 'Rich 4')

Distribution, thickness and facies

The Khebchia Formation again represents a complete 'rich' cycle beginning with limestones and marlstones followed by shales and ending with a thick sandstone unit. It follows above the Oui-n'-Mesdoûr Formation in the SW Dra Valley. The thickness reaches up to *c*. 300 m. The formation has been subdivided into five members (see R. T. Becker, Jansen *et al.* 2004) which, however, are difficult to recognize in the section at Torkoz due to partly unfavourable exposure (Jansen, G. Becker *et al.* 2004*b*): *Hollardops* Limestone Member, Brachiopod Marl Member, *Sellanarcestes* Limestone Member, Bou Tserfine Member, 'Rich 4' Sandstone Member.

Conodont fauna C 14

The Khebchia Formation starts in the section Torkoz with a 26 m thick interval of limestone beds within marls. These beds represent a shallow water to mixed neritic–pelagic facies and contain a rather diverse icriodid conodont fauna (Fig. 5, Table 1: conodont fauna C 14) with *Caudicriodus culicellus culicellus* (Bultynck 1976), *Icriodus corniger ancestralis* Weddige 1977, *I. c. leptus* Weddige 1977, *I. c. rectirostratus* Bultynck 1970, *I. fusiformis* Carls & Gandl 1969 and *Icriodus* sp., aff. *I. werneri* Weddige 1977. This fauna shows icriodid species without lateral processes, demonstrating a higher stage of phylogenetic development. Such icriodids are known from the Upper Emsian neritic facies in the Rheinisches Schiefergebirge (e.g. Bultynck 1970; Weddige 1977) as well as from the hemipelagic goniatite facies of the Lezna Mbr. in the Palentinian Domain where they are accompanied by *Latanarcestes* (Jahnke *et al.* 1983).

However, the stratigraphic entry of such icriodids without lateral processes within the Upper Emsian is—hitherto—insufficiently documented, as pointed out by Weddige & Requadt (1985, pp. 363–366, text-fig. 7) who described forms that demonstrate the phylogenetic loss of lateral processes. These forms are associated with brachiopods of the lower to middle Upper Emsian in the sense of the Rhenish regional stages, e.g. *Arduspirifer arduennensis arduennensis* (Schnur 1853). There is, however, no age assignment directly to the global standard conodont zonation, because of the lack of polygnathids as decisive guide fossils. After indirect correlation, Weddige & Requadt (1985) and consequently Bultynck (2003) as well, dated a probable entry within the *laticostatus–inversus* Zone (see Weddige 1996*b*, within DCT interval di ~14.15 to 15.85 cm). Because the icriodids from the Khebchia Formation include the evolutionary more advanced form *I. c. rectirostratus*, an age within the interval *serotinus* to *patulus* Zone is also probable for the Khebchia Formation, as well (see Carls & Weddige 1996, DCT interval di ~15.85 to 18.85 cm). The conodont fauna allows a correlation with the upper sandstones of the Mdâouer-el-Kbîr Formation, from where the same conodont association has been reported (Bultynck & Hollard 1980; see above, fauna C 15).

Tentaculitids

In the lower Khebchia Formation (Unit 22) stratigraphically insignificant styliolinids, a badly preserved specimen of ?*Homoctenus* sp. and representatives of viriatellinid dacryoconarids are present. They include *Viriatellina* cf. *pseudogeinitziana* Bouček 1964, *V.* cf. *hercynica* Bouček 1964, and *V.* cf. *gracilistriata* (Hall 1879)—and transitional forms (comp. Jansen, G. Becker *et al.* 2004*b*). Even taxa unquestionably assigned to these species are difficult to be separated from each other as already pointed out by Lardeux (1969, p. 138). He assigns this group to be typical for Emsian strata preferably close to the Zlichovian/Dalejian boundary (as also indicated for *V.* cf. *hercynica* by Alberti 1998) even when *V.* cf. *hercynica* may range as high as the Emsian/Eifelian boundary level (Lardeux 1969). Due to the occurrence of *V.* cf. *gracilistriata* and forms of *V.* cf. *hercynica* transitional to *V.* cf. *gracilistriata* in the youngest bed with dacryoconarids (Bed 22e), a position in the Dalejian may be indicated. This observation fits with Lardeux (1969, p. 126) who reports *V.* cf. *gracilistriata* from the La Grange Limestone in the French Armorican Massif together with the Dalejian *Nowakia cancellata* (Rh. Richter 1854). In Truyóls-Massoni & García-Alcalde (1994, p. 223), *V.* cf. *hercynica* and *V.* cf. *gracilistriata* are figured to enter the La Ladrona–Cabo La Vela section (Asturia, Spain) in the uppermost parts of the Lower Emsian and reaching well into the Upper Emsian. In Figure 7 specimens of *V.* cf. *pseudogeinitziana* and *V.* cf. *hercynica* are shown. Stratigraphically, the viriatellinid fauna is in accordance with the age assignment by other faunal groups mentioned above and below.

Brachiopod fauna B 9

The Khebchia Formation begins with the Brachiopod Marl Member containing small and smooth-shelled brachiopods and a plectodontid

form (Becker, Bockwinkel *et al.* 2004) that are, according to present knowledge, without any biostratigraphic significance. The 'Rich 4' sandstones, however, yielded *Arduspirifer* cf. *steiningeri* (Solle 1953), *Alatiformia* sp., and *Iridistrophia* cf. *hipponyx* (Schnur 1851) suggesting a late Late Emsian or early Eifelian age (brachiopod fauna B 9: Table 1 and Fig. 5).

Trilobites, goniatites and ostracodes

A trilobite fauna has been described from units 22c-e of the section Torkoz II, situated in the lower Khebchia Formation (Schraut 2000); it includes the following taxa: *Hollardops mesocristata* (Le Maître 1952), *Psychopyge elegans* Termier & Termier 1950, and *Diademaproetus holzapfeli praecursor* Alberti 1969. *Psychopyge elegans* is supposed to be confined to the *cancellata* to *Sellanarcestes wenkenbachi* zones of the Upper Emsian (Morzadec 1988, p. 158; Schraut 2000). *D. h. praecursor* occurs in the uppermost part of the *S. wenkenbachi* Zone (Alberti 1969, pp. 215–216), resp. DCT interval 16.4 to 17.5 cm. Bultynck & Hollard (1980) mentioned *Gyroceratites gracilis* (Bronn 1835) from the lower Khebchia Formation which has its onset near the base of the Dalejian (Chlupáč & Lukeš 1999) and characterizes the *G. gracilis* Zone of the lower Dalejian (R. T. Becker 1996*a*, DCT di 14.3 to 15.1 cm). In Unit 22e of the Torkoz section, *Latanarcestes noeggerathi* (von Buch 1832) indicates the *L. noeggerathi* Zone of the Lower Dalejian (upper *laticostatus* to basal *serotinus* Zone resp. DCT di 15.1 to 16.4 cm, R. T. Becker 1996*a*). The *Sellanarcestes* Limestone Member contains a goniatite fauna including the genera *Sellanarcestes* and *Anarcestes* corresponding to the *serotinus* Zone of the middle Upper Emsian (R. T. Becker, Jansen *et al.* 2004; R. T. Becker, Bockwinkel *et al.* 2004) resp. the DCT interval di 16.4 to 18.7 cm.

According to G. Becker *et al.* (2003), ostracodes from Unit 22 of the Torkoz section indicate a Late Emsian age.

Correlation and age

Due to the icriodid conodont and goniatite faunas, the Khebchia Formation seems to start in a lower part of the Upper Emsian, i.e. in the *laticostatus* Zone. The *Sellanarcestes wenkenbachi* Limestone Member indicating the *serotinus* Zone is a marker horizon which can be traced from the SW to the NE Dra Valley, where it is present within the Timranrhart Formation (see below). In the Maïder and Tafilalt areas, the same horizon is also present (Bultynck & Walliser 2000). The 'Rich 4' sandstones can only be dated on the base of the brachiopods, indicating a latest Emsian to probably early Eifelian age. It is not clear whether the Lower/Middle Devonian boundary is surpassed.

Timrhanrhart Formation

Distribution, thickness and facies

The Timrhanrhart Formation follows above the Mdâouer-el-Kbîr Formation in the NE Dra Valley, well exposed in the upper part of the Foum Zguid section (Jansen, G. Becker *et al.* 2004*a*). The formation starts with trilobite limestones overlain by a solid *Sellanarcestes* Limestone which, finally, is followed by nodular limestones, marls and greenish shales. Unfortunately, the uppermost parts of the formation are lacking in the studied section, because the succession is cut off by a dolerite. At the type locality, the total thickness reaches 37 m (Hollard 1978).

Conodont faunas C 16 to C 17

In some beds of the Timrhanrhart Formation in the Foum Zguid section (16 k-3 to 17top; Fig. 5, Table 1: conodont fauna C 16 to C 17), a few fragments of stratigraphically significant conodonts were found with *Eucostapolygnathus costatus costatus* (Klapper 1971), ?*Linguipolygnathus cooperi cooperi* (Klapper 1971), ?*L. linguiformis pinguis* (Weddige 1977), ?*Polygnathus trigonicus* Bischoff & Ziegler 1957, and ?*P. benderi* Weddige 1977. For the first conodont occurrence (sample 16 k-3) with a questionable subspecies of *E. costatus*, the Middle Devonian *partitus* Zone may be considered. The following assemblages, however, although badly preserved, plead for the *costatus costatus* Zone. The early part of the *c. costatus* Zone can more or less be assumed (see Carls & Weddige 1996, DCT interval dm 0.7 to about 2.3 cm).

Tentaculitids

The two nowakiids *Nowakia* (*Dmitriella*) *sulcata sulcata* (F. A. Roemer 1843) and *N.* (*Maureriana*) cf. *procera* (Maurer 1880) indicate the start of the Eifelian stage in the Foum Zguid section (e.g. Alberti 1993). A specimen of the former taxon from bed 16 k-1 is shown in Figure 7.

Goniatites, trilobites, brachiopods and ostracodes

The *Sellanarcestes* Limestone in the lower part of the Timrhanrhart Formation with its abundant goniatites corresponds to the *serotinus* Zone of the Upper Emsian. Specimens of the goniatites *Fidelites* and ?*Foordites* in Unit 16 k indicate the start of the Eifelian in the Foum Zguid section (Jansen, G. Becker *et al.* 2004*a*). Hollard (1978) recorded

joint occurrences of *Pinacites* and *Paraspirifer cultrijugatus* (C. F. Roemer 1844) which, however, require modern revision.

The formation yielded a diverse trilobite fauna in the Foum Zguid section (det. G. Schraut, O. Vogel; see Jansen, G. Becker *et al.* 2004*a*). Up to Unit 16j, ?*Treveropyge* sp. occurs still demonstrating a Late Emsian age, whereas *Thysanopeltis* sp. in Unit 16 k already indicates the Eifelian.

Finally, a highly diverse ostracode fauna of E Thuringian provenance is present in the same section (G. Becker *in* Jansen, G. Becker *et al.* 2004*a*). The faunal association shows close relationships to that of the uppermost Emsian to lowermost Eifelian Moniello and Polentinos formations of the Cantabrian Mountains. The overall aspect is Emsian until bed 16 k-3 proved by species of several genera. Distinct *Polyzygia* species found in 16 k samples agree with the Emsian/Eifelian boundary as indicated by other fossil groups.

Correlation and age

The Timrhanrhart Formation of the Foum Zguid section begins slightly below the *Sellanarcestes* Zone in the lower part of the Dalejian or, respectively, in the Upper Emsian. Higher in the section, conodonts, dacryoconarid tentaculitids, trilobites and ostracodes allow to place the Emsian/Eifelian boundary precisely (for details, see Jansen, G. Becker *et al.* 2004*a*, Fig. 7). In the section, the *costatus* Zone is the most probable assignment for the upper parts. According to R. T. Becker, Jansen *et al.* (2004), the formation ranges to the *australis* Zone in sections where its upper part is preserved.

Summary of results

Lower Devonian successions are widely exposed in the Dra Valley (Southern Anti-Atlas, Moroccan Pre-Sahara). Thanks to lateral and vertical facies changes from pelagic or hemipelagic limestones and shales to neritic sandstones, it is possible to correlate bio- and chronostratigraphies of the two contrasting facies realms.

The Lmhaïfid Formation of the el Ayoun section in the NE Dra Valley has an early to middle Lochkovian age in the global sense due to the conodonts and can be attributed by brachiopods to lower and upper parts of the Lower Gedinnian in the sense of the Rhenish subdivision. On the contrary, in the SW Dra Valley the formation seems to document the whole Lochkovian resp. Gedinnian according to literature data (Hollard 1977).

The Oued-el-Mdâouer Formation in the NE Dra Valley has its onset within the Middle Lochkovian and reaches into the Pragian; this assignment in the sense of the Bohemian subdivision is mainly provided by means of conodonts.

The Pragian to Upper Emsian succession generally shows four main sedimentary cycles which are called 'Rich 1' to 'Rich 4', each generally composed of limestones at the base followed by shales in the middle part and sandstones at the top. The Assa Formation resp. the 'Rich 1' in the SW Dra Valley probably starts in the uppermost Lochkovian, but already in its basal part a Pragian age is indicated according to nowakiids. The formation has yielded at its top *Latericriodus steinachensis* indicating an early to middle Pragian age below the *pireneae* Zone. In the sense of the Rhenish stratigraphy, brachiopods in the sandstones of the upper Assa Formation allow an assignment to the upper Lower Siegenian.

The Merzâ-Akhsaï Formation ('Rich 2') is distributed almost in the whole Dra Valley as a typical 'rich' succession. The basal limestone interval still contains *Latericriodus steinachensis* but also questionably determinable specimens of *Caudicriodus curvicauda* which point to a younger age of the *steinachensis* range; that would plead for a later Pragian age (in the GSSP sense) below the *pireneae* Zone. In comparison with the Achguig region (Tafilalt), the basal limestone interval of the Merzâ-Akhsaï Formation is coeval with the 'Pragian' Limestone *sensu* Bultynck & Walliser (2000). Brachiopod faunas from the 'Rich 2' sandstones indicate a Middle to Late Siegenian age in terms of the Rhenish subdivision. The change from shallow-water sediments of the upper Merzâ-Akhsaï Formation to pelagic limestones of the overlying formations may correspond to the Basal Zlíchov Event (Chlupáč & Kukal 1988).

The Mdâouer-el-Kbîr Formation ('Rich 3') is restricted to the NE Dra Valley. Its basal limestones contain dacryoconarids such as *Nowakia praecursor* and the goniatite *Erbenoceras advolvens* demonstrating a Zlichovian age in terms of the Bohemian subdivision. The conodonts include *Eucostapolygnathus excavatus*, *Caudicriodus sigmoidalis* and *Latericriodus celtibericus* which indicate the *excavatus* Zone. In comparison to the Achguig region, the basal limestone well corresponds with the '*Jovellania*' Limestone (Bultynck & Walliser 2000). The brachiopods in the upper sandstones of the formation represent a fauna from the upper Lower Emsian to the lower Upper Emsian in the classical Rhenish sense; the Lower/Upper Emsian boundary can approximately be reproduced by detailed brachiopod comparisons. The same beds have yielded *Mimagoniatites fecundus* indicating the upper Zlichovian to lower Dalejian.

The Oui-n'-Mesdoûr Formation is restricted to the SW Dra Valley and correlates nearly completely with the Mdâouer-el-Kbîr Formation in the NE. It consists of dark limestones and marls with dacryoconarids and conodonts indicating the *excavatus* Zone

and the *Nowakia praecursor* Zone. In comparison with the Achguig region, the lower part of the formation, just like the base of the Mdâouer-el-Kbîr Formation, is correlative with the '*Jovellania*' Limestone, in its upper parts with the *Anetoceras* Limestone and blue *Mimagoniatites* Limestone (Bultynck & Walliser 2000).

The Khebchia Formation resp. the 'Rich 4' in the SW Dra Valley contains in its lower part the *Hollardops* Limestone, a goniatite fauna with *Latanarcestes* and a level with *Sellanarcestes* corresponding to the *serotinus* Zone, i.e. a middle Dalejian age in the sense of the Bohemian subdivision. Brachiopods from the 'Rich 4' sandstone document the uppermost Emsian and probably lower Eifelian.

The Timrhanrhart Formation in the NE Dra Valley partly represents an age equivalent of the Khebchia Formation in the SW. *Sellanarcestes* Beds with goniatites corresponding to the *serotinus* Zone are present slightly above the base of the formation. Trilobites, dacryoconarids, goniatites, conodonts and ostracods allow the recognition of the Emsian/Eifelian boundary in a succession of marlstones with intercalated layers of nodular limestones (Foum Zguid section).

According to present knowledge, the following neritic–pelagic correlations can be stated: The Lower Gedinnian correlates with lower and middle parts of the Lochkovian. The upper part of the Lower Siegenian corresponds to the middle Pragian in the GSSP sense. The Middle and Upper Siegenian correlate approximately with the upper Pragian and lowermost Emsian, both stages in the GSSP sense. The Lower/Upper Emsian boundary in the traditional sense corresponds with the Zlichovian/Dalejian boundary in terms of the Bohemian subdivision.

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