The Devonian of the Oued Cherrat Zone (Western Meseta) – review and new data

RALPH THOMAS BECKER, ZHOR SARAH ABOUSSALAM, AHMED EL HASSANI, STEPHAN EICHHOLT & STEPHAN HELLING

Fig. 1: View of massive lower Emsian reefal (biostromal) carbonates of the Dhar-es-Smene Formation (Cakhrat-ach-Chleh Member) at Mechra al Kraker just E of the Oued Cherrat, ca. at x = 351.1, y = 342.2, 12 km NE of Ben Slimane.

1. Introduction

The Oued Cherrat Zone is named after the N-S running and deeply incised Oued Cherrat valley, which follows a N-S running, synsedimentarily active fault and sheer zone beginning between Rabat and Casablanca in the western Central Massif (PIQUE et al. 1980; Fig. 2). In the W, it is delimited by the faults, which separate predominating Lower Devonian neritic to reefal carbonates from the siliciclastic Famennian and Lower Carboniferous of the Ben Slimane area. In the E follow the thick Famennian to Lower Carboniferous deposits of the Sidi Bettache Basin. Within the Oued Cherrat Zone, the succession ranges from the upper Silurian (Ludlow) to the basal Serpukhovian (NEQQAZI et al. 2014). CHALOUAN & HOLLARD (1979) and CHALOUAN (1981) introduced a lithostratigraphic subdivision, which was refined by ABOUSSALAM et al. (2013) and EICHHOLT & BECKER (2016). Further lithostratigraphic terms are introduced here, mostly because intensive conodont sampling provided a refined time framework. The special significance of the Oued Cherrat Zone lies in their well-exposed and thick Lower (Emsian) and Middle (Givetian) reef complexes, which have been studied by several authors (e.g., GENDROT et al. 1969; GENDROT 1973, ZAHRAOUI 1991; CATTANAEO et al. 1993; EICHHOLT & BECKER 2016). Reefal limestones occur on both sides of the Oued

Cherrat valley and are of high economic significance (NAHRAOUI et al. 2012). This resulted in the creation of large, active, and fast expanding quarries that, unfortunately, destroy gradually some of the best outcrops. Equally significant are major Eovariscan block faulting and reworking events, which led to block tilting, erosion, and the re-deposition of partly very thick conglomerate and breccia units during specific phases of a long total interval (Givetian to Famennian), with activity peaks in the upper Givetian and middle/upper Famennian. Uplifted blocks were partly deeply eroded, exposing Lower Palaeozoic quartzites and magmatic rocks.

Our summary is based on new data for four different successions, from Aïn Khira (or Aïn El Khira) in the N, to Aïn Dakhla/Cahkrat-ach-Chleh and Aïn-al-Aliliga in the middle, and to Aïn-as-Seffah in the southern part of the reefal band. It re-appears further to the S, in the Al Attamna region (e.g., FADLI 1990; BENFRIKA & BULTYNCK 2003; EICHHOLT & BECKER 2016).

2. Research History

LECOINTRE (1926): Initial survey of the region, with a recognition of strata ranging from the upper Silurian to Lower Carboniferous limestones with "*Spirifer tornacensis*".

ROCH (1950): Records of Emsian trilobites and spiriferids and of a rich Givetian fauna with stromatoporids, tabulate and rugose corals (including the colonial genus *Phillipsastrea*), and the index brachiopod *Stringocephalus*. On the eastern flank, the occurrence of *Archaeocalamites* in Upper Devonian clastics was noted.

HOLLARD (1967, fig. 4): Brief summary of the Oued Cherrat Devonian.

GENDROT et al. (1969): Initial study of reefal carbonates at two localities (Atiliga Syncline and "Sokrat Md. Ben Brahim" (= Cakhrat Mohammed-Ben-Brahim).

KERGOMARD (1970): Unpublished report on the Silurian-Devonian of the Western Meseta, with data for the Oued Cherrat, e.g., a section log for Aïn-al-Aliliga.

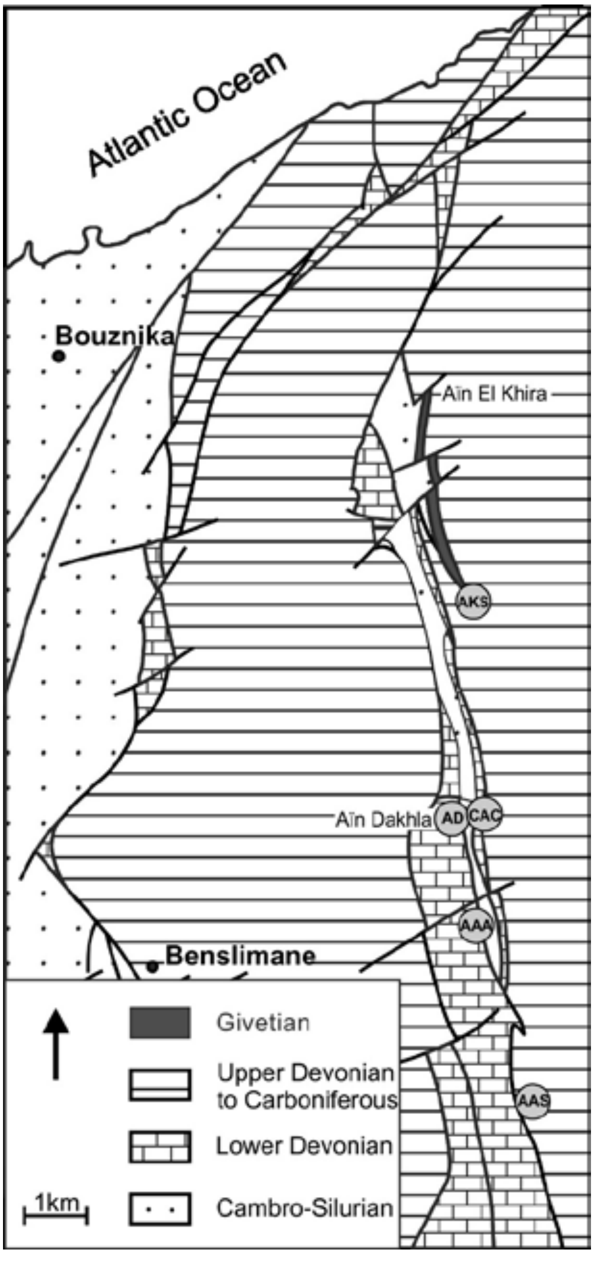


Fig. 2: Position of the four re-studied successions in the narrow Oued Cherrat Zone. **AKS** = Aïn Khira South, **AD** = Aïn Dakhla (W of the river) and CAC = Cakhrat-ach-Chlee (E of the river), **AAA** = Aïn-al-Aliliga, and **AAS** = Aïn-as-Seffah (EICHHOLT & BECKER 2016, fig. 2, redrawn from ZAHRAOUI 1991).

GENDROT (1973): Study on Devonian reefs in the Moroccan Meseta, including the Oued Cherrat.

KELLING & MULLIN (1975): Sedimentological analysis of coral- and brachiopod-bearing shallow-water carbonates, interpreted as Viséan tempestites.

CHALOUAN & HOLLARD (1979): Brief summary of Oued Cherrat lithostratigraphy, introducing numerous new formations.

PIQUE et al. (1980): Recognition of the Oued Cherrat as a distinctive tectonic unit within the wider Western Meseta Shear Zone.

CHALOUAN (1981): Detailed lithostratigraphy and faunal characteristics, providing geological cross-sections for five key successions.

RACHEBEUF (1990): Record of Lower Devonian chonetids from Aïn Dakhla.

ZAHRAOUI (1991, 1994a, 1994b): Summary of Oued Cherrat Silurian to Middle Devonian litho- and biostratigraphy.

CATTANEO et al. (1993): Comprehensive analysis of the Givetian reefal succession at Aïn Khira.

LAAMRANI ELIDRISSI (1993): Unpublished Diplom Thesis on the structural geology of the Bouznika-Cherrat region.

EL HASSANI (1994): Tectonics of the N-S trending Oued Cherrat-Oued Ikem band.

FADLI (1994a, 1994b): Summaries of Famennian to Viséan litho- and biostratigraphy of the Meseta, including the Oued Cherrat.

VACHARD et al. (1994): Description of fifteen species of foraminifers from the Givetian at Aïn Khira, including two new taxa, *Tubeporina (?) polydermoides* (Tuberitinidae) and *Palachemonella maroccana* (Issinellidae).

EL HASSANI & BENFRIKA (1995, 2000): Review of the Meseta Devonian, including a stratigraphic summary for the Oued Cherrat.

CASIER et al. (1997): Description of a rich (fifty species) Givetian ostracod fauna and its paleoecology from Aïn Khira.

BENFRIKA (1999): Description of the lower Emsian *Caudicriodus celtibericus* from Aïn al Quob at the southern end of the Oued Cherrat Devonian outcrop strip.

MAMET et al. (1999): Description of calcareous algae from the Oued Cherrat region, with the Emsian of Aïn Dhakla as the type locality and level of *Sphaerocodium tortuosum*.

BENFRIKA & BULTYNCK (2001, 2003): Report on lower Emsian conodonts from the Dar-es-Smene Formation and of upper Emsian to Eifelian conodonts from the Kheneg-en-Nmer Formation.

JANSEN (2001): Brief comments on Lower Devonian brachiopods of the Oued Cherrat (CHALOUAN material).

KAISER et al. (2007): Comparison of the Upper Devonian of the Oulmes Region with other contemporaneous Meseta successions, including the Oued Cherrat.

ABOUSSALAM et al. (2012): Preliminary note on new conodont data for the Oued Cherrat Devonian.

EICHHOLT et al. (2013): Preliminary new data on reefal faunas and microfacies at Aïn Khira and Aïn-as-Seffah.

NAHRAOUI et al. (2012): Study on the quality of the reefal limestones of the Oued Cherrat as a new source for the regional cement industry.

ABOUSSALAM et al. (2013a): Refined lithostratigraphy and preliminary new conodont data for the isolated reefal olistolite at Aïn-as-Seffah.

ABOUSSALAM et al. (2013b): Dating the onset of Middle Devonian reef growth in the Oued Cherrat as lower Givetian.

NEQQAZI et al. (2014): Discovery of conodonts from the Viséan-Serpukhovian transition in two northern sections near Souk el Had and at Dhar Bou Ghazouani (= Dhar Bou Ghazwani).

SCHWERMANN (2014): Unpublished M.Sc. Thesis on Middle/Upper Devonian shark teeth from Morocco, including the description of *Phoebodus fastigatus, Ph. gothicus gothicus*, and *Ph. gothicus transitans* from Aïn-al-Aliliga and Aïn-as-Seffah.

HELLING, S. & BECKER, R. T. (2015): Preliminary data on a new Pragian trilobite

assemblage from the Aïn-al-Dakhla Formation of Aïn-al-Aliliga.

EICHHOLT & BECKER (2016): Detailed microfacies and reef development study in the Oued Cherrat Zone, with a revised regional lithostratigraphy and facies logs for Aïn Khira South and Aïn-as-Seffah.

BECKER & ABOUSSALAM (2019): Note on the development of Emsian/Eifelian global events in the Meseta, including remarks on the Daleje Event in the Oued Cherrat.

3. Summary of succession

In terms of palaeogeography and synsedimentary structural geology, the Cherrat River Subzone sensu PIQUE et al. (1980) belonged in the Devonian to a narrow and elongated elevation with shallow-water sedimentation and adjacent steep slopes that caused mass flow and turbidite re-deposition. Reworked Lower Devonian clasts show that both shallow and deeper-water facies existed at the same time. Givetian strata were strongly affected by syn- and post-sedimentary block tilting and partial uplift, which caused the closely-spaced interfingering of reef beds, intra-formational breccias and mass flows. Well-rounded pebbles and the deep erosion into Lower Palaeozoic strata suggest that the top of tilted blocks formed synsedimentary islands, at least in the middle/upper Famennian. These may have been a source of clastic detritus for the Ben Slimane and Sidi Bettache Basins in the W and E, respectively. However, the regional provenance of thick Famennian/Tournaisian silt- and sandstones requires further analyses. The main Variscan deformation occurred towards the end of the Lower Carboniferous, after an episode of upper Viséan to Serpukhovian carbonates with still open marine conodonts (NEQQAZI et al. 2014).

Refinements of the original lithological division of CHALOUAN & HOLLARD (1979) and CHALOUAN (1981) result in the following formation and member sequence:

3.1. Upper Silurian

The oldest Palaeozoic of the Oued Cherrat is represented by Ludlow graptolite shales and limestones (S_s), which have not yet received a formation name. They may reflect the post-Caledonian transgression, as in the Rabat-Tiflet Zone to the N (e.g., EL HASSANI et al. 1988).

CHALOUAN (1981) speculated that beds with scyphocrinitids, which are so characteristic for the Silurian-Devonian transition in other Meseta and Anti-Atlas regions, including the adjacent Ben Slimane region (ZAHRAOUI 1991), might have been cut off by faulting.

3.2. Lochkovian

CHALOUAN (1981) did not recognize Lochkovian beds, probably caused by the strong fault fragmentation of the region, not due to non-deposition. ZAHRAOUI (1991, 1994a) observed the Silurian-Devonian transition, with shallow-water shales and limestones of assumed Lochkovian age, in the Kaf Nzaha section in northern parts of the Oued Cherrat (S of Aïn Khira, see Fig. 2). The unit requires further investigations. *Uncinatograptus uniformis*, the defining graptolite for the Devonian base, has been recognized near Ben Slimane (DESTOMBES & JEANETTE 1996; ZAHRAOUI 1991).

An isolated pebble of black "*Orthoceras* Limestone" from Aïn Dakhla yielded unexpectedly a faunule with middle Lochkovian index conodonts (*Ancyrodelloides transitans*). It proves that a pelagic Lochkovian limestone setting was also developed in the region although it did not leave any known current outcrop. Middle Lochkovian conodonts are in general practically unknown so far from the Western Meseta (e.g., absent from the Rabat-Tiflet Zone, BENFRIKA et al. 2007).

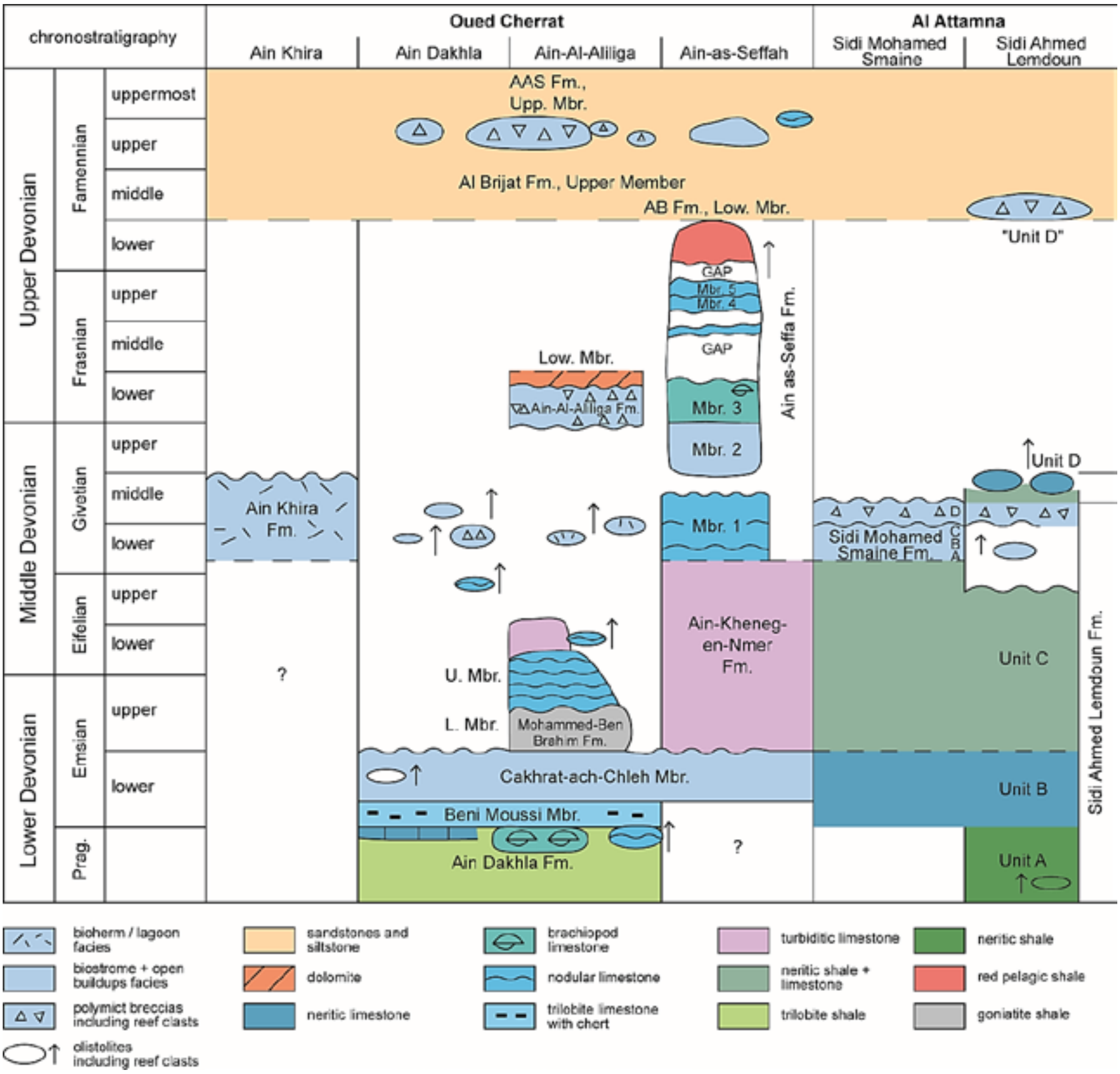


Fig. 3: Revised Devonian lithostratigraphy and correlation of the Oued Cherrat (four successions, from N to S) with the Al Attamna (two successions), the continuation of the reef belt to the S, for comparison (re-drawn from EICHHOLT & BECKER 2016, fig. 3).

3.3. Pragian

The **Aïn-ad-Dekhla Formation** (d_2) is a package of grey, greenish-grey or dark-grey silty shales with intercalated thin sandstones and a diverse, neritic Pragian fauna. Fossils are commonly coated by yellowish limonite, which indicates hypoxic conditions within the sediment – not at the sea floor. The rich brachiopod and trilobite fauna requires revision (e.g., RACHEBEUF 1980; JANSEN 2001; HELLING & BECKER 2015). The preliminary faunal list, with some updated brachiopod identifications by U. JANSEN (Frankfurt a. M.; marked by an *), gives an impression of a rich benthic ecosystem:

various bivalves
gastropods
Ctenochonetes ibericus (abundant, first recorded as "*Strophochonetes (Ctenochonetes)* cf. *aremoricensis*")
Rhenoschizophoria sp. (resembling *Rh. torkozensis*)*
Dalejodiscus aff. *subcomitans** (see Fig. 42.3)
Eucharitina oehlerti
Torosospirifer sp. (previously *Brachyspirifer crassicosta*)*

"Hysterolites nerei" (normally a spiriferid from Bohemia)
*Dixonella ayensis**
Filispirifer e.g. *merzakhsaiensis*. (previously recorded as *Acrospirifer fallax* Group)*
Oligoptycherhynchus cf. *daleidensis*
other rhynchonellids ("*Camarotoechia*")
Reedops cephalotes
possibly other phacopids ("*Phacops* sp.")
Metacanthina sp. (two species)
other asteropygids (previously listed as "*Pilletina* sp.", "?*Paracryphaeus* sp.", and "*Pseudocryphaeus*")
Odontochile sp.
Wenndorfia sp. (?= "*Parahomalonotus* sp.")
large benthic ostracods
solitary rugose corals
tabulate corals

The brachiopods suggest a correlation with the Pragian Assa Formation (Rich 1) of the Dra Valley in the western Anti-Atlas (compare JANSEN 2001 and JANSEN et al. 2007). In the upper part, lenticular and bioclastic limestones with a rich brachiopod fauna, including *Euryspirifer* sp. (not the quoted, younger *E. pellicoi*; see JANSEN 2001), give a transition towards the overlying carbonate formation. The dacryoconarid *Nowakia (Turkestanella) acuaria* provides a firm Pragian age for this upper part/member.

An isolated allochthonous block of micritic griotte limestone re-deposited in the Famennian of Aïn-al-Aliliga yielded unexpectedly upper Pragian icriodids (*Latericriodus steinachensis*). This block of deeper-water, non-siliceous, nodular facies suggests that there was originally a carbonate ramp dipping eastward. This palaeorelief was reversed by Eovariscan tectonic uplift of the eastern Oued Cherrat Zone, leading to reworking and westward shedding.

3.4. Emsian

The subsequent **Dhar-es-Smene Formation** (d_3) is revised and subdivided here. It includes all the thin-bedded and neritic to massive, biostromal, limestones exposed in cliffs and large quarries W and E of the Oued Cherrat (Fig. 1). 20-30 m of well-bedded, light- or dark-grey, sometimes dolomitized limestones with abundant chert nodules are assigned to the new **Beni Moussi Member** (d_{3-1}), named after the hill/area W of the type-section at the Aïn Dakhla spring. The rich shallow-water fauna consists of crinoid debris, brachiopods (various spiriferids, atrypids, rhynchonellids, chonetids), ostracods (beyrichiids), trilobites (phacopids, asteropygids), rugose corals, tabulate corals (*Thamnopora, Favosites*), receptaculitids, calcareous algae, bryozoans, dacryoconarids, and gastropods. The taxonomy of the fauna needs to be revised. The diagenetically mobilized chert derived probably from siliceous sponges. Based on the insufficiently known brachiopod fauna, the new member seems to range from the Pragian-Emsian transition to the lower Emsian. So far, there are no conodonts; several samples from the upper part were barren or included only non-diagnostic single cone genera.

CHALOUAN (1981) noted an up to 20 m thick upper intercalation of silty shales and yellowish, dolomitic limestone with neritic fauna (including "*Euryspirifer* sp. cf. *extensus"*, which, however, is an upper Emsian species of *Arduspirifer*, see JANSEN 2001). ZAHRAOUI et al. (2000, fig. 4) published a detailed section log showing several shallowing-upwards sequences, with two main regressive episodes in the lower/middle part, separated by more argillaceous deepening intervals. The formation and member base should be placed at the base of their massive Bed 8.

The main, upper part of the Dhar-es-Smene Formation provides the cliffs and active limestone quarries of Dhar-es-Smene, Aïn Dakhla (=Aïn-ed-Dekhla), and Aïn-al-Aliliga. ABOUSSALAM et al. (2012, 2013) showed that the thick, main reef belt E of the Cherrat river (Fig. 1) is also lower Emsian age, since the index conodont *Latericriodus bilatericrescens*

bilatericrescens occurs at its base at Cakhrat-ach-Chleh, as well as in typical d_3 limestones of Aïn Dakhla. Consequently, the type Cakhrat-ach-Chleh Formation sensu CHALOUAN & HOLLARD (1979) became a synonym of their Dhar-es-Smene Formation. However, the lithostratigraphic term could be kept as a member name (**Cakhrat-ach-Chleh Member** in EICHHOLT & BECKER 2016; d_{3-u}) for the main, up to 250 m thick reefal part of the Oued Cherrat Lower Devonian carbonate platform. Typical are grey to bluish-grey, partly dolomitized, medium- (20-30 cm) or thick-bedded (up to 2 m), biostromal to non-bedded (biohermal) bioclastic limestones with crinoid debris, stromatoporids, receptaculitids, colonial and solitary Rugosa, tabulate corals (thamnoporids, favositids, alveolitids), bryozoans, brachiopods (atrypids, schizophoriids), gastropods, rare trilobites (phacopids and asteropygids), and calcimicrobes, such as *Sphaerocodium tortuosum* MAMET, 1999. As in the Beni Moussi Member, there was considerable facies and thickness variability along strike.

Towards the S (Aïn-al-Qcob and beyond), the facies became more detrital, dark (organic-rich), or rose to violet in color, and somewhat siliceous. In this undivided Dhar-es-Smene Formation, BENFRIKA & BULTYNCK (2003, "Unit A") found *Caud. celtibericus*, which ranges in the Anti-Atlas from equivalents of the classical (Czech) upper Pragian (= basal Emsian sensu the current Zinzilban GSSP) ca. into the middle of the lower Emsian (ABOUSSALAM et al. 2015). Rich typical lower Emsian *Latericriodus* faunas occur in reworked crinoidal limestone olistolites at Aïn Dakhla. We assume that they derived from uplifted and eroded strata of the Cakhrat-ach-Chleh Member of the region.

The top of this member is often cut off by faulting (e.g., at its type locality and at Aïn Dakhla). Where the succession is complete (e.g., at Cakhrat Mohammed-Ben-Brahim), a gradual deepening is indicatated by the change to finer bioclastic and finally to micritic and nodular limestone. CHALOUAN (1981) reported apart from small brachiopods (*Plectospira*), ostracods, single corals, dacryoconarids, and *Caudicriodus* cf. *curvicauda*. However, typical *Caud. curvicauda* do not range above the basal Emsian and hardly overlap with *Lat. bilatericrescens bilatericrescens* (see ABOUSSALAM et al. 2015). Our new data prove that the initial deepening at the top of the Dhar-es-Smene Formation occurred within the range of *Criteriognathus steinhornensis*, which characterizes the upper half of the lower Emsian. This suggests a possibly correlation with the transgressive, global Upper Zlíchov Event sensu GARCÍA-ALCALDE (1997).

EL HASSANI & BENFRIKA (1995, 2000) emphasized facies and palaeobathymetric differentiation within the Dhar-es-Smene Formation along the Oued Cherrat resulting from synsedimentary tectonic instability. Therefore, it is difficult to follow individual beds/packages from one section to the next. This aspect recommends future more detailed microfacies and sequence stratigraphic analyses along a N-S transsect, combined with a revision of brachiopod taxonomy. As an example, a unique, isolated thick brachiopod coquina followed by detrital limestones occurs in our new "central section" at Aïn-al-Aliliga (see below).

The subsequent, argillaceous **Mohammed-Ben-Brahim Formation** (d_{4-1}) is restricted to its type region around Cakhrat Mohammed-Ben-Brahim in the ca. middle part of the Oued Cherrat. It is characterized by up to 100 m of dark-grey, calcareous and partly pyritic shale. It contains a pelagic assemblages of goniatites, orthocones, bivalves, small solitary rugose corals, and rare, relatively large phacopids. A squashed *Gyroceratites* Fauna (Fig. 4) from the base, typical for the basal upper Emsian (LD IV-A in the zonal scheme of BECKER & HOUSE 2000b), proved that its sharp base correlates

with the global Daleje Event (BECKER et al. 2019). E. A. HILALI found a specimen of "*Anarcestes lateseptatus*" in the shale (CHALOUAN 1981), which places higher parts of the formation in middle/upper parts of the upper Emsian (LD IV-D), even if the species identification requires confirmation. It should be noted that upper Emsian strata with anarcestids were placed for a long time (but wrongly) in the "Couvinian" or Eifelian (see KERGOMARD 1970, CHALOUAN 1981, and ZAHRAOUI 1994b). Records of the large-sized and spinose asteropygid *Psychopyge elegans* from Cakhrat Mohammed-Ben-Brahim are in full accord with an upper Emsian age (see MORZADEC 1988).

Fig. 4: Squashed *Gyroceratites* sp. from reddish-weathering pyritic (secondarily limonitic) shales in the basal part of the Mohammed-Ben-Brahim Formation at Cakhrat Mohammed-Ben-Brahim.

Due to its soft rheology, the Mohammed-Ben-Brahim Formation tends to be affected by tectonism. In our new "central section" at Aïn-al-Aliliga, it can be subdivided into two members. The **Lower Member** (d_{4-1l}) is shaly, the new **Upper Member** (d_{4-1u}) consists of ca. 6.5 m of nodular, micritic limestone with anarcestids and conodonts of the *Icriodus fusiformis* Zone (basal part of the upper Emsian, ABOUSSALAM et al. 2015).

Fig. 5: The Aïn-Kheneg-en-Nmer Formation at Aïn-as-Seffah in the southern Oued Cherrat, showing two limestone units to the right and left (Cherrat Valley slope) interrupted by a more shaly interval with poor outcrop.

3.5. Eifelian

The **Aïn-Kheneg-an-Nmer Formation** (d_{4-2}) is defined as a 20-150 m thick alternation of dark-grey shales and dark-grey to black, thin- to medium-bedded, detrital or turbiditic limestones. The thickness increases from Aïn-al-Aliliga to the S (Aïn-as-Seffah), where two limestone units are separated by a more shaly middle package (Fig. 5). The macrofauna is very sparse. Some tabulate corals, phacopids, small brachiopods, and deeper-water bivalves (*Panenka*) were noted by CHALOUAN (1981). Conodonts identified by P. BULTYNCK include a range of "middle" Eifelian (middle/upper *Po. costatus* Zone) polygnathids and icriodids, such as *Po. angusticostatus, Po. angustipennatus, Po. robusticostatus, Po. pseudofoliatus, Linguipolygnathus linguiformis, Icriodus regularicrescens, I. curvirostratus/introlevatus,* as well as *Tortodus intermedius*. Observed agoniatite cross-sections may refer to *Fidelites* or *Foordites*. BENFRIKA & BULTYNCK (2003), however, showed that the formation begins more to the S, at Aïn-al-Qcob, already in the upper Emsian *L. serotinus* to *Po. patulus* Zones. This is fully supported by data from our new "central section" at Aïn-al-Aliliga, where the formation base falls within the *L. serotinus*

Zone. Therefore, it starts within the ca. upper half of the upper Emsian. The lower Eifelian was recognized ca. 13 m above the base but the still crude sampling has not yet pinpointed the series boundary. The basal Eifelian Choteč Event is locally not distinctive. Upper Eifelian conodonts, including the index species *T. kockelianus*, are regionally known from the top of the formation (Aïn-as-Seffah) and from reworked blocks in Famennian olistolite units. The Eifelian/Givetian boundary is not preserved within the faulted sections that have been studied so far. As a result, and unlike as in the Rabat-Tiflet Zone to the NE, there is no regional record of the global Kačak Event(s).

3.6. Givetian

Thick (50-100 m) Givetian reef limestones form a narrow, third, eastern outcrop strip in northern parts of the Oued Cherrat (Fig. 2), which is intensively quarried. EICHHOLT & BECKER (2016) introduced for this economically important unit the term **Aïn Khira Formation** (d_5). The best outcrops from the research period between ZAHRAOUI (1991) and ZAHRAOUI et al. (2000), shown to an international audience during the SDS-IGCP 421 Morocco Field Meeting in spring 1999, have, unfortunately, disappeared in the meantime by quarrying. CATTANEO et al. (1993) recognized eight principle reef facies, which were arranged vertically into two major regressive cycles and several subcycles. Characteristic facies types are:

F1. Argillaceous dacryoconarid mud-wackestones (outer ramp or platform)
F2. Wacke-floatstones with some isolated reef corals, stromatoporids and crinoid debris (subtidal external platform with distal reef talus)
F3. Peloidal and crinoidal pack-grainstone with bryozoans (external platform with crinoid meadows)
F4. Stromatoporid and coral float-rudstone (proximal reef talus of the upper marginal slope or within the lagoon)
F5. Stromatoporid-coral frame-bindstone with massive reef builders (reef core)
F6. Amphiporid floatstone with parathuramminids and various bioclasts (deeper lagoonal)
F7. Amphiporid-parathuramminid mud-wackestone (deepest or most protected lagoonal parts)
F8. Peloidal birds-eye boundstones, peloidal micrites, and laminated bindstones (intertidal reef flat)

ZAHRAOUI (1991, 1994b) reconstructed a carbonate platform/ramp that deepened from the W to E. EICHHOLT & BECKER (2016) subdivided the inner platform/lagoonal facies set (F4 and F6-8) into eight microfacies types:

MF A1: Peloidal grainstone (lagoon parts with moderate water agitation and strongly restricted fauna).
MF A2: Detrital grain-rudstone or back reef breccias (= F4, coarse proximal talus on the inner side of the reef core or around patch reefs)
MF A3: *Stringocephalus-Amphipora* rudstone (storm layers within the lagoon)
MF A4: *Stachyodes-Thamnopora* float-rudstone (storm layers around patch reefs)
MF A5: Stromatoporiod float-rud-boundstone with up to 20 cm large bulbous stromatoporids (upper patch reef, part of F5)
MF A6: *Amphipora* float-rud-boundstone (= F6, protected deeper lagoon)
MF A7: Bioclastic mud-wackestone (= F7/8, protected and restricted, calm lagoon with occasional freshwater influx)
MF A8: *Stringocephalus* floatstone with bioturbation (protected wide lagoon with overall good living conditions)

Probably based on a third outcrop, CASIER et al. (1997) distinguished ten microfacies types. We did not observe their bioturbated siltstones (M1) and silty mud-wackestones (M2) in our section (see below), nor an abundance of (microbial) fenestrae, as in their M7 (ca. = MF A4), M8 (ca. = MF A6), and M10 (ca. our MF A7). The detailed analysis of the locally common foraminifers by VACHARD et al. (1994) resulted in the record of ten species of Parathuramminina and five species of Moravamminida (possible calcareous algae), including the new issinellid *Palachemonella maroccanica*.

The Givetian age of the Aïn Khira Formation is confirmed by the index brachiopod genus *Stringocephalus* and the colonial marker coral *Phillipsastrea*. Records of *Cyrtospirifer* show that the succession ranged at least locally into the upper Givetian. Among the diverse ostracods (50 taxa of the Eifelian shallow-water ecotype), *Polyzygia beckmanni beckmanni* and rare *Poly*. cf. *insculpta* confirm the Givetian age (CASIER et al. 1997).

Towards the S, at Aïn Dakhla, Givetian reef limestones are only known as reworked olistolites within the much younger Al Brijat Formation. Crinoidal limestone blocks with lower/middle Givetian conodonts show that originally an open, lower ramp/platform (with F2) was developed before tectonic uplift and erosion destroyed it completely.

Further to the S, at Aïn-al-Aliliga, an open neritic to biostromal carbonate ramp was subject to recurrent, strong synsedimentary seismic events. This led to a more than 50 m thick alternation of coarse breccia beds (mass and debris flow deposits), biostromal limestones with silicified stromatoporids and corals, and intercalated, well-bedded, conodont-bearing limestones (Flinz-type facies). All rock types yielded in several samples exclusively middle Givetian to basalmost Frasnian (*Ancyrodella rotundiloba pristina* Zone, MN 1 Zone) conodont assemblages. Therefore, we assign the part of the **Aïn-al-Aliliga Formation** of CHALOUAN & HOLLARD (1979) that lacks any volcanite or quartzite pebbles/blocks to a new **Lower Member** (d_{7-1}) It overlies N of the W-E running track with an angular unconformity the Dhar-es-Smene Formation. Basal beds are rich in icriodids, higher parts are in polygnathid biofacies.

GENDROT et al. (1969) suggested that the second, up to 200 m thick eastern reef limestone cliff at Cakhrat Mohammed-Ben-Brahim is of Givetian age, as it is also shown in the cross-section of CHALOUAN (1981). This would make it a preserved southern continuation of the Aïn Khira Formation but currently there is no biostratigraphic age control. Re-sampling is required, especially since there is a fault contact to the supposedly older beds (Mohammed-Ben-Brahim Formation; CHALOUAN 1981, ZAHRAOUI 1994b).

Fig. 6: Weathered *Manticoceras* specimen as seen on a bedding plane of the "*Manticoceras* Limestone" (Member 5) at Aïn-as-Seffah, southern Oued Cherrat.

The term **Aïn-as-Seffah Formation** (d_6) of CHALOUAN & HOLLARD (1979) has been revised by ABOUSSALAM et al. (2013b) to include all parts of the internally complex large limestone olistolites embedded at Aïn-as-Seffah within the Al Brijat Formation. Only the thin-bedded **Member 1** (d_{6a}) and the open biostromal **Member 2** (d_{6b}) fall in the Givetian. But their contact is disconformable and much of the middle Givetian is missing. This proves an intra-Givetian tectonic phase preserved within the big main allochthonous block.

3.7. Frasnian

There is only a poor previous record of Frasnian strata from the Oued Cherrat, which agrees with the general pattern of the Meseta Devonian. In the N, there is no section that display strata that overlie conformably the Aïn Khira Formation. Since the Lower Member of the Aïn-al-Aliliga Formation yielded basalmost Frasnian index conodonts, overlying thin-bedded dolomites are also of (lower)

Frasnian age. *Belodella*, the only conodont recovered, did not survive the end-Frasnian mass extinction.

The best Frasnian evidence comes from Aïn-as-Seffah, where it is strongly condensed and incomplete, with unconformities between **Member 3** (d_{6c}, lower Frasnian, massive brachiopod limestone) and **Member 4** (d_{6d}, top-middle to upper Frasnian flaserlimestone). The famous rose limestone with *Manticoceras* (**Member 5**, d_{6e}, Fig. 6) is just 65 cm thick. Based on MN 13a Zone (KLAPPER 1989; = *Pa. bogartensis* Zone) conodonts, it correlates in time with the latest Frasnian starting at the top of the Lower Kellwasser level. There is no regional evidence for the Upper Kellwasser Limestone; the Frasnian-Famennian transition falls in another hiatus.

3.8. Famennian

Evidence for lower Famennian strata is even weaker in the Oued Cherrat region. ABOUSSALAM et al. (2013b) emphasized at Aïn-as-Seffah a lenticular, up to 10 m thick unit of red shale, which was obviously attached to the main limestone olistolite prior to its re-deposition. It was assigned to a new **Lower Member** ($d_{7\text{-}2}$) of the Al Brijat Formation but it is so distinctive and regionally unique that it should receive its own lithostratigraphic name in future.

The typical or **Upper Member** ($d_{7\text{-}3}$) of the **Aïn-al-Aliliga Formation** sensu CHALOUAN & HOLLARD (1979) and CHALOUAN (1981) is an up to 70 m thick channel fill consisting of chaotically-bedded, strongly polymict and extremely coarse, massive breccia unit, best exposed at the Aïn-al-Aliliga spring. Apart from a wide array of up to 3 m large reworked limestone clasts, including many Givetian reefal blocks, there are (sub)rounded Lower Palaeozoic, dark-grey quartzite pebbles, and light-grey weathering volcanites. The matrix is calcareous, iron-rich (reddish) or siliceous. CHALOUAN (1981) noted irregularly interbedded sandstone and quartzite beds, which may refer to large, flat olistolite blocks. The age of the unit is difficult to assess. Individual clasts and a large bulk sample yielded to us only sparse to diverse middle/upper Givetian conodonts. This is in contrast with records from supposed breccia matrix of *Bispathodus costatus* (towards *B. spinulicostatus*) and *I. cornutus* in CHALOUAN (1981). Two upper Givetian species, *I. expansus* and *Po.* ex gr. *pennatus,* were allegedly associated, which suggests a mixed, reworked fauna. *Bispathodus costatus* is the index taxon of the *B. costatus* Subzone (of the *B. aculeatus aculeatus* Zone) in the upper half of the upper Famennian (see HARTENFELS 2011). There is some support from our Sample VFP, which yielded no Famennian conodonts but some middle/upper Famennian *Phoebodus* teeth (SCHWERMANN 2014: two subspecies of *Phoeb. gothicus*). The combined evidence suggests an upper Famennian re-deposition age. It was preceded by a long interval of non-deposition (main Frasnian to lower Famennian) and middle/upper Famennian block tilting causing uplift, deep erosion, and reworking, with some rounding in a coastal setting. Seismic events on steep elevated flanks induced gravitational mass flow transport down a steep ramp. Due to the large clast size and localized occurrences, the source areas must have been very close, right at the eastern margin of the Oued Cherrat Zone. Some of the mass flows seem to have ended in "shark-infested" open water or even killed them.

The **Al Brijat Formation** (dh) is an even more complex unit since is consists locally very variably of thick siliciclastics (grey to brownish or greenish silty shales, micaceous siltstones, and thin- or cross-bedded sandstones), intercalated mass flows, and isolated or accumulated olistolites of highly variable age and lithology. Compact packages of reworked limestones and breccias may be seen as local tongues of the Aïn-al-Aliliga

Formation (Fig. 7). However, there was repeated seismic activity all along the extended Oued Cherrat and not necessarily any continuity between individual mass flow units. The recognition of double reworking (olistolites consisting of cannibalized Givetian breccias) is of principle importance to understand the polyphase regional synsedimentary tectonics.

Fig. 7: Large corroded olistolite blocks of reworked Middle Devonian limestone breccias, re-deposited as mass flow in the Famennian Al Brijat Formation (tongue of Aïn-al-Aliliga Formation) at Aïn Dakhla (picture width 1 m).

CHALOUAN (1981) proposed a synthetic (combined from different localities) succession for the Al Brijat Formation, which extends widely into the adjacent southern Sidi Bettache Basin to the E. For example, their upper succession includes the distinctive Tournaisian and Viséan limestones of Sidi Jilali and Sidi Radi (IZART & VIESLET 1988). Concentrating on the Oued Cherrat area, our observations support the following succession:

Unit 1: Conglomerate/breccia with reworked reef limestone of Cakhrat Mohammed-Ben-Brahim. A supposed lower Famennian age (KERGOMARD 1970) is not based on published conodont data. A correlation with the Upper Member of the Aïn–al-Aliliga Formation (*B. costatus* Subzone) seems more likely but requires further sampling.

Unit 2: Thick package (150 m or more) of silty shales and siltstones, upwards with increasingly dominant sandstones.

Unit 3: 10-20 m thick, lenticular, polymict breccias, conglomerates and isolated olistolites with reworked Lower/Middle Devonian limestones, including many reefal blocks, cannibalized breccias, and sandstone/quartzite clasts. Our new samples from several localities provided no evidence for reworked Upper Devonian limestones. This is not really surprising since the youngest strata will have been eroded first and should have been re-deposited in Unit 1.

Unit 4: Ca. 300 m of alternating silty shales, siltstones and, increasing towards the top, sandstones.

Unit 5: Up to 30 m thick, relatively fine conglomerate/breccia with rounded limestone and angular quartzite clasts. This unit underlies in the S, at Ghar al Anz (in the SW of topographic sheet, 1 : 50 000, Sidi Bettach), a thin black shale with laminated limestone concretions and an overlying dolomitized carbonate unit. Unfortunately, the first did not yield any conodonts to us.

The age of the formation and especially the precise timing of Eovariscan reworking events is still poorly constrained. As stated by CHALOUAN (1981), there have been two peak intervals of Famennian re-deposition. Unless good palynological data become available, it will remain impossible to separate upper/uppermost Famennian and Tournaisian strata in the upper part of the formation. Some samples have been given to C. HARTKOPF-FRÖDER (Krefeld) but results are not yet available. So far, there is no record of black shales that might mark the onset of the global Hangenberg Crisis, as in the Oulmes region to the E (KAISER et al. 2007). As a hypothesis, the D/C boundary regression may be represented by the upper part of Unit 4 to Unit 5.

3.9. Lower Carboniferous

The thick, upper and eastern part of the Al Brijat Formation comprises the lower Tournaisian since it is overlain at Sidi Jilali, in the southern Sidi Bettache Basin, by a limestone with middle Tournaisian conodonts (IZART & VIESLET 1988; new samples). As

suggested in FADLI (1994a), the term Al Brijat Formation should be restricted to the siliciclastics below this Sidi Jilali Member and below the supposedly equivalent dolomitic limestones of Ghar al Anz in the S (Ghar al Anz Member). The middle Tournaisian to middle Viséan clastics and intercalated limestones (e.g., the Viséan Sidi Radi Member) of the southern Sidi Bettache Basin fall in the complex, flyschoid Khourifla Formation. In the Oued Cherrat, transgressive, upper Viséan limestones with index foraminifers have been named by CHALOUAN & HOLLARD (1979) as Mechra-al-Kraret (open shelf limestones and shales) and Kaf-Anzaha Formations (shallow-water limestones). NEQQAZI et al. (2014) showed that the Mechra-al-Kraret Formation ranges into the Viséan-Serpukhovian transition with *Lochriea cruciformis* and *Mestognathus bipluti*. Whilst the latter was widespread in the upper Viséan (e.g., ABOUSSALAM et al. 2017: Marrakech region), *L. cruciformis* enters above *L. ziegleri*, the proposed future Serpukhovian index species (e.g., BARHAM et al. 2015). However, this level is much older than the traditional Viséan-Namurian boundary of Central Europe (e.g., WANG et al. 2018). Therefore, the conodont evidence does not prove that the open marine Oued Cherrat Carboniferous includes Namurian equivalent strata.

Since we have not studied or re-sampled the Viséan, our detailed review and summary of Oued Cherrat stratigraphy ends with the Al Brijat Formation.

4. Key successions

4.1. Givetian reef at Aïn Khira South

Givetian reefs stretch as a narrow band from Aïn Khira, ca. 6 km E of Bouznika, for ca. ca. 3 km to the SSE. The successions described by ZAHRAOUI (1991), CATTANEO et al. (1993), and ZAHRAOUI et al. (2000) have been quarried away. This is unfortunate since former small quarries exposed reef facies types beautifully in sawed walls. As a consequence, EICHHOLT & BECKER (2016) published a section log (from 2012) and the facies history for an inner platform succession at the southern margin of the most southern quarry at that time (Fig. 8), here named as section Aïn Khira South. The evidence can be summarized as follows:

The local total thickness of the Aïn Khira Formation is almost 100 m. Conodont samples were barren but *Stringocephalus* cross-sections found at 12 and 59 m above base prove a lower to middle Givetian age (Fig. 9). At the base, there are middle- to dark-gray peloidal grainstones (MF A1) with gastropods and subordinate brachiopods. At 7 m there are up to 30 cm thick, late diagenetic dolomite boulders, followed by a re-onset of MF A1. At 9 m begins a short interval with bioclastic grainstone (MF A2, Fig. 10) containing fragmented stromatoporids, corals, and some crinoid debris.

Back-reef shedding of crinoid fragments in channels or during storms is also known from contemporaneous German reefs (e.g., KREBS 1974). An *Amphipora* Boundstone (MF A6**)** at 11 m documents the return to restricted, calm lagoonal conditions. It is overlain by storm beds consisting of *Stringocephalus-Amphipora* float-/rudstone (MF A3, 11.5-15 m, Fig. 11). At 16-20 m, more peloidal grainstones (MF A1) are overlain by *Stachyodes-Thamnopora* float-/rudstones (MF A4). Subsequent bioclastic mud-/wackestones indicate even more restricted conditions and a deepening interval from 23 m on (MF A7). The fossil content is poor (ostracodes, rare gastropods, parathuramminid foraminifers). Small-sized sparite fenestrae indicate a microbial content (Fig. 12). Between 33 and 35 m, peloidal grainstones (MF A1) are intercalated, as evidence for an interval of again increased turbidity. At 44-46 m a small patch reef episode with MF A6 (*Amphipora* float-bafflestone) is developed. A thicker patch reef

interval ranges from 48-59 m. *Stachyodes-Thamnopora* float-rudstones (MF A4) occur at the base, followed by MF A5 (Fig. 13). Such reefal structures within the inner platform are characterized by small bulbous or laminar stromatoporids, which interspaces were settled by solitary Rugosa, branching tabulates, and dendroid stromatoporids (*Stachyodes, Amphipora*). At 59 m, MF A8, *Stringocephalus* floatstones (Fig. 9), become characteristic. Despite their thick shells, this brachiopod group preferred protected lagoons (e.g., Becker et al. 2016a). Wide-spread disarticulated valves show their sensivity to episodic major storm events.

At 64-65 m and 70-71 m, there are thin *Amphipora* rud-bafflestones (see Fig. 14), a typical back-reef facies that re-occurs at the top (95-97 m, Fig. 15). The main upper part of the succession is formed by the deeper lagoonal MF A7. This suggests a second deepening phase, as it was also shown in the more northern locality of Cattaneo et al. (1993). MF A4, *Stachyodes-Thamnopora* float-rudstone, occur at 75-76 and ca. 83 m. They are typical for lagoon parts adjacent to patch reefs; both forms are more robust and storm-resistant than *Amphipora*.

Characteristic for our section is the lack of cyclicity and the rarity of fenestral/microbial facies. It lacks the unit with laminites (F8 of Cattaneo et al. 1993) separating the two deeper lagoonal sequences. Instead, there are the solid patch reef boulders of 48-59 m. We did not reach the reef top. Therefore, we cannot asses at Aïn Khira South the reasons for the reef extinction. Further studies are required to solve this question.

Fig. 8: View on the logged Givetian inner platform reefal succession exposed in 2012 near the southern end of Aïn Khira. Beds are exposed in large, partly poorly stratified boulders (GPS coordinates N33°42'56,9'' W007°01'12,8'').

Fig. 9: Field photo from Aïn Khira South showing a typical, thick-shelled *Stringocephalus* cross-section with median septum, embedded in fine-grained bioclastic limestone.

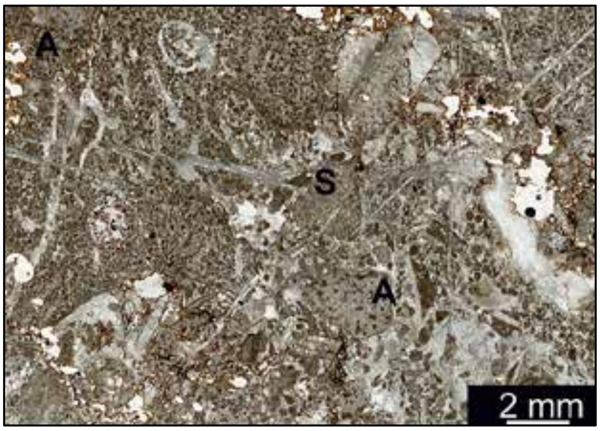


Fig. 10: MF A2, bioclastic peloidal grainstone with debris of blocky stromatoporoids (S), and *Amphipora* (A), Aïn Khira South at 10 m.

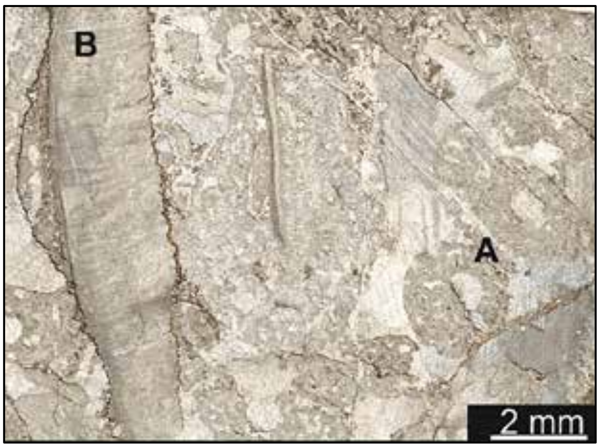


Fig. 11: MF A3, sparitic rudstone with *Amphipora* (A) and thick *Stringocephalus* shells (B), Aïn Khira South at ca. 12 m.

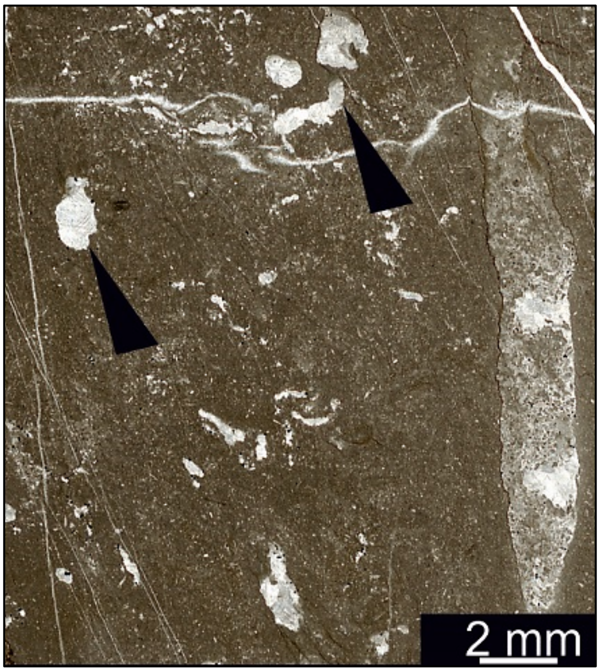


Fig. 12: MF A7, dense mudstone with fenestral (microbial) birdseyes (black arrows), AKS at 29 m.

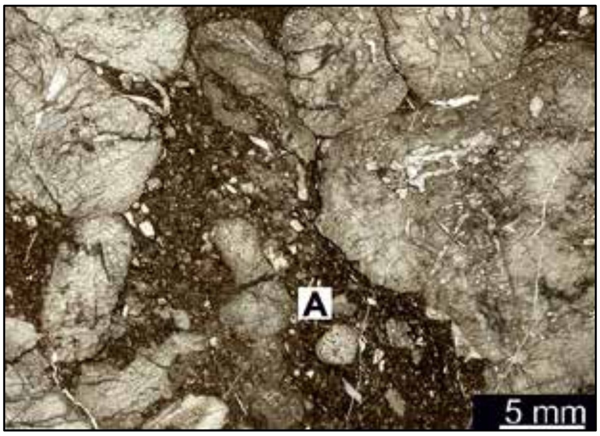


Fig. 13: MF A5, stromatoporoid float-rudstone: between bulbous stromatoporids lie delicate *Amphipora* (A)-rich mud seams. Irregular component contacts create a stylobreccioid structure, Aïn Khira South at 56 m.

Fig. 14: Field example of a weathered *Amphipora* rud-bafflestone (MF A6) from Aïn Khira South.

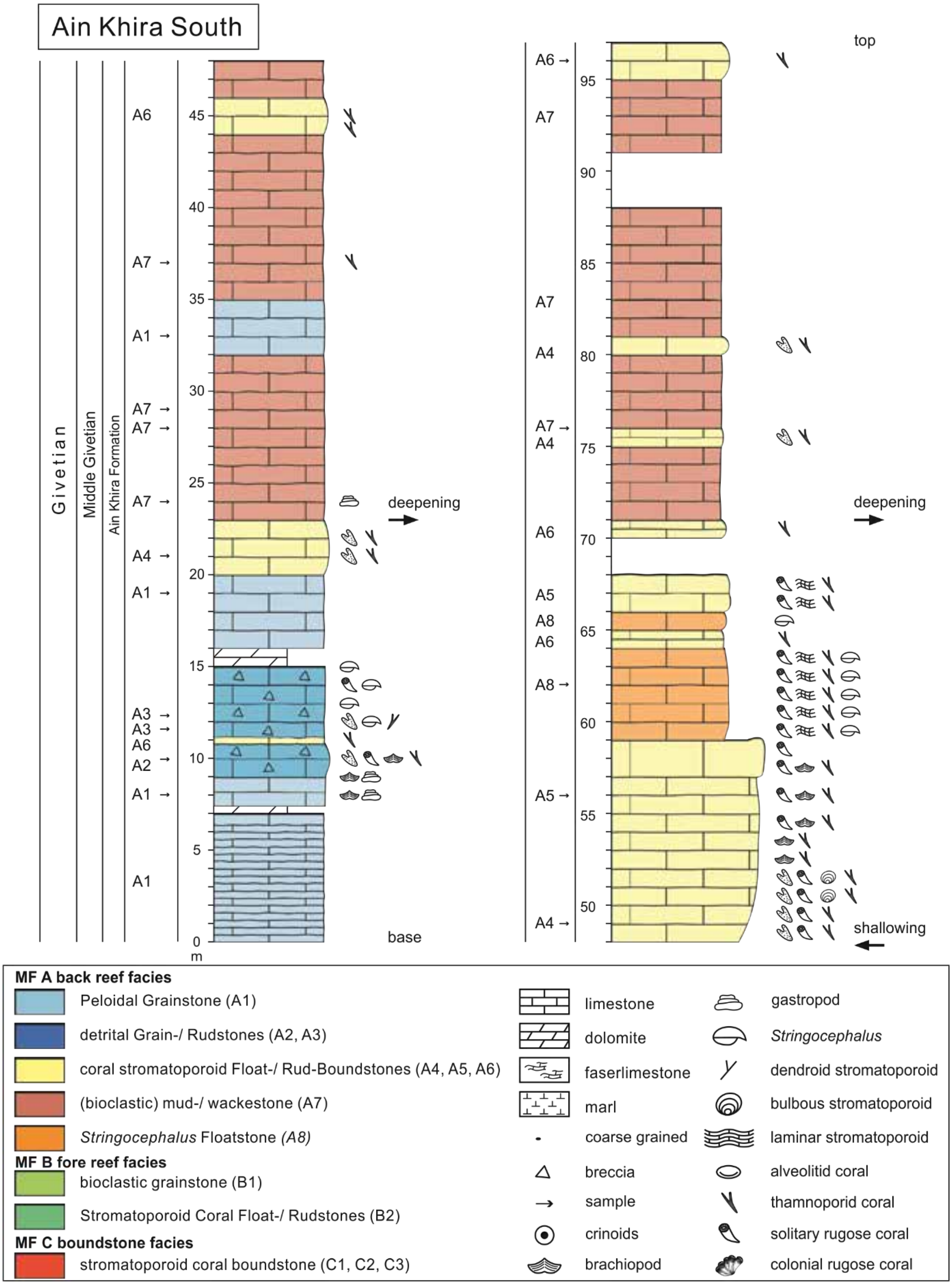


Fig. 15: Inner platform macro- and microfacies succession at Aïn Khira South, based on logging in 2012. Two transgressive episodes but no cyclicity are evident (EICHHOLT & BECKER 2016, fig. 9)

4.2. Pragian to Famennian at Aïn Dhakla

CHALOUAN & HOLLARD (1979) and CHALOUAN (1981) published a geological cross-section from the Beni Moussi/Aïn Dhakla area W of the Oued Cherrat (Fig. 17) to Cakhrat-ach-Chleh (Fig. 1) on the eastern side. This includes the type localities for the Pragian Aïn-ed-Dekhla, Emsian Dhar-es-Smene, and originally supposed Givetian (but also Emsian) Cakhrat-ach-Chleh Formations. Based on our re-sampling, the ca. W-E succession can be summarized as follows:

The shales of the Aïn-ed-Dekhla Formation at the western end are rather deeply weathered and often covered. ZAHRAOUI et al. (2000, fig. 4) illustrated a detailed section log for the increasingly calcareous Pragian/Emsian transition. Starting from the Aïn Dhakla spring at x = 349.2 and y = 340.85 (topographic sheet, 1 : 50 000, NI-29-XI-4b Benslimane), the new Beni Moussi Member consists of well-bedded, fossiliferous light- to medium-grey crinoidal and bioclastic limestones with many chert nodules. In the higher part there are frequent phacopid trilobites and some gastropods. Conodont samples from this part were, unfortunately, barren.

There is a gradual transition towards the massive, thick- or non-bedded, biostromal Cakhrat-ach-Chleh Member. A middle-grey, fine-grained crinoidal limestone from the base yielded a rich conodont fauna with *Caudicriodus celtibericus* (Figs. 18.12-13), *Lat. bilatericrescens multicostatus* (Figs. 18.14-15), and the single-cone species *Neopanderodus perlineatus* (Fig. 18.16). This assemblage is typical for shallow settings of the *Lat. bilatericrescens bilatericrescens* Zone in the ca. lower half of the lower Emsian (see ABOUSSALAM et al. 2015). The subsequent, light-grey, thick and massive reefal blocks are partly rich in stromatoporids and alveolitids. Gastropod limestones, beds with small brachiopods, and fine-grained bioclastic limestones to mudstones are intercalated. Towards the top there is a strong increase of dolomitization, which destroyed the fossil content.

The upper part of the lower Emsian reef is cut off by a normal fault. Many big dolomitized blocks lie on the slope of the plateau E of the fault (Fig. 16). Due to poor outcrop, it is not really clear if they only cover the slope or whether they are embedded in a shale matrix. CHALOUAN (1981) placed the subsequent, very thick, first brownish weathering, then green shales (Figs. 16, 19), which weather in small, narrow ravines, in his d_2 ("Siegenian argillites"). However, the shales are unfossiliferous, unlike the typical Aïn-ed-Dekhla Formation. Unlike as in the W, they grade on the next hill to the E into cross-bedded sandstones and reddish dolomite beds (Fig. 20).

A single slab of "Orthoceratid Limestone" from the base of the problematical shales yielded single Pa-elements of *Ancyrodelloides transitans* (Fig. 21) and *Wurmiella* sp. (possibly a new species with arched low carina and narrow, triangular basal cavity). The first is the index species for the *Anc. transitans* Zone in the lower half of the middle Lochkovian; it does not range above the middle Lochkovian (e.g., CORRADINI & CORRIGA 2012; VALENZUELA-RÍOS et al. 2015). Although the limestone block is alien to the thick green hales, it leads to the suspicion that at least large parts of the shale unit are of Lochkovian age. This has to be resolved by palynological data (Fig. 19).

Fig. 16: View on the blocky, reefal part (Cakhrat-ach-Chleh Member, d_{3u}) of the Dhar-es-Smene Formation (upper left) at Aïn Dakhla, followed after a fault contact by deeply weathered, brownish, possibly Lochkovian shales, which are partly covered by dolomitized reef blocks (to the upper right).

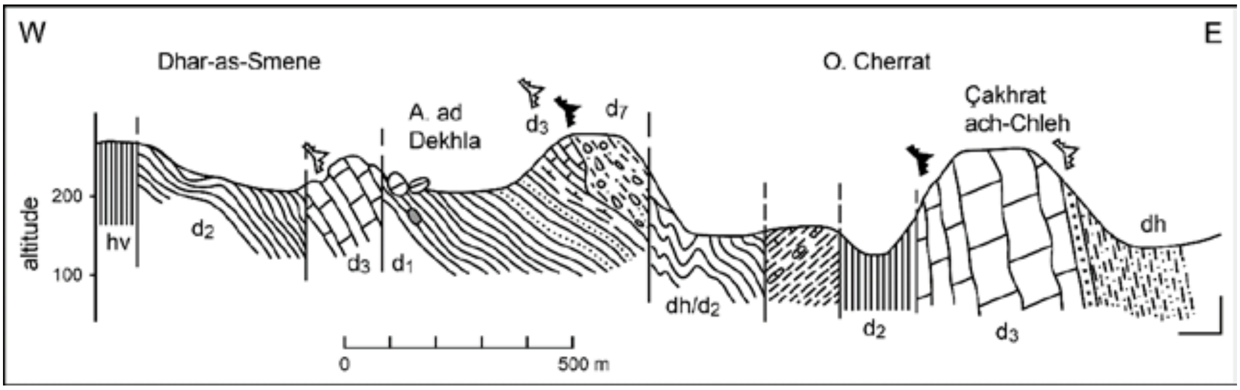


Fig. 17: Revised stratigraphy of the transsect from Beni Moussi and Dhar-es-Smene in the W to the eastern slope of the reef cliff at Cakhrat-ach-Chleh (middle Oued Cherrat region, updated from CHALOUAN & HOLLARD 1979).

The plateau with a quarry and small settlement between Dhar-es-Smene and the Cherrat valley to the E exposes banks of crinoidal to biostromal limestone (Fig. 22), which CHALOUAN & HOLLARD (1979) assigned to d_3. Two conodont samples were barren, which is typical for the upper Dhar-es-Smene Formation. Downslope and on the next hill E of the sandstones mentioned above, there is a thick succession of grey shales and siltstones (Al Brijat Formation, Fig. 22) with intercalated accumulations of isolated, up to 2 m large limestone olistolites and massive, compact limestone breccias (Figs. 7, 23). This 10-20 m thick unit, a tongue of the Aïn-al-Aliliga Formation, (d_{7-3}) can be followed downslope to the main road, where the number of reworked blocks decreases. Among the olistolites, middle to dark grey crinoidal limestones are dominant.

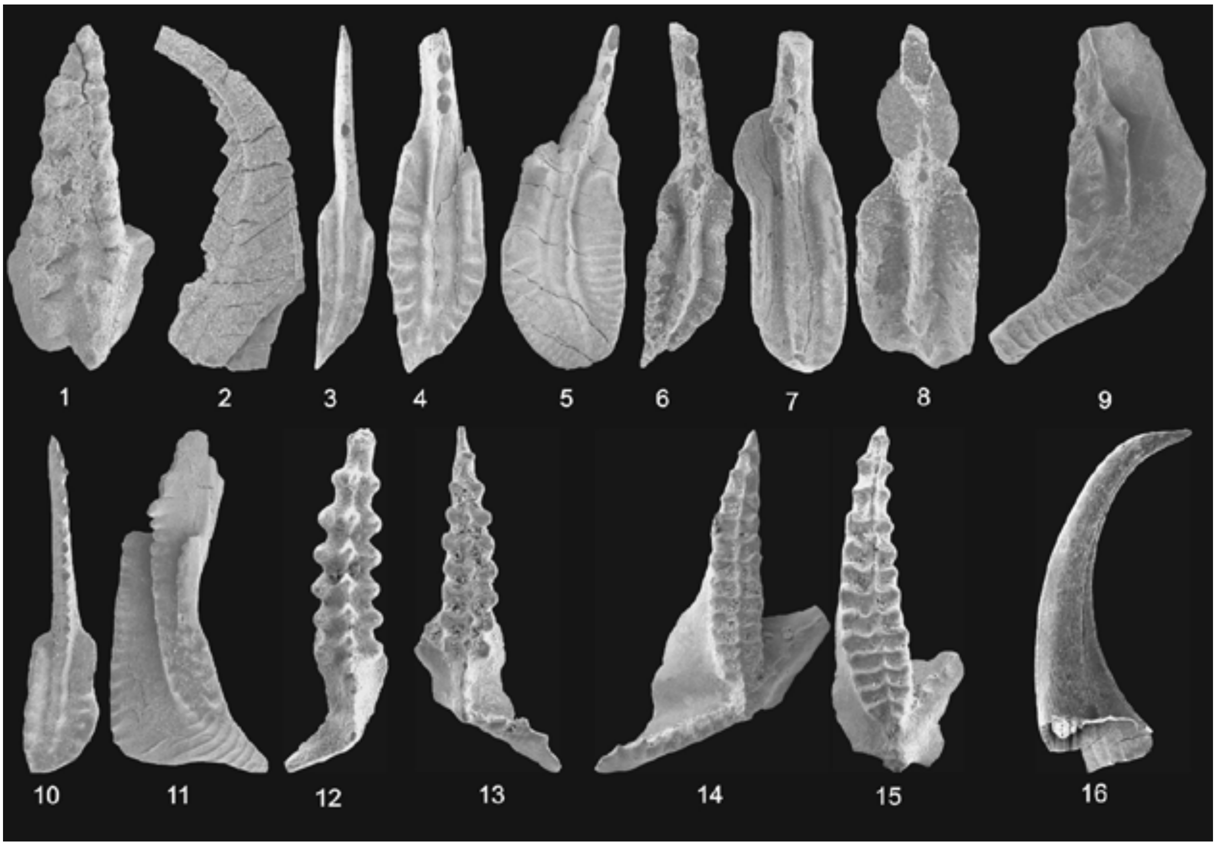


Fig. 18: Conodonts from a double reworked breccia (1-8) and from other olistolites (9-11) within the Al Brijat Formation (dh) at the eastern summit W of the Oued Cherrat, and from the basal Cakhrat-ach-Chleh Formation at Aïn Dakhla (12-16, d_{3u}) **1.** *Icriodus retrodepressus*, x 45; **2.** *Belodella resima*, x 80; **3.** *Polygnathus* aff. *xylus*, with narrowly angular posterior platform end, x 65; **4.** *Po. paradecorosus*, x 75; **5.** *Po. costatus*, x 30; **6-7.** *Po. timorensis*, x 50 and x 60; **8.** *Po. varcus*, x 50; **9.** *Linguipolygnathus klapperi*, x 30; **10.** *Po. ansatus*, x 40; **11.** *L. linguiformis*, x 35; **12-13.** *Caudicriodus celtibericus*, x 80 and x 50; **14-15.** *Lat. bilatericriodus multicostatus*, x 35 and 55; **16.** *Neopanderodus perlineatus*, x 55.

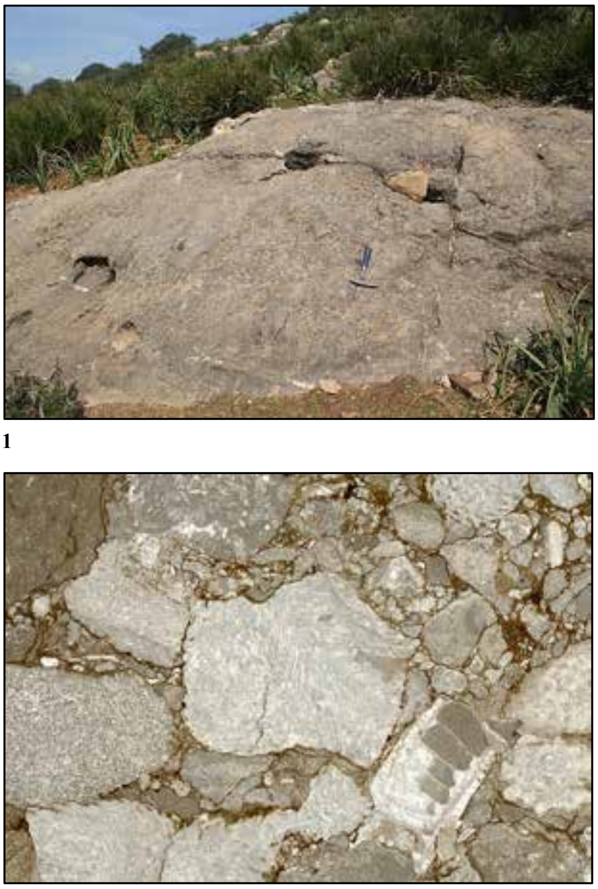
Sample S2 yielded lower Givetian conodonts (*Linguipolygnathus klapperi*, Fig. 18.9, and *L. linguiformis*, Fig. 18.11), Sample S3 *Po. ansatus* (Fig. 18.10), the index species of the *Po. ansatus* Zone in the upper half of the middle Givetian. A double reworked breccia block (Fig. 23.2) displayed the very heterogenous nature of a strongly unsorted and angular clast assemblage. There are reworked dark-grey mudstones, middle-grey bioclastic wackestones, partly with irregular, microbial fenestrae, peloidal grainstones, coarse, bioclastic crinoid rudstones, and isolated fragments of different species of tabulate corals (thamnoporids, *Roseoporella*). Most clasts are in diagenetic dissolution contacts with thin brownish, sideritic or goethitic seams. Such a breccia produced a mixed conodont fauna, consisting of Eifelian (*Po. costatus*, Fig. 18.5, *Icriodus retrodepressus*, Fig. 18.1) and lower/early middle Givetian taxa (*Po. timorensis*, Figs. 18.6-7, *Po. varcus*, Fig. 18.8, and *Po.* aff. *xylus*, Fig. 18.3), in association with the long-ranging *Belodella resima* (Fig. 18.2). One specimen is identified as the top-Givetian to lower Frasnian *Po. paradecorosus* (Fig. 18.4). Reefal blocks typically do not have conodonts. Rud- and boundstones contain up to 20 cm large components, such as abundant tabulate corals (alveolitids, favositids, thamnoporids), stromatoporids, receptaculitids, brachiopods, and rare trilobite remains. There is no evidence of middle Frasnian to Famennian clasts.

Fig. 19: Outcrop of monotonous green shales (?Pragian) exposed along the road and on the lower slope below (SE) of the Dhar-es-Smene reef; with C. HARTKOPF-Fröder (Krefeld) sampling for palynomorphs.

Fig. 20: View from the main road from Aïn Dakhla to the E, showing the slope occupied by Lochkovian/Pragian shales, followed high on the next hill (Hill E) by sandstones.

Fig. 21: Conodonts from the "Orthoceratid Limestone" clast embedded in lower parts of the shale unit, E of the fault that cuts off the Dhar-es-Smene reef (see Fig. 16). Left: *Ancyrodelloides transitans* (blade length = 1.2 mm); middle-right: *Wurmiella* sp. (blade length = 1.47 mm).

Fig. 22: Well-bedded, grey crinoidal limestones exposed at the southern shoulder of the plateau between Dhar-es-Smene and the Oued Cherrat, interpreted by CHALOUAN & HOLLARD (1979) as an eastward re-occurrence of the Dhar-es-Smene Formation (d_3).



1

2

Fig. 23: Tongue of Aïn-al-Aliliga Formation within the Al Brijat Formation at the hill E of Dhar-es-Smene. **1.** Field photo of large, compact, very solid breccia mass exposed on the SE slope; **2.** Thin-section of breccia: polymict intraclast rudstone with unsorted, angular clasts, often in dissolution contact, and with only a small amount of brownish, iron-rich, fine matrix.

Our incipient analysis of the clast spectrum proves that an Eifelian-Givetian carbonate ramp, both with biostromes and adjacent open and deeper marine settings (polygnathid biofacies), once extended to the Aïn Dakhla region. It was obviously completely eroded by uplift after the middle/upper Givetian and then further reworked and re-sedimented in the upper Famennian (considering the sparse conodont data from Aïn-al-Aliga). The following thick shales and siltstones occupying the main eastern slope towards the Oued Cherrat probably represent the upper Brijat Formation, not the Aïn-ed-Dakhla Formation, as shown in the cross-section of CHALOUAN & HOLLARD (1979; Fig. 9).

4.3. Cakhrat-ach-Chleh region

The Cakhrat-ach-Chleh Member extends from its type locality northwards to an active quarry at Kaf al Baroud and from there, across the winding piste coming from Aïn Dakhla, to the central elevation of Mechra al Kraker (Fig. 1). We sampled and measured the section along the northern slope of the road, just opposite to Mechra al Kraker, at x = 350.7, y = 342.1 (Fig. 24). The bedding is steep, vertical or slightly overturned.

Since CHALOUAN & HOLLARD (1979) assigned the Cakhrat-ach-Chleh Formation to the Givetian, we were surprised to find unequivocal lower Emsian conodonts at the formation base (ABOUSSALAM et al. 2012, 2013). The record of *Lat. bilatericrescens bilatericrescens* (Fig. 25.1.), associated with *Bel. resima* (Fig. 25.2), resembles the *Lat. bilatericrescens* assemblage found at the base of the biostromal upper part of the Dhar-es-Smene Formation W of the Cherrat river. There is also no principle difference in the macrofauna of both reef units: we did not encounter any stringocephalids or Givetian-type rugose corals at Kaf al Baroun.

The lower Cakhrat-ach-Chleh Member (previously formation) consist of different carbonate platform microfacies types (Fig. 26) which re-occur in distinctive episodes. There was no bioherm but a wide, storm- and current-influenced shallow platform with dominant crinoid forests in deeper and marginal parts and with low-relief coral-stromatoporid patch reefs, that sheltered areas dominated by branching forms (thamnoporids, *Stachyodes*). Recurrent large storms destroyed almost completely the in-situ record of reef builders. Typical lagoonal facies, such as *Amphipora* or microbial limestones, are rare or missing. Our comprehensive section logging (at meter scale) established the following succession characterized by minor sea-level change and lateral shifts of patch reef construction (with some identifications my A. MAY, Unna; compare MAY 1993, 2005).

Base (0-3 m): middle-grey, variably coarse (pack- to rudstone), detrital crinoidal limestones; typical microfacies (Fig. 26.1): strongly recrystallized, flaser-bedded, crinoid-intraclast rudstone; storm-swept, open neritic, marginal, deeper platform setting with crinoid forests and an influx of open marine organisms (conodonts).

4-5 m: level with phaceloid rugose corals; subtidal patch reef.

5 m-A: fine-grained, recrystallized, micritic to microsparitic, bioturbated dacryoconarid packstone with fine and large pyrite aggregates (Fig. 26.2); short-termed deepening causing an intercalation of pelagic or at least deep neritic facies.

5 m-B: biostromal limestone with blocky stromatoporids (*Stromatoporella* sp.), laminar alveolitids (*Squameoalveolites?*), chaetetids, brachiopod debris, and solitary Rugosa; microfacies: stromatoporid-coral rudstone with fragmented crinoids and dark, brownish micrite matrix (Fig. 26.3); storm-influenced biostrome core.

Fig. 24: Well-bedded crinoidal limestone at the base of the Cakrat-ach-Chleh Member on the northern slope of Kaf al Baroun, which yielded typical lower Emsian conodonts.

13 m: light-grey to reddish, thick-bedded storm beds; microfacies: partly dolomitized grain-rudstone with large brachiopod fragments, intraclasts, crinoid and stromatoporid debris (Fig. 26.4); tempestitic biostrome platform.
14 m: light-grey, detrital crinoid limestone; deeper platform influenced by storms.
20 m: light grey or reddish-grey crinoid-reefal debris with thamnoporids; minor shallowing of platform.

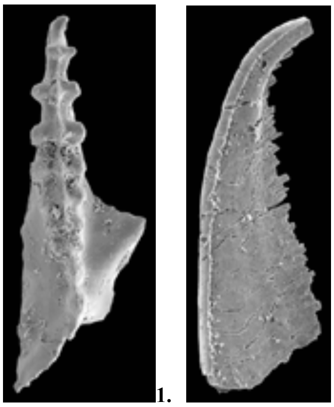


Fig. 25: Conodonts from the base of the Cachrat-ach-Chleh Member at Kaf al Baroun E of the Oued Cherrat. **1.** *Lat. bilatericrescens bilatericrescens*, **2.** *Bel. resima*.

22 m: light-grey reefal debris with crinoids, tabulate and solitary rugose corals; storm-ridden biostrome platform.
24 m: middle- to dark-grey stromatoporid and coral limestone; microfacies: *Stachyodes-Thamnopora* floatstone with some nodular stromatoporids; moderately protected reef patch on the platform.
30 m, increasingly coarse crinoid limestones; shallowing-upwards of deeper platform with crinoid forests.
50 m: laminar stromatoporids; biostrome core.
52 m: *Amphipora* floatstone with dense, micrite to microsparite matrix (Fig. 26.5); protected platform depression.
53-59 m: light-to middle grey crinoid limestone; deeper platform with storm-destructed crinoid forests.
60 m: middle-grey, detrital limestone with crinoids and alveolitids; microfacies: wacke-floatstone with fine shell debris, small, rounded tabulate coral clasts, very fine, reddish dolomite, and partly washed out micrite matrix (Fig. 26.6); storm-and current-influenced, moderately deep platform.
61-62 m: middle-grey, fine-grained crinoid limestone; deeper platform.
63-64 m: middle- to dark-grey Tabulata (*Scoliopora* sp.)-stromatoporid (*Stachyodes* sp.) limestones; microfacies: stromatoporid-coral floatstone with

subrounded reef builder clasts, shell filaments, and dark micrite to calcisiltite matrix (Fig. 26.7); moderately protected platform near a patch reef.
65-77 m: middle- to dark-grey crinoid limestones, occasionally with stromatoporids (69 m); longer-lasting episode of platform drowning with storm-ridden crinoid forests.
78 m: dolomitized *Stachyodes* baffle-rudstone; moderately protected platform near a patch reef.
80-84 m: middle grey, partly reddish-grey crinoid limestones; deeper platform.
84-85 m: reddish *Stachyodes* limestone; microfacies: *Stachyodes* rudstone with stylolithic clast contacts and fine, pyritic micrite matrix (Fig. 26.8); moderately protected reef patch.
86-88 m: reddish crinoid limestone; deeper platform.
89-91 m: middle- to dark-grey micritic limestone; platform drowning (?), but without influx of open water organisms.
92 m: detrital crinoid limestone; drowned/deeper platform.

At the eastern end, the limestones are sharply cut off by a fault; the biostrome extinction patterns cannot be studied. The following silty shales and laminated, micaceous siltstones belong to the Al Brijat Formation, possibly to higher parts since we did not observe any limestone olistolites.

Fig. 26: Heterogeneous microfacies of the Cachrat-ach-Chleh Emsian reef platform. **1.** Coarse, strongly recrystallized, flaser-bedded, crinoid-intraclast rudstone with oblique running, post-sedimentary calcite vein, at 3 m, x 2.8; **2.** Dark, fine-grained, recrystallized, micritic to microsparitic, bioturbated dacryoconarid packstone with fine and large pyrite aggregates, at ca. 5 m, x 2.4; **3.** Stromatoporid-coral rudstone with chaetetids, some fragmented crinoids and dark, brownish micrite matrix, at ca. 5 m, x 1.9; **4.** Coarse, partly dolomitized grain-rudstone with large brachiopod fragments, intraclasts, crinoid and stromatoporid debris, at 13 m, x 2.4; **5.** *Amphipora* floatstone with dense, micrite to microsparite matrix, at 52 m, x 2.7; **6.** Wacke-floatstone with fine shell debris, small, rounded coral clasts, very fine, reddish dolomite, and partly washed out micrite matrix, at 60 m, x 2.8; **7.** Stromatoporid-Tabulata floatstone with subrounded reef builder clasts, shell filaments, and black, micrite to calcisiltite matrix, at 64 m, x 1.7; **8.** *Stachyodes* rudstone with stylolithic clast contacts and fine, pyritic micrite matrix, at 85 m, x 2.

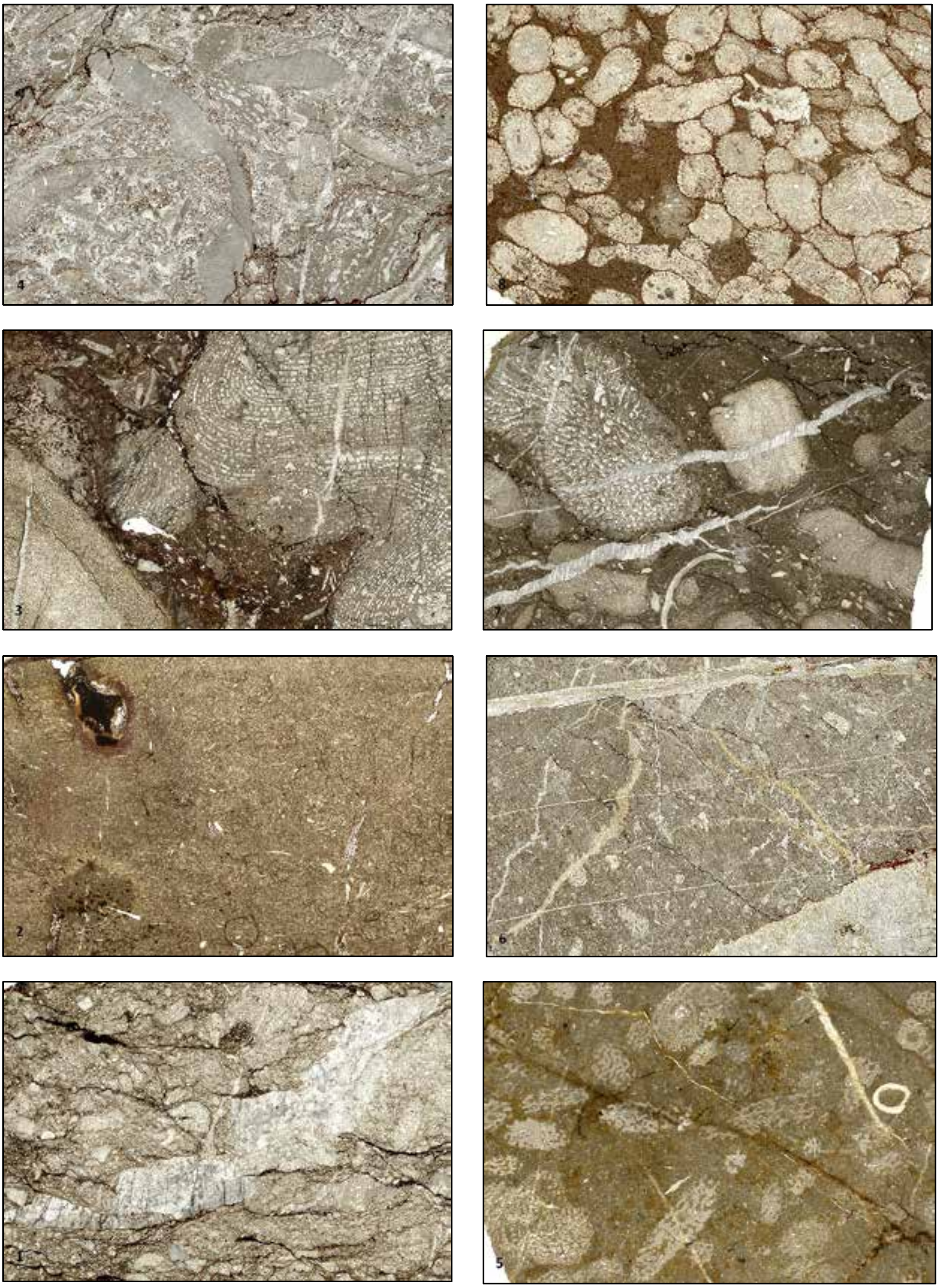


Fig. 26

Fig. 27: Thick-bedded alternation of basal Frasnian limestone breccias and biostromal limestone at the type locality of the Lower Member of the Aïn-al-Aliliga Formation.

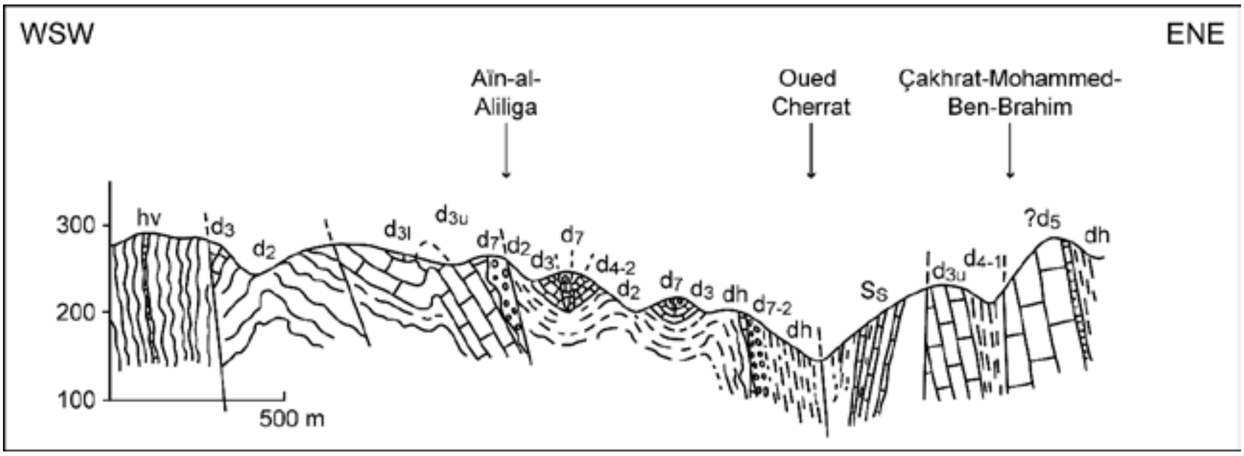


Fig. 28: Geological cross-section from the area W of Aïn-al-Aliliga to Cakhrat Mohammed-Ben-Brahim in the E; for detailed explanation see text (updated from CHALOUAN 1981, fig. 4); d_2 = Pragian, d_3 = lower Emsian, d_{4-1} = upper Emsian, d_{4-2} = Eifelian, d_5 = Givetian, d_7 = upper Famennian, dh = upper Famennian/Tournaisian, hv = Viséan).

4.4. Pragian to Famennian at Aïn-al-Aliliga to Cakhrat Mohammed-Ben-Brahim

The locality name Aïn-Al-Aliliga stands for a ca. W-E running secondary valley starting on topographic sheet Benslimane, 1 : 50 000, just E of the asphalt road coming from Beni Moussi in the N, or just N of Dayet ach Choum. Following the 'piste' eastwards, which has been much improved in 2015, there is the Aïn-Al-Aliliga spring at ca. x = 350.55, y = 337.05 (GPS N33°37'16.3'' W007°00'48.9''). From there, the track winds down to the Oued Cherrat, where it takes a sharp turn, reaching the bases of the two massive limestone units of

Cakhrat Mohammed-Ben-Brahim (the first at ca. x = 351.5, y = 337.75). Our detailed logging and re-sampling followed the cross-section of CHALOUAN (1981, fig. 4), resulting in stratigraphic revisions and improvements (Fig. 28). We did not study the Viséan and Pragian strata W of Aïn-Al-Aliliga (Fig. 28).

4.4.1. Beni Moussi Member

At the western end of the widely visible limestone outcrop (GPS N33°37'17.0'' W007°01'09.2''), there is a ca. 20 m thick succession of medium- to dark-grey, well-bedded, solid, neritic limestones with crinoid debris, poorly reserved phacopids, brachiopods, receptaculites (Fig. 28), and common chert nodules, the Beni Moussi Member of the Dhar-es-Smene Formation (d_{3u}). A typical microfacies are peloidal, bioclastic mud-wackestones (Fig. 30). Conodont samples were barren. Therefore, the position of the Pragian/Emsian boundary is locally unknown, especially with respect to the currently open stage boundary definition (current Zinzilban GSSP definition versus the proposed new level at the entry of *Eolinguipolygnathus excavatus* M114; see discussion in CARLS et al. 2008, 2009).

4.4.2. Cackrat-ach-Chleh Member and Lower Member of the Aïn-Al-Aliga Formation

There is a gradual transition into the massive boulders of the thick, poorly studied lower Emsian reef (Cakhrat-ach-Chleh Member, Fig. 31). It occupies as an anticline the top of the northern hill, where it is increasingly exploited by a new quarry. In the woody SE slope, it is sometimes difficult to locate precisely the boundary between the Emsian reef complex and the overlying Aïn-Al-Aliga Formation. Controlled by folding and faulting, the latter cuts down variably into the Beni Moussi or Cakhrat-ach-Chleh Members.

The Lower Member of the Aïn-Al-Aliga Formation begins with distinctive, thick, polymict limestone conglomerates and breccias (Figs. 32-33) that show neither sorting nor grading. Uplift and erosion of a local carbonate platform occurred after lithification; many clasts show cut off corals. There must have been a long period of erosion that reached down into different units, as represented by black (lagoonal) mudstones, middle-grey crinoid limestones, and middle-grey coral-stromatoporid float-rudstones (Fig. 33). At least partially, recurrent reworking in a nearshore high-energy setting led to clast rounding prior to re-deposition. The matrix is a brownish dolomite-siderite mud. It suggests that the unit originated in a nearshore setting with incipient evaporation and the accumulation of fine, iron-rich terrestrial mud. During the seismically triggered downslope transport, the mass flow picked up isolated tabulate corals and branching stromatoporids (*Stachyodes*). Their fragments lie free in the matrix, next to fragmented reefal limestone clasts (Fig. 33). These corals and sponges lived shortly before or at the time of the seismic event. Matrix lamination may be the result of current-induced winnowing after the main re-deposition event.

Fig. 29: Field photo of a limestone slab with a large, eroded *Receptaculites* (total diameter = 11 cm; problematical thallus of green algae), upper part of Beni Moussi Member at Aïn-Al-Aliliga.

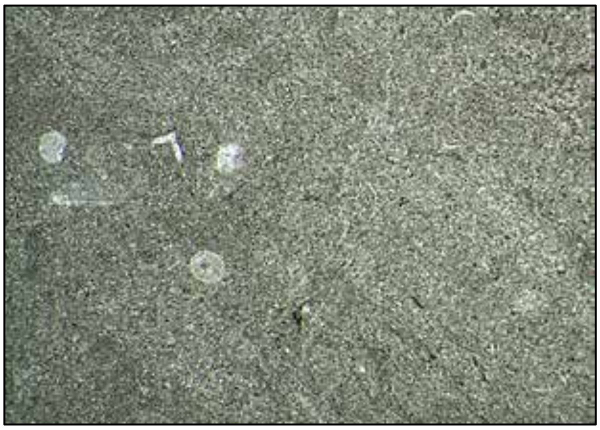


Fig. 30: Rather monotonous peloidal mudstone with some crinoid debris from the upper Beni Moussi Member at Aïn-Al-Aliliga.

Fig. 31: Massive reef boulders of the Emsian Cakhrat-ach-Chleh Member at Aïn-Al-Aliliga (slope NW of spring), view from the W-E track.

Fig. 32: Coarse, unsorted breccia (mass flow deposit) from near the base of the Lower Member of the Aïn-Al-Aliliga Formation (basal Frasnian). Clasts are angular to subrounded, light-grey weathering limestones embedded mostly without contact in a brownish, non-calcareous matrix (picture width = 13 cm).

Fig. 33: Polished section of the same slab as in Fig. 31, showing the heterogeneity of limestone clasts: dark-grey mudstones (lower part, partly rounded), medium-grey crinoid limestones (wacke-packstones, middle to upper part), coral-rich float-rudstones, and isolated tabulate corals (alveolitids, thamnoporids). The fine dolomite-siderite matrix is laminated in the upper part.

Fig. 34: Slab of bluish *Stachyodes* floatstone from the Lower Member, typical for a shallow lagoonal setting.

Fig. 35: Floatstone with isolated, silicified rugose and tabulate corals from the middle, non-brecciated biostromal limestone within the Lower Member of the Aïn-Al-Aliliga Formation.

Fig. 36: Medium-sized *Heliolites* colony from the Lower Member of the Aïn-Al-Aliliga Formation, typical for Givetian reefs (picture width ca. 10 cm).

Fig. 37: Silicified *Phillipsastrea* colony from the Lower Member of the Aïn-Al-Aliliga Formation, index rugose coral for the Givetian/Frasnian (picture widths 5 cm).

Fig. 38: Large, silicified alveolitid coral from the Lower Member, Aïn-Al-Aliliga Formation (picture width 15 cm).

The more than 50 m thick Lower Member consists of two boulder units with breccias and a bedded middle interval with silicified coral-brachiopod limestones (Fig. 35) and detrital, dark-grey, autochthonous limestones that resemble the inter-reefal Flinz limestones of the Rhenish Massif. We observed the following facies types:

a. well-sorted crinoidal grainstones with syntaxial cements (Eichholt & Becker 2916, fig. 7a, MF B1a) – crinoid meadows
b. bioclastic crinoid grainstone with brachiopods and solitary Rugosa, often silicified – biostrome margin
c. brachiopod-solitary Rugosa floatstone, often silicified (Eichholt & Becker 2016, fig. 7e, MF C1) – biostrome margin
d. coral floatstone with thamnoporids, alveolitids, laminar stromatoporids, and solitary Rugosa, often silicified (Fig. 34, MF C3) - biostrome
e. *Stachyodes-Thamnopora* floatstone (MF A7, Fig. 34) – protected inner biostrome or bioherm lagoon
f. gastropod floatstone – biostrome depression or lagoon
g. coral float-rudstone with tabulate (*Favosites, Thamnopora, Alveolites*) and rugose (*Phillipsastrea*) corals, sometimes silicified (Fig. 37) – storm affected biostrome to bioherm
h. coral-rich reef breccias (extraclast rudstones, Figs. 41.1-4) with Tabulata (MF B2b, *Heliolites*, Fig. 36, *Alveolites*, Fig. 38*, Thamnopora*, Fig. 41.3), bulbous or laminar stromatoporids (up to 20 cm large), and solitary Rugosa (Fig. 41.1) – seismically shocked biostrome (in-situ brecciass) and proximal mass flows on the upper slope of tilted block
i. crinoidal grainstones with reefal slump blocks – seismically shocked biostrome margin, receiving clasts from uplifted, tilted block
j. organic-rich mudstones - lagoon

The facies assemblage shows that there was a biostromal carbonate platform bordered by crinoid forests and brachiopod-rugose coral banks (see facies model of Eichholt & Becker 2016, fig. 6). The bulbous stromatoporids and common rudstones combined with some back-reef facies types indicate that a small bioherm with steep slopes and a sheltered lagoon developed eventually. Since most samples yielded at least some conodonts, an influx of open-water organisms persisted. In the lower part, icriodid-rich shallow-water conodont faunas are typical. The platform was strongly affected by syn- and post-sedimentary seismic shocks (block tectonics), leading to internal brecciation and the shedding of mass and debris flows from uplifted and tilted near-by areas. The polymict nature of the breccias (Figs. 41.1-4) shows that they do not represent "normal" marginal slope

debris flows of a bioherm. At the top of the Lower Member, a reworked polygnathid-dominated assemblage shows that outer ramp limestones started to be uplifted and eroded.

The age of the destructed carbonate platform can be assessed by the dating of individual blocks and of mixed faunas from breccia units (Tab. 1). The oldest breccias should provide the youngest age, the age of carbonates which were eroded first. This approximates the onset of Eovariscan reworking. None of our samples from the Lower Member includes any Famennian conodonts. The stratigraphically youngest taxon, indicating the basalmost Frasnian (MN 1 Zone), is an *Ad. rotundiloba pristina* from the "lower conglomerate" (Fig. 39). It is associated with *Po. webbi* and *Po. paradecorosus*, two species that straddle the Givetian-Frasnian boundary (e.g., ABOUSSALAM & BECKER 2007). Typical lower/middle Givetian *Linguipolygnathus* (*L. linguiformis* and *L. mucronatus*) show that some of the clasts derived from much older parts of the carbonate platform that pre-dated the global Taghanic Crisis (ABOUSSALAM 2003). This is supported by reworked *L. linguiformis* in younger conglomerates (Fig. 40.7). A second sample from the basal part of the Lower Member ("basal breccia") may be upper Givetian in age but all taxa found range into the basal Frasnian. Sample AAA is dominated by *Icriodus expansus* (56 %), followed by two morphotypes of *I. subterminus* (47.5 %, Fig. 40.1-2); *I. tafilaltensis* is present, too. The assemblage falls in the *I. subterminus* Zone sensu NARKIEWICZ & BULTYNCK (2010) but it is not possible to specify a subzone.

A sample from the main part of the conglomerate/breccias is rather species-rich, heterogeneous and heterochronous in nature. There are single cone taxa typical for very shallow reefal settings (*Belodella resima, Neopanderodus perlineatus*), a small amount of lower/middle Givetian forms (*L. linguiformis*, Fig. 40.7), middle/upper Givetian icriodids (*I. brevis*, 40.3, *I. difficilis*, Fig. 40.4, *I. expansus*,

Fig. 39: *Ancyrodella rotundiloba pristina* from the "lower conglomerate" near the base of the Lower Member of the Aïn-Al-Aliliga Formation (max. width = 0.43 mm)

Fig. 40.5, *I. tafilaltensis*, Fig. 40.6), long-ranging lower-upper Givetian polygnathids (*Po. xylus*, Fig. 40.11, *Po. varcus*, Fig. 40.10), and upper Givetian index polygnathids, such as *Po. ordinatus* (Fig. 40.12, *Po. paradecorosus, Po.* cf. *paradecorosus* (Fig. 40.9: approaching the platform size and ornament of *Avignathus decorosus*), and *Po. dengleri dengleri.* One specimen (Fig. 40.8) represents a still un-named new genus and species, which ABOUSSALAM (2003) illustrated as *?Skeletognathus* n. sp. from the top-Givetian *Skel. norrisi* Zone of the Montagne Noire. According to NARKIEWICZ & BULTYNCK (2010), the presence of *I. symmetricus* indicates that basal Frasnian clasts are present. Associated are agglutinating foraminifers (*Hyperammina, Thurammina, Tolypammina*), indicative for clasts from condensed sedimentation, intertidal ooids with polished surface, and pyritized juvenile bivalves, evidence for hypoxia – each representing completely different biofacies.

	Ain-Al-Aliliga Formation, Lower Member						**Upper Mbr.**		**Al Brijat Fm.**	
Conodont zones	**?MN 1**	**MN 1**	***subt.***	**MN 1**	**MN 1**	**Frasn.**	**Frasn.**	**(Fam.)**	***steinach.***	**L.Giv.**
Sample no.	**base breccia**	**lower cgl.**	**AAA**	**main cgl.**	**top reef**	**top dom.**	**Klotz**	**VFP**	**griotte**	**block**
Belodella resima	2			11	22	**6**		3		
Prionodina sp.	1									
Po. xylus	7	1		4			3	3		
Po. varcus	1			6	34					
Po. ovatinodosus	1									
Po. paradecorosus	**2**	3	1	17	82			623		
I. tafilaltensis	3		2	4	1?			94		
I. expansus	1		114	9				35		
Ling. linguiformis M δ1b		1		4			2			2
Ling. mucronatus		1								
Ad. rotundiloba pristina		**1**								
Po. webbi		1					?2	25		
I. subterminus Morph alpha			67					9		
I. subterminus Morph beta			30					23		
Neopand. perlineatus				7						
I. symmetricus				**3**			**1**	3		
I. difficilis				3						
I. brevis				2			2			
Po. cf. *paradecorosus*				3						
Po. dengleri dengleri				1						
Po. ordinatus				1				1		
N. Gen. n. sp.				**1**						
Po. aff. *xylus*					17					
I. n. sp. aff. *symmetricus*					9					
Po. aff. *paradecorosus*					1					
Po. timorensis							3			
Po. alatus								42		
Po. aff. *dubius*								16		
Po. pollocki								2		
Polygnathus sp. (pathol.)								1		
T. variabilis								6		
T. aff. *caelatus*								3		
Phoebodus gothicus								**x**		
T. aff. *weddigei*								2		
Caud. steinachensis									**3**	
Panderodus sp.									9	

Tab. 1: Range of conodonts and sharks in samples from the type Aïn-Al-Aliliga and olistolites within the Al Brijat Formation.

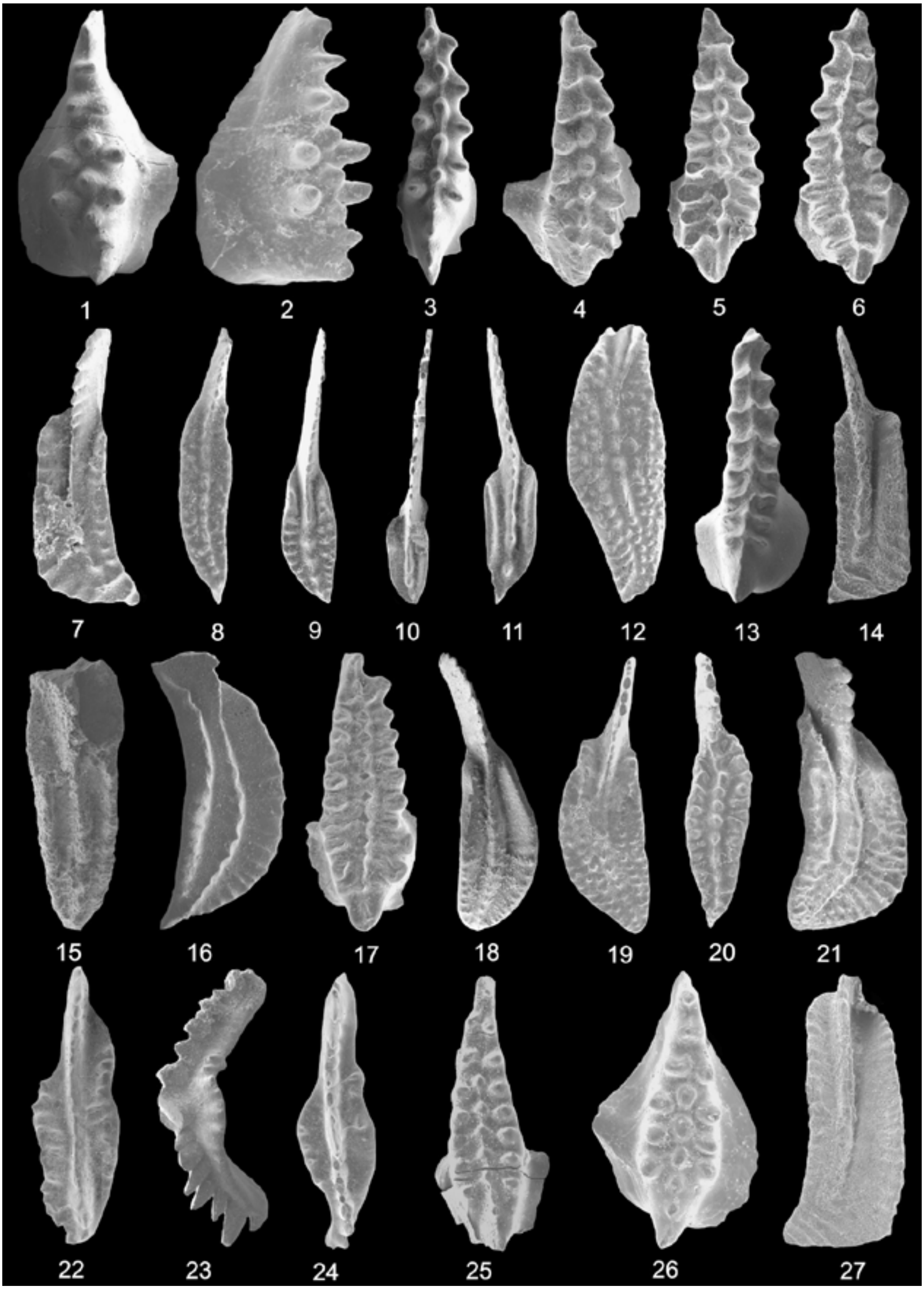


Fig. 40: Conodonts from Aïn-Al-Aliga, samples AAA (1-2), main conglomerate (3-12), "Klotz" (13-16), VFP (17-26), and Al Brijat (sample "block", 27). **1-2.** *I. subterminus*, x 90; **3.** *I. brevis*, x 85; **4.** *I. difficilis*, x 65; **5.** *I. expansus*, x 70; **6.** *I. tafilensis*, x 60; **7.** *L. linguiformis*, x 70; **8.** N. Gen. n. sp., x 60; **9.** *Po. paradecorosus*, with long free blade, transitional towards the Pa element of *Avignathus decorosus*, x 60; **10.** *Po. varcus*, x 55; **11.** *Po. xylus*, x 80; **12.** *Po. ordinatus*, x 45; **13.** *I. symmetricus*, x 60; **14.** *L. linguiformis*, x 70; **15.** *Po. timorensis*, x 85; **16.** *Po. webbi*, x 50; **17.**

I. tafilaltensis, x 55; **18.** *Po. alatus*, x 35; **19.** *Po. ordinatus*, x 40; **20.** *Po. pollocki*, distorted, x 45; **21.** *Po. webbi*, x 40; **22.** *T.* aff. *caelatus*, with partially free blade, x 35; **23.** *T.* aff. *weddigei*, x 40; **24.** *T. variabilis*, x 40; **25.** *I. expansus*, x 60; **26.** *I. subterminus*, x 85; **27.** *L. linguiformis*, x 50.

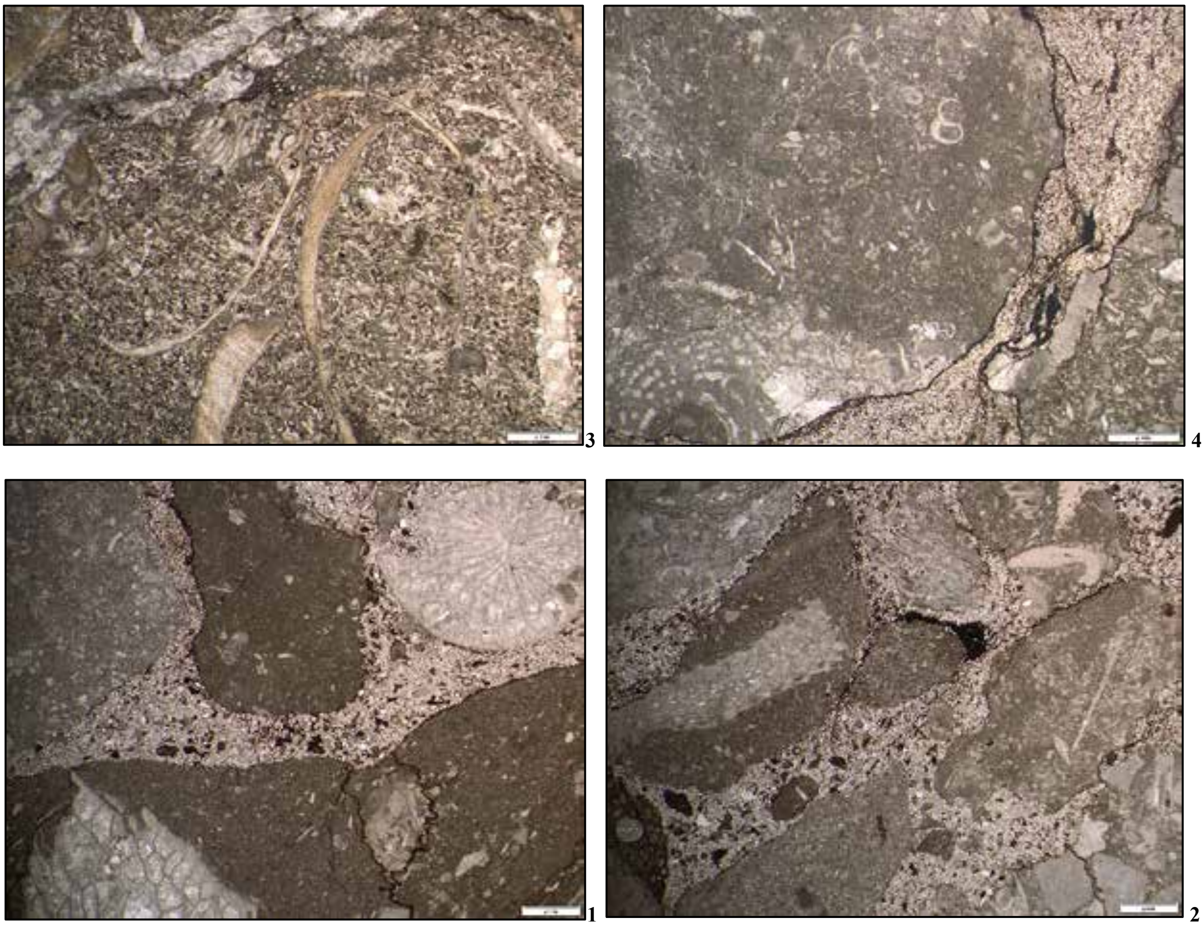


Fig. 41: Microfacies of breccia samples from the Lower Member of the Aïn-Al-Aliliga Formation; scale bar = 2 mm. **1.** Extraclastic rudstone with subrounded clasts of dark-grey bioclastic wackestone with gastropod (upper center), middle-grey bioclastic wackestone with crinoid debris (upper left), bioclastic coral floatstone with favositids (lower part), and an isolated solitary rugose coral, all sitting in a dense, unsorted, bioclastic packstone matrix, "Lower conglomerate" (MN 1 Zone); **2.** Extraclastic rudstone showing additional, mostly angular clast types, such as coarse crinoidal packstone (lower right), dark-grey intraclast pack-rudstone with a parathuramminid foraminifer (lower left, *Cribrosphaeroides (Parphia) robusta*), middle-grey bioclastic floatstone with a thamnoporid branch (middle left), and an isolated fragment of tabulate coral (upper center), "Lower conglomerate" (MN 1 Zone); **3.** Sparitic brachiopod-coral grain-rudstone with variably recrystallized, thin to thick brachiopod shells, thamnoporids, and other tabulate corals in a fine intraclast matrix, "main breccia" (basal Frasnian); **4.** Coarse extraclastic rudstone with clasts of middle-grey bioclastic wackestones rich in fine crinoid debris, small gastropods, and tabulate coral (perhaps *Coenites*, lower left), "basal breccia" (top-Givetian).

From the top of the middle, non-brecciated interval of the Lower Member comes a sample ("top reef") with some scolecodonts (typical for neritic limestones) and spherical "conodont pearls" (see Lindskog et al. 2017 for a recent discussion). Among the conodonts, *Po. paradecorosus* and *Po. varcus* are dominant. Associated are *I.* n. sp. aff. *symmetricus* sensu Schumacher (1971), *Po.* aff. *xylus* (with *Po. varcus*-type anterior basal pit), and *Po.* aff. *paradecorosus* (even more transitional towards *Av. decorosus*; with a long free blade and wider, flatter small platform than in typical *paradecorosus*). This fauna indicates a top-Givetian age for the clasts.

The combined evidence dates the first main episode of Eovarican uplift and reworking as top-Givetian to basal Frasnian. It is remarkable that there are no pre-Givetian clasts/conodonts. Erosion had not yet penetrated the Givetian carbonate platform. A younger age should have resulted in the presence of typical Frasnian or Famennian conodont assemblages. At the eastern end of the main Aïn-Al-Aliliga hill, the Lower Member is overlain by yellowish, thin-bedded dolomites without macrofauna that dip gently to the E. They yielded only belodellids (Tab. 1). This suggests a post-reefal calm, very condensed, and very shallow to slightly evaporitic sedimentation that was no younger than the Frasnian.

4.4.3. Upper Member of Aïn-al-Aliliga Formation

The typical Aïn-al-Aliliga Formation is exposed around the spring and characterized by up to 3 m large, rounded or angular clasts, abundant dark-grey weathering quartzites, light-grey volcanites, and mixed limestones (Fig. 42). The clast size decreases upwards, whilst dolomitization increases. One block ("Klotz") yielded a mixed conodont fauna with lower/middle Givetian (*L. linguiformis*, Fig. 40.14, *Po. timorensis*, Fig. 40.15, *Po. xylus, I. brevis*) and basal Frasnian species (*I. symmetricus*, Fig. 40.13, and *Po. webbi*, Fig. 40.16). A very rich and diverse conodont assemblage came from Sample VFP (Tab.1), collected just N of the track. It is by far dominated by *Po. paradecorosus* (70 %), followed by common (10.5 %) *I. tafilaltensis* (Fig. 40.17). There are various polygnathids of the Givetian-Frasnian transition: *Po. ordinatus* (Fig. 40.19), *Po. alatus* (Fig. 40.18), *Po. webbi* (Fig. 40.21), *Po.* aff. *dubius*, and *Po. pollocki* (Fig. 40.20). Lower/middle Givetian index species or even older taxa are absent. A minor content of tortodids (*T.* aff. *caelatus*, Fig. 40.22, *T.* aff. *weddigei*, Fig. 40.23, *T. variabilis*, Fig. 40.24) resembles the bloom of the genus in the Taghanic Crisis Interval at the middle/upper Givetian boundary (ABOUSSALAM 2003; ABOUSSALAM & BECKER, 2011). Three *I. symmetricus* indicate the basal Frasnian (NARKIEWICZ & BULTYNCK 2010).

The mixture of (only) upper Givetian/basal Frasnian and Lower Palaeozoic clasts is intriguing. It could be explained by the original transgression of an upper Givetian carbonate platform directly on an uplifted Lower Paleozoic block - prior to the second Eovariscan uplift. This aspect requires confirmation by further sampling: the search for clasts of other time intervals. We could not confirm the upper Famennian conodonts reported in CHALOUAN (1981). However, we found in Sample VFP five teeth of *Phoebodus gothicus gothicus* and four teeth of *Ph. gothicus transitans* (SCHWERMANN 2014). The first subspecies ranges in the Anti-Atlas from high in the lower Famennian (*Pa. glabra pectinata* Zone) to the upper Famennian (*B. costatus* Subzone). In Poland, it ranges even higher, until the global Hangenberg Event (e.g., GINTER & IVANOV 2000). The second subspecies was so far only known from the supposed middle/upper Famennian of Algeria (GINTER et al. 2002). The combined data show that the second regional Eovariscan reworking event occurred high in the upper Famennian.

4.4.4. Aïn-ad-Dekhla Formation

Down towards the Oued Cherrat, the western slope of the winding track exposes, after an obvious fault, Pragian fossiliferous silty shales (Fig. 44). There are very common trilobites, especially asteropygids (two species of *Metacanthina*, Fig. 43.2), homalonotids (*Wenndorfia,* Fig. 43.1), and *Odontochile*, as well as spiriferids, strophomenids (*Dalejodiscus* aff. *subcomitans*, det. U. JANSEN, Frankfurt a. M., Fig. 43.3), large ostracods (zygobeyrichiid, det. H. GROOS-UFFENORDE, Göttingen, Fig. 43.4), and solitary

rugose corals (HELLING & BECKER 2015; HELLING in BECKER 2015). As typical for the formation, fossils are stained by limonite. The neritic siliciclastic facies is in contrast with the subsequent shallow-water limestones. There must have been a change in the weathering regime and in the discharge of fine detritus, perhaps induced by a change from humid to arid conditions.

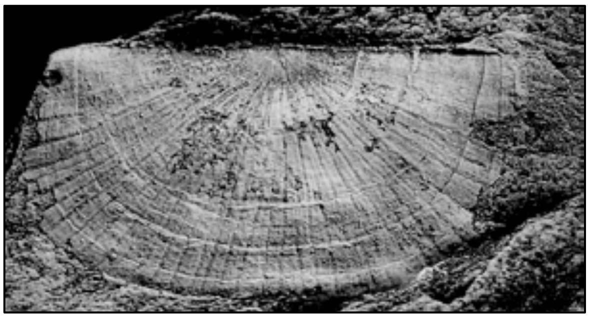
Fig. 42: Upper Member of the Aïn-Al-Aliliga Formation in outcrop (type locality), with unsorted, subrounded, polymict clasts.

4.4.5. "Central Section"

Around the next corner to the E, another fault delimits the Pragian shales and the dip changes, with beds becoming younger from E to W. This was not evident in the cross-section of CHALOUAN (1981), who suggested, instead, a syncline structure. Along the track lies our "central section", which ranges from the upper Pragian (Fig. 45) into the Eifelian (Figs. 48, 50). The basal, greenish-grey shale (Bed 1) belongs to the upper part of the Aïn-ad-Dekhla Formation. This is supported by some trilobites found in a shale package below (to the E). Bed 2 is a peculiar, 70 cm thick, dark-grey, massive but lenticular brachiopod floatstone (Figs. 45, 46). Apart from a few scolecodonts, it yielded a monotypic conodont fauna with *Caud*. cf. *curvicauda*. Typical representatives of the species and similar cf. specimens (without curved posterior end) range in the Anti-Atlas from the upper Pragian *Lat. steinachensis* Zone into the basal Emsian. Therefore, we place the brachiopod limestone close to the Pragian-Emsian transition. Since there is no change of bedding (Fig. 45), the contact to the overlying shale appears to be conformable (Beds 3 and 5, with limestone lenses = Bed 4). However, the overlying limestone (Bed 6, bioclastic wackestone, Fig. 50.1) yielded much younger conodonts from the lower-upper Emsian transition (Tab. 2). Where is the thick Dhar-es-Smene Formation? In the field we did not observe a fault (Fig. 45) but the lenticular nature of the brachiopod limestone is suspicious and indicates tectonic contacts. The fauna of Bed 6 includes common *Bel. resima,*

1

2



3

4

Fig. 43: Trilobites and brachiopods from the Aïn-ad-Dekhla Formation at Aïn-al-Aliliga. **1.** *Wenndorfia* sp., cephalon, length = 10.4 mm; **2.** Four cephala of *Metacanthina* n. sp.; **3.** Small strophomenid *Dalejodiscus* aff. *subcomitans* (Plectambonitoidea; det. U. JANSEN), width 12 mm; **4.** Large zygobeyrichiid (width = 6 mm).

Fig. 44: Trilobite-rich shales of the Aïn-ad-Dekhla Formation on the eastern slope at Aïn-al-Aliliga.

Fig. 45: Upper Pragian brachiopod limestone, followed conformably (?) by a shale unit (base of measuring stick), limestones with basal upper Emsian conodonts, and (above the stick) supposed Daleje Shale equivalents (Lower Member of Mohammed-Ben-Brahim Formation).

Fig. 46: Upper Pragian brachiopod limestone (floatstone), Bed 2 of "central section" at Aïn-al-Aliliga.

Neop. perlineatus, acrotetrids (minute, phosphatic, cone-shaped inarticulate brachiopods), and acanthodian dermal scales. Age diagnostic is *Latericriodus beckmanni sinuatus*, which enters in the Anti-Atlas in the *Lat. latus* Zone (upper part of lower Emsian), but it ranges into the upper Emsian (ABOUSSALAM et al. 2015). *Icriodus homorectus* first occurs in the basal upper Emsian *I. fusiformis* Zone.

The shales of Beds 3 and 5 and the 1.3 m thick greenish shale of Bed 5 are tentatively correlated with the Daleje Shales at the base of the upper Emsian. At the top is an up to 2 m large slump block (Bed 10) and evidence of faulting. It is followed by ca. 6.5 m (Beds 11-27a) of thin-bedded, bioturbated, macrofauna-poor nodular limestone and flaserlimestone. This unit, which has no other described exposure in the Oued Cherrat, is assigned to a new, local Upper Member of the Mohammed-Ben-Brahim Formation (Figs. 47, 49). Bed 13b is a trilobite floatstone (Fig. 50.2) with anarcestid cross-sections (Fig. 48). It also contains *Bel. resima* and *Caudicriodus culicellus culicellus* (Tab. 2). The latter is an alternative index species for the basal upper Emsian *I. fusiformis* Zone (GOUWY & BULTYNCK 2003; ABOUSSALAM et al. 2015).

Beds 27b–57b represent fine crystalline, macrofauna-poor calcisiltites that alternate with dark-grey shales. They are assigned to the Aïn Kheneg-en-Nmer Formation. Typical are dark-grey, detrital, weakly bioturbated mudstones with trilobite debris (Fig. 50.3), small shell filaments, or parathuramminids (Fig. 49.4). The latter are normally typical for Givetian lagoons (VACHARD et al. 1994; EICHHOLT & BECKER 2016) but may range into hypoxic open marine settings (see BECKER et al. 2016b for a Famennian example), As an exception, we collected a large *Favosites* colony in Bed 33. This tabulate coral genus is also known to range from reefal into deeper-water, muddy settings (e.g., POTTHAST & OEKENTORP 1987).

In the lower part, Bed 31 yielded *L. bultyncki*, an alternative index species for the upper Emsian *L. serotinus* Zone. It is more common in Morocco than the zonal name-giving species (ABOUSSALAM et al. 2015). In the middle and upper part (top Bed 31, Beds 45/46, Bed 55b) there is evidence for slumping and synsedimenary seismic instability but this is overprinted by the post-sedimentary tectonics. Bed 41 is rich in trilobite debris. The *L. serotinus* Zone ranges at least until Bed 50-3. Due to the still too crude sampling, the Emsian-Eifelian boundary cannot be fixed. There is no sedimentary expression of the global Choteč Event in the basal Eifelian. Bed 57b yielded a typical lower Eifelian conodont assemblage (*Po. costatus* Zone) with dominant single cones (*Bel. resima*, Fig. 51.1, *Neop. perlineatus*, Fig. 51.2), rare *Po. costatus* (Fig. 51.3) and *Po. zieglerianus* (Fig. 51.4). The conodont biofacies indicates a neritic setting but associated planktonic ostracods (entomozoids, Fig. 52) are more typical for a pelagic environment. A small shale/marl cliff (Bed 59) follows.

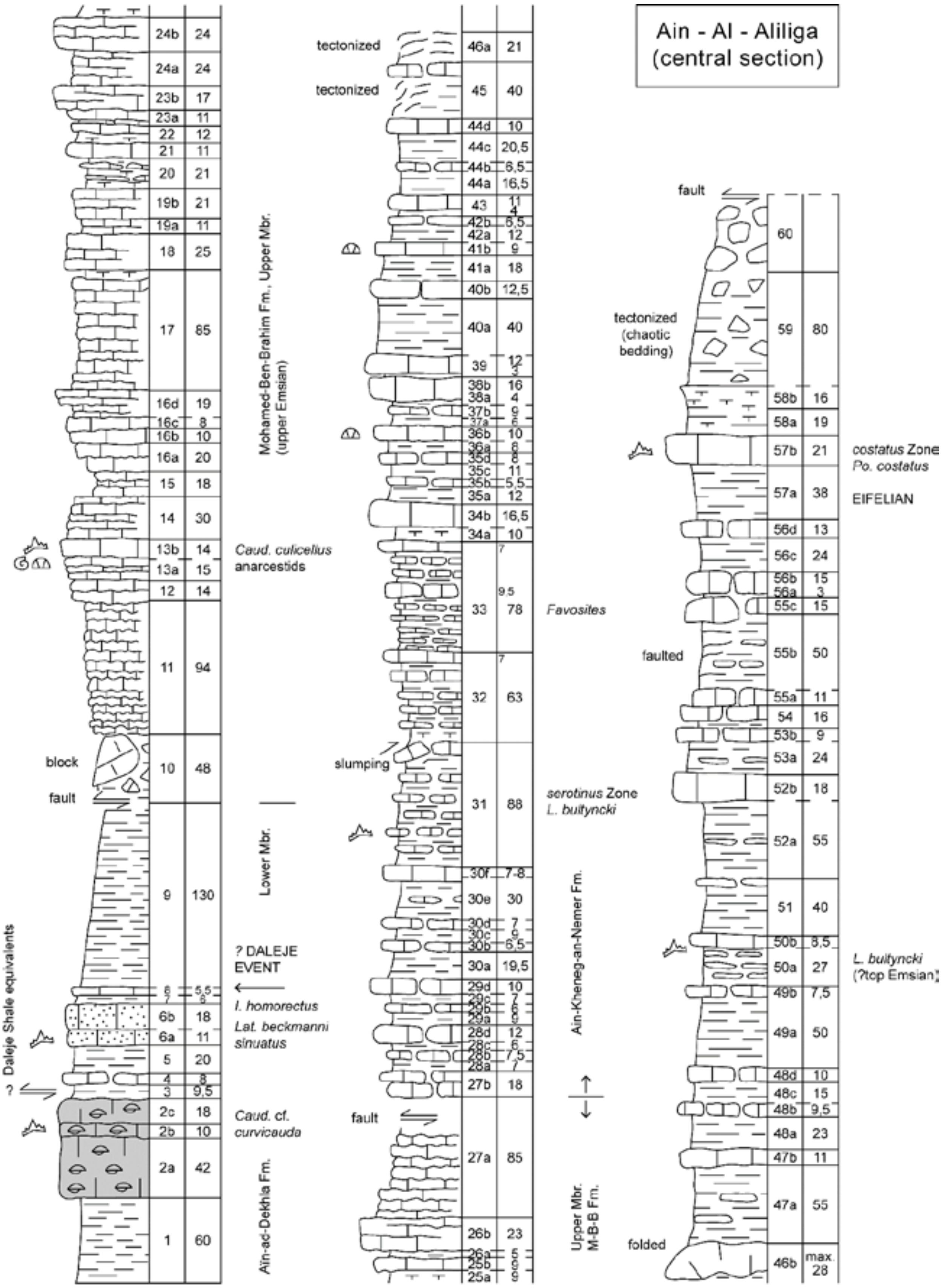


Fig. 47: Section log for the Emsian/Eifelian "central section" at Aïn-al-Aliliga showing the lithostratigraphy, slumping intervals, position and age of conodont samples, and the sparse macrofauna record.

Aïn-al-Aliliga, central section						
Conodonts zones	***steinachensis***	***fusiformis***		***serotinus***		***costatus***
Sample no.	**brachiopod lst.**	**base "Eif. lst."**	**Em 13**	**Em 31-2**	**Em 50-3**	**top D3**
bed no.	**2a**	**6a**	**13b**	**31-2**	**50-3**	**57-b**
Caud. cf. *curvicauda*	**32**					
Lat. beckmanni sinuatus		**5**				
I. homorectus		**5**				
Bel. resima		27	7	*	1	17
Neopand. perlineatus		10	*	1	*	9
Caud. culicellus culicellus			**15**			
Ling. bultyncki				**1**	1	
Po. costatus						**1**
Po. zieglerianus						1
total conodonts	**32**	**47**	**22**	**2**	**2**	**28**

Tab. 2: Conodonts from the "central section" at Aïn-al-Aliliga, illustrating the mysterious gap between top-Pragian and top lower Emsian limestones.

Fig. 48: Cross-sections of phacopids and an anarcestid in the Upper Member of the Mohammed-Ben-Brahim Formation at Aïn-al-Alilig (Bed 13b, picture width 7 cm).

The western end of the "central section" is characterized by irregular bedding and slumping (Fig. 53). Limestone beds disintegrated to bands of limestone blocks. This interval ranges to the fault zone that separates the Aïn-ad-Dekhla Formation (d_2) in the W.

4.4.6. Al Brijat Formation (dh)

CHALOUAN (1981) showed a second small syncline with limestones of the Dhar-es-Smene Formation (d_3) in his cross-section (Fig. 28). Limestones do not crop out along the track that winds down towards the Oued Cherrat. A fault zone separates greenish shales of the Aïn-ad-Dekhla Formation (d_2) from unfossiliferous, grey silty shales of the Al Brijat Formation (dh). On the gentle slope above the main curve to the E, close to the Cherrat river, the shales are deeply weathered and include numerous isolated olistolites. Dominant are reef limestone blocks with solitary Rugosa, *Thamnopora* and stromatoporids, crinoid limestones, and cannibalized (secondarily reworked) breccia clasts. One of the conglomerate block yielded two specimens of *L. linguiformis* (Fig. 40.27).

Fig. 49: New Upper Member of the Mohammed-Ben-Brahim Formation at Aïn-al-Aliliga, consisting of micritic, pelagic flaserlimestone.

This proves that parts of a lower/middle Givetian carbonate ramp were excavated and double reworked. In addition, there are laminated limestone concretions without conodonts. A single clast of light-grey griotte limestone (bioturbated bioclastic wackestone, Fig. 54) contained, surprisingly, three specimens of the upper Pragian index icriodid *Lat. steinachensis*. Associated are more common *Panderodus* and acrotetrid brachiopods. This deeper neritic, calcareous litho- and biofacies is in strong contrast to the ca. contemporaneous, siliciclastic Aïn-ad-Dekhla Formation to the W. Most likely, the clasts derived from a deeper neritic upper Pragian carbonate ramp that once existed E of the clastic shelf area. It may have been equivalent to the transitional limestones reported from Aïn Dakhla (CHALOUAN 1981; see 3.4.) but the biofacies is clearly different. It is unlikely that the “griotte” block was transported over a large distance.

4.4.7. Cakhrat Mohammed-Ben-Brahim

The main track follows the NW side of the Oued Cherrat. According to CHALOUAN (1981) the shales in this part are Silurian in age, which implies a steep fault separating them from the shales and siltstones of the Al Brijat Formation. The following area named as Cakhrat Mohammed-Ben-Brahim is marked by two steep cliffs with reef limestone, the first of which is in fault contact with the shales at its western end (Fig. 55). The general succession and geological structure of the area has first been documented by GENDROT et al. (1969).

Fig. 50: Mikrofacies of carbonates from the "central section" at Aïn-al-Aliliga; scale bar = 2 mm. **1.** Bioclastic wackestone with dense, fine, bioturbated micrite matrix, shell filaments and rare trilobite fragment,s Bed 6a, *I. fusiformis* Zone, basal upper Emsian; **2.** Bioturbated, nodular trilobite floatstone with partly microsparitic matrix and many dissolution seams, Bed 13b, *I. fusiformis* Zone, basal upper Emsian, Upper Member of Mohammed-Ben-Brahim Formation; **3.** Detrital, bioclastic mud-wackestone (calcisiltite) with trilobite debris and shell filaments, Bed 31-3, *L. serotinus* Zone, upper Emsian, basal Kheneg-an-Nmer Formation); **4.** Detrital, dark-grey mudstone (calcisiltite) with parathuramminid foraminifers (*Moravammina*, *Bisphaera*), Bed 57b, *Po. costatus* Zone, lower Eifelian, Kheneg-an-Nmer Formation.

Fig. 51: Conodonts from the lower Eifelian of the "central section" of Aïn-al-Aliliga (Bed 57b). **1.** *Bel. resima*, x 75; **2.** *Neop. perlineatus*, x 80; **3.** *Po. costatus*, x 80; **4.** *Po. zieglerianus*, x 85.

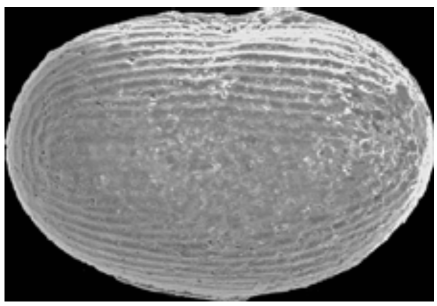


Fig. 52: Entomozoid ostracod from Bed 57b (lower Eifelian) of Aïn-al-Aliliga, "central section".

Fig. 53: Top part of the "central section" at Aïn-al-Aliliga showing poor bedding due to strong slumping, overprinted by the main Variscan tectonics.

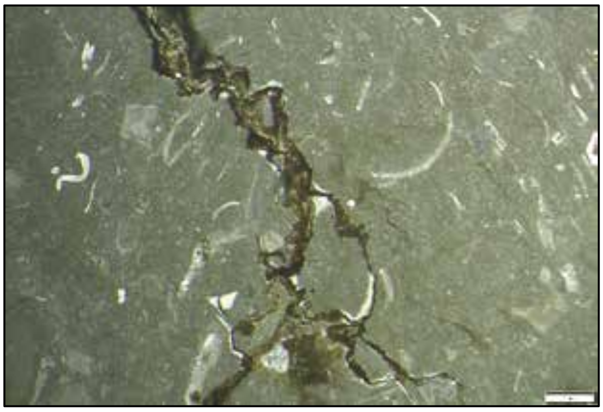


Fig. 54: Microfacies of the upper Pragian "griotte clast" found in the Al Brijat Formation at Aïn-al-Aliliga, a light-grey, bioclastic wackestone with trilobite, crinoid, and mollusk debris.

The Emsian "ensemble récifal inférieur" sensu GENDROT et al. consist of an anticlinal structure, complicated by faulting and secondary folding. Along the track, medium- to thick-bedded limestones of the Cakhrat-ach-Chleh Member stand near-vertical or dip variably steeply (with 80°) to the W and E (in the eastern part). Dominant are light- to middle-gray crinoidal limestones with only subordinate reefal organisms. The typical microfacies are bioclastic wacke-floatstones and calcisiltites (Fig. 56). GENDROT et al. (1969) separated a fore-reef slope setting in the W from dominant off-reef bank carbonates in the E. Two samples from the western and main part of the up to 130 m thick sequence yielded, in accord with the shallow litho- and biofacies, only single cone taxa (Sample R2 with six *Bel. resima* and acrotetrids, Sample S7 with six *Bel. resima* and six *Neop. perlineatus*).

Towards the eastern end, the track slope exposes an isolated giant stromatoporid with ca. 1 m diameter. It is overlain by well-bedded, bioclastic to increasingly nodular limestones. A sample from this interval yielded *Caud. celtibericus* (12 specimens), *Criteriognathus steinhornensis* (12 specimens), *Lat. beckmanni beckmanni* (two specimens), *Lat. bilatericrescens bilatericrescens* (four specimens), *Neop. perlineatus* (13 specimens), and, by far dominant, *Bel. resima* (90 specimens, 63 %). This assemblage is typical for the upper part of the lower Emsian (*Crit. steinhornensis* Zone or *Lat. latus* Zone of the icriodid zonation, ABOUSSALAM et al. 2015). The absence of polygnathids and the *Belodella* enrichment confirm a neritic environment.

The well-bedded top of the Dhar-es-Smene Formation is sharply overlain by reddish shales of the (main) Mohammed-Ben-Brahim Formation. This facies break represents regionally the global Daleje Event and transgression, which suddenly drowned the extensive lower Emsian carbonate platform. The squashed fauna consists of common goniatites (*Gyroceratites* sp., Fig. 57), orthoconic cephalopods, rare phacopids, and up to 8 cm large bivalves (*Panenka*). This assemblage is typical for a basal upper Emsian (LD IV-A) pelagic setting, as it is widespread in the eastern Anti-Atlas (Tafilalt, e.g., BECKER et al. 2018a, 2018b) or in the classical Daleje Shale region of Bohemia (e.g., CHLUPÁČ & KUKAL 1988; CHLUPÁČ & LUKEŠ 1999).

Separated by a fault zone (Fig. 27) follows the second, near vertically bedded, up to 200 m thick reefal unit ("barre calcaire supérieur" of GENDROT et al. 1969). It has been assigned to the Givetian/Frasnian but we do not have new biostratigraphic data that could confirm or reject this dating. GENDROT et al. (1969) showed the presence of for-reef breccias W and

E of a wide, central part with bank facies and a thinner back-reef interval. At the eastern end, the reef was shown to have been eroded by another tongue of the calcareous, conglomeratic Aïn-al-Aliliga Formation, locally with a siliciclastic matrix (GENDROT et al. 1969, pl. 3, fig. 6).

Fig. 55: View from the track next to the Cherrat river on the steep and faulted first (western) reefal limestone cliff at Cakhrat Mohammed-Ben-Brahim, here assigned to the Cakhrat-ach-Chleh Member (lower Emsian).

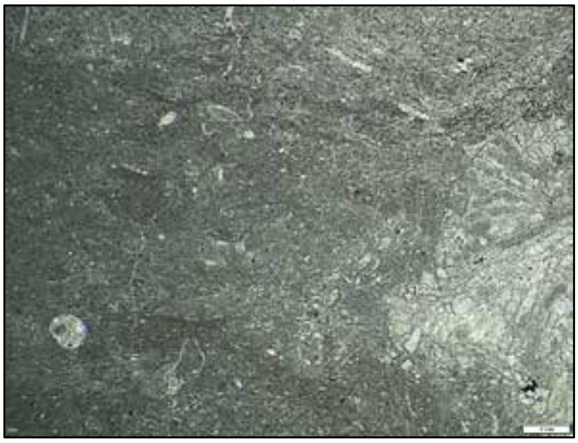


Fig. 56: Example for the dominant microfacies of the Cakhrat-ach-Chleh Member of the Dhar-es-Smene Formation at Cakhrat Mohammed-Ben-Brahim, a bioturbated, bioclastic (detrital) wacke-floatstone with shell filaments, trilobite remains, gastropods, and an isolated favositid coral, grading into calcisiltite in the upper part.

Fig. 57: Limonitic, flattened *Gyroceratites* sp. with typical concave flank lirae from the basal Mohammed-Ben-Brahim Formation at its type locality (max. diameter = 27 mm.).

Fig. 58: The isolated olistolite complex of Aïn-as-Seffah on the upper eastern slope towards the Oued Cherrat, recognizable from the distance by its marker tree, and surrounded by middle/upper Famennian siliciclastics of the Al Brijat Formation. The limestones in the front left represent the top of the Eifelian (*Po. eiflius* Zone) Aïn Kheneg-an-Nmer Formation, which is cut off by a fault.

4.4. Middle/Upper Devonian at Aïn-as-Seffah

The Emsian reef band of the Oued Cherrat (Fig. 2) is not well exposed in the area of Aïn-as-Seffah (or Aïn-as-Safah, topographic sheet, 1 : 50 000, Benslimane, x = 351.45, y = 334.9, GPS N33°34'30.8'' W006°59'18.7''). However, this locality is peculiar because of an isolated, allochthonous, ca. 40 m thick, internally structured slump unit of Givetian reef limestone and adjacent strata (Fig. 58). It has been named by CHALOUAN & HOLLARD (1979) as Aïn-as-Seffah Formation. ABOUSSALAM et al. (2013) introduced a member subdivision (Fig. 59) and provided preliminary conodont data, which enable a precise dating of unconformities, changes in facies and sea-level, the reef extinction, and for under- and overlying pelagic units (members). EICHHOLT & BECKER (2016) studied the microfacies succession of the biostrome (Members 2-3). The olistolite ends in the S by a fault but grades on the northern slope into a level of many smaller olistolites.

4.4.1. Aïn Kheneg-an-Nmer Formation.

Between the N-S running road and the main olistolite lies the plateau of Dhar al Qlaqez. It is occupied by an upper Emsian to upper Eifelian succession, the Aïn Kheneg-an-Nmer Formation. Beds dip mostly to the E with a variably inclination of ca. 45-90° (average ca. 60°). In the W, there are ca. 30 m of platy, marly, detrital to crinoidal, thin-bedded (up to 10 cm thick), dark-grey limestones alternating with calcareous shales. The microfacies is monotonous (silty, dark-grey calcisiltites, Fig. 58). Conodont sampling was without success.

After a ca. 45 m wide outcrop gap, probably occupied by weathered shales, follows to the E a second, limestone-dominated part of the formation (ca. 80 m).

Fig. 59: The monotonous microfacies of the lower Aïn Kheneg-an-Nmer Formation: unfossiliferous, silty, poorly bioturbated mudstones (calcisiltites; scale bar = 1 mm).

This upper part tends to form small cliffs in the upper slope towards the Oued Cherrat (Figs. 5, 58). The basal alternation of dark-grey, poorly fossiliferous (some small brachiopods, crinoid debris) limestones and shale exposed in a fenced area did not yield conodonts (Sample 1). Further ca. 150 m to the E, solid limestones (10-20 cm thick) were exploited in a small quarry, where (?overturned) beds fall steeply to the E. Laminated beds suggest a tempestitic or turbiditic origin. Sample 2 from the eastern quarry margin falls in the top-Eifelian *Po. eiflius* Zone (NARKIEWICZ & BULTYNCK 2018), an upper subdivision of the former *Tortodus kockelianus* Zone. Apart from both index species (1 and 3 specimens), we found *Po. angustipennatus* (3 specimens), *Po. parawebbi* (3 specimens), *L. linguiformis* (3 specimens), and two questionable *I. hollardi*. There is no evidence for the global Kacak Event Interval before the limestones are cut off by a fault; the Eifelian-Givetian transition is not preserved.

4.4.2. Member 1 of Aïn-as-Seffah Formation

Unlike the Eifelian succession, beds within the main olistolite fall with 50-70° to the SW (202°/50° to 220°/69°). ABOUSSALAM et al. (2013) assigned the more than 20 m thick alternation of light- to middle-grey, unfossiliferous, thin- to medium-bedded (2-20 cm) and often lenticular flaserlimestones and calcareous shales to Member 1 of the Aïn-as-Seffah Formation. It underlies the reef sequence but continues on the southern side in parallel (laterally) to the reef boulders, with a strictly disconformable contact of both members. In the lower part (Unit A, Fig. 60) there are only isolated limestone lenses in shale, which increase in number in the top 2 m.

The ca. 4 m thick Unit B consists of many isolated, thin limestones in calcareous shale matrix. Conodont Sample 3 from its main part was barren. Sample 4 from the top yielded *I. difficilis* (Fig. 61.1) and *I. obliquimarginatus*. (Fig. 62.1). In the zonal scheme of BULTYNCK (1987), both taxa should not overlap but a late morphotype ranges in the Montagne Noire (southern France) until the Taghanic Crisis (WALLISER 1990; ABOUSSALAM 2003). *Icriodus difficilis* is the index species of the shallow-water *I. difficilis* Zone, which base has been correlated with the ca. middle part of the *Po. varcus-rhenanus* Zone (GOUWY & BULTYNCK 2002). Therefore, Unit B is assigned to the lower part of the middle Givetian, while the underlying, thicker Unit A probably includes parts of the lower Givetian.

Just a little bit higher, the base of Unit C (Sample 5) produced *I. difficilis* (Figs. 61.2-3) in association with *L. linguiformis* (Fig. 61.5) and *L. klapperi* (Fig. 61.4). The latter two taxa are long-ranging in the top Eifelian to middle Givetian (e.g., WALLISER & BULTYNCK 2011). Sample 6a with *I. difficilis* (Fig. 62.2), *Po. xylus* (Fig. 62.4), and *L. linguiformis* (Fig. 62.3) from the top of Unit C, and the laterally equivalent Sample 6b (= C+14m; collected 14 m above a solid limestone within Unit A) with *L. linguiformis* and *Bel. triangularis* (Fig. 62.5) still fall in the same conodont zone (Tab. 3). The neritic microfacies of Sample 6b (Fig. 72.1) is a middle-grey to brownish, flaser-bedded, bioturbated, bioclastic wacke-

packstone with brachiopods, tabulate corals, shell filaments, crinoid debris, micrite to calcisiltite matrix, and iron-stained, dark pressure solution seams.

conodont zones	***difficilis***						***cristatus ectypus***		***norr.***	**MN 1**	**MN 1**
sample no.	**4**	**5**	**6a**	**6b**	**7a**	**7b**	**8**	**9**	**L**	**10**	**11**
unit and field no.	**top B bel. C**	**base C**	**C top**	**top C +14m**	**base D b. reef**	**AAS 2 loose**	**low. D 1.5m**	**50cm ab. C**	**AAS 1 loose**	**top reef**	**top D 1.4m**
L. linguiformis	*	2	8	1							
I. difficilis	**1**	5	9	*	5	*	1	*	*	*	*
I. obliquimarginatus	2	*	*	*	3						
L. klapperi		1									
Po. xylus			1	*	*	4	*	2	4		
Bel. triangularis				1							
Prioniodina sp.					1						
Po. pseudofoliatus					4						
I. brevis brevis						1					
I. expansus							3	*	1		
Po. cristatus ectypus							**3**				
Po. dubius							**3**	*	*	8	3
Po. pennatus								1	*	*	1
Po. paradecorosus									**9**	2	19
S. pietzneri									7		
I. tafilaltensis									2	14	
Po. webbi									3	*	5
Po. alatus									**1**	*	1
I. subterminus										2	
Po. cf. *lanei*										1	*
Po. pollocki										3	*
I. symmetricus										**24**	23
Ancyrodella sp.										**1**	*
Bel. resima											1
Ad. rotund. pristina											42
Po. cristatus cristatus											2

Tab. 3: Ranges of conodonts in Member 1 to the lower part of Member 3 of the Aïn-as-Seffah Formation.

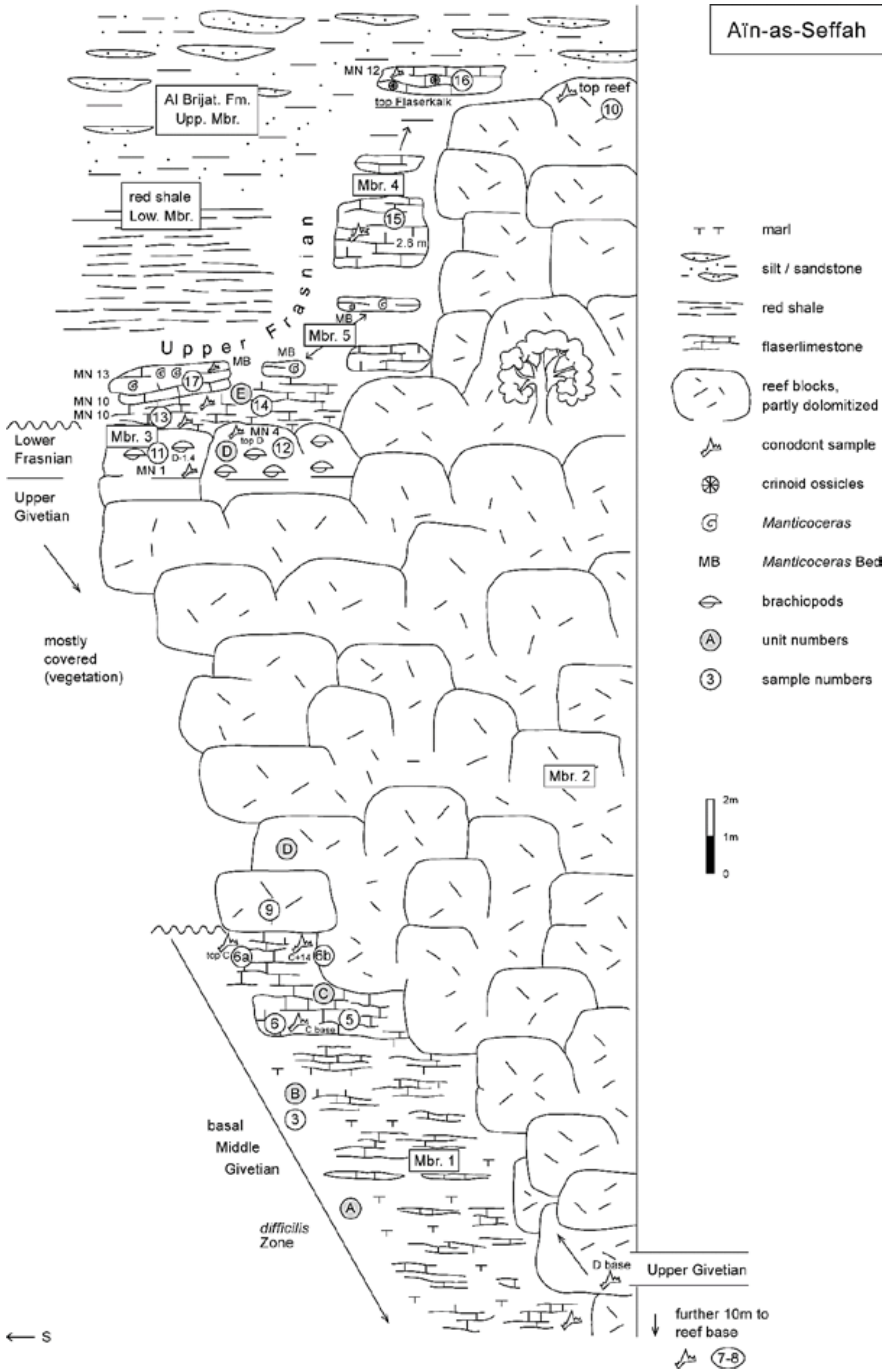


Fig. 60: Sketch showing the spatial relationship of units/members and conodont samples for the southern part of the Aïn-as-Seffah Formation, with the marker tree providing orientation in the field.

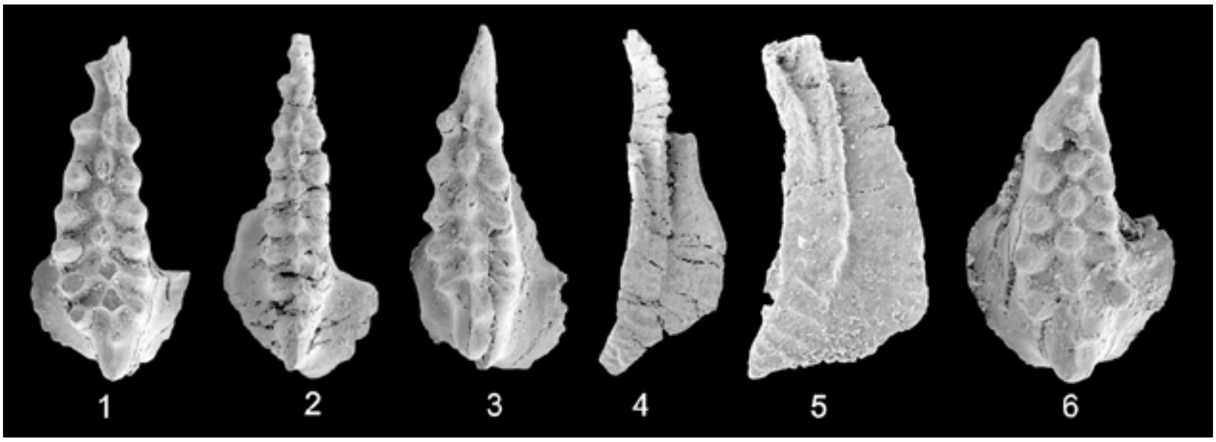


Fig. 61: Conodonts from Units B/C within Member 1 of the Aïn-as-Seffah Formation, showing the variability in icriodids. **1.** *Icriodus difficilis*, typical morphptype, top of Unit B (Sample 4), x 60; **2.** *I. difficilis*, narrow and straight morphotype, base of Unit C (Sample 5), x 60; **3.** *I. difficilis*, morphotype with low number of node rows, base of Unit C (Sample 5), x 60; **4.** *L. klapperi*, base of Unit C (Sample 5), x 30; **5.** *L. linguiformis*, base of Unit C (Sample 5), x 55; **6.** *I difficilis*, robust and curved morphotype with strongly alternating nodes, trending towards *I. expansus*, top of Unit C (Sample 6a), x 65.

4.4.2. Reefal Member 2 of Aïn-as-Seffah Formation

Member 2 consists of up to 3 m large, massive limestone boulders (Fig. 63), which made the section logging difficult. Therefore, Fig. 60 is a simplified sketch using a rough meter scale. Within the member, three regressive episodes can be recognized following changes in macro- and microfacies (EICHHOLT & BECKER 2016, fig. 10).

The Aïn-as-Seffah "reef" was originally a small, isolated patch reef that developed on the neritic, muddy carbonate platform of Member 1. A distinctive zonation with fore reef, reef core, and back reef never developed. The initial phase of Member 2 consists of crinoid grainstone (MF B1a), representing a subtidal crinoid bank. Subordinate biostrome organisms, such as stromatoporoids and *Alveolites*, were fragmented and scattered by storms. One meter above base, fragments become larger and more divers. This suggests initial biostrome growth (a "parabiostrome" sensu ÁLVARO et al. 2007) but there are only few in-situ reef builders (Fig. 65). There are now coral-intraclast rudstones with washed out, peloidal grainstone matrix and solitary Rugosa (Sample 7a, Figs. 67, 72.2) or detrital coral-stromatoporoid float-rudstones (MF B2a, Fig. 66.2). Both formed probably by high-energy storm events but we cannot exclude some slumping due to synsedimentary tectonism. Between 8 and 16 m above base, floatstones with fragments of *Thamnopora*, *Alveolites* and solitary Rugosa prevail. Laminar stromatoporoids dominate at 4 and 8 m (Fig. 66.1).

In situ laminar stromatoporoids are preserved at 17 to 18 m. They stabilized detritus-rich float-/rudstones in the transition towards coral-stromatoporoid boundstones (MF C2a and MF C2b, 19-22 m). *Phillipsastrea* boundstones appear 19 m above the base (Fig. 64). This interval marks the first of the three shallowing upwards cycles. It is overlain by detrital coral-stromatoporoid float-rudstones at 22-28 m (MF B2a). Intercalated is a crinoid grainstone at 24-26 m, which deposited during relative deepening. At 28 m, coral-stromatoporoid boundstones reappear, either with *Phillipsastrea* (MF C2a) or as *Thamnopora* or *Stachyodes* rud-bafflestones (MF C2b, Fig. 66.3).

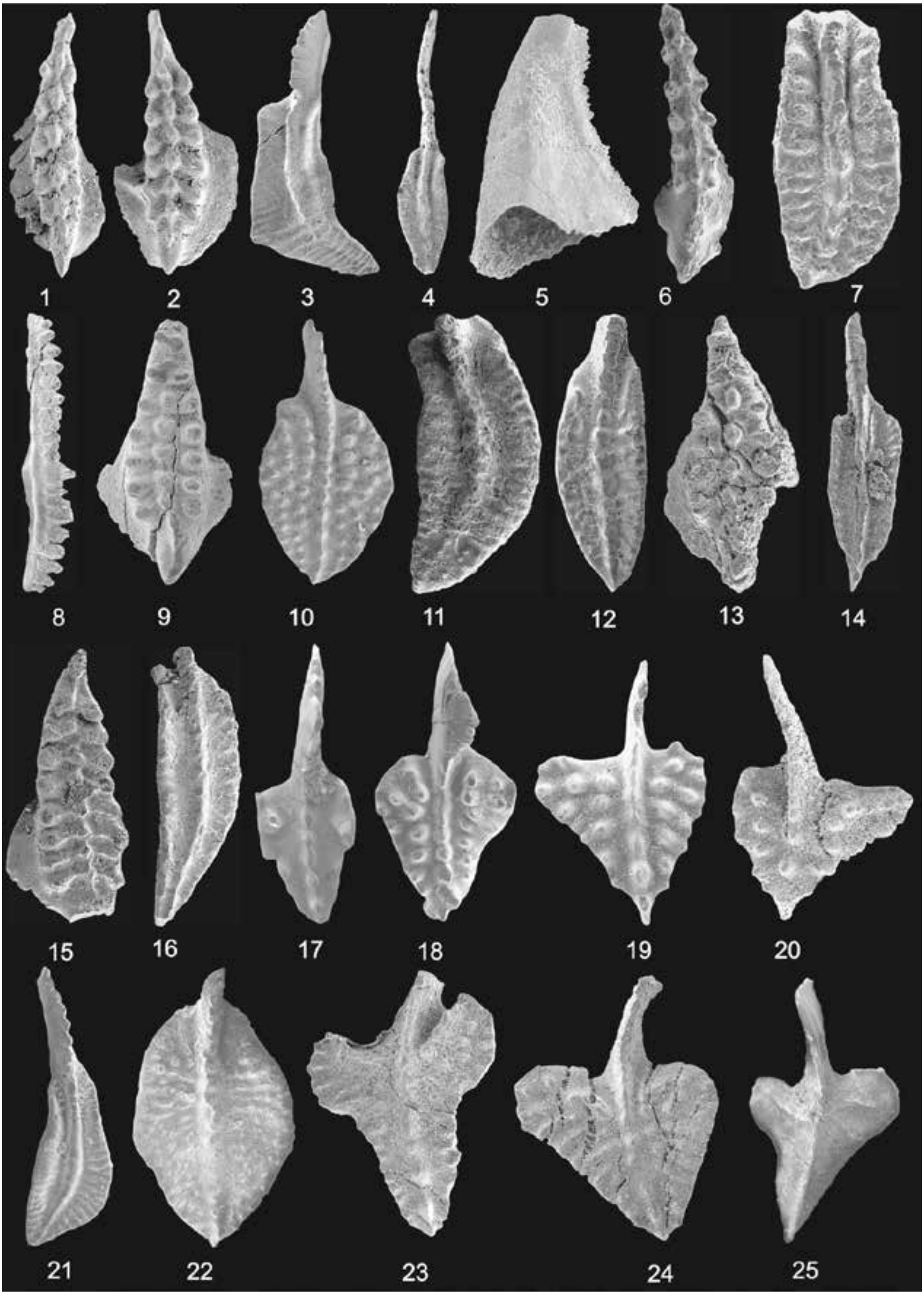


Fig. 62: Conodonts from Member 1 (Units B/C) to the lower part of Member 3 (Samples 11-12) of the Aïn-as-Seffah Formation. **1.** *I. obliquimarginatus*, top Unit B (directly below Unit C; Sample 4), x 55; **2.** *I. difficilis*, top Unit C (Sample 6a), x 60; **3.** *Ling. linguiformis*, top Unit C (Sample 6a), x 30; **4.** *Po. xylus*, top Unit C (Sample 6a), x 30; **5**

Bel. triangularis, top Unit C (Sample C+14m = 6b), x 65, **6.** *I. obliquimarginatus*, base Unit D (Sample 7a), x 80; **7.** *Po. pseudofoliatus*, base Unit D (Sample 7a), x 90; **8.** *Prioniodina* sp., base Unit D (Sample 7a), x 40; **9.** *I. expansus*, 1.5 m above base Unit D (Sample 8), x 65; **10.** *Po. cristatus ectypus*, 1.5 m above base Unit D (Sample 8), x 40; **11.** *Po. pennatus*, middle Unit D, 50 cm above top Unit C (Sample 9), x 50; **12.** *Po.* cf. *tafilensis*, middle Unit D, 50 cm above top Unit C (Sample 9), x 70; **13.** *I. subterminus*, top reef, top Unit D (Sample 10), x 80; **14.** *Po.* cf. *lanei*, top reef, top Unit D (Sample 10), x 45; **15.** *I. tafilaltensis*, top reef, top Unit D (Sample 10), x 60; **16.** *Po. pollocki*, top reef, top Unit D (Sample 10), x 50; **17.** *Ad. rotundiloba pristina*, early morphotype, Member 3, upper 1.4 m of Unit D (Sample 11), x 50; **18.** *Ad. rotundiloba pristina*, larger, therefore more advanced morphotype, Member 3, upper 1.4 m of Unit D (Sample 11), 30; **19-20.** *Ad. africana*, top Unit D, top Member 3 (Sample 12), both x 65; **21.** *Po. webbi*, Member 3, upper 1.4 m of Unit D (Sample 11), x 35; **22.** *Po. cristatus cristatus*, Member 3, upper 1.4 m of Unit D (Sample 11), x 40; **23.** *Ad. hamata* (= *gigas* M2), top Unit D, top Member 3 (Sample 12), x 50; **24-25.** *Ad. pramosica*, top Unit D, top Member 3 (Sample 12), x 54 and x 40.

Fig. 63: Massive (up to 3m thick) reef boulders of Member 2 on the logged southern side at Aïn-as-Seffah.

Fig. 64: Field photo of a *Phillipastrea* from the lower half of Member 2 at Aïn-as-Seffah (picture width ca. 4 cm).

Laterally to a dolomitized part of the second and rather massive biostrome unit, at the southern margin (left in Fig. 60), Sample 9 (Fig. 68) is a recrystallized coral-crinoid pack-rudstone with fragmentary favositids, other tabulate corals, and coarse, angular crinoid debris. It represents a shallow platform storm facies but the tectonic and diagenetic overprint is very strong.

Fig. 65: Field photo of silicified alveolitids encrusting in situ a solitary rugose coral at Aïn-as-Seffah (picture width ca. 10 cm).

A strongly brecciated coral-stromatoporoid float-rudstone (MF B2a) at 37 m signals the deepening above the second biostrome phase. Above, dolomitization obscures the facies trend at 40-42 m: this interval forms the top reef on the southern side (Fig. 60). Subsequent (higher) reef boulders with breccias and rudstones can be found around and just above the marker tree. The brecciated interval ends at ca. 46 m, slightly higher than the tree level. It is overlain up to the top by the third regressive, biostromal phase with *Phillipsastrea* Boundstones (MF C2a, Fig. 69). These contain crinoid debris, alveolitids, and laminar stromatoporids.

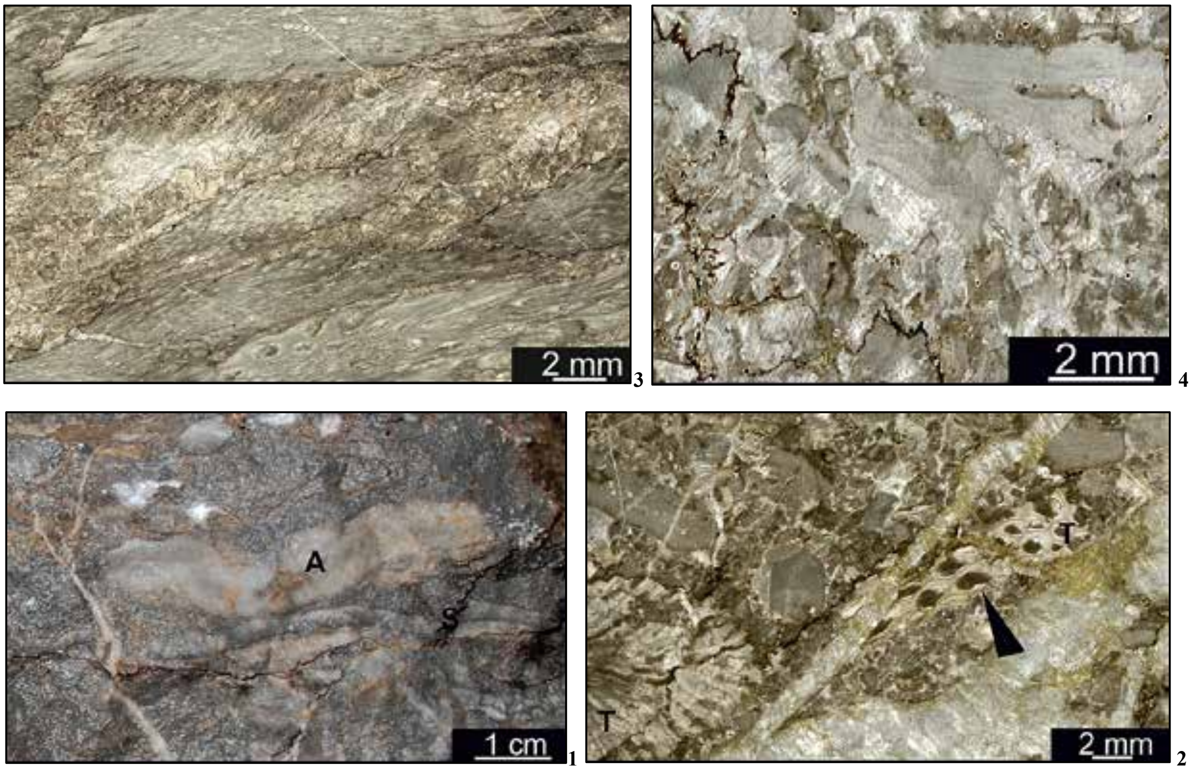


Fig. 66: Examples of reef facies from Unit D of the Aïn-as-Seffah Formation. **1.** MF B2a, open marine reef breccia with laminar stromatoporoids (S) and alveolitids (A) as clasts within a crinoidal grainstone matrix, lower part of Member 2; **2.** MF B2a (Aïn-as-Seffah type), tempestitic rudstone with thamnoporid branches (T, with geopetal fillings marked by arrow), other tabulate corals (lower left), and coarse crinoid debris, within a sparitic, crinoidal grainstone matrix, lower part of Member 2; **3.** Tectonically elongated MF C2b, *Thamnopora* rud-bafflestone with a sparitic matrix, Member 2, 29 m above base; **4.** MF B1b, coarse, recrystallized crinoid-brachiopod grainstone, top of Unit D (Member 3, Sample 12).

The age of the Aïn-as-Seffah reef is fairly well constrained by conodont data. The presence of conodonts within reef breccias and crinoid limestones proves a recurrent influx of open water biota, unlike as in Devonian bioherms. A conodont sample from near the base of Member 2 provides the same early middle Givetian age (*I. difficilis* Zone) as Member 1. Sample 7a yielded the same association of *I. difficilis* and late forms of *I. obliquimarginatus* (Fig. 62.6). The presence of *Po. pseudofoliatus* (Fig. 62.7) and *Prioniodina* (Fig. 62.8) indicate a slightly deeper neritic setting. A different fauna with *I. brevis brevis* and *Po. xylus* was obtained from a loose block (Sample AAS 2). These conodont data suggest that the initial biostrome was established in the middle Givetian when the mud supply stopped. This resembles the Givetian reef initiation in the Rhenish Massif (Becker et al. 2016a).

Sample 8 from ca. 1.5 m above the member base is markedly younger. There are three typical upper Givetian species, *I. expansus* (Fig. 62.9), *Po. dubius*, and *Po. cristatus ectypus* (Fig. 62.10), the index species of the *Po. cristatus ectypus* Zone (Aboussalam 2003). Combined with the irregular lateral contact to Member 1, we suspect that the main part of Member 2 is an allochthonous slump mass that glided onto Member 1 in the upper Givetian. Accordingly, at the lateral end of the outcrop (left in Fig. 60), the same age gap exists between the top of Member 1 (Unit C, Sample 6b) and Sample 9 from the light-grey, massive, detrital limestones (Fig. 68) just 50 cm above. The latter yielded with *Po. pennatus* (Fig. 62.11) and *Po.* cf. *tafilensis* (Fig. 62.12)

two further upper Givetian species. They are typical for deeper-water settings, for example of the eastern Anti-Atlas (ABOUSSALAM & BECKER 2007). An even younger, top-Givetian age (*Skel. norrisi* Zone) applies to the conodont assemblage from a block of reef breccia collected loose at the base of the outcrop (Sample AAS 1). Age diagnostic are the most common polygnathid, *Po. paradecorosus*, as well as *Po. alatus* (see lowest range established by ABOUSSALAM & BECKER 2007), The sample yielded also the only local *Schmidtognathus pietzneri*, a species that does not range above the *Skel. norrisi* Zone.

Fig. 67: Microfacies near the base of Unit D (Member 2, Sample 7a, middle Givetian): biostrome breccia (MF B2a), coral-intraclast rudstone with solitary rugose corals and a peloidal grainstone matrix (picture width = 4.2 cm).

The detrital limestone at the top of Member 2 (Sample 10) falls in the basal Frasnian, based on a fragmentary *Ancyrodella* sp. (Fig. 70.1) and frequent (ca. 45 % of the fauna) *I. symmetricus* (Fig. 68.2). Other typical forms for this level are *I. subterminus* (Fig. 62.13), *Po.* cf. *lanei* (Fig. 62.14; with a different platform shape than in the types of *lanei*; compare ABOUSSALAM & BECKER 2007, figs. 6L-M), *Po. paradecorosus, I. tafilaltensis* (Fig. 62.15), and *Po. pollocki* (Fig. 62.16). The relatively diverse conodont sample indicates a deeper neritic, non-reefal environment. This suggests that the reef drowning occurred in the course of the second (MN 1 Zone) phase of the global, transgressive Frasnes Events.

Fig. 68: Strongly recrystallized coral-crinoid pack-rudstone with tabulate corals, diffuse crinoid debris, dolomite crystals, and iron-stained dissolution seams (Sample 9, Member 2, upper Givetian, scale bar = 2 cm).

Fig. 69: Vertically cut, tectonically distorted *Phillipsastrea* colony from the biostromal upper part of Member 2 at Aïn-as-Seffah (picture width = 3 cm).

4.4.3. Brachiopod limestone, Member 3

At the southern margin (Fig. 60), thick, dolomitized reef limestone boulders with bulbous, laminar and branching (*Stachyodes*) stromatoporids turn without a bed boundary rapidly into ca. 2 m of light-grey, brachiopod-rich detrital limestones, Member 3 sensu ABOUSSALAM et al. (2013). There are coarse, recrystallized crinoid-brachiopod grain-floatstones (MF B1b, EICHOLT & BECKER 2016). The brachiopods are thick-shelled but not well preserved and difficult to extract.

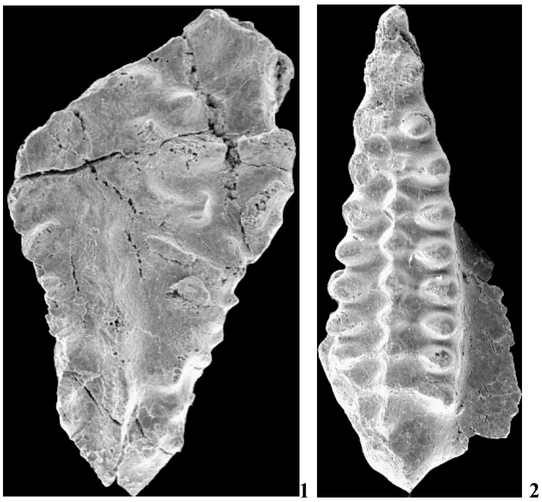


Fig. 70: Basal Frasnian index conodonts from Sample 10, collected from the last solid limestone at the top of Member 2 of the Aïn-as-Seffah Formation, ca. 8 m above the marker tree. **1.** Fragmentary *Ancyrodella* sp. (possibly an advanced *Ad. rotundiloba pristina*); **2.** *I. symmetricus*.

Conodonts from the lower 1.4 m (Sample 11) gave the same basal Frasnian age as the top of Member 2, despite the lateral height difference of 9-10 m of reef limestone (Fig. 60). Early (Fig. 62.17) and larger, more advanced (Fig. 62.18) morphotypes of *Ad. rotundiloba pristina*, the MN 1 Zone index species, are common (43 % of the fauna). They are followed in terms of abundance by *I. symmetricus* (24 %) and *Po. paradecorosus* (ca. 20 %). Apart from some usual lower Frasnian polygnathids (*Po. webbi, Po. alatus, Po. pennatus*), there are two specimens of the much rarer *Po. cristatus cristatus* (Fig. 62.22). The rather sudden change from reefal boundstones to conodont-rich (ancyrodellid-icriodid-polygnathid biofacies), deeper neritic brachiopod limestones underlines the role of reef drowning as the main extinction agent and the local significance of the Frasnes Events (see BECKER & ABOUSSALAM 2004).

Member 3 is a strongly condensed and probably stratigraphically incomplete unit, since Sample 12, a crinoid-brachiopod grainstone (Fig. 66.4), yielded already rich conodonts from the top of the lower Frasnian (top MN 4 or *Ad. nodosa* Zone; ABOUSSALAM & BECKER in PIZARZOWSKA et al. in press; Tab. 4). Typical for a post-reefal, current- and storm-influenced neritic facies are the dominant ancyrodellids (see VANDELAER et al. 1989). The most common form is *Ad. nodosa* (= *gigas* M1), whose early to middle stages may resemble closely the older *Ad. rotundiloba soluta* (Fig. 71.1.). Associated are almost equally common *Ad. africana* (Figs. 62.19-20), rarer *Ad. pramosica* (Figs. 62.24-25), and a constricted form with marginal ribbing (Fig. 62.23) that we include in *Ad. hamata* (= *gigas* M2, *Ad. symmetrica* or *Ad. buckeyensis*). However, that species occurs normally higher, in the late middle Frasnian (KLAPPER & KIRCHGASSER 2016). Among the polygnathids, there are *Po. webbi* (Fig. 62.21), more common *Po. paradecorusus* (Fig. 71.14), *Po. alatus*, and "*Po.* aff. *angustidiscus*" sensu HUDDLE (1981) (Fig. 71.13). Among the icriodids, we found *I. symmetricus*, unusually young *I. difficilis* (Fig. 71.2), and a form with large basal cavity, tentatively assigned to *I. pupus*. The palmatolepids (s.l.) are represented by *Mesotaxis guanwushanensis* M3 (sensu ABOUSSALAM & BECKER in PIZARZOWSKA et al. in press; Figs. 71.6-7), with a slight widening of the elongated basal pit, *Mes. asymmetrica* (Figs. 69.4-5), slender *Mes. bogoslovskyi*, different morphotypes of *Zieglerina unilabius* (Figs. 71.8-10), and an unusually narrow morphotype of *Pa. transitans* (Fig. 71.12, transitional towards *Pa. keyserlingi*), the MN 4 Zone index species. The presence of *Nothognathella ziegleri* (Fig. 71.11), its assumed Pb element, supports our *Palmatolepis* identification.

The long interval of the MN 2 to main part of MN 4 Zone is either missing or extremely condensed within the less than 50 cm between Samples 11 and 12. On the originally exposed central reef top, there was a much longer period of non-deposition. Member 3 is lacking and the top of Member 2 is laterally bordered by upper Frasnian flaserlimestone (Fig. 60).

Conodonts zones	**MN 4**	**MN 10**		**?MN 10**	**MN 12**	**MN 13**
sample no.	**12**	**13**	**14**	**15**	**16**	**17**
unit and field no.	**top D (Mbr. 3)**	**base E (Mbr. 4)**	**below *Mant.* Bed**	**2.8m above tree**	**top flaserlst.**	***Mant.* Bed (Mbr. 5)**
I. difficilis	6					
Po. paradecorosus	19	14	22	24 def		
Po. webbi	2	*	*	*	6 + 1 def.	7
Po. alatus	1					1
Po. cf. *lanei*	1					
Po. pollocki	*	*	*	6 def		
I. symmetricus	3	20	50	59 def	23	
Ad. africana	90					
Ad. nodosa (*gigas* M1)	**100**	5				
Ad. hamata (*gigas* M2)	10					
A. pramosica	13					
I. pupus	2					
Z. unilabius	8					
Pa. transitans	2					
M. guanwushanensis M3	4					
M. asymmetrica	6					
M. bogoslovskyi	5					
Po. "aff. *angustidiscus*"	3					
Nothognathella sp.	1	2	*	4	*	2
Pa. plana		**1**	**1**	*	*	2
I. curvatus			9			
Ad. curvata early morph			38	2		
Ag. coeni			7	*	1	
Ag. leonis			2			
Ag. triangularis					12	1 + 1 cf.
Pa. hassi					1?	16
Pa. winchelli					**1**	
Pa. wildungensis					2	
I. alternatus alternatus					5	
Ad. curvata late morph					14	52
Pa. "ljaschenkoae"						21
Ag. asymmetricus						**10**
Po. amana						5
Pa. "proversa"						2
Palmatolepis sp. (def.)						3
Po. imparilis						7
Po. aff. *incompletus*						3
Pa. bogartensis morph B						**4**

Tab. 4: Stratigraphic ranges of conodonts in the top of Unit D (upper Member 3) to Member 5 (*Manticoceras* Limestone) at Aïn-as-Seffah.

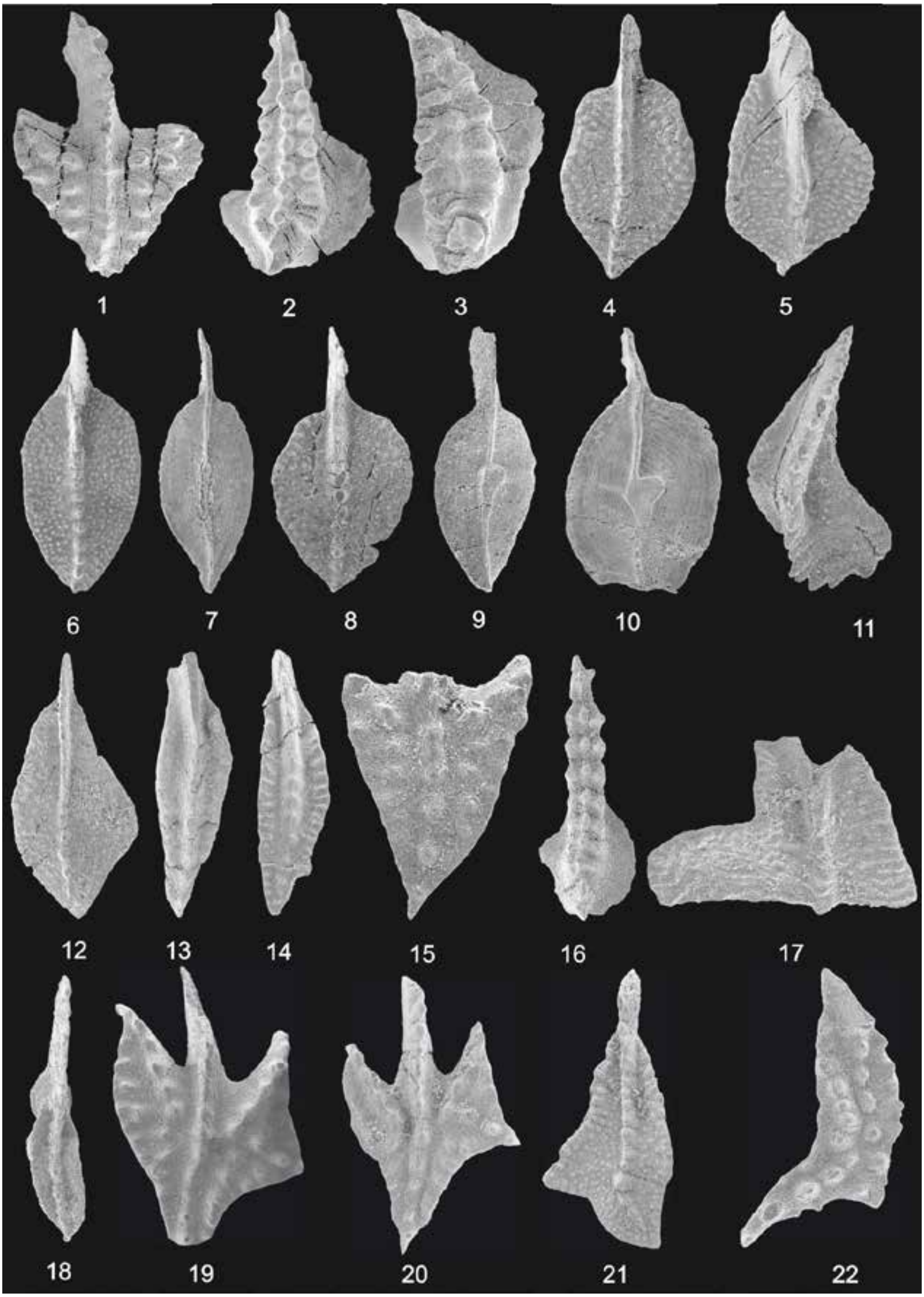

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

Fig. 71: Conodonts from the top Member 3 to top Member 4 of the Aïn-as-Seffah Formation; Sample 12 (top Unit D, 1-14), Sample 13 (base Unit E, 15-16, 18), Sample 14 (top Member 4, 17, 19), and Sample 16 (20-22). **1.** *Ad. nodosa* (resembling *Ad. rotundiloba soluta*), x 40; **2.** *I. difficilis,* x 55; **3.** *I. pupus*, x 65; **4-5.** *Mes. asymmetrica*, two different morphotypes, x 40 and x 45; **6-7.** *M. guanwushanensis* M3, slightly transitional towards *Z. ovalis*, both x 40; **8.** *Z. unilabius*, nodose morphotype, x 40; **9.** *Z. unilabius*, narrow morphotype, x 45; **10.** *Z. unilabius*, wide morphotype, x 50; **11.** *Nothognathella ziegleri*, x 60; **12.** *Pa. transitans*, narrow form, transitional towards *Pa, keyserlingi*, x 35; **13.** *Po.* aff. *angustidiscus* sensu HUDDLE (1981), x 40; **14.** *Po. paradecorosus*, x 40; **15.** *Ad. nodosa* (= *gigas* M1), posterior fragment, x 75; **16.** *I. symmetricus*, narrow form, x 50; **17.** *Pa. plana*, fragment showing the rectangular anterior margin of the outer lobe, x 45; **18.** *Po. xylus*, x 80; **19.** *Ad. curvata* early morph, x 55; **20.** *Ad. curvata* late morph, x 60; **21.** *Pa. winchelli*, tectonically elongated, x 30; **22.** *Ag. coeni*, fragmentary, x 80.

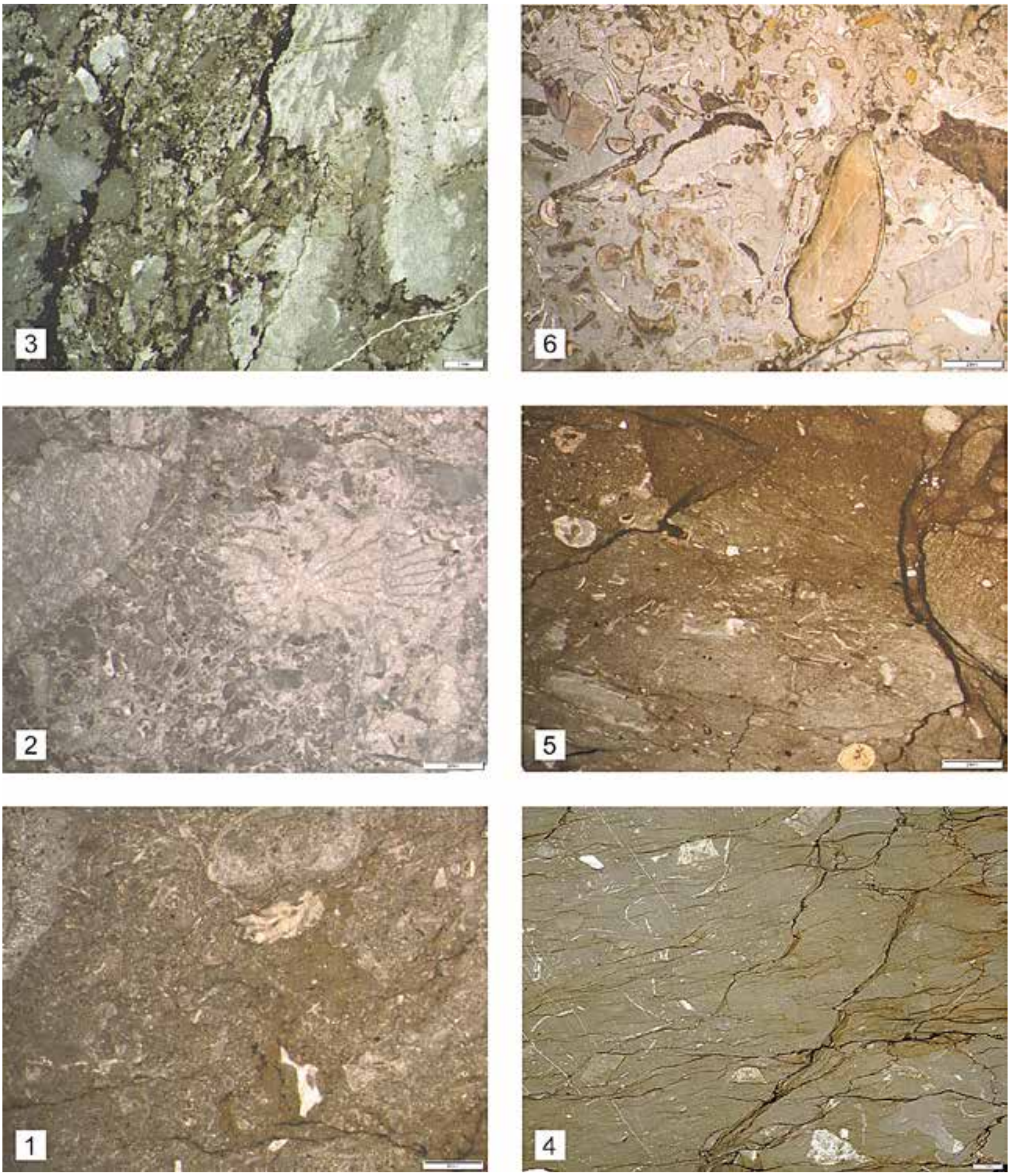


Fig. 72: Microfacies of non-reefal carbonates at Aïn-as-Seffah (Members 3-5, scale bar = 2 mm). **1.** Bioturbated, flaser-bedded bioclastic wackestone with shell filaments, crinoid debris, fragmentary tabulate corals and variably micritic or calcisiltite matrix, Sample 6b (top Unit C, Member 1, *I. difficilis* Zone); **2.** Details of Fig. 65: intraclast-coral float-rudstone with peloidal grainstone matrix, rich in crinoid debris and with eroded solitary Rugosa, Sample 7a (Member 2, base Unit D, *I. difficilis* Zone); **3.** Strongly unsorted, heterogeneous flaser-bedded intraclast pack-rudstone with angular crinoid fragments, tabulate corals, and a peloidal matrix, Sample 13 (base Member 4, top middle Frasnian, MN 10 Zone); **4.** Flaser-bedded mud-floatstone with dense, weekly bioturbate micrite matrix, isolated crinoid fragments, shell filaments, and a *Sphaeromanticoceras* cross-section (lower right), Sample 15 (upper Member 4, 2.8 m above marker tree, middle Frasnian); **5.** Nodular, bioturbated, bioclastic mud-wackestone with crinoid debris, shell filaments, and iron-coated dissolution seams, Sample 16 (top Member 4, upper Frasnian, MN 12 Zone); **6.** Cephalopod-extraclast floatstone with dense, fine micrite matrix, many coated, unsorted grains, juvenile goniatites, phosphate clasts, and shell filaments, Sample 17 (*Manticoceras* Bed, Member 5).

4.4.4. Member 4 of Aïn-as-Seffah Formation.

The outcrop distribution of Member 4 is highly irregular, curving backwards around the upper margin of the reef boulders in the SW and re-appearing, after an interruption by a Member 5 block, adjacent to the top of Member 2 (left in Fig. 60). The strike and dip do not follow this outcrop pattern, which suggests an array of individual, slumped blocks. The main macroscopic lithology is grey, thin-bedded, platy, flaser- and nodular limestone. Above the sharp and marly base, there are still some clasts of reefal organisms. Sample 13 (Fig. 72.3) is a heterogeneous, flaser-bedded intraclast pack-rudstone without any sorting, strongly fragmented crinoid debris, some thamnoporid branches, hematite enrichments, especially along dissolution seams, and with a washed out, sparitic peloid-intraclast grainstone matrix. It represents a proximal debris flow originating from the flank of the drowned reef, which was exposed for a long time to erosion and submarine carstification. This interpretation is supported by the neritic conodont biofacies (Tab. 4: dominance of *I. symmetricus*, Fig. 71.16, and *Po. paradecorosus*, rare *Ad. nodosa*, Fig. 71.15, and *Po. xylus*, Fig. 71.18), and a fragmentary *Pa. plana*, (Fig. 71.17), the index species of MN 10 Zone (top middle Frasnian). The main middle Frasnian, MN 5-9 Zones, falls in a long period of non-deposition and erosion. Just slightly higher, Sample 14 represents a deeper neritic setting, characterized by a mixed icriodid-ancyrodellid-polygnathid facies (with 33 % *I. symmetricus*, 25.5 % *Ad. curvata*, Fig. 71.19, and 15 % *Po. paradecorosus*). A single *Pa. plana, Ancyrognathus coeni* (Fig. 71.22) and *Ag. leonis* suggest that the sample still falls in the MN 10 Zone (= *Pa. plana* Zone). The thin section (Fig. 73) shows a strongly nodular mudstone with some crinoid and shell debris, deposited during increasing sea-level rise and under calm conditions. As a contrast to the base of the member (Sample 13), there are now a few dacryoconarids, a typical pelagic (planktonic) organism group. The abundance of minute iron oxide grains indicates hypoxic conditions.

Fig. 73: Microfacies of the main part of Member 4 (Unit E, Sample 14), a nodular, hypoxic mudstone with dacryoconarids, rare crinoids, other bioclasts, and a dense matrix rich in small iron oxide grains (scale bar = 2 mm).

Fig. 74: SW corner of the Aïn-as-Seffah outcrop, with massive, dolomitized boulders to the right, overlain by flaserlimestone (Members 4 and 5) in the foreground, and with a few higher isolated blocks in the midground, followed by bushy outcrop of the Al Brijat Formation.

Sample 15 from a flaserlimestone succession lateral to the last reef boulders (Figs. 60, 74) continues the calm mudstone facies (Fig. 72.4). Pelagic biota are here represented by shark teeth (*Phoebodus fastigatus*, SCHWERMANN 2014) and the cross-section of a goniatite (*Sphaeromanticoceras*). This genus ranges from the lower middle (UD I-F3) to the top-Frasnin (BECKER et al. 1993). Conodonts belong to a similar biofacies as below, but with only rare ancyrodellids. The majority of specimens is affected by tectonic deformation. Although we did not find a single *Palmatolepis*, we assume the same age as for the similar samples below: MN 10 Zone.

The youngest part of Member 4 (Sample 16) lies as isolated blocks adjacent to the southern corner of the last reef boulders (Figs. 60, 74), well above the block with Sample 15. In thin-section, the microfacies (Fig. 72.5) is a brownish, bioturbated, nodular, bioclastic mud-wackestone with crinoid debris and shell filaments. No planktonic or nektonic groups are present. Most conodonts are less deformed than below. Apart from abundant *I. symmetricus* (35 % of the fauna), there are ca. equally frequent *Ancyrognathus* (20 %, mostly *Ag. triangularis*) and *Ancyrodella* (22 % *Ad. curvata*). An upper Frasnian age is based on the joint occurrence of *Ag. triangularis* and *I. alternatus alternatus*. A single, tectonically elongated *Pa. winchelli* (= *Pa. subrecta*, Fig. 71.21, with some resemblance of the platform shape to *Pa. khaensis* from Thailand; SAVAGE 2013) dates the fauna as MN 12 Zone (= *Pa. winchelli* Zone). Currently we have no local record of the basal upper Frasnian (MN 11 Zone) but there is an un-sampled interval between Samples 15 and 16.

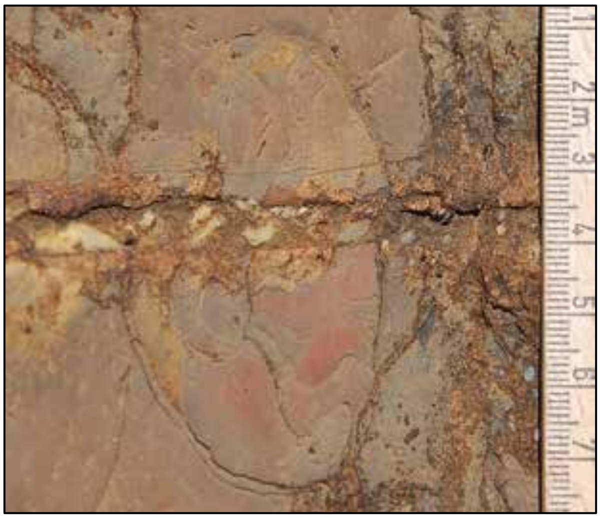


Fig. 75: Fully septate, eroded *Manticoceras* sp., cut by a healed fracture, as seen in the field (Member 5 of Aïn-as-Seffah Formation).

4.4.5. Manticoceras Limestone, Member 5

Because of its exceptional nature for the Moroccan Meseta, the grey to reddish goniatite limestone of Member 5 has been frequently mentioned in the literature (e.g., CHALOUAN & HOLLARD 1979; EL HASSANI & BENFRIKA 1995; ZAHRAOUI et al. 2000). However, there was no data base for the assumed early Frasnian age. The up to 8 cm large manticoceratids are too poorly preserved to provide a specific age. One cross-section belongs to the strongly compressed, long-ranging *M. lamed* Group; others have somewhat wider whorls. Associated are breviconic oncoceratids, longi-orthocones, small, solitary, deep-water Rugosa, and crinoid debris. The microfacies is rather unusual (Fig. 72.6), a cephalopod-extraclast floatstone with

many coated grains, crinoid pieces, juvenile goniatites, phosphate clasts, and shell filaments floating in a very dense, reddish, fine micrite matrix. The dark micrite or phosphatic envelopes of the coated particles show that these were reworked prior to re-deposition. There is no grading or sorting and the up to 6 mm large allochems/extraclasts stand in a remarkable contrast to the very fine matrix that indicates a calm sedimentary regime. The depositional mechanism is currently obscure but shedding from the drowned reef after a phase of non-deposition and reworking is evident. This interpretation fits the conodont age. Almost all conodonts are distorted or twisted by tectonism (Fig. 76). This severely hampers a precise identification, especially of palmatolepids, in which the platform shape is the most diagnostic feature. Despite this complication, we could identify *Ag. asymmetricus* (Fig. 76.3) and *Pa. bogartensis* (Fig. 76.5), the index species of the MN 13a Zone (*Pa. bogartensis* Zone). In some specimens of *Ag. triangularis* (Fig. 76.1), the outer lobe has been bent backwards, as in *Ag. barbus*. The same deformation may explain specimens with *Pa. proversa*-type anterior lobe (Fig. 76.4) and a platform shape and ornament as in *Pa. nasuta* or *Pa. ultima*. Tectonically elongated forms (Fig. 76.2) resemble *Pa. ljaschenkoae* or *Pa. khaensis* but cannot be identified reliably. Polygnathids are often easier to name (*Po. amana*, Fig. 76.6, *Po. imparilis*, *Po. webbi, Po. alatus, Po.* aff. *incompletus*).

The MN 13a Zone age means a correlation with the interval from the top of the Lower Kellwasser to the intra-Kellwasser levels (e.g., KLAPPER 1997; HOUSE et al. 2000; BECKER et al. 2016c). The mixed ancyrodellid (37.5 %)-palmatolepid (35 %) facies indicates a deeper carbonate ramp setting. There are no dark Kellwasser beds; the Frasnian-Famennian boundary is not preserved.

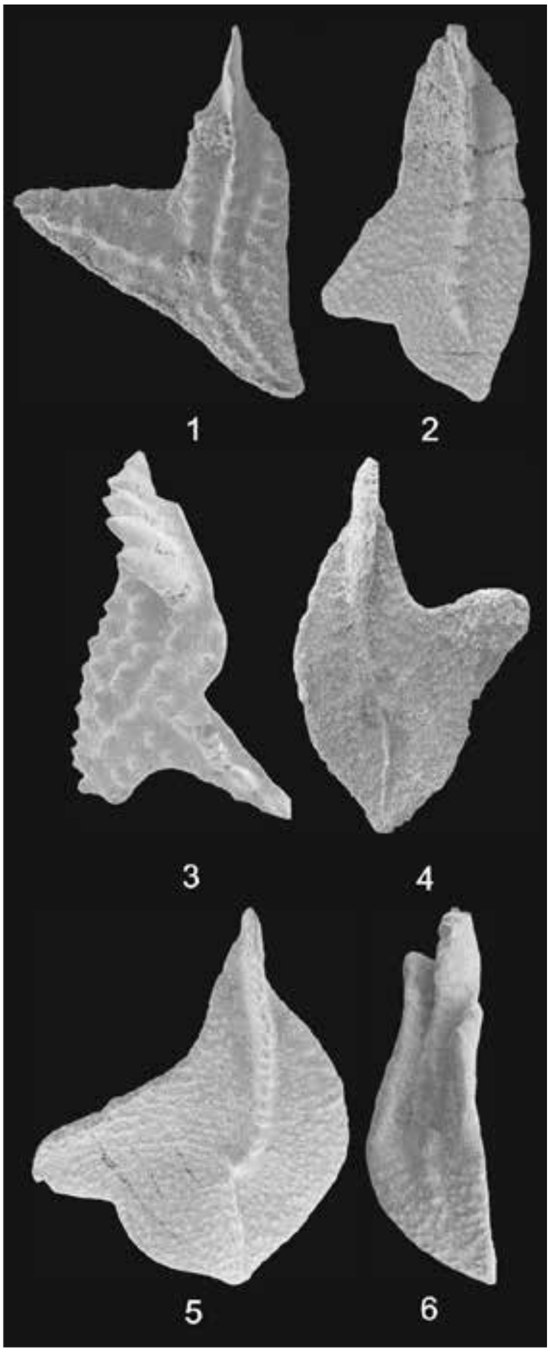


Fig. 76: Tectonically distorted upper Frasnian conodonts from Member 5 of the Aïn-as-Seffah Formation (Sample 17). **1.** *Ag. triangularis* with anterior direction of the side lobe due to distortion, x 45; **2.** Specimen resembling "*Pa. ljaschenkoae*", x 30; **3.** Folded *Ag. asymmetricus*, x 50; **4.** "*Pa. proversa,* with anterior orientation of side lobe due to distortion (otherwise resembling *Pa. nasuta*), x 50; **5.** *Pa. bogartensis* morph B, x 45; **6.** *Po. amana*, x 45.

4.4.6. Al Brijat Formation

Restricted to the SE corner of the outcrop (upper left in Fig. 60) is a distinctive,

unfossiliferous, 4-10 m thick package of red shale, the **Lower Member** of the Al Brijat Form sensu ABOUSSALAM et al. (2013). Its palaeotopographically constrained distribution laterally to the last reef boulders, indicates that it was originally attached to the main olistolite prior to redeposition. The red shale resembles the red, basal middle Famennian, basinal (deep pelagic) "Cypridinenschiefer" (lower Hemberg Formation) of the Rhenish Massif (e.g., DENCKMANN 1905; KREBS 1979; BECKER 1992). However, this lithofacies similarity does not necessarily mean an identical age. So far, there are no fossils that date the Lower Member. The fully oxygenated, strongly oligotrophic, C_{org}-poor lithology prevents any palynological analysis.

The **Upper Member** lies above a sharp lower contact (basal unconformity). It begins with ca. 30 m of deeply weathered shales, siltstones, and lenticular sandstones that exhibit common slump folding. As evident from the olistolites, there was recurrent seismic activity. A higher, ca. 20 m thick unit consists of fine or silty shales, reddish at the base and then olive-colored, with siltstone nodules. The latter have prospects for palynological data. By comparison with Aïn-Al-Aliliga, we assume preliminarily an upper Famennian age. We did not observe limestone clasts above the main olistolite level.

References

ABOUSSALAM, Z. S. (2003): Das „Taghanic-Event“ im höheren Mittel-Devon von West-Europa und Marokko. – Münstersche Forschungen zur Geologie und Paläontologie, **97**: 1-332.

ABOUSSALAM, Z. S. & BECKER, R. T. (2002): The base of the *hermanni* Zone as the base of an Upper Givetian substage. – SDS Newsletter, **19**: 25-34.

ABOUSSALAM, Z. S. & BECKER, R. T. (2007): New upper Givetian to basal Frasnian conodont faunas from the Tafilalt (Anti-Atlas, Southern Morocco). – Geological Quarterly, **51** (4): 345-374.

ABOUSSALAM, Z. S. & BECKER, R. T. (2011): The global Taghanic Biocrisis (Givetian) in the eastern Anti-Atlas, Morocco. – Palaeogeography, Palaeoclimatology, Palaeoecology, **304**: 136-164.

ABOUSSALAM, Z. S., BECKER, R. T. & EICHHOLT, S. (2012): Conodont dating of reefs and carbonate platforms in the Middle and Upper Devonian of the Moroccan Meseta. – Terra Nostra, **2012** (3): 27-28.

ABOUSSALAM, Z. S., BECKER, R. T., EICHHOLT, S. & EL HASSANI, A. (2013a): Conodont biostratigraphy and the timing of facies changes at Ain-as-Seffah (Oued Cherrat Zone, Moroccan Meseta). – Documents de l´Institut Scientifique, Rabat, **26**: 11-13.

ABOUSSALAM, Z. S., BECKER, R. T., EICHHOLT, S., EL HASSANI, A., BENFRIKA, M. EL. & EL KAMEL, F. (2013b): The precise timing of Devonian reef growth and extinctions in the Moroccan Meseta. – In: REITNER, J., YANG, Q, WANG, Y.-D. & REICH, M. (Eds.), Palaeobiology and Geobiology of Fossil Lagerstätten through Earth History, A joint Conference of the “Paläontologische Gesellschaft” and the “Palaeontological Society of China”, Göttingen, Germany, September 23-27, 2013, Abstract Volume: 13; Universitätsverlag Göttingen.

ABOUSSALAM, Z. S., BECKER, R. T. & BULTYNCK, P. (2015): Emsian (Lower Devonian) conodont stratigraphy and correlation of the Anti-Atlas (Southern Morocco). – Bulletin of Geosciences, **94** (4): 893-980.

ABOUSSALAM, Z. S., BECKER, R. T., EL HASSANI, A., EICHHOLT, S. & BAIDDER, L. (2017): Late Early Carboniferous conodonts from a supposed Middle Devonian reef limestone of the Marrakech region (Morocco). – Stratigraphy, **14** (1/4): 7-14.

ACOTTO, C., MARTÍNEZ POYATOS, D., AZOR, A., JABALOY, A., AZDIMOUSA, A., TAHIRI, A. & EL HADI, H. (2018): First U/Pb detrital zircon age populations from the Eastern Variscan Moroccan Meseta. – In: EGU General Assembly 2018. Geophysical Research Abstracts, **20**: 1 p.

ACOTTO, C., MARTÍNEZ POYATOS, D. J., AZOR, A. & JABALOY-SÁNCHEZ, A. (2019): Structural and geochronological constraints on the Early Variscan evolution of the Eastern Moroccan Meseta. – Geological Society of America, Abstracts with Programs, **51** (5), 1 p., doi: 10.1130/abs/2019AM-332308.

AGARD, J., MORIN, P. & TERMIER, H. (1955): Exquisse d´une histoire géologique de la région de Mrirt (Maroc central). – Notes et Mémoires du Service Géologique du Maroc, **12** (125): 15-28.

AGARD, J., BALCON, J.-M. & MORIN, P. (1958): Etude géologique et metallogenique de la region mineralisée du Jebel Aouam (Maroc central). – Notes et Mémoires du Service Géologique du Maroc, **132**: 1-127.

AGER, D. V., COSSEY, S. P. J., MULLIN, P. R. & WALLEY, C. D. (1976): Brachiopod ecology in mid-Palaeozoic sediments near Khenifra, Morocco. – Palaeogeography, Palaeoclimatology, Palaeoecology, **20**: 171-185.

ALBERTI, G. K. B. (1969): Trilobiten des jüngeren Siluriums sowie des Unter- und Mittel-Devons. I. Mit Beiträgen zur Silur-Devon-Stratigraphie einiger Gebiete Marokkos und Oberfrankens. – Abhandlungen der senckenbergischen naturforschenden Gesellschaft, **520**: 1-692.

ALLARY, A., ANDRIEUX, J., LAVENU, A. & RIBEYROLLES, M. (1972): Les nappes hercyniennes de la Meseta sud orientale (Maroc central). – Comptes Rendus de l´Academie des Sciences Paris, **274**: 2284-2287.

ÀLVARO, J. J., ARETZ, M., BOULVAIN, F., MUNNECKE, A., VACHARD, D. & VENNIN, E. (2007): Fabric transition from shell accumulations to reefs: an introduction with Palaeozoic examples. – In: ÀLVARO, J. J., ARETZ, M., BOULVAIN, F., MUNNECKE, A., VACHARD, D. & VENNIN, E. (Eds.), Palaeozoic Reefs and Bioaccumulations: Climatic and Evolutionary Controls. Geological Society, London, Special Publications, **275**: 1-16.

AMLER, M. R. W. & HERBIG, H.-G. (2006): Ostrand der Kohlenkalk-Plattform und Übergang in das Kulm-Becken im westlichsten Deutschland zwischen Aachen und Wuppertal. – Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, **41**: 441-477.

ARETZ, M. & HERBIG, H.-G. (2010): Corals from the Upper Viséan of the southern Azrou-Khenifra Basin (Carboniferous, Central Moroccan Meseta). – Palaeoworld, **19**: 294-305.

AVERBUCH, O., TRIBOVILLARD, N., DEVLEESCHOUWER, X., RIQUIER, L., MISTIAEN, B. & VAN VLIET-LANOE, B. (2005): Mountain building-enhanced continental weathering and organic carbon burial as major causes for climatic cooling at the Frasnian-Famennian boundary (c. 376 Ma)? – Terra Nova, **17**: 25-34.

BACHTADSE, V., VAN DER VOO, R. & HAELBICH, I. W. (1987): Paleozoic paleomagnetism of the western Gondwana. – Earth and Planetary Sciece Letters, **84**: 487-499.

BAHRAMI, A., KÖNIGSHOF, P., VAZIRI-MOGHADDAM, H., SHAKERI, B. & BOMNCHEVA, I. (2019): Conodont stratigraphy and conodont biofacies of the shallow-water Kuh-e-Bande-Abdol-Hossein section (Anarak, Central Iran). – Palaeodiversity and Palaeoenvironments, **99**: 477-494.

BAIDDER, L., RADDI, Y., TAHIRI, M. & MICHARD, A. (2008): Devonian extension of the Pan-African crust north of the West African craton, and its bearing on the Variscan foreland deformation: evidence from eastern Anti-Atlas (Morocco). – In: ENNIH, N. & LIÉGEOIS, J.-P. (Eds.), The Boundaries of the West Africxan Craton. Geological Society, London, Special Publications, **297**: 453-465.

BAIRD, G. C., BRETT, C. E., BECKER, R. T., ABOUSSALAM, Z. S., DESANTIS, M. & BARTHOLOMEW, A. J. (2009): Comparatitive stratigraphy of Eifelian successions in southern Morocco and the Appalachian Basin; implications for global events. – Palaeontoigraphica Americana, **63**: 193-194.

BALBUS, S. (2015): Devonian tides and some of their consequences. – Proceedings of the Royal Society, A, 11 pp.

BALINSKI, A. & BIERNAT, G. (2003): New observations on rhynchonellid brachiopod *Dzieduszyckia* from the Famennian of Morocco. – Acta Palaeontologica Polonica, **48** (3): 463-474.

BALTER, V., MARTIN, J. E., TACAIL, T., SUAN, G., RENAUD, S. & GIRARD, C. (2019): Calcium stable isotopes place Devonian conodonts as first level consumers. – Geochemical Perspectives Letters, **10**: 36-39, Supplement with 5 tabs., 3 figs, and references.

BAMOUMEN, H. AARAB, M. & SOULAIMANI, A. (2008): Evolution tectono-sédimentaire et magmatique des bassins viséen supérieur d´Azrou-Khénifra et des Jebilet orientales (Meseta marocaine). – Estudios Geológicos, **64** (2): 1-16.

BARHAM, M., MURRAY, J., SEVASTOPULO, G. D. & WILLIAMS, M. (2015): Conodonts of the genus *Lochriea* in Ireland and the recognition of the Viséan-Serpukhovian (Carboniferous) boundary. – Lethaia, **48** (2): 151-171.

BARBERO, L., JABALOY, A., GÓMEZ-ORTIS, D., PÉREZ-PEÑA, J. V., RODRÍGUEZ-PECES, M. J., TEJERO, R., ESTUPIÑÁN, J., AZDIMOUSA, A., VÁZQUEZ, M. & ASEBRIY, L. (2011): Evidence for surface uplift of the Atlas Mountains and the surrounding peripheral plateux: Combining apatite fission-track results and geomorphic indicators in the Western Moroccan Meseta (coastal Variscan Paleozoic basement). – Universidad Complutense, E-Prints, 15 pp., online at https://eprints.ucm.es/17114/1/1-s2.90.pdf; Madrid.

BEAUCHAMP, J. & IZART, A. (1987): Early Carboniferous basins of the Atlas-Meseta domain (Morocco): Sedimentary model and geodynamic evolution. – Geology, **15**: 797-800.

BECKER, R. T. (1992): Zur Kenntnis von Hemberg-Stufe und *Annulata*-Schiefer im Nordsauerland (Oberdevon, Rheinisches Schiefergebirge, GK 4611 Hohenlimburg). – Berliner geowissenschaftliche Abhandlungen, Reihe E, **3**: 3-41.

BECKER, R. T. (1993a): Stratigraphische Gliederung und Ammonoideen-Faunen im Nehdenium (Oberdevon II) von Europa und Nord-Afrika. – Courier Forschungsinstitut Senckenberg, **155**: 1-405, 26 pls.

BECKER, R. T. (1993b): Kellwasser Events (Upper Frasnian, Upper Devonian) in the Middle Atlas (Morocco) – implications for plate tectonics and anoxic event generation. – In: Global Boundary Events. An Interdisciplinary Conference, Kielce – Poland, September 27-29, 1993, Abstracts: 9.

BECKER, R. T. (1993c): Anoxia, eustatic changes, and Upper Devonian to lowermost Carboniferous global ammonoid diversity. – In: HOUSE, M. R. (Ed.), The Ammonoidea: Environment, Ecology, and Evolutionary Change. Systematics Association Special Volume, **47**: 115-163.

BECKER, R. T. (1994): Faunal and sedimentary succession around the Frasnian-Famennian boundary in the eastern Moroccan Meseta. – 64. Jahrestagung der Paläontologischen Gesellschaft, 26-30. September 1994, Budapest, Vortrags- und Posterkurzfassungen: 44.

BECKER, R. T. (2013): Membership News: The Münster Devonian Team. – SDS Newsletter, **28**: 59-63

BECKER, R. T. (2015): Membership News: TM R. Thomas BECKER and the Münster Group. – SDS Newsletter, **30**: 50-55.

BECKER, R. T. & ABOUSSALAM, Z. S. (2004): The Frasne Event – a phased 2nd order global crisis and extinction period around the Middle-Upper Devonian boundary. – In: Devonian neritic-pelagic correlation and events, International Meeting on Stratigraphy, Rabat, Morocco 1-10, 2004, IUGS

Subcommission on Devonian Stratigraphy and Institute Scientifique, University Mohammed V – Agdal, Rabat, Morocco, Abstracts: 8-9.

BECKER, R. T. & ABOUSSALAM, Z. S. (2013a): The global Chotec Event at Jebel Amelane (western Tafilalt Platform) – preliminary data. – In: BECKER, R. T., EL HASSANI, A. & TAHIRI, A. (Eds.), International Field Symposium "The Devonian and Lower Carboniferous of northern Gondwana", 22nd to 29th March 2013, Field Guidebook. Document de l´Institute Scientifique, Rabat, **27**: 129-133.

BECKER, R. T. & ABOUSSALAM, Z. S. (2013b): Middle Givetian – middle Frasnian event stratigraphy at Mdoura-East (western Tafilalt). - In: BECKER, R. T., EL HASSANI, A. & TAHIRI, A. (Eds.), International Field Symposium "The Devonian and Lower Carboniferous of northern Gondwana", 22nd to 29th March 2013, Field Guidebook. Document de l´Institute Scientifique, Rabat, **27**: 143-150.

BECKER, R. T. & ABOUSSALAM, Z. S. (2014): Devonian global events in the Moroccan Meseta – an update. – In: 4th International Palaeontological Congress, "The history of life: A view from the Southern Hemisphere", Septemner 28 – October 3, 2014, Mendoza, Argentina, (digital) Abstract Volume: 1 p.

BECKER, R. T. & ABOUSSALAM, Z. S. (2019): Impact of Emsian/Eifelian global events on faunas and biofacies in the Moroccan Meseta. – In: Paleo & Life, Abstracts of the 90th Annual Meeting of the Paläontologische Gesellschaft, Munich 2019, 15-18 September 2019: 20; Bayrische Staatssammlung für Geologie und Paläontologie, München.

BECKER, R. T. & HOUSE, M. R. (1993): New early Upper Devonian (Frasnian) goniatite genera and the evolution of the "Gephurocerataceae". – Berliner geowissenschaftliche Abhandlungen, Reihe E, **9**: 111-133.

BECKER, R. T. & HOUSE, M. R. (1994a): International Devonian goniatite zonation, Emsian to Givetian, with new records from Morocco. – Courier Forschungsinstitut Senckenberg, **169**: 79-135.

BECKER, R. T. & HOUSE, M. R. (1994b): Kellwasser Events and goniatite successions in the Devonian of the Montagne Noire with comments on possible causations. – Courier Forschungsinstitut Senckenberg, **169**: 45-77.

BECKER, R. T. & HOUSE, M. R. (1998): Prospects for an international substage subdivision of the Frasnian. – SDS Newsletter, **15**: 17-22.

BECKER, R. T. & HOUSE, M. R. (2000a): Sedimentary and faunal successions of the allochthonous Upper Devonian at Gara d´Mrirt (Eastern Moroccan Meseta). – Notes et Mémoires du Service Géologique du Maroc, **399**: 109-114.

BECKER, R. T. & HOUSE, M. R. (2000b): Devonian ammonoid zones and their correlation with established series and stage boundaries. – Courier Forschungsinstitut Senckenberg, **220**: 113-151.

BECKER, R. T. & HOUSE, M. R. (2009): Devonian ammonoid stratigraphy of the Canning Basin. – Geological Survey of Western Australia, Bulletin, **145**: 415-438.

BECKER, R. T., FEIST, R., FLAJS, G., HOUSE, M. R. & KLAPPER, G. (1989): Frasnian-Famennian extinction events in the Devonian at Coumiac, southern France. – Comptes Rendus de l`Academie des Sciences Paris, Série II, **309**: 259-266.

BECKER, R. T., HOUSE, M. R. & KIRCHGASSER, W. T. (1993): Devonian goniatite biostratigraphy and timing of facies movements in the Frasnian of the Canning Basin, Western Australia. – In: HAILWOOD, E. A. & KIDD, R. B. (Eds.), High Resolution Stratigraphy. Geological Society Special Publication, **70**: 293-321.

BECKER, R. T., HOUSE, M. R. & MARSHALL, J. E. (1997): The allochthonous Upper Devonian at Mrirt (eastern Moroccan Meseta) – North African continuation of a Montagne Noire carbonate platform? – In: FEIST, R. (Ed.), First International Conference on North Gondwanan Mid-Palaeozoic Biodynamics, IGCP Project 421, Vienna, 17-21 Septembre 1997, Meeting Program and Abstracts: 7-8.

BECKER, R. T., HOUSE, M. R., MENNER, V. V. & OVNATANOVA, N. (2000): Revision of ammonoid biostratigraphy in the Frasnian (Upper Devonian) of the Southern Timan (Northeast Russian Platform). – Acta Geologica Polonica, **50** (1): 67-97.

BECKER, R. T., HOUSE, M. R., BOCKWINKEL, J., EBBIGHAUSEN, V. & ABOUSSALAM, Z. S. (2002): Famennian ammonoid zones of the eastern Anti-Atlas (southern Morocco). – Münstersche Forschungen zur Geologie und Paläontologie, **93**: 159-205.

BECKER, R. T., BOCKWINKEL, J., EBBIGHAUSEN, V., ABOUSSALAM, Z. S., EL HASSANI, A. & NÜBEL, H. (2004): Lower and Middle Devonian stratigraphy and faunas at Bou Tserfine near Assa (Dra Valley, SW Morocco). – In: EL HASSANI, A. (Ed.), Devonian neritic-pelagic correlation and events in the Dra Valley (western Anti-Atlas, Morocco). International Meeting on Stratigraphy, Rabat, March 1-10, 2004. Dopcuments de l´Institute Scientifique, Rabat, **19**: 99-110.

BECKER, R. T., GRADSTEIN, F. M. & HAMMER, O. (2012): The Devonian Period. – In: GRADSTEIN, F. M., OGG, J. G., SCHMITZ, M. & OGG, G. (Eds.), The Geologic Time Scale 2012, Volume **2**: 559-601; Elsevier, Amsterdam, Boston etc.

Becker, R. T., El Hassani, A. & Tahiri, A. (Eds., 2013): International Field Symposium „The Devonian and Lower Carboniferous of northern Gondwana", Field Guidebook. – Document de l´Institut Scientifique, Rabat, **27**: 1-150.

Becker, R. T., Aboussalam, Z. S., El Hassani, A., Hartenfels, S. & Baidder, L. (2015): The timing of Eovariscan block faulting, reworking and re-deposition in the Moroccan Meseta. – Strata, Série 1, **16**: 14-15.

Becker, R. T., Aboussalam, Z. S., Stichling, S., May, A. & Eichholt, S. (2016a): The Givetian-Frasnian Hönne Valley Reef Complex (northern Sauerland) – an outline of stratigraphy and facies development. – Münstersche Forschungen zur Geologie und Paläontologie, **108**: 126-140.

Becker, R. T., Hartenfels, S., Helling, S. & Schreiber, G. (2016b): The „Nehden Goniatite Shale" (lower Famennian, Brilon Reef Complex, NE Rhenish Massif). – Münstersche Forschungen zur Geologie und Paläontologie, **108**: 179-195.

Becker, R. T., Piecha, M., Gereke, M. & Spellbrink, K. (2016c): The Frasnian/Famennian boundary in shelf basin facies north of Diemelsee-Adorf. – Münstersche Forschungen zur Geologie und Paläontologie, **108**: 220-231.

Becker, R. T., Aboussalam, Z. S., El Hassani, A. & Hartenfels, S. (2016d): The distribution of Devonian pelagic facies in the western Moroccan Meseta as a key for palaeogeographic reconstructions in the Prototethys. – In: International Geoscience Programme Project 591 – Closing Meeting "The Early to Mid Palaeozoic Revolution", Ghent University, Ghent, Belgium, 6-9 July 2016, Abstracts: 24-25.

Becker, R. T., El Hassani, A., Aboussalam, Z. S., Hartenfels, S. & Baidder, L. (2018a): The Devonian and Lower Carboniferous of the eastern Anti-Atlas: introduction to a „cephalopod paradise". – Münstersche Forschungen zur Geologie und Paläontologie, **110**: 145-157.

Becker, R. T., Aboussalam, Z. S., Hartenfels, S., El Hassani, A. & Baidder, L. (2018b): Bou Tchrafine – central Tafilalt reference section for Devonian stratigraphy and cephalopod succession. – Münstersche Forschungen zur Geologie und Paläiontologie, **110**: 158-187.

Becker, R. T., Aboussalam, Z. S. & Hartenfels, S. (2018): The Frasnian-Famennian boundary mass extinction – widespread seismic events, the timing of climatic pulses, „pelagic death zones", and opportunistic survival. – In: The Fossil Week, 5th International Palaeontological Congress, July 9th to 13th, 2018, Abstract Book: 107; Paris.

Becker, R. T., Marshall, J. E. A. & Da Silva, A.-C. (2020 in press): Devonian. – In: Gradstein, F. et al. (Eds.), The Geological Time scale 2020; Elsevier (Amsterdam).

Belka, Z., Kaufmann, B. & Bultynck, P. (1987): Conodont-based quantitative biostratigraphy for the Eifelian of the eastern Anti-Atlas. – Geological Society of America, Bulletin, **109** (6): 643-651.

Benfrika, M. El (1999): Some upper Silurian – middle Devonian conodonts from the northern part of Western Meseta of Morocco: systematic and palaeogeographical relationships. – Bolletino della Società Paleontologica Italiana, **37** (2/3): 311-319.

Benfrika, M. El & Bultynck, P. (2001): Lower to Middle Devonian conodonts from Oued Cherrat – North-Western Meseta (Morocco). – In: Jansen, U., Königshof, P., Plodowski, G. & Schindler, E. (Eds.), 15th International Senckenberg Conference, Mid-Palaeozoic Bio- and Geodynamics – The North Gondwana-Laurussia Interaction, May 11-121, 2001, Frankfurt a. M., Abstracts: 13; Forschungsinstitut Senckenberg, Frankfurt a. M.

Benfrika, M. El & Bultynck, P. (2003): Lower to Middle Devonian conodonts from the Oued Cherrat area and its southern extension (North-Western Meseta, Morocco). – Courier Forschungsinstitut Senckenberg, **242**: 209-215.

Benfrika, M. El, Bultynck, P. & El Hassani, A. (2007): Upper Silurian to Middle Devonian conodont faunas from the Rabat-Tiflet area (northwestern Moroccan Meseta). – Geological Quarterly, **51** (4): 393-406.

Bensaid, M. (1979): L´Ordovicien supérieur, le Silurien et le Dévonien dans l´Est du Maroc Central. – Mines, Géologie et Energie, Rabat, **46**: 83-86.

Berkhli, M. (1999): Sédimentologie, biostratigraphie et stratigraphie séquentielle du NE de la Mèseta occidentale marocaine le Carbonifère inférieur (Viséen-Serpukhovien). – Thèse État, Université Moulay Ismail de Meknes, 290 pp.

Berkhli, M., Vachard, D., Paicheler, J.-C. & Tahiri, A. (2000): Modèle sédimentaire et évolution géodynamique du Nord-Est de la Méseta occidentale marocaine au cours du Carbonifère inférieur. – Comptes Rendus de l´Academie des Sciences Paris, Sciences de la Terre et des planètes, **331**: 251-256.

Berkyová, S. (2009): Lower-Middle Devonian (upper Emsian-Eifelian, *serotinus-kockelianus* zones) conodont faunas from the Prague Basin, the Czech Republic. – Bulletin of Geosciences, **84** (4): 667-686.

Beun, N., Huvelin, P., Brice, D., Bultynck, P., Destombes, J., Mergl, M. & Morzadec, P. (1992): Le Paléozoique de Khemis-n´Ga:

discordance du Silurien supérieur sur l´Arenig (region de Safi, Maroc). – Annales de la Société Géologique du Nord, 2éme Série, **1**: 171-177.

BIERNAT, G. (1967): New data on the genus *Dzieduszyckia* SIEMIRADZKI, 1909 (Brachiopoda). – Acta Palaeontologica Polonica, **12** (2): 133-155, pls. I-II.

BLIECK, A., CLEMENT, G., BLOM, H., LELIEVRE, H., LUKSEVICZ, E., STREEL, M., THOREZ, J. & YOUNG, G. C. (2007): The biostratigraphical and palaeogeographical framework of the earliest diversification of tetrapods (Devonian). – In: BECKER, R. T. & KIRCHGASSER, W. T. (Eds.), Devonian Events and Correlations. Geological Society, London, Special Publications, **278**: 219-235.

BOCKWINKEL, J., BECKER, R. T. & EBBIGHAUSEN, V. (2008): Upper Givetian ammonoids from Dar Kaoua (Tafilalt, SE Anti-Atlas, Morocco). – Berliner paläobiologische Abhandlungen, **10**: 61-128.

BOCKWINKEL, J., BECKER, R. T. & EBBIGHAUSEN, J. (2013): Late Givetian ammonoids from Hassi Nebech (Tafilalt Basin, Anti-Atlas, southern Morocco). – Fossil Record, **16** (1): 5-65 + online supplement, 58 pp.

BOCKWINKEL, J., BECKER, R. T. & ABOUSSALAM, Z. S. (2017): Ammonoids from the late Givetian *Tazouites* Bed of Ouidane Chebbi (eastern Tafilalt, SE Morocco). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, **284** (3): 307-354.

BOGOSLOVSKIY, B. I. (1969): Devonskie Ammonoidei, I. Agoniatity. – Trudy Paleontologicheskiy Institut, **124**: 1-341, 29 pls.

BOHRMANN, G. & FISCHER, G. (1985): Stratigraphie und Fazies des Paläozoikums nördlich von Azrou. Ein Beitrag zur Geologie der nordöstlichen marokkanischen Meseta. – Geologica et Palaeontologica, **19**: 15-37.

BOLLELI, E., DESTOMBES, J. & KARPOFF, R. (1953): Découverte du Tournaisien à goniatites dans la Meseta côtière marocaine. – Comptes Rendus hebdomadaires des Séances de l`Academie des Sciences, **1953**: 1906-908.

BOUABDELLI, M. (1989): Tectonique et sédimentation dans un bassin orogénique: Le sillon viséen d´Azrou-Khénifra (Est du massif hercynien central du Maroc). – Unpublished Thesis, University Straßbourg, 256 pp.

BOUABDELLI, M. (1994): Tectonique de l´Est du Massif hercynien central (zone d´Azrou-Khénifra). – Bulletin de l`Institute Scientifique, Rabat, **18**: 145-168.

BOUABDELLI, M., FAIK, F. & HABIBI, M. (1989): Tectonique en blocs basculés et glissement contemporains dans le Dévonien moyen et supérieur du Jebel Bouechot: un nouvel élément pour la comprehension de l´évolution ante-viséenne de l´Est du Maroc central. – Comptes Rendus de l´Academie des Sciences Paris, **308**: 761-766.

BRETT, C. E., ZAMBITO, J. J. IV, BAIRD, G. C., ABOUSSALAM, Z. S., BECKER, R. T. & BARTHOLOMEW, A. J. (2018): Litho-, bio-, and sequence stratigraphy of the Boyle-Portwood Succession (Middle Devonian, Central Kentucky, USA). – Palaeodiversity and Palaeoenvironments, **98** (2): 331-368.

BRICE, D., CHARRIÈRE, A., DROT, J. & REGNAULT, S. (1984): Mise en evidence, par des faunes de Brachiopodes, de l´extension des formations dévoniennes dans la boutonnière d´Immouzer du Kandar (Sud de Fès, Maroc). - Annales de la Sociètè Géologique du Nord, **103**: 445-458.

BUDIL, P., HÖRBINGER, F. & MENCL, R. (2009): Lower Devonian dalmanitid trilobites of the Prague Basin (Czech Republic). – Earth and Environmental Science Transactions of the Royal Society of Edinburgh, **99**: 61-100.

BUGGISCH, W. (1972): Zur Geologie und Geochemie der Kellwasserkalke und ihrer begleitenden Sedimente (Unteres Oberdevon). – Abhandlungen des Hessischen Landesamtes für Bodenforschung, **62**: 1-68, 13 pls.

BUGGISCH, W. & JOACHIMSKI, M. M., 2006. Carbon isotope stratigraphy of the Devonian of Central and Southern Europe. - Palaeogeography. Palaeoclimatology, Palaeoecology, **240**: 68-88.

BULTYNCK, P. (1985): Lower Devonian (Emsian) – Middle Devonian (Eifelian and lowermost Givetian) conodont successions from the Ma´der and the Tafilalt, southern Morocco. – Courier Forschungsinstitut Senckenberg, **75**: 261-286.

BULTYNCK, P. (1986): Accuracy and reliability of conodont zones: the *Polygnathus asymmetricus* “zone” and the Givetian-Frasnian boundary. - Bulletin de l´Institute Royal des Sciences Naturelles de Belgique, Sciences de la Terre, **57**: 149-181.

BULTYNCK, P. (1987): Pelagic and neritic conodont successions from the Givetian of pre-Sahara Morocco and the Ardennes. – Bulletin de l´Institute Royal des Sciences Naturelles de Belgique, Sciences de la Terre, **57**: 149-181.

BULTYNCK, P. (2005): Proposal for a threefold subdivision of the Givetian. – SDS Newsletter, **21**: 20-22.

BULTYNCK, P. & HOLLARD, H. (1980): Distribution comparée de Conodontes et Goniatites dévoniens des plaines du Dra, du Ma´der et du Tafilalt (Maroc). – Aardkundige Mededelingen, **1**: 1-73.

BULTYNCK, P. & SARMIENTO, G. N. (2003): Reworked Ordovician and autochthonous Siluro-Devonian conodonts from Khemis-n`Ga (Moroccan Meseta) – Depositional, environmental, and palaeogeographic implications. – Courier Forschungsinstitut Senckenberg, **242**: 257-283.

BURCHETTE, T. P. (1981): European Devonian reefs: a review of current concepts and models. – SEPM Special Publication, **30**: 85-142.

BURKHARD, M., CARITG, S., HELG, U., ROBERT-CHARRUE, C. & SOULAIMANI, A. (2006): Tectonics of the Anti-Atlas of Morocco. – Comptes Rendus Geoscience, **338**: 11-24.

CABRERA-PORRAS, Á., RODRÍGUEZ-CAÑERO, R. & MARTÍN-ALGARRA, A. (2019): Primeros conodontos del Frasniense en el Complejo Maláguide de Granada (Cordillera Bética). – Spanish Journal of Palaeontology, **34** (2): 163-186.

CARLS, P., SLAVÍK, L. & VALENZUELA-RÍOS, J. I. (2008): Comments on the GSSP for the basal Emsian stage boundary: the need for its redefinition. – Bulletin of Geosciences, **83** (4): 383-390.

CARLS, P., SLAVÍK, L. & VALENZUELA-RÍOS, J. I. (2009): Request and comments concerning the GSSP for the basal Emsian stage boundary. – SDS Newsletter, **24**: 20-27.

CASIER, J.-G., LEHMAMI, M. & PREAT, A. (1997): Ostracodes et sédimentologie du Givétien à Ain Khira (Meseta nord-occidentale du Maroc). - Revue de Paléobiologie, **16** (1): 151-167.

CATTANEO, G., TAHIRI, A., ZAHRAOUI, M. & VACHASRD, D. (1993): La sedimentation récifale du Givétien dans la Meswta Marocaine nord-occidentale. - Comptes Rendus de l´Academie des Sciences Paris, Série II, **1993**: 73-80.

CHAKIRI, S. (2002): Sédimentologie et géodynamique du Maroc Central Hercynien pendant le Dévonien. – Unpublished Ph. D. Thesis, Ibn Tofail University, Khenitra.

CHAKIRI, S. & TAHIRI, A. (2000): La formation chaotique famenno-tournaisiene du Grou: témoin de la bordure orientale du bassin de Sidi Bettache (Meseta marocain). – Bulletin de l´Institute Scientifique, Rabat, **22**: 9-15

CHALOUAN, A. (1981): Stratigraphie et structure du Paléozoique de l´Oued Cherrat: un segment du couloir de cisaillement de Meseta occidentale (Maroc). - Notes et Mémoires du Service géologique du Maroc, **42** (308): 33-100, 4 pls.

CHALOUAN, A. & HOLLARD, H. (1979). Stratigraphie des terrains du Paléozoique moyen de l´oued Cherrat (Meseta occidentale marocaine). - Comptes Rendus de l´Academie des Sciences Paris, Série D, **288**: 199-202.

CHARLOT, R., RHALIB, M. & TISSERANT, D. (1973): Etude géochronologique préliminaire des granites de la region de Rabat-Tiflet (Maroc occidental). – Noters et Mémoires du Service Géologique Maroc, **249**: 55-58.

CHARRIÈRE, A. (1989): Mise en évidence de différents ensembles lithostratigraphiques et structuraux dans le socle du Moyen Atlas tabulaire (Msroc). - Notes et Mémoires du Service géologique du Maroc, **335**: 37-48.

CHARRIÈRE, A. (1990): Héritage hercynien et évolution géodynamique alpine d´une chaîne intracontinentale: le Moyen-Atlas au SE de Fès (Maroc). – Unpublished Ph. D. Thesis, University Toulouse, 589 pp.

CHARRIÈRE, A. & RÉGNAULT, S. (1983): Stratigraphie du Dévonien de la boutonnière d´Immouzer-du-Kandar (Sud de Fès). Conséquences paléogéographiques. – Symposium P.I.G.C. 27, Rabat.

CHARRIÈRE, A. & RÉGNAULT, S. (1989): Stratigraphie du Dévonien de la boutonnière d´Immouzer du Kandar (Sud de Fès); conséquences paléogeographiques. - Notes et Mémoires du Service géologique du Maroc, **335**: 25-35.

CHARRIÈRE, A., CYGAN, C. & REGNAULT, S. (1984): Un exemple d´évolution de facies carbonaté dans le Dévonien marocain. – 10è Réunion, Annales de l`Sciences de la Terre, Bordeaux: 133; Société Géologique du France.

CHATTERTON, B. F. (1974): Middle Devonian Conodonts from the Harrogate Formation, Southeastern British Columbia. – Canadian Journal of Earth Sciences, **11**: 1461-1484.

CHLUPÁČ, I. & KUKAL, Z. (1986): Reflection of possible global Devonian events in the Barrandian area, C.S.S.R. – Lecture Notes in Earth Sciences, **8**: 171-179.

CHLUPÁČ, I. & KUKAL, Z. (1988): Possible global events and the stratigraphy of the Palaeozoic of the Barrandian (Cambrian-Middle Devonian), Czechoslowakia). – Sborník geologických věd, Geologie, **43**: 83-146.

CHLUPÁČ, I. & LUKEŠ, P. (1999): Pragian/Zlíchovian and Zlíchovian/Dalejan boundary sections in the Lower Devonian of the Barrandian area, Czech Reopublic. – Newsletters on Stratigraphy, **37** (1/2): 75-100.

COCKS, L. R. M. & TORSVIK, T. H. (2002): Earth geography from 500 to 400 million years ago: a faunal and palaeomagnetic review. – Journal of the Geological Society London, **159**: 631-644.

COGNEY. G. (1967): Sur le Dévonien de la région d´Oulmès (Maroc central). – Comptes Rendus

Somnaires et Séances, Société Géologique du France, **7é série** (9): 283-284.

CORNÉE, J.-J. (1989): Le Haut Atlas Occidental Paleozoique: un reflet de l´histoire hercynienne du Maroc occidental. – Unpublished Ph.D. Thesis, Université de Droit, d´Economique et des Sciences, d`Aix-Marseille, 335 pp.

CORNÉE, J. J., RACHEBEUF, P. R., TAYEBI, M. & WILLEFERT, S. (1990): Les Formations dévoniennes de la nappe des Aït Tounart (partie occodentale du massif ancient du Haut Atlas, Maroc hercynien). – Géologie Méditerrannéenne, **17** (3/4): 331-342.

CORRADINI, C. & CORRIGA, M. G. (2012): A Přídolí-Lochkovian conodont zonation in Sardinia and the Carnic Alps: implications for a global zonation scheme. – Bulletin of Geosciences, **87** (4): 635-650.

CORRIGA, M. G., CORRADINI, C., HAUDE; R. & WALLISER, O. H. (2013): Conodont and crinoid stratigraphy of the upper Silurian and Lower Devonian scyphocrinoid beds of the Tafilalt, southeastern Morocco. – GFF, **2013**: 1-5.

COZAR, P., VACHARD, D., IZART, A. & CORONADO, I. (2019 online): Survival of early Viséan foraminifers in the Western Meseta of Morocco. – Palaeoworld, 33 pp., doi.org/10.1016/j.palwor.2019.06.001.

CRONIER, C., FEIST, R. & AUFFRAY, J.-C. (2004): Variation in the eye of *Acuticryphops* (Phacopina, Trilobita) and its evolutionary significance: a biometric and morphometric approach. – Paleobiology, **30** (3): 471-481.

CYGAN, C., CHARRIÈRE, A. & REGNAULT, S. (1990): Datation par Conodontes du Dévonien (Emsien – Frasnian basal) dans le substratum du Moyen-Atlas au Sud de Fés (Maroc); Implications paléogéographiques. - Géologie Méditerranéennne, **17** (3/4): 321-330.

DALZIEL, I. W. D., DALLA SALIDA, L. H. & GAHAGAN, L. M. (1994): Paleozoic Laurentia-Gondwana interaction and the origin of the Appalachian-Andean mountain system. – Geological Society of America, Bulletin, **106**: 243-252.

DAVYDOV, V. I., KORN, D., SCHMITZ, M. D., GRADSTEIN, F. M. & HAMMER, O. (2012): The Carboniferous Period. – In: GRADSTEIN, F. M., OGG, J. G., SCHMITZ, M. & OGG, G. (Eds.), The Geologic Time Scale 2012, Volume **2**: 603-651; Elsevier, Amsterdam, Boston etc.

DE BAETS, K., KLUG, C. & PLUSQUELLEC, Y. (2010): Zlíchovian faunas with early ammonoids from Morocco and their use for the correlation of the eastern Anti-Atlas and the western Dra Valley. – Bulletin of Geosciences, **85** (2): 317-352.

DE KONING, G. (1957): Geologe des Ida ou Zal (Maroc) – Stratigraphie, Petrographie et Tectonique de la partie SW du Bloc Occidental du Massif Ancien du Haut Atlas. – Leidse Geologische Mededelingen, **23**: 1-209.

DELCHINI, S., LAHFID, A., LACROIX, B., BAUDIN, T., HOEPFFNER, C., GUERROT, C., LACH, P., SADDIQI, O. & RAMBOZ, C. (2018): The Geological Evolution of the Variscan Jebilet Massif, Morocco, Inferred From New Structural and Geochronological Analyses. – Tectonics, **37**: 1-24.

DENCKMANN, A. (1905): Über das Devon und Carbon des Sauerlandes. – Jahrbuch der Preußischen Geologischen Landesanstalt, **23**: 534-596.

DESTOMBES, J. & JEANETTE, A. (1966): Mémoire explicative de la carte géotechnique de la Meseta Cotière à l´Est de Casablanca au 1/50 000. – Notes et Mémoires du Service Géologique du Maroc, **180bis**: 1-104.

DOPIERALSKA, J. (2003): Neodymium isotopic composition of conodonts as a palaeoceanographic proxy in the Variscan oceanic system. – Unpublished Ph. Thesis, Justus-Liebig-University Gießen, 111 pp.

DOPIERALSKA, J. (2009): Reconstructing seawater circulation on the Moroccan shelf of Gondwana during the Late Devonian: Evidence from Nd isotope composition of conodonts. – Geochemistry, Geophysics, Geosystems, **10** (3): 1-13, doi:10.1029/2008GC002247.

DOPIERALSKA, J., BELKA, Z. & WALCZAK, A. (2015 online): Nd isotope composition of conodonts: An accurate proxy of sea-level fluctuations. – Gondwana Research, **34**: 284-295.

DREESEN, R. & THOREZ, J. (1994): Parautochthnous – allochthonous carbonates and conodont mixing in the Late Famennian (Uppermost Devonian) Condroz Sandstones of Belgium. – Courier Forschungsinstitut Senckenberg, **168**: 159-182.

EBBIGHAUSEN, V., BECKER, R. T. & BOCKWINKEL, J. (2000): Morphometric Analyses and Taxonomy of Oxyconic Goniatites (Paratornoceratinae n. subfam.) from the Early Famennian of the Tafilalt (Anti-Atlas, Morocco). – Abhandlungen der Geologischen Bundesanstalt, 57: 167-180.

ECHARFAOUI, H., HAFID, M. & Aït Salem, A. (2002): Structure sismique du socle paléozoique du basin des Doukkala, Môle côtier, Maroc occidental. Indication en faveur de l´existence d´une phase éo-varisque. – Comptes Rendus Geoscience, **334**: 13-20.

EICHHOLT, S. & BECKER, R. T. (2016): Middle Devonian reef facies and development in the Oued Cherrat Zone and adjacent regions (Moroccan Meseta). - Facies, **62** (7): 29 pp.

EICHHOLT, S., BECKER, R. T. & STICHLING, S. (2013): Microfacies and Devonian reef development in the Oued Cherrat Zone (Aïn Khira South and Aïn-as-

Seffah), Moroccan Meseta. – Documents de l´Institut Scientifique, Rabat, **26**: 37-39.

El Hassani, A. (1990): La Zone de Rabat-Tiflet: Bordure nord de la chaîne calédono-hercynienne du Maroc. – Bulletin de l´Institute Scientifique, **15**: 134 pp.

El Hassani, A. (1994): Tectonique de la Meseta nord occidentale. – Bulletin de l´Institute Scientifique, **18**: 107-124.

El Hassani, A. (Ed., 2004): Devonian neritic-pelagic correlation and events in the Dra Valley (western Anti-Atlas, Morocco). International Meeting on Stratigraphy, Rabat, March 1-10, 2004. – Documents de l´Institute Scientifique, **19**: 1-100.

El Hassani, A. & Benfrika, M. El (1995): Biostratigraphy and correlations of the Devonian of the Morfoccan Meseta: a synopsis. – Bulletin de l`Institut Scientifique, Rabat, **19**: 29-44.

El Hassani, A. & Benfrika, M. El (2000): The Devonian of the Moroccan Meseta: biostratigraphy and correlations. – Courier Forschungsinstitut Senckenberg, **225**: 195-209.

El Hassani, A. & El Kamel, F. (2000): Tectonic control of Devonian reef building in Mechra ben Aboou area (northern Rehamna, Morocco). – In: Tahiri, A. & El Hassani, A. (Eds.), Proceedings of the Subcommission on Devonian Stratigraphy (SDS) – IGCP 421 Morocco Meeting. Travaux de l. Institute Scientifique, Rabat, **20**: 25-30.

El Hassani, A. & Tahiri, A. (Eds., 1994): Géologie du Maroc central et de la Meseta orientale. – Bulletin de l´Institute Scientifique, **18**: 1-214.

El Hassani, A. & Tahiri, A. (Eds., 1999): SDS-IGCP 421 Morocco Meeting, April 24th – May 1st 1999, Excursion Guidebook, Part I: Tafilalt and Maider (eastern Anti-Atlas). – 107 pp., Institute Scientifique, Rabat (see also Notes et Mémoires du Service Géologique du Maroc, **399**, 2000).

EL HASSANI, A. & TAHIRI, A. (2000): The Eastern part of Central Morocco (Western Meseta). - Notes et Mémoirs du Service géologique Maroc, **399**: 89-92.

El Hassani, A., Destombes, J. & Willefert, S. (1988): Le problème de l´Arenig-Llanvirn (Ordovicien), la discordance calédonienne et la preparation de l´orogenèse hercynienne dans la region de Rabat-Tiflet (Maroc occidental). – Bulletin de l´Institute Scientifique, Rabat, **12**: 27-45.

El Hassani, A., Tahiri, A. & Walliser O. H. (2003). The Variscan Crust between Gondwana and Laurasia. - Courier Forschungsinstitut Senckenberg, **242**, pp: 81-87.

El Hassani, A., Aboussalam, Z. S., Becker, R. T., El Wartiti, M. & El Hassani, F. (2017): Patrimoine géologique marocain et développement durable: l´exemple du Dévonien du Tafilalt, Anti-Atlas oriental. – Géologues, Revue Officielle de la Société Géologique de France, **194**: 112-117.

El Kamel, F. (2004): Études géologiques du Paléozoique de Mechra Ben Abbou et d´Oulad Abbou, Meseta occidentale, Maroc. – Notes et Mémoires du Service Géologique, **462**: 1-187.

El Kamel, F., El Hassani, A. & Dafir, J. E. (1992): Présence d´une tectonique synsédimentaire dans le Dévonien inférieur des Rehamna septentrionaux (Meseta marocaine occidentale). – Bulletin de l`Institute Scientifique, Rabat, 16: 37-43.

Ernst, A. & Rodriguez, S. (2010): Broyozoan fauna from the oolithic limestone from Pajarejos, SW Spain. – Revista Española de Paleontologia, **25** (2): 83-88.

Fadli, D. (1990): Evolution sédimentaire et structural des massifs de Mdakra et du Khatouat; deux segments hercyniens de la Meseta marocaine nord-occidentale. - Unpublishhed Ph.D. Thesis, University Rabat, 272 pp.; Rabat.

Fadli, D. (1994a): Le Fameno-Tournaisian. – Bulletin de l´Institut Scientifique, Rabat, **18**: 57-70.

Fadli, D. (1994b): Le Viséen. - Bulletin de l´Institut Scientifique, Rabat, **18**: 71-83.

Fadli, D., Bouabdelli, M., Cailleux, Y., El Hassani, A., El Wartiti, M;, Hoepffner, Ch., Kharbouch, F., Tahiri, A. & Zahraoui, M. (2008): Hercynian geological map of Central Morocco. Presented at IGC-Oslo-2008.

Faik, F. (1988): Le Paléozoique de la région de Mrirt (Est du Maroc central). Evolution stratigraphique et structurale. – Unpublished Thesis of the 3rd Cycle, University P. Sabatier, Tolouse, 233 pp.

Fairon-Demaret, M. & Regnault, S. (1990): Macroflores dévoniennes dans le Nord du Maroc (Boutonnière d´Immouzer-du-Kandar, Sud de Fés). Etude Paléobotanique – Implications stratigraphiques et paléogéographiques. – Annales de la Société géologiques de Belgique, **109**: 499-513.

Fedorowski, J. (1973): Rugose corals Polycoelaceae and Tachylasmatina subord. n. from Dalnia in the Holy Cross Mts. - Acta Geologica Polonica, **23** (1): 89-133, 6 pls.

Feist, R. (1985): Devonian Stratigraphy of the Southeastern Montagne Noire (France). – Courier Forschungsinstitut Senckenberg, **75**: 331-352.

Feist, R. (2002): Trilobites from the latest Frasnian Kellwasser crisis in North Africa (Mrirt, Central Moroccan Meseta). – Acta Palaeontologica Polonica, **47** (2): 203-210.

Feist, R. (2003): Biostratigraphy of Devonian tropidocoryphid trilobites from the Montagne Noire

(southern France). – Bulletin of Geosciences, **78** (4): 431-446.

FEIST, R. (2019): Post-Kellwasser event recovery and diversification of phacopid trilobites in the early Famennian (Late Devonian). – Bulletin of Geosciences, **94** (1): 1-22.

FERONI, A., ELLERO, A., MALUSÀ, M. G., MUSUMECI, G., OTTRIA, G., POLINO, R. & LEONI, L. (2010): Transpressional tectonics and nappe stacking along the Southern Variscan Front of Morocco. – Internationa Journal of Earth Sciences, **99**: 1111-1122.

FRANCOIS, J.-M., REGNAULT, S. & CHEILLETZ, A. (1986): Mise au point concernant les series de l´Ordovicien-Silurien-Dévonien inférieur du Djebel Aouam (Maroc Central). – Bulletin de l´Société Géologique du France, **1986** (2): 293-297.

FRANKE, W. (2000): The mid-European segment of the Variscides: tectonostratigraphic units, terrane boundaries and plate tectonic evolution. – Geological Society, London, Special Publications, **179**: 35-61.

FRANKE, W., COCKS, L. R. M. & TORSVIK, T. H. (2017): The Palaeozoic Variscan oceans revisited. – Gondwana Research, **48**: 257-284.

FRECH, F. (1887): Die palaeozoischen Bildungen von Cabrières (Languedoc). – Zeitschrift der Deutschen Geologischen Gesellschaft, **39**: 360-488, pl. 24.

GARCÍA-ALCALDE, J. (1997): North Gondwanan Emsian events. – Episodes, **20** (4): 241-246.

GENDROT, C. (1973): Environnements du Dévonien récifal au Maroc. – Notes du Service géologique du Maroc, **34**: 55-86.

GENDROT, C., KERGOMARD, D. & RABATÉ, J. (1969): Etude des formations récifale du dévonien de la meseta occidentale. – Vol. I: 68 pp. + 5 figs., vol. II: 16 pls.; Charia Moulay Hassan, Rabat.

GENTIL, L. (1918): Notice sur les titres et travaux scientifiques de L. GENTIL. – 132 pp., Larose, Paris.

GEORGE, A. D., TRINAJSTIC, K. M. & CHOW, N. (2009): Frasnian reef evolution and palaeogeography, SE Lennard Shelf, Canning Basi, Australia. – In: KÖNIGSHOF, P. (Ed.), Devonian Change: Case Studies in Palaeogeography and Palaeoecology. The Geological Society, London, Special Publications, **314**: 73-107.

GERRIENNE, P., MEYER-BERTHAUD, B., LARDEUX, H. & RÉGNAULT, S. (2010): First record of *Rellimia* LECLERQ & BONAMO (Aneurophytales) from Gondwana, with comments on the earliest lignophytes. – In: VECOLI, M., CLÉMENT, G. & MEYER-BERTHAUD, B. (Eds.), The Terrestrialisation Process: Modelling Complex Interactions in the Biosphere-Geosphere Interface. Geological Society, Special Publication, **339**: 81-92.

GHOLAMALIAN, H. & KEBRIAEI, M.-R. (2008): Late Devonian conodonts from the Hojedk Section, Kerman Province, southeastern Iran. – Rivista Italiana di Paleontologia e Stratigrafia, **114** (2): 179-189.

GHOLAMALIAN, H., HAIRAPETIAN, V., BARFEHEI, N., MANGELIAN, S. & FARIDI, P. (2013): Givetian-Frasnian boundary conodonts from Kerman Province, Central Iran. – Rivista Italiana di Paleontologia e Stratigrafia, **119** (2): 133-146.

GINTER, M. & IVANOV, A. (2000): Stratigraphic distribution of chondrichthyans in the Devonian on the East European Platform margin. – Courier Forschungsinstitut Senckenberg, **223**: 325-339.

GINTER, M., HAIRAPETIAN, V. & KLUG, C. (2002): Famennian chondrichthyans from the shelves of North Gondwana. – Acta Geologica Polonica, **52**: 169-215.

GIRARD, C. & ALBARÈDE, F. (1996): Trace elements in conodont phosphates from the Frasnian/Famennian boundary. – Palaeogeography, Palaeoclimatology, Palaeoecology, **126**: 195-209.

GIRARD, C. & RENAUD, S. (2008): Disentangling allometry and response to Kellwasser anoxic events in the Late Devonian conodont genus *Ancyrodella*. – Lethaia, **41**: 383-394.

GIRARD, C., KLAPPER, G. & FEIST, R. (2005): Subdivision of the terminal Frasnian *linguiformis* conodont Zone, revision of the correlative interval of Montagne Noire Zone 13, and discussion of stratigraphically significant associated trilobites. – In: OVER, D. J., MORROW, J. R. & WIGNALL, P. B. (Eds.), Understanding Late Devonian and Permian-Triassic Biotic and Climatic Events; Towards an Integrated Approach. Developments in Palaeontology & Stratigraphy, **20**: 181-198.

GIRARD, C., PHUONG, T. H., SAVAGE, N. & RENAUD, S. (2010): Temporal dynamics of the geographic differentiation of Late Devonian *Palmatolepis* assemblages in the Prototethys. – Acta Palaeontologica Polonica, **55** (4): 675-687.

GLENISTER, B. F. (1958): Upper Devonian amonoids from the *Manticoceras* Zone, Fitzroy Basin, Western Australia. – Journal of Paleontology, 32 (1): 58-96, pls. 5-15.

GLENISTER, B. F. & KLAPPER, G. (1966): Upper Devonian conodonts from the Canning Basin, Western Australia. – Journal of Paleontology, **40** (4): 777-482.

GOLONKA, J. (2007): Phanerozoic paleoenvironment and paleolithofacies maps. Late Paleozoic. – Geologia, **33**: 145-209.

GOMEZ, F., BEAUCHAMP, W. & BARAZANGI, M. (2000): Role of the Atlas Mountains (northwest Africa) within the African-Eurasian plate-boundary zone. – Geology, **28** (9): 775-778.

GOUWY, S. & BULTYNCK, P. (2002): Graphic correlation of Middle Devonian sections in the Ardene region (Belgium) and the Mader-Tafilalt region (Morocco): development of a Middle Devonian composite standard. – In: Proceedings of the first Geologica Belgica International Meeting, Leuven, 11-15 September 2002. Aardkundige Mededelingen, **12**: 105-108.

GOUWY, S. & BULTYNCK, P. (2003): Conodont based graphic correlation of the Middle Devonian formations of the Ardenne (Belgium): implications for stratigraphy and construction of a regional composite. – Revista Española de Micropaleontología, **35** (3): 315-344.

GOUWY, S., HAYDUKIEWICZ, J. & BULTYNCK, P. (2007): Conodont-based graphic correlation of upper Givetian-Frasnian sections of the Eastern Anti-Atlas (Morocco). – Geological Quarterly, **51** (4): 375-392.

GRABAU, A. W. (1928): Palaeozoic Corals of China. Part I. Tetraseptata II. Second contribution to our knowledge of the Streptelasmoid Corals of China and Adjacent Territories. - Palaeontologica Sinica, series B, **2** (2): 1-175, 6 pls.

GRAHAM, J. R. & SEVASTOPULO, G. D. (2008): Mississippian Platform and Basin Successions from the Todrha Valley (northeastern Anti-Atlas), southern Morocco. – Geological Journey, **43**: 361-382.

GROBE, M. (1993): Stratigraphie, Fazies, Tektonik und Maturität des Paläozoikums von Dchar-Ait-Abdallah (östliches Zentral-Marokko), unter besonderer Berücksichtigung der faziellen Entwicklung des Mittel- und Oberdevons. – Unpublished Diplomarbeit, Universität Tübingen, 104 pp.

GROBE, M. (1997): The allochthonous Devonian units of Dchar-Aït-Abdallah, southeastern Meseta, east-central Morocco: a facies model. – Gaea heidelbergensis, **3**: 149.

HAHN, G., MÜLLER, P. & BECKER, R. T. (2012): Unter-karbonische Trilobiten aus dem Anti-Atlas (S-Marokko). – Geologica et Palaeontologica, **44**: 37-74.

HALL, J. (1874): Descriptions of new species of Goniatitidae. With a list of previously described species. – Annual Reports of the Regents of the University of the State New York, **26**: 1-4.

HARTENFELS, S. (2011): Die globalen *Annulata*-Events und die Dasberg-Krise (Famennium, Oberdevon) in Europa und Norda-Afrika – hochauflösende Conodonten-Stratigraphie, Karbonat-Mikrofazies, Paläoökologie und Paläodiversität. – Münstersche Forschungen zur Geologie und Paläontologie, **105**: 17-527.

HARTENFELS, S. & BECKER, R. T. (2016): The global *Annulata* Events: review and new data from the Rheris Basin (northern Tafilalt) of SE Morocco. – In: BECKER, R. T., KÖNIGSHOF, P. & BRETT, C. E. (Eds.), Devonian Climate, Sea Level and Evolutionary Events. Geological Society, London, Special Publications, **423**: 291-354.

HARTENFELS, S., BECKER, R. T. & TRAGELEHN, H. (2009): Marker conodonts around the global *Annulata* Events and the definition of an Upper Famennian substage. – SDS Newsletter, **24**: 40-48.

HARTENFELS, S., BECKER, R. T., EL HASSANI, A. & LÜDDECKE, F. (Eds., 2018): 10th International Symposium „Cephalopods – Present and Past", Fes, 26th March – 3rd April 2018, Field Guidebook. – Münstersche Forschungen zur Geologie und Paläontologie, **110**: 110-306.

HARTENFELS, S., BECKER, R. T. & ABOUSSALAM, Z. S. (2016): Givetian to Famennian stratigraphy, Kellwasser, *Annulata* and other events at Beringhauser Tunnel (Messinghausen Anticline, eastern Rhenish Massif). – Münstersche Forschungen zur Geologie und Paläontologie, **108**: 196-219.

HAUDE, R., CORRIGA, M. G., CORRADINI, C. & WALLISER, O. H. (2014): Bojen-Seelilien (Scyphocrinitidae, Echinodermata) in neu-datierten Schichten vom oberen Silur bis untersten Devon Südost-Marokkos. – Göttingen Contributions to Geosciences, **77**: 129-145.

HAVLÍČEK, V. (1956): Brachiopods of the Bráník and Hlubočepy limestones in the immediate vicinity of Prague. – Sborník Ústředniho ústavu geologického, **22**: 535-565.

HECKEL, P. H. & WITZKE, B. J. (1979): Devonian world palaeogeography determined from distributions of carbonates and related lithic palaeoclimatic indicators. – Special Papers in Palaeontology, **23**: 99-123.

HELLING, S. & BECKER, R. T. (2015): A new Pragian trilobite assemblage from Aïn-al-Aliliga (western Meseta, NW Morocco). – In: MOTTEQUIN, B., DENAYER, J., KÖNIGSHOF, P., PRESTIANNI, C. & OLIVE, S. (Eds.), IGCP 596 – SDS Symposium "Climate change and Biodiversity patterns in the Mid-Palaeozoic", September 20-22. 2015, Brussels – Belgium, Abstracts. Strata, Travaux de Géologie sédimentaire et Paléontologie, Série 1: communications, **16**: 68-69.

HINDERMEYER, J. (1954): Découverte du Tournaisian, et tectonique prémonitoire hercynienne dans la region

de Tinerhir (flanc nord du Sarho-Ougnat). – Comptes Rendus hebdomadaires des Séances de l´Academie des Sciences, Paris, **239**: 1824-1826.

HINDERMEYER, J. (1955): Sur le Dévonien et l´existence de mouvements calédoniens dans la region de Tinerhir. – Comptes Rendus de l´Academie des Sciences, Paris, **240** (26):2547-2549.

HOEPFFNER, C., SOULAIMANI, A. & PIQUE, A. (2005): The Moroccan Hercynides. – Journal of African Earth Sciences, **43**: 144-165.

HOEPFFNER, C., HOUASRI, M. R. & BOUABDELLI, M. (2006): Tectonics of the North African Variscides (Morocco, western Algeria): an outline. – Compte Rendus Geosciences, **338**: 25-40.

HOLLARD, H. (1967): Le Dévonien du Maroc et du Sahara nord-occidentale. – In: OSWALD, D. H. (ed.), International Symposium on the Devonian System, Calgary, 1967, **I**: 203-244; Alberta Society of Petroleum Geologists, Calgary.

HOLLARD, H. & MORIN, P. (1973): Les gisements de *Dzieduszyckia* (Rhynchonellida) du Famennien inférieur du Massif hercynien central du Maroc. – Notes et Mémoires du Service Géologique du Maroc, **33** (249): 7-14.

HOLLARD, H. (1978): Corrélations entre niveaus à brachiopods et á goniatites au voisinage de la limite Dévonien inférieur – Dévonien moyen dans les plaines du Dra (Maroc présaharien). – Newsletters on Stratigraphy, **7** (1): 8-25.

HOLLARD, H., LYS, M., MAUVIER, A. & MORIN, P. (1970): Précisions sur l´age famennien inférieur des *Dzieduszyckia* (Rhynchonellida) du Massif hercynien central du Maroc. – Comptes Rendus de l´Academie des Sciences Paris, Série D, **270**: 3177-3180.

HOLLARD, H., MICHARD, A., JENNY, P., HOEPFFNER, C. & WILLEFERT, S. (1982): Stratigraphie du Primaire de Mechra-Ben-Abbou, Rehamna. – In: MICHARD, A. (Ed., 1982), Le massif Paléozoique des Rehamna (Maroc). Stratigraphie, Tectonique et Petrogenese d´un segment de la Chaine Varisque. - Notes et Mémoires du Service Géologique, **303**: 180 pp.

HORON, O. (1954): Note sur la géologie des affleurements de Primaire de la region du Kandar. – Unpublished Report, Archive of B.R.P.M.

HOU, H.-F. (1988, Ed.): Devonian stratigraphy, Paleontology and Sedimentary Facies of Longmenshan, Sichuan. – Chengdu Institute of Geology and Mineral Resources; Geological Publishing House, Beijing.

HOUSE, M. R. (1975): Facies and Time in Devonian Tropical Areas. – Proceedings of the Yorkshire Geological Society, **40** (2): 233-288.

HOUSE, M. R. & KIRCHGASSER, W. T. (1993): Devonian goniatite biostratigraphy and timing of facies movements in the Frasnian of eastern North America. – In: HAILWOOD, E. A. & KIDD, R. B. (Eds.): High Resolution Stratigraphy. Geological Society Special Publication, **70**: 267-292.

HOUSE, M. R. & KIRCHGASSER, W. T. (2009): Late Devonian goniatites (Cephalopoda, Ammonoidea) from New York State. – Bulletins of American Paleontology, **374**: 1-285.

HOUSE, M. R. & ZIEGLER, W. (1977): The Goniatite and Conodont sequences in the early Upper Devonian at Adorf, Germany. – Geologica et Palaeontologica, **11:** 69-108.

HOUSE, M.R., BECKER, R.T., FEIST, R., FLAJS, G., GIRARD, C. & KLAPPER, G. (2000a): The Frasnian/Famennian boundary GSSP at Coumiac, southern France. - Courier Forschungsinstitut Senckenberg, **225**: 59-75.

HOUSE, M.R., MENNER, V.V., BECKER, R.T., KLAPPER, G., OVNATANOVA, N.S., KUZ´MIN, V., (2000b): Reef episodes, anoxia and sea-level changes in the Frasnian of the southern Timan (NE Russian platform). - In: INSALACO, E., SKELTON, P.W., PALMER, T.J. (Eds.), Carbonate Platform Systems: components and interactions. Geological Society, London, Special Publications, **178**: 147-176.

HUDDLE, J. W., assisted by REPETSKI, J. E. (1981): Conodonts from the Genesee Formation in Western New York. – Geological Survey Professional Paper, **1032-B**: 1-66 + 31 pls.

HUDSON, R. G. S. (1936): On the Lower Carboniferous Corals: *Rhopalolasma*, gen. nov. and *Cryptophyllum*, CARR. - Proceedings of the Yorkshire Geological Society, **23** (2): 91-102, pls. 4-5.

HÜNEKE, H. (2001): Gravitative und strömungsinduzierte Resedimente devonischer Karbonatabfolgen im marokkanischen Zentralmassiv (Rabat-Tiflet-Zone, Decke von Ziar-Mrirt). – Unpublished Habilitation Thesis, Ernst-Moritz-Arndt-Universität Greifswald, 230 pp.

HÜNEKE, H. (2006): Erosion and deposition from bottom currents during the Givetian and Frasnian: Response to intensified oceanic circulation between Gondwana and Laurussia. – Palaeogeography, Palaeoclimatology, Palaeoecology, **234**: 146-167.

HÜNEKE, H. (2007): Pelagic carbonate ooze reworked by bottom currents during Devonian approach of the continents Gondwana and Laurussia. – In: VIANA, A. R. & REBESCO, M. (Eds.), Economic and Palaeoceanographic significance of Contourite Deposits. Geological Society, London, Special Publication, **276**: 299-328.

HÜNEKE, H. (2013): Facies and sedimentary architecture of Upper Devonian limestones at Gara de Mrirt, Eastern Moroccan Central Massif: Resedimentation in response to block faulting. – In: EL HASSANI, A., BECKER, R. T. & TAHIRI, A. (Eds.), International Field Symposium "The Devonian and Lower Carboniferous of northern Gondwana", Abstract Book. Documents de l´Institut Scientifique, **26**: 62-64.

HUVELIN, P. (1970): Mouvements hercyniens précoces dans le region de Mrirt (Maroc). – Comptes Rendus de l´Academie des Sciences, Paris, **271**: 953-955.

HUVELIN, P. (1977): Etude géologique et gitologique du massif hercynien des Jebilet (Maroc occidental). – Notes et Mémoires du Service Géologique, **232 bis**: 307 pp.

HUVELIN, P. & MAMET, B. (1997): Transgressions, faulting and redeposition phenomenon during the Visean in the Khenifra area; Western Moroccan Meseta. – Journal of African Earth Sciences, **25** (3): 383-389.

IKENNE, M., SOUHASSOU, M., ARAI, S. & SOULAIMANI, A. (2016): A historical overview of Moroccan magmatic events along northwest edge of the West African Craton. – Journal of African Earth Sciences, **127**: 3-15.

IZART, A. & VIESLET, J. L. (1988): Stratigraphie, Sédimentologie et Micropaléontologie des sédiments du bassin de Sidi Bettache et ses bordures (Meseta marocaine nord-occidentale) du Famennien au Viséen supérieur. – Notes et Mémoirs du Service géologique du Maroc, **334**: 7-41.

JANSEN, U. (2001): Morphologie, Taxonomie und Phylogenie unter-devonischer Brachiopoden aus der Dra-Ebene (Marokko, Prä-Sahara) und dem Rheinischen Schiefergebirge (Deutschland). – Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, **554**: 1-389-

JANSEN, J., LAZREQ, N., PLODOWSKI, G., SCHEMM-GREGORY, M., SCHINDLER, E. & WEDDIGE, K. (2007): Neritic-pelagic correlation in the Lower and basal Middle Devonian of the Dra Valley (Southern Anti-Atlas, Moroccan Pre-Sahara). – In: BECKER, R. T. & KIRCHGASSER, W. T. (Eds.), Devonian Events and Correlations. Geological Society, London, Special Publications, **278**: 9-37.

JEANETTE, D. & PIQUE, A. (1981): Le Maroc hercynien: plate-forme disloquée du craton oust-africain. – Comptes Rendus de l´Academie des Sciences, Paris, Série II, **293**: 79-82.

JOACHIMSKI, M. M. & BUGGISCH, W. (1993): Anoxic events in the late Frasnian - Causes of the Frasnian-Famennian faunal crisis? - Geology, **21**: 657-678.

JOACHIMSKI, M. M., OSTERTAG-HENNING, C., PANCOST, R. D., STRAUSS, H., FREEMAN, K. H., LITTKE, R., SINNINGHE DAMSTÉ, J. S. & RACKI, G. (2001): Water column anoxia, enhanced productivity and concomitant changes in $\delta^{13}C$ and $\delta^{34}S$ across the Frasnian-Famennian boundary (Kowala – Holy Cross Mountains / Poland). - Chemical Geology, **175**: 109-131.

JOACHIMSKI, M. M., PANCROST, R. D., FREEMAN, K.A., OSTERTAG-HENNING, C. & BUGGISCH, W. (2002): Carbon isotope geochemistry of the Frasnian - Famennian transition. - Palaeogeography, Palaeoclimatology Palaeoecology, **181**: 91-109.

KAISER, S. I., BECKER, R. T. & EL HASSANI, A. (2007): Middle to Late Famennian succession at Aïn Jemaa (Moroccan Meseta) – implications for regional correlation, event stratigraphy and synsedimentary tectonics of NW Gondwana. – In: BECKER, R. T. & KIRCHGASSER, W. T. (Eds.), Devonian Events and Correlations. Geological Society, London, Special Publications, **278**: 237-260.

KAISER, S. I., BECKER, R. T., SPALLETTA, C. & STEUBER, T. (2009): High-resolution conodont biostratigraphy, biofacies, and extinctions around the Hangenberg Event in pelagic successions from Austria, Italy, and France. – In: OVER, J. D. (Ed.), Studies in Devonian Stratigraphy: Proceedings of the 2007 International Meeting of the Subcommission on Devonian Stratigraphy and IGCP 499. Palaeontographica Americana, **63**: 99-143.

KAISER, S. I., BECKER, R. T., STEUBER, T. & ABOUSSALAM, Z. S. (2011): Climate-controlled mass extinctions, facies, and sea-level changes around the Devonian-Carboniferous boundary in the eastern Anti-Atlas (SE Morocco). – Palaeogeography, Palaeoclimatology, Palaeoecology, **310**: 340-364.

KELLING, G. & MULLIN, P. R. (1975): Graded limestones and limestone-quartzite couplets. possible storm-deposits from the Moroccan Carboniferous. – Sedimentary Geology, **13**: 161-190.

KERGOMARD, D. (1970): Contribution à l´ètude du Siluro-Dévonien de la Meseta occidentale. – Unpublished Report B.R.P.M., Rabat.

KLAPPER, G. (1989): The Montagne Noire Frasnian (Upper Devonian) conodont succession. – In: MCMILLAN, N. J., EMBRY, A. F. & GLASS, D. J. (Eds.), Devonian of the World, Proceedings of the Sercond International Symposium on the Devonian System, Calgary, Canada. Canadian Society of Petroleum Geologists, Memoir, **14** (III): 449-468 [imprint 1988].

KLAPPER, G. (1997): Graphic correlation of Frasnian (Upper Devonian) sequences in Montagne Noire,

France, and western Canada. – In: KLAPPER, G., MURPHY, M. A. & TALENT, J. A. (Eds.), Paleozoic Sequence Stratigraphy, Biostratigraphy, and Biogeography: Studies in Honor of J. Granville ("Jess") JOHNSON. Geological Society of America, Special Paper, **321**: 113-129.

KLAPPER, G. (2009): Upper Devonian conodonts in the Canning Basin. - Geological Survey of Western Australia, Bulletin, **145**: 405-413.

KLAPPER, G. & KIRCHGASSER, W. T. (2016): Frasnian Late Devonian conodont biostratigraphy in New York: graphic correlation and taxonomy. – Journal of Paleontology, **90** (3): 525-554.

KLAPPER, G., KUZ´MIN, A. & OVNATANOVA, N. S. (1996): Upper Devonian conodonts from the Timan-Pechora region, Russia, and correlation with a Frasnian Composite Standard. – Journal of Paleontology, **70** (1): 131-152.

KLAPPER, G. & VODRÁŽKOVÁ, S. (2013): Ontogenetic and intraspecific variation in the late Emsian – Eifelian (Devonian) conodonts *Polygnathus serotinus* and *P. bultyncki* in the Prague Basin (Czech Republic) and Nevada (western U.S.). – Acta Geologica Polonica, **63** (2): 153-174.

KLUG, C. (2002): Quantitative stratigraphy and taxonomy of late Emsian and Eifelian ammonoids of the eastern Anti-Atlas (Morocco). – Courier Forschungsinstitut Senckenberg, **238**: 1-109.

KONONOVA, L. I. & KIM, S.-Y. (2003): Eifelian Conodonts from the Central Russian Platform. – Paleontological Journal, **39**, Supplement 2: 55-134.

KOPTIKOVÁ, L. (2011): Precise position of the Basal Choteč event and evolution of sedimentary environments near the Lower-Middle Devonian boundary: the magnetic susceptibility, gamma-ray spectrometric, lithological, and geochemical record of the Prague Synform (Czech Republic). – Palaeogeography, Palaeoclimatology, Palaeoecology, **304**: 96-112.

KREBS, W. (1974): Devonian carbonate complexes of Central Europe. - SEPM Special Publication, **18**: 155-208.

KREBS, W. (1979): Devonian basinal facies. – Special Papers in Palaeontology, **23**: 125-139.

LAAMRANI ELIDRISSI, A. (1993): Relations deformations-deplacements le long de failles hercyniennes: Systeme de Bouznika et Systemes du Cherrat-Ben Slimane et du Cherrat-Yquem. – Unpublished Diplom Thesis, Université Mohammed V, Rabat, 200 pp., online at http://archives.cnd.hcp.ma/uploads/news/017942.pdf.

LAVENU, A. (1976): Etude tectonique et microtectonique d´un segment de chaine hercynienne dans la partie sud-orientale du Maroc central (Région situeé entre Khénifra et Kef-en-Nsour). – Notes et Mémoires du Service Géologique, **261**: 57-111.

LAVILLE, E. (1980): Tectonique et Microtectonique d´une partie du versant sud du Haut Atlas marocain (Boutonnière de Skoura, Nappe de Toundout). – Notes et Mémoires du Servioce géologique du Maroc, **41** (285): 81-183.

LAZREQ, N. (1990): Devonian Conodonts from Central Morocco. – Courier Forschungsinstitut Senckenberg, **118**: 65-79.

LAZREQ, N. (1992a): Le Dévonien du Maroc central: biostratigraphie des Conodontes. Biofaciès et événement Kellwasser. – Unpublished Ph. D. Thesis, University Marrakech, 260 pp.

LAZREQ, N. (1992b): The Upper Devonian of Mrirt (Morocco). Courier Forschungsinstitut Senckenberg, **154**: 107-123.

LAZREQ, N. (1999): Biostratigraphie des conodontes du Givétien au Famennien du Maroc central – Biofaciès et événement Kellwasser. – Courier Forschungsinstitut Senckenberg, **214**: 1-111.

LAZREQ, N. (2017): A propos de l´existence du Famennien au sud des Jebilet Centrales et altération des conodontes: cas de Koudiat Laabid (Jbel Guéliz, Marrakech, Maroc). – Bulletin de l´Institute Scientifique, Rabat, Section Sciences de la Terre, **39**: 79-86.

LECOINTRE, G. (1926) Recherches géologiques dans la Meseta marocaine. – Mémoires de l´Société des Sciences Naturelles du Maroc, **14**: 1-158.

LE HOUEDEC, S., GIRARD, C. & BALTER, V. (2013): Conodont Sr/Ca and δ^{18}O record seawater changes at the Frasnian-Famennian boundary. – Palaeogeography, Palaeoclimatology, Palaeoecology, **376**: 114-121.

LINDSKOG, A., ERIKSSON, M. E., BERGSTRÖM, S. M., TERFELT, F. & MARONE, F. (2017): Palaeozoic ´conodont pearls` and other phosphatic microsphaerules. – Lethaia, **50**: 26-40.

MAMET, B., PREAT, A. & LEHMAMI, M. (1999): Algues calcaires marines du Dévonien marocain (Meseta). – Revue de Micropaléontologie, **42** (4): 301-314.

MATTE, P. (2001): The Variscan collage and orogeny (480-290 Ma) and the tectonic definition of the Armorica microplate: a review. – Terra Nova, **13**: 122-128.

MAY, A. (1993): Korallen aus dem höheren Eifelium und unteren Givetium (Devon) des nordwestlichen Sauerlandes (Rheinisches Schiefergebirge). Teil I: Tabulate Korallen. - Palaeontographica, Abt. A, **227**: 87-224, pls. 5-19.

MAY, A. (2005): Die Stromatoporen des Devons und Silurs von Zentral-Böhmen (Tschechische Republik)

und ihre Kommensalen. - Zitteliana, **B25**: 117-250, pl. 1-43.

McKerrow, W. S., Mac Niocaill, C., Ahlberg, P. E., Clayton, G., Cleal, C. J. & Eagar, R. M. C. (2000): The Late Palaeozoic relations between Gondwana and Laurussia. – Geological Society, London, Special Publications, **179**: 9-20.

Michard, A. (1976): Eléments de géologie marocaine. – Notes et Mémoires du Service Géologique du Maroc, 252: 408 pp.

Michard, A. (Ed., 1982): Le massif Paléozoique des Rehamna (Maroc). Stratigraphie, Tectonique et Petrogenese d´un segment de la Chaine Varisque. – Noters et Mémoires du Service Géologiquw, **303**: 180 pp.

Michard, A., Yazidi, A., Benziane, F., Hollard, H. & Willefert, S. (1982): Foreland thrusts and olistostromes on the pre-Sahara margin of the Variscan orogen, Morocco. – Geology, 10: 253-256.

Michard, A., Hoepffner, C., Soulaimani, A. & Baidder, A. (2008): The Variscan Belt. – In: Michard, A., Saddiqi, O., Chalouan, A. & Fritz de Lamotte, D. (Eds.), Continental Evolution: The Geology of Morocco. Lecture Notes in Earth Sciences, **116**: 65-132.

Michard, A., Soulaimani, A., Hoepffner, C., Ouzanaimi, H., Baidder, L., Rjimati, E. C. & Saddiqi, O. (2010): The South-Western Branch of the Variscan Belt: Evidence from Morocco. – Tectonophysics, **492**: 1-24.

Morzadec, P. (1988): Le genre *Psychopyge* (Trilobita) dans de Dévonien inférieur du nord de l´Afrique et l´ouest de l´Europe. – Palaeontographica, Abt. A, **200** (4/6): 153-161, 2 pls.

Mottequin, B. & Poty, E. (2016): Kellwasser horizons, sea-level changes and brachiopod-coral crises during the late Frasnian in the Namur-Dinant Basin (southern Belgium): a synopsis. – In: Becker, R. T., Königshof, P. & Brett, C. E. (Eds.), Devonian Climate, Sea Level and Evolutionary Events. Geological Siciety, London, Special Publications, **423**: 235-250.

Mountjoy, E. W. & Jull, R. K. (1978): Fore-reef carbonate mud bioherms and associated reef-margin, Upper Devonian, Ancient Wall Reef complex, Alberta. – Canadian Journal of Earth Sciences, **15**: 1304-1325.

Münster, G., Graf zu (1831): Über das geognostische Vorkommen der Ammoneen in Deutschland. – Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde, **1831**: 367-375.

Münster, G., Graf zu (1832): Ueber die Planuliten und Goniatiten im Uebergangs-Kalk des Fichtelgebirges. – 38 pp., 6 pls.; Birner, Bayreuth.

Münster, G., Graf zu (1839): Nachtrag zu den Goniatiten im Fichtelgebirge. – Beiträge zur Petrefaktenkunde, **1**: 43-55, pls. 3-5.

Mullin, P., Bedsaïd, M. & Kelling, G. (1976): Les nappes hercyniennes au sud-est du Maroc central; une nouvelle interpretation. – Comptes Rendus de l´Academie des Sciences, Paris, Série D, **282**: 827-830.

Nahraoui, F. Z., Wartiti, M. El, Boukili, B., Moutaouakkil, N. El, Kacimi, I., Amrani Idrissi, H., Kharchof, A. El K. & Maalam, B. (2012): The cement Temara: needs a new deposit of limestone (case the deposit of oued Cherrat). – MATEC Web of Conference, **2** (05003): 1-7.

Nance, R. D., Gutiérrez-Alonso, G., Keppie, J. D., Linnemann, U., Murphy, J. B., Quesada, C., Strachan, R. A., Woodcock, N. H. (2012): A brief history of the Rheic Ocean. – Geoscience Frontiers, **3** (2): 125-135.

Narkiewicz, K. & Bultynck, P. (2007): Conodont biostratigraphy of shallow marine Givetian deposits from the Radom-Lublin area, SE Poland. – Geological Quarterly, **51** (4): 419-442.

Narkiewicz, K. & Bultynck, P. (2010): The upper Givetian (Middle Devonian) *subterminus* conodont zone in North America, Europe and North Africa. – Journal of Paleontology, **84** (4): 588-625.

Narkiewicz, K., Narkiewicz, M. & Bultynck, P. (2016): Conodont biofacies of the Taghanic transgressive interval (middle Givetian): Polish record and global comparisons. – In: Becker, R. T., Königshof, P. & Brett, C. E. (Eds.), Devonian Climate, Sea Level and Evolutionary Events. Geological Society, London, Special Publications, **423**: 201-222.

Narkiewicz, K., Narkiewicz, M., Bultynck, P. & Königshof, P. (2017): The past, present and future of the upper Eifelian conodont zonation. – In: Liao, J.-C. & Valenzuela-Ríos, J. I. (Eds.), Fourth International Conodont Symposium, ICOS IV "Progress on Conodont Investigation". Cuadernos del Museo Geominero, **22**: 137-140.

Nazik, A. & Groos-Uffenorde, H. (2016): Notes on beyrichiacean ostracods from the Early Devonian of NW Turkey and their palaeobiogeographical relations. – Turkish Journal of Earth Sciences, **25**: 201-226.

Neqqazi, A., Raji, M. & Benfrika, M. El (2014): Conodontes du Carbonifère inférieur de la région de l`Oued Cherrat (Meseta nord-occidentale, Maroc). – International Journal of Innovation and Applied Studies, **9** (1): 81-88.

Neugebauer, J. (1988): The Variscan plate tectonic evolution: an improved „Iapetus model". –

Schweizerische Mineralogische und Petrographische Mitteilungen, **68**: 313-333.

NICOLL, R. S. (1980): The multielement genus *Apatognathus* from the Late Devonian of the Canning Basin, Western Australia. – Alcheringa, **4**: 133-152.

OUANAIMI, H. & PETIT, J. P. (1992): La limite sud de la chaîne hercynienne dans le Haut-Atlas marocain: reconstitution d´un saillant non déforme. – Bulletin de l`Société Géologie du France, **163**: 63-73.

OUANAIMI, H., SOULAIMANI, A., HOEPFFNER, C. & MICHARD, A. (2019): The "Eovariscan Synmetamorphic Phase" of the Morioccan Meseta Domain Revisited; A Hint for Late Devonian Extensional Geodynamics Prior to the Variscan Orogenic Evolution. – In: ROSSETTI, F. et al. (Eds.), The Structural Geology Contribution to the Africa-Eurasia Geology: Basement and Reservoir Structure, Ore Mineralisation and Tectonic Modelling: 259-261; Advances in Science, Technology & Innovation.

OUARHACHE, D. (1987): Ètude géologique dans le Paléozoique et le Trias de la bordure NW du causse Moyen-Atlasique (S et SW de Fès, Maroc). – Thèse 3ème cycle, Université de Toulouse, 130 pp.

OUARHACHE, D., BAUDELOT, S., CHARRIÈRE, A., PERRET. M. F. & VACHARD, D. (1991): Nouvelles datations micrpaléontologiques et palynologiques dans le Viséen de la bordure nord occidentale du Causse moyen-atlasique (Maroc). – Géologie Méditerranéenne, **18** (1/2): 43-59.

OVNATANOVA, N. S. & KONONOVA, L. I. (2008): Frasnian Conodonts from the Eastern Russian Platform. – Paleontological Journal, **42** (10): 997-1166.

PÉREZ-CÁZERES, I., MARTÍNEZ POYATOS, SIMANCAS, J. F. & AZOR, A. (2017): Testing the Avalonian affinity of the South Portuguese Zone and the Neoproterozoic evolution of SW Iberia through detrital zircon populations. – Gondwana Research, **42**, 177-192.

PETTER, G. (1959): Goniatites dévoniennes du Sahara. – Publications du Service de la Carte Géologique de l´Algérie, Nouvelle Série, Paléontologie, **2**: 1-313, 26 pls.

PIQUE, A. (1975): Différenciation des aires de sédimentation au Nord-Ouest de la Meseta marocaine; la distension dévono-dinantienne. – Comptes Rendus de l´Academie des Sciences Paris, **281**: 767-770.

PIQUE, A. (1979): Évolution structural d´un segment de la chaîne hercynienne: La Meseta Marocaine nord-occidentale. – Sciences Géologiques, Mémoire, **56**: 243 pp.

PIQUE, A. (1984): Facies sédimentaire et evolution d´un basin: le Bassin dévono-dinantien de Sidi Bettache (Maroc nord-occidental). – Bulletin de l`Société Géologique du France, (7), **26** (6): 1015-1023.

PIQUE, A. & MICHARD, A. (1981): Les zones structurales du Maroc hercynien. – Sciences Géologiques, Bulletin, **34** (2): 135-146.

PIQUE, A. (1994): Géologie du Maroc. Les domaines régionaux et leur évolution structurale. – 284 pp., Marrakech.

PIQUE, A. (2001): Geology of Northwest Africa. – 310 pp., Bornträger, Berlin.

PIQUE, A. & MICHARD, A. (1989): Moroccan Hercynides: a synopsis. The Paleozoic sedimentary and tectonic evolution at the northern margin of West Africa. – American Journal of Science, **289**: 286-330.

PIQUE, A., JEANETTE, D. & MICHARD, A. (1980): The Western Meseta Shear Zone, a major and permanent feature of the Hercynian belt in Morocco. – Journal of Structural Geology, **2** (1/2): 55-61.

PISARZOWSKA, A., SOBSTEL, M. & RACKI, G. (2006): Conodont-based event stratigraphy of the Early-Middle Frasnian transition on the South Polish carbonate shelf. – Acta Palaeontologica Polonica, **51** (4): 609-646.

PISARZOWSKA, A., BECKER, R. T., ABOUSSALAM, Z. S., SZCZERBA, M., SOBIEN, K., KREMER, B., OWOCKI, K. & RACKI, G. (2020 in press): Middlesex/*punctata* Event in the Rhenish Basin (Padberg section, Sauerland, Germany) – multidisziplinary clues to the early-middle Frasnian global biogeochemical perturbation. – Global and Planetary Change.

PLAYFORD, P. E., HOCKING, M. R. & COCKBAIN, A. E. (2009): Devonian Reef Complexes of the Canning Basin, Western Australia. – Geological Survey of Western Australia, Bulletin, **145**: 1-403.

POLLOCK, C. A. (1968): Lower Upper Devonian conodonts from Alberta, Canada. – Journal of Paleontology, **42** (2): 415-443, pls. 61-64.

POTTHAST, I. & OEKENTORP, K. (1987): Eine Favositiden-Fauna aus dem Emsium/Eifelium des Hamar Laghdad, Tafilalt (SE-Marokko). – Münstersche Forschungen zur Geologie und Paläontologie, **66**: 57-93.

PRESTIANNI, C., MEYER-BERTHAUD, B., BLANCHARD, R., RÜCKLIN, M., CLÉMENT, G. & GERRIENNE, P. (2012): The Middle Devonian plant assemblage from Dechra Aït Abdallah (Central Morocco) revisted. – Review of Palaeobotany and Palynology, **179**: 44-55.

RACHEBEUF, P. R. (1990a): Chonetacés (Brachiopodes) éo- et mésodévoniens de la Meseta Hercynienne et

de l´Anti-Atlas, Maroc. - Géologie Méditerranéenne, **17** (3/4): 301-319.

RACHEBEUF, P. R. (1990b): Silurian to Middle Devonian chonetacean brachiopods from the northwestern Gondwanaland margin: A review in time and space. – In: MACKINNON, D. I., LEE, D. E. & CAMPBELL, J. D. (Eds.), Brachiopods through time: 319-323; A. A. Balkema (Rotterdam, Brookfield).

RAJI, M. & BENFRIKA, E. M. (2009): L´indice de l´altération de la couleur des conodontes: Indicateur d´activité hydrothermale. L´exemple du Dévonien de Mrirt (Maroc central oriental). – Notes et Mémoires du Service Géologique du Maroc, **530**.

RAUMER, J. F. VON, BUSSY, F. & STAMPFLI, G. M. (2009): The Variscan evolution in the External massifs of the Alps and place in their Variscan framework. – Comptes Rendus Geoscience, **341**: 239-252.

RÈGNAULT, A. (1985): Les Scyphocrinitidae (Crinoidea, Camerata) du Silurien terminal-Dévonien basal au Maroc. Répartition stratigraphique et paléogeographique. Discussion. – Actes 110e Congress des Naturelle Société du Savantes, Montpellier Sciences, **4**: 9-20.

RÉGNAULT, S. & CHAUVEL, J. (1987): Découverte d´un échinoderme carpoide (Stylophora – Mitrata) dans le Dévonien Inférieur du Maroc. – Geobios, **20** (5): 669-674.

RIBEYROLLES, M. (1976): Etude tectonique et microtectonique d´un segment de chaine hercynienne dans la partie sud-orientale du Maroc central (Region située entre Aguelmous et Mrirt) – Notes et Mémoires du Service Géologique du Maroc, **261**: 9-56.

RICHTER, J. (2017): Biostratigraphie und Fazies im Devon von Immouzer-du-Kandar südlich von Fes (Marokkanische Meseta). – Unpublished M. Sc. Thesis, WWU Münster, 112 pp.

RICHTER, J., HARTENFELS, S., ABOUSSALAM, Z. S., BECKER, R. T. & EL HASSANI, A. (2016): Biostratigraphy of the isolated Devonian (Emsian to Famennian) at Immouzer du Kandar (south of Fes, Moroccan Meseta). – In: International Geoscience Programme Project 591 - Closing Meeting "The Early to Mid palaeozoic Revolution", Ghent University, Ghent, Belgium, 6-9 July 2016, Closing Meeting Abstracts: 127.

RIQUIER, L., TRIBOVILLARD, N., AVERBUCH, O., JOACHIMSKI, M. M., RACKI, G., DEVLEESCHOUWER, X., EL ALBANI, A. & RIBOULLEAU (2005): Productivity and bottom water redox conditions at the Frasnian-Famennian boundary on both sides of the Eovariscan Belt: constraints from trace-element geochemistry. – In: OVER, D. J., MORROW, J. R. & WIGNALL, P. B. (Eds.), Understanding Late Devonian and Permian-Triassic Biotic and Climatic Events; Towards an Integrated Approach. Developments in Palaeontology & Stratigraphy, **20**: 199-224.

RIQUIER, L., AVERBUCH, O., TRIBOVILLARD, N., EL ALBANI, A., LAZREQ, N. & CHAKIRI, S. (2007): Environmental changes at the Frasnian-Famennian boundary in Central Morocco (Northern Gondwana): integrated rock-magnetic and geochemical studies. – In: BECKER, R. T. & KIRCHGASSER, W. T. (eds.), Devonian Events and Correlations. Geological Society, London, Special Publications, **278**: 197-217.

ROBARDET, M. (2003): The Armorica ´microplate` fact or fiction? Critical review of the concept and contradictory palaeobiogeographical data. – Palaeogeography, Palaeoclimatology, Palaeoecology, **195**: 125-148.

ROBARDET, M., PARIS, F. & RACHEBEUF, P. R. (1990): Palaeogeographic evolution of southwestern Europe during Early Palaeozoic times. – In: MCKERROW, W. S. & SCOTESE, C. R. (Eds.), Palaeozoic Palaeogeography and Biogeography. Geological Society, Memoir, **12**: 411-419.

ROCH, E. (1939): Descxriptions géologiques des montagne à l´Est de Marrakech. – Notes et Mémoires du Service des Mines et Carte géologiques du Maroc, **51**: 438 pp.

ROCH, E. (1950): Histoire Stratigraphique du Maroc. – Notes et Mémoires du Service Géologique du Maroc, **80**: 1-435, 11 maps.

RYTINA, M.-K., BECKER, R. T., ABOUSSALAM, Z. S., HARTENFELS, S., HELLING, S., STICHLING, S. & WARD, D. (2013): The allochthonous Silurian-Devonian in olistostromes at “the Southern Variscan Front” (Tinerhir region, SE Morocco) – preliminary data. – Documents de l´Institut Scientifique, Rabat, **27**: 11-21.

SANDBERG, C. A. (1976): Conodont biofacies of Late Devonian *Polygnathus styriacus* Zone in Western United States. – The Geological Association of Canada, Special Paper, **15**: 171-186.

SANDBERG, C. A., ZIEGLER, W., DREESEN, R. & BUTLER, J. L. (1992): Conodont Biochronology, Biofacies, Taxonomy, and Event Stratigraphy around Middle Frasnian Lion Mudmound (F2h), Frasnes, Belgium. – Courier Forschungsinstitut Senckenberg, **150**: 1-87.

SANDBERG, C. A., MORROW, J. A. & ZIEGLER, W. (2002): Late Devonian sea-level changes, catastrophic events, and mass extinctions. – In: KOEBERL, C. & MACLEOD, K. G. (Eds.), Catastrophic Events and Mass Extinctions: Impacts

and Beyond. Geological Society of America, Special Paper, **356**: 473-487.

SANDBERGER, G. (1855): *Clymenia subnautilina* (nova species), die erste und bis jetzt einzige Art aus Nassau. – Jahrbücher des Vereins für Naturkunde im Herzogthum Nassau, **10**: 127-136, pl. 1.

SANDBERGER, G. & SANDBERGER, F. (18450-1856): Die Versteinerungen des rheinischen Schichtensystems in Nassau. Mit einer kurzgefassten Geognosie dieses Gebietes und mit steter Berücksichtigung analoger Schichten anderer Länder. – XIV + 564 pp., 41 pls.; Wiesbaden.

SANDY, M. R. (1995): A review of some Palaeozoic and Mesozoic brachiopods as members of cold seep chemosynthethic communities: "unusual" palaeoecology and anomalous palaeobiogeographic patterns explained. – Földtani Közlöny, **125** (3/4): 241-258.

SAVAGE, N. (2013): Late Devonian conodonts from northwestern Thailand. – 48 pp., Trinity Press, Eugene, Oregon.

SCHINDEWOLF, O. H. (1942): Zur Kenntnis der Polycoelien und Plerophyllen. Eine Studie über den Bau der "Tetrakorallen" und ihre Beziehungen zu den Madreporarien. - Abhandlungen des Reichsamts für Bodenforschung, Neue Folge, **204**: 1-324, 36 pls..

SCHINDLER, E. (1990): Die Kellwasser-Krise (hohe Frasne-Stufe, Ober-Devon). – Göttinger Arbeiten zur Geologie und Paläontologie, **46**: 1-115.

SCHÜLKE, I. (1999): Conodont multielement reconstructions from the early Famennian (Late Devonian) of the Montagne Noire (Southern France). – Geologica et Palaeontologica, SB **3**: 1-124.

SCHUMACHER, E. (1971): Conodonts from the Middle Devonian Lake Church and Milwaukee Formations. – In: CLARK, D. L. (Ed.), Conodonts and Biostratigraphy of the Wisconsin Paleozoic. Wisconsin Geological and Natural History Survey, Information Circular, **19**: 55-67, 90-99.

SCHWERMANN, K. (2014): Devonische Haizähne aus Marokko – Taxonomie, Stratigraphie und fazielle Verbreitung. – Unpublished M.Sc. Thesis, WWU Münster, 80 pp.

SIMANCAS, J., AZOR, A., MARTÍNEZ-POYATOS, D., TAHIRI, A., EL HADI, H., GONZÁLEZ-LODEIRO, F., PÉREZ-ESTAÚN, A. & CARBONELL, R. (2009): Tectonic relationships of Southwest Iberia with the allochthonous of Northwest Iberia and the Moroccan Variscides. – Comptes Rendus Geosciences, **341**: 103-113.

SOBSTEL, M., MAKOWSKA-HAFTKA, M. & RACKI, G. (2006): Conodont ecology in the Early-Middle Frasnian transition on the South Polish carbonate shelf. – Acta Palaeontologica Polonica, **51** (4): 719-746.

SÖTE, T., HARTENFELS, S. & BECKER, R. T. (2017): Uppermost Famennian stratigraphy and facies development of the Reigern Quarry near Hachen (northern Rhenish Massif)´, Germany). – Palaeodiversity and Palaeoenvironments, **97**: 633-654.

SOULAIMANI, A. & BURKHARD, M. (2008): THE ANTI-ATLAS CHAIN (MOROCCO): the southern margin of the Variscan belt along the edge of the West African craton. – In: ENNIH, N. & LIÉGEOIS, J.-P. (Eds.), The boundaries of the West African craton. Geological Society, London, Special Publications, **279**: 433-452.

SPALLETTA, C., PERRI, M. C., OVER, D. J. & CORRADINI, C. (2017): Famennian (Upper Devonian) conodont zonation: revised global standard. – Bulletin of Geosciences, **92** (1): 31-57.

TAHIRI, A. (1983): Lithostratigraphie et structure du Jebel Ardouz – Maroc hercynien. – Bulletin de l´Institute Scientifique, Rabat, **7:** 1-16.

TAHIRI, A. (1994): Tectonique hercynienne de l´anticlinorium de Khouribga-Oulmès et du synclinorium de Fourhal. – Bulletin de l´Institute Scientifique, Rabat, **8**: 125-144.

TAHIRI, A. & HOEPFFNER, C. (1988): Importance des mouvements distensifs au Dévonien supérieur en Meseta nord-occidentale (Maroc); les calcaires démantelés de Tiliouine et la ride d`Oulmès, prolongement oriental de la ride des Zaèr. – Comptes Rendus de l`Academie des Sciences, Paris, **306** (Série II): 223-226.

TAHIRI, A. & LAZREQ, N. (1988): Précisions stratigraphiques sur le Dévonien de la ride d´El Hammam (Nord d´Oulmès), consequences paléogeographiques. – Bulletin de l´Institute Scientifique, Rabat, **12**: 47-51.

TAHIRI, A., EL HASSANI, A., EL HADI, H., SIMANCAS, F., LODEIRO, F. G., AZOR, A., POYATOS, D. M. & SAIDI, A. (2011): Circuit C13: Meseta nord-occidentale. – Notes et Mémoires du Service Géologique du Maroc, **563** (8): 9-44.

TAHIRI, A., MONTERO, P., EL HADI, H., MARTÍNEZ POYATOS, D., AZOR, A., BEA, F., SIMANCAS, J. F. & GONZÁLEZ LODEIRO, F. (2010): Geochronological data on the Rabat-Tiflet granitoids: Their bearing on the tectonicvs of the Moroccan Variscides. – Journal of African Earth Sciences, **57**: 1-13.

TAHIRI, A., BELFOUL, A. & BAIDER, L. (2013): Chaotic deposits in the Lower Carboniferous formations of the Merzouga area (Tafilalet, Eastern Anti Atlas,

Morocco): Geodynamic importance. – Documents de l´Institute Scientifique, Rabat, **27**: 103-108.

TAHIRI, A., EL HADI, H., POCELET, A., POYATOS, D., AZOR, A., LODEIRO, F. & SIMANCAS, F. (2017): Ediacarian to Cambrian U-Pb ages of granite pebbles in the Lower Devonian conglomerate of Immouzer Kandar (Northwestern Middle Atlas, Morocco). – In: The First West African Craton and Margins International Workshop "WACMA1", Dakhla, Morocco, 24 to 29th April, 2017, Abstracts, 1 p.

TAIT, J., SCHÄTZ, M., BACHTATDSE, V. & SOFFEL, H. (2000): Palaeomagnetism and Palaeozoic palaeogeography of Gondwana and European terranes. – In: FRANKE, W., HAAK, V., ONCKEN, O. & TANNER, D. (Eds.), Orogenic Processes: Quantification and Modelling in the Variscan Belt. Geological Society, London, Special Publications, **179**: 21-34.

TAYLOR, E. L., TAYLOR, T. N. & KRINGS, M. (2009): Paleobotany: The Biology and Evolution of Fossil Plants. – 1252 pp., Academic Press.

TERMIER, H. (1927a): Sur la stratigraphie du Maroc central. – Bulletin de la Société Géologique du France, 4è série, **27**: 21.

TERMIER, H. (1927b): Observations nouvelles en Maroc central. - Bulletin de la Société Géologique du France, 4è série, **27**: 100-102.

TERMIER, H. (1936): Etudes géologiques sur le Maroc central et le Moyen-Atlas septentrional. Tome III. Paléontologie, Pétrographie. – Notes et Mémoires, Service des Mines et Carte géologique du Maroc, **33**: 1-1566.

TERMIER, H. (1938a): Sur l´existence des *Halorella* au Dévonien supérieur. – Comptes Rendus somnaire des Séances de la Société Géologique de France, 5è série, **7**: 108.

TERMIER, H. (1938b): Noveaux affleurements de Famennien dans le Maroc central. - Comptes Rendus somnaire des Séances de la Société Géologique de France, 5è série, **8**: 40-42.

TERMIER, H. & TERMIER, G. (1948): Les phénomènes de speciation dans le genre *Halorella*. Notes et Mémoires du Service Géologique du Maroc, **71**: 47-63.

TERMIER, H. & TERMIER, G. (1949): Sur les genres *Halorella* et *Dzieduszyckia*. – Notes et Mémoires du Service Géologique du Maroc, **74**: 113-115.

TERMIER, H. & TERMIER, G. (1950a): Paléontologie Marocaine. II. Invértebrés de l´ère Primaire. Fascicule II. Bryozoaires et brachiopodes. Notes et Mémoires du Service géologique du Protectorate Francaise de Maroc, **77**: 21-252.

TERMIER, H. & TERMIER, G. (1950b): Paléontologie Marocaine. II. Invértebrés de l´ère Primaire. Fascicule III. Mollusques. – Notes et Mémoires, Service géologique du Protectorate Francaise de Maroc, **78**, 246 pp. (pls. 123-183).

TERMIER, H. & TERMIER, G. (1951): Stratigraphie et Paléobiologie des Terraions Primaires de Benhamed (Chaouïa sud, Maroc). – Notes et Mémoires du Service Géologique Maroc, **5** (85): 47-104.

TERMIER, H. & TERMIER, G. (1970): Sur la géologie de la région de Dchar-Aït-Abdallah (Maroc Central). – Comptes Rendues de l´Academie des Sciences, Paris, Série D, **271**: 1612-1614.

TERMIER, H., TERMIER, G. & VACHARD, D. (1975): Recherches micropaléontologiques dans le Paléozoïque supérieur du Maroc central. - Cahiers de Micropaléontologie, **4**: 1-99 + 10 pls.

TIDTEN, G. (1972): Morphogenetisch-ontogenetische Untersuchungen an Pterocorallia aus dem Permo-Karbon von Spitzbergen. - Palaeontographica, Abt. A, **139** (1-3): 1-63, 15 pls.

TOTO, E. A., KAABOUBEN, F., ZOUHRI, L., BELARBI, M., BENAMMI, M., HAFID, M. & BOUTIB, L. (2007): Geological evolution and structural style of the Paleozoic Tafilalt subbasin, eastern Anti-Atlas (Morocco, North Africa). – Geological Journal, **43**: 59-73.

TRIBOVILLARD, N., AVERBUCH, O. DEVLEESCHOUWER, X., RACKI, G. & RIBOULLEAU, A. (2004): Deep-water anoxia over the Frasnian-Famennian boundary (La Serre, France): as tectonically induced oceanic snoxic event? – Terra Nova, **16**: 288-295.

VACHARD, D., ZAHRAOUI, M. & CATTANEO, G. (1994): Parathuramminines et Moravamminides (Foraminiferes ?) du Givetien du Maroc central. – Revue de Paléobiologie, **14** (1): 1-19.

VALENZUELA-RÍOS, J. I., SLAVÍK, L., LIAO, J.-C., HUŠKOVÁ, A. & CHADIMOVÁ, L. (2015): The middle and upper Lochkovian (Lower Devonian) conodont successions in key peri-Gondwana localities (Spanish Central Pyrenees and Prague Synform) and their relevance for global correlations. – Terra Nova, **27**: 409-415.

VANDELAER, E., VANDORMAEL, C. & BULTYNCK, P. (1989): Biofacies and Refinement of Conodont Succession in the Lower Frasnian (Upper Devonian) of the Type Area (Frasne-Nismes, Belgium). – Courier Forschungsinstitut Senckenberg, **117**: 321-351.

VAN DER VOO, R. (1988): Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: Comparisons of paleomagnetism with paleoclimatology and biogeographical patterns. – Geological Society of America, Bulletin, **100**: 311-324.

VODRÁŽCOVÁ, S., KLAPPER, G. & MURPHY, M. A. (2011): Early Middle Devonian conodont faunas (Eifelian, *costatus-kockelianus* zones) from the Roberts Mountains and adjacent areas in central Nevada. – Bulletin of Geosciences, **84** (4): 737-764.

WALLISER, O. H. (1990): Marble Quarry at Pic de Bissous. – Document submitted to the Subcommission on Devonian Stratigraphy (ICS, IUGS), Frankfurt/M., September 1990, 2 pp.

WALLISER, O. H., EL HASSANI, A. & TAHIRI, A. (1995): Sur le Dévonien de la Meseta marocaine occidentale. – Courier Forschungsinstitut Senckenberg, **188**: 21-30.

WALLISER, O. H., EL HASSANI, A. & TAHIRI, A. (2000): Mrirt: A Key Area for the Variscan Meseta of Morocco. – Notes et Mémoires du Service Géologique du Maroc, **399**: 93-108.

WALLISER, O. H. & BULTYNCK, P. (2011): Extinctions, survival and innovations of conodont species during the Kacák Episode (Eifelian-Givetian) in south-eastern Morocco. – Bulletin de l´Institut royal des Sciences naturelles de Belgique, **81**: 5-25.

WANG, Z. H., BECKER, R. T., ABOUSSALAM, Z. S., HARTENFELS, S., JOACHIMSKI, M. M. & GONG, Y. M. (2016): Conodont and carbon isotope stratigraphy near the Frasnian/Famennian (Devonian) boundary at Wulankeshun, Junggar Basin, NW China. – Palaeogeography, Palaeoclimatology, Palaeoecology, **448**: 279-297.

WANG, Q.-L, KORN, D., NEMYROVSKA, T. & QI, Y.-P. (2018): The Wenne river bank section – an excellent section for the Viséan-Serpukhovian boundary based on conodonts and ammonoids (Mississippian; Rhenish Mountains, Germany). – Newsletters on Stratigraphy, **51**: 427-444.

WARD, D., BECKER, R. T., ABOUSSALAM, Z. S., RYTINA, M. & STICHLING, S. (2013): The Devonian at Oued Ferkla (Tinejdad region, SE Morocco). – In: BECKER, R. T., EL HASSANI, A. & TAHIRI, A. (Eds.), International Field Symposium „The Devonian and Lower Carboniferous of northern Gondwana“, Field Guidebook. Document de l´Institut Scientifique, Rabat, **27**: 23-29.

WEDEKIND, R. (1913a): Die Goniatitenkalke des unteren Oberdevon von Martenberg bei Adorf. – Sitzungsberichte der Gesellschaft naturforschender Freunde, Berlin, **1913** (1): 23-77, pls. IV-VI.

WEDEKIND, R. (1913b): Beiträge zur Kenntnis des Oberdevons am Nordrande des Rheinischen Gebirges. 2. Zur Kenntnis der Prolobitiden. – Neues du Jahrbuch für Mineralogie, Geologie und Paläontologie, **1913**: 78-95, pl. 8.

WEDEKIND, R. (1918): Die Genera der Palaeoammonoidea (Goniatiten). Mit Ausschluß der Mimoceratidae, Glyphioceratidae und Prolecanitidae. – Palaeontographica, **62**: 85-184, pls. 14-22.

WENDT, J. & BELKA, Z. (1991): Age and Depositional Environment of Upper Devonian (Early Frasnian to Early Famennian) Black Shales and Limestones (Kellwasser Facies) in the Eastern Anti-Atlas, Morocco. - Facies, **25**: 51-90.

WHALEN, M. T., DAY, J., EBERLI, G. P. & HOMEWOOD, P. W. (2002): Microbial carbonates as indicators of environmental change and biotic crisis in carbonate systems: examples from the Late Devonian, Alberta basin, Canada. – Palaeogeography, Palaeoclimatology, Palaeoecology, **181**: 127-151.

WILLEFERT, S. (1963): Graptolites du Silurien et du Lochkovien de Touchchent (anticlinorium de Kasba-Tadla – Azrou, Maroc central). – Notes et Mémoires du Service Géologique du Maroc, **23**: 69-98.

WILLEFERT, S. & CHARRIÈRE, A. (1990): Les formations à Graptolithes des boutonnières de Moyen-Atlas tabulaire (Maroc). – Géologie Méditerranéennne, **17** (3/4): 279-299.

WORK, D. M., MASON, C. E. & KLAPPER, G. (2007): The Middle Devonian (Givetian) ammonoid *Pharciceras* from the New Albany Shale, Kentucky. – Journal of Paleontology, **81** (6): 1510-1515.

XIAN, S., WANG, S., ZHOU, X., XIONG, J. & ZHOU, T. (1980): Nandan typical stratigraphy and paleontology of the Devonian in South China. – Guihou People´s Publishinh House (Guyang).

XU, G. (1977): Fossil Atlas of South-Central China, part 2, Cephalopoda. – Yichang Institute of Geological Science: 537-582, pls. 204-218; Geological Publishing House, Beijing.

YOUNG, G. C. (1981): Biogeography of Devonian vertebrates. – Alcheringa, **5**: 225-243.

YOUNG, G. C. (2003): North Gondwana mid-Palaeozoic connections with Euramerica and Asia: Devonian vertebrate evidence. – Courier Forschungsinstitut Senckenberg, **242**: 169-185.

ZAHRAOUI, M. (1991): La plate-forme carbonate dévoniene du Maroc occidentale et sa dislocation hercynienne. – Unpublished Ph. D. Thesis, University of the Bretagne Occidentale, 261 pp.; Brest.

ZAHRAOUI, M. (1994a): Le Silurien. - Bulletin de l´Institut Scientifique, Rabat, **18**: 38-42.

ZAHRAOUI, M. (1994b): Le Dévonien inférieur et moyen. – Bulletin de l´Institut Scientifique, Rabat, **18**: 43-56.

ZAHRAOUI, M., EL HASSANI, A. & TAHIRI, A. (2000): Devonian outcrops of the Oued Cherrat shear zone. – Notes et Mémoires du Service géologique du Maroc, **399**: 123-128.

ZIEGLER, P. A. (1989): Laurussia – The Old Red Continent. - In: MCMILLAN, N. J., EMBRY, A. F. & GLASS, D. J. (Eds.), Devonian of the World, Proceedings of the Sercond International Symposium on the Devonian System, Calgary, Canada. Canadian Society of Petroleum Geologists, Memoir, **14** (I): 15-48 [imprint 1988].

ZIEGLER, W. (Ed., 1975): Catalogue of conodonts, Volume **2**. – 404 pp.; Schweizerbart, Stuttgart.

ZIEGLER, W. & SANDBERG, C. A. (1990): The Late Devonian standard conodont zonation. – Courier Forschungsinstitut Senckenberg, **121**: 1-115.

ZIEGLER, W., SANDBERG, C. A. & AUSTIN, R. L. (1974): Revision of *Bispathodus* group (Conodonta) in the Upper Devonian and Lower Carboniferous. – Geologica et Palaeontologica, **8**: 97-112.

ZONG, P., BECKER, R. T. & MA, X. (2015): Upper Devonian (Famennian) and Lower Carboniferous (Tournaisian) ammonoids from western Junggar, Xinjiang; northwestern China – stratigraphy, taxonomy and palaeobiogeography. – Palaeobiodiversity and Palaeoenvironments, **95**: 159-202.

Dépôt légal : 2012 PE 0007
ISSN : 2028 - 7615

ACADEMY Press MA

Email : fse@academiesciences.ma
www.academiesciences.ma/fse/