Devonian of the Mechra Ben Abbou region (Rehamna) – new data on the reef succession, microfacies, stratigraphy, and palaeogeography

Stephan EICHHOLT, Ralph Thomas BECKER, Zhor Sarah ABOUSSALAM, Ahmed EL HASSANI, Andreas MAY, Ulrich JANSEN, Andrej ERNST & Fouad EL KAMEL

Fig. 1: View from the top of the Givetian limestone cliff at Sidi bou Talaa on the meandering Oum Er Rbia, which cuts off the outcrop at the eastern end.

Summary. The Devonian of the northeastern Rehmna, from Mechra Ben Abbou in the NW to the area north of Aïn el Melah in the southeast, has been dealt with in numerous publications and theses, but the precise ages, sedimentology, and terminology of numerous lithostratigraphic units were far from being resolved. Based on sampling for conodonts, brachiopods, other macrofauna, and microfacies, we report some progress. At Sakhrat et Taïra in the SE, a new shallow-water faunule with *Howellella* cf. *mercurii* confirms that significant synsedimentary block movements occurred locally in the lower Lochkovian. It is followed by a level with limestone turbidites and hostile shelf basin facies before quartzites indicate regression. The facies development differs clearly from the Lochkovian of Koudiat ed Diab in the north. The Pragian and Emsian of the whole region is characterized by neritic, storm-influenced, non-reefal shelf successions. This includes in the NE the Emsian Oued Kibane Formation, which may range just into the lower Eifelian. But the Foum el Mejez region lacks so far evidence of undoubted Middle Devonian fossils. The Middle Devonian Mechra Ben Abbou Formation is defined as a compact succession of shallow-water limestones. It is subdivided into the thin- to medium-bedded, upper Emsian to middle Eifelian, mostly crinoidal Bouchhada Member, the cherty and bioclastic upper Eifelian or lower Givetian Koudiat El Gara Member, and the lower/middle Givetian, massive, reefal Sidi bou Talaa

Member. At Sidi bou Talaa, the latter is assigned to four facies assemblages: reef core limestone, seismically induced inner platform reef breccias, fenestral limestones, and thin-bedded lagoonal limestones. 38 species of reef builders (tabulate corals, chaetetids, stromatoporids, calcimicrobes) are regionally identified, 17 of them for the first time in Morocco. Due to regional uplift, non-deposition, condensation or reworking, there is no in-situ Rehamna record of upper Givetian and Frasnian strata. The silty-sandy middle part of the Oued Ater Member of the Foum el Mejez Formation yielded a new middle Famennian brachiopod fauna. It represents a fault-controlled narrow basin with prodelta facies and high subsidence that has no equivalents anywhere else in the Rehamna. At Gare Mechra Ben Abbou, the Givetian reef limestone was erosionally truncated in the upper Famennian, with stromatolite encrustations, karstification, and breccia formation by rockfall, followed by quartzites with *Mesoplica praelonga* coquinas. This Douar Nahilat Formation correlates with the quartzites of the Dalaa Member of the Foum el Mejez region to the east. A survey of the clast spectrum in the at least 500 m thick reddish breccia at Koudiat ed Diab yielded limited evidence for a Givetian and upper Frasnian age of eroded reefal limestone. Carboniferous clasts are rare but a brachiopod-bryozoan pebble with *Rhabdomeson* suggests that a part of the regional upper Viséan carbonate platform was reworked, too. This supports the long assumed post-orogenic age of the thick unit that represents massive rockfall talus after the main Variscan relief had formed.

1. Introduction

The Rehamna is an important but complex Palaeozoic massif in the SW of the Western Meseta, extending for more than 80 km in W-E and for more than 60 km in N-S direction, ending slightly more than 100 km to the south of Casablanca. Following a famous monograph edited by A. MICHARD in 1982, recent attention has been on the tectono-metamorphic evolution of the strongly deformed southern part (e.g., CHOPIN et al., 2014; WERNERT et al. 2016). For Devonian palaeontologists and stratigraphers, the much less tectonized northern part, from Mechra Ben Abbou in the central north to Foum-el-Mejez in the northeast, and to the area north of the El Massira dam in the southeast (Fig. 2), is of much higher interest. This “Rehamna septentrionaux” lies east of the Western Meseta Shear Zone, which separates the Western Rehamna in the south (PIQUE et al. 1980).

After the pioneer explorations of TERMIER (1928, 1931), DELEPINE & YOVANOVITCH (1938), and LE MAÎTRE (1938), and early work by GIGOUT (1951, 1955a) and GENDROT (1973), HOLLARD et al. (1982) established the principle Palaeozoic stratigraphy of the region. Subsequently, the Devonian was studied intensively in the frame of Ph.D. theses, such as RAIS-ASSA (1984), BEN BOUZIANE (1995), and EL KAMEL (2004). These studies investigated many Palaeozoic sections, their sedimentology and structural geology, resulting in thorough cross-sections and reconstructions of the tectono-sedimentary history. However, there was little progress concerning biostratigraphy and the precise dating of facies changes. The available carbonate microfacies descriptions do not follow modern standard terminology and many identifications of neritic (brachiopods, trilobites) or reefal fauna (corals, stromatoporids) are now outdated and require revision.

In the frame of our overall refinements and reviews of Meseta biostratigraphy, facies, palaeogeography, and synsedimenatry tectonism, our work in the Rehamna concentrated on a few chosen representative sections and topics. These are a new approach to reef microfacies near Mechra Ben Abbou (Sidi bou Talaa and Gare Mechra Ben Abbou), including revised identifications of reef builders, revised dating of the Foum-el-

Mejez Devonian, attempts to improve the Lower Devonian stratigraphy at Sakhrat et Taïra (localities of El Kamel et al. 1992), and a preliminary inventory of reworked pre-Variscan clasts in the supposed post-Variscan conglomerate at Koudiat ed Diab. We are well aware that there is great potential for further investigations but available results, based on short field seasons from 2012 to 2018, are significant enough to combine them in this state-of-the-art chapter.

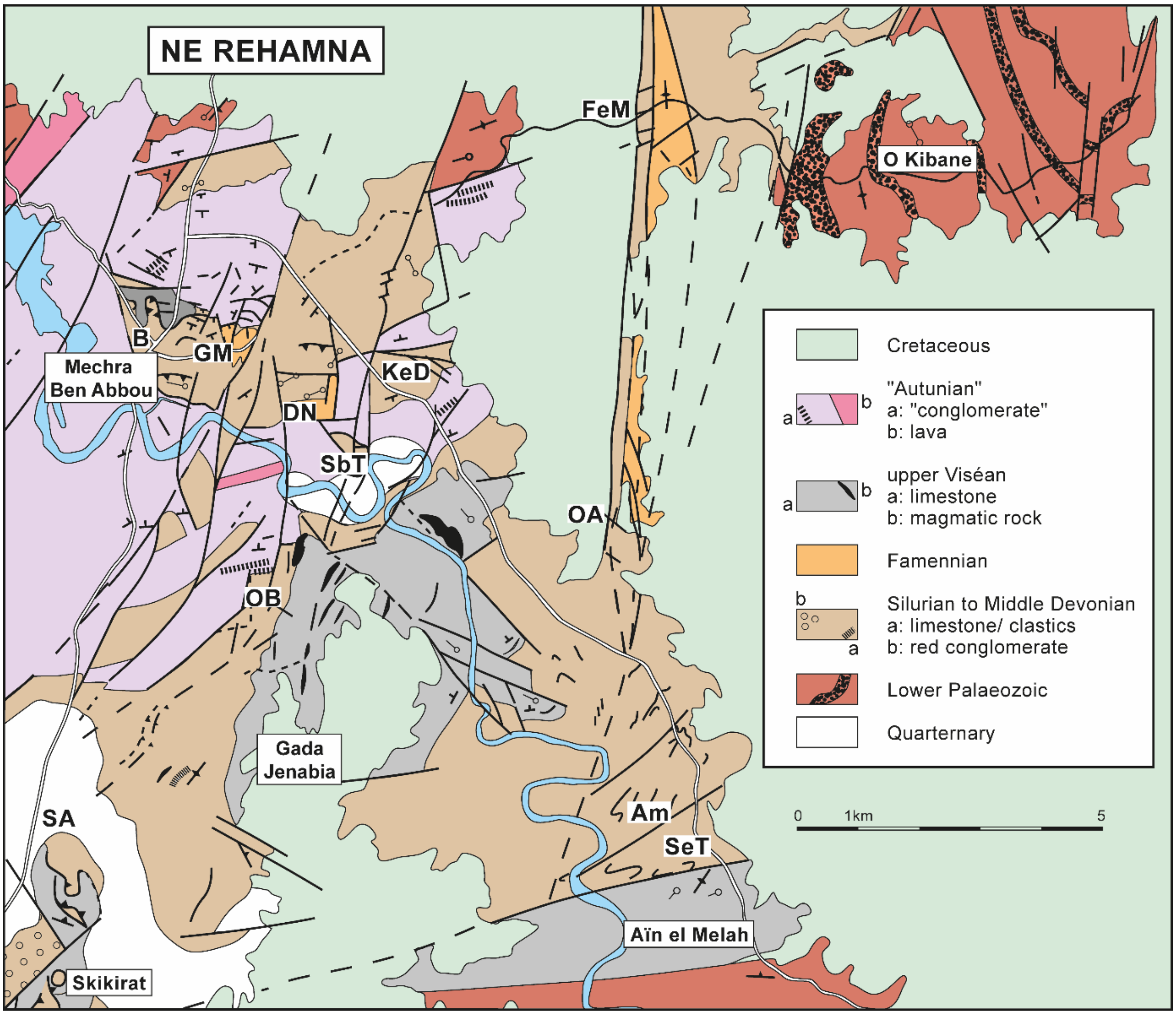

Fig. 2: Simplified geological map of the northeastern Rehamna, showing the position of studied or mentioned successions and localities. B = Bouchhada; DN = Douar Nahilat, FeM = Foum el Mejez, GM = Gare Mechra Ben Abbou, KeD = Koudiat ed Diab, OA = Ouled el Abid/Oued Ater, OB = Ouled Barka, SA = Sidi Abdallah, SbT = Sidi bou Talaa, SeT = Sakhrat et Taïra (re-drawn from Michard, Ed., 1982, fig. 32).

2. Devonian Research History of the northern Rehamna

TERMIER (1928, 1931, 1936): First investigations of the Palaeozoic of the Mechra Ben Abbou region.

DELEPINE & YOVANOVITCH (1938): Brief note on the discovery of Givetian reef limestone and Famennian quartzites at Mechra Ben Abbou.

LE MAÎTRE (1938): Note on Devonian limestone localities of the Mechra Ben Abbou region, with a record of upper Emsian brachiopods (*Euryspirifer paradoxus*) at the Oued Kibane, and Eifelian beds with *Calceola sandalina*, scutelluids and phacopids near the Gare Mechra Ben Abbou.

RICHTER & RICHTER (1943): Description of a Givetian "*Scutellum* cf. *costatum*" from Gare Mechra Ben Abbou.

LE MÂITRE (1947): Description of Eifelian rugose corals from Mechra Ben Abbou, including *"Schizophyllum" acanthicum* and (type locality) *Heliophyllum moghrabiense*.

ROCH (1950): Summary of the known evidence at the time, giving faunal examples for the recognized stages.

RICHTER & RICHTER (1950): Description of the Givetian proetid trilobite *Dechenella (Dechenella) gigouti* from a quarry (probably Bouchhada) at Mechra Ben Abbou.

GIGOUT (1951, 1955a, 1955b, 1956): Geological studies in the Rehamna with a detailed investigation of Devonian faunas.

TERMIER & TERMIER (1950b): Illustration of some Mechra Ben Abbou brachiopods.

TERMIER & TERMIER (1950d): Illustration of some Devonian trilobites from the Rehamna.

BÄCKER et al. (1965): Unpublished report on the Devonian and Lower Carboniferous of some Meseta region, including the northern Rehamna.

HOLLARD (1967): Summary of the published evidence, noting in a synthesized stratigraphic column the absence of upper Givetian to Frasnian strata.

ALBERTI (1967): Description of the odontopleurid trilobite *Isoprusia (Mauraspis) cyrius* from the assumed Eifelian (but perhaps Emsian) near Sidi Abdallah.

GENDROT et al. (1969) and GENDROT (1973): Description of reef facies and development at Sidi bou Talaa and Sidi Abdallah, also with some examples from Bouchhada.

ALBERTI (1969): Description of *Proetus (Proetus) prox umerbianus*, now a species of *Gerastos*, and of *Cornuproetus (Cornuproetus) cornutus marrakechensis* from Middle Devonian crinoid limestones (GIGOUT locality 1486); description of *Proetus (Proetus) rehamnanus*, another possible *Gerastos*, from Lower Devonian limestone south of Mechra Ben Abbou.

ALBERTI (1970): Description of the scutelluid *Paralejurus dormitzeri rehamnanus*, now a full species (see SCHRAUT & FEIST 2004 for supposed new material from the Emsian of the Anti-Atlas, which BASSE 2012 did not accept to be conspecific) and of *Phacops (Phacops) speculator*, now a species of *Austerops*, from the assumed Eifelian (or Emsian) near Sidi Abdallah.

JENNY (1974): Unpublished thesis on the geology and structural evolution of the Rehamna, including Devonian faunal records (e.g., from Foum el Mejez).

HOLLARD et al. (1982): Principles of Mechra Ben Abbbou Palaeozoic stratigraphy, with detailed section descriptions and important faunal lists.

RAIS-ASSA, R. (1984): Unpublished Ph.D. Thesis on the stratigraphy and structural geology of the northern Rehamna.

EL KAMEL et al. (1985) and EL KAMEL (1987, 2004): Thesis and monograph on the Palaeozoic of the Oulad Abbou (Coastal Block) and Mechra Ben Abbou regions, with a focus on lithostratigraphy, reef development and structural geology.

EL KAMEL & MULLER (1987): Study on the post-orogenic conglomerates of Mechra Ben Abbou that include reworked Devonian limestones.

RACHEBOEUF (1990a, 1990b): Record of the upper Pragian chonetid *Plebejochonetes buchoti* from two localities (Aïn Tolba and Aïn Aissa) of the Mechra Ben Abbou region.

EL KAMEL et al. (1992): Ordovician to Lower Devonian succession of the Aïn El Melah region SW of Mechra Ben Abbou, and its synsedimentary tectonism.

LEGRAND-BLAIN (1994, p. 82): Reference to GIGOUT´s Famennian brachiopod fauna from Mechra Ben Abbou.

EL HASSANI & BENFRIKA (1995, 2000): Summary of the northern Rehamna Devonian successions and their palaeogeography and synsedimentary tectonism.

BEN BOUZIANE (1995): Ph.D. Thesis on the Devonian sedimentary history and diagenesis of the western Meseta (Mechra Ben Abbou, Oulad Abbou, and Doukkala regions).

BENFRIKA (1999): Record of the mostly lower Emsian conodont *Caudicriodus celtibericus* from Koudiat ed Diab.

EL KAMEL & EL HASSANI (1999), and EL KAMEL et al. (2000, 2004): Impact of synsedimentary extensional tectonics on reef development at Sidi bou Talaa and comparisons with the Foum el Mejez succession.

PEDDER (1999): Redescription of LE MÂITRE´s "*Schizophyllum*" as the new species *Stringophyllum coenauberti*, and placing her *Heliophyllum moghrabiense* as a subspecies in *H. halli*.

JANSEN (2001): Brief comments on Rehamna brachiopods illustrated in TERMIER & TERMIER (1950b) and GIGOUT (1951).

MAMET et al. (1999): Reference to the occurrence of calcareous algae in the Mechra Ben Abbou reef limestones.

RAJI et al. (2004) and BENFRIKA et al. (2008): Abstracts noting the discovery of upper Emsian, Eifelian, and Givetian conodonts in the Bouchhada Quarry north of Mechra Ben Abbou.

BASSE & MÜLLER (2004): Re-illustration of *Dechenella gigouti* (based on the cast deposited at the Senckenberg Museum, Frankfurt a. M.).

NICOLLIN & BRICE (2004, p. 447): Brief reference to possibly Strunian age brachiopod faunas from Mechra Ben Abbou.

ADRAIN et al. (2008): Revision of koneprusiid trilobites, including *Isoprusia (Mauraspis) cyrius* from the Eifelian of Mechra Ben Abbou.

ABOUSSALAM et al. (2012): Abstract mentioning the discovery of Emsian conodonts at Foum-el-Mejez.

BASSE (2012): Type catalogue of North African trilobites, including the previously established Mechra Ben Abbou species.

FEDAN (2014): Catalogue of fossil collection in the Institut Scientifique (Rabat), including Devonian brachiopods from Rehamna sections, such as the Oued Kibane and Sidi Abdallah.

KHOLAIQ et al. (2015): Influence of synsedimentary faulting on the development of the Devonian-Lower Carboniferous Mechra Ben Abbou Basin.

OUKASSOU & NAUGOLNYKH (2021): Description of an unusual new plant from the uppermost Famennian Dalaa Member of Foum el Mejez.

Fig. 3: SE dipping quartzite marker cliff (Upper Member of Formation C sensu EL KAMEL et al. 1982, middle Member ST3 of Sakhra Touila Formation sensu EL KAMEL 2004) at Sakhrat et Taïra (= Sakhra Touila), close to the road to the El Massira dam (in the middle ground), underlain by shales and microconglomerates (Lower Member Formation C in the front), followed on the other side of the road (in the background) by siliciclastics and slump blocks of Formation E (= Members ST4-6), with A. EL HASSANI for scale.

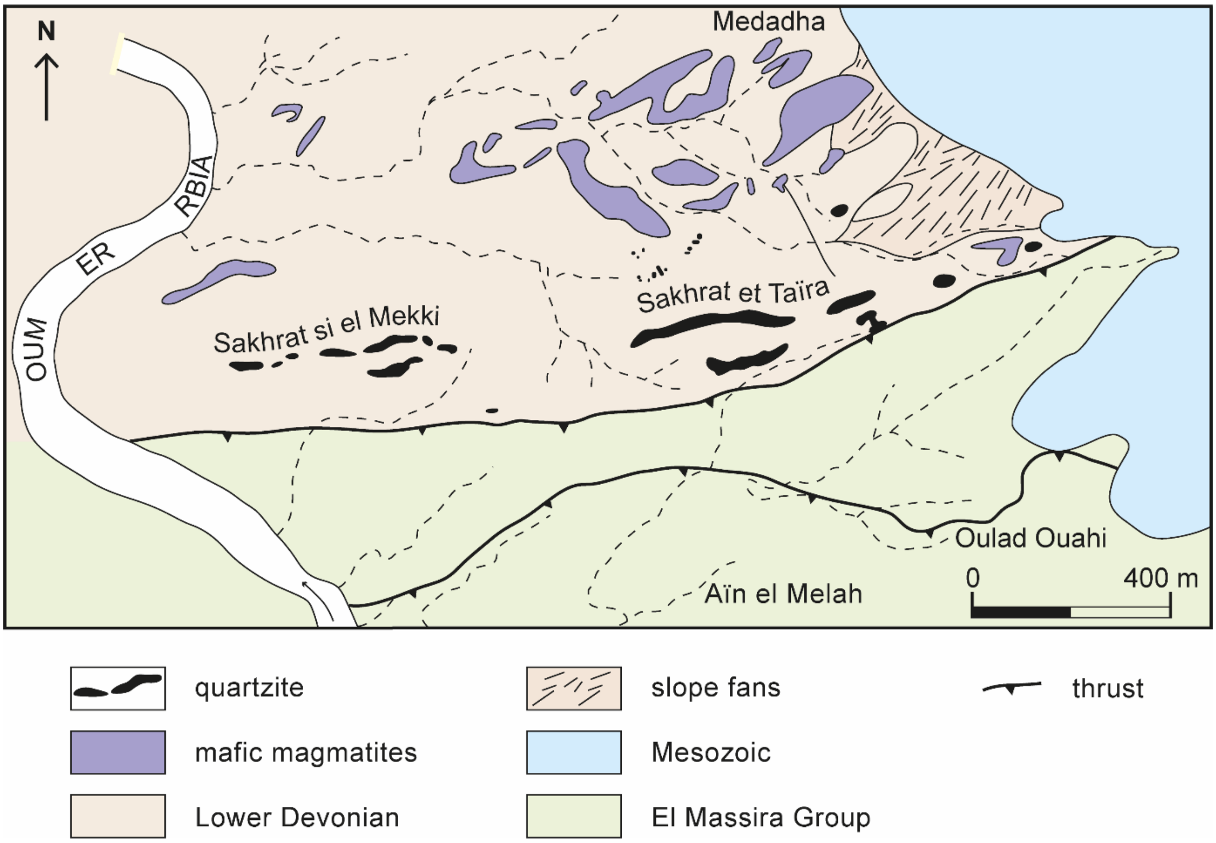

Fig. 4: Simplified geological map of the Aïn el Melah area from the Oum Er Rbia in the west to Sakhrat et Taïra in the east (re-drawn from EL KAMEL et al. 1982, fig. 2).

3. Lower Devonian at Sakhrat et Taïra

El Kamel et al. (1982) and El Kamel (2004) described the structurally complex Palaeozoic succession in the southeast of the "Rehamna septentrionaux". It is of special relevance for the understanding of the regional tectonic evolution because of its evidence for a long interval of earliest Devonian synsedimentary block faulting, resulting in slumping, olistolite embedding, and seismically triggered sediments, such as microconglomerates and turbidites. El Kamel (2004) used the different locality name Sakhra Touila. Since both studies included only limited data on ages, the precise timing of "Antevariscan" (Becker et al. 2015) tectonic episodes remained vague. Therefore, we re-visited the region in 2017 and tried to improve the local stratigraphy and facies history by conodont, macrofauna, and microfacies sampling. This was only partly successful.

The study area lies north of Aïn el Melah and east of the Oum Er Rbia (Fig. 4), ca. 21 km SE of Mechra Ben Abbou (Fig. 2). El Kamel et al. (1982) subdivided the succession into five informal formations (A-E) with member subdivisions. El Kamel (2004) introduced the term Sakhra Touila Formation, with a subdivision into six members (ST1-6). His section log shows a simple superposition sequence, in contrast to the earlier lithological log and cross-section (El Kamel et al. 1992, fig. 5) that assumed repetitions bound by faults. Our field survey and limited new data support the older interpretation.

A quartzite cliff forms a local marker level (Upper Member of Formation C = middle unit of Member ST3; Fig. 3), which was originally (El Kamel et al. 1992) regarded as Ordovician. Thick beds dip uniformly to the SE. El Kamel (2004, p. 43) noted arenitic to microconglomeratic grain size, cross-bedding, and iron mineralisations and nodules at the top. There is no fauna and, therefore, no biostratigraphic control. But limestones in the overlying Upper Member of Formation D (= upper part of Member ST3), which has restricted outcrop, yielded apart from orthocones and brachiopods top-Silurian conodonts and graptolites (det. N. Lazreq and S. Willefert).

The marker quartzite is underlain by reddish to black, microconglomeratic shale with dark, ferruginous pebbles (< 1 cm) and irregularly intercalated, ochre, dolomitized and partly decalcified limestones. These represent slump blocks and are fossiliferous. Apart from crinoid ossicles, we collected the negative of a favositid coral (Fig. 5.5) but conodont sampling remained unsuccessful. The coral is not stratigraphically useful but it proves a neritic, shallow-water setting. The lower contact of the quartzite is rather sharp (Fig. 3) and may be disconformable.

The lower Formation C occupies a gentle slope ending in a small depression, which, as depicted by El Kamel et al. (1992, fig. 5), seems to follow a fault zone because beds on both sides dip differently. Therefore, the "Upper Member" of Formation B (= Member ST2) is obviously older than its "Lower Member" (Member ST1). Formation B begins from SE to NW in a low slope with fossiliferous grey to black shales with intercalated siderite nodules and slump blocks consisting of brownish weathering calcareous sandstone. There is a small-sized neritic fauna preserved in light-grey to yellowish (limonitic) marl and limestone.

We found brachiopods (*Howellella* cf. *mercurii*, Fig. 5.1, undetermined atrypids, and others), crinoid ossicles, gastropods (calcite-shelled *Euomphalus* sp., Figs. 5.3-4, mold of turriform pleurotomariacean, Fig. 5.2, spirally striated bellerophontids), bryozoans (Figs. 5.6-5.7), and rare trilobites. *Howellella mercurii* is a lower Lochkovian index species

(e.g., JANSEN 2016). Its occurrence in the northern Rehamna has been previously established by HOLLARD (1967) and HOLLARD et al. (1982). The new record confirms that Formation B (ST2) is younger than Formation D (ST3), in accord with the bedding orientation and the log of EL KAMEL et al. (1992), but disproving the simplified log of EL KAMEL (2004, fig. 23). We confirm the lower Lochkovian age of synsedimentary slumping and extensional tectonism, as postulated by EL KAMEL et al. (1992) and illustrated by EL KAMEL (2004, pl. 1).

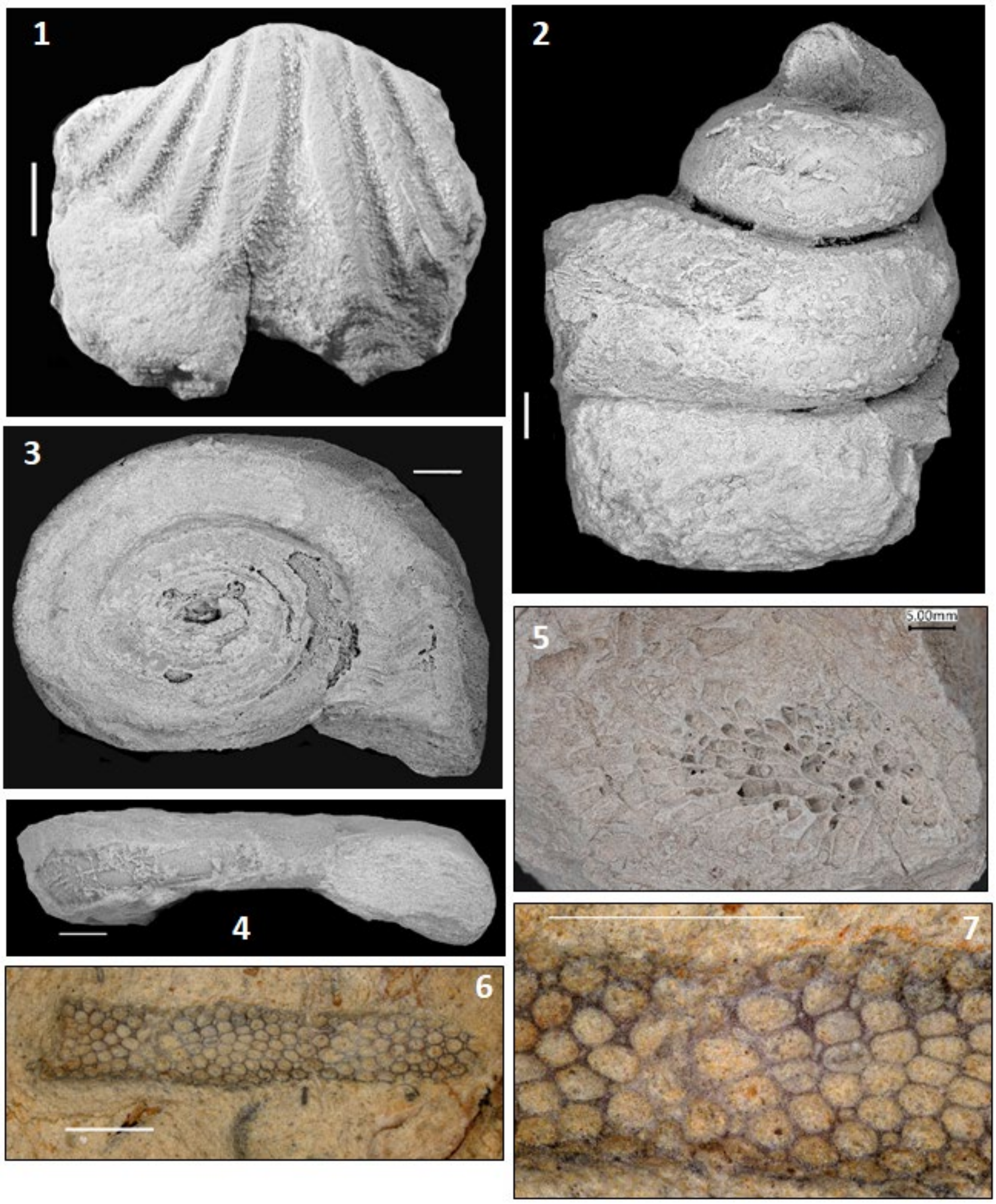

Fig. 5: Fossils from Sakhrat et Taïra (Sakhra Touila Formation sensu EL KAMEL 2004); 1-6 from the "Upper Member" of Formation B sensu EL KAMEL et al. (1992) = Member ST2, 7 from the Lower Member of Formation C (= lower Member ST3); scale bar = 2 mm if not specified. **1.** *Howellella* cf. *mercurii*, incomplete, SMF 102133; **2.** Pleurotomariid gastropod, GMM B6B.11.8; **3-4.** *Euomphalus* sp., upper and adoral views of calcitic shell, showing the outer upper whorl edge lying in a growth line sinus and the flat, very low-spired coiling, GMM B6B.11.9; **5.** *Favosites* sp. (negative imprint in decalcified limestone slump block), GMM.57.1; **6-7.** Branch of bryozoan colony, overview and detail, GMM B5A.4.1.

The upper part ("Lower Member") of Formation B occupies the crest of a low hill and the subsequent backslope to the NW. There are slumped masses of yellow to brownish limestone and calcareous sandstone. A thin-section (Fig. 6) consists of slightly peloidal and silty wacke-floatstone with micritized crinoid ossicles, rare tabulate corals, brachiopod and mollusk debris, and rare dacryoconarids. Conodont sampling was not successful. The setting was deep (subtidal) neritic.

Fig. 6: Thin-section of yellowish limestone from the lower part of Formation B at Sakhrat et Taïra, a slightly peloidal, silty, bioturbated wacke-floatstone with micritized, therefore hardly visible crinoid debris and other neritic fauna, impregnated by iron hydroxides.

Slightly higher follow alternating grey or brownish shales and calcareous turbidites with grading and cross-bedding (Fig. 7.2) as typical four Bouma cycles. Conodont samples were, again, barren. The dip of bedding varies and the solid beds are strongly fractured (compare El Kamel 2004, pl. I, fig. C). El Kamel et al. (1992) mentioned a syringoporid coral from the "base", which suggested a Devonian age. Apart from this shallow-water element, the turbidites represent a deeper and slope setting, probably reflecting the increasing block tilting and seismic events. At the top, yellow to reddish mudstones lack any fossils (Fig. 7.3) pointing to a hostile shelf basin facies. Recrystallization and iron impregnation proceeded from the many healed fractures.

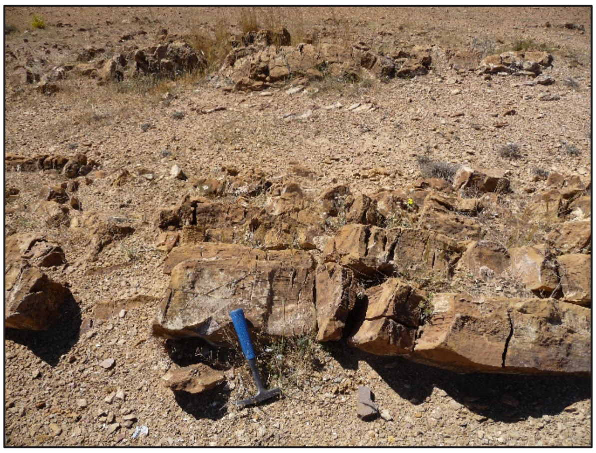

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Fig. 7: Field photos and thin-section of limestones in the upper part ("Lower Member") of Formation B sensu El Kamel et al. (1992; = "top" of Member ST1 of El Kamel 2004). **1.** Exposure of a succession of brownish weathering silty limestones dipping downslope; **2.** Details of a turbiditic bed, showing turbidite-typical Bouma cycles; **3.** Unfossiliferous, partly recrystallized, fractured and iron-impregnated mudstone, top of formation.

The subsequent lower part of Formation A ("Upper Member") has fewer yellowish limestones, which stand vertically. They crop out in the lower slope of the hill and on the next hill to the NW. Upslope, towards a farmhouse, follows the quartzitic "Lower Member" of Formation A (= lower ST1). It suggests a relative sea level fall by basin filling, after synsedimentary tectonism ended.

Formation E (= ST4-5) is poorly exposed on the SE side of the road to the El Massira dam. It resembles the Lower Member of Formation C in the presence of ochre, dolomitized and sandy slump blocks (see EL KAMEL 2004, pl. I) intercalated in micaceous, silty shales. No fossils were found. Above, a sandstone-quartzite level is followed by yellowish pelagic limestones with orthocones and *Zieglerodina remscheidensis* (det. N. LAZREQ), which proved to be Lochkovian in age. We have not yet re-examined the higher parts of Formation E (= Member ST6), which is said to have more (or the same?) levels of quartzite and pelagic limestone with orthocones.

EL KAMEL (2004) described from the area a few hundred meters to the NW of Formation A, in his section Amdidih, a folded, cyclic and thick alternation of shales, thin sandstones and bioclastic limestones (compare BEN BOUZIANE 1995). The age of this Amdidih Formation is not well constrained. The reported (GIGOUT 1951, p. 56) tabulate coral *Cleistopora* and close relatives had a global distribution in the middle Lochkovian/Pragian interval (e.g., PLUSQUELLEC 1973; BOUMENDJEL et al. 1996: Lochkovian record from southern Algeria; FREY et al. 2014: Pragian record from the Tafilalt). A lithologically similar, thick neritic succession occurs ca. 15 km to the NW and was described by BEN BOUZIANE (1995) and EL KAMEL (2004) as Ouled Barka Formation. Based on *Cleistopora*, *Hysterolites hystericus* and *Athyris undata* (reported by GIGOUT 1951) this unit falls mostly in the upper Pragian (see brachiopod zonation of JANSEN 2016).

In summary, the tectonized area north of Aïn el Melah is a difficult terrain for Devonian stratigraphy. It requires more attempts to find conodonts or other stratigraphically relevant fossils (brachiopods, trilobites). Lower Devonian subsidence was high and episodically affected by block tilting, resulting in the interruption of dominant neritic facies by seismically triggered sedimentation. There were facies differences to the Lower Devonian of Koudiat ed Diab and Foum el Mejez in the north.

4. Lower/Middle Devonian of Mechra Ben Abbou

4.1. Lower Devonian

The Lower Devonian of the Mechra Ben Abbou region consists of alternating, cyclic silty shales and bioclastic limestones assigned to the Amdidih and Ouled Barka Formations (EL KAMEL 2004). Since GIGOUT (1951, 1955), Lochkovian to Emsian neritic faunas with brachiopods and trilobites are known but only a few of them have been revised (e.g., RACHEBOEUF 1990a; ADRAIN et al. 2008). A re-evaluation of brachiopods from GIGOUT´s (1951, p. 57) locality 191 suggests a Pragian age. The figured (his pl. 6, figs. 1-2) "*Spirifer hystericus*" is a species of the Pragian genus *Hysterolites*. The figured *Athyris undata* (pl. 6, figs. 29-30) resembles indeed *Septathyris? undata*, which is a lower Pragian species, known, for example, from the Lebanza Formation of the Cantabrian Mountains (BINNEKAMP 1965). "*Schizophoria provulvaria*" (pl. 5, figs. 7-9) is close to *Rhenoschizophoria provulvaria* but has been questionably linked with *Rh. torkozensis* that occurs in the Assa Formation (Rich 1) of the Dra Valley (JANSEN 2001). "*Stropheodonta explanata*" (pl. 5, fig. 10, also TERMIER & TERMIER 1950b, pl. 79, figs. 12-14) belongs to

the genus *Mclearnites*, possibly to *Mc. saharianus* JANSEN, 2001, which also occurs in the lower Pragian Assa Formation.

We visited briefly the Lower Devonian at Douar Bou Jemaa (GPS N32°38´39,7´´, W7°45´30,8´´). Exposed are middle-grey, coarse-grained, brachiopod-rich crinoidal limestones. Conodont samples were barren, obviously because of too shallow facies.

4.2. Middle Devonian of Sidi bou Talaa

HOLLARD et al (1982) introduced the Mechra Ben Abbou Formation for compact to massive limestones without shale/marl interbeds exposed in quarries around Bouchhada (= Bou Chehada) and in natural cliffs of the Mechra Ben Abbou region (Fig. 2). Other outcrops lie to the south at Ouled Barka and Sidi Abdallah (Fig. 2). Based on the faunal list of HOLLARD et al. (1982), updating the records of LE MÂITRE (1938, 1947) and GIGOUT (1951, 1955a), an Eifelian to middle Givetian range is well established. In lower parts, faunas with *Calceola sandalina* are locally typical. RAJI et al. (2004) reported *Icriodus corniger ancestralis* from well-bedded limestones in the lower part, a taxon that is restricted to the upper Emsian (e.g., ABOUSSALAM et al. 2015). Therefore, the influx of fine siliciclastics and change to a fully carbonatic platform occurred obviously high in the Lower Devonian (see also EL KAMEL 2004, fig. 45). The recognition of the pentamerid *Glyptogypa multiplicata* and the spiriferid *Paraspirifer cultrijugatus* by LE MÂITRE (1938, 1947; see also HOLLARD et al. 1982, tab. 2), if identified correctly, the latter species lends further support for the inclusion of beds at the Emsian-Eifelian transition (see range in JANSEN 2016).

The Mechra Ben Abbou Formation was subdivided by BEN BOUZIANE (1995) into Lower, Middle, and Upper Members, with Bouchhada North as the selected type-section. The 9 m thick, thin-bedded lower part is here named as **Bouchhada Member**, the more nodular middle part with characteristic chert nodules as **Koudiat El Gara Member**, named after a lateral section of BEN BOUZIANE (1995). The combination of both in a "Oulad Barka 2 Formation" is not possible from nomenclatorial reason; the term Ouled Barka Formation should be restricted to the cyclic Pragian-Emsian succession at Ouled Barka (see description by EL KAMEL 2004). The term "Sidi bou Talaa Formation" can be transferred as a member name for the massive reefal limestones, the main part of the Mechra Ben Abbou Formation.

Fig. 8: Overview of the Mechra Ben Abbou Formation at the southern end of Sidi bou Talaa, with the Bouchhada and Koudiat El Gara Members in the middle slope, and massive, cliff-forming reef boulders of the Sidi bou Talaa Member at the top.

We re-sampled the Sidi Bou Talaa section along the western bench of the meandering Oum Er Rbia, ca. 4 km SE of Mechra Ben Abbou village (Fig. 8). The reefal succession was first studied by GENDROT et al. (1969), who recognized pre-reefal cherty limestones, overlying bioclastic limestones with reefal corals, a biostrome stadium and fore-reef breccias, a patch of back-reef breccias, and lagoonal facies sheltered by a main belt of true reef (bioherm). Generally, we can confirm this analysis. But the later studies by EL KAMEL & EL HASSANI (1999), EL HASSANI & EL KAMEL (2000), EL KAMEL (2004), and EL KAMEL et

al. (2004) showed a strong control of reef growth by synsedimentary tectonism. It resulted in seismically induced, episodic shedding of reef breccias from the reef crest (see local map of EL KAMEL 2004, fig. 46). All studies recognized the somewhat unusual close affiliation of high-energy mass flow deposition and of *Amphipora* Limestones as indicator of quiet back-reef settings.

Our investigations had several aims: 1. to provide some new biostratigraphical data, 2. to establish a meter-scale succession of reef macro- and microfacies, 3. to re-evaluate the local reef model, 4. to compare the recognized facies types with those of the contemporaneous Oued Cherrat and Al Attamna reefs (EICHHOLT & BECKER 2016), and 5. to supply modern taxonomic data for Rehamna reef builders, which are thought to be representative for the Meseta region.

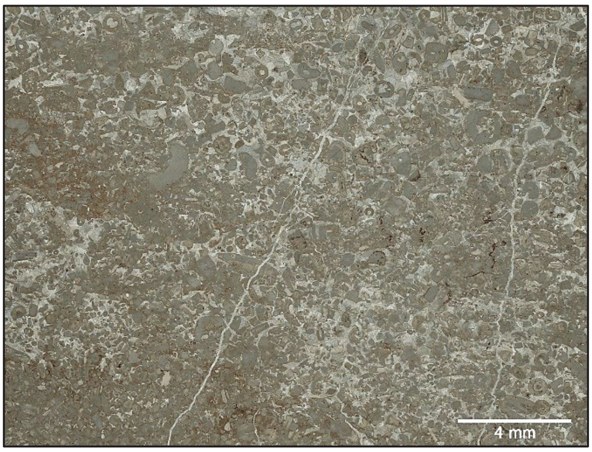

Fig. 9: Crinoid pack-grainstone with partly washed out micrite matrix and some brachiopod debris, lower Bouchhada Member, Sidi bou Talaa.

4.2.1. Bouchhada Member

We estimated on the southern slope of Sidi bou Talaa (Fig. 8) for the exposed, rather flat lying Bouchhada Member a local thickness of 35-40 m. The base (at N32°38´10.3´´, W7°45´41.7´´) is covered. Typical are middle-bedded (up to 20 cm thick), light-grey, often coarse-grained crinoid pack-grainstones (Fig. 9) with rare, small gastropods and thick-shelled ostracods. The micrite was variably washed out by currents. Some dolomitization occurred and there are fine, calcite-healed fractures. EL KAMEL (2004) noted bioclasts of other neritic fauna, syntaxial cements and micritization of crinoid ossicles. The setting was a neritic middle carbonate ramp seawards from storm-ridden crinoid forests.

The lithofacies interpretation is supported by the conodont fauna, with a mixed dominance of *Linguipolygnathus linguiformis* (5 specimens) and *Icriodus regularicrescens* (four specimens, Fig. 11.1), accompanied by single *Polygnathus parawebbi* (Fig. 11.3) and *Neopanderodus perlineatus* (Fig. 11.2). Both *I. regularicrescens* and *Po. parawebbi* enter ca. in the middle of the Eifelian, within the *Po. pseudofoliatus* Subzone, but the second is more typical from the upper Eifelian *kockelianus* Zone onwards (GOUWY & BULTYNCK 2002). A second sample with *I. regularicrescens* (three specimens), *L. linguiformis* (five specimens), *Po. pseudofoliatus* (two specimens), and *Po. angusticostatus* confirmed the middle/upper Eifelian age. It is also in accord with conodonts reported by RAJI et al. (2004) and EL KAMEL (2004, p. 74), who found in addition to our species *Po. costatus, Tortodus kockelianus*, and a *Pelekysgnathus*.

Fig. 10: Large, brownish chert nodules weathering out of the Koudiat El Gara Member at Sidi bou Talaa.

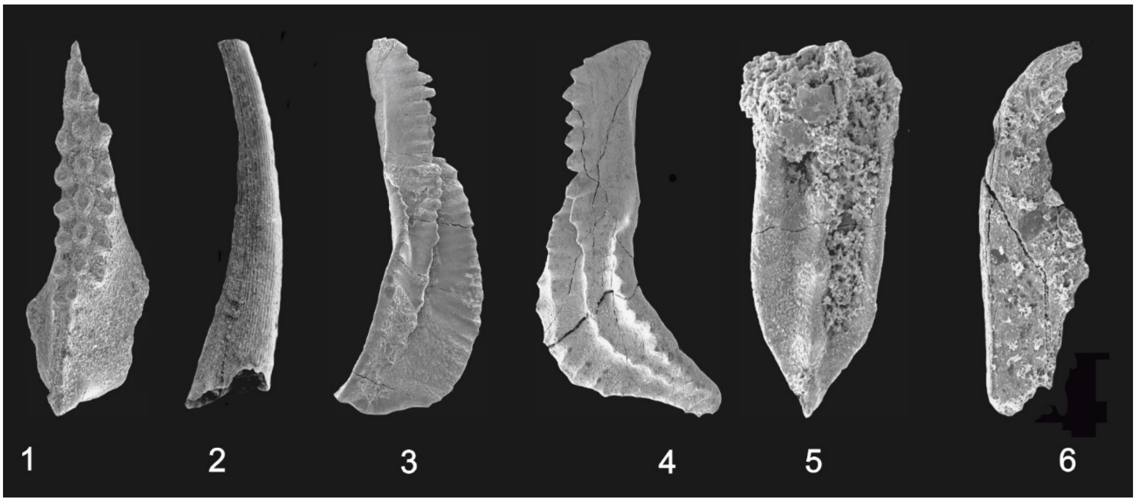

Fig. 11: Middle Devonian conodonts from the Bouchhada (1-3) and Koudiat El Gara Members (4-6) at Sidi bou Talaa, GMM B4C.2.111-116. **1.** *Icriodus regularicrescens*, x 60; **2.** *Neopanderodus perlineatus*, x 55; **3.** *Polygnathus parawebbi*, x 50; **4.** *Linguipolygnathus linguiformis*, x 27; **5.** *Po. varcus?*, only the platform, not showing the position of the basal pit, x 145, **6.** *Belodella resima*, poorly preserved, x 95.

4.2.2. Koudiat El Gara Member

The locally ca. 8 m thick second member of the Mechra Ben Abbou Formation is characterized by finer crinoid debris, partly thinner beds, and distinctive, brownish chert nodules that weather out on limestone surfaces due to surface karstification (Fig. 10). As suggested by previous authors, we assume diagenetic mobilization of sponge spicules although we did not observe these in thin-section. The microfacies is a strongly bioturbated, bioclastic wackestone (Fig. 12) with micritization of crinoids and all other bioclasts, which include fragments of brachiopods and tabulate corals, as well as some dacryoconarids, indicators of a deeper ramp position. The micritic matrix is partly peloidal or was locally washed out by minor currents. There are several generations of calcite-healed fractures.

A conodont sample from the lower part yielded one *L. linguiformis* (Fig. 11.4), two poorly preserved *Belodella resima* (Fig. 11.6), and a questionable, broken *Po. varcus* (Fig. 11.5). This faunule could be of Givetian age but the position of the Eifelian-Givetian boundary, especially of the level of the global Kačák Event, is currently not fixed and requires more samples.

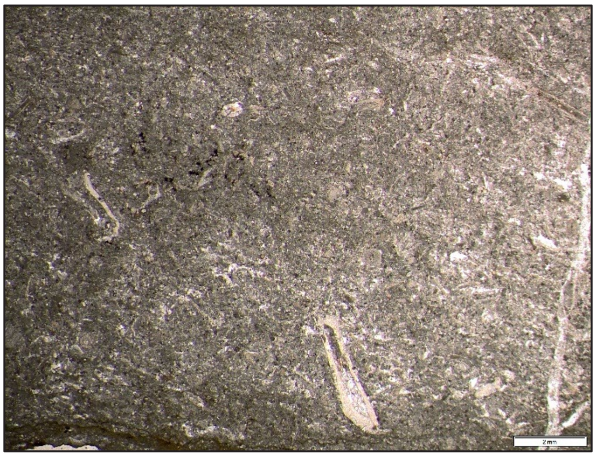

Fig. 12: Bioturbated, partly dolomitized bioclastic wackestone with micritization of crinoid debris and other small bioclasts.

4.2.3. Reefal Sidi bou Talaa Member

There is a gradual transition from thin-bedded to more massive limestones with abundant reef builders. The crest of the ridge represents the main, ca. 150 m thick reef succession characterized by a succession of "domes" (El Kamel & El Hassani 1999). Our logging progressed along the lower slope of the ridge, along the Oum Er Rbia (Figs. 13-14), representing the right part of the

lithological column in El Kamel (2004, fig. 47). The section is dominated by brecciated slope deposits intercalated with back reef facies. This association characterizes the inner slope of a bioherm, which was steepened and episodically shaken by recurrent seismic events. Because of limited access along the Oum Er Rbia, the logging proceeded in two parts (Figs. 13-14, 17-18). The lower part centered around GPS N32°58´10.3´´, W7°45´41.7´´.

Fig. 13: Sampled succession of the lower Sidi bou Talaa Member along the Oum Er Rbia, showing breccia levels “crawling” downslope.

Four principle microfacies types are distinguished (compare Gendrot et al. 1969), which can be characterized as follows:

SBT F1, Brecciated inner slope limestone

(Figs. 15.1-5, 16.7-10; compare Gendrot et al. 1969, pl. 2, fig. 1, and El Kamel 2004)

Stromatoporoid-coral float-rudstone: Middle- to dark-gray brecciated limestones with clasts (diameter max. 20 cm) of bulbous and laminar stromatoporoids (e.g., *Pseudotrupetostroma* sp., *Clathrocoilona, Actinostroma*), and alveolitid corals. Some *Pseudotrupetostroma* sp. are bored by worm tubes (*Streptindytes* sp., Fig. 15.1). Secondary are fragmented branches of dendroid tabulate corals (*Scoliopora denticulata*) or broken dendroid stromatoporoids. Additional bioclasts are fragmented brachiopod shells and rare solitary rugose corals. The matrix consists of very slightly winnowed micrite.

Interpretation: Storm-influenced inner slope talus of reef core or platform domes, additionally destabilized by seismic activity (compare MF A2 of Eichholt & Becker 2016).

SBT F2, Reef core limestone

(Figs. 15.6, 19-20; compare El Kamel 2004)

Very thick bedded (up to 90 cm) stromatoporoid-coral boundstones. The middle-gray limestones are constructed by laminar and bulbous stromatoporoids (e.g., *Trupetostroma*, *Anostylostroma*, *Clathrocoilona*, *Actinostroma*), alveolitid corals (e.g., *Platyaxum*), and subordinate colonial rugose corals (e.g., *Sociophyllum* sp.) encrusting each other. Uncommon are chaetetid sponges (*Rhaphidopora*). The stromatopores reach a diameter up to 20 cm. Secondary reef builders are dendroid stromatoporids, especially *Stachyodes* and *Amphipora*, tabulate corals, and solitary Rugosa, which settled in niches between the main constructors. The matrix consists of slightly winnowed micrite. Clay seams and microstylolites are common (e.g., SBT upper part, at 12 m).

Interpretation: Reef core facies or reef dome facies with slopes within a wider platform (compare MF A5 of Eichholt & Becker 2016).

SBT F3, Back reef limestones with dendroid stromatoporids

(Figs. 15.7-8. 16.4-6, 21(compare Gendrot 1973)

Branching stromatoporid float-rud-bafflestone, (*Amphipora-Stachyodes* Bafflestone and *Stromatoporella* Bafflestone): Thin bedded, middle- to dark-gray limestone constructed by dendroid stromatoporoids (e.g., *Amphipora*, *Stachyodes*, *Stromatoporella, Clavidictyon*).

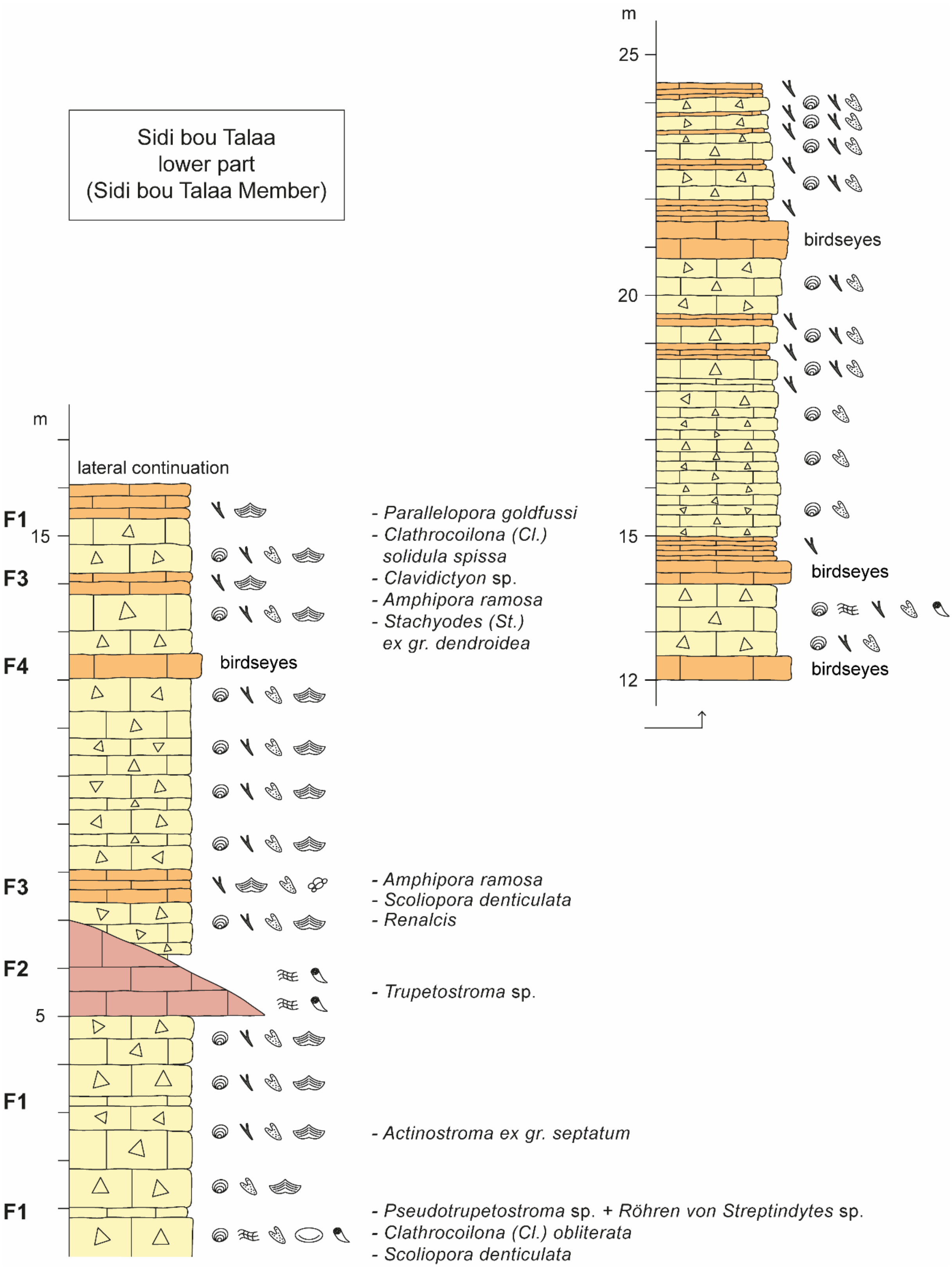

Fig. 14: Simplified macro- and microfacies log for the lower Sidi bou Talaa Member, showing the principle facies types (SBT F1-4), macrofauna observed in the field, and fauna identified in thin-sections. The dominance of reef breccias and their association with fenestral or *Amphipora*-rich lagoonal limestones is distinctive. For legend see Fig. 18.

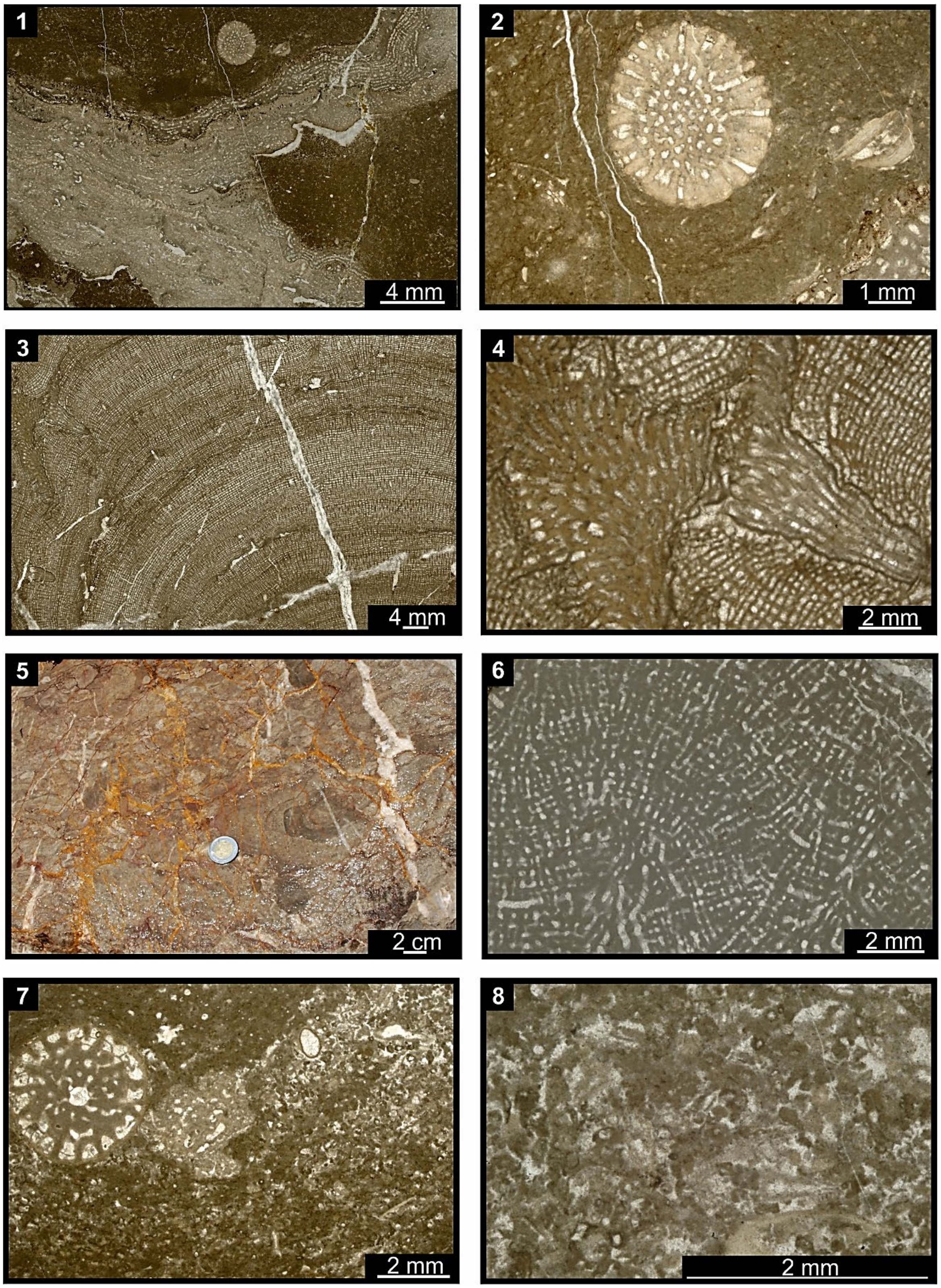

Fig. 15: Microfacies and reef fauna of lower 8 m of measured Sidi bou Talaa section, 1-5: SBT F1, reef breccia with stromatoporoid-coral float-/rudstone, 6 = SBT F2, reef core limestone, 7-8: SBT F3, lagoonal *Amphipora* bafflestone. **1.** Laminar stromatoporoid *Pseudotrupetostroma* sp. with "worm tubes" (*Streptindytes* sp.), overgrown by *Clathrocoilona (Cl.) obliterata*, at 1 m; **2.** Magnification of 1. with cross section of dendroid tabulate coral *Scoliopora denticulata*; **3-4.** Bulbous stromatoporoid *Actinostroma* ex gr. *septatum*, at 3 m (4 = magnification with alveolitid); **5.** Field photo of stromatoporoid-coral float-/rudstone, at 3 m; **6**. Stromatoporoid *Trupetostroma* sp., at 6 m; **7-8.** Cross section of dendroid stromatoporoid *Amphipora ramosa,* with parathuramminid foraminifera and supposed cyanobacteria *Renalcis* (magnified in 8.), at 7.8 m.

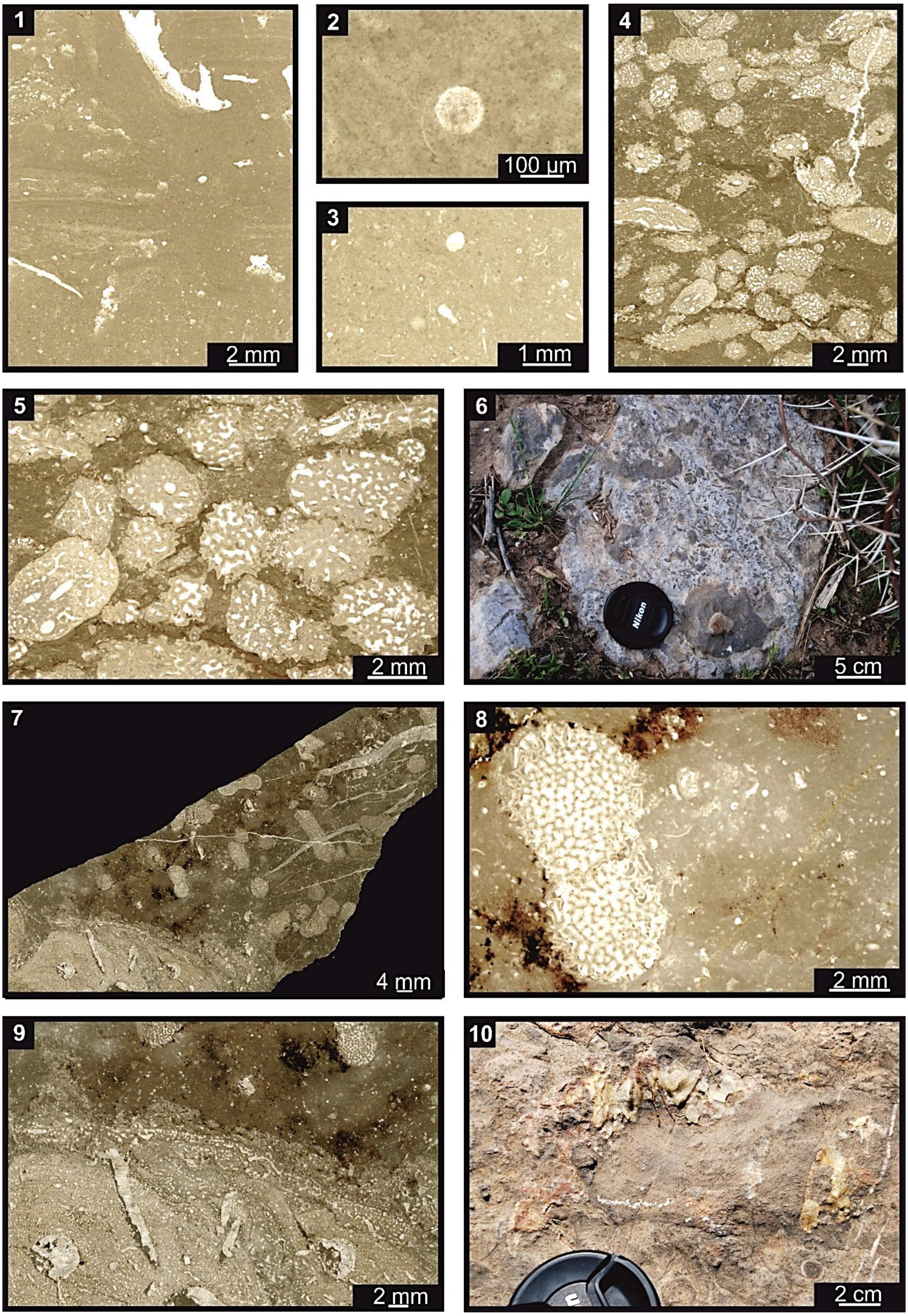

Fig. 16: Reef facies of lower Sidi bou Talaa Member between ca. 12 and 15.5 m, 1-3 = SBT F4, back reef bioclastic mud-wackestone, 4-6 = *Amphipora-Stachyodes* bafflestone, 7-10 = SBT F1, stromatoporid-coral float-rudstone. **1-3.** Bioclastic mud-wackestone with birdseye structures, archaespheres (2., enlarged), and shell fragments (3., enlarged), at 12.1 m; **4-5.** Cross sections of *Amphipora ramosa* and *Stachyodes (St.)* ex gr. *dendroidea* (on the left), at 14 m; **6.** Field photo of *Amphipora-Stachyodes* bafflestone, at 14 m; **7-10.** Stromatoporid-coral float-rudstone (10. = field photo) with laminar stromatoporids (*Parallelopora goldfussi, Clathrocoilona (Cl.) solidula spissa,* 9., enlarged) and dendroid stromatoporid bafflestone with *Clavidictyon* sp. (8., enlarged), at 15.3 m.

The preservation as in-situ baffelstone is very rare; the common facies type is float- or rudstones, which reflects recurring events with high turbulence. The additional fossil content is very low (shell fragments, parathuramminid foraminifers, and the supposed cyanobacteria *Renalcis*). The matrix consists of coarse-grained micrite and peloids.
Interpretation: Protected, calm back reef with episodic destruction by major storms (compare MF A6 of EICHHOLT & BECKER 2016).

SBT F4, Back reef fenestral (microbial) limestone

(Figs. 16-1-3; compare GENDROT 1973)
Back reef bioclastic mud-wackestone: middle to dark gray micrite with restricted macrofossil content. In thin sections occur shell fragments of small ostracods, gastropods, brachiopods, parathuramminids, and archaespheres. The limestones show "birdseye structures" filled with calcite cement and fenestral structures filled with micrite, peloids, or calcite cement. Some cavities are filled with geopetals (Fig. 16.1).
Interpretation: Quiet and calm but shallow environments within the restricted platform interiors, allowing the growth of benthic microbial aggregates (compare part of Facies F8 in CATTANEO et al 1993, Oued Cherrat).

As said above, inner reef talus dominates. At 5-6 m above our section base, it is interrupted by a tongue of stromatoporid boundstone with rugose corals, which suggests a reefal backstepping episode during transgression. We recognized in the lower part three thin intervals (at ca. 12 m, 14 m, and 21 m) of fenestral facies that reflect periods of lagoon shallowing (regression). The upper two are followed by *Amphipora* bafflestone, formed when relative-see level started to rise again. The more massive limestones of the logged upper succession (Fig. 17, starting at GPS 32°38´15.7´´, W7°45´32.2´´) are biohermal reef limestones, with one interval of more thin-bedded back reef limestones with *Amphipora* and *Stachyodes* at 14-15 m. Thin phases of lagoon expansion indicate an outwards progradation of true reef belt. Two breccia intervals at 15-19 m and 22.7 to 25 m show that synsedimentary tectonism was re-occurring throughout the reef growth. Our logging did not reach the section top.

Fig. 17: The logged, partly massive upper succession at Sidi bou Talaa, with Stephan EICHHOLT for scale.

The composition of the Rehamna reef fauna has last been summarized by HOLLARD et al. (1982, tab. 2). This list is outdated since the taxonomy of corals, chatetetid sponges, and stromatoporids has proceeded. Based on thin-sections, we recognized the following taxa at Sidi bou Talaa (* = new record for Morocco):

Stromatoporida:
Actinostroma ex gr. *septatum* LECOMPTE, 1951 (Figs. 15.3, 20.6)*
Actinostroma stellulatum NICHOLSON, 1886 (Fig. 21.5)*
Actinostroma verrucosum
Amphipora ramosa (PHILLIPS, 1841) (Figs. 15.7, 16.5, 20.2)
Anostylostroma sp. (Fig. 20.3)*
Clathrocoilona (Cl.) ex gr. *damnoniensis* (NICHOLSON, 1886) (Figs. 20.4-5)*
Clathrocoilona (Cl.) obliterata (LECOMPTE, 1951) (Fig. 15.1)*

Clathrocoilona (Cl.) solidula spissa (Lecompte, 1951) (Fig. 16.9)*
Clavidictyon sp. (Figs. 16.8, 21.7)*
Habrostroma ?sp.*
Parallelopora goldfussi Bargatzky, 1881 (Fig. 16.7)*
Pseudotrupetostroma sp. (Fig. 15.1)*
*Stachyodes (St.) caespitosa** Lecompte, 1952 (Figs. 19.3, 20.8)
Stachyodes (St.) ex gr. *dendroidea* Etheridge, 1918 (Figs. 16.4, 21.7)*
Stachyodes (St.) ex gr. *paralleloporoides* Lecompte, 1952 (Fig. 21.6)*
Stromatoporella sp. (Fig. 20.6)
Stromatoporella mudlakensis Galloway in Galloway & Ehlers 1960 (Fig. 21.2)*
Trupetostroma sp. (Figs. 15.6, 19.1)

Chaetetida
Rhaphidopora sp. (Fig. 19.6)

Tabulata:
Alveolites sp. (Fig. 15.4)
Auloporid (Fig. 21.3)
Platyaxum (Roseoporella) taenioforme (Schlüter, 1889) (Fig. 20.7)*
Scoliopora denticulata (Milne-Edwards & Haime 1851) (Figs. 15.1, 19.5)*
Syringopora sp. (Fig. 19.6)

Rugosa:
Sociophyllum sp. (Figs. 20.4-5)
Mesophyllum (Cystiphylloides) sp. (Fig. 22)

Calcimicrobes
Renalcis sp. (Fig. 15.8)
parathuraminnids (Figs. 15.7, 16.2)

Dasycladaceae
Vermiporella sp. (Fig. 21.4)*

The *Stromatoporella mudlakensis* from the upper succession (13.5 m) is the unusual record of a North American taxon (Galloway & Ehlers 1960) with short branches, unlike as in typical species of the genus. Biogeographic links with Michigan are also given by the *Clavidictyon*. Moroccan *Trupetostroma* were previously mentioned by Jakubowicz et al. (2017) from the Givetian Aferdou el Mrakib reef in the southern Maïder (eastern Anti-Atlas). The only previous North African record of *Sociophyllum* was from the far distant “Zemmour noir” of northern Mauritania (Coen-Aubert 2017). The Sidi bou Talaa assemblages are characterized by a dominance of stromatoporids and rarity of rugose corals, as typical for reef core to back reef facies. Favositids, alveolitids and heliolitids, which tend to dominate biostromes and initial reef stages, are more or less lacking. Somewhat unusual is the absence of thamnoporids, which are often closely associated with *Stachyodes* (see Eichholt & Becker 2016 for Meseta examples). The reefal calcimicrobe *Renalcis* was first recorded from Morocco (Immouzer-du-Kandar, Middle Atlas basement) by Aboussalam et al. (2020). Normally, it is more common in Frasnian reefs and typical for reef tops or marginal slopes. In our case, it is part of the talus that was shed into the lagoon.

Together with the Gendrot (1973) and Hollard et al. (1982) records of alveolitids (three taxa), heliolitids (three taxa), *Coenenites* (one species), *Thamnopora* (one species), favositids (three taxa), one additional species of *Actinostroma* (*Act. clathratum*), further chaetetids (two taxa), two further stromatoporids found at Gare Mechra Ben Abbou (see below), there is now a total of 38 reef building taxa (stromatoporids, tabulate corals, chaetetids, calcimicrobes, calcareous algae; rugose corals excluded) known from the Mechra Ben Abbou Formation. With respect to the limited number of thin-sections and sampled localities, this is probably only a part of the true local biodiversity. But it indicates that the alpha biodiversity was not low, as one may expect from a reef growing at relatively high palaeolatitude.

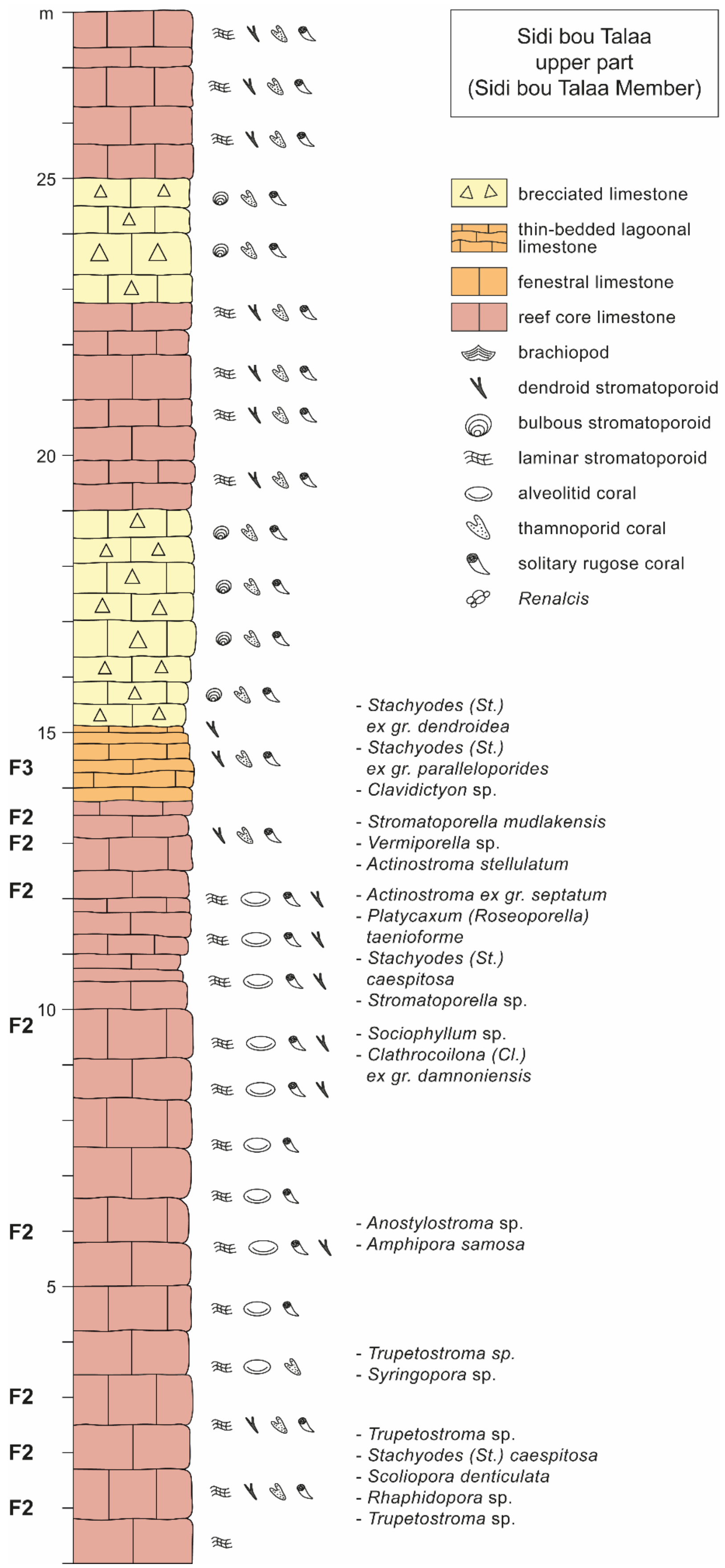

Fig. 18: Simplified macro- and microfacies log for the upper Sidi bou Talaa Member, showing the principle facies (SBT), macrofauna observed in the field, and fauna identified in thin-sections. Note the dominance of true reef facies indicating reef backstepping during transgressive phases.

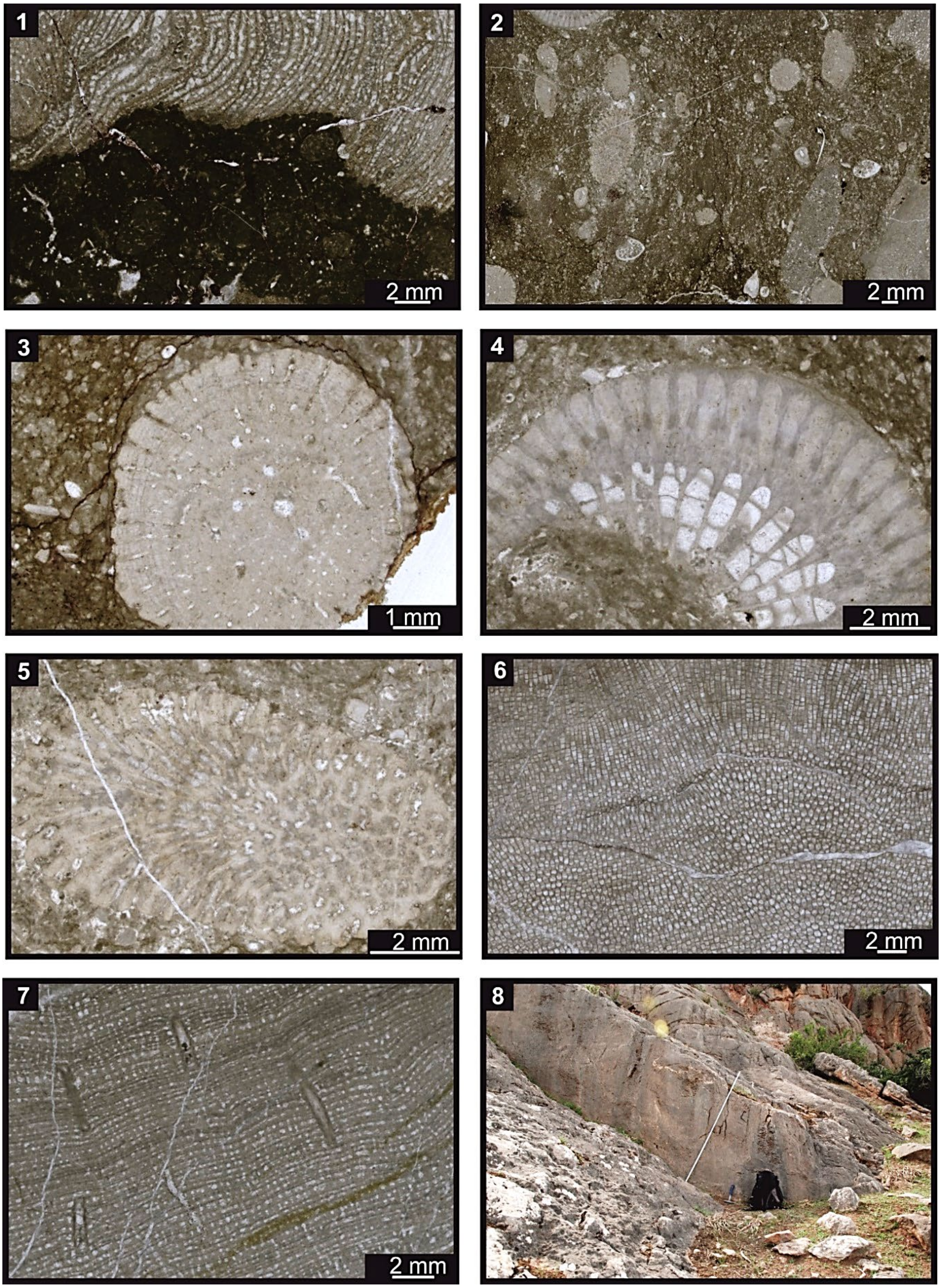

Fig. 19: Macro- and microfacies of upper part of Sidi bou Talaa Member (from base to 6 m), SBT MF2, stromatoporoid-coral boundstone with large laminar, bulbous and dendroid stromatoporids, and tabulate corals. **1.** *Trupetostroma* sp., at 1 m; **2-5.** Cross sections of dendroid stromatoporoids (*Stachyodes (St.) caespitosa*, enlarged in 3.), tabulate (*Scoliopora denticulata,* enlarged in 5.), and fragmentary solitary rugose corals (enlarged in 4.) within a bioclastic wacke-floatstone matrix, at 2 m; **6.** Chaetetid sponge *Rhaphidopora* sp. at 2 m; **7.** *Trupetostroma* sp. with tube-shaped corallites of *Syringopora* sp., at 3 m; **8.** Field photo of thick-bedded stromatoporid-coral boundstones, at 4-6 m.

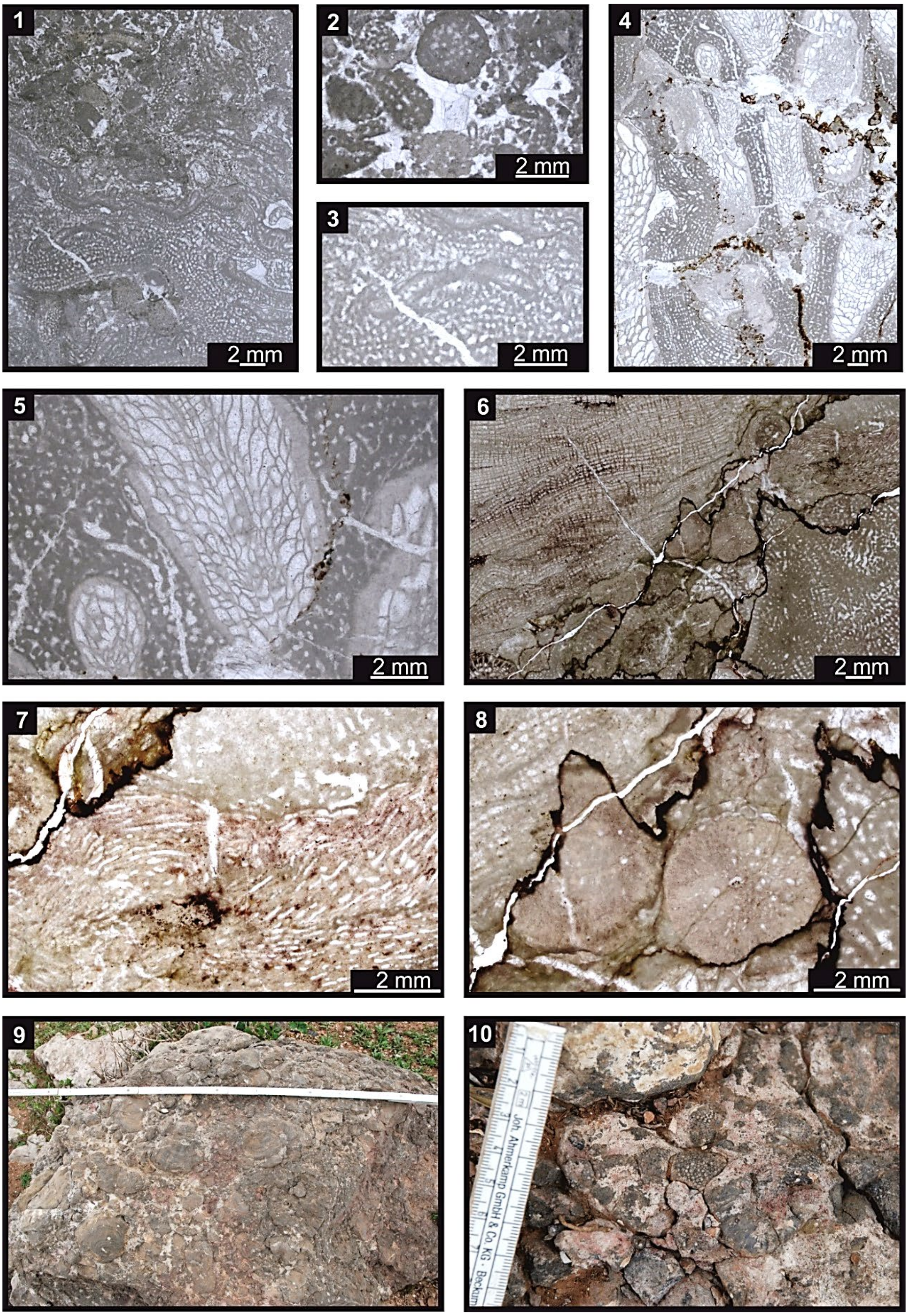

Fig. 20: Macro- and microfacies of upper part of Sidi bou Talaa Member (6-12 m), SBT MF2, stromatoporoid-coral boundstone with large laminar, bulbous and dendroid stromatoporids, and tabulate corals. **1-3.** *Anostylostroma* sp. (enlarged in 3.) encrusting delicate dendroid stromatoporoid branches (poorly preserved *Amphipora ramosa*, enlarged in 2.), at 6 m; **4-5.** Colonial rugose coral *Sociophyllum* sp. (enlarged in 5.) encrusted by *Clathrocoilona (Clathrocoilona)* ex gr. *damnoniensis*, at 10 m; **6-8.** *Actinostroma* ex gr. *septatum* (on the left in 6.), alveolitid *Platyaxum (Roseoporella) taenioforme* (top right corner in 6., enlarged in 7.), *Stromatoporella* sp. (at the bottom right in 6.), and *Stachyodes (St.) caespitosa* (enlarged in 8.), at 12 m; **9-10.** Field photos of slightly brecciated stromatoporid-coral rud-boundstones, at 12 m.

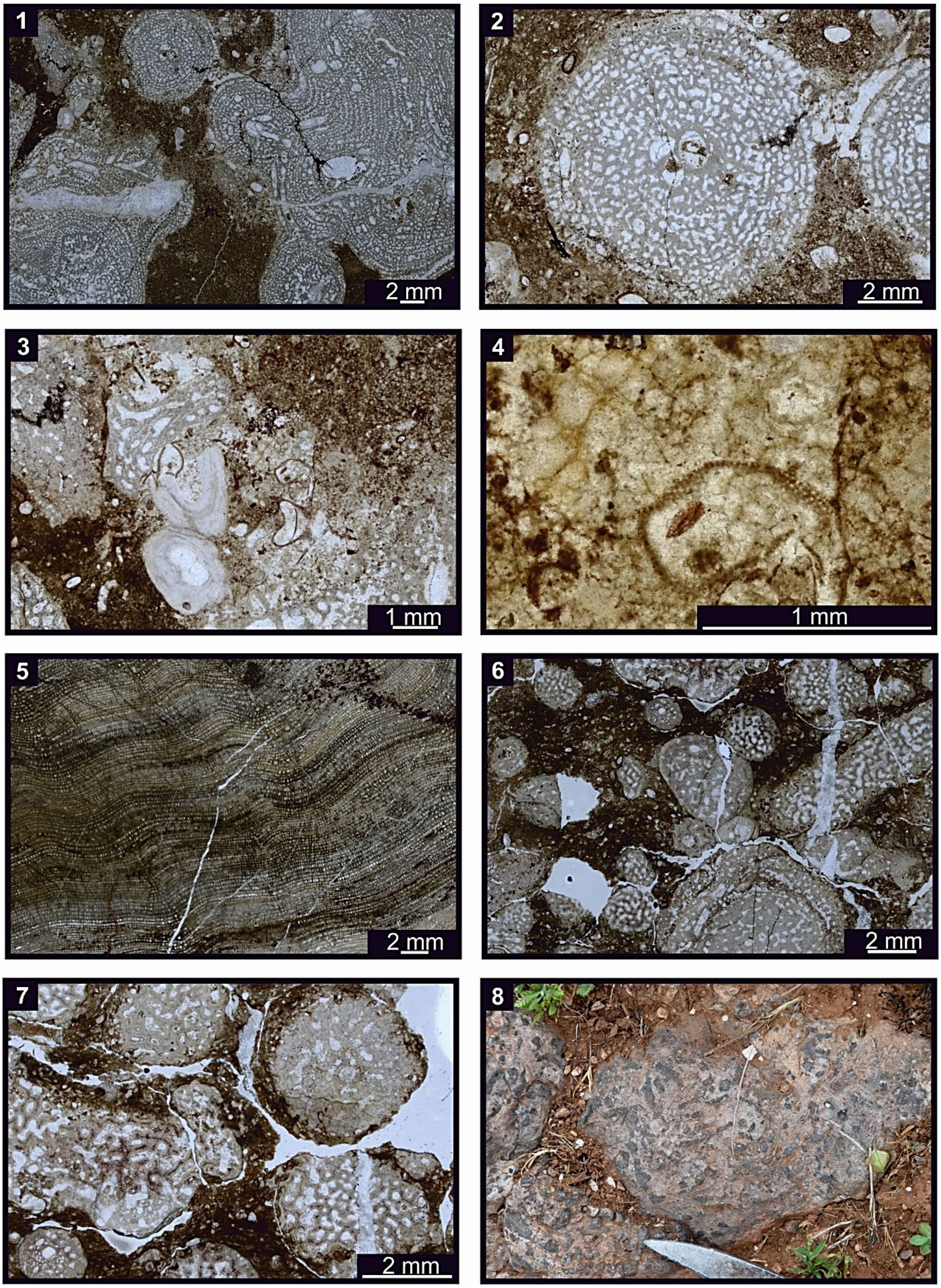

Fig. 21: Macro- and microfacies of upper part of Sidi bou Talaa Member (13-14 m), SBT MF 3, stromatoporoid-bafflestone. **1-4.** Bafflestone with dendroid stromatoporoid *Stromatoporella mudlakensis* (enlarged in 2.) fragment of auloporoid tabulate coral (enlarged in 3.), and a fragment of the dasycladacean green alga *Vermiporella* sp. (enlarged in 4.), at 13.5 m; **5.** *Actinostroma stellulatum*, at 13 m; **6-7.** Dendroid stromatoporids *Stachyodes (St.)* ex gr. *paralleloporoides*, *St. (St.)* ex gr. *dendroidea* (enlarged in 7., top right), and *Clavidictyon* sp. (enlarged in 7., left side), at 14 m; **8.** Field photo of stromatoporoid bafflestone, at 14 m.

The reef belt from the Meseta in the north to the "Zemmour noir" of northern Mauritania in the south had a published record of ca. 70 Givetian/Frasnian reef builders plus almost 90 rugose coral species, some of which (the phillipsastreids and cystiphyllids) may form biostromes or small mounds (e.g., WENDT 1993; NÜBEL & BECKER 2004; JAKUBOWICZ et al. 2017). Therefore, our high number of new Moroccan records (17 = ca. 2/3) just underlines the still poor taxonomic knowledge of Moroccan Devonian reefs. At least at the generic level, there is no difference to European Givetian reefs. EICHHOLT & BECKER (2016) emphasized that Oued Cherrat/Al Attamna reefs share the principle paleoecology and facies types of German reefs. With respect to the significant spatial difference (> 3.000 km) at the southern margin of the subtropical belt, this pattern has palaeoclimatic implications: the assumption of a very low climatic and palaeoecological gradient from the tropics into the middle latitudes. On the other side, as noted by JAKUBOWICZ et al. (2017), the Aferdou el Mrakib reef of the southern Maïder (Anti-Atlas), represents a rather different reef type than those of the Meseta.

The recognition of stringocephalids at 7.8 m (lower succession) confirms the established lower/middle Givetian age. RAJI et al. (2004) found *Po. varcus* and *Po. timorensis* in the Bouchhada quarry. The first is an index species of the middle Givetian (*rhenanus-varcus* Zone of BULTYNCK 1987). We tested brecciated limestones and beds with micrite matrix in the lower part of the Sidi bou Talaa Member without success for conodonts, which is no surprise since these are mostly lacking in reef core and backreef settings.

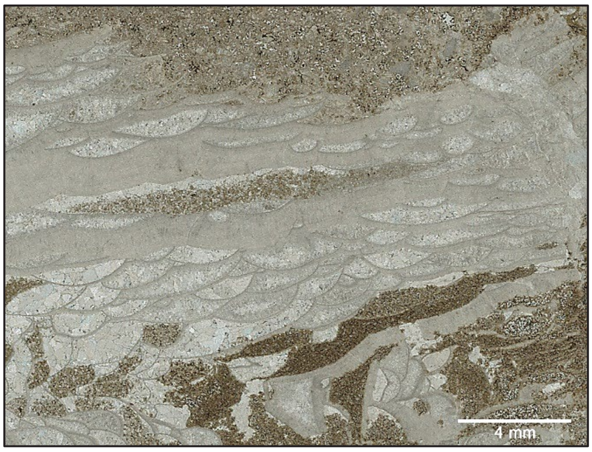

Fig. 22: Longitudinal section through a *Mesophyllum (Cystiphylloides)* from the northern top of Sidi bou Talaa.

Fig. 23: Fault-controlled upper (northwestern) end of the Sidi bou Talaa reef.

The poorly-bedded reef core limestones continue beyond our section log, with large boulders forming the crest of the ridge. At the top, the macrofauna evidence is sparse. In thin section, the only cystiphyllid (Fig. 22) was found. This peculiar group of rugose corals is rather diverse in the Ouihlane Reef of the northern Maïder, Anti-Atlas (SCHRÖDER & KAZMIERCZAK 1999). The sharp termination of reef blocks (Fig. 23) supports the interpretation of EL KAMEL (2004, map of fig. 46) that the reef top was cut off by a fault.

Fig. 24: The steeply dipping Lower Devonian (new) Oued Kibane Formation on the southern side of the main road to Sidi et Tnine (to the left), showing thin-bedded Lower and Upper Members and a massive, thick-bedded Middle Member dipping steeply to the right = west (Fouad EL KAMEL, Zhor Sarah ABOUSSALAM and Julian Shahin BECKER for scale at the section base, photo from April 2012).

5. Devonian at Foum el Mejez

After an interruption of Palaeozoic outcrops by Cretaceous cover (Fig. 2), the Devonian re-appears in the NE Rehamna in narrow, ca. N-S oriented graben structures at Foum el Mejez, with good exposures north and south of the Oued Kibane, ca. 9-10 km NE of Mechra Ben Abbou. These successions have previously been studied by GIGOUT (1955a), BÄCKER et al. (1965), JENNY (1974), HOLLARD et al. (1982), and EL KAMEL (2004). EL KAMEL & EL HASSANI (2000) documented important phases of Lower Devonian tectonism, resulting in slumping, tilted blocks, decametric synsedimentary faults, and pillow structures. Despite this intensive past research, the precise dating of strata and the documentation of faunas is still poor. Separated by graben faults, a western limestone-dolomite succession (Fig. 24) and an eastern, Famennian siliciclastic sequence can be separated. The term Foum el Mejez Formation was introduced by HOLLARD et al. (1982) for the latter and, therefore, cannot be applied to the much older carbonates, as it was done by EL KAMEL (2004) or OUKASSOU & NAUGOLNYKH (2021). Consequently, a new formation term, the Oued Kibane Formation, is introduced. EL KAMEL (2004, fig. 50) published a fine, detailed geological map of the Foum el Mejez Devonian, which illustrated the numerous, ca. SSW-NNE running normal faults that displace the overall graben structure (Fig. 25). Our limited field work aimed at new biostratigraphic, faunal

and facies data but was restricted to the outcrops just north and south of the road to Sidi et Tnine in the NE.

Fig. 25: Series of limestone/dolomite ridges in the south of the sampled section at Foum el Mejez, illustrating the dislocation of the Oued Kibane Formation by normal faults.

5.1. Lower Devonian (new) Oued Kibane Formation

The calcareous to dolomitic Oued Kibane Formation has a total thickness of 50-60 m and can be subdivided into three members (Fig. 24). Our section at x = 283.35, y = 235.05 is identical with the western part of the cross-section of Jenny (1974) and Hollard et al. (1982, fig. 1.5). Beds dip constantly and steeply to the west. Below the formation lie poorly exposed and unfossiliferous siltstones, assigned by Oukassou & Naugolnykh (2021) to the Sakhra Touila Formation. The up to 20 m thick **Lower Member** of the Oued Kibane Formation consists of middle-grey, thin-bedded, middle- to coarse-grained, partly dolomitic bioclastic limestones. Limestones may be separated by minor marl interbeds. Recrystallization was partly so strong (Fig. 26) that only remnants of crinoid fragments are poorly recognizable. El Kamel (2004) noted debris of brachiopods, crinoids, mollusks, corals, bryozoans, and trilobites. This points to a storm-ridden, neritic, open (non-reefal) carbonate ramp. This is in accord with our monotypic record of *Caudicriodus celtibericus* (six specimens, Fig. 27.1), which ranges from the top-Pragian to high in the lower Emsian (e.g., Aboussalam et al. 2015). We assume a basal Emsian age for the time of carbonate platform initiation, which either reflects a deepening pulse, in accord with eustatic trends, or a weathering- and climate-related reduction of clastic influx.

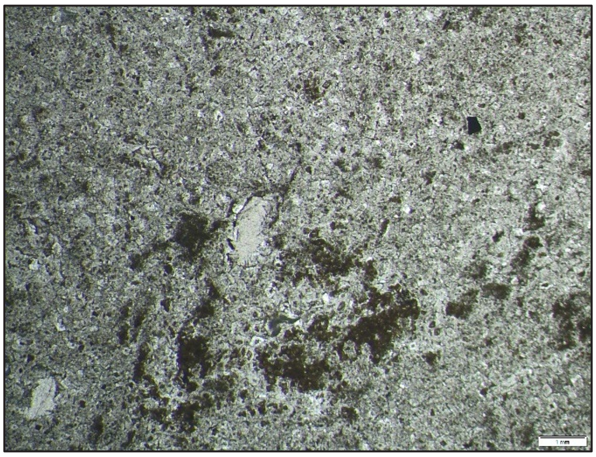

Fig. 26: Pseudosparitic thin-section from the lower part of the Lower Member of the Oued Kibane Formation showing the complete recrystallization that destroyed all local fossil record.

Fig. 27: Conodonts from the Oued Kibane Formation at Foum el Mejez, GMM B4C.2.117-118. **1.** *Caudicriodus celtibericus*, lateral process broken off, middle part of Lower Member, length = 0.6 mm; **2.** Corroded *Neopanderodus perlineatus* showing a very strong lateral depression (perhaps for venom transport) and only weak remnants of fine striation, top part of dolomitic Upper Member, length = 0.97 mm.

The 20-30 m thick **Middle Member** consists of thick-bedded to massive dolomitic limestones that are laterally affected by synsedimentary faulting, slumping and in-situ brecciation (EL HASSANI & EL KAMEL 2000). Macroscopically few fossils are visible apart from crinoid fragments but the niches of boulders are inhabited by large snakes, who leave impressive dry skins. In thin-sections, EL KAMEL (2004) observed a similar bioclast spectrum as in the Lower Member. There was a regressive trend towards a crinoid-dominated higher ramp position but no evidence for a biostrome setting as one may deduce from the term "peri-reefal" (e.g., OUKASSOU & NAUGOLNYKH 2021). Accordingly, HOLLARD et al. (1982, p. 21) refer to a rather diverse neritic fauna from LE MÂITRE (1938) and the unpublished report of BÄCKER et al. (1965), including orthids, atrypids, pentamerids, *Glossinulus mimicus*, *Paraspirifer cultrijugatus, "Alatiformia" mischkei* (which is probably a species of a different genus)*, Euryspirifer paradoxus*, favositids, and solitary corals. If identifications are correct, the four listed species provide an upper/uppermost Emsian age (see zonation in JANSEN 2016).

Fig. 28: Field photo of thin-bedded, yellowish dolomites, Upper Member of Oued Kibane Formation at Foum el Mejez.

The 20-25 m thick **Upper Member** is an alternation of thin-bedded, decimetric, dolomitic limestones, yellowish dolomites (Fig. 28), and marls. The latter become more prominent in the upper half. EL KAMEL (2004) noted chert levels originating from the mobilized SiO_2 of sponge spicules. He also recorded debris of crinoids, mollusks, brachiopods, trilobites, and ostracodes. However, recrystallization and dolomitization destroyed all the original microfabric, especially in the upper part (Fig. 29). The environment returned to a deeper ramp setting. The top of the formation is sharp and possibly a fault contact.

None of the previous studies reported any Middle Devonian fossil from Foum el Mejez. Our conodont sample from the top of the Oued Kibane Formation yielded, despite the complete dolomitization, two specimens of *Neopanderodus perlineatus* (Fig. 27.2). This is a long-ranging shallow-water species and, based on its strong longitudinal furrow, may have been venomous (SZANIAWSKI 2009). It has been found as a dominant form in the lower/upper Emsian and lower Eifelian of the Tiflet and Oued Cherrat successions (BENFRIKA et al. 2007; BECKER et al. 2020a) or, far away, in Emsian beds of the Istanbul area (SAYDAM-DEMIRAY & ÇAPCINOĞLU 2012). It was also found to be common in a lower Givetian limestone of Dar Cheik el Mfaddel (Benahmed region) and in a basal Frasnian breccia at Aïn-al-Aliliga (Oued Cherrat). Since the Eifelian was characterized by deepening and by blooms of organic silica both at Mechra Ben Abbou and at Jebel Ardouz (see that chapter, this volume), we assume tentatively a basal Middle Devonian age for the Upper Member. However, there are no data to support a correlation of the middle/upper Oued Kibane Formation with the main reefal Mechra Ben Abbou Formation (Sidi bou Talaa Member). This has implications for the facies and

palaeogeography model. There is no evidence for a west-east facies differentiation in the Middle Devonian. Currently, we know nothing about the upper Eifelian to Frasnian of the Foum el Mejez region. The important local phase of Eovariscan tectonism occurred in the lower/upper Emsian. This block faulting obviously masked the global Daleje Event, which is well-expressed in other Meseta regions (e.g., Oued Cherrat, BECKER et al. 2020a) and possibly in the Benahmed region (see Benahmed chapter, this volume).

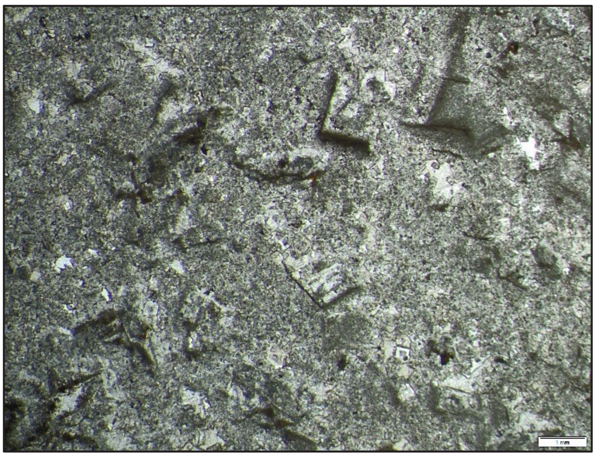

Fig. 29: Thin-section of a thin-bedded dolomitic limestone from the top of the Upper Member of the Oued Kibane Formation, showing the complete recrystallization and destruction of bioclasts.

5.2. Famennian Foum el Mejez Formation

Separated by a steep, ca. N-S running fault, the more than 200 m thick Foum el Mejez Formation lies nearly horizontally just 400-500 m NE of the steeply dipping Lower Devonian outcrop (Fig. 30). In our section, at x = 283.7, y = 235.3 (see map of EL KAMEL 2004), we estimated ca. 50 m of exposed fossiliferous laminated to cross-bedded silty shales, siltstones, and fine sandstones, followed rather sharply by massive quartzites. The section has previously been studied by GIGOUT (1955a) and HOLLARD et al. (1982, see cross-section in fig. 15.1). EL KAMEL (2004) used the term Dalaa Formation, which is pre-occupied by the Foum el Mejez Formation introduced by HOLLARD et al. (1982). Since Dalaa is the name for the quartzite hill top, it is suitable as name for the upper member. For the main lower part (EL KAMEL´s members OA1-3), the term Oued Ater Member is used, adopted from the Oued Ater Formation of EL KAMEL (2004). Its type locality is in the south of the Foum el Mejez Graben (Fig. 2) and was first studied by HOLLARD et al. (1982: Unit 3).

Fig. 30: Overview of the nearly horizontally bedded Oued Ater Member at Foum el Mejez, with Lea Amira BECKER for scale (photo from April 2012). Quartzite blocks are debris from the Dalaa Member at the top.

5.2.1. Oued Ater Member

The main lithology is an alternation of greenish-grey silty shale and thin-bedded (up to 7 cm thick), greenish to yellowish-grey weathering, cross-bedded, fine sandstones with wavy lower and upper surfaces. A thin-section reveals very good sorting and variably amounts of fine quartz and iron mineral grains. Sandstones become more common in the upper ca. 40 m of the exposure, characterizing locally “Member D2” sensu EL

KAMEL (2004). At this level, there are trace fossils and common brachiopods that are concentrated in specific intervals, especially at 35 to 30 m below the top. The preservation is at best moderate. Shells have been dissolved and molds and negatives are incomplete, distorted and abraded. We observed/collected (identifications by D. BRICE, Lille):

small orthids
cf. *Gastrodetoechia* sp. (Fig. 31.1A, 2)
Leptoterorhynchus sp. (cf. Fig. 31.1B)
cf. *Ptychomaletoechia* or *Sinotectiorostrum* sp. (Fig. 31.3)
cf. *Petasmaria* or *Porostictia* sp.
spiriferids indet. (Figs. 31.4-5)

The rhynchonellids are dominant. *Gastrodetoechia* is a middle to lower upper Famennian genus (SARTENAER 1967). *Leptoterorhynchus* was described from the middle Famennian of Poland and the Rhenish Massif (SARTENAER 1998). *Ptychomaletoechia* and *Sinotectirostrum* have long ranges through the Famennian (SARTENAER 1967). The type level of *Porostictia* is in the upper middle to lower upper Famennian of New Mexico (Percha Shale). In combination, our brachiopod collection from the lower part is assigned to the middle Famennian but higher parts of the member fall probably in the upper Famennian. We took some spore samples for C. HARTKOPF-FRÖDER (Krefeld) but results are not yet available. The environment was a prodelta on an open, subtidal shelf. The brachiopod-poor lower part may represent the lower Famennian although the reported bivalve *Buchiola* (BÄCKER et al. 1965; HOLLARD et al. 1982) has no stratigraphic value without a species-level identification. It indicates a deeper outer shelf biofacies. The change to brachiopod facies may well reflect the eustatically controlled Condroz Regression (BECKER 1993) at the lower/middle Famennian transition. As illustrated in the cross-section of HOLLARD et al. (1982, fig. 1.9), the Oued Ater Member has no equivalents in the west, which confirms the interpretation that it deposited in a subsiding fault zone, which was later transformed into the graben structure.

5.2.2. Dalaa Member

The Dalaa Member consists of coarse-grained, cross-bedded, light-grey to reddish weathering, thick-bedded and cliff-forming quartzites. It equals Unit 4a-c of HOLLARD et al. (1982, fig. 1.5). To the south, at Oued Ater (Fig. 2), conglomerates occur (EL KAMEL 2004). At Foum el Mejez, OUKASSOU & NAUGOLNYKH (2021) recognized three quartzite bars. Based on collections of GIGOUT (1955a; compare HOLLARD et al. 1982) and EL KAMEL (2004), there is a relatively diverse brachiopod fauna, including *Sphenospira julii*, other cyrtospiriferids that require revision, various productellids, *Mesoplica praelonga*, rhynchonellids, including *Centrorhynchus letiensis*, and *"Athyris royssi"*. The member clearly correlates with the similar quartzites of the Douar Nahilat Formation at Gare Mechra Ben Abbou (see below). The first listed species is regarded as the most characteristic uppermost Famennian ("Strunian") spiriferid of Europe (NICOLLIN & BRICE 2004; MOTTEQUIN et al. 2013). The types of the productid *Mesoplica praelonga* come from the uppermost Famennian (LE spore zone) Lower Pilton Formation of North Devon. But the species is wide-spread in the upper/uppermost Famennian, including Algeria and the Dra Valley (e.g., KAISER et al. 2004; NICOLLIN & BRICE 2004; BRICE et al. 2007). *Centrorhynchus* has a long range in the middle to uppermost Famennian but, as the other taxa, did not survive into the Carboniferous (BRICE et al. 2007; MOTTEQUIN et al. 2013). It occurs widely in Morocco, including the western

(BRICE et al. 2007) and eastern Anti-Atlas (e.g., BECKER et al. 2013b). The last listed species refers in fact to *Cleiothyridina deroissyi* (LÉVEILLÉ, 1835), which is an upper Tournaisian species. The Foum el Mejez record is most likely based on a different athyrid; for example, there are older species of the genus *Cleiothyridina* (see, e.g., MOTTEQUIN 2008).

Fig. 31: Brachiopods from ca. 35 to 30 m below the top of the Oued Ater Member at Foum el Mejez (det. D. BRICE, Lille). **1.** Field photo of a slab (GMM B5B.16.3) with several rhynchonellids (A = cf. *Gastrodetoechia*, B = *Leptoterorhynchus*): **2.** cf. *Gastrodetoechia* sp., GMM B5B.16.4; **3.** cf. *Ptychomaletoechia* or *Sinotectirostrum* sp., GMM B5B.16.5; **4-5.** Spiriferids indet., GMM B5B.16.6-7.

In summary, a "Strunian" age of the Dalaa Member is supported by the published brachiopod data but all previous records require confirmation by description or illustration. GIGOUT (1951, p. 64) mentioned from a locality named as Aïn Belmesk (loc. 633) "*Phacops* cf. *bergicus*", which refers to a species of the genus *Omegops* (see STRUVE 1976), a typical phacopid of the shallow-water "Strunian". The Dalaa Member is also the type-level of the unusual new plant described by OUKASSOU. & NAUGOLNYKH (2021). The environmental setting is interpreted as delta lobes prograding eastwards.

In their lateral section south of the Oued Kibane, HOLLARD et al. (1982) recorded two overlying units, which are currently not included in the Foum el Mejez Formation. Unit 5 was a thick silty shale, unit 6 a sandy calcarenite with gastropods, a poorly preserved goniatite, and spiriferids. EL KAMEL (2004, p. 92) did not consider a Tournaisian age but further work has to clarify their age.

6. Devonian at Koudiat ed Diab

Incorporating fossil reports by GIGOUT (1951, 1955a) and BÄCKER et al. (1965), HOLLARD et al. (1982) established a detailed Lower Devonian succession at Koudiat ed Diab (= Koudiat ed Dib), ca. 5 km ENE of Mechra Ben Abbou (Fig. 2). This, not the Ouled Barka section to the SW, as later proposed by BEN BOUZIANE (1995), is the type-section of the Koudiat ed Diab Formation. We tried to follow the HOLLARD et al. succession on the way to the "Autunian" conglomerate in the north but outcrops are episodic and we did not find all levels. Therefore, we took only few samples, which did not deliver a single conodont. Therefore, the Koudiat ed Diab Formation is only briefly summarized and commented on, from base to top.

1. Silty black or violet shales with thin or lenticular, dolomitic limestones with large orthocones and *Scyphocrinites* debris. This seems to be the widespread *Scyphocrinites* level at the Silurian-Devonian boundary (e.g., RÉGNAULT 1985), which, however, does not occur in the Sakhra et Taïra succession. With respect to the lower Lochkovian faunas occurring higher, Unit 1 may be Pridoli in age.
2. Yellowish to ochre, dolomitic limestone with orthocones and sandstone/quartzite, followed by a thick, un-numbered shale.
3. Thin sandstone, followed by shale with intercalated yellowish limestone with orthocones (up to 30 cm) and eventually bioclastic, fossiliferous limestone. The reported tentaculitoid *Volynites* (BÄCKER et al. 1965) has a long range in the Lochkovian (e.g., TRUYOLS-MASSONI 1995) to Frasnian (e.g., FARSAN 1974); it proves a Devonian (Lochkovian) age for the unit.
4. Silty shale with intercalated bioclastic limestone.
5. Rose-colored, cross-bedded quartzite, laterally conglomeratic.
6. Shales and dark siltstones with subordinate bioclastic limestone.
7. White to reddish, cross-bedded quartzite with plant remains and conglomeratic channels.
8. Silty shale (not numbered), followed by a 15 m wide area with alternating ochre marls and fossiliferous limestone with brachiopods, corals, trilobites, and bryozoans. Loc. 1314 of GIGOUT (1955a) yielded lower Lochkovian index species, such as *Howellella mercurii*, *Lanceomyonia borealiformis* (now type-species of *Ktenopotamorhynchus* SARTENAER, 2015), *Warburgella rugosa*, and *Acastella patula*. The latter was originally described from the Lochkovian Lmhaifid Formation of the Dra Valley (HOLLARD 1963b).
9. Silty shale (not numbered) followed by bioclastic limestone.
10. 5 m of bioclastic limestone, sampled without success for conodonts. In thin-section (Fig. 32), it is a moderately sorted crinoid-brachiopod grainstone with favositids, sparite matrix, and iron hydroxide impregnations. Ribbed rhynchonellids (Fig. 33) are common

but always incomplete. The setting was a storm-ridden shallow carbonate platform. From the lateral sample 184 of GIGOUT (1951), Pragian brachiopods were reported. These include *Torosospirifer rousseaui,* "*Hysterolites? nerei*" (possibly a *Dixonella* sp.), *Stenorhynchia nympha* (SARTENAER 2010 doubted that forms from outside Bohemia belong to this genus and species), and "*Euryspirifer* cf. *pellico*" (which ranges into the Emsian).

11. Poorly exposed interval of shales, thin limestones and sandstones in the slope below the cliff-forming Mechra Ben Abbou Formation.

Fig. 32: Microfacies of ca. Unit 10 at Koudiat ed Diab, a poorly sorted crinoid-brachiopod grainstone deposited by storms on a shallow carbonate platform.

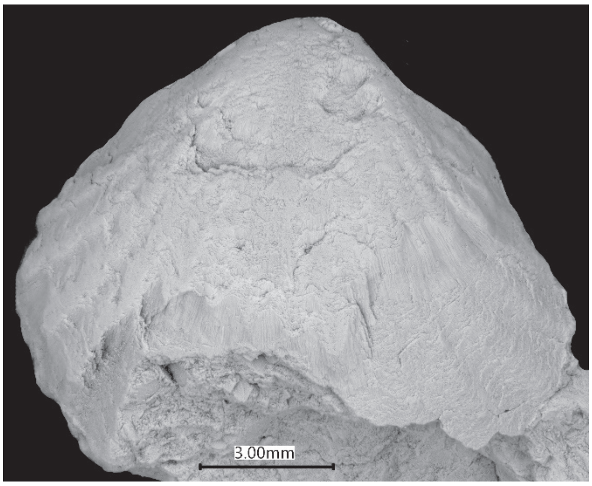

Fig. 33: Small rhynchonellid from Koudiat ed Diab, ca. Unit 10 sensu HOLLARD et al. (1982), GMM B5B.16.14.

7. Douar Nahilat Formation at Gare Mechra Ben Abbou

Following the initial discovery by DELEPINE & YOVANOVITCH (1938), the formal term Douar Nahilat Formation was introduced by HOLLARD et al. (1982) for often reddish (hematite impregnated) Famennian quartzites that truncate the Givetian reef limestones of the Mechra Ben Abbou Formation. The type section is at Douar Nahilat (Fig. 2), ca. 2 km SE of the railway station, on the southern slope of the Koudiat Forcha (see also GIGOUT 1951, BÄCKER et al. 1965, BEN BOUZIANE 1995: "Nahilat Formation"; EL KAMEL 2004). There, a thick alternation of silty shales, quartzites and conglomerates, partly including reworked Devonian limestones, was illustrated by HOLLARD et al. (1982, fig. 1.7). It was named as Koudiat el Forcha Formation by EL KAMEL (2004), which is a junior synonym.

We re-studied the unconformable contact between the Mechra Ben Abbou and Douar Nahilat Formation just northeast of the Mechra Ben Abbou railway station, at GPS N32°39´22.0´´, W7°46´53.1´´. The Givetian reef limestone is locally very massive and poorly bedded (Fig. 34), representing a true reef facies. Its top is a sharp, undulating, iron impregnated, erosional and karstification surface (Fig. 35.1). This suggests a long period of exposure, probably due to block tilting. The basal Douar Nahilat Formation consists of breccias mixing unsorted, variably sized, angular reef limestone clasts (Figs. 35.3-4), quartzite (Fig. 35.2), and a hematite-rich, partly laminated matrix (Fig. 35.6). Conodont sampling of both isolated clasts or of whole rock breccia was not successful. This is not surprising since Devonian biohermal reef facies normally lacks any conodonts. Thin-sections of reworked clasts yielded the stromatoporids *Stromatoporella* ex gr. *solitaria* NICHOLSON, 1892 (Fig. 35.4) and

Clathrodictyon (Synthetostroma) actinostromoides (LECOMPTE, 1951) (Fig. 35.5). Both species have not been recorded from Morocco so far. But *Stromatoporella* and *Clathrodictyon (Synthetostroma)* are in general wide-spread Middle Devonian genera/subgenera (e.g., STEARN et al. 1999). The first ranges only questionably into the Frasnian but has been identified in the lower Givetian of the Anti-Atlas (JAKUBOWICZ et al. 2018). The second ranges into the Frasnian in Czechia. The new records are not surprising since Moroccan Devonian stromatoporids have been studied poorly (MISTIAEN 1999).

Other important features are the interval brecciation of reworked clasts (Figs. 35.3, 6), partly complete recrystallization and lithification before reworking and re-sedimentation. The tight internal suturing (Fig. 35.6) suggests synsedimentary (Givetian) tectonism, as it is well-established at Sidi bou Talaa (see above). Other clasts consist of unsorted crinoidal pack-rudstone (Fig. 35.5), suggesting reef slope debris. The breccia represents a rockfall, followed by stromatolithic encrustation (Fig. 36) at a time of arid, lateritic weathering and a constant influx of iron-rich fluids. The tilted reef limestone formed obviously a coastal palaeocliff, which was transgressed after a long gap (upper Givetian to upper Famennian). In the overlying lower part of the Douar Nahilat Formation, we collected quartzite coquinas of *Mesoplica praelonga* (Fig. 37), an upper/uppermost Famennian marker productid. Their shells were removed in the carbonate undersaturated pore water. The created cavities were partly filled by authigenic hematite grains (Fig. 38). A very good sorting of quartz grains and monotypic faunas are typical for nearshore sand bars.

From the type-locality of the formation, DELEPINE & YOVANOVITCH (1938) and GIGOUT (1951) listed a richer brachiopod fauna, including *Whidbornella caperata, Productella subaculeata, Centrorhynchus letiensis, Sphenospira julii*, and others. This fauna clearly falls in the uppermost Famennian (see MOTTEQUIN et al. 2013). However, it needs to be stressed that the documentation is poor and modern taxonomic revisions are required. For example, the also listed "*Rhynchonella pleurodon*", now the type-species of *Pleuropugnoides* FERGUSON, 1966, is a Lower Carboniferous species (e.g., PARKINSON 1969).

Fig. 34: Givetian reef limestone (main slope with massive limestone boulders), followed in the middle ground by a more reddish weathering hill formed by resistant quartzites of the lower Douar Nahilat Formation.

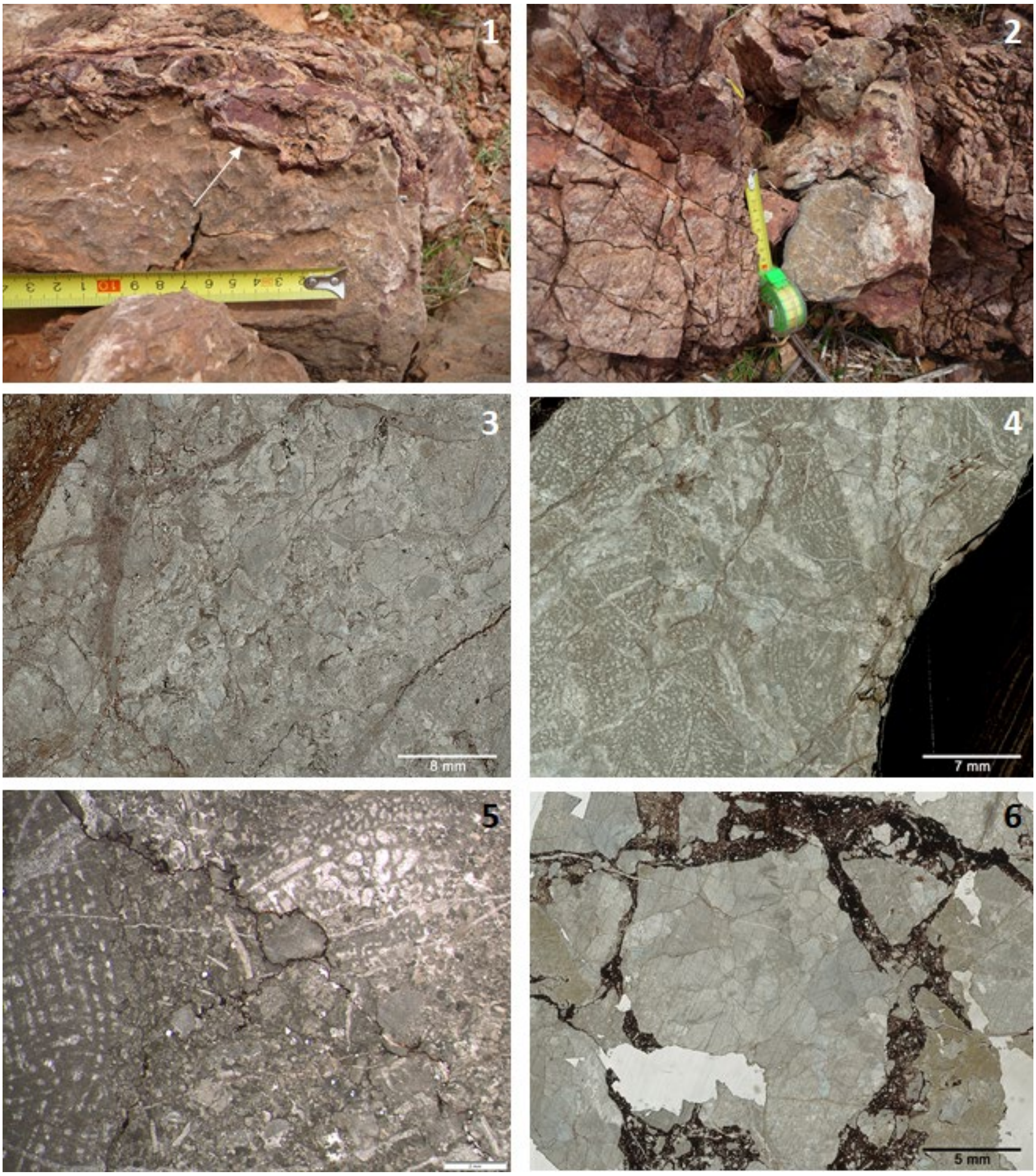

Fig. 35: Field photos and thin-sections of the brecciated and disconformable base of the Douar Nahilat Formation at Gare Mechra Ben Abbou. **1.** Undulating truncation surface (white arrow) between the top reef limestone and the reddish (hematite-impregnated) basal Douar Nahilat Formation; **2.** Breccia in the lower part of the latter with angular clasts of reef limestone (e.g., right next to the measuring tape) between quartzites; **3.** Block of internally brecciated and recrystallized intraclast rudstone within the basal breccia, with stromatolithic and hematitic encrustation (upper left); **4.** Reworked block of reef limestone with *Stromatoporella* ex gr. *solitaria*; **5.** Unsorted reef breccia (intraclast-crinoid pack-rudstone) with the stromatoporid *Clathrocoilona (Synthetostroma) actinostromoides* (left), evidence for double reworking in the breccia unit; **6.** Unsorted rockfall breccia consisting of strictly angular, internally brecciated, recrystallized limestone clasts and iron-mineralized matrix.

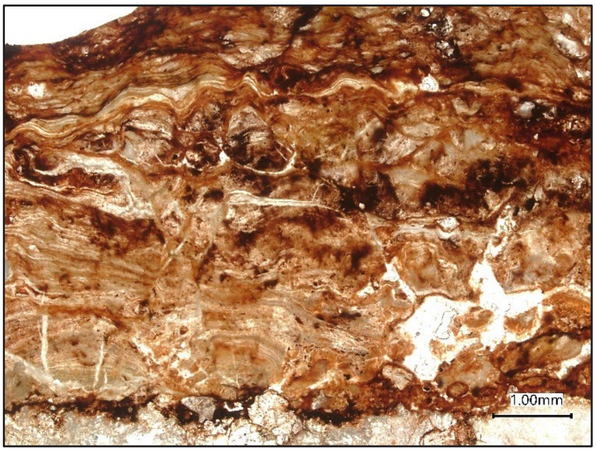

Fig. 36: Encrustation of a reworked block of recrystallized reef limestone (at the base) by iron stromatolites, breccia at the base of the Douar Nahilat Formation, Gare Mechra Ben Abbou.

Fig. 37: Iron-stained quartzite coquina with the upper/uppermost Famennian productid *Mesoplica praelonga*, lower part of Douar Nahilat Formation at Gare Mechra Ben Abbou, GMM B5B.16.8.

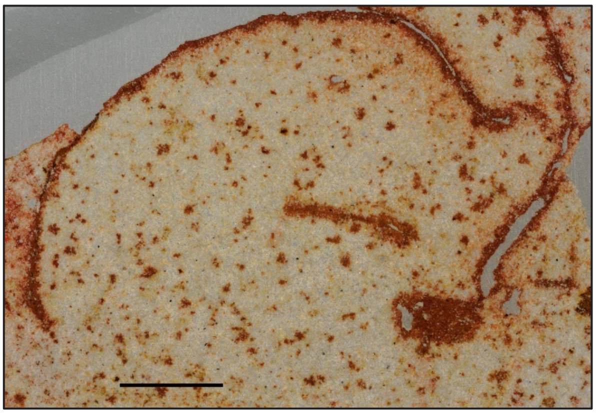

Fig. 38: Thin-section of the *Mesoplica* coquina at Gare Mechra Ben Abbou, showing the good sorting of quartz and coating of the brachiopod mold by hematite grains, embedded convex-up and leaving a part of the secondary porosity created by shell dissolution.

Fig. 39: Unsorted, coarse breccia north of Koudiat ed Diab, dominated by angular clasts of Devonian limestone, with reddish clastic matrix in interspaces.

8. "Autunian conglomerate" at Koudiat ed Diab

More than 500 m thick breccias crop out in boulders and ledges north of the Koudiat ed Diab Lower Devonian (Fig. 39). Hollard et al. (1982) suggested a fault contact. In the regional absence of any fossils from the matrix, an "Autunian" age was assumed based on the correlation with other regions, such as the Jebilet. El Kamel & Muller (1987) distinguished two un-named formations separated by an angular disconformity. We logged briefly the clasts spectrum, in the hope to find Devonian lithologies that are not common in Rehamna outcrops, and in search for Carboniferous pebbles that could constrain the maximum reworking age. We also looked

for double reworked clasts, consisting themselves of conglomerate/breccia, which were not found. Quartzites are subordinate to limestone clasts. The size of the latter ranges from 25 to 45 cm. Recognized clasts include:

1. Light-grey, well-rounded Ordovician quartzites.
2. Reddish, well-rounded quartzites.
3. Light-grey micritic limestone.
4. Middle-grey, detrital limestone.
5. Dark-grey, fine-grained brachiopod limestone.
6. Yellowish, dolomitized coquinas limestone.
7. Light-grey platform limestone with *Stringocephalus*-type, very thick-shelled brachiopods (Fig. 40), probably representing Givetian reef facies.
8. Coarse-grained, crinoidal debris limestone.
9. Colony of *Frechastrea pentagona* (Fig. 41) surrounded my middle-grey micritic to wackestone matrix with thick- and double-shelled ostracods and coral debris.
10. Red weathering, strongly iron-impregnated brachiopod-bryozoan rudstone (coquina) with the trepostome *Dyscritella* and the cryptostome *Rhabsomeson* (Fig. 42).

There is no sorting and only little reddish (hematite-rich) microconglomeratic matrix in interspaces. This suggests deposition by rockfall and during arid conditions with lateritic weathering. The rounding of the assumed Lower Paleozoic quartzites shows that they were moved for a long time along a shore or in rivers before they were mixed with the angular to subrounded Devonian material which originated from the immediate vicinity. The colonial rugose coral *Frechastrea pentagona* occurs typically rather late in the upper Frasnian of the Ardennes (see review by Coen-Aubert 2015). Closely related forms, which previously were regarded as subspecies, occur widely in the upper Frasnian of Europe and also in South China. A supposed previous North African record of the genus was *Fr. goldfussi* from the Smara region (Rodríguez Mellado 1948; Hernández Sampelayo 1948). These specimens belong to *Phillipsastrea* ex gr. *irregularis* (see May 2008), which is also a Frasnian taxon (of North America). Its recognition in a clast at Koudiat ed Diab is remarkable since the Rehamna reef complexes were so far not known to range above the middle Givetian.

Fig. 40: Light-grey limestone with *Stringocephalus*-type, very thick-shelled brachiopods (probably Givetian).

Since phillipsastreids are typical for deeper photic biostromes (e.g., Nübel & Becker 2004), mounds and drowned reefs (e.g., Poty & Chevalier 2007), we must assume that the uplifted Mechra Ben Abbou reef was locally and episodically flooded during the upper Frasnian sea level maximum. Therefore, a more intensive sampling campaign has the potential to recover Frasnian conodonts from the breccia unit.

The trepostome bryozoan genus *Dyscritella* is a typical Carboniferous-Permian genus. From the middle to uppermost Famennian, only a few forms have been described (e.g., Tolokonnikova et al. 2014, 2015). The situation is more distinctive for the genus *Rhabdomeson*. There are two

problematical species from the Devonian of China, but it characterizes especially the Viséan to Serpukhovian interval, followed by later Upper Carboniferous to Upper Permian representatives. Since there are no Rehamna outcrops with Famennian limestones, the bryozoan clast can be assigned to the shallow-water limestones of the mostly upper Viséan Bled Mekrach Formation (see, e.g., El Kamel & El Hassani 2006). It proves that the reworking post-dated the upper Viséan and suggests that the uplift occurred during the subsequent main Variscan tectophase, with redeposition in a fast subsiding, early post-orogenic "intramountain" basin, which is the common interpretation for a long time.

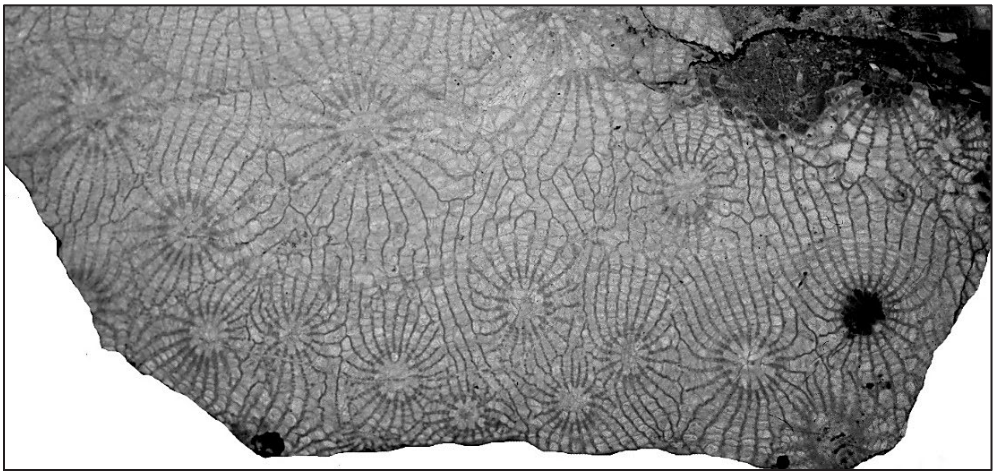

Fig. 41: Thin-section of a Frasnian *Frechastrea* colony (*Fr. pentagona* Goldfuss, 1826, GMM B2C.57.2) embedded in dark-grey bioclastic limestone and reworked in the Koudiat ed Diab breccia.

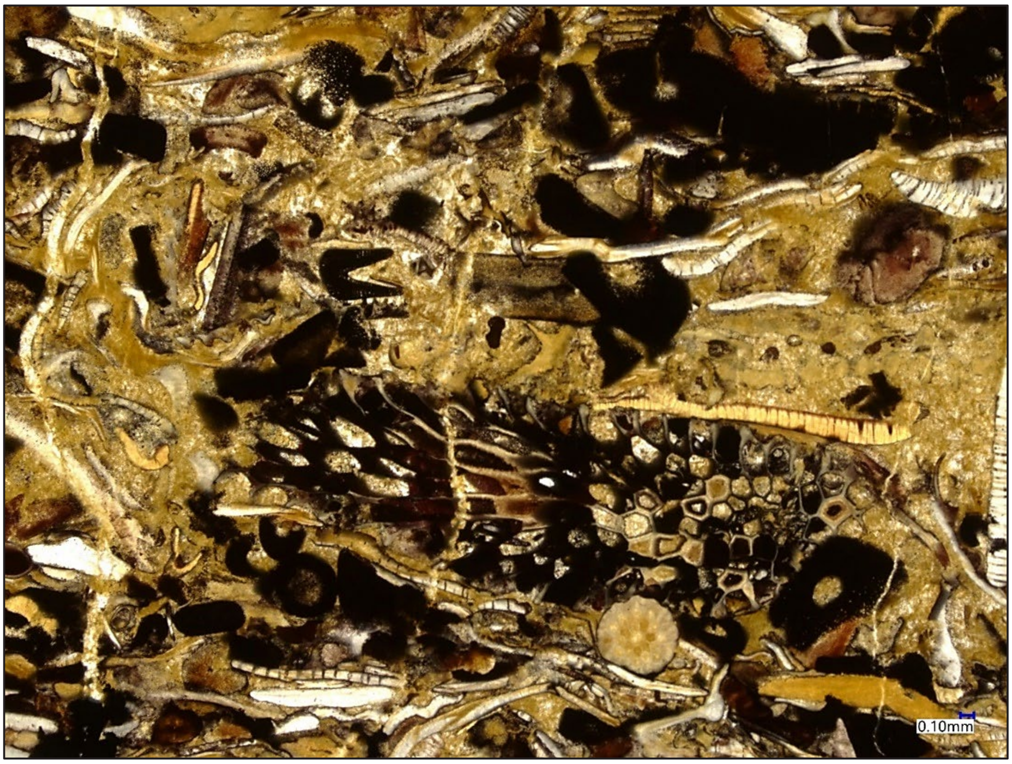

Fig. 42: Thin-section of a strongly iron impregnated rudstone with thick-shelled, punctate brachiopod fragments, the trepostome *Dyscritella* (large branch in the lower half) and the cryptostome *Rhabdomeson* (small circular cross-section just below).

9. Regional facies development of northern Rehamna Devonian

The top-Silurian is known from pelagic, black scyphocrinitid-orthocone facies in the north (Koudiat ed Diab, HOLLARD et al. 1982) and mixed neritic-pelagic limestones with graptolites and orthocones in the southeast (Formation D of EL KAMEL & EL HASSANI 1992). The Lochkovian/Pragian of the northeastern Rehamna belonged to a mixed carbonatic-siliciclastic neritic, open, subtidal but storm-influenced shelf. It continued the palaeogeographic setting of Oued Cherrat to Benahmed regions in the north. In the southeast (Sakhrat et Taïra), the Lochkovian was affected by strong synsedimentary block faulting, creating a shelf basin with slumping, gravitational movement of olistolite blocks, and turbidite shedding. Therefore, there was some transition towards the pelagic outer shelf setting of the Jebilet further to the SE. This trend suggests a western source of silt/ sand (Imfout Ridge, e.g., BEN BOUZIANE 1995).

During the Emsian, the clastic influx decreased gradually. In the Foum el Mejez region, a shallow-water carbonate ramp was established in the lower Emsian. Due to regression, there was a peak development in the upper Emsian (Middle Member of Oued Kibane Formation). The deepening of the global Daleje Event left regionally no clear sedimentary signature, which is also true for the Jebilet (see following chapter, this volume). In the upper Emsian neritic brachiopod-trilobite facies prevailed throughout the study region, differentiated by synsedimentary tectonism at Foum el Mejez. The latter supports the view that the graben structure had an early structural origin.

The Eifelian Choteĉ and Kačák Events have also not yet been recognized regionally, which is typical for neritic facies, where detailed bed-by-bed facies, faunal and geochemical studies are required to detect them (e.g., BROCKE et al. 2016; KÖNIGSHOF et al. 2016). Such high-resolution studies are still to be conducted in the Mechra Ben Abbou, Ouled Barka, and Sidi Abdallah regions. Nodular bedding and sponge blooms indicate a minor deepening in the top-Eifelian.

The overall Givetian regression and the severed siliciclastic influx enabled the establishment of a wide reef platform, with subsidence fully compensated by fast bioherm growth. Wide-spread reef breccias document recurrent seismic events, which appear to have started earlier than in the Oued Cherrat-Al Attamna-Mdakra regions (EICHHOLT & BECKER 2016; BECKER et al. 2020a) to the north, where they characterize the upper middle Givetian to basal Frasnian interval. There was non-deposition in the uplifted Foum el Mejez area. Block tilting terminated eventually everywhere in the Rehamna reef growths, leading to current-controlled non-deposition, karstification, and stromatolite encrustation. Based on Frasnian colonial rugose corals (in the post-orogenic Koudiat ed Diab breccia), small reef patches must have formed locally during the upper Frasnian eustatic high.

There are no Frasnian sections in the Rehamna and nothing is known about regional effects of the Frasnian-Famennian boundary events. However, synsedimentary faulting created at Foum el Mejez a narrow and shallow shelf basin that received in the lower to upper Famennian fine prodeltaic detritus from the west (Oued Ater Member). It gradually filled up the basin, so that delta lobes of the quartzitic Douar Nahilat Formation prograded to the area in the uppermost Famennian (Dalaa Member). Some of the tilted Givetian reef blocks formed shoals and island with steep slopes, where mixed quartzite-reef limestone breccias formed by rockfall. The Devonian-Carboniferous boundary interval has not yet been sufficiently studied.

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