

Devonian of the Benahmed region, western Moroccan Meseta

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Fig. 1: View on the Emsian-Givetian hill opposite of Dar Cheihk el Mfaddel with a large quarry in massive Lower Devonian limestones (right background) and a Middle Devonian succession exposed in minor limestone beds on the lower slope, from the white house in the middle to the small house on the left (photo from spring 2012).

Abstract. Based on new field work, sampling for conodonts, ammonoids, and microfacies analysis, the Lower to Upper Devonian stratigraphy of the Benahmed region is refined. Fossiliferous neritic limestones of the Pragian/lower Emsian represent a continuation of the shallow carbonate platform of the Al Attamna region to the north (Units A/B of Sidi Ahmed Lemdoun Formation). More argillaceous upper Emsian/Eifelian strata are regionally still poorly known. In the southern Chaouïa or Beni Sekten region NW of Benahmed, Givetian deep neritic to shallow pelagic mud-wackestones of the new Oulad Amar Formation were partly reworked and re-sedimented together with crinoidal grainstones in conglomeratic debris flow beds. Peaks of Eovariscan block faulting and reworking occurred high in the middle (*ansatus* Zone) and at the top of the Givetian (*norrisi* Zone). Lower/middle Frasnian strata are still unknown in outcrop but limestones with corals of possible Givetian/Frasnian age have been reported from E/SE of Benahmed. In the NW, the new upper Frasnian Boudouda Formation is characterized by transgressive hypoxic goniatite shales, which are unique for the Moroccan Meseta and which strongly resemble the contemporaneous Büdesheim Goniatite Shales of Germany. Unfortunately, the top-Frasnian and Frasnian-Famennian boundary are not exposed. Upper/uppermost (“Strunian”) limestones and siliciclastics belong to a neritic succession that requires further research. In the southern Mdakra Massif E of Benahmed, there was a distinctive, middle/upper Famennian basin with richly fossiliferous, hypoxic ammonoid shales, the new Oued Aricha Formation. More than forty goniatite and clymeniid species are recorded, with up to 13 new forms that are currently left in open nomenclature. They fall in the UD III-C to V-A₂ interval of the international ammonoid zonation and include many common taxa with the contemporaneous Fezzou Formation (Lahfira to Jebel el Krabis Members) of the Maïder Basin of the eastern Anti-Atlas. The associated fauna is composed of

rugose corals, including the revised *Hebukophyllum arichense*, nautiloids, bivalves, gastropods, brachiopods, and trilobites. As the Chabet el Baya Formation of the northern Mdakra Massif, the Oued Aricha Formation grades upwards into the poorly fossiliferous Mgarto Formation that straddles the Devonian-Carboniferous boundary.

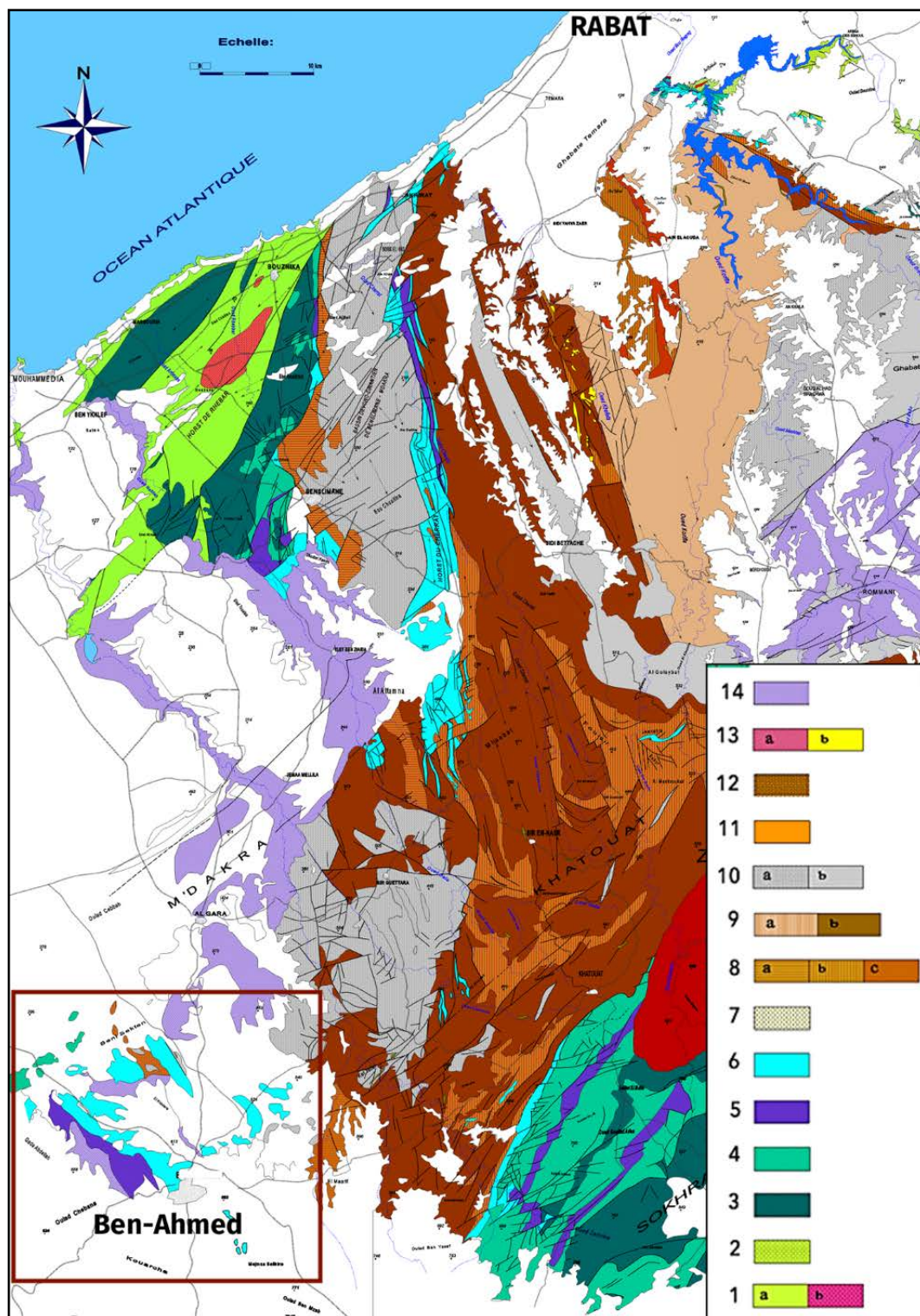


Fig. 2: Hercynian geological map of Western Central Morocco (FADLI et al. 2008) showing the regional geological position (square) of the Benahmed Palaeozoic. 1. Cambrian (a: greywackes, siltstones and quartzites; b: trachyandesites and rhyolites); 2. Cambrian-Ordovician (Zain quartzites and phyllites of the Sehoul Block); 3. Lower Ordovician; 4. Upper Ordovician; 5. Silurian; 6. Lower-Middle Devonian; 7. Undifferentiated Devonian; 8. Upper Devonian and Tournaisian; 9. Lower Viséan ; 10. Middle/upper Viséan and lower Namurian; 11. Upper Namurian to lower Westphalian; 12. upper Westphalian; 13. Stephanian/Permian; 14. Triassic.

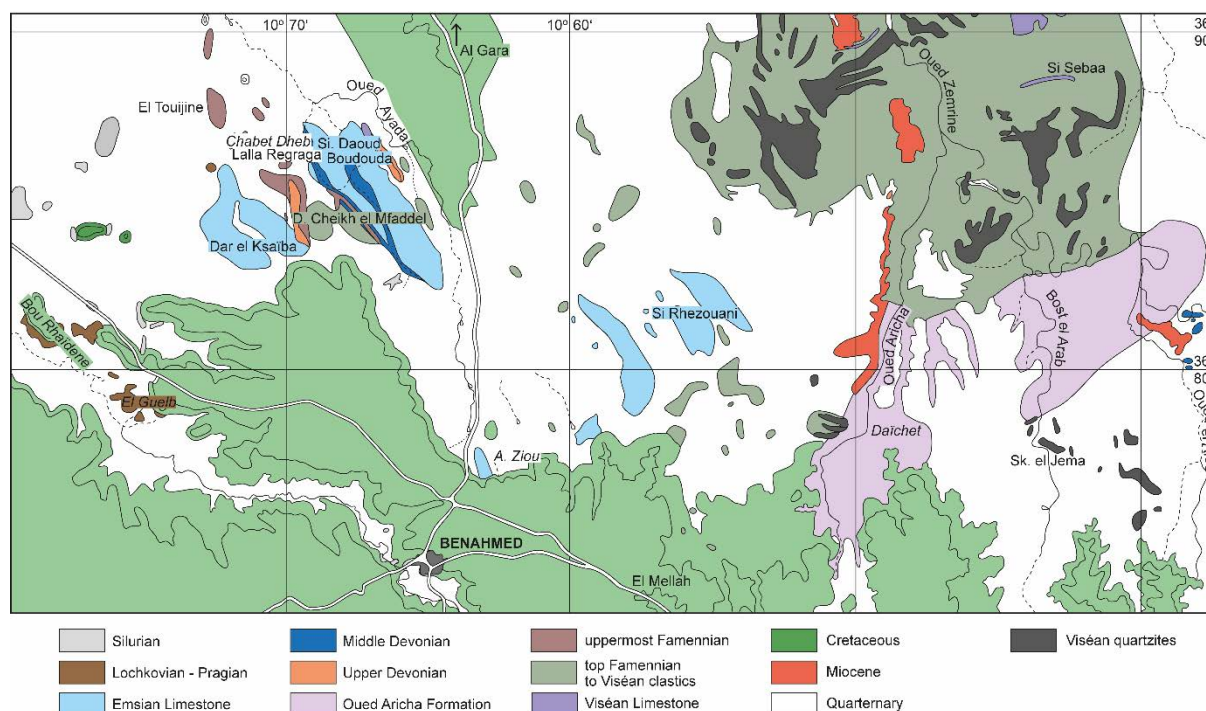


Fig. 3: Simplified geological map of the Benahmed region, based on TERMIER & TERMIER (1951a), showing the position of localities mentioned in the text (not showing the new motorway; see later Google Earth figures). The Beni Sekten region lies NW of Benahmed, the area to the NE belongs to the southern Mdakra Massif.

1. Introduction

Within the Western Meseta, the Devonian outcrops around Benahmed are positioned ca. in the middle (on a NE-SW transect) between the Oued Cherrat Zone south of Rabat and the Mechra-Ben-Abbou region of the northern Rehamna (HOLLARD 1967). Benahmed lies ca. 110 km SSW of Rabat (Fig. 2). In structural terms, its Palaeozoic belongs to the Central Meseta Zone sensu PIQUE & MICHARD (1981). Despite its intermediate position, almost nothing has been added on Devonian biostratigraphy and faunas since the pioneer monograph by TERMIER & TERMIER (1951a). The regional Devonian successions belong to two different palaeogeographic and structural units. The outcrops to the north and northwest of Benahmed (or between Benahmed and Al Gara,) are assigned to the southern part of the Chaouïa or Beni Sekten region, whilst a unique Famennian goniatite shale basin of the Oued Aricha-Bost el Arab-Oued el Aleg region, ca. 10-23 km to the east/northeast of

Benahmed, forms the southern extension of the Mdakra Massif (Figs. 2-3). Isolated minor Emsian to ?Givetian outcrops are also known at ca. 6-8 km to the southeast of Benahmed, surrounded by Cretaceous strata (e.g., GENTIL 1909; outside the map of Fig. 3).

In 2012-2014 we logged and sampled sections for conodonts, ammonoids, other fauna, and microfacies. There was a focus on the Middle/Upper Devonian and on intervals with Eovariscan reworking. Therefore, only a summary of literature knowledge is provided for the highly fossiliferous Lower Devonian. Frasnian goniatite faunas and the Lower Carboniferous transgression, including rich foraminifer faunas and reworked Devonian conodonts, are dealt with in separate chapters.

2. Research history

GENTIL (1909): First report of a Lower Devonian ("Coblentzian") fauna with trilobites (*Cryphaeus laciniatus*, *Odontochile*) and brachiopods (e.g.,

- “*Spirifer Pellicoi*, *Sp. Rousseaui*, *Sp. Bischofi*, *Uncinulus subwilsoni*”) from the Chaouïa region.
- JORDAN in DOUVILLE (1910): Report mentioning Lower Devonian strata with brachiopods in the area of the Cretaceous plateau (Mejmâa es Salihine = Majma Ac-Calihine region southeast of Benahmed, SW corner of topographic sheet Mgarto, NI-29-XI-2b, 1 : 50 000).
- RUSSO (1924): Unpublished map showing the presence of the Devonian at Sidi Daoud.
- BEAUGÉ (1924): Reference to supposed “Gothlandian” trilobites from Benahmed, including *Phacops fecundus*, which is the Devonian type-species of the genus.
- TERMIER (1927a): Brief reference to the discovery of the Famennian at Oued Aouïja (= Oued Aricha).
- TERMIER (1927b): New records of Devonian strata and faunas, including Emsian (“Coblentzian”) neritic assemblages from Aïn Zian (= Aïn Ziou) and Sidi Rezouani in the north and northeast of Benahmed, Emsian phacopids (*Ph. potieri*) from Sidi Daoud to the northwest, and Famennian shales with sporadoceratids from the Oued Aricha.
- TERMIER (1936): Lower Devonian brachiopod and trilobite faunas; illustration of some (originally) pyritized *Erfoudites* from the Oued Aricha as *Sporadoceras biferum*, of a probably squashed goniatite as *Tornoceras retrorsum* var. *acutum* SANDBERGER, and of a platyclymeniid as *Pl. gr. laevigata*; discovery of an isolated, supposed Frasnian reefal limestone with *Alveolites tenuissimus* east of the Oued Aricha and ca. 9 km SSE of Sidi Sebaa; discovery of an uppermost Famennian (Strunian) fauna with brachiopods and trilobites at Sidi-el-Haj-Tarhi northeast of Benahmed.
- RICHTER & RICHTER (1943): Description of the rare trilobite *Malladaia?* sp. from Mejmâa es Salihine (= Mejma-Salihine), *Phacops* sp. indet. from Sidi Daoud, and of *Ph. (Ph.) accipitrinus accipitrinus* from the uppermost Famennian crystalline limestone discovered by TERMIER (1936).
- TERMIER & TERMIER (1950a): Documentation of four Emsian species of tabulate corals, of two Emsian species of rugose corals, including the new *Hapsiphyllum maroccanum*, “*Loepophyllum*” *arichense* (correct spelling *Loiphyllum*) from the upper Famennian of Oued Aricha, and of the uppermost Famennian (see POTY et al. 2006) *Clisiophyllum omaliusii* from the Benahmed region
- TERMIER & TERMIER (1950b): Documentation of four bryozoans and of more than 40 species of brachiopods from the Benahmed region (23 from the Lower Devonian, 18 from the Upper Devonian), including the new upper Famennian *Ambocoelia pentagonalis*, which was left out from later revisions of the genus, and related forms (e.g., GOLDMAN & MITCHELL 1990; ZAMBITO & SCHEMM-GREGORY 2013).
- TERMIER & TERMIER (1950c): Documentation of Lower and Upper Devonian gastropods of the Benahmed region, of six species of Emsian bivalves, of eight species of Upper Devonian bivalves, including the new upper Famennian nuculoids *Ctenodonta maroccana* and *Nucula arichensis*, of two species of Frasnian manticoceratids, of 13 species of upper Famennian ammonoids and a bactritid from the Oued Aricha, and of five species of orthocones/nautiloids.
- TERMIER & TERMIER (1950d): Documentation of a few Emsian ostracods, 14 species of Lower Devonian trilobites, including the new, later often ignored *Odontochile chaouiensis* (e.g., in BUDIL et al. 2009), of the new upper Famennian *Phacops arichensis* (which requires revision), and of the upper/uppermost Famennian blastoid *Pentremites toujiniensis*.

- ROCH (1950): Summary of Devonian localities in the Benahmed region, mentioning the fossiliferous Emsian of Sidi Rhezouani in the northeast, reefal limestones at Medjma es Salihine, the Famennian ammonoids of Oued Aricha, and strata with *Phacops accipitrinus* (= *Omegops*), spiriferids and *Productella*.
- TERMIER & TERMIER (1951a): Compact monograph on the Benahmed Silurian to Carboniferous, with extensive faunal lists and locality information.
- TERMIER & TERMIER (1951b): Discussion of Benahmed Upper Devonian pyritic faunas.
- PETTER (1959): Re-illustration of "*Lobotornoceras*" *bicaniculatum*.
- ALBERTI (1969, p. 27-28, 414): References to earlier Benahmed trilobite records.
- HOLLARD (1967: fig. 4): Summary of the Devonian succession at Benahmed.
- STRUVE (1976): Re-description of the Sidi-el-Haj-Tarhi phacopid as *Phacops (Omegops) accipitrinus insolatus* (*Omegops* is now a full genus).
- LOBOZIAK et al. (1990): Palynostratigraphy of the Tournaisian-Viséan Sidi Sebaa Formation at Oued Zemrine, overlying the Mgarto Formation in the southern Mdakra Massif NE of Benahmed.
- FADLI (1990): Unpublished Ph.D. Thesis including a new geological map and the sedimentology and structural geology of the southern Mdakra Massif.
- RACHEBOEUF (1990a): Description of the chonetids *Plicaoplia alani*, *Loreleiella termierorum*, and *Plebejochonetes moniellensis* from Mejma Salihine.
- ZAHRAOUI (1994): Brief reference to Pragian clastics, assumed Emsian limestones and overlying shale with goniatites at Sidi Daoud, and to Frasnian nodular limestones and shales of the Beni Sekten region.
- FADLI (1994b): Summary of the Famennian to Tournaisian successions both in the Oued Aricha and Beni Sekten regions.
- EL HASSANI (1994): Tectonic style of the Beni Sekten and Oued Aricha regions.
- SARTENAER (1998, 2000): Comments on Oued Aricha "*Calvinaria undulata*".
- EL HASSANI & BENFRIKA (1995, 2000): Review of the Devonian of the Mdakra Massif and Beni Sekten succession.
- JANSEN (2001): Comments on previously reported Benahmed brachiopods.
- SARTENAER & PLODOWSKI (2003): Description of *Araratella centralis* from the "Strunian" of El Touijine.
- KAISER et al. (2007): Literature-based re-identification and stratigraphic re-evaluation of the Oued Aricha fauna and brief comments on the Strunian brachiopod fauna from Lalla Regraga.
- BASSE (2012): Re-assignment of *Odontochile chaouiensis* to the genus *Spinodontochile*, which other authors regard as a subjective synonym of *Zlichovaspis*.
- SCHWERMANN (2014): Description of an *Omalodus* shark tooth from the Givetian.

3. Regional and structural context

The Benahmed area is part of the southwestern part of central Morocco, where the Devonian facies constitute the southern continuation of the Oued Cherrat, Al Attamna, and Mdakra regions (Fig. 2). Silurian-Devonian outcrops occur often only in small places, compared to those we know from further north. The region was part of a mapping program in 1956 (published in 1959). Fig. 3 is based on the map in TERMIER & TERMIER (1951a), which shows in detail the position of Silurian to Viséan outcrops. They lie east of the large "flexure de la Meseta", a NE-SW alpine normal fault, which is easily seen in the general morphology of this region.

The Benahmed Palaeozoic represents the SW end of the Khouribga-Oulmes Anticlinorium, a structure stretched over a distance of more than 100 kilometers in NE-

SW direction. This anticlinorium consists of a succession of anticlines and synclines in the same direction and involves Palaeozoic strata (TERMIER, 1936; VAN LECKWIJK et al. 1955; CAILLEUX 1975; TAHIRI 1991; ZAHRAOUI 1991). Ordovician deposits constitute the largest outcrop areas and contribute mainly to the structure's morphology, notably by small quartzitic massifs that often form high peaks.

A significant regional Eovariscan phase of the region corresponds to the opening of Lower Carboniferous basins at the edge of tilted block (generally Devonian), which provided polygenic conglomerates that are seen in several regions on the western edge of the Khouribga-Oulmes Anticlinorium, and which crop out in the Boudouda area (see Carboniferous chapter). The fundamental Hercynian fold is characterized by kilometric and decametric folds, straight, with a large curvature radius, trending NNW-SSE, with axes slightly dipping to the south, and without schistosity, even in the soft shale levels of the Silurian, Eifelian, and "Strunian".

The Oued Aricha-Souk Jemaa area constitutes the southern part of the Mdakra Massif, limited to the north by the Kef Tallal Fault, to the south by the phosphate plateau, and to the east by the southern extension of the Cherrat zone (referred to by FADLI 1990 as Setti Meryem area). The Mdakra Massif, again, was in sedimentary continuity with the Upper Devonian to Viséan of the Khataout Massif and Sidi Betache Basin to the northeast. From the Oued Aricha valley to the east of Viséan quartzites, there are NW-SE decametric and hectometric large synclines. But moving north, they take NE-SW directions with a SE vergence. This variation in the direction of the Hercynian major folding is the expression of the dextral clearance virgation of the Kef Tallal Fault.

As a general rule, the Hercynian fundamental folding shows increasing intensity towards the east. Their arrangement

in the echelon, along the N-S Cherrat area, indicates that the zone acted as N-S dextral setback during the fundamental folding.

4. Devonian of the Beni Sekten region

4.1. Lower Devonian

As noted in the introduction, the Lower Devonian of the Benahmed region is very poorly studied despite its richness in fossils. So far, there are no data at all for conodont stratigraphy or microfacies/sedimentology.

4.1.1. "Lochkovian"/Pragian"

Possible Lochkovian-Pragian beds are thought to occur in the area northwest of Benahmed, e.g., around El Guelb (= El Goulb) and at the Bou Rheïdene (Fig. 3). TERMIER & TERMIER (1951a) noted in the first locality shales with limestones with crinoids and brachiopods of Silurian ("Gothlandien") age, followed at the top (SW flank) by beds with the tabulate coral *Cleistopora geometrica*. FREY et al. (2014) described cf. specimens of this species from the Pragian of the southern Tafilalt. But in the Ougarta region of Algeria, *Cl. geometrica* is abundant in the Lower Member of the Dkhissa Formation, which was dated by chitinozoans as middle Lochkovian *Fungochitina lata* Zone (BOUMENDJEL et al. 1996). *Cleistopora* had obviously a global Lochkovian/Pragian distribution, living even on the far distant shelf around the Jiamusi-Mongolian block of NE China (WANG et al. 2013). However, the precise taxonomy of cleistoporids is complex (e.g., PLUSQUELLEC 1973, 2007).

The facies setting of the supposed Lochkovian/Pragian west of Benahmed appears to have been a mixed siliciclastic-carbonatic shallow (neritic) shelf. In the facies model of OUALI MEHADJI et al. (2011) for the Saoura-Ougarta region (Algeria), *Cleistopora* was noted in an intermediate position of neritic shallowing upwards cycles.



Fig. 4: Geographic position of sampled Devonian localities in the Beni Sekten region NW of Benahmed, based on a satellite photo of Google Earth.

4.1.2. “Emsian limestone” (Pragian to lower Emsian)

Limestones of “Coblentzian” age are widespread in the northwest and northeast of Benahmed (Fig. 2), where they are partly exploited in large quarries, for example opposite Dar Sheik el Mfaddel (Figs. 1, 4). Small occurrences lie within the Cretaceous plateau southeast of Benahmed near Mejma Salihine, which yielded distinctive brachiopods (GENTIL 1909; DOUVILLE 1910; RACHEBEUF 1990a). TERMIER (1936) and TERMIER & TERMIER (1950a-d, 1951a) listed or illustrated six species of corals 23 species

of brachiopods, 13 species of trilobites, six species of bivalves, bryozoans, and the crinoid-affine gastropod *Platyceras*. Their new “*Hapsiphyllum*” *maroccanum* is probably a species of *Adradosia* BIRENHEIDE & SOTO, 1977; the true *Hapsiphyllum* is based on Carboniferous forms. Unfortunately, the rich fauna has never been dealt with in sufficient detail and all previous identifications require revision.

Most common are solid, light-grey and bluish-grey, sometimes sandy or silicified, often dolomitized, then brownish or reddish weathering limestones. Decalcification led to

an unusual application of the term “greywacke”. TERMIER & TERMIER (1951a) mention from east of El Menzeh intercalated cross-bedded sandstones. Locally (e.g., at Dar el Kseiba, TERMIER & TERMIER 1951a), abundant tabulate and rugose corals mark transitions towards biostromes. A true reefal facies is not known from the Beni Sekten region. The setting was a neritic and storm-influenced carbonate platform. It can be seen as a southern continuation of the Dhar-es-Smene Formation of the Oued Cherrat (see BECKER et al. 2020b) and Units A/B of the Sidi Ahmed Lemdoun Formation of the Al Attamna (BENFRIKA & BULTYNCK 2003).

Until the brachiopod and trilobite faunas are revised, it is difficult to derive precise biostratigraphic ages from the published faunal lists. Among the brachiopods, the early (GENTIL 1909; DOUVILLE 1910) quoted *Spirifer Rousseaui* now belongs to *Torosospirifer* GOURVENNEC, 1989, which occurs low in the Pragian of the Oued Cherrat (BECKER et al. 2020b) and of the Ougarta region of Algeria (PARIS et al. 1996). In Spain, *Tor. rousseaui* is characteristic for the upper Nogueras Formation (also lower Pragian, VALENZUELA-RÍOS et al. 2019). *Spirifer Trigeri*, quoted by DOUVILLE (1910), is the type-species of *Vandercammenina* BOUCOT, 1975 and also a lower Pragian species, but the identification requires confirmation. For example, JANSEN (2001, p. 288) rejected the identification of a specimen from a different locality figured by TERMIER & TERMIER (1950b), as it has bifurcating costae on its flanks. *Schizophoria provulvaria* became the type-species of the subgenus *Rhenoschizophoria* JANSEN, 2001 (in the meantime used as a separate genus; see JANSEN 2016) and is a Pragian to lower Emsian species. Based on a restudy of the material housed in Rabat in 1996, JANSEN (2001, p. 123) excluded the Benahmed specimen figured by TERMIER & TERMIER

(1950b, pl. 71, figs 10-11) and called it an early form which can be regarded as close to *Rhenoschizophoria torkozensis* from the Assa Formation (lower Pragian, Dra Valley). The restudy of the specimens recorded as “*Acrospirifer arduennensis*” (today genus *Arduspirifer*), that would actually indicate an upper Emsian age, has shown that these do not belong to that species. They may represent a very early *Arduspirifer* or even an advanced species of *Hysterolites*, both suggesting a Pragian age. *Stropheodonta gigas*, figured by TERMIER (1936, pl. 3, figs 6-7) and TERMIER & TERMIER (1951a, pl. 78, fig. 20), belongs to the genus *Gigastropheodonta* JANSEN, 2014, ranging from upper Pragian to upper Emsian beds; the Benahmed specimens are determined as *G. cf. gigas* and plea for a middle to late Siegenian (Pragian) age in the Rhenish sense. The other specimens figured as the same species (op. cit., pl. 78, figs 18-19) belong to *Crinistrophia* HAVLÍČEK, 1967, ranging from upper Pragian to lower Emsian beds. *Eodevonaria dilatata* (today genus *Loreleiella*) from the “region of Benahmed”, (TERMIER & TERMIER 1951a, pl. 77, fig. 12) would, if correctly identified, suggest an Emsian age. *Chonetes tenuicosta* (today genus *Ctenochonetes*), figured by TERMIER (1936, pl. 3, fig. 11) and TERMIER & TERMIER (1951a, pl. 84, fig. 9), is redetermined as *Ct. aremoricensis*, an upper Pragian species common in the Dra Valley and Meseta (Morocco), the Iberian Chains (Spain), and the Armorican Massif (France) (e.g., RACHEBOEUF 1981, 1990a). The reported *Euryspirifer pellicoi* is an Emsian species but JANSEN (2001, p. 194) placed forms from the Meseta into undifferentiated *Euryspirifer* sp. and noted that these partly come probably from the Pragian (Siegenian). The true *Iridistrophia* (*Flabellistrophia*) *hipponyx*, listed in TERMIER & TERMIER (1951a) as *Hipparionyx hipponyx*, is in Germany an uppermost Emsian to basal Eifelian species.

But the ancestral species *Ir. (Flab.) musculosa* JANSEN, 2016 and possibly conspecific relatives from the Anti-Atlas (*Ir. cf. hipponyx* of JANSEN 2001) enter earlier, near the lower/upper Emsian boundary. The affiliation of the Benahmed representative is not clear. These are just a few examples and it is currently not conclusive to comment on the other brachiopod species that are only known from faunal lists and pencil drawings.

The situation is not easier for the recorded trilobites. *Malladia* (?) sp. described by RICHTER & RICHTER (1943) was later not recognized as a member of the genus, which proven geographic range did not list Morocco (e.g., STRUVE in BOUCOT et al. 1989, p. 562). Odontochilids range from the basal Pragian to the top of the lower Emsian (BUDIL et al. 2009), not higher. In modern taxonomy, specimens identified in the past as *Cryphaeus laciniatus* could belong to several genera of asteropygids (see BASSE 2004). *Kayserops kochi* is a species from the upper Emsian of Germany but the name has been used for other, partly even slight younger asteropygids that are not necessarily congeneric (see BASSE 2004). *Calymene curvicauda* and *Asteropyge lips* were first described by RICHTER & RICHTER (1943) from the Ezzhiliga region of the Meseta and could be of Pragian or lower Emsian age. The first was episodically placed with a query in *Gravicalymene* (ALBERTI 1969, p. 414), the second is a species of *Metacanthina* (see BASSE 2012). Previously it was placed by SMEENK (1983) in *Pilletina* but it has been omitted from the revision of Devonian asteropygid systematics and phylogeny by BIGNON & CRÔNIER (2013). The reported homalonotids *Digonus rhenanus* and *Dipleura simplex* are species described originally from the Rhenish Facies of Germany. The first is a synonym of *Digonus ornatus ornatus* (BASSE & MÜLLER 2004), which occurs in the lower Emsian of the Taunus region (southern Rhenish Massif,

Germany). The second species is a possible junior synonym of *Dipl. laevicauda* and originally from the lower Emsian of the Eifel Mountains (see WENNDORF 1990; BASSE & MÜLLER 2004). It has also been recorded from the lower Emsian of Libya (MERGL & MASSA 2000). It needs to be proven whether the North Gondwana specimens are really conspecific with the Rhenish taxa.

In summary, the literature record suggests that the widespread Lower Devonian limestone unit of the Benahmed region begins rather early in the Pragian and that it ranges through the lower Emsian. An upper Emsian age for highest parts is less likely.

4.1.3. Lower Devonian of Sidi Daoud

We examined the Lower Devonian limestones at two localities in the Sidi Daoud (= Sidi Dawd) region NW of Benahmed (Fig. 4). At Aïn Lahjare (GPS N33°16,012', W7°24,814'), blocks of light-grey micritic to slightly crinoidal limestones with 2-3 cm large brachiopods crop out. A conodont sample was unfortunately barren.

The second locality is the elongated hill above/behind the school and small sanctuary at Sidi Daoud itself (GPS N33°10'46.5'', W7°16'18.4''). In the lower part of the up to 150 m thick succession, there are fine-grained detrital limestones with rare brachiopods. A small conodont fauna with *Latericriodus bilatericrescens* was collected by M. RAJI & E. M. BENFRIKA (oral comm. 2012) in the ca. middle part. It confirms a lower Emsian age. The ca. upper third exposed along the top of the hill in a trench dug for a watering system is characterized by up to 30 cm thick, unfossiliferous dolomite beds alternating with deeply weathered shales. Because of the dull, altered lithology, no samples were taken. The top of the unit is not exposed.

TERMIER (1927a, 1936) and ROCH (1950) recorded *Cryphaeus laciniatus* (see comments above) and *Phacops potieri* from Sidi Daoud.

The latter is a species originally described from the Pragian or lower Emsian of France (see revision by MORZADEC 1969).

4.2. Upper Emsian/Eifelian

The regional knowledge of the upper Emsian and Eifelian is very poor. TERMIER & TERMIER (1951a, p. 66) assigned a shale unit excavated at Chat ed Dheb, west of Sidi Daoud, to the Eifelian. It yielded bivalves, brachiopods, phacopids, crinoid ossicles, orthocones, and a pyritic goniatite illustrated by TERMIER & TERMIER (1950c) as “*Mimagoniatites cf. evexus*”. Based on the drawings, it is difficult to interpret. It could be either an upper Emsian mimagoniatitid or a lower Eifelian agoniatitid, such as *Fidelites bicanaliculatus* (see EBBIGHAUSEN et al. 2011). The associated “*Thysanopeltis* (?) *bifidum*” TERMIER & TERMIER, 1950d has been re-assigned to the genus *Tenuipeltis* LÜTKE, 1965 (see BASSE 2012, p. 118), which occurs elsewhere in the Meseta only in the pelagic upper Emsian of Dechra-Aït-Abdallah (RICHTER & RICHTER 1943: *Thys. maurus*). The type-species (*Thys. tenuicosta*) is also from upper Emsian pelagic facies (of the Harz Mountains) but the genus is thought to range higher.

As a research hypothesis, the deepening and onset of low-oxygen conditions above the neritic carbonate platform represents regionally the global Daleje Event at the base of the upper Emsian. It is well-developed in the Oued Cherrat area (BECKER et al. 2020b) but less distinctive in the Al Attamna (EICHHOLT & BECKER 2016; new data).

4.3. Givetian (new Oulad Amar Formation)

The Givetian of the Benahmed region yielded rich, new conodont faunas. There was considerable Eovariscan synsedimentary tectonic overprinting that caused reworking and re-sedimentation. In terms of facies and faunas, differences to contemporaneous units

known to the north (Al Attamna) and south (Rehamna) are large. Therefore, a new Oulad Amar Formation is introduced, based on the name marked on the topographic map, Benahmed, 1 : 50.000, NI-29-XI-2a, for the Palaeozoic region east of Beni Sekten and north of the Cretaceous lobe of Oulad Zahra. Type locality is the section near Dar Cheikh el Mfaddel (see below).

4.3.1. Givetian at Zwayir

Givetian crinoidal limestones and conglomerates are exposed in boulders along an agricultural track at Zwayir (= Zwaouir = Az Zwir on the topographic map). This is Section ZW of M. RAJI (Fig. 5). Most limestones are light to middle grey and grade macroscopically from fine or coarse-grained crinoidal limestone to conglomerates with variably small or large, fine-grained pebbles surrounded by crinoidal matrix (Fig. 6). Some beds provide evidence for double reworking: pebbles sitting in coarse crinoid matrix consist themselves of mixed smaller-sized pebbles and fine crinoidal matrix. A simplified overview of the exposed succession is shown in Fig. 7. In nature, the bedding is partly not well defined and crinoidal and conglomeratic parts intergrade within boulders exceeding a meter of thickness. Intercalated shales/marls are deeply weathered and poorly exposed.

In order to understand the local facies and age relationships, seven samples were taken (ZW S1-7), which all yielded conodonts, partly monospecific (ZW S1, S7), partly with up to nine species (ZW S3, S4; Tab. 1). There are two principle microfacies types that show some variation. Limestone pebbles are darker grey than the conglomerate matrix and consist of variably fossiliferous and bioturbated mud-wacke- to packstones with dense, micrite matrix, non-orientated styliolinids (ZW S1), very fine shell detritus, some ostracods, large trilobite remains (ZW S2, Fig. 8.2), rare gastropods (ZW S6), occasional idiomorphic

pyrite (ZW S2, Fig. 8.3), and secondary dolomitization. Mudstones tend to be peloidal (ZW S4, Fig. 8.5) and occasionally the micrite has been washed out (ZW S7, Fig. 8.8). Subrounded to rounded but irregularly shaped pebbles range in size from a few mm to 2 cm (ZW S2, Fig. 8.3) and up to 10 cm (Fig. 6; ZW S4, S7). As an exception, small terebratuloid brachiopods, resembling in shape and ribbing

style the genus *Ense* STRUVE, 1992 (“*pumilio* type”), occur as plasters (ZW-S1, Fig. 11.6). As these have a distinctly larger size and more costae than all known species of *Ense*, they are tentatively assigned to ?*Rhipidothyris* sp., possibly ex gr. *africana* BOUCOT, MASSA & PERRY, 1983, suggesting a Givetian age (see BOUCOT et al. 1983; HAVLÍČEK & RÖHLICH 1987; MERGL & MASSA 2004).



Fig. 5: The middle Givetian (Eovariscan) conglomerate unit exposed in the curve of an agricultural track at Zwayir (oldest bed in the lower foreground).



Fig. 6: Field photo of intergrading coarse conglomerate and crinoidal limestone at the base of the section at Zwayir.

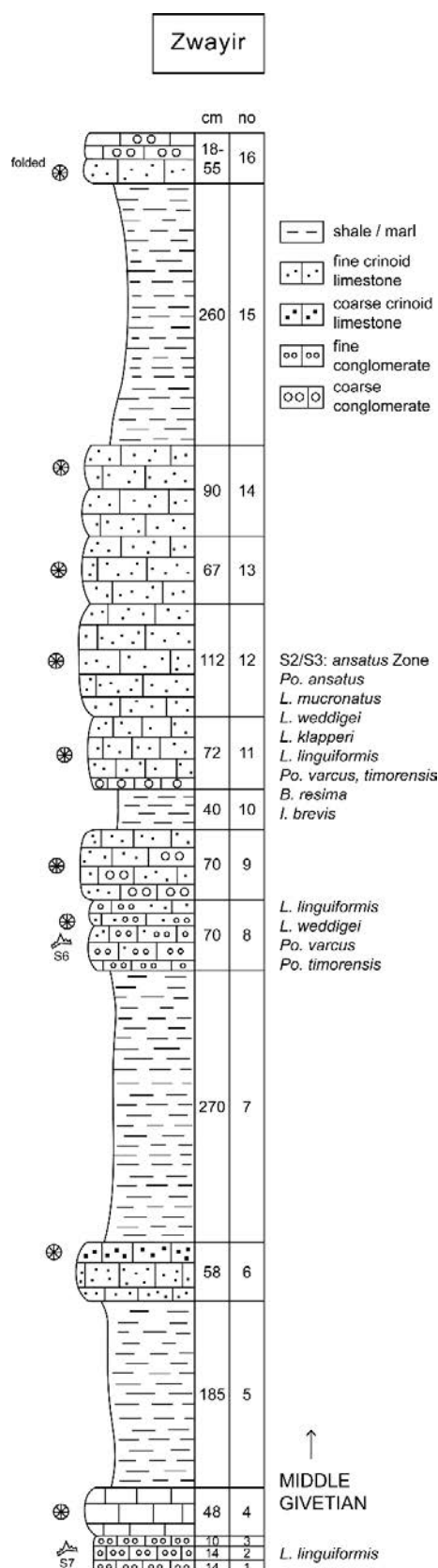


Fig. 7: Simplified lithological log and conodont data for the conglomerate section at Zwayir.

The original environmental setting of the mudstones was deep neritic to shallow pelagic, without or with only weak bottom

currents. This is supported by an outer shelf polygnathid conodont biofacies. Skeletal remains of photic zone organisms are lacking.

The crinoidal limestone and matrix of the conglomerates (extraclast float-rudstones) consist of light-grey, more or less strongly recrystallized and partly dolomitized (then more brownish) grainstones without any sorting or grading (Figs. 8.3, 8.6), fine or coarse, angular crinoid debris, sometimes complete ossicles, and shell fragments. As noted above, Sample ZW S1 is very rich in brachiopods (Fig. 8.1), while there are peloids and styliolinids in the sparitic matrix of ZW S2 and ZW S6 (Fig. 8.6); the latter sample shows also trilobite fragments. Diagenetic compaction caused styliolithic pressure solution contacts with ferromanganese encrustation of angular pebbles in ZW S3 (Fig. 8.4) and ZW S6 (Fig. 8.7). In ZW S3, original micrite was only partly washed out, causing a gradual change from crinoidal grain- to packstone.

The irregular bedding, lack of any sorting or grading, both among the extraclasts and within the matrix, indicates deposition by debris flows that originated due to synsedimentary Eovariscan seismic activity near a former fault scarp. The hemipelagic mud-wackestones must have been uplifted by block faulting, were eroded and turned in a shallower setting into pebbles of variable size. The rather good rounding in some of the samples requires an extended period of high-energy conditions, adjacent to a setting, where currents and storms accumulated crinoid and brachiopod debris. However, the local lack of corals and other shallow neritic organisms and the presence of planktonic styliolinids in the grainstone matrix suggests that the complete reworking took place around an offshore crinoid shoal/ramp. Finally, seismic events at the persisting fault scarp caused imbalances of slope sediment sheets that moved as debris flows downslope.

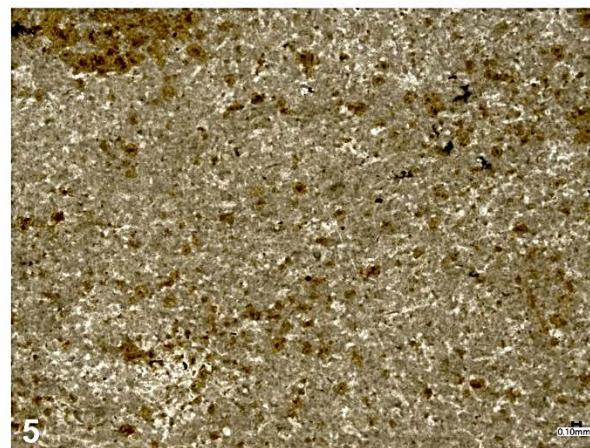
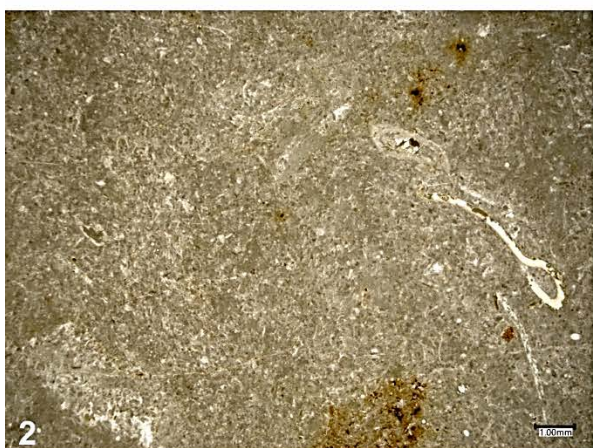
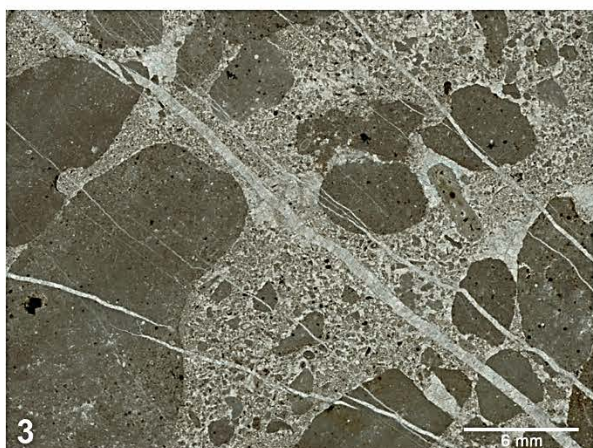
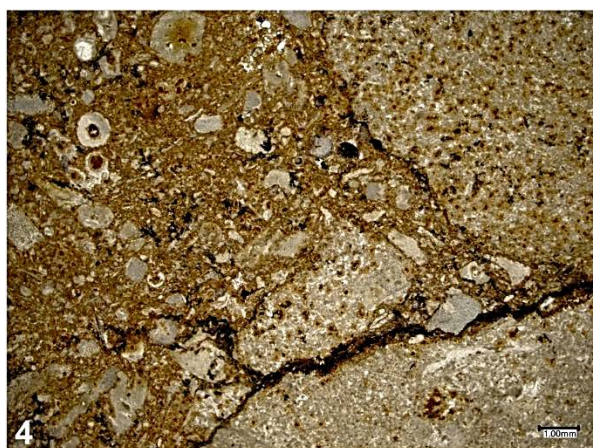


Fig. 8: Microfacies of limestone samples from Zwayir. **1.** Recrystallized bioclastic grainstone with many fragmentary brachiopod shells, crinoid debris, and some styliolinids (ZW S1); **2.** Pebble of slightly peloidal mud-wackestone with dense micrite matrix and large trilobite piece (ZW S2); **3.** Large-scale picture of extraclast float-rudstone of ZW S2, showing the lack of sorting or grading, rounding of unsorted pebbles, and variable grain size of matrix; **4.** Stylolithic and Fe-M-impregnated contact of peloidal and bioturbated mud-wackestone clasts with unsorted, heterogeneous crinoidal packstone matrix (ZW S3); **5.** Detailed view of peloidal mudstone of pebble ZW S4, with very low amount of fine shell debris; **6.** Extraclast float-rudstone of ZW S6 with angular shape of very differently sized mud-wackestone pebbles and peloidal grainstone matrix with poorly preserved styliolinids and trilobite fragments; **7.** Larger view of ZW S6, showing the stylolithic contact of angular mudstone extraclasts; **8.** Pebble of peloidal mudstone with partly washed out micrite matrix and trilobite fragment (ZW S8).

The conodont data suggest that the complete interval of hemipelagic deposition, reworking, and re-deposition took place within the upper half of the middle Givetian. While mudstone pebble ZW S7 from the lower part of the succession yielded only a few *Linguipolygnathus linguiformis* (Figs. 10.14-15), the dolomitized mudstone pebble ZW S4 contained also *Polygnathus varcus* (Fig. 9.24), *Po. xylus* (Fig. 9.25), *L. klapperi*, *L. weddigei*, *L. mucronatus* (Fig. 9.20), and *Tortodus caelatus* (Fig. 9.26). The combination of the latter two species indicates the *ansatus* Zone (former Middle *varcus* Zone; ABOUSSALAM 2003) in the upper part of the middle Givetian. In the top-middle Givetian facies model of NARKIEWICZ et al. (2016), a relative dominance of both *L. linguiformis* (Figs. 9.18-19, ca. 33 % of the assemblage) and *Belodella resima* (Fig. 9.17, ca. 39 %) is assigned to a “brackish lagoon or estuary”. At Zwayir, such an interpretation is clearly contradicted by the microfacies and overall setting. It is long known that *Belodella*-rich faunas occur also in Lower Devonian pelagic limestones in offshore facies (ABOUSSALAM et al. 2015). In the Givetian, a rarity of icriodids, as at Zwayir, indicates a deeper ramp deposition.

Conodonts from samples ZW S2, S3, and S6 can either come from the grainstone matrix or from reworked pebbles. The index species of the *ansatus* Zone was found both in ZW S2 (Fig. 9.5) and S3 (Figs. 9.14-15), in both cases jointly with *L. mucronatus* (Figs. 9.3, 9.13),

which has its main level in the *ansatus* Zone (see discussion in BRETT et al. 2018). Sample ZW S3 yielded locally the only icriodid, *I. brevis* (Figs. 9.9-10; < 0.5 % of all specimens). *Polygnathus varcus* is moderately common (ca. 10-30 % of faunas). The bioclastic grainstone with large amounts of styliolinids and brachiopods (ZW S1) gave a monotypic *L. linguiformis* assemblage, which differs from the faunas from conglomerate samples. This suggests that the diverse conodont faunas derive mostly from the reworked mud-wackestones, in agreement with their original deeper-water deposition. Locally rare taxa are *Prioniodina* sp. (Sample ZW S4, Fig. 9.27), “*Ozarkodina*” *plana* (Sample ZW S5, Fig. 10.3), and *L. weddigei* (Sample ZW S2, Fig. 9.4).

The overall conodont fauna does not differ from middle Givetian pre-reefal assemblages of the southern Oued Cherrat (flaserlimestone of Aïn-as-Seffah, BECKER et al. 2020a) or from the Anti-Atlas (ABOUSSALAM 2003). The local carbonate ramp was open. This suggests that the reef platforms to the north (At Attamna) and south (northern Rehamna) were separated by wide deeper shelf areas. As suspected by previous authors, the spatial distributions of Givetian biostromes and bioherms in the Western Meseta was probably constrained by the mosaic of synsedimentary block movements that later caused the uplift and reworking.

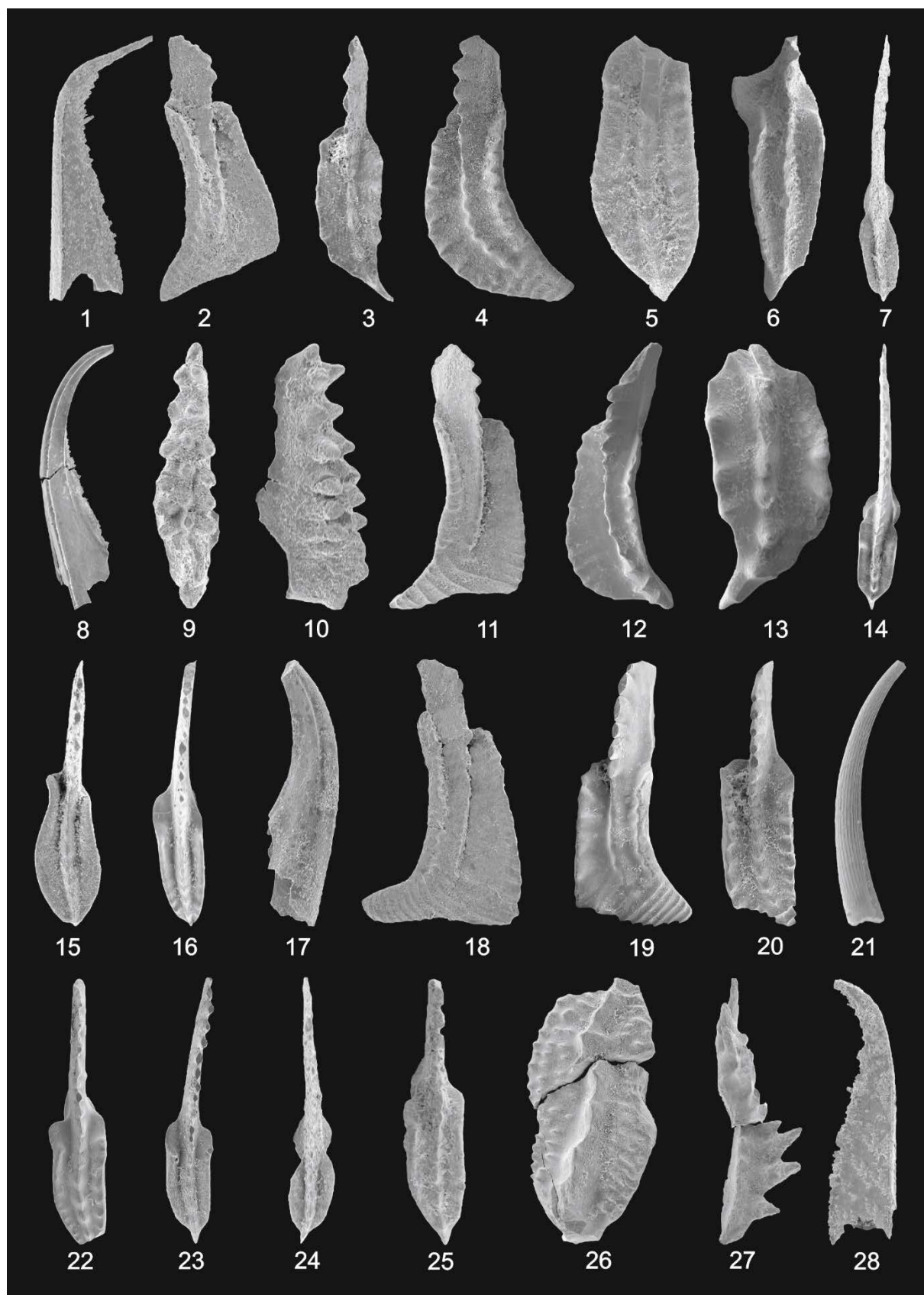


Fig. 9: Givetian conodonts from Zwayir (1-7 = ZW S2, 8-16 = ZW S3, 17-27 = ZW S4, 28 = ZW S5), GMM B4C.2.1-28. **1, 8, 17, 28.** *Belodella resima* (x 60, 40, 55, 55); **2, 11-12, 18-19.** *Linguipolygnathus linguiformis* (x 30, 40, 70, 30, 30); **3, 13, 20.** *L. mucronatus* (x 65, 95, 35); **4.** *L. weddigei* (x 35); **5, 14-15.** *Polygnathus ansatus* (x 60, 45, 60); **6, 16, 22-23.** *Po. timorensis* (x 60, 60, 45, 65); **7, 24.** *Po. varcus* (x 55, 85); **9-10.** *Icriodus brevis* (x 65); **21.** *Neop. perlineatus* (x 65); **25.** *Po. xylus* (x 80); **26.** *Tortodus caelatus* (x 40); **27.** *Prioniodina* sp. (x 40).

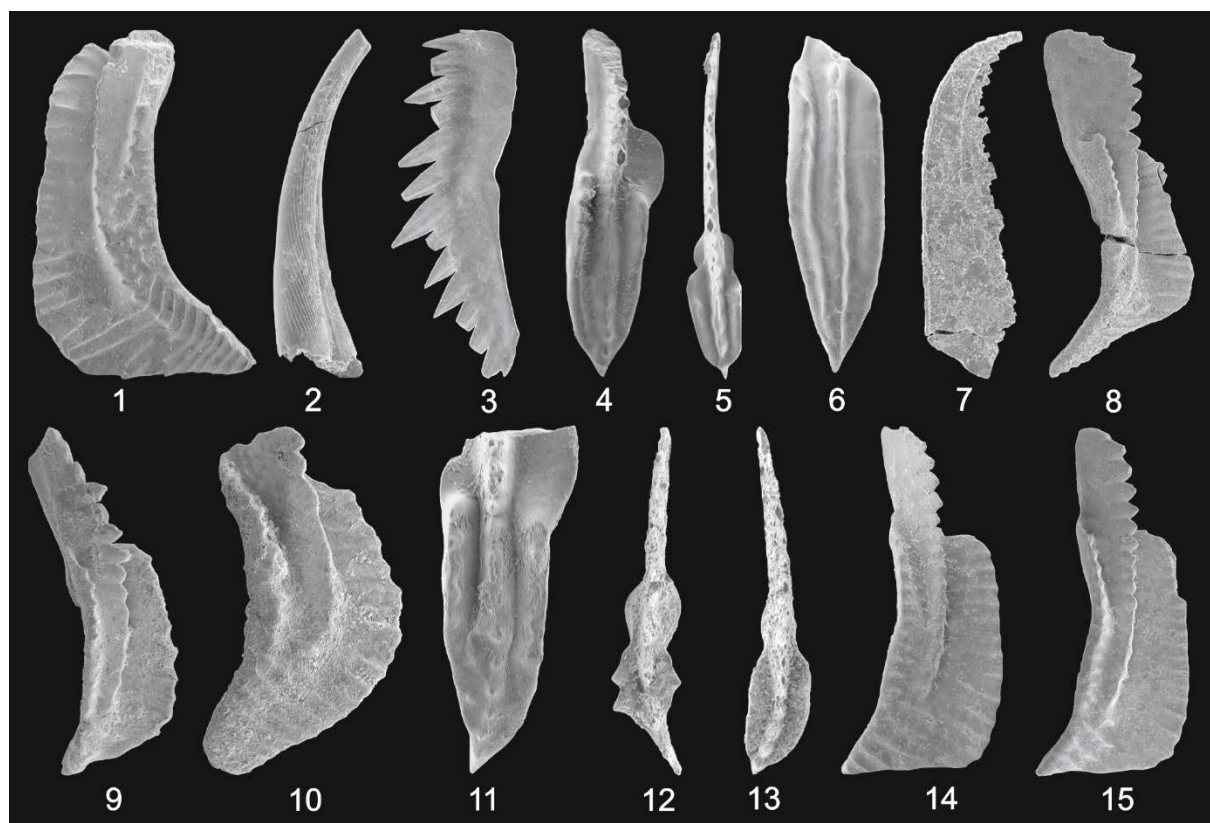


Fig. 10: Givetian conodonts from Zwayir, part II (1-6 = ZW S5, 7-13 = ZW S6, 14-15 = ZW S7), GMM B4C.2.29-43. **1, 8, 10, 14-15.** *Linguipolygnathus linguiformis* (X 40, x 30, x 40, x 50, x 55); **2.** *Neopanderodus perlineatus* (x 60); **3.** “*Ozarkodina*” *plana* (x 65); **4, 11.** *Polygnathus timorensis* (x 45, x 75); **5, 12-13.** *Po. varcus* (x 60, x 65, X 65), including an unusual morphotype with spinose side nodes (12.); **6.** *Po. xylus* (x 80); **7.** *Belodella resima* (x 60); **9.** *L. mucronatus* (x 65).

Zwayir							
Conodont zones	<i>rhenanus-varcus - ansatus</i>						
Sample no.	S1	S2	S3	S4	S5	S6	S7
<i>L. linguiformis</i>	20	16	12	22	5	7	2
<i>L. klapperi</i>		1	2	3		3	
<i>L. weddigei</i>		1		1			
<i>L. mucronatus</i>		1	1				
<i>Po. timorensis</i>		1	4	2	2	5	
<i>Po. ansatus</i>		1	7				
<i>Po. varcus</i>		10	5	9	3	3	
<i>Bel. resima</i>		5	11	26	6	1	
<i>I. brevis</i>			1				
<i>T. caelatus</i>				1			
<i>Prioniodina</i> sp.				1			
<i>Po. xylus</i>				2	1		
<i>Neop. perlineatus</i>			1		3		
“ <i>Oz.</i> ” <i>plana</i>					1		
total conodonts	20	36	44	67	21	19	2

Tab. 1: Conodont abundance and diversity in the seven samples from Zwayir.



Fig. 11: Middle Devonian brachiopods from the brachiopod bed at Dar Cheikh el Mfaddel (1-5, Bed 1, SMF 102134.1-5) and from Zwayir (6, Sample ZW S1, SMF 102135). 1. *?Devonochonetes* sp., external and internal moulds; 2. Chonetid, ventral valve, internal mould (left specimen) and orthotetide brachiopod, dorsal valve, internal mould (large specimen); 3. *?Strophodonta* sp., dorsal valve, external mould; 4. *Tropidoleptus* sp., ventral internal mould; 5. Chonetid, ventral internal mould; 6. *Pumilio*-like terebratulide, tentatively assigned to *?Rhipidothyris* sp. ex gr. *africana* BOUCOT, MASSA & PERRY, 1983, decorticated ventral valve exterior.



Fig. 12: Overview of the middle/upper Givetian succession opposite of Dar Cheikh el Mfaddel, showing the position of sampled beds.

4.3.2. Givetian at Dar Cheikh el Mfaddel

The Middle Devonian succession exposed along the hill opposite of Dar Cheikh el Mfaddel (Figs. 1, 12) is the type locality of the new **Oulad Amar Formation**. GPS coordinates for the top of the section (Bed 12b) are N33°9'57.2'', W7°16'39.4''. In total, the formation includes a range of lithologies: deeply weathered shale/marl, peloidal mudstones, bioclastic wackestones with abundant styliolinids, bioclastic wackestones with dominant shell debris and brachiopods, grainstones with variable amounts of crinoid, brachiopod or trilobite debris, styliolinids and peloids, styliolinid pack-grainstones, and coarse, unsorted conglomerates (extraclast float-rudstones). In the Beni Sekten area, corals are rare.

At Dar Cheikh el Mfaddel, the calculated thickness SW of the Lower Devonian quarry (Fig. 1) is in the range of 80-90 m but the precise formation base has not been established. The bedding changes laterally, with more solid units cropping out or disappearing on strike (Fig. 12). Figure 13 is, therefore, a representative but simplified section log for the ca. upper half of the

formation. It begins close to the house visible in the middle of Fig. 1, at GPS N33°9'56.5'', W7°16'34.6'' (on the right in Fig. 12). Stratigraphically below, towards the quarry, more limestones crop out for a distance of ca. 75 m.

The resistant Bed 1 contains abundant univalved brachiopods that partly cover the bed. A larger block contained ?*Devonochonetes* sp. (Fig. 11.1), a large orthotetide (Fig. 11.2), ?*Strophodonta* sp. (Fig. 11.3), and *Tropidoleptus* sp. (Fig. 11.4). *Devonochonetes* is a Middle Devonian genus; the specimens resemble *D.*? cf. *scitulites* sensu RACHEBOEUF, 1981 from the Givetian of Palencia (Spain) or *D. salami* MERGL & MASSA, 1992 from the Givetian-Frasnian transition of Libya. The genus *Strophodonta* has been reported from the uppermost Silurian to Frasnian, the only external mould is a coarsely ribbed form. *Tropidoleptus* is widely known in North Africa (from Mauritania to Niger), from the Pragian (JANSEN et al. 2007) to the Givetian (e.g., ARDEN & RHERIG 1964; BOUCOT et al. 1983; MERGL & MASSA 1992, 2004; RACHEBOEUF et al. 2001), with the main

occurrences in the Pragian-Emsian and Givetian. In summary, the brachiopods suggest a Middle Devonian and possibly a Givetian age for the base of our logged section. The unit yielded no conodonts. The microfacies is a dull, strongly recrystallized microsparite. Laterally to the west (Fig. 12), the beds dip more or less in parallel with but slightly steeper than the slope. Thickness calculations of covered intervals are arbitrary; partly distances on the slope between limestones are given. Bed 6b on the upper slope is an irregularly-bedded, up to 2 m thick conglomeratic interval. Pebbles consist of light-grey, bioturbated mud-wackestone with dense micrite matrix, fine shell and trilobite debris, abundant, and poorly preserved crinoid fragments (Fig. 14.1). Conodonts (Tab. 2) of this deep neritic facies belong mostly to single cone genera, such as *Belodella* (Figs. 16.1, 4) and *Neopanderodus* (Fig. 16.3). A single *Icriodus brevis* (Fig. 16.2) gives a position no older than the late lower Givetian *brevis* Zone, correlating ca. with the *timorensis* Zone of the polygnathid succession (BULTYNCK 1987).

The next conglomerate (Bed 7b) contains 1-4 cm large, subrounded pebbles, partly in stylolitic contact, of a slightly deeper (shallow pelagic) facies: bioclastic wacke-floatstones with abundant, poorly preserved styliolinids, some ostracods, and orthocones (Fig. 14.2). A second pebble is rich in fine filaments and sparite fenestrae. The rudstone matrix is a peloidal, bioclastic grainstone with poorly preserved styliolinids (Fig. 14.3). Rests of a micrite matrix are partly preserved and there is some dolomitization. The unit produced a much more diverse conodont fauna (eight species, Tab. 2). The mixed polygnathid-belodellid facies is in accord with the neritic microfacies. It includes the index species of the *difficilis* Zone of the icriodid zonation (BULTYNCK 1987; Fig.

16.5) and *Po. varcus* (Fig. 16.9), one of the index species of the middle Givetian *rhenanus-varcus* Zone. *Polygnathus* is slightly more common than linguipolygnathids (*L. linguiformis*, Fig. 16.6, *L. weddigei*, Fig. 16.7). There are two rather distinctive prioniodinids with high anterior blade (e.g., Fig. 16.10); their dense denticulation resembles *Tortodus sardinia* (see ABOUSSALAM 2003, pl. 26, fig. 12) but there is no incipient platform along the blade.

After an outcrop gap of 43 m distance, a sequence of solid limestones crops out close to a smaller house on the lower slope (Figs. 1, 12). A conodont fauna from the almost 1 m thick Unit 10b, which consists of subunits, is rather poor and dominated by *L. linguiformis* (Fig. 16.11). The microfacies is a recrystallized bioclastic grainstone with styliolinids, ostracods, pyrite, and shell debris, but without peloids and with only subordinate crinoid debris (Fig. 14.4). Above, the conglomeratic Bed 11b yielded with *L. mucronatus* (Fig. 16.12) an indicator that the top of the *rhenanus-varcus* or (more likely) *ansatus* Zone has been reached (BULTYNCK 1987; BRETT et al. 2018). There is also a poorly preserved, incomplete shark tooth belonging to *Omalodus grabau* (see SCHWERMANN 2014). In Morocco, *Omalodus* has previously been described from contemporaneous limestones of the southern Tafilalt (HAMPE et al. 2004). Reworked pebbles of Bed 11b are ca. 1-3 cm large, are surrounded by sparitic dissolution seams, and consist of peloidal mudstone. Within one pebble, there is a mixed amalgamated micrite-fenestral fabric, which may represent a small sponge (Fig. 14.5; see discussion in KERSHAW et al. 2021). The rudstone matrix differs from that in Bed 10b; it is a very shell-rich grainstone (calcarenite) with ostracods, trilobite, some fragmentary corals and crinoid debris (Fig. 14.6). This indicates deposition at shallower depth than before.

At the foot of the hill, just above a small gully, Bed 12b is an irregularly-bedded, massive boulder unit (Fig. 12). A thin-section shows peloidal grainstone with fine shell debris and some retained micrite (Fig. 14.7), followed above a pyrite enrichment by recrystallized styliolinid packstone with partly washed out micrite matrix, ostracods, brachiopod and crinoid debris (Fig. 14.8). This upper part may represent a contourite deposit, as it is known from the Tafilalt Platform (HÜNEKE et al. 2021 submitted). The rich and diverse (23 species) conodont fauna includes some top-Givetian species that are new for the western parts of the Meseta. This applies to some species of *Schmidtognathus* (9.6 % of the total assemblage; *Schm.* aff. *hermanni*, Fig. 15.7, *Schm.* *wittekindti*, Fig. 15.12, *Schm.* *pietzneri*, Fig. 15.11, *Schm.* *latifossatus*, Fig. 15.8, *Schm.* aff. *latifossatus*, Fig. 15.9, *Schmidtognathus* n. sp. DCM, Figs. 15.10), “*Ozarkodina*” aff. *adventa* (Fig. 16.23), and *Klapperina* (*Kl.* *vysotzkii*, Fig. 16.20, < 0.4 %). Unusually dominant for the stratigraphic position is a flood of *Po. xylus* (Figs. 15.5-6, 36 % of the assemblage), followed in terms of abundance by *Po. dubius* (Fig. 16.25, ca. 18 %), *Po. pardecorosus* (Fig. 15.1, 15.4 %), and belodellids (*B. resima*, Fig. 16.15, *B. triangularis*, Fig. 16.16; both = 12.2 %). This polygnathid facies, with close to 80 % of the total fauna, is indicative for an offshore setting. It includes some “*Oz.*” *semialternans* (Figs. 16.21-22, 1.3 %) and *Po. cristatus*

ectypus (Fig. 16.26, 1.5 %) and only a very minor contents of icriodids (*I. expansus*, Fig. 16.19, < 0.2 %), *Elsonella* (Figs. 16.17-18, 0.6 %), and *Tortodus* (*caelatus* Group, Fig. 15.13, < 0.2 %). Associated are rare shark teeth (Fig. 15.14) and phosphatic brachiopod remains (Fig. 15.15). It is likely that the fauna represents by condensation several upper Givetian zones; otherwise there is a considerable gap between Beds 11b and 12b. The common *Po. pardecorosus* and single specimens of *Po. alatus* (Fig. 16.24) and *Po.* aff. *pennatus* (Fig. 15.4; pathological) give a topmost Givetian age for the final deposition (*norrisi* Zone); an absence of *Skeletognathus norrisi* is also known from top-Givetian samples of the Tafilalt (see ABOUSSALAM & BECKER 2007). Two somewhat pathological polygnathids belong probably to *Po. tafilaltensis* (Figs. 15.2-3), which enters in its type-region in the *dengleri dengleri* Subzone (ABOUSSALAM & BECKER 2007). Two features of the assemblage are noteworthy: 1. The occurrence of pathological specimens of several polygnathid species, and 2. The extreme rarity of *Klapperina*, which suggests that sediment of the *disparilis* Zone was poorly represented by our sample, perhaps due to a gap or strong condensation.

The reworking at Dar Sheik el Mfaddel was probably related to the same fault scarp as at Zwayir. Early consolidated lime mud and sand (calcarenite) of both deep neritic and shallow pelagic origin was uplifted and transformed into pebbles.

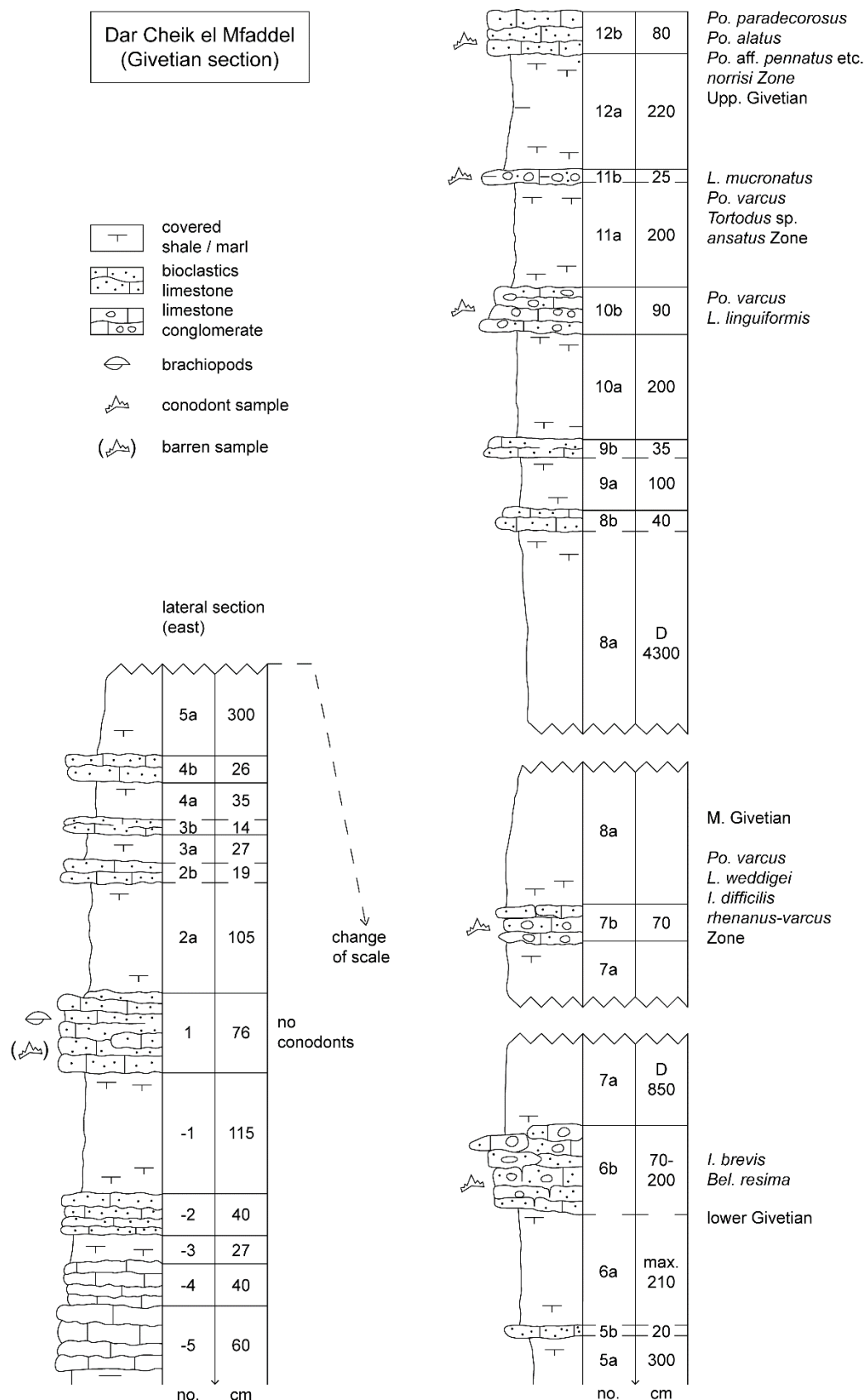


Fig. 13: Simplified section log for the Givetian at Dar Cheikh el Mfaddel, showing the position of conodont faunas and their age.

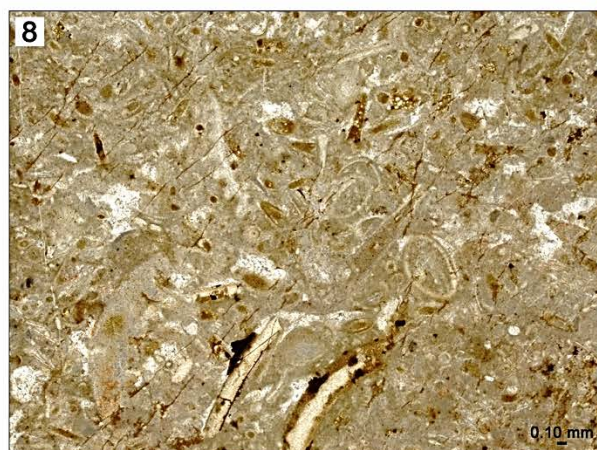
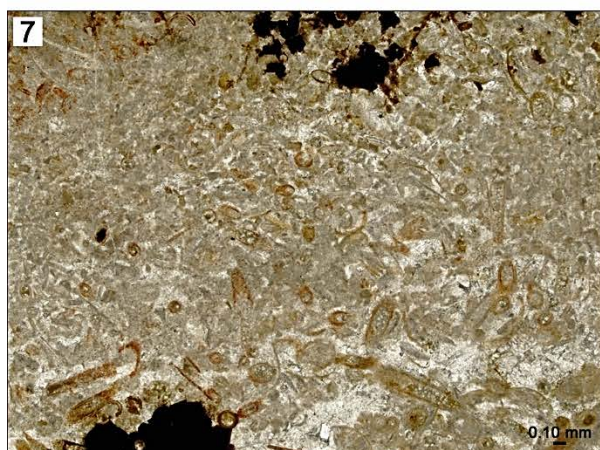
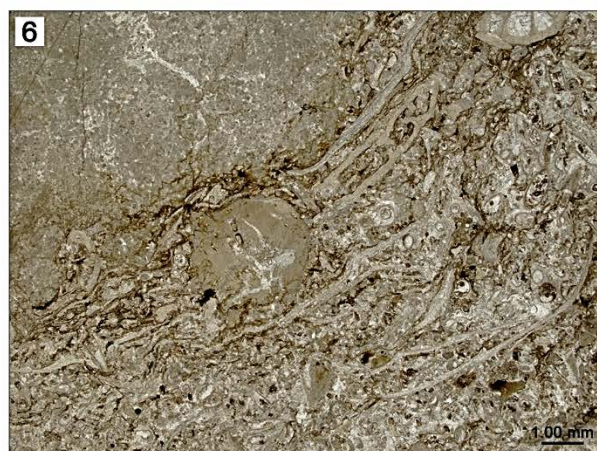
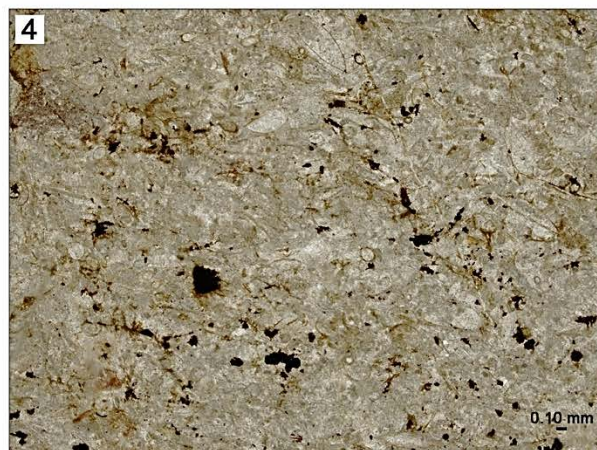
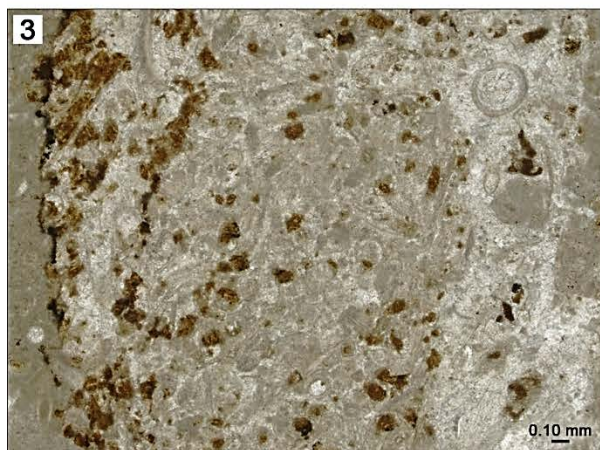


Fig. 14: Microfacies of limestones from the upper part of the Oulad Amar Formation at Dar Cheik el Mfaddel. **1.** Pebble consisting of bioturbated mud-wackestone with fine shell debris, poorly preserved crinoid fragments, and dense micritic matrix, Bed 6b; **2.** Pebble of bioturbated, bioclastic wacke-floatstone with a few poorly preserved styliolinids, some ostracods, a crinoid ossicle, an orthoconic cephalopod, and dense micrite matrix Bed 7b; **3.** Matrix of conglomerate of Bed 7b, partly dolomitized peloidal and bioclastic grainstone with poorly preserved styliolinids and remnants of original micrite matrix; **4.** Recrystallized, partly micritic, partly sparitic bioclastic wacke-grainstone with abundant shells, Bed 10b; **5.** Possible sponge remain within a peloidal mudstone matrix of a pebble within Bed 11b; **6.** Bioclastic grain-packstone matrix of the conglomerate of Bed 11b, rich in fragmented brachiopod shells, with a coral fragment (upper right corner), and crinoid fragments; **7.** Recrystallized styliolinid pack-grainstone, partly enriched in pyrite, Bed 12b, lower part; **8.** Peloidal grain-packstone with abundant shell debris and partly washed out micrite matrix, Bed 12b, upper part.

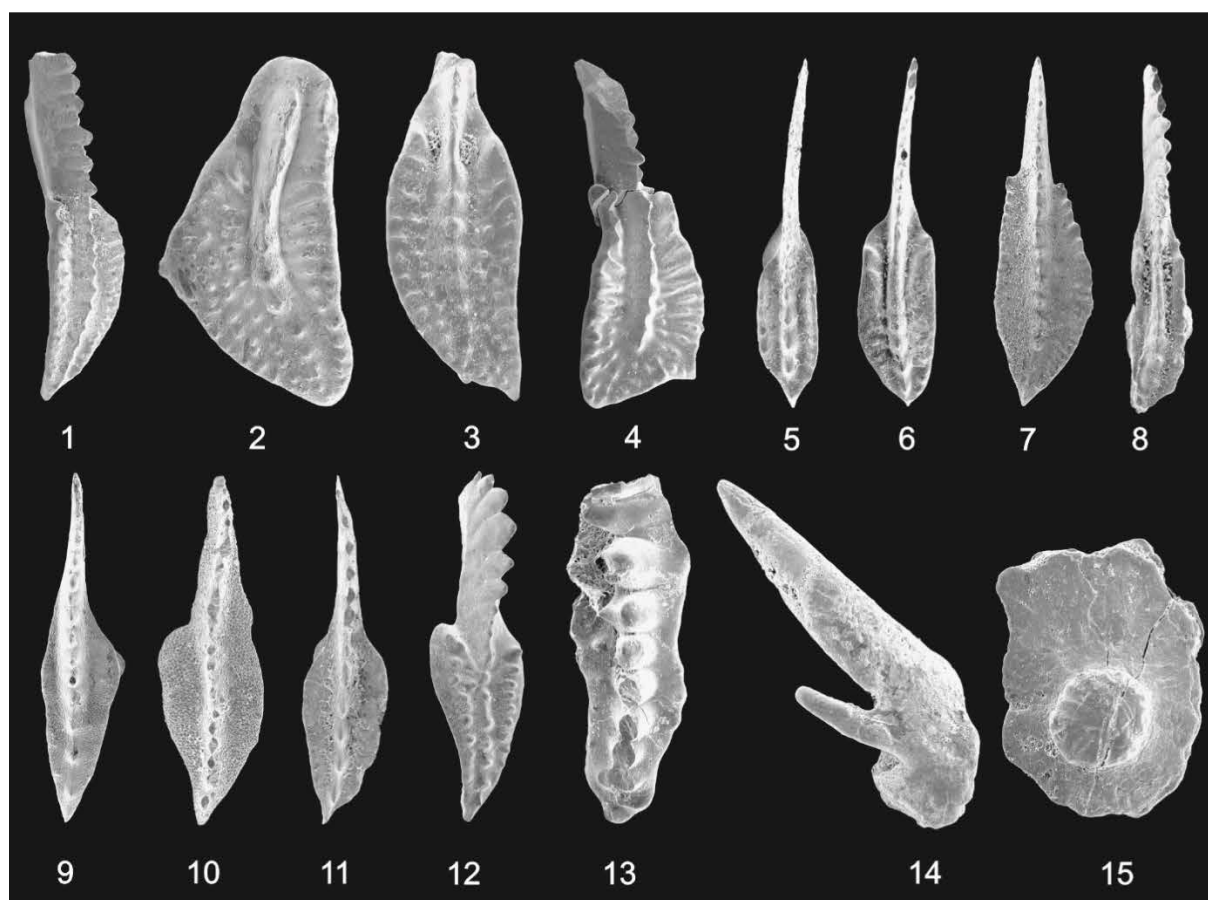


Fig. 15: Conodonts from the upper Givetian (top Oulad Amar Formation) at Dar Cheikh el Mfaddel, all from Bed 12b, GMM B4C.2.44-56. **1.** *Polygnathus paradercorosus*, x 40; **2-3.** *Po. tafilaltensis*, pathological, both x 55; **4.** *Po. aff. pennatus*, pathological, x 40; **5-6.** *Po. xylus*, x 75, x 50; **7.** *Schmidtognathus aff. hermanni*, x 35; **8.** *Schm. latifossatus* with rather irregular, narrow platform. x 40; **9.** *Schm. aff. latifossatus*, x 60; **10.** *Schmidtognathus* n. sp. DCM with chagrin platform surface, x 60; **11.** *Schm. pietzneri*, x 50; **12.** *Schm. wittekindti*, x 35; **13.** *Tortodus* sp. (*caelatus* Group), x 45; **14.** Skark tooth (?symmoriid), lateral view, x 45, GMM A1C.5.1; **15.** phosphatic brachiopod piece (?acrotetrid valve), GMM B5B.16.2, x 65.

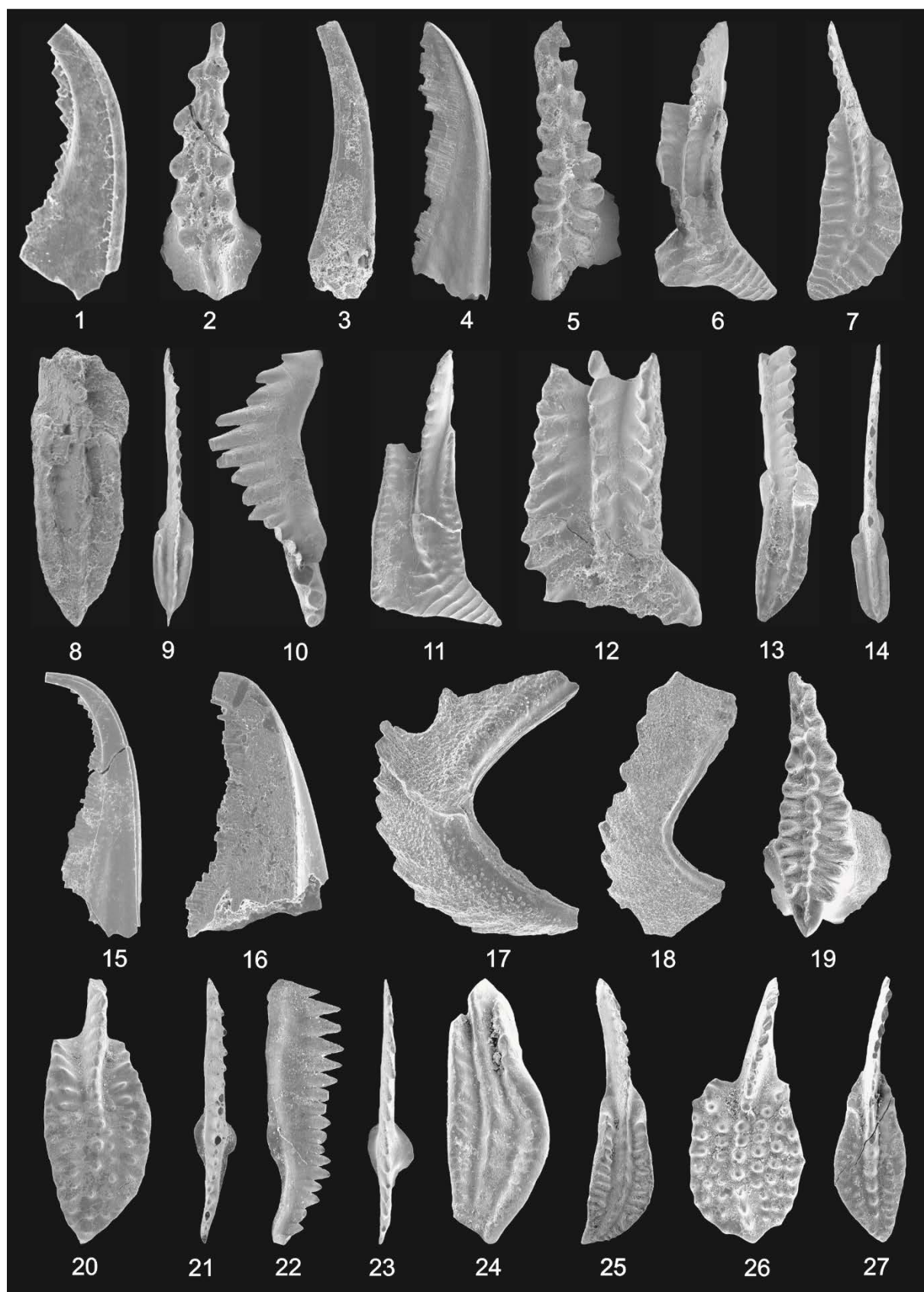


Fig. 16: Conodonts from the Givetian Oulad Amar Formation at Dar Cheikh el Mfaddel (1-4 = Bed 6b, 5-10 = Bed 7b, 11 = Bed 10b, 12-14 = Bed 11b; 15-27 = Bed 12b), GMM B4C.2.57-82. **1.** *Belodella resima*, x 140; **2.** *Icriodus brevis*, x 90; **3.** *Neopanderodus perlineatus*, x 55; **4.** *Bel. resima*, x 55; **5.** *I. difficilis*, x 50; **6.** *Linguipolygnathus linguiformis*, x 35; **7.** *L. weddigei*, x 45; **8.** *Polygnathus timorensis*, x 80; **9.** *Po. varcus*, x 55; **10.** *Prioniodina* sp., x 35; **11.** *L. linguiformis*, x 35; **12.** *L. mucronatus*, x 60; **13.** *Po. timorensis*, x 40; **14.** *Po.*

varcus, x 50; **15.** *Bel. resima*, x 60; **16.** *Bel. triangularis*, x 95; **17-18.** *Elsonella rhenana*, x 90, x 60; **19.** *I. expansus*, x 60; **20.** *Klapperina vysotzkii*, x 40; **21-22.** "*Ozarkodina*" *semialternans*, x 45; **23.** "*Oz.*" aff. *adventa*, x 60; **24.** *Po. alatus*, x 55; **25.** *Po. dubius*, x 35; **26.** *Po. cristatus ectypus*, x 50; **27.** *Po. ovatinodosus*, x 45.

Dar Cheik el Mfaddel					
Conodont zones	<i>timorensis</i>	<i>rhenanus-varcus</i>		<i>ansatus</i>	<i>norrisi</i>
Bed no.	6b	7b	10b	11b	12b
<i>Neop. perlineatus</i>	6	5			
<i>Bel. resima</i>	1	25	*	20	61
<i>I. brevis</i>	1				
<i>L. linguiformis</i>		6	10	62	
<i>L. weddigei</i>		10	*	1	
<i>Prioniodina</i> sp.		2			
<i>Po. varcus</i>		13	4	6	26
<i>Po. timorensis</i>		5	*	5	
<i>I. difficilis</i>		2	*	1	
<i>Tortodus</i> sp.				1	
<i>L. mucronatus</i>				8	
<i>I. expansus</i>					2
<i>Bel. triangularis</i>					5
<i>Elsonella rhenana</i>					3
<i>Tortodus</i> sp.					1
<i>Po. dubius</i>					96
<i>Po. xylus</i>					194
<i>Po. alatus</i>					1
<i>Po. aff. pennatus</i> (path.)					1
<i>Po. paradercorosus</i>					83
<i>Po. ovatinodosus</i>					13
<i>Po. tafilensis</i> (path.)					2
<i>Po. cristatus ectypus</i>					8
" <i>Oz.</i> " <i>semialternans</i>					7
" <i>Oz.</i> " aff. <i>adventa</i>					1
<i>Schm. wittekindti</i>					18
<i>Schm. hermanni</i>					9
<i>Schm. aff. hermanni</i>					1
<i>Schm. planus</i> n. sp.					2
<i>Schm. pietzneri</i>					3
<i>Schm. latifossatus</i>					1
<i>Klapperina vysotzkii</i>					2
total conodonts	8	68	14	104	539

Tab. 2: Conodont abundances at Dar Cheik el Mfaddel.

Re-deposition occurred by debris flows that mixed pebbles and shell or crinoid-rich debris. The most conodont- and dacryoconarid-rich bed at the top (Bed 12b) shows that the succession ended in a moderately deep outer shelf environment.

4.3.3. Possible Givetian E/SE of Benahmed

TERMIER (1936) reported from a locality named as Tantana, 9 km SSE of Sidi Sebaa (see Fig. 2), a limestone lense with alveolitids that he compared with the Frasnian of the Ardennes. Alveolitids are typical for the initial stadium of biostromes, both in Europe and in Morocco (e.g., MAY 1992, 1994; BOULVAIN et al. 1995; MÉNDEZ-BEDIA et al. 1994; FRÖHLICH 2003 for an Anti-Atlas example; compare facies diagram of EICHHOLT & BECKER 2016, fig. 6). The isolated occurrence of Givetian or Frasnian reefal facies far away from the Oulad Amar Formation outcrops has not been re-studied. The same applies to the assumed Givetian limestone with various tabulate corals (three genera) from Sidi Cadi Hajja SE of Benahmed (TERMIER & TERMIER 1951a, pp. 66-67). Both occurrences leave the possibility that biostrome facies stretched from the Al Attamna (Sidi Mohammed Smaine Formation) and Khatouat Massif (Jennabia Formation) areas far southwards. New data on age and microfacies are needed.

4. Frasnian at Boudouda

TERMIER & TERMIER (1951a, 1951b) noted that thin limestones and shales with pyritic fauna, including two species of *Buchiola* and two species of *Manticoceras*, were found NNW of Sidi bou Chatah, with the most fossiliferous occurrence at Boudouda (Fig. 3). A piste leading from Benahmed to the NW exposes in the low slope of a roadcut on its NE side (Fig. 17, coordinates x = 100, y = 200) a fine upper Frasnian succession that we

sampled in October 2012 bed-by-bed for ammonoids, conodonts, and other fauna.



Fig. 17: Exposure of the new Boudouda Formation in a roadcut (NE slope) at its type locality at Boudouda, NW of Benahmed.

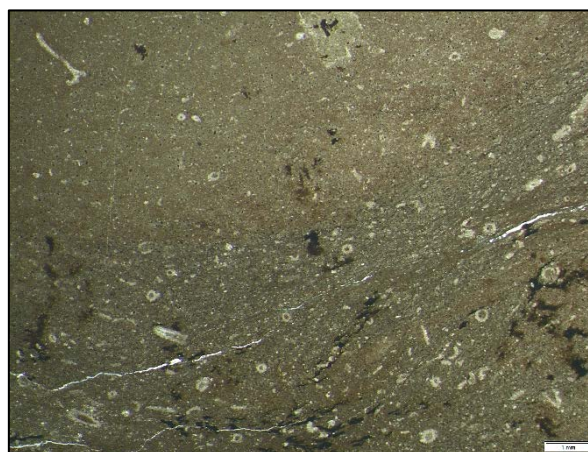


Fig. 18: Microfacies of Frasnian Bed 6b, a dark-grey, pyrite-rich mud-wackestone with recrystallized dacryoconarids.



Fig. 19: Surface of Frasnian marker Bed 9, with randomly distributed, partly fragmentary styliolinids.

The section log is illustrated, with local ammonoid ranges, in the following taxonomic

chapter. All beds dip steeply to the SE, with the oldest strata commencing ca. 30 m to the SE of an electricity pole that can be used as a landmark. The succession is unique for all of the Meseta and assigned to the **new Boudouda Formation**, which is defined as an alternation of thin nodular limestones and pyritic, hypoxic goniatite shale. The exposed thickness on the NE side is ca. 13 m but there are several more meters of outcrop on the SW side of the roadcut, where logging is difficult due to the Quarternary cover.

The section commences with red limestone nodules, followed by alternating gray shales and slightly more solid marls (Beds 1-4). These yielded both gephuroid ceratids and tornoceratids (see following chapter), bactritids, other orthocones, two species of rhynchonellids (smooth and ribbed), *Buchiola* and other bivalves, and ribbed gastropods representing a new genus. This is a typical faunal assemblage of Frasnian goniatite shales, as long-known and famous for the Eifel Mountains of Germany (Büdesheim Goniatite Shale = Büdesheim Formation; e.g., CLAUSEN 1968, 1969). A similar contemporaneous litho- and biofacies is not known from the Anti-Atlas, where goniatite shales with different faunal compositions occur in the top-Frasnian of the Tafilalt Basin (undescribed UD I-K faunas) and in the Middle/Upper Frasnian of the eastern Dra Valley (e.g., at Oued Mzerreb, BECKER et al. 2004a).

Bed 5a is a distinctive red shale with restricted fauna and yellowish nodules at the top. Bed 6a is richer in goniatites and rhynchonellids and yielded a crinoid stem piece. The top, a reddish-weathering nodular limestone, contains a relatively diverse conodont fauna. In contrast to the dominance of pelagic macrofauna, its conodont facies is of shallow-water type (mixed polygnathid-icriodid). There are only two juvenile

palmatolepids that cannot be identified at species level. The common icriodid, *I. symmetricus* (Fig. 20.8; 31.5 % of the assemblage) occurs both in neritic and pelagic settings. All the polygnathids are long-ranging within the Frasnian and provide no zonal age: *Po. alatus* (Figs. 20.3 and 9), *Po. webbi*, *Po. aequalis*, *Po. varcus* (Fig. 20.2), *Po. "aff. angustidiscus"* sensu HUDDLE (1981) (Fig. 20.1, a widely distributed un-named species; compare ABOUSSALAM et al. 2020, figs. 33.10 and 21), and *Ctenopolygnathus angustidiscus* (Fig. 20.10). The microfacies of Bed 6b is an argillaceous mud-wackestone with recrystallized dacryoconarids and abundant, fine, regularly distributed pyrite, as typical for offshore shelf basin facies. However, the contrast between litho-, micro-, macrobio- and conodont biofacies suggests that the local basin was not very deep.

Beds 7 and 8 are two further cycles of shale, with only a few goniatites, and argillaceous limestone nodules at the top. Bed 9 stands out because laminated shales grade upwards into a very fossiliferous, fissile, dark-grey, laminated shale with masses of squashed goniatites, orthocones, mantidoceratid anaptychi, styliolinids (Fig. 19), homocentrids, and entomozoid ostracods. This faunal bloom level has been sampled by C. HARTKOPF-FRÖDER (Krefeld) for palynomorphs but results are not yet available.

Bed 11 is another shale-nodule couplet, followed by the unfossiliferous Bed 12. The subsequent interval of Beds 13-17 has the richest goniatite faunas, with a maximum of twelve species found in Bed 15. Bed 13a contains pyritic microspheres, perhaps the internal moulds of tasmanitid algae. From Bed 14a, a distinctive, possibly new lunulacardiid bivalve was collected; the group occurs regularly in pelagic facies (e.g., NAGEL-MYERS & AMLER 2007), but mostly in cephalopod limestones.

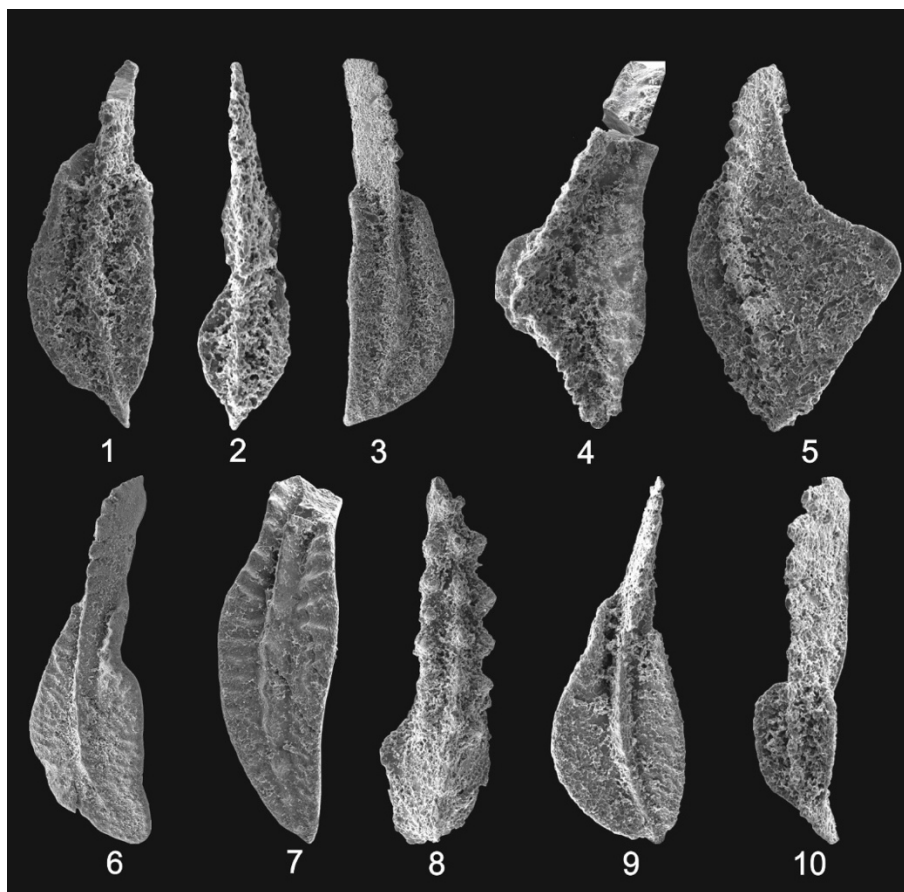


Fig. 20: Frasnian conodonts from Boudouda (1-3 and 8-10= Bed 6, 4-5 = Bed 21, 6-7 = sample from last limestone of the SW side of the roadcut, GMM B4C.2.83-92. **1.** *Polygnathus* “aff. *angustidiscus*” sensu HUDDLE (1981), x 90; **2.** *Po. varcus*, x 140; **3.** *Po. alatus*, x 50; **4.** *Nothognathella* sp., x 100; **5.** *Palmatolepis* sp. juv., x 85; **6.** *Po.* aff. *reitlingerae*, form with pronounced anterior platform rostra, higher on the right side, x 35; **7.** *Po. paradercorosus*, x 70; **8.** *Icriodus symmetricus*, x 70; **9.** *Po. alatus*, x 80; **10.** *Ctenopolygnathus angustidiscus*, x 90.

In Bed 15a, smooth rhynchonellids are accompanied by small-sized *Ambocoelia*- or *Crurithyris*-type brachiopods. Their range into hypoxic facies is widely known (BECKER et al. 2004a; ZAMBITO & SCHEMM-GREGORY 2013). The ribbed gastropod re-appears in Bed 16a. Buchioides occur in most beds, associated in Bed 17a by a different bivalve.

The fossiliferous Bed 21a ends with variably thick limestone concretions (Bed 21b), which was sampled for conodonts. Apart from a broken *Ancyrognathus triangularis*, a typical species for the lower half of the upper Frasnian (KLAPPER 1990), we found *I. symmetricus*, a juvenile *Palmatolepis* (Fig. 20.6), and a *Nothognathella* sp. (Fig. 20.5), the supposed Pb element of *Palmatolepis*. The previously

dominant polygnathids have vanished, indicating a deepening trend. The microfacies, a poorly fossiliferous mudstone with a single, sparite filled juvenile goniatite (Fig. 21) provides full support for this interpretation. Above follow more goniatite shales but the local biodiversity becomes reduced. The number of ammonoid species declines to four or five.

On the other (SW) side of the roadcut, younger strata are partly exposed. There is an alternation of red shales and of a few, up to 10 cm thick, micritic, reddish-grey limestones. Loose fauna included rare orthocones and poorly preserved brachiopods, no goniatites. The highest limestone found in a corner within the Quaternary cover, a mud-wackestone with abundant dacryoconarids (Fig. 22), continues

the monotonous pelagic facies. It yielded three specimens of *Po. pardecorosus* (Fig. 20.7), a questionable *Ancyrodella lobata*, and the first North African relative of the Russian *Po. reitlingerae* (Fig. 20.6; see taxonomy paragraph). The assemblage is not zonally diagnostic but indicates that the highest Frasnian has not been reached. Unfortunately, Boudouda provides no outcrop to study regionally the Frasnian-Famennian boundary.



Fig. 21: Almost unfossiliferous pelagic mudstone of Frasnian Bed 21 at Boudouda.

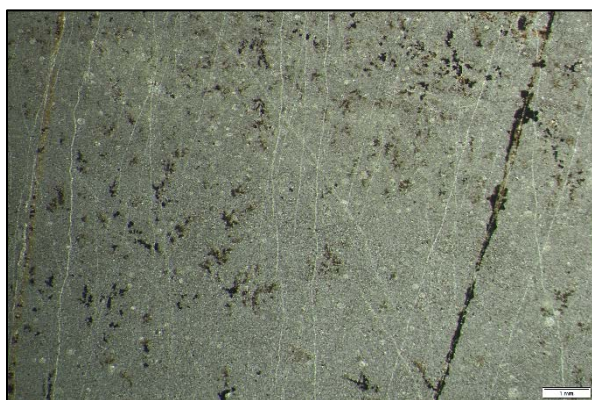


Fig. 22: Argillaceous mud-wackestone with abundant, recrystallized dacryoconarids, last Frasnian limestone exposed on the SW side of the roadcut at Boudouda.

4.5. Famennian of the Beni Sekten area

There is currently no outcrop with Famennian pelagic limestones around Boudouda or in the wider Beni Sekten area. However, conodonts of this interval were originally deposited, as evidenced by reworked material in Viséan limestones (see Carboniferous Boudouda chapter).

TERMIER & TERMIER (1951a) described briefly several localities in the Beni Sekten

area, where mixed silt- and sandstones and limestones yielded neritic “Strunian” faunas, notably with brachiopods (15 genera and species), bivalves (four taxa), rugose corals (“*Clisiophyllum omaliusi*”), trilobites (*Omegops accipitrinus*, see RICHTER & RICHTER 1943), and echinoderms. The latter includes the blastoid *Pentremitidea toujinensis*, which in modern taxonomy should belong to the genus *Hyperblastus* (wr. comm. J. WATERS, February 2021).

The types of the reported productid *Mesoplica praelonga* come from the uppermost Famennian (LE spore zone) Lower Pilton Formation of North Devon. But the species is wide-spread in the upper/uppermost Famennian, including Algeria and the Dra Valley (e.g., KAISER et al. 2004; NICOLLIN & BRICE 2004; BRICE et al. 2007). Caution is required since there are related species of the genus, which can be confused; these enter also in the upper Famennian (BRICE et al. 2005). The reported “*Mucrospirifer*” *strunianus* now belongs to the genus *Prospira*. The types are from the uppermost Famennian of the Avesnois (northern France) but the species appears to have a lower, upper Famennian range in the Dra Valley (Lower Fauna, BRICE et al. 2005: jointly with *Mes. praelonga*). *Punctospirifer laminosus* is now a species of *Tylothyris*, and normally a widespread Lower Carboniferous taxon (BRUNTON 1984; BRICE et al. 2005). But the genus commences in the uppermost Famennian of the Dra Valley (KAISER et al. 2004; BRICE et al. 2007). Again, there are several related taxa, which underline the importance of taxonomic stringency. Rhynchonellids from El Toujine identified originally as “*Camarotoechia moresnetensis*” (det. F. DEMANET) were described as *Araratella centralis* by SARTENAER & PLODOWSKI (2003). The genus is a globally widespread marker for the “Strunian”.

Omegops is a typical “Strunian” genus in the Rhenish Massif; the Benahmed specimen was re-assigned to *Om. accipitrinus insolatus* STRUVE, 1976. The genus has an upper Famennian (UD V) range in Iran (FEIST et al. 2003; GHOBADI POUR et al. 2018). In summary, the brachiopod/trilobite records support an uppermost Famennian (UD VI) age for “Strunian” deposits described by TERMIER & TERMIER (1951a) but it cannot be ruled out that some beds are older (UD V). After a revision of sections and sedimentology, a new lithostratigraphic term will be required.

5. The Famennian Oued Aricha Basin

5.1. Overview

The Famennian goniatite shales of the badlands in the upper (southern) reaches of the Oued Aricha (Figs. 23-24) were discovered by TERMIER (1927a, 1927b), who later (TERMIER 1936) figured the locally most common sporadoceratids and a platyclymeniid, which indicated a UD IV (early upper Famennian) age. The later fossil monograph by TERMIER & TERMIER (1950a-d) included many drawings of other taxa and a long faunal list was provided by TERMIER & TERMIER (1951a). TERMIER & TERMIER (1951b, p. 21) compared the pyritic fauna with the Fezzou region of the eastern Anti-Atlas. PETTER (1959) re-illustrated the type-specimen of *Gundolficeras bicaniculatum*, which subsequent loss resulted in a neotype designation (using a Maïder specimen) by BECKER (1995). The records of TERMIER & TERMIER (1950c, 1951a) were re-interpreted based on the subsequent taxonomic advances by BECKER in KAISER et al. (2007). This suggested that most of the fauna comes from the Upper Hembergian (UD IV, *Platyclymenia* Stufe) of German terminology. However, there also a few records that indicated the subordinate presence of Lower Hembergian (UD III, late middle Famennian,

Prolobites Stufe) and lower Dasbergian (UD V, *Clymenia* Stufe) taxa. We sampled in 2012 and 2014 four localities within different parts of the Oued Aricha, here named as Oued Aricha A-C and Oued Aricha Z (Fig. 25). At Oued Aricha Z, we logged a detailed section (Figs. 24, 26-27) and tried, without success, to retrieve conodonts from thin calcareous levels.

The dominating lithologies are alternating grey and reddish, hematite-rich shales with originally pyritic, secondarily goethitic to hematitic mollusk faunas and thin, fine, sometimes calcareous siltstone beds (Fig. 26). Brachiopods, rugose corals, and crinoid stems retained their light-grey calcitic skeletons; only aragonite shells were dissolved and filled with pyrite during diagenesis. In the northern badlands, faunas disappear and siltstones become more abundant. Lithofacies and faunas are unique for all of the Meseta. Comparable and contemporaneous beds occur only in the Maïder Basin of the eastern Anti-Atlas (e.g., BECKER et al. 2018d).



Fig. 23: Southern entry to the badlands of Oued Aricha east of Benahmed (middle/upper Famennian Oued Aricha Formation), with Locality A to the right of the central gully and Locality/Section B on the slope in the background to the right (east). Section Z lies behind the hill in the central background.

FADLI (1994) placed the distinctive Oued Aricha goniatite shales in the lower part of his Chabet-el-Baya Formation, which occurs in the northern Mdakra Massif. However, the differences are too large. The typical Chabet-el-Baya Formation consists of practically unfossiliferous grey shales and siltstones

(Lower Member), followed by an increasing content of quartzites in the Upper Member. Locally there are boulders (olistolites) of older Devonian rocks, as in the Al Brijat Formation of the Oued Cherrat region (e.g., BECKER et al. 2020b) or in the middle part (Biar Setla Member) of the Fouizir Formation of the Khatouat Massif to the east (FADLI 1994). We propose to assign the Oued Aricha shales, which represents a much more distal and hypoxic setting undisturbed by synsedimentary tectonism, to a **new Oued Aricha Formation**. Upwards, it grades, as the Chabet-el-Baya Formation, into the siltstones and greenish shales alternating with thin sandstones of the Mgarto Formation (FADLI 1994), which straddles the Devonian-Carboniferous boundary.

The preliminary faunal list of the Oued Aricha Formation comprises the following ammonoids (*type locality):

Famennian III

Planitornoceras aff. *euryomphalum* (with ventral varices; **B**, **Z**; Figs. 28.5-6)

Sporadoceras *angustisellatum* (poorly preserved; **A**; Figs. 28.7-8).



Fig. 24: Overview of the upper Famennian Section Z at Oued Aricha (for section log see Fig. 26).

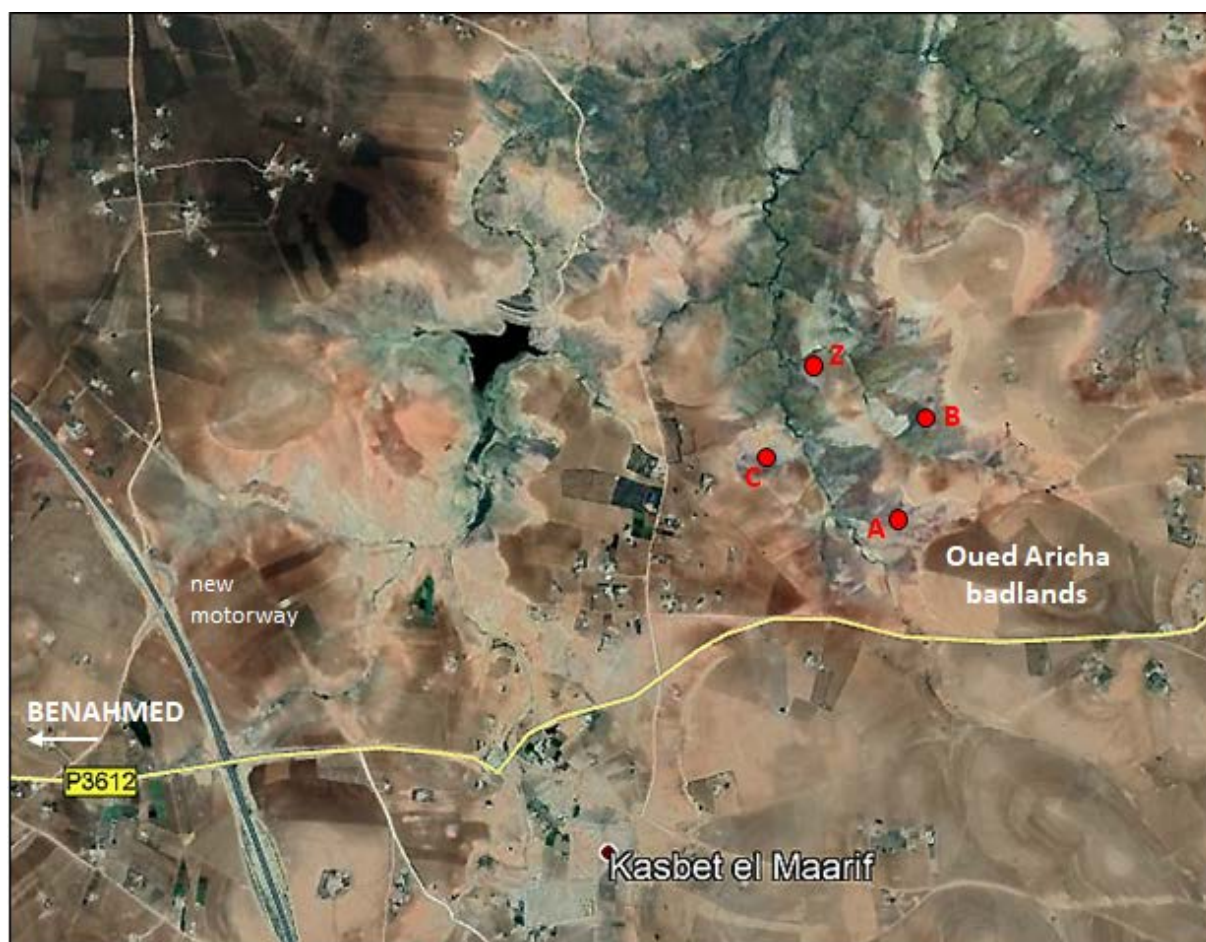


Fig. 25: Position of the Oued Aricha badlands and sampled localities east of Benahmed on a satellite photo of Google Earth.

Enkebergoceras cf. *varicatum* (= *Sp. muensteri* in TERMIER & TERMIER 1951a; rare; **A**; Figs. 28-3-4)

“*Prolobites*” n. sp. aff. *korni* (micromorphic form with prolobitid constrictions and very shallow lobes; very rare; **A**; Figs. 28.1-2)

?*Praeglyphioceras* sp. (= *Sp. biferum* in TERMIER & TERMIER 1950c: small specimen with open umbilicus and *Lagowites*-type secondary E-lobes)

Protactoclymenia implana Group (with ventral varices, single fragment; **B**)

Famennian IV

Gundolficeras bicaniculatum (= *Lobotornoceras Sandbergeri* in TERMIER & TERMIER 1950c, 1951a)

Gundolficeras reisdorfi (rare; **Z**; Figs. 29.11-12)

Pr. (Prionoceras) divisum lamellosum (= *Imitoceras intermedium* in TERMIER & TERMIER 1950c; **A, B, C2, C4, Z**; Figs. 28.3-4)

Pr. (Prionoceras) aff. *divisum* (extremely thick, ww/wh > 2; **Z**)

Pr. (Prionoceras) n. sp. (compressed, with unique shape of A-lobe; **Z**)

Pr. (“Prionoceras”) lentis (thinly discoidal, with trilobate varices, **A, Z**; Figs. 29.1-2)

Pr. (“Prionoceras”) sp. 2 (moderately thick, with only two varices at small size; **Z**)

Pr. (“Prionoceras”) sulcatum Group (thickly discoidal and tegoid; **A**; Figs. 29.5-6)

Pr. (“Prionoceras”) vetum (rare, with quadripartite varices at small size; **A**)

Erfoudites rherisensis (with high whorls, very common, = *Sporadoceras rotundolobatum* in TERMIER & TERMIER 1950c, 1951a; **A, B, C2, Z**; Figs. 29.9-10)

Erfoudites zizensis (with lower whorls, locally rare; **A, Z**)

Sporadoceras muensteri orbiculare (rare, = *Sporadoceras* sp. and possibly *Sp. cf. Unger* in TERMIER & TERMIER 1950c; **A**)

Ungusporadoceras unguiferum (rare, **A, Z**; Figs. 29.7-8)

Protactoclymenia stenomphala (smooth, subinvolute, compressed; = *Cyrtoclymenia angustiseptata* in TERMIER & TERMIER 1950c, 1951a; **A, B, C2, C4, Z**; Figs. 29.17-18)

Protactoclymenia aff. *subcostata* (with umbilical ribs, subevolute, high whorls, see HARTENFELS & BECKER 2016a; **Z**)

Protactoclymenia “crassa” (sensu PETTER 1960, (which is an invalid junior homonym; depressed until middle stages, and with nodose ribbing of early whorls; **A, B**)

Procymaclymenia pudica (with ventral varices; **A**, cf. **C1, Z**; Figs. 30.6-7)

Carinoclymenia beuelensis (very rare; **A**; Figs. 29.15-16)

Platyclymenia (Pl.) levata (ww/wh = 0.76-0.79 around ca. 20 mm dm, partly with weak, undulating ribbing; **A, B**; Figs. 29.13-14)

Platyclymenia (Pl.) annulata richteri (rare; **Z**)

Pl. (Trigonoclymenia) protacta (rare, = *Platyclymenia Barrandei* in TERMIER & TERMIER 1950c, fragments only; **A**)

Protoxyclymenia cf. *dunkeri* (only fragments with oval whorls, moderately evolute, A-lobe subangular; = *Oxyclymenia* in TERMIER & TERMIER 1950c; **A, B, Z**; Figs. 30.1-3)

Protoxyclymenia ?n. sp. (rather evolute, uw/dm > 0.50 at ca. 20 mm dm, compressed fragment with tegoid cross-section, rare; **A, B**; Figs. 30.4-5)

Protoxyclymenia sp. 2 (small, compressed fragment with well-developed E-lobe; **Z**)

Famennian V

?*Gundolficeras* n. sp. (= *Lobotornoceras* sp. in TERMIER & TERMIER 1950c; strongly compressed at small size, with strong ventrolateral furrows, subinvolute, and suboxyconic; if the suture drawing is correct, then the A-lobe is not of *Gundolficeras*-type and this unique specimen could represent a new genus)

Ebbighausenites weyeri (only whorl fragments, = *Discoclymenia cucullata* in TERMIER & TERMIER 1950c, 1951a; **A**; Figs. 30.14-15)

Pr. (Rectimitoceras) jeranense (subglobular; **top B**; Figs. 30.8-9)

Pr. (“Prionoceras”) aff. mrakibense (only 2 varices/whorl until 10 mm dm, **top B**; Figs. 30.10-11)

Erfoudites cf. *ungeri* (fragment with narrow and pointed A₁-lobe; **top B**)

Erfoudites rherisensis (**top B**)

Ungusporadoceras n. sp. (rare, with strongly biconvex varices and low ventral saddle; **top B**)

Sporadoceras muensteri orbiculare (**top B**, Figs. 30.12-13)

?*Nanoclymenia* sp. (evolute fragments with very shallow, simple flank lobe; **top B**)

Protoxyclymenia sp. (fragments, probably cf. *dunkeri*; **top B**)

Protoxyclymenia ?*wendti* (compressed fragment, venter tabulate; **top B**)

Kosmoclymenia sp. (= *Oxyclymenia undulata* in TERMIER & TERMIER 1950c; **B**, **top B**; Figs. 30.20-21)

Kosmoclymenia n. sp. (extremely evolute; **C2**; Fig. 30.22)

Protactoclymenia sp. OA (fragment, whorls smooth and depressed; **top B**, **C2**)

Cymaclymenia striata formosa (strongly compressed at early stages and subevolute, smooth; **top B**, **C2**; Figs. 30.18-19)

Cymaclymenia n. sp. (fragment with rib-like lirae crossing the venter; **top B**; Figs. 30.16-17)

Specimens assigned to "*Platyclymenia* gr. *laevigata*" in TERMIER (1936) and "*Clymenia laevigata*" in TERMIER & TERMIER (1950c) are difficult to interpret; they may belong to *Platyclymenia*. A supposed "*Tornoceras retrorsum* var. *acutum*" figured by TERMIER (1936) is probably a squashed goniatite, not an oxyconic form. The ammonoid taxonomy used here is preliminary. Only studies of ontogenetic morphometry will enable a better comparison with the contemporaneous species of the Anti-Atlas. This is especially relevant for the prionoceratids, sporadoceratids, and protactoclymeniids. Among the first, *Pr.* ("*Prionoceras*") refers to species with subevolute ($uw/dm > 0.30$) early whorls. Species which are not known to have strictly dorsolateral shell constrictions in early to middle stages are assigned to *Pr.* (*Rectimitoceras*) BECKER, 1996.

As an oddity, there is a small, incomplete goniatite with low whorls, strong varices and a suture with v-shaped A_1 -lobe and very incipient A_2 -lobe resembling *Maeneceras subvaricatum nuntio* BECKER, 1993, which is a marker for the base of the middle Famennian

(UD II-G). No other UD II ammonoid has been found and differences to *M. subvaricatum nuntio* are strong enough to suspect that the specimen belongs to a new, younger sporadoceratid (not *Erfoudites*).

Associated Oued Aricha fauna (including literature records):

*Hebukophyllum arichense** (see taxonomic paragraph)

Bactrites cf. *declivis* (slightly oval cross-section, sutures rectiradiate, rare; **A**)

Lobobactrites sp. indet. (rare; **A**)

"*Troedssonoceras* sp."

"*Dawsonoceras annulatum*" (type-species of the genus, wrongly placed by TERMIER & TERMIER 1950c, 1951a in *Neocycloceras*; however, the true *D. annulatum* is an Ordovician to Silurian species; see KRÖGER & ISAKAR 2006; new fragments with reticulate ornament; **Z**)

"*Orthoceras Murchisoni*" (type-species of the Silurian genus *Murchisoniceras* BABIN, 1966, which ranges in the Anti-Atlas into the lower Emsian, e.g., KLUG et al. 2008; a Famennian range is rather unlikely)

"*Orthoceras amaltheum*"

"*Orthoceras* sp. (cf. *captor*)"

Bogoslovskiya sp. (with subcircular cross-section and subventral siphuncle; **A**, **B**, **top B**, **C2**)

brevicone indet. (**C2**)

*Orthonychia heterogena** (platyceratid)

"*Loxonema*" sp.

"*Worthenia*" sp.

Bellerophontid

"*Planitrochus*" sp. (new record, rare; **top B**, **C2**)

Ctenodonta maroccana TERMIER & TERMIER, 1951a nom. nud. (= *Ctenodonta* sp. in TERMIER & TERMIER 1950c; deposition of figured specimen unknown, see COLO & PETITOT 1956, p. 69)

"*Nucula*" *arichensis** (new topotype, holotype deposited under no. ds 601 in the collection of the Service géologique du Maroc, see COLO & PETITOT 1956, p. 39; re-assigned questionably to *Nuculoma (Palaeonucula)* in FRENEIX 1957, p. 32; however, *Palaeonucula*, now a full genus, is based on a Jurassic type-species and not known from the Devonian; **top B**, **Z**)

other nuculid (**top B**)

Guerichia venusta

Loxopteria gibbosa (= *Kochia laevis* in TERMIER & TERMIER 1950c, see NAGEL-MYERS et al. 2009; new specimen; **A**)

Vetupraeca venusta (see revision in NAGEL-MYERS et al. 2008).

?*Hadyrhyncha meridionalis* (= two of the rhynchonellids placed by TERMIER & TERMIER 1950b in *Calvinaria undulata*; see SARTENAER 1998, 2000; excluding the Anti-Atlas type of that species; collection of new material from **A** and **Z**)

*Ambocoelia pentagonalis**

Aulacella sp. (rare; **Z**)

chonetid

crinoid stem pieces

"*Phacops*" *arichensis**

"*Phacops*" *erfoudensis*

All nautiloids require revision; genus and species names of the literature merely can give some orientation concerning superficial morphological similarities. Both phacopids are inadequately known but may belong to the *Ph. granulatus* Group, for which the name *Rabienops* is available. BASSE (2008, p. 179) was misgiven to assume for *Ph. arichensis* possible relationships with *Prokops* and a Lower Devonian age; there are no Lower Devonian outcrops near Oued Aricha.

5.2. Oued Aricha A

Trekking from the road northwards, the first exposed red shales of the Oued Aricha Formation yielded only rare fauna. Exceptional is a large-sized *Gundolficeras reisdorfi*. From there to the northeast, the area around a small, ca. west-east running valley is Locality A. It yielded from the slopes and base a rich loose fauna, marked in the faunal lists by an A.

5.3. Oued Aricha B

Section B ranges from the base of the badlands upwards the eastern slope, which is capped by flat lying Cretaceous strata (Fig. 24). At the base, a grey shale package yielded *Pr. (Prionoceras) divisum lamellosum* and *Erfoudites rherisensis*, indicative of UD IV-A. It is followed by ca. 28 m red shale with poor fauna in the lower part (*Prionoceras* sp. indet.). At the top, *Pr. (Pr.) divisum lamellosum*, *Erf. rherisensis*, and *Protacto. stenomphala* are abundant (UD IV-A fauna).

Laterally, a minor plateau yielded a mixed fauna collected mostly by Lea Amira BECKER. It combines species of UD III B/C (*Planitornoceras* aff. *euryomphalum*), UD IV, and rare *Kosmoclymenia* sp. from the basal UD V. The complete record is indicated in the fossil lists by a B. The local rarity of prionoceratids is remarkable.

A ca. 12 m thick second grey shale interval includes a steep minor gully. Just above, S. EICHHOLT collected a small but important fauna of the lower Dasberg Stufe (UD V-A₁), with *Kosmoclymenia* sp. (Figs. 30.20-21), *Cymaclymenia striata formosa* (Figs. 30.18-19), and *Sp. muensteri orbiculare* (Figs. 30.12-13). The fragmentary kosmoclymeniid may belong to the same early species as the oldest members of the genus from the thick Dasberg Crisis Interval of the Maïder (see BECKER et al. 2018d). In the continuously anoxic shelf basin setting of Oued Aricha, the Dasberg Events (see HARTENFELS & BECKER 2009) left no specific sedimentary signature.



Fig. 26: 1. Beds 4-7 of Oued Aricha Z showing regular bedding of thick, dark-grey to slightly reddish shale and thin siltstone intercalations; 2. Detailed view showing the grading of siltstone layers into thicker, irregular concretions; scale lies on the top of Bed 4b.

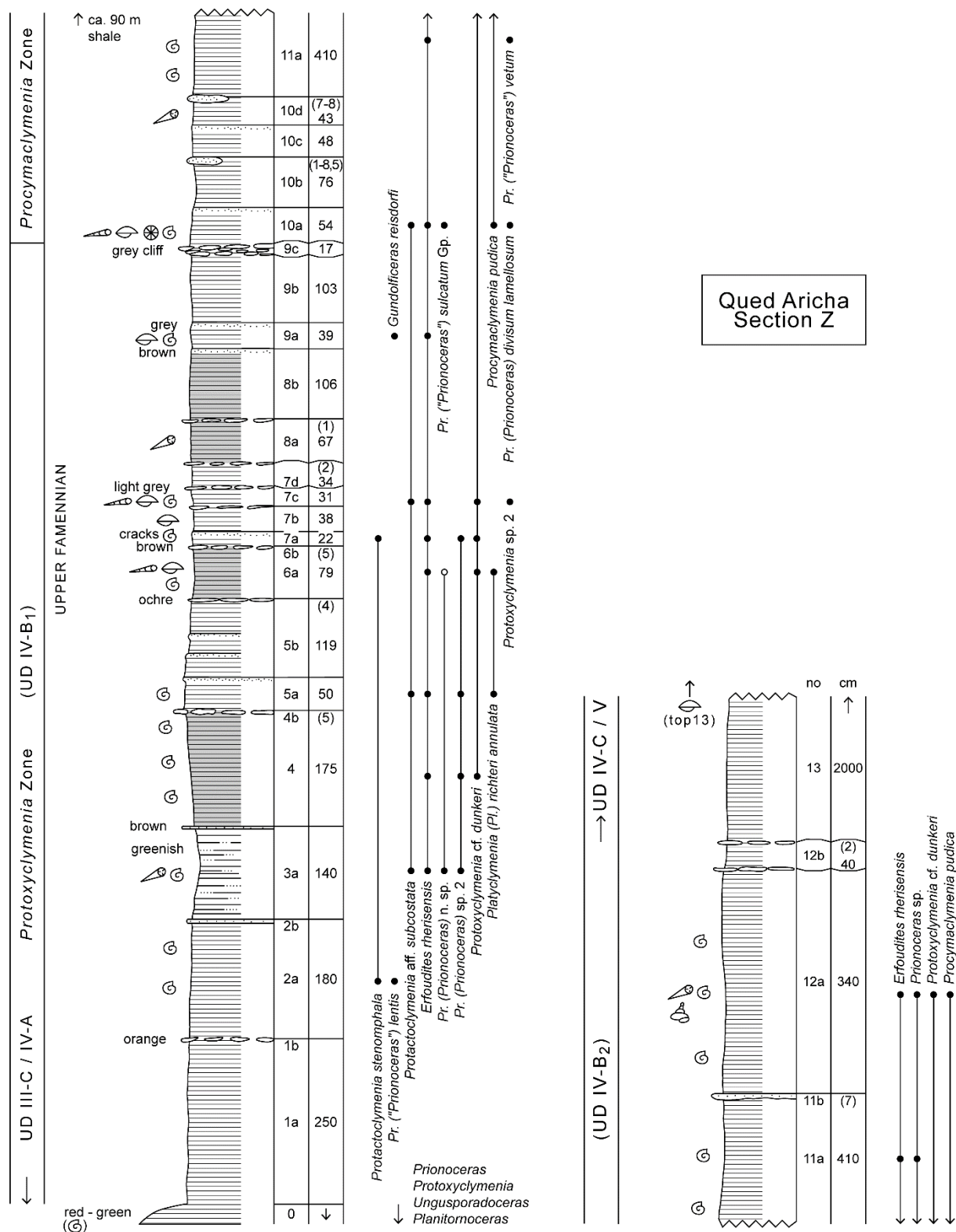


Fig. 27: Lithological log and ammonoid ranges in section Qued Aricha Z.



Fig. 28: Representative ammonoids from the upper middle Famennian (UD III-B/C) of Oued Aricha, loose from Locality A if not stated otherwise; GMM B6C.54.157-160. **1-2.** “*Prolobites*” n. sp. aff. *korni*, lateral and adoral views, with characteristic prolobitid inner flank constriction, x 5; **3-4.** *Enkebergoceras* cf. *varicatum*, lateral and septal views, x 3; **5-6.** *Planitornoceras* aff. *euryomphalum*, lateral and ventral views, tabulate venter with varices, Locality Z, from below measured section, x 4; **7-8.** *Sporadoceras angustisellatum*, lateral and ventral views, poorly preserved but showing the typical sutures with $A_2\text{-lobe} > A_1\text{-lobe}$, x 2.5.

A second faunule from the top of the grey unit included *Pr. (Rectimitoceras) jeranense*, an index species for the Upper Dasberg Event level in the southern Tafilalt (KORN et al. 2014; HARTENFELS & BECKER 2018). Associated is a squashed *Erfoudites* with narrow and v-shaped A_1 -lobe.

The main slope below the Cretaceous comprises an up to 50 m thick upper red shale with fauna collected at 20-22 m (only *Erf. rherisensis*) and 14-16 m below the top. In the latter position, ammonoids were mostly small-sized and fragmentary, but there are taxa not known from other Oued Aricha spots (marked as “top B” in the faunal lists). Especially remarkable is a new species of *Ungusporadoceras*, a genus that was previously only known from UD IV-A of the northern Tafilalt and Maïder (KORN et al. 2015;

HARTENFELS & BECKER 2016a). The presence of *Cymaclymenia* (Figs. 30.16-17) and *Kosmoclymenia* proves a lower Dasbergian (UD V-A₁) age. A prionoceratid is similar to the slightly older Tafilalt *Pr. (“Pr.”) mrakibense* but differs in its lower number of varices. The so far youngest Oued Aricha ammonoid, a second *Pr. (“Pr.”) aff. mrakibense* (Figs. 30.10-11), is from 5-6 m below the top of the upper red shale.

5.4. Oued Aricha Z (Figs. 25-26)

A suitable succession for bed-by-bed measurements and collecting was encountered in more northern parts of the badlands. Unfortunately, only some of the fauna is well-preserved. A thick lower succession of dominantly red, partly yellowish weathering shales (to the right in Fig. 26.1) is poorly

exposed on a hill to the south. A loose sample of S. HARTENFELS yielded a nice *Planitornoceras* aff. *euryomphalum*, the barrel-shaped *Pr. (Pr.)* aff. *divisum*, juvenile *Pr. (Pr.)* *divisum lamellosum*, *Pr. ("Pr.")* *lentis*, *Erf. rherisensis*, a single, incomplete *Ungusporadoceras unguiferum*, fragments of *Protoxy. cf. dunkeri*, rhynchonellids and a minute *Aulacella*. This is a mixture of UD III-C to IV-B₁ species.

Different faunal elements commence in Beds 2a and 3a: *Protacto. stenomphala*, *Protacto.* aff. *subcostata* sensu HARTENFELS & BECKER (2016a), *Pr. (Prionoceras)* n. sp., and *Pr. (Prionoceras)* sp. 2. with only two varices per whorl at small size. The complete ammonoid ranges of Section Z are illustrated in Fig. 27. Shales are dark-grey (especially Beds 6a, 8a, 8b) to greenish-grey (Fig. 26) while the thin siltstones weather orange-brown (Bed 1b), brown (Bed 3b, 4b, 6b, top of 8b), ochre (Bed 5c), or light-grey (top of Bed 7c, top of 9a, 9c, marly Bed 11b). Solitary rugose corals were found in several beds but are rare. The rather irregular, often platy, up to 8 cm thick and unfossiliferous siltstone concretions (Fig. 26.1) are a diagenetic feature.

Since *Protoxyclymenia* is known from below, all beds of Section Z fall in the middle part of UD IV (IV-B). The entry of *Procymaclymenia* in Bed 10a marks the base of UD IV-B₂ (compare HARTENFELS & BECKER 2016a; BECKER et al. 2018a, 2018d) and this zone continues to Bed 12a (Fig. 27). Remarkable is the local rarity of platyclymeniids (only in Beds 5a and 6a), a major difference to the Anti-Atlas, and the differentiated prionoceratid sequence, with only early *Pr. ("Pr.")* *lentis* and rather late and sporadic occurrences of *Pr. (Pr.)* *divisum lamellosum* (Bed 10a) and *Pr. ("Pr.")* *vetum* (Bed 11a).

5.5. Section C

A rather fossiliferous stretch of steeply bedded Oued Aricha Formation was found in the western part of the badlands and named as Locality C. Locally, the shales are partly more

deeply weathered and softer but due to strong fracturing and incrustations, many specimens are not well preserved and distorted. During a brief stay, faunas were collected at four spots (SP1-4). SP1 yielded fragmentary *Procymaclymenia* and *Prionoceras*. It falls in UD IV-B₂ (*Procymaclymenia* Zone). SP2 was richer but not in species; its faunal content is marked in the fossil lists as C2. By far dominant is *Pr. (Pr.)* *divisum lamellosum*, followed in terms of abundance by *Protactoclymenia stenomphala*, as typical for UD IV. Most peculiar is a single, fragmentary *Kosmoclymenia* with a rather advanced suture that is more evolute (uw/dm > 0.60) than any described species (e.g., PRICE 1982; KORN & PRICE 1987; NIKOLAEVA & BOGOSLOVSKIY 2005). It is even more evolute than *K. linearis* (MÜNSTER, 1832), which unjustifiably has been neglected in the recent clymeniid literature. However, to some extent the evolute coiling may have been exaggerated by deformation. A mixture of UD IV/V species in Sample SP2 is further indicated by several *Cyma. striata formosa*.

5.6. Palaeobiogeographic relationships of Oued Aricha ammonoid faunas

TERMIER & TERMIER (1951b) compared the overall similar Oued Aricha and Fezzou region (Maïder Basin, eastern Anti-Atlas) faunas. A large number of the Oued Aricha ammonoids occurs also in the Ibaouane Formation (BECKER et al. 2018d). *Enkebergoceras varicatum*, rare prolobitids, and *Planitornoceras* with ventral varices are typical for the Lahfira Member. However, *Sulcoclymenia*, which is abundant in its upper part, also on the Tafilalt Platform (BECKER et al. 2002; HARTENFELS & BECKER 2016a), is not yet known from the Meseta. The new prolobitid is closest to "*Prol. korni*" DZIK, 2006 from the Holy Cross Mountains of Poland but, based on the suture, there are also relationships with the endemic *Afrolobites mrakibensis* BECKER & BOCKWINKEL in BECKER et al., 2002 from the Maïder.

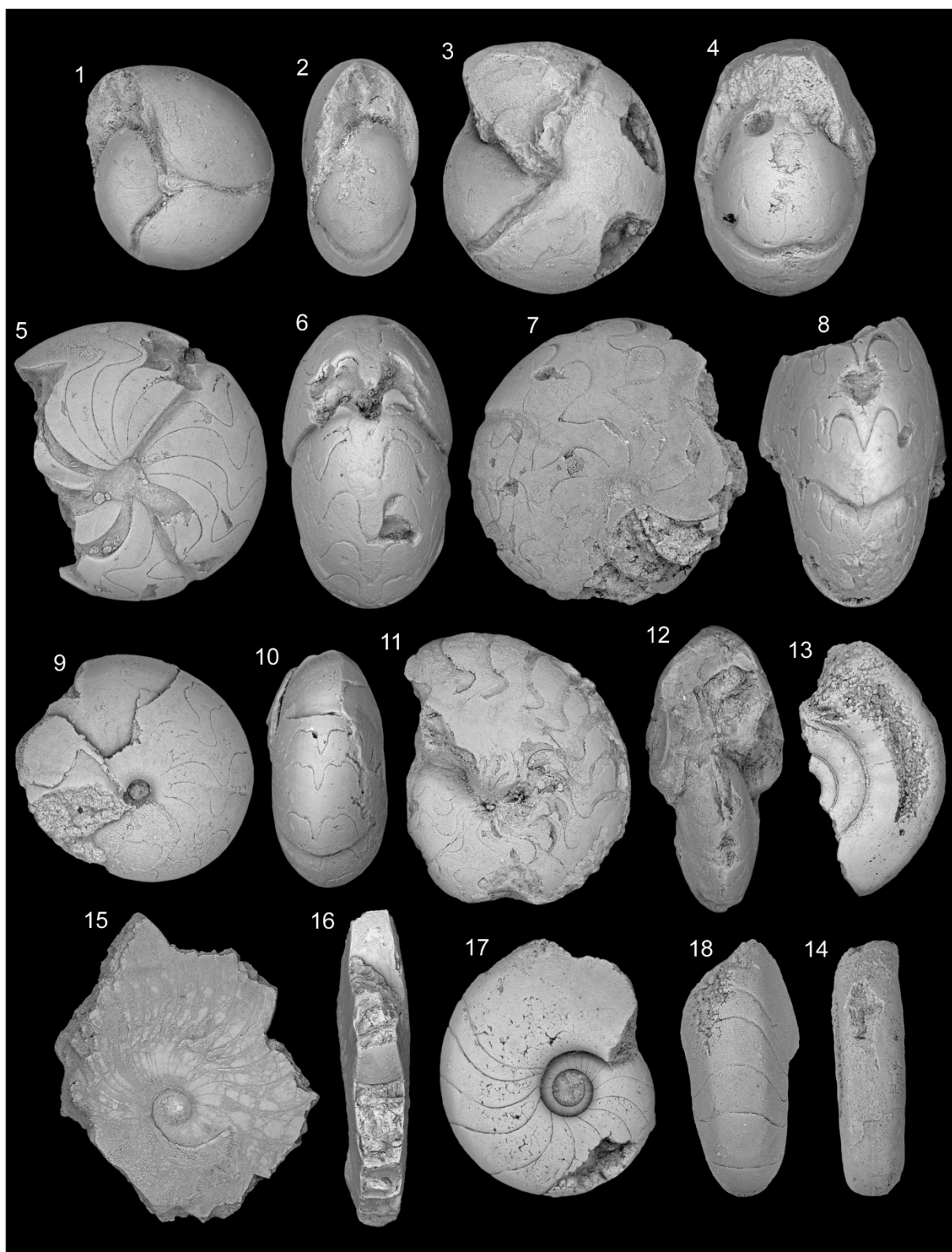


Fig. 29: Representative ammonoids from the lower upper Famennian (UD IV) of Oued Aricha, all loose from Locality A, if not stated otherwise; GMM B6C.54.161-169. **1-2.** *Pr. ("Prionoceras") lentis*, x 4; **3-4.** *Prionoceras (Pr.) divisum lamellosum*, x 4; **5-6.** *Pr. ("Prionoceras") sulcatum* Group, x 3.5; **7-8.** *Ungusporadoceras unguiforme*, Locality Z, Bed 9a, x 3; **9-10.** *Erfoudites rherisensis*, x 4; **11-12.** *Gundolficeras reisdorfi*, x 2.5; **13-14.** *Platyclymenia (Pl.) levata*, x 3; **15-16.** *Carinoclymenia beuelensis*, oxyconic outer flanks broken off, x 2; **17-18.** *Protactoclymenia stenomphala*, x 4.

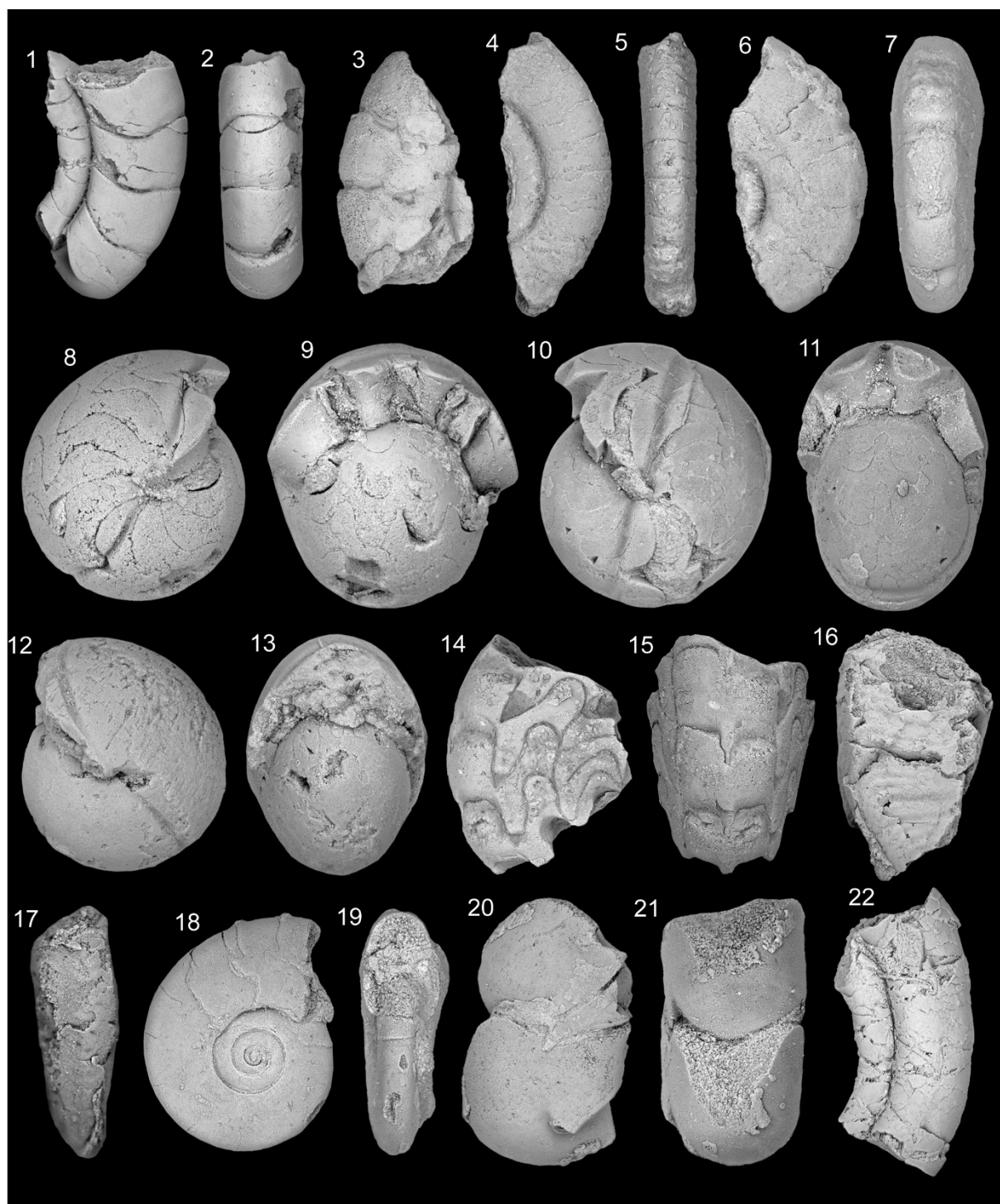


Fig. 30: Representative ammonoids from the upper Famennian (UD IV-B = 1-7 to V-A₁ = 8-22) of Oued Aricha; GMM B6C.54.170-181. **1-3.** *Protoxyclymenia* cf. *dunkeri*, whorl fragments, Locality A, loose, x 3 and x 2.5; **4-5.** *Protoxyclymenia* ?n. sp., widely evolute, Locality A, loose, x 2.5; **6-7.** *Procymaclymenia pudica*, juvenile with ventral varices, Locality Z, Bed 10a; x 5, **8-9.** *Prionoceras* (*Rectimitoceras*) *jeranense*, Locality B, second grey interval, x 5; **10-11.** *Pr.* ("Prionoceras") aff. *mrakibense*, with only two varices per whorl, Locality B, second red interval, 5-6 m below top, x 4; **12-13.** *Sporadoceras muensteri orbiculare*, Locality B, second grey interval, x 4; **14-15.** *Ebbighausenites weyeri*, whorl fragment, Locality A, loose, x 4; **16-17.** *Cymaclymenia* n. sp., fragment with lirate flanks and venter, Locality B, second red interval, 14-16 m below top, x 3.5; **18-19.** *Cymaclymenia striata formosa*, juvenile, Locality B, second grey interval, x 4; **20-21.** *Kosmoclymenia* sp., two septa only, Locality B, second grey interval, x 5; **22.** *Kosmoclymenia* n. sp., widely evolute fragment, Locality C.

Joint species occurrences of Oued Aricha and the Anti-Atlas Mrakib Member (UD IV) are *Pr. (Pr.) divisum lamellosum*, *Pr. ("Pr.") vetum*, *Pr. ("Pr.") lentis*, *Erfoudites rherisensis*, *Erf. zizensis*, *Platyclymenia (Pl.) levata*, *Pl. (Trigonoclymenia) protacta*, *Protoxyclymenia cf. dunkeri*, *Carinoclymenia beuelensis*, *Sporadoceras muensteri orbiculare*, *Ungusporadoceras unguiferum*, and some of the protacto- and protoxyclymeniids. However, it is interesting that *Procymaclymenia* is represented at Oued Aricha not by *Pro. ebbighauseni*, but by *Pro. pudica* with ventral varices, known from Poland (CZARNOCKI 1989) and the Rhenish Massif (BECKER 1992). At the genus-level, similarities with European UD III/IV faunas are not as strong as in the Boudouda Formation (see chapter by SÖTE & BECKER).

For the basal UD V, the new Oued Aricha records of *Ebbighausenites weyeri*, *Prionoceras (Rectimitoceras) jeranense*, abundance of *Erf. rherisensis*, early *Kosmoclymenia*, possible *Nanoclymenia*, and *Cymaclymenia striata formosa* suggest close links with the lower part of the Jebel el Krabis Member of the Maïder (BECKER et al. 2018d). This is supported by joint occurrences of the nuculoid "*Palaeonucula*" *arichensis* (see FRENEIX 1957). However, there are some rare endemic forms at Oued Aricha, such as the new *Ungusporadoceras*, *Cymaclymenia*, and *Kosmoclymenia*, which show that there was no complete faunal continuity. Rather unusual is the lack of *Costaclymenia* at Oued Aricha, which is the zonal index genus of UD V-A₁ and very common in the eastern Anti-Atlas.

6. Palaeogeographic trends and regional comparisons of the Benahmed Devonian

Unlike as in most regions of the Moroccan Meseta, there is no evidence for hypoxic, dark, organic-rich graptolite, "orthoceratid",

or scyphocrinitid facies around the Silurian/Devonian boundary in the Benahmed region. Supposed Lochkovian shales and limestones may correspond to poorly studied, similar strata of the northern Oued Cherrat Zone (ZAHRAOUI 1991, 1994). In the northern (HOLLARD et al. 1982) and northeastern Rehamna (EL KAMEL et al. 1992), there is also mixed shale, siltstone and limestone facies in the Lochkovian (Fig. 31). This suggests a general pattern, a shallow basal Devonian shelf occupying all of the western part of the Central Meseta.

The Pragian and lower Emsian thick limestones of the Benahmed region represent a southern continuation of the non-reefal Al Attamna carbonate platform (Sidi Ahmed Lemdoun Formation, Units A/B; BULTYNCK & BENFRIKA 2003). Future work has to clarify whether the Al Attamna formation name can be simply extended to the Benahmed "Emsian Limestone". Macrofaunas and microfacies of the Sidi Ahmed Lemdoun Formation are also largely unstudied. The neritic platform extended further to the Rehamna, from Mechra Ben Abbou to Foug el Mejez (e.g., HOLLARD et al. 1982; EL KAMEL 2004).

The currently poor data for the Benahmed upper Emsian and Eifelian indicate a deepening, perhaps as a consequence of the global Daleje Transgression. The same trend is recognizable at the base of Unit C of the Sidi Ahmed Lemdoun Formation in Al Attamna (BENFRIKA & BULTYNCK 2003). Further northwards, in the Oued Cherrat Zone, it introduced the lateral shaly Mohammed-Ben Brahim (Lower Member) and shaly-turbiditic Ain-Kheneg-en-Nmer formations (EICHHOLT & BECKER 2016; BECKER et al. 2020b). By contrast, the Eifelian of the Rehamna represents a deep neritic platform setting with biogenic chert content (e.g., BEN BOUZIANE 1995; EL KAMEL 2004; lower member of Mechra Ben Abbou Formation).

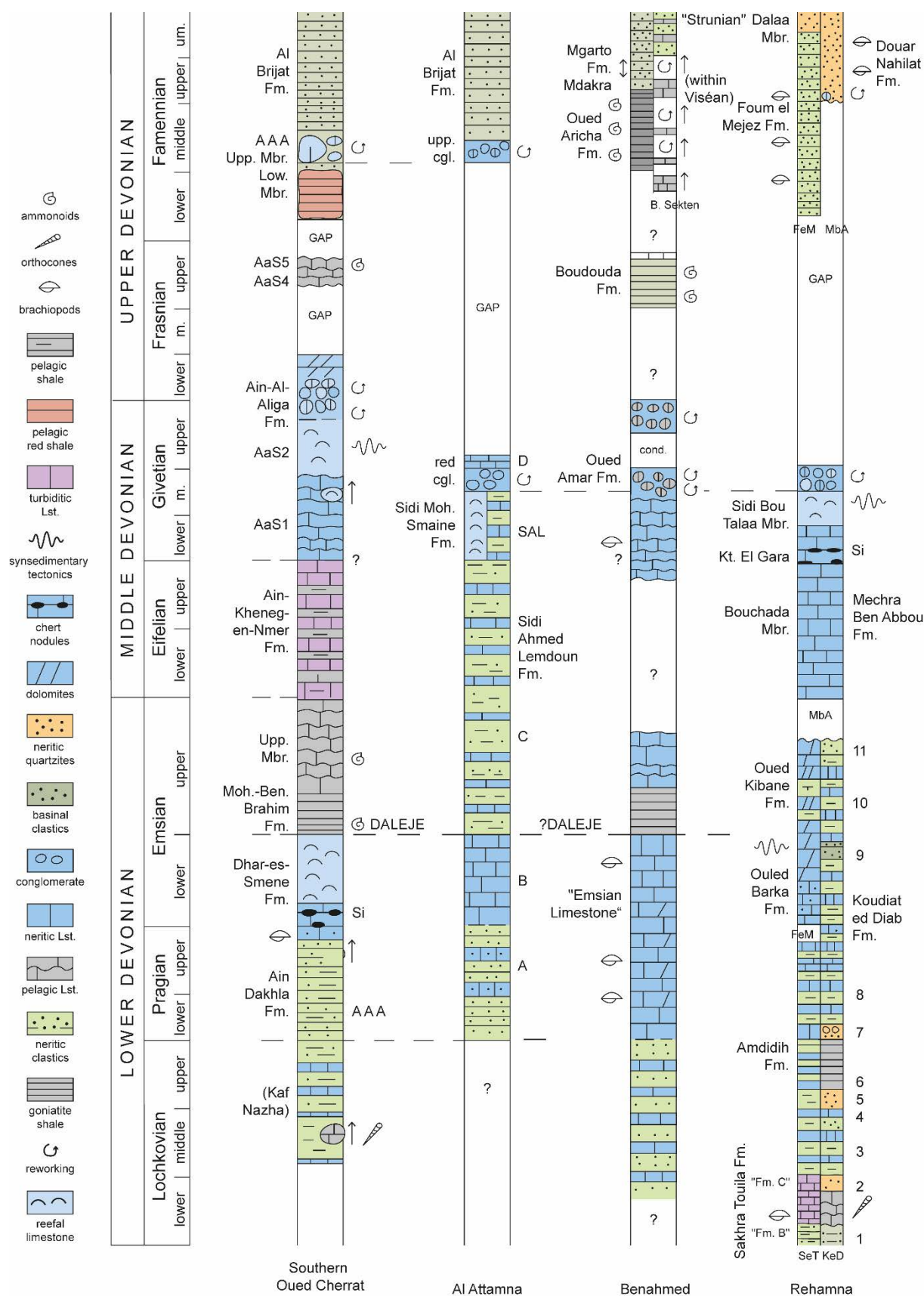


Fig. 31: Correlation of Devonian successions of the Oued Cherrat (BECKER et al. 2020a; AaS1-5 = members of Aïn-as-Seffah Formation), Al Attamna (EICHHOLT & BECKER 2016, SAL = Sidi Ahmed Lemdoun succession), Benahmed, and northern Rehamna (see Rehamna chapter) regions.

The Givetian of the Benahmed region differs from the partly thick reefs of the Oued Cherrat Zone and El Attamna (EICHHOLT & BECKER 2016). The environment was a deep neritic carbonate platform or ramp receiving distal, fine carbonate and clastic detritus of a shallower platform, perhaps from the north. The two Givetian episodes of synsedimentary faulting, reworking and re-deposition recognized at Zwayir and Dar Cheik el Mfaddel underline that this first major interval of Eovariscan block movements (BECKER et al. 2015) shook the whole belt from the Oued Cherrat (BECKER et al. 2020b) to the Rehamna (see EL HASSANI & EL KAMEL 2000; Rehamna chapter), and beyond (see Jebel Ardouz and Skoura chapters). In the Al Attamna, only the “red conglomerate” is an equivalent, which terminated the Givetian reef growth (EICHHOLT & BECKER 2016).

Facies similarities and palaeogeographic relationships ended after the top-Givetian tectonism. The hypoxic, pelagic goniatite shales of Boudouda may have formed on the subsiding side of a tilted block in combination with the overall trend of Frasnian eustatic rise, and specifically with the *semichatovae* Transgression. Frasnian strata are unknown from the uplifted blocks of the Al Attamna and northern Rehamna. This facies difference increased further in the Famennian: the thick basinal siliciclastics with conglomerates, breccias and olistolites of the Al Brijat (Oued Cherrat, Al Attamna) and Chabet el Baya formations (northern Mdakra) contrast with the calm, hypoxic goniatite shales of Oued Aricha. In the Beni Sekten area, there was a subsequently eroded, small deep-water carbonate platform, which is only known by reworked pelagic conodonts (see Carboniferous Boudouda chapter). The topmost Devonian is represented by the mixed sand-limestone “Strunian” facies of the Beni Sekten region.

None of these facies extend to the Rehamna, where upper Famennian quartzites with brachiopods transgressed the Givetian reef platform (Mechra Ben Abbou region: Douar Nahilar Formation, HOLLARD et al. 1982; BEN BOUZIANE 1995), grading into first prodeltaic brachiopod-rich siltstones and then quartzites of the thicker Fom el Mejez Formation (HOLLARD et al. 1982; EL KAMEL 2004; see Rehamna chapter).

7. Taxonomic notes

7.1. Conodonts

Schmidtognathus aff. *hermanni* ZIEGLER, 1965

Fig. 15.7

Description: A single specimen (GMM B7A.12.50) from Bed 12b of Dar Sheikh el Mfaddel (upper Givetian) is characterized by a slightly asymmetric platform with an almost straight free blade and a carina that does not reach the posterior end. The moderately wide and flat platforms bear fine ribs and nodes restricted to the margin, turning on the outer anterior side into a series of more pronounced margin denticles. The anterior platform ends abruptly on both sides, with the last nodes forming a narrow, sharply defined shoulder.

Discussion: A similar form with wider platforms and almost straight anterior platform shoulders has been described by ABOUSSALAM (2003) from the *hermanni* Zone (basal upper Givetian) of the Tafilalt as *Schm.* aff. *hermanni*. *Schmidtognathus hermanni* is a rather variable species but irregular platform shapes and ornamentation are typical (e.g., ZIEGLER 1965; ABOUSSALAM 2003; ABOUSSALAM & BECKER 2007). We are confident that the two Moroccan specimens fall outside the variability spectrum of *Schm. hermanni*, especially with respect to the anterior platform end and regular, fine ribbing. It is

not yet clear whether both specimens represent the same new species. Therefore, we apply open nomenclature until more material becomes available.

Schmidtognathus n. sp. A of MAWSON & TALENT (1989) differs in asymmetrically leaf-shaped platforms with rounded anterior margins and regular, fine transverse ribs that almost reach the carina.

***Schmidtognathus* aff. *latifossatus* WITTEKINDT, 1965**

Fig. 15.9

Discussion: Within the genus *Schmidtognathus*, there are currently two distinctive species groups, which may be separated in future taxonomically. In the *Schm. latifossatus* Group, platforms are small and narrow and the basal pit is wide and extends posteriorly almost to the end. This is true for a specimen from Dar Cheik el Mfaddel, Bed 12b (GMM B7A.12.51), identified as *Schm. aff. latifossatus*. It differs from typical representatives of the species, including local aberrant forms (Fig. 15.8), by its small, asymmetric, triangular platform that is smooth apart from minor marginal folds and nodes. Both the blade and carina are very gently bent (convex), with low and small denticles of the free blade that is much shorter than the platform. Since we have so far only one specimen, we apply open nomenclature.

***Schmidtognathus* n. sp. DCM**

Figs. 15.10

Description: Blade and carina slightly sinuous, with a cockscomb-type, very high free blade (defined by platform end on the left side) consisting of five merged denticles, and a few isolated denticles near the posterior end of the carina. The platform is convexly bent but in general flat, asymmetric, slightly wider on one side, smooth, with chagrin surface, and reaches on the right side almost the anterior end. The basal cavity is median-

sized, in a central position, as in the typical *Schm. hermanni* Group.

Discussion: None of the named *Schmidtognathus* species shows a similar platform shape and smooth ornament. The specimen (GMM B7A.12.12.52) lies clearly outside the well-established variability of common species, such as *Schm. hermanni*, *Schm. peracutus*, *Schm. wittekindti*, and *Schm. pietzneri*. However, since we have so far only one specimen, open nomenclature is currently applied.

The only known similar form was described by TIAN (in HOU 1988) as *Schmidtognathus* n. sp. A from the Longmenshan section of Sichuan, South China. It differs in narrower platforms and a more elongated basal pit and may not be conspecific.

***“Ozarkodina”* aff. *adventa* POLLOCK, 1968**

Fig. 16.23

Discussion: A single ozarkodinid from Bed 12b of Dar Cheik el Mfaddel (upper Givetian; GMM B7A.12.79) differs from other upper Givetian forms by its small, asymmetric basal cavity platform, which lies ca. one third from the posterior end of the almost straight blade, below teeth no. 8-12 (counting from the anterior end). There is a strong, irregular alternation of long and minor teeth. At the anterior margin, there is a very small first tooth, followed by three larger ones that are inclined backwards and higher than all the posterior teeth.

In the slightly older *“Oz.” maroccanica* ABOUSSALAM & BECKER, 2007, the blade is curved and the cavity platform smaller, without an asymmetric extension. In *“Oz.” adventa*, which also has some larger anterior teeth, the smooth incipient platforms are even larger. In the much older (upper Eifelian) *“Oz.” bidentata* BISCHOFF & ZIEGLER, 1957, the somewhat larger cavity platforms sit in a more anterior position and the blade

denticulation is denser. Until more specimens become available, we apply open nomenclature.

The Middle Devonian ozarkodinids are not related to the type *Ozarkodina* from around the Silurian/Devonian boundary. While the *Oz. brevis* Group now falls in *Nicollidina* DZIK, 2002, all other species (e.g., *maroccanica*, *plana*, *semialternans*, *sannemanni*, *proxima*) are currently not assigned to a valid genus. Until the required revision has proceeded, they are placed in “*Ozarkodina*”.

***Polygnathus* aff. *reitlingerae* OVNATANOVA & KONONOVA, 2008**

Fig. 20.6

Description: A single polygnathid (GMM B7A.12.88) from Bed 6b at Boudouda is characterized by a wide, flat lappet-like platform with delicate ornament consisting of fine ridges and nodes and a marked anterior rostrum, which steep sides are slightly higher on the right side. The free blade is short and consist of equally high, merged teeth. The carina is fine, not bordered by marked adcarinal groves after the rostrum, and does not reach the rounded posterior platform end.

Discussion: A somewhat similar species is *Po. reitlingerae* described from the top middle and early upper Frasnian of the southern Timan. Previously, it has not been recorded from outside of Russia. Most characteristic is its class 3b asymmetry of platform shape with weakly developed anterior rostra, and with a higher right platform margin. Only right-curved specimens (as ours) may have wide platforms (see OVNATANOVA & KONONOVA 2008: pl. 24, fig. 5). Apart from the weaker rostrum, further differences to our specimen are a different denticulation of the free blade and a fine, curved carina that reaches the posterior end of the platform. Therefore, we assign the Benahmed specimen, which has the

same age as the Russian types, preliminarily with an aff. to *Po. reitlingerae*.

The only other similar Frasnian polygnathid is *Po. frons* HUDDLE, 1981, which has been ignored by later authors. It occurs in older strata (upper Givetian Leicester Pyrite to lower Frasnian Genundewa Limestone) of New York State. In comparison to our specimen, the species is characterized by a somewhat longer anterior rostrum and a wider outer than inner platform with rather dense and somewhat coarser nodes.

7.2. Ammonoids

***Gundolficeras bicaniculatum* (PETTER, 1959)**

Discussion: We found two new *Gundolficeras* specimens in the UD IV of Oued Aricha but both are much larger and more compressed than known *G. bicaniculatum* and lack ventrolateral furrows. The cross-section is tegoid, the umbilicus is narrow, with very steep walls. The preservation is not suitable to produce a cross-section in order to observe the shell ontogeny.

After the juvenile Oued Aricha type specimen of *G. bicaniculatum* could not be traced in the Paris collection, BECKER (1995) selected a neotype from the Fezzou region of the Anti-Atlas, which became the new type region. The two new specimens agree largely with the slightly younger (UD V-A₁) *Gund. reisdorfi* KORN, BOCKWINKEL & EBBIGHAUSEN, 2016a from the southern Tafilalt. In the absence of specimens of intermediate size, it is difficult to judge whether the thick-whorled juvenile *G. bicaniculatum* changes perhaps during ontogeny into *reisdorfi*-type adults. Juvenile *G. reisdorfi* from the Anti-Atlas are clearly more compressed than the *bicaniculatum* original of TERMIER & TERMIER (1950c) and PETTER (1959), or the neotype of Becker (1995).

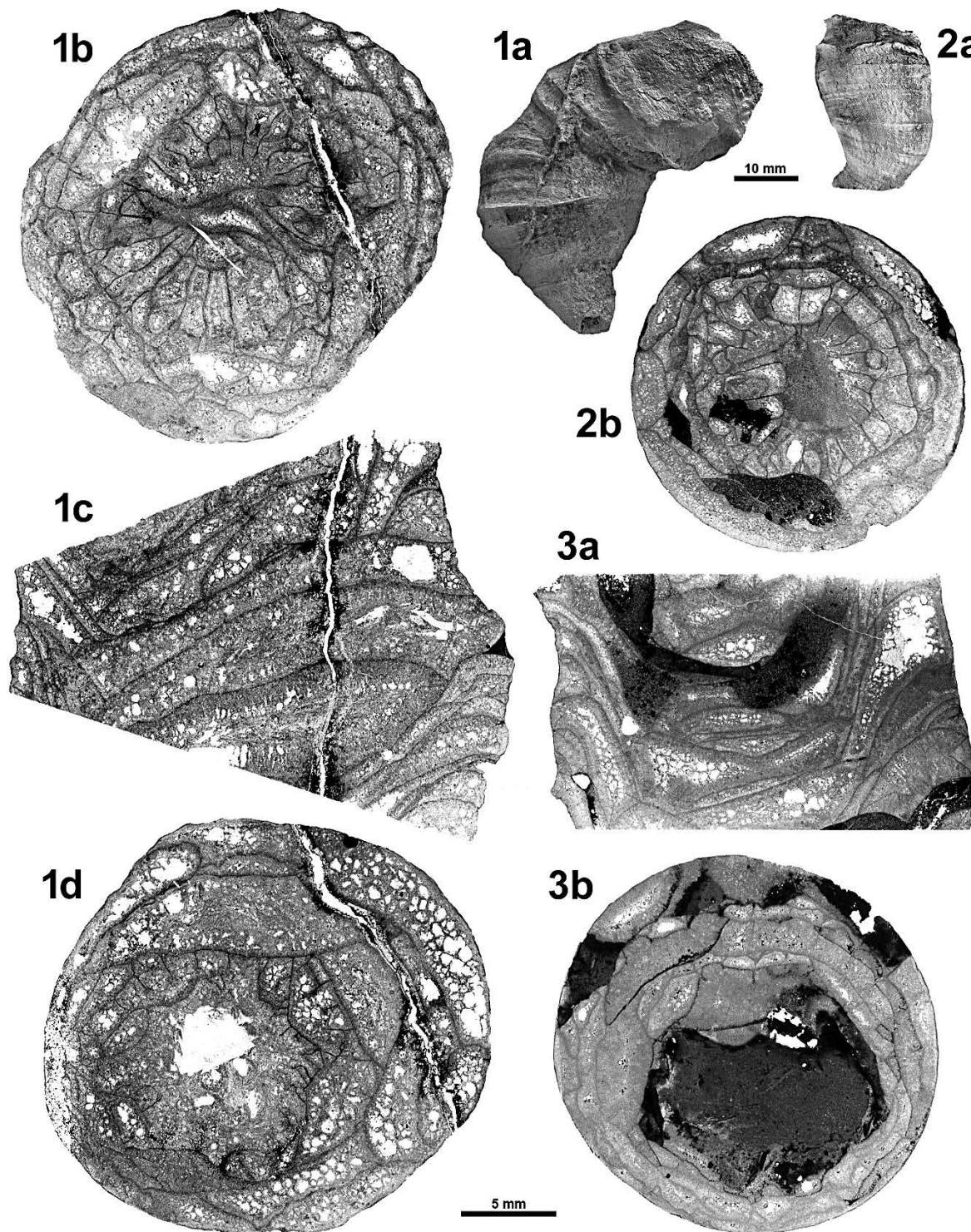


Fig. 32: *Hebukophyllum arichense* (TERMIER & TERMIER, 1950a), new topotypes from Oued Aricha, Section Z, upper Famennian. **1.** MB.K.8071a., Bed 12a, a. Side view of coral, x 1, b, d. Late subtabular transverse sections, x 3, c. Median longitudinal section, x 3; **2.** MB.K.8071c., Bed 8a, a. Side view of coral, x 1, b. Subtabular transverse section, x 3; **3.** MB.K.8071b., Bed 8a, a. Median longitudinal section, x 3, b. Adult transverse section, x 3 [6 protosepta not identifiable; perhaps? correct orientation, with cardinal septum above, only in Fig. 2b, according to possible cardinal fossula indicated by tabulae].

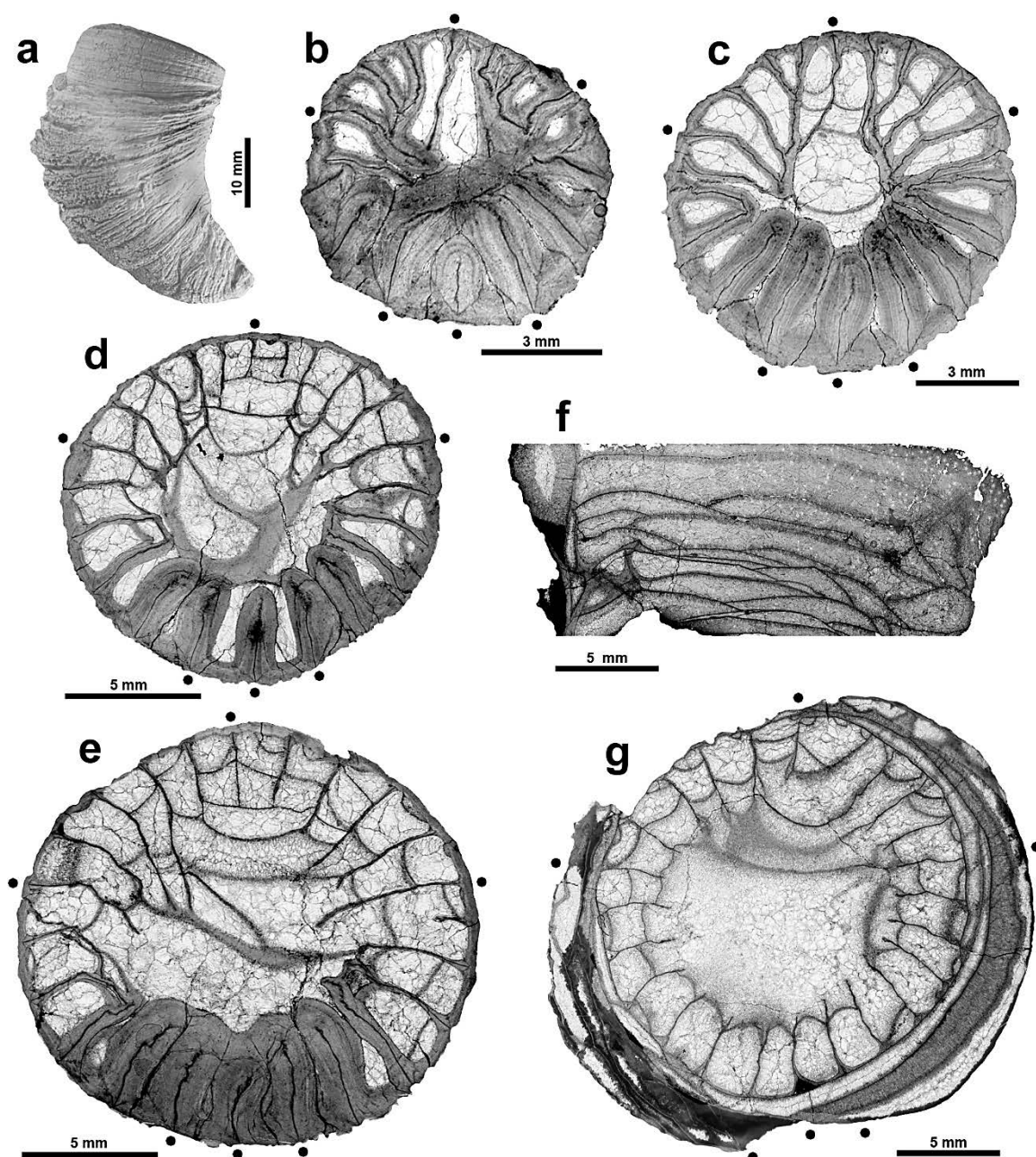


Fig. 33: *Hebukophyllum* sp. M, upper Famennian (upper *Platyclymenia* “Stage”), *orbiculare* Bed (Bed R1b, see KORN et al. 2014: fig. 3, BECKER et al. 2018d), *Sporadoceras muensteri orbiculare* Zone (UD IV-C, BECKER et al. 2002) or *Prionoceras subtum*-Zone sensu KORN et al. (2014), Madène el Mrakib 27 km SE Fezzou, Maïder Basin, eastern Anti-Atlas. Specimen MB.K.8072. (collection R. T. BECKER 1996) = 8cs, 1ls, 2R. **a.** Coral in side view, x 1; **b-e.** Series of transverse sections (early and middle growth stages), x 6 (b), x 5 (c), and x 4 (d, e); **f.** Median longitudinal section, x 3; **g.** Adult transverse section, x 3.

septal formulae:	<u>3 3</u>	<u>4 4</u>	<u>4 4</u>	<u>5 5</u>	<u>5 5</u>	<u>5 5</u>
	5 5	5 5	6 6	6 6	6 7	7 7
n	20	22	24	26	27	28
N	32	36	40	44	46	48
D mm	7,7	10,5	12	14	17	24
Figs.	b	c	—	d	e	g

(abbreviations: n = number of protosepta + metasepta, N = number of all septa, D = diameter)

The latter was re-illustrated by KORN et al. (2016b) but their supposed adult *bicaniculatum* specimen (MB.C.27032) is a “G”. *fezzouense* (BECKER, 1995), which is characterized by an additional L-lobe right at the umbilical seam.

KORN et al. (2016b) correctly noted that there is a small difference of whorl form between the Oued Aricha original and neotype of *G. bicaniculatum*. Both may represent closely related but different species. Since we did not retrieve a potential Oued Aricha *bicaniculatum* neotype, the matter cannot be resolved at present. However, the Oued Aricha badlands have not been fully exploited by us, leaving options for future collecting.

7.3. Rugose corals (by DW)

Suborder Cyathaxoniina SPASSKIY, 1977

Family Petraiidae DE KONINCK, 1872

Subfamily Guerichiphyllinae RÓŻKOWSKA, 1969

Genus *Hebukophyllum* LIAO & CAI, 1987

*1987 *Hebukophyllum* gen. nov. - LIAO & CAI: 698, 704

1988 *Hebukephyllum* CAI: 45 [nomen vanum]

Type species: *Hebukophyllum xinjiangense* LIAO & CAI, 1987.

Further species:

Cyathophyllum priscum MÜNSTER, 1840

Loepophyllum arichense TERMIER & TERMIER, 1950a (Fig. 32)

Siphonophyllia cf. *caninoides* (SIBLY, 1906) in WU (1964: p. 66), see YU (1988: p. 189)

Guerichiphyllum parvum RÓŻKOWSKA, 1969

Guerichiphyllum concavum RÓŻKOWSKA, 1969

Siphonophyllia minor ZUO in JIA et al. 1977 (according to YU 1988: p. 189)

Guerichiphyllum sp. in SANDO & BAMBER (1985: p. 22, pl. 2, figs. 6-7)

Circellia guangxiensis YU, 1988

Guerichiphyllum sp. in SEMENOFF-TIAN-CHANSKY (1988: p. 130, fig. 12)

Guerichiphyllum hebukeense SOTO & LIAO, 2002

Guerichiphyllum mirabile WEYER, 2002

Hebukophyllum sp. M (Fig. 33)

Problematical Famennian-Tournaisian species:

Caninia rudis HILL, 1954 (assigned to *Guerichiphyllum* by WEYER 1978: p. 495, and by SORAUF & PEDDER 1986: p. 1284; including HILL & JELL 1971: pl. 2, fig. 18)

Catactotoechus sp. aff. *irregularis* HILL, 1954 (sensu HILL & JELL 1971; assigned to *Guerichiphyllum* by WEYER 1978: p. 495, and by SORAUF & PEDDER 1986: p. 1284)

Guerichiphyllum kazakhstanicum ULITINA, 1975

Caninia tregaensis POTY, 1982

Tabulophyllum normale platetabulatum CAI in ZENG & CAI, 1983

Guerichiphyllum sinense LIAO & CAI, 1987 (see SOTO & LIN 2000 and SOTO & LIAO 2002)

Tabulophyllum postnormale LIAO & CAI, 1987

Siphonophyllia hobokensis WANG & ZHAO, 1987

Siphonophyllia karamayensis WANG & ZHAO, 1987

Circellia xinjiangensis WANG & ZHAO, 1987

Circellia minor WANG & ZHAO, 1987

Guerichiphyllum gansuense CAO in CAO & OUYANG, 1987

Guerichiphyllum crassiseptatum CAO in CAO & OUYANG, 1987

Guerichiphyllum minor CAO in CAO & OUYANG, 1987

Guerichiphyllum angustivesiculosum CAO in CAO & OUYANG, 1987

Hebukephyllum equitabulatum CAI, 1988

Hebukephyllum curvuse CAI, 1988

Hebukephyllum elegantum CAI, 1988

Kielcephyllum guangxiense WU & LIAO, 1988

Guerichiphyllum elegantum FAN in HE & FAN, 1988

Guerichiphyllum jirongi FAN in HE & FAN, 1988

Guerichiphyllum convexitabulatum SOTO & LIN, 2000

Guerichiphyllum sp. A, SOTO & LIN, 2000

Discussion: TERMIER & TERMIER (1950) described an upper Famennian solitary rugose coral from Oued Aricha as *Loepophyllum arichense* nov. sp. (Rugosa). This taxon was never revised on the base of additionally collected specimens, which are now available.

Loipophyllum is a nomen vanum introduced by LANG, SMITH & THOMAS (1940: p. 79) for *Loipophyllum* WEDEKIND, 1925. Type species is *Loipophyllum kerpense* WEDEKIND, 1925 from the upper Eifelian, originally introduced as a subgenus of *Neospongophyllum* WEDEKIND, 1922. BIRENHEIDE (1962b: pp. 119-120) revised *Loipophyllum kerpense* as identical with *Neospongophyllum rotundum* WEDEKIND, 1925, and as a junior synonym of the Givetian *Stringophyllum* (*Neospongophyllum*) *primordiale* WEDEKIND, 1922. *Neospongophyllum* is classified either as a separate genus (ENGEL & SCHOUPE 1958: pp. 88, 93, LIN et al. 1995: p. 291) or as a subgenus of *Stringophyllum* WEDEKIND, 1922 (BIRENHEIDE 1962a: p. 52, 1962b: p. 118; HILL 1981: p. F248). These corals are taxa of the Ptenophyllina WEDEKIND, 1927 (family Stringophyllidae WEDEKIND, 1922), a suborder, which had disappeared before the end-Frasnian Kellwasser Event. There are no relationships with the Oued Aricha species.

In the times around 1950, the Rugosa of the Famennian Stage were extremely poorly known globally. This changed with the outstanding monograph of RÓŹKOWSKA (1969), who described corals from the lower and upper Famennian of the Holy Cross Mountains (Poland) as the new genus *Guerichiphyllum*. Hereafter, further Famennian species of that genus were described (mainly from China): *Guerichiphyllum kazakhstanicum* ULITINA, 1975, *Guerichiphyllum sinense* LIAO & CAI, 1987, *Guerichiphyllum jirongi* FAN in HE & FAN, 1988, *Guerichiphyllum elegantum* FAN in HE & FAN, 1988, *Guerichiphyllum convexitabulatum* SOTO & LIN, 2000, and *Guerichiphyllum hebukeense* SOTO & LIAO, 2002. The Moroccan *Loipophyllum arichense* was now included into *Guerichiphyllum*: WEYER (1978: p. 495), SORAUF & PEDDER (1986: p. 1284). In addition, also a lower Tournaisian species, *Cyathophyllum priscum* MÜNSTER, 1840, was transferred to *Guerichiphyllum*: WEYER (1979: p. 100, pl. 5,

fig. 8), BARTZSCH & WEYER (1982: p. 31, pl. 7/1-3, pl. 10, figs. 1-4). This taxon is now an excellent index fossil of the lower Hastarian (lower Tournaisian) *Gattendorfia* "Stage" (in cephalopod facies), recorded mainly from Germany and sporadically from Poland, France, and southern Morocco.

Then it became more and more evident that the widely defined genus *Guerichiphyllum* RÓŹKOWSKA, 1969 represents a polyphyletic classification of homoeomorphic taxa. LIAO & CAI (1987) separated in a first step their new genus *Hebukophyllum*, characterized by developing only lonsdaleioid dissepiments. This was accepted in WEYER (1994: p. 186). *Circellia* YE & WANG, 1983 (also used by WANG & ZHAO 1987: p. 480, and BERKOWSKI 2002: p. 22) was preferred by YU (1988: p. 188) as senior synonym of *Hebukophyllum* LIAO & CAI, 1987. This was refused by LIAO & SOTO (2001), after the restudy of the *Circellia* type collections, which came from upper (not lower) Tournaisian beds. The longitudinal sections of *Circellia irregularis* YE & WANG, 1983 (with a concave tabularium: their pl. 9, figs. 1c, 2b, 3b, refigured in LIAO & SOTO 2001: pl. 2, figs. 4c, 5e, 6b) even suggest relationships to the Uraliniidae DOBROLYUBOVA, 1962, which are typical at this younger stratigraphical level. WEYER (2002: p. 17) also doubted the generic identity of several Famennian "*Guerichiphyllum*" with the basal Givetian type species, *Guerichiphyllum skalense* (GÜRICH, 1896), as restudied by FEDOROWSKI (1965).

Currently, *Hebukophyllum* LIAO & CAI, 1987 seems to be the best choice among available genus names for the group of Famennian – lower Tournaisian so-called *Guerichiphyllum* species that bear only lonsdaleioid dissepiments. In Europe, these are mainly *Hebukophyllum parvum* (RÓŹKOWSKA, 1969), *Hebukophyllum concavum* (RÓŹKOWSKA, 1969),

Hebukophyllum priscum (MÜNSTER, 1840), and *Hebukophyllum mirabile* (WEYER, 2002). In Morocco, there are *Hebukophyllum arichense* (TERMIER & TERMIER, 1950a) in the upper Famennian, and *Hebukophyllum priscum* (MÜNSTER, 1840) in the basal Tournaisian (Tafilalt, Ouidane Chebbi region, locality Mkarig, see KAISER et al. 2011, figs. 2, 6, Beds 37-38a = level with *Acutimitoceras* (*Stockumites*) *intermedium* sensu BECKER et al. 2002: p. 173, collections of R. T. BECKER 2001, 2003: six specimens in hematite preservation). Other so-called *Guerichiphyllum*-like Rugosa with regular dissepiments between major septa are also found in the upper Famennian of Morocco (Fig. 34); this new species, preliminarily named as *Guerichiphyllum?* sp. EA, resembles *Guerichiphyllum?* *kowalense* RÓŻKOWSKA, 1969.

Caninia tregaensis POTY, 1982 (lower Tournaisian, lower and basal upper Hastarian, Belgium) was transferred into their new genus *Hebukophyllum* by LIAO & CAI (1987). This was not accepted by POTY & BOLAND (1996: pp. 203, 205), when they proposed a new genus *Conilophyllum* (type species *Conilophyllum streeli* POTY & BOLAND, 1996, lower Tournaisian), with a second species, *Conilophyllum priscum* (MÜNSTER, 1840), which included *Caninia tregaensis* as junior synonym (see also BOLAND 1997: p. 78, and DENAYER et al. 2011: p. 159). Any synonymy between the warm and shallow water (photoc zone) coral *Conilophyllum tregaense* (POTY, 1982) and the cold/deep water (dysphotoc/aphotoc zone, cephalopod facies) coral *Hebukophyllum priscum* (MÜNSTER, 1840) was refused by KORN & WEYER (2001: p. 111) This is based on unpublished studies of rich *tregaensis* collections from the northern margin of the Eastern Rhenish Mountains (debris of former HEINRICH mine, near Lintorf N of Ratingen) and from boreholes on the Baltic Sea island of Rügen. These well-preserved materials allowed intensive early ontogenetic studies, necessary to verify phylogenetic relationships. Also, LIAO & SOTO (2001: p. 47)

argued for a classification of *Hebukophyllum* and *Conilophyllum* in different families.

Distribution in time and space: The genus *Hebukophyllum* had a cosmopolitic geographic distribution. There are records from middle Famennian to lower Tournaisian strata (dysphotoc-aphotoc *Cyathaxonia* facies sensu HILL 1938) on five continents, mainly Europe, Asia, and North Africa. Also, the Famennian of western Australia yields such corals in the ammonoid facies of the Canning Basin, described as *Catactotoechus* HILL, 1954 and *Caninia* MICHELIN in GERVAIS, 1840 (HILL 1954; HILL & JELL 1971). The only North American record was *Guerichiphyllum* sp. of SANDO & BAMBER (1985: p. 22, pl. 2, figs. 6-7) from the lower Tournaisian (Kinderhookian) of Montana, Idaho, and Utah. The only published adult transverse section is very similar to *Hebukophyllum priscum* (MÜNSTER, 1840).

***Hebukophyllum arichense* (TERMIER & TERMIER, 1950a)**

Fig. 32

*1950a *Loepophyllum arichense* nov. sp., TERMIER & TERMIER: 46, pl. 46, figs. 15-18

Material: Three topotype specimens (collection R. T. BECKER 2012), Oued Aricha Formation, upper *Platyclymenia* "Stage" (UD IV-B₂), *Procymaclymenia pudica* Zone, southern Mdakra Massif E of Benahmed (western Moroccan Meseta), Oued Aricha section Z (see coral signatures in Fig. 27). The specimens are stored in the Museum für Naturkunde, Berlin, under the following numbers:

MB.K.8071a (Bed 12a) = 10cs, 2ls, 3R, Figs. 32.1a-d.

MB.K.8071b (Bed 8a) = 7cs, 2ls, 2R, Figs. 32.3a-b.

MB.K.8071c. (bed 8a) = 6cs, 2R, Figs. 32.2a-b.

(cs = transverse section, ls = longitudinal section, R = remaining piece)

Description: The three available specimens are conical and cornute (juvenile) to subcylindrical and straight (adult), in Fig. 32.2a with basal talon. Their preservation is not the best: slightly silicified, destroyed juvenile part. Calicular diameters are 18, 21 and 23 mm; the maximal length is 53 mm (Fig. 32.1a, with previous even larger calices of 27 and 25 mm diameter before rejuvenations). The archaeotheca bears fine and coarse transverse growth rings and very weak narrow longitudinal septal furrows of major and minor septa (no hyposepta). The position of the cardinal septum cannot yet be determined by external wall furrows or by ontogenetic analysis, but there seems to be a somewhat shortened septum surrounded by a fossular depression on the convex side (calice, Fig. 32.2), as mostly in *Hebukophyllum priscum* (MÜNSTER, 1840). Visible upper septal margins in the calice show no trabicular spines.

The transverse sections offer in middle and late growth phases thin filiform major septa, longer and still slightly thicker in the youth (but not reaching the center), later more and more shortening (and amplexoid), but never totally reduced as in *Hebukophyllum mirabile* (WEYER, 2002). Minor septa are not visible; they exist as active protuberances only at the upper calicular margin, as in *Hebukophyllum priscum* (MÜNSTER, 1840) (see WEYER 1994, figs. 5.3d, f). Deeper in the calice, these catasepta are reduced and disappear within the thickening wall. Dissepiments of small and large, even extremely extended lonsdaleioid vesicles in 2 or 3 rows, characterize middle and late growth stages. These start at diameters of 9-15 mm. Simple horizontal tabulae and rare similar tabellae cross the interior lumen and fall down peripherally, thus presenting a weakly domed appearance.

Discussion: The taxon seems to be the second-oldest valid species of *Hebukophyllum* (after *Cyathophyllum priscum* MÜNSTER, 1840); all other (and especially the many Chinese) members were introduced with and after RÓŹKOWSKA (1969). Comparisons are difficult in this not yet intensively (using greater populations) studied genus, and the present revision is incomplete due to the still missing, but indispensable early ontogenetic stages. Even a new, nearly synchronous record from Morocco (Fig. 33) seems to present a separate species, not developing lonsdaleioid dissepiments up to a diameter of 17 mm, and during this youth with extremely thickened major septa in the counter quadrants. It is provisionally named as *Hebukephyllum* sp. M and comes from the upper Famennian *orbiculare* Bed (UD IV-C) of the Maïder.

Two middle Famennian species from the Holy Cross Mountains (Poland) differ in size - *Hebukophyllum parvum* (RÓŹKOWSKA, 1969) - and in the dominating normal, not lonsdaleioid dissepiments - *Hebukophyllum concavum* (RÓŹKOWSKA, 1969: her holotype, figs. 23A₁₋₂, 24A₁₋₅). The latter species was also cited by BERKOWSKI (2002: p. 22, assigned to *Circellia* YE & WANG, 1983) from Kowala, but this record might be not conspecific because of the solely lonsdaleioid dissepiments, and could be a new taxon.

For comparison, another new form, named as *Guerichiphyllum?* sp. EA, is illustrated from the upper Famennian *Gonioclymenia* Limestone of the southern Tafilalt (Amessoui Syncline, Fig. 34). It underlines that the diversity of the Guerichiphyllinae was much higher in the Famennian cephalopod facies of Morocco than previously known. The two forms of the subfamily left in open nomenclature require further studies based on additional material.

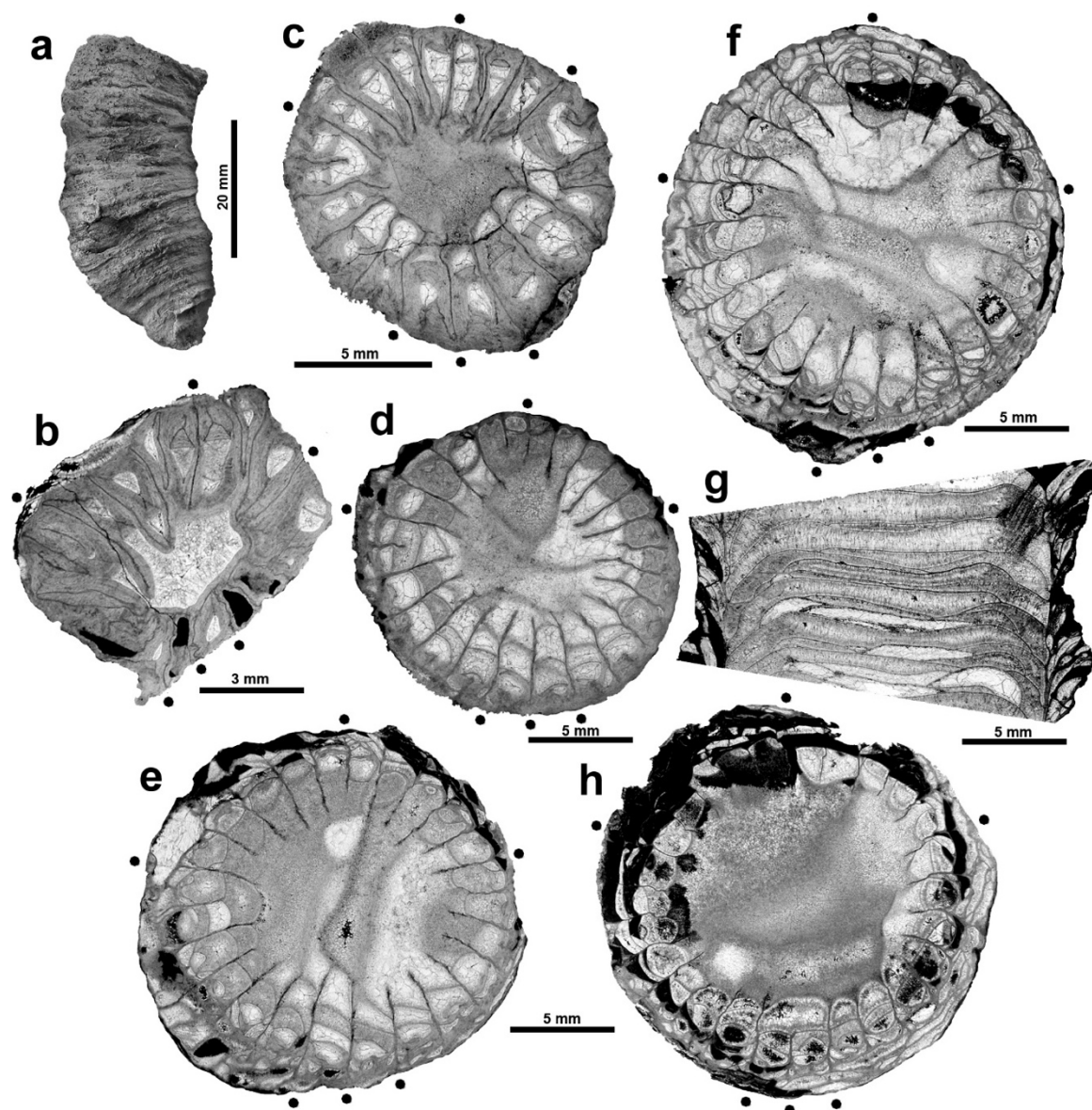


Fig. 34: *Guerichiphyllum?* sp. EA, upper Famennian (*Clymenia* “Stage”), *Gonioclymenia* Limestone (UD V-B, *Bi. costatus* Zone), trenches W of abandoned village El Atrous (Amessoui Syncline, 15 km NW Taouz), Tafilalet, eastern Anti-Atlas (see section description in HARTENFELS 2011). Specimen MB.K.8073. (= 8cs, 4ls, 4R; collection D. WEYER 1995); **a.** Side view of coral, x 1; **b-f.** Transverse sections of early and middle growth stages, x 5 (b), x 4 (c) and x 3 (d-f); **g.** Median longitudinal section, x 3; **h.** Adult transverse section, x 3.

septal formulae:	<u>3 2</u>	<u>4 3</u>	<u>5 5</u>	<u>5 5</u>	<u>5 5</u>
	5 5	6 6	7 7	8 7	8 8
n	19	23	28	29	30
N	30	38	48	50	52
D mm	9	12,2	16/18,6	19,7	19,8
Fig.	b	c	d, e	f	h

(abbreviations: n = number of protosepta + metasepta, N = number of all septa, D = diameter)

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