The Devonian and Viséan transgression in the Eastern Jebilet (Moroccan Meseta) – review and new data

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Fig. 1: Lower Devonian succession of Section Jaïdet West (western limb of anticline) with Stephan EICHHOLT for scale in the foreground. Silurian/Lochkovian black shales of the (new) Jebel Smaha Formation at the base are followed by folded and slumped, upper Lochkovian to Emsian yellowish nodular limestones of the (new) Jaïdet Formation reaching the hill crest.

Abstract. Based on new field work, sampling for conodonts, ammonoids, and microfacies analysis, the allochthonous Lower/Middle Devonian stratigraphy and facies history of the Eastern Jebilet NNE of Marrakech is revised and refined. Silurian to Pragian partly siliceous black shales are assigned to the new Jebel Smaha Formation, which yielded HUVELIN (1977) in its upper part graptolites of very different age (lower/middle Lochkovian in the W, up to the upper Pragian in the E). In the Jaïdet region, upper Lochkovian to upper Emsian nodular limestones with deep neritic to pelagic faunas form the new Jaïdet Formation, which deposited in an outer shelf setting. In the Middle Devonian, this basin deepened by increased subsidence, resulting in a thick, poorly fossiliferous siltstone succession, initially and locally with hypoxic *Zoophycos-Chondrites* ichnofauna, later with limestone turbidites (new El Kahla Formation). Currently, there is no biostratigraphic proof of Upper Devonian strata in the Eastern Jebilet; the youngest known conodonts fall in the top middle Givetian *ansatus* Zone but the thick upper El Kahla Formation is not dated. With the help of corals, foraminifers, and bryozoans, detrital and microbial coral limestones at the base of the thick carbonate platform at Koudiat Lahmara (Tekzim Formation)

can be dated as upper Viséan (Cf6γ1, upper Asbian). An associated basal conglomerate contains reworked pebbles of an older (lower/middle Viséan) platform. The transgressive oldest allochthonous limestones of the Tekzim Formation correlate probably with goniatite shales of the (par)autochthonous upper Kharrouba Formation, which also record an upper Asbian deepening episode. With shallowing upwards in the top Asbian/Brigantian, the carbonate platform prograded basinwards, leading to local top-Kharrouba inner shelf limestone deposition before the onset of wildflysch conditions.

The allochthonous Lower Devonian of the eastern Jebilet shows significant similarities with the Skoura region at the southern margin of the High Atlas and, slightly less distinctive, with the Azrou-Khenifra Basin in the east. They belonged to the same outer shelf basin but the timing and effects of Eovariscan block movements were regionally different. The Eastern Jebilet source region and Skoura successions experienced major facies changes and synsedimentary tectonic events around the Lower/Middle Devonian transition. Originally, both may have represented different sides of the same tilted block. There were no close palaeogeographic relationships of the Jaïdet source area with the western Jebilet (Jebel Ardouz) or the Rehamna to the north. Only the upper Viséan transgression led to a more uniform palaeogeography characterized by shallow-water carbonate platforms throughout the southern and eastern parts of the Western Meseta.

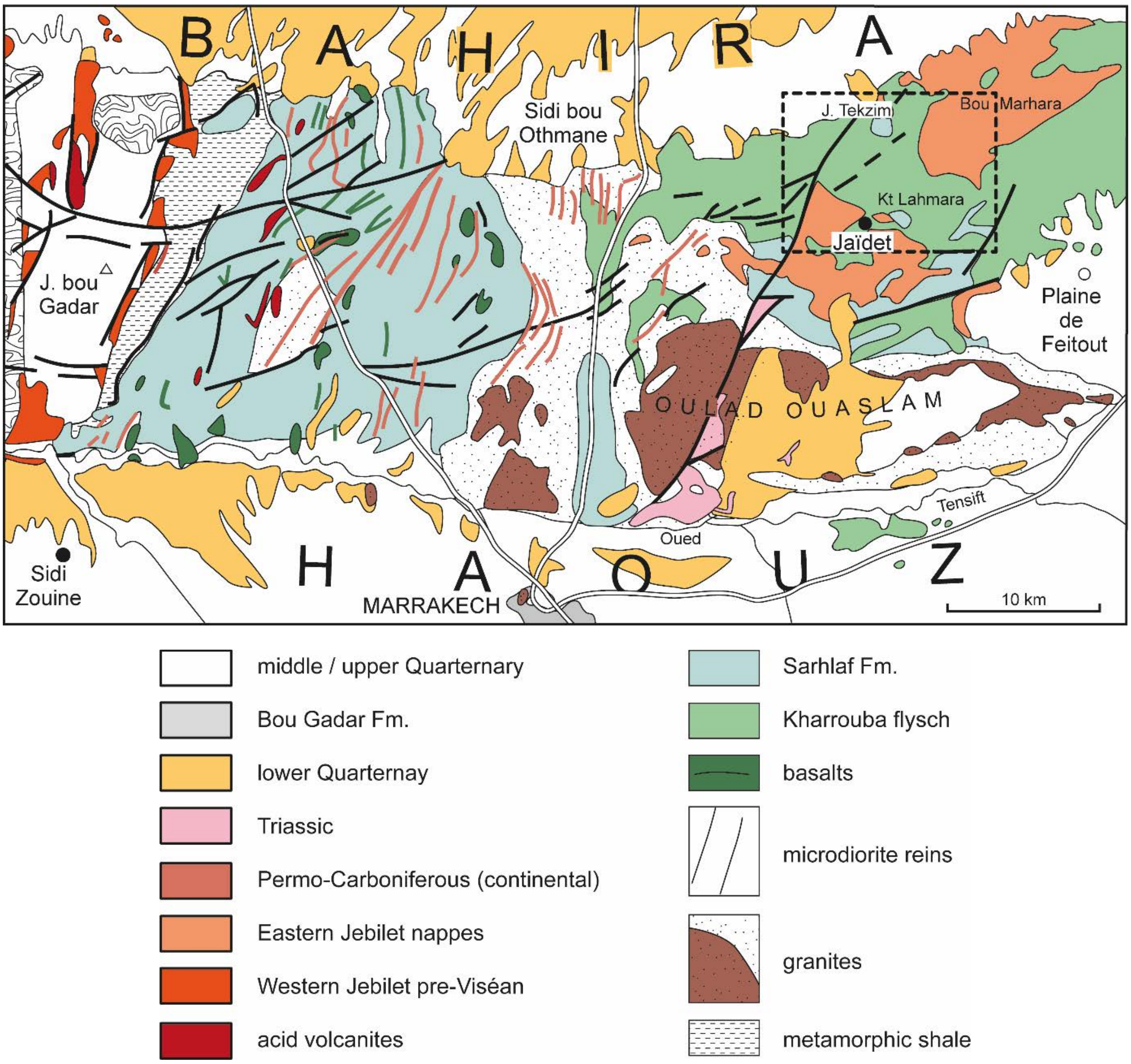


Fig. 2: Simplified geological overview of the central and western part of the Eastern Jebilet showing the position of the study area (rectangular field) SE of Sidi bou Othmane and SSW of the Jebel Tekzim; extracted from the geological map of the Central Jebilet, 1 : 100 000, by HUVELIN (1972).

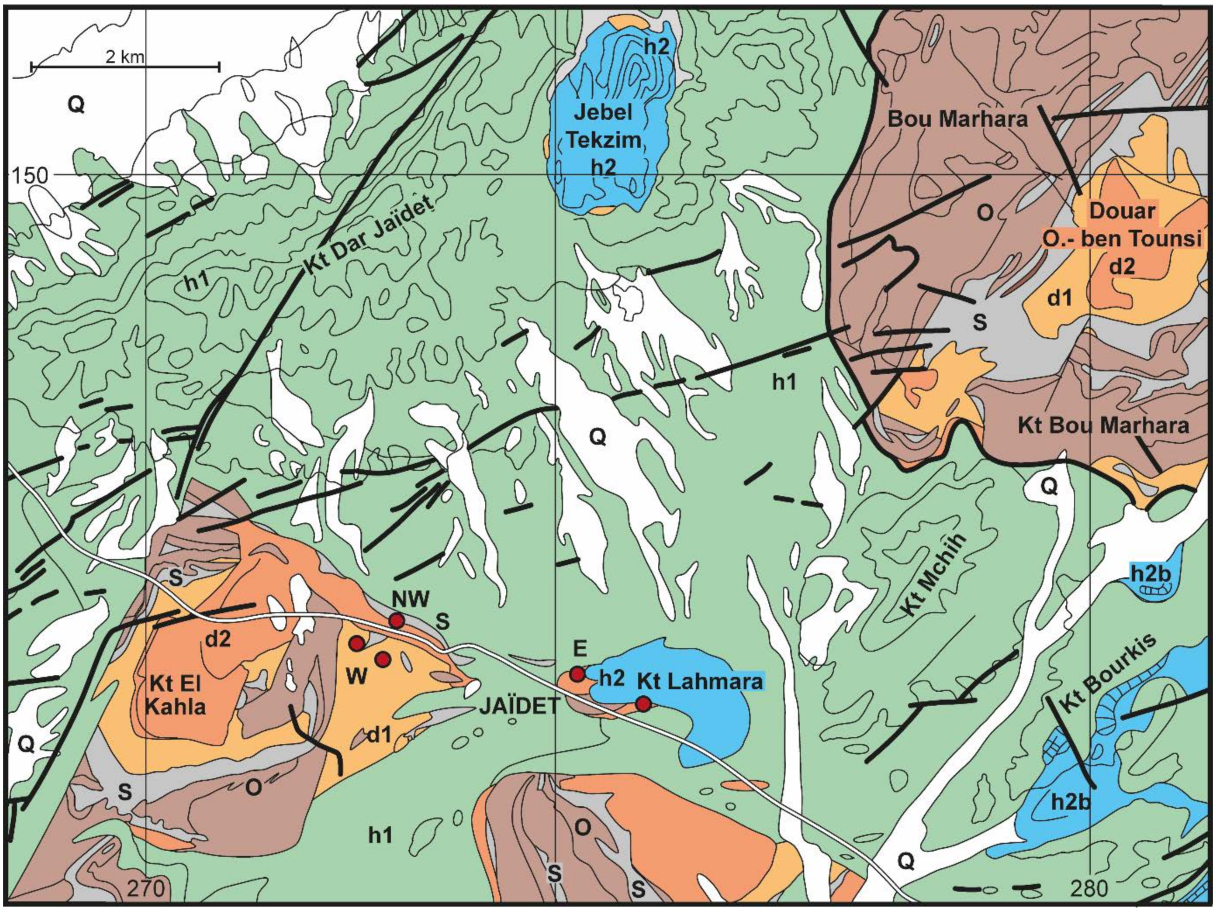


Fig. 3: Position of studied localities (circled red dots) on the simplified geological map of the Jaidet-Jebel Tekzim-Bou Marhara region ESE of Sidi bou Othmane in the Eastern Jebilet. O = Ordovician quartzites, S = Silurian to Lochkovian Jebel Smaha Formation, d1 = Lochkovian to Emsian Jaïdet Formation, d2 = Middle Devonian El Kahla Formation, h1 = Viséan Kharrouba Formation ("Kharrouba Flysch"), h2 = transgressive upper Viséan Tekzim Formation s. str., h2b = regresive shallow-water limestones (Tekzim Fm. s.l.) in the top Kharrouba Formation, Q = Quarternary; re-drawn from a magnified extract of the geological map of the Central Jebilet by P. HUVELIN (1972).

1. Introduction

The Jebilet forms a more than 150 km wide, west-east trending Variscan Massif stretching in the NW to the NE of Marrakech in the southern part of the Western Meseta. The north-south extension of the Palaeozoic belt varies between ca. 20 km (just north of Marrakech) and 45 km (at the western end). The Jebilet is structurally subdivided into western, central, and eastern parts (see HUVELIN 1977) but authors disagree on boundary positions. The Western Jebilet is characterized by Lower Palaeozoic strata overlain unconformably by Upper Carboniferous post-tectonic clastics, the Central Jebilet by the Viséan slate complex of the Sarhlef Series, imbedded massif sulfide deposits and volcanics, and late Variscan granites, and the Eastern Jebilet by the autochthonous Carboniferous Kharrouba Flysch, Viséan carbonates of the Tekzim Formation, nappes with Ordovician-Devonian strata, and a large granite in the south. The lithologically and structurally distinctive Sidi bou Othmane region (Fig. 2) north of Marrakech has been regarded as an eastern part of the Central Jebilet (e.g., EL HASSANI 1980, 1982). By contrast, ESSAIFI et al. (2001, fig. 1, 2003: fig. 1) and DELCHINI et al. (2018) included it in the Eastern Jebilet, using the NNW-SSE trending Marrakech Shear Zone as

the boundary (see map of BEAUCHAMP et al. 1989, fig. 2). There was no continuity of the Palaeozoic of the Jebilet with the High Atlas in the south or with the Rehamna to the north; these regions were separated by block faults.

Moderately deformed and fossiliferous Devonian strata are restricted to nappes in the Eastern Jebilet, especially of the Jebel Tekzim (= Teksim)-Jaïdet-Bou Marhara region 40-45 km NNW of Marrakech (Figs. 2, 3). The Devonian of the Western Jebilet refers mostly to the Jebel Ardouz, which represents a distinctive sedimentary and structural unit (see Jebel Ardouz chapter, this volume). Isolated Devonian olistolites have been reported from the Skhirat Formation in the eastern part of the Western Jebilet (HUVELIN, 1977; TAHIRI 1984; MAYOL 1987). These are poorly described and dated, include the "red conglomerate", and have been compared with the Jebel Ardouz Devonian.

The Devonian succession of the area east of Sidi bou Othmane (typical Eastern Jebilet) was described in the monograph by HUVELIN (1977). In the subsequent more than 30 years, no data concerning its biostratigraphy, sedimentology, and faunal content have been added, whilst there was very active research on the Jebilet structural geology, magmatism, and metamorphism. We conducted new field work in the Jaïdet area (Fig. 3) in spring 2012 and 2017, including bed-by-bed logging, sampling for conodonts, ammonoids, associated fauna, and for carbonate microfacies. This was extended to the basal beds of the unconformably overlying Lower Carboniferous at Koudiat Lahmara ca. 1 km east of Jaïdet (Fig. 3). This section was previously studied by HOLLARD et al. (1977) and ANDRÉ (1986) but we attempted to refine the nature and age of the local Carboniferous transgression. We did not re-investigate the subsequent main upper Viséen carbonate platform succession nor laterally the siliciclastic Kharrouba Flysch or the "Schistes du Sarhlef" of the Central Jebilet.

2. Research History of the Eastern Jebilet

RUSSO (1917): Discovery of allochthonous Lower Devonian strata north of the Jebel Tekzim based on brachiopods and bivalves.

TERMIER (1942): Recognition of the upper Viséan with foraminifers (including *Climacammina*) at the Jebel Tekzim.

ROCH (1950): References to the RUSSO and TERMIER faunas from the Jebel Tekzim.

PERMINGEAT (1951): New data on the Jebilet Viséan and recognition of Pragian pelagic facies with orthoconic cephalopods and dacryoconarids (identified by G. & H. TERMIER) at Koudiat-er-Reïet (near Koudiat Lahmara) and Sidi Daoud (ca. 3.5 km west of Jaïdet).

PERMINGEAT (1954): Note on the shallow-water Viséan in the south of the Eastern Jebilet (Jebel Oulad Abid south of the Oued Tensift).

HUVELIN (1967): Initial study on the Jebilet nappe movements.

HUVELIN (1972): Geological map of the Jebilet.

HUVELIN (1977): Monograph on the geology, mineralogy, magmatism, mineral deposits, and tectonics of the Jebilet.

HOLLARD et al. (1977): Viséan stratigraphy and discussion of the age of nappe movements; with detailed macro- and microfauna lists for shales of the Kharrouba Formation (*Goniatites crenistria, Posidonia becheri*), limestones of the Tekzim Formation (Jebel Tekzim, Koudiat Lahmara, Douar Oulad ben Tounsi, Bou Marhara), limestones at the top of the Kharrouba Formation (Koudiat Bourkis), and the shallow-water Viséan of the Jebel Oulad Abid in the south.

BORDONARO et al. (1979): Comparison of the sedimentary history of the Jebilet with the Huelva Basin of southern Spain.

GAILLET (1979): Discussion of the correlation between the Central Jebilet Sarhlef Series and Eastern Jebilet Kharrouba Flysch, recognizing structurally overlying Viséen carbonates as new Tekzim Formation.

EL HASSANI (1980, 1982): Thesis and publication on the mapping, lithostratigraphy, with refined formation terminology, and tectonics of the Sidi Bou Othmane region between the typical Central and Eastern Jebilet successions.

PIQUE (1981): Placing the Eastern Jebilet as a southwestern extension of the Variscan Azrou-Khenifra belt into his "Meseta centre-orientale".

GAILLET & BORDONARO (1981): Structural geology of the Central Jebilet (including the western part of the re-defined Eastern Jebilet).

ZARHAOUI (1981): Unpublished thesis on the stratigraphy and nappes of the Jebel Tekzim area.

EL HASSANI & ZAHRAOUI (1982): Note on the tectonic transport of Ordovician to Devonian onto Carboniferous substratum before the major phase of Variscan deformation and metamorphism.

GRAHAM (1982a): Sedimentological analysis of the more than 2.000 m thick, shallowing upwards upper Viséan Kharrouba Flysch between Koudiat Mchich and Koudiat Bourkis east of Koudiat Lahmara (for location see Fig. 3).

GRAHAM (1982b): Sedimentology of the shallow-water upper Viséan at Jebel Oulad Abid in the south of the Eastern Jebilet.

BEAUCHAMP (1984): Stratigraphic and sedimentological analysis of the Kharrouba Flysch succession at Mourhar el Beida west of the Jaïdet region, and comparisons with the High Atlas Viséan.

BEAUCHAMP & CORTINAT (1985): Sedimentology of shallow-water sandstones and calcarenites in the southern part of the Eastern Jebilet.

ANDRÉ (1986): Sedimentology of the mixed carbonate-siliciclastic to reefal upper Viséan at Koudiat Lahmara.

BEAUCHAMP & IZART (1987): Common tectono-sedimentary model for Lower Carboniferous basins of the Meseta, including the Jebilet.

TOURANI & BEAUCHAMP (1987): Sedimentology of the Carboniferous flysch of the Central Jebilet.

OUKEMENI (1987): Unpublished thesis on the Carboniferous nappes of the Eastern Jebilet.

ESSEMANI (1988): Unpublished thesis on the sedimentology of the Carboniferous of the Eastern Jebilet.

NOUIDAR (1988): Unpublished thesis on sedimentology and tectonics of the Viséan platform limestones of the Jebel Tekzim.

VACHARD (1988): New Viséan foraminifer data for the Kharrouba Flysch.

BAMOUMEN (1988): Unpublished thesis on the deformation of the nappes of the Central and Eastern Jebilet.

BEAUCHAMP et al. (1989): Analyses of the gravity-induced upper Viséan sedimentation of the Jebilet, from turbidites and debris flows of the extensional Eovariscan interval to olistostromes and klippen/nappe movements of the compressional main Variscan stage.

IZART et al. (1997): Sequence and biostratigraphy of the Lower Carboniferous of the Eastern and Central Jebilet and correlations with the contemporaneous High Atlas successions.

EL HASSANI & BENFRIKA (1995, 2000): Summary of the Jebilet Devonian.

BAMOUMEN et al. (2008): Comparison of the upper Viséan of the Jebilet and Azrou-

Khenifra Basin based on the tecto-sedimentary and magmatic evolution.

YAHYAOUI & ESSAIFI (2011): Excursion guidebook showing the Devonian nappe at Jaïdet and mass flow breccias.

IZART et al. (2017): New summary of the Viséan basin of the Jebilet to High Atlas.

DELCHINI et al. (2018): New reconstruction of the Variscan tectono-metamorphic and magmatic evolution of the Jebilet (partly based on stratigraphic assumptions that have no factual base and neglecting some previously published details concerning the Devonian/Carboniferous contacts and Viséan biostratigraphic ages).

ARIBA (2019): M.Sc. Thesis on the structural geology and metamorphism of the Sidi bou Othmane region.

CÓZAR et al. (2020a): Discussion of previously published Viséan ages for Central and Eastern Jebilet strata, commenting on the foraminifer data of ESSAMANI (1988) and IZART et al. (1997, 2017), and on interpretations by DELCHINI et al. (2018).

3. Geological overview of the Eastern Jebilet

The Eastern Jebilet is dominated by the Lower Carboniferous Kharrouba Flysch, which shows a shallowing upwards trend from a turbidite-rich siliciclastic lower-middle succession to shallow-water sandstones and cross-bedded bioclastic limestones in the upper part (e.g., GRAHAM 1982a; BEAUCHAMP 1984; IZART et al., 1997; BEAUCHAMP et al. 1989). The sediment transport direction was to the northwest, indicating a NE-SW trending shoreline in the area SE of the Jebilet, where there is no Palaeozoic surface outcrop. An overlying widespread olistostrome complex, e.g., of the Jebel Kharrouba (BEAUCHAMP et al. 1989), marks a change of the tectono-sedimentary regime high in the upper Viséan (e.g., BEAUCHAMP & IZART 1987). This culminated in the movement of klippen and glide nappes consisting mostly of Ordovician to Middle Devonian strata. This interpretation is fully supported by the irregular and angular contact between Ordovician/Devonian blocks and the underlying Kharrouba Formation (HUVELIN 1972; Fig. 3). The allochthonous Lower/Middle Palaeozoic was originally deposited in the east/southeast but the transport distance is not known. Synsedimentary facies and structural relationships with Silurian/Devonian outcrops further to the southeast (Skoura region at the southern foot of the High Atlas) and east (Azrou-Khenifra Basin; see PIQUE 1981; BAMOUMEN et al. 2008) will be discussed later. Based on the youngest known foraminifers from the olisthostrome at the top of the Kharrouba Formation (Cf6δ/Cf7; IZART et al. 1997), tectonic uplift in the source region, leading to basin slope steepening and gravitational transport, probably occurred in the higher Serpukhovian. However, true Cf7 (Namurian) foraminiferes have not been documented from the region. In any case, the klippen and nappe movements occurred before the onset of the main Variscan deformation and metamorphism (EL HASSANI & ZAHRAOUI 1982). BEAUCHAMP et al. (1989) ascribed this interval to the onset of a compressional stage.

The sedimentary and structural relationships between the single basin of the Kharrouba Flysch and westwards lying, more than 1.000 m thick Sarhlef Series (e.g., BORDONARO et al. 1979; GAILLET 1979; BEAUCHAMP & IZART 1987; BEAUCHAMP et al. 1989), and the shallow-water to reefal limestones of the Tekzim Formation are controversial. In the eastern Jebilet, it is important to recognize Viséan limestones that occur in different tectonic and sequence stratigraphic contexts, as discussed by HUVELIN (1977) and HOLLARD et al. (1977).

Later, GAILLET (1979), GAILLET & BORDONARO (1981) and DELCHINI et al. (2018) assumed that a widespread mixed clastic-calcareous Tekzim Formation overlies in general the Kharrouba Formation and Sarhlef Series, which include both strata of upper Viséan (Asbian) age (HUVELIN 1961, 1977; HOLLARD et al. 1977; IZART et al. 1997; PLAYFORD et al. 2008). However, the typical Tekzim Formation (e.g., Jebel Tekzim, Koudiat Lahmara, Bou Marhara) occurs at least partly in unconformable and transgressive but not necessarily tectonic contact with the underlying Devonian. Especially important is a locality 1.5 km ESE of Douar Oulad-ben-Tounsi, where HOLLARD et al. (1977) proved that upper Viséan sandy and bioclastic limestones eroded directly into Lower Devonian griotte limestones, resulting in reworked Devonian clasts swimming in the Viséan calcarenite matrix. This evidence suggests to keep a distinction between allochthonous carbonates of the type Tekzim Formation, which transgressed the Devonian and which were obviously part of klippen/nappes, and the (par)autochthonous shallow-water limestones that deposited during regression in the upper part of the Kharrouba Flysch (e.g., GRAHAM 1982a: Koudiat Bourkis, Unit 8). The latter limestones were dated by IZART et al. (1997: Koudiat Mchih = ca. Koudiat Bourkis and Koudiat Kouchina in the east) as Cf6γ (= V3bγ = ca. lower Zone 16i = top MFZ 13 to lower MFZ 14 sensu POTY et al. 2006, upper Asbian; see correlation charts of HERBIG 2006, fig. 4, and CÓZAR et al. 2020a, fig. 1). The same age is known from some limestones embedded in the Sarhlef Series (VACHARD in ZAIM 1990; quoted in BEAUCHAMP et al. 1989) whilst others unexpectedly proved to be of Upper Devonian age (LAZREQ et al. 2021). Metamorphosed limestones embedded in the Sidi bou Othmane Formation (EL HASSANI 1980, 1982; ARIKA 2019) have not yet been dated biostratigraphically. In this wider context, new data for the transgression at the base of the thick Tekzim Formation at Koudiat Lahmara (see ANDRÉ 1986) were hoped to shed further light on the age relationships between the different Viséan limestone occurrences.

4. Devonian sedimentary and faunal succession

HUVELIN (1977) outlined the principle Devonian litho- and biostratigraphy of the Eastern Jebilet but our data provide further precision, especially since the conodont and ammonoid scales and chronostratigraphy developed significantly in the meantime. Previous records of graptolites, brachiopods, and trilobites have to be re-evaluated. Also, no formal lithostratigraphic units were proposed originally. HUVELIN (1977) showed lateral variability of facies and faunas from west to east in the Eastern Jebilet. Different successions than at Jaïdet were described from Bou Marhara and Douar Oulad-ben-Tounsi (ca. 8 km NE of Jaïdet, Fig. 3), the Jebel Smaha at the NE end of the Eastern Jebilet (SW of El Kelâa des Srarhna), and from Douar Abichat (ca. 11 km S of El Kelâa des Srarhna). The increasingly shaly facies towards the east suggests that allochthonous blocks representing shallower settings were transported farthest to the west. Neritic faunas listed by RUSSO (1917) from the Jebel Tekzim underline an Emsian facies differentiation in the source region. The new lithostratigraphic terminology for the Jaidet region follows HUVELIN´s “Termes inférieur, moyens and supérieur”. A revised stratigraphic model for the wider regional correlation, updating HUVELIN (1977, figs. 17-18), is depicted in Fig. 4.

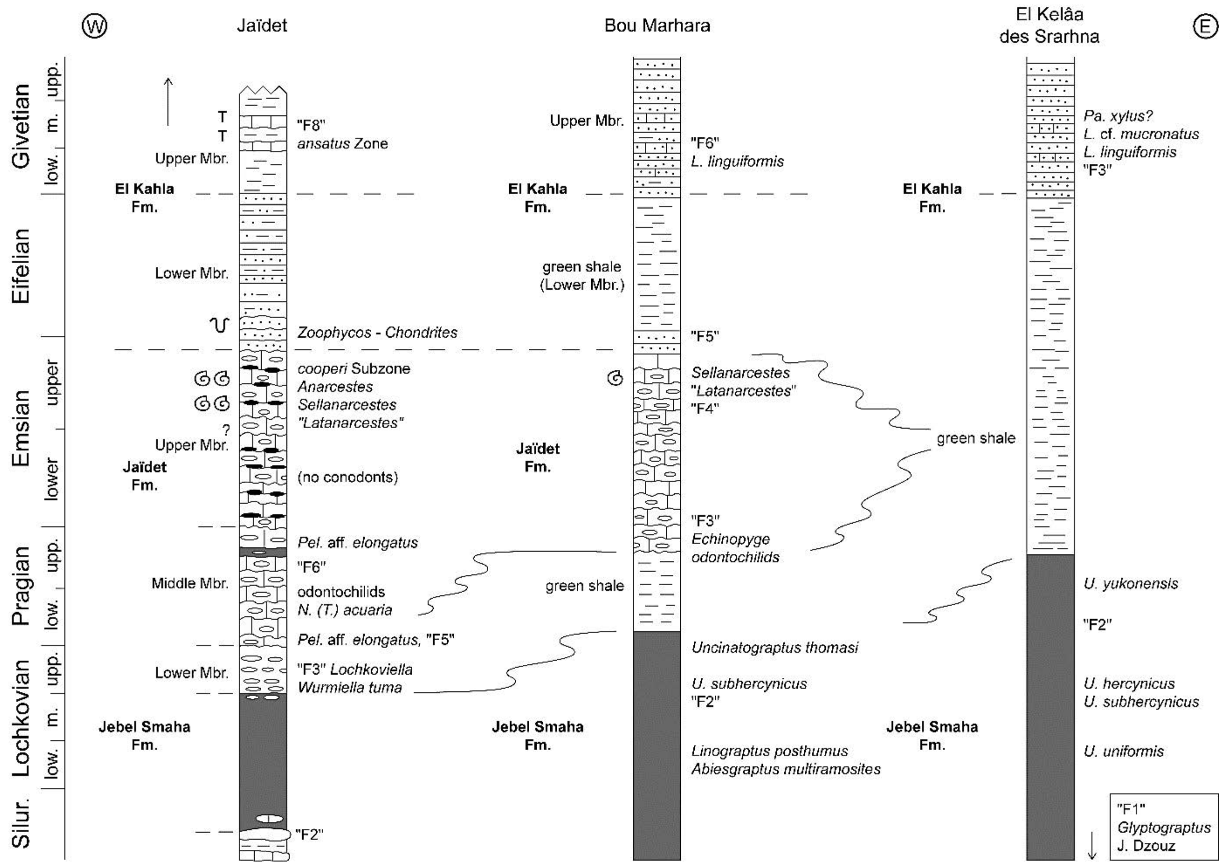


Fig. 4: New model for the litho-, bio- and chronostratigraphic correlation of the Silurian-Devonian of the Eastern Jebilet, based on HUVELIN (1977), a re-evaluation of his faunas, and on our new data. Vertical scale against chronostratigraphy, not against thicknesses.

The Lower/Middle Devonian is best exposed on the two limbs of an anticline with roughly northeast-southwest trending axis at ca. 1.2 km WNW of Jaïdet, just south of the main road (Figs. 1, 3), here called Section Jaïdet West (compare HUVELIN 1977: p. 42 and summary fig. 17, also YAHYAOUI & ESSAIFI 2011, figs. 3A-B). GPS coordinates are N31°52´39.1´´, W7°48´19.7´´. The succession is the type-locality of two new lithostratigraphic units, the top-Lochkovian to Emsian Jaïdet Formation (with three informal members) and the Middle Devonian El Kahla Formation (with two members).

4.1. Jebel Smaha Formation (Silurian to Lochkovian/Pragian)

A package of poorly fossiliferous black shales forms in Section Jaïdet West a wide depression and the core of the anticline, as a case of relief inversion. The exposed part has a thickness of more than 10 m (Fig. 1). In the upper part, there is the transitional, ca. 50 cm thick Bed 1, composed of calcareous, organic-rich black shale with numerous limestone nodules (Fig. 5).

The black shale of Section Jaïdet West belongs to HUVELIN´s "Termes inférieur" and can be interpreted as an upper tongue of his more widespread "Phtanites et schistes à Graptolithes", For this unit, the new term Jebel Smaha Formation is based on the Jebel Smaha succession SW of El Kelâa des Srarhna, ca. 33 km NE of Jaïdet. HUVELIN (1977, 45-46, figs. 15, 18B) described for this locality 100-120 m of partly siliceous bluish to black shales with graptolites that overly Upper Ordovician quartzites.

Fig. 5: Boundary between the black shales of the Jebel Smaha Formation and the brownish weathering basal Jaïdet Formation (top of photo) formed by the transitional Bed 1 (at the hammer) with numerous limestone nodules sitting in black calcareous shale matrix (partly covered by nodule debris).

The age of the Jebel Smaha Formation appears to be strongly diachronous from west to east (Fig. 4). In the Jaïdet region, it is apparently underlain (no direct contact described) by upper Silurian sandy shales and alternating bioclastic limestones with large-sized orthocones and bivalves (*Vlasta, Cardiola*; det C. Babin in Huvelin 1977; his "F2" from Jaïdet). Slightly to the west, at Koudiat El Kahla, Huvelin (1977, p. 43) mentions a lower Ludlow graptolite fauna from possibly contemporaneous green shales. The upper range of the Jebel Smaha Formation in the Jaïdet region is constrained by the upper Lochkovian age of the overlying basal Jaïdet Formation (see below).

In the Bou Marhara Syncline NE of Jaïdet (Fig. 3), the upper part of the Jebel Smaha Formation yielded graptolites that could represent three successive levels (Huvelin 1977, fig. 18A, "F2" from Bou Marhara). *Abiesgraptus* and *Linograptus* are genera that do not range above the middle Lochkovian *Uncinatograptus praehercynicus* Zone (e.g., Jaeger 1978), while *U. subhercynicus* is typical for the middle/early upper Lochkovian (not top Lochkovian) *U. hercynicus* Zone (see also Jaeger 1989). Finally, *U. thomasi* is a lower Pragian index species. The combined evidence suggests a younger range of the Jebel Smaha Formation than at Jaïdet. However, it should be stressed that the Jebilet graptolites have not been properly described or figured, and a revision would be important.

For the El Kelâa des Srarhna region, Huvelin´s graptolite data suggest an even longer range of the Jebel Smaha Formation. The lower part yielded at Douar Abichat a lower Silurian assemblage (middle/upper Llandovery, fig. 18B, "F1"). The upper part at the Jebel Smaha produced *Uncinatograptus uniformis*, the basal Lochkovian index species. However, other monograptids from the same "F2" (see his fig. 18B) signal a much younger age. *Uncinatograptus subhercynicus* and *U. hercynicus* fall in the middle to early upper Lochkovian *hercynicus* Zone (see zonal review of Jaeger 1989). The record of *U. yukonensis*, if identified correctly, even suggests an upper Pragian age (Lenz 1989), contemporaneous with conodonts faunas from the Lower/Middle Members of the Jaïdet Formation to the west (see below). Until the Eastern Jebilet graptolites are revised, a strong diachroneity of the Eastern Jebilet graptolite shales is the most likely interpretation. It has to be stressed that the Jaïdet Formation is missing from the northeastern part of the Eastern Jebilet and its interval could be well represented by different facies. Other easternmost Jebilet localities (section Rass-el-Kebir/Jebel Dzouz) contain also a different Lower Silurian facies, sandstones and white to rose graptolite shales with a lower Llandovery *Glyptograptus* fauna ("F1" of Huvelin´s fig 18B).

4.2. Jaïdet Formation (upper Lochkovian to upper Emsian)

The base of the new Jaïdet Formation is marked in Section Jaïdet West, at the base of Bed 2 (Figs. 6-7), by the onset of brownish

weathering nodular shales. The argillaceous matrix of the limestone nodules is light-grey; the organic-rich black facies ended sharply. The formation can be subdivided lithologically into three members.

4.2.1. Lower Member

The Lower Member comprises thin-bedded and strongly weathering nodular shales (Beds 2-10) and is locally ca. 4.5 m thick. It correlates with HUVELIN´s "Schistes et calcaires à Trilobites". Characteristic is a macrofauna of orthoconic cephalopods, bivalves typical for pelagic facies (*Panenka*), and trilobites (see HUVELIN´s "F3-4" in fig. 17). Bed 2 yielded a small conodont fauna with *Belodella resima* (Fig. 8.1; dominant, > 50 % of the assemblage), *Wurmiella wurmi* (Fig. 8.2-3), *W. tuma* (Fig. 8.4-5), and *Panderodus* sp. (Fig. 8.6, 23.5 % of the assemblage). The locally common single cone genera *Belodella* and *Panderodus* are not helpful for biostratigraphy. *Wurmiella wurmi* is long-ranging in the Lochkovian (e.g., VALENZUELA-RÍOS et al. 2015) but survived into the lower Pragian (e.g., WEDDIGE 1987; SLAVÍK & HLADIL 2004). *Wurmiella tuma* enters in the middle Lochkovian (e.g., MURPHY et al. 2004) and disappears at the Lochkovian-Pragian boundary in South China (WANG et al. 2018; compare top-Lochkovian range in CORRADINI & CORRIGA 2012) but cf. specimens were recorded from the basal Pragian of Bohemia (SLAVÍK et al. 2012).

Locally, a relative sea level fall ended gradually the black shale deposition by increased bottom turbulence and ventilation. This is supported by the microfacies of Bed 2 (Fig. 9.1), a bioturbated, flaser-bedded, recrystallized (microsparitic) bioclastic wackestone with poorly preserved dacryoconarids (probably nowakiids) lacking any orientation, ostracods, rare mollusk shells, and small to large idiomorphic pyrite cubes. It indicates calm deposition on a deep, subphotic outer shelf carbonate ramp with restricted benthos. The pyrite formed during early diagenesis under hypoxic conditions within the sediment, followed later first by micrite recrystallization, then by weak dolomitization.

HUVELIN (1977) reported three groups of trilobites from the Lower Member of the Jaïdet Formation. His "F3" fauna included harpids ("*Harpes* sp."), phacopids (*Reedops miser,* "*Phacops (?Denckmannites)* sp. C aff. *akouchensis*" sensu ALBERTI 1970), and proetids (*Prodrevermannia rabatensis senior*). *Reedops miser* is the type-species of the upper Lochkovian marker genus *Lochkovella* CHLUPÁČ, 1972, which is common in the Rabat-Tiflet Zone of the northern Western Meseta (ALBERTI 1969, fig. 50, 1970, p. 144). The second phacopid was originally described from the top Lochkovian (*Paranowakia intermedia* Zone) black nodular limestones of the Ben Slimane region (ALBERTI 1970). It was re-named by ALBERTI (1981a) as *Phacops (Reedops?) slimanensis*, re-assigned to the subgenus *Prokops* by ALBERTI (1983), and regarded as a representative of the genus *Boeckops* (or possibly *Prokops*) by BASSE (2012, p. 155). The *Prodrevermannia* is also known from the Ben Slimane upper Lochkovian (ALBERTI 1970).

HUVELIN´s "F4" fauna from the upper part of the Lower Member at Jaïdet included only "*Phacops (Reedops)* sp. A aff. *akouchensis*". This taxon was listed as *Lochkovella* sp. A in CHLUPÁČ (1977) but was re-described as *Phacops (Prokops) benziregensis ezzhiligensis* by ALBERTI (1983), who gave as type-level nodular shales of the Ezzhiliga area of the northern Meseta. The associated *Paranowakia geinitziana* is the index species of the terminal Lochkovian dacryoconarid subzone but the species just straddles the Lochkovian/Pragian boundary (e.g., ALBERTI 1981b, 1995; BECKER et al. 2020a).

In summary, the combined conodont-trilobite evidence places the Lower Member in the upper to uppermost Lochkovian.

Fig. 6: Lower and Middle Members of the Jaïdet Formation (boundary just above the hammer) in the western limb of Section Jaïdet West. The formation base is marked by the sharp color change at the base of Bed 2 in the lower third of the photo.

4.2.2. Middle Member

The Middle Member of the Jaïdet Formation is marked in Section Jaïdet West by a strong decrease of shale content and a change to cliff-forming solid, beige to orange weathering, nodular griotte limestones (Figs. 6, 7, 10). The fresh limestone is much darker (middle- to dark-grey). The clear regressive trend seems to correlate with the eustatic fall at the Lochkovian-Pragian boundary (e.g., CHLUPÁČ & KUKAL 1988; BECKER et al. 2020a). It was named by TALENT et al. (1993) as global "end-*Pesavis* Event" and by WALLISER (1996) as "Lochkovian-Pragian Boundary Event". The Middle Member equals the lower part of HUVELIN´s "Calcaires rognoneux et calcaires griottes à Tentaculites". Macrofauna is sparse in our section but HUVELIN (1977) reported from several localities trilobites and various bivalves (*Panenka, Kralowna, Praecardium, Pterochaenia, Eoplectodonta*). Locally, the bedding is irregular and suggests slumping (Fig. 1), as observed by HUVELIN (1977) in the Bou Marhara Syncline.

A Pragian age is known since the record of its index dacryoconarid, *Nowakia (Turkestanella) acuaria,* by G. & H. TERMIER (in PERMINGEAT 1951). A small new conodont fauna from the base (Bed 7) yielded only a single conodont similar to but not identical with *Pelekysgnathus elongatus*, here identified as *Pel.* aff. *elongatus*. Typical and cf. specimens of *Pel. elongatus* occur in the middle Lochkovian of the Cantabrian Mountains (e.g., GARCÍA-LÓPEZ et al. 2002; VALENZUELA-RÍOS et al. 2015) and in the Barrandian (SLAVÍK et al. 2012). But both conspecific or related (aff.) forms cross the Lochkovian-Pragian boundary in the Anti-Atlas (PLODOSWKI et al. 2000) and in the Armorican Massif of Western France (WEYANT et al. 2010). Therefore, our new Jaïdet specimen does not contradict a basal Pragian age for the basal Middle Member. HUVELIN´s "F5" fauna from this level at Jaïdet included *Odontochile*, which in modern taxonomy could refer to a species of several related genera/subgenera (BUDIL et al. 2009). But none of these enter before the Pragian.

The microfacies of Bed 7 (Fig. 9.2) differs from the basal Lower Member by the lack of microsparitization and a minor increase of benthic fauna. Middle- to dark-grey, partly dolomitized mudstone with rare crinoid debris, a bivalved ostracod and very fine shell debris overlie light- to middle-grey bioclastic wackestone with nowakiids, ostracods, and fine mollusk filaments. The median-sized phragmocone of an orthocone was filled by several generations of light to dark-grey mudstone with rare nowakiids and idiomorphic pyrite. There is a strange, sparite-filled, multichambered, partly biserial microfossil with very thin walls and a pointed tip, resembling a calcareous foraminifer.

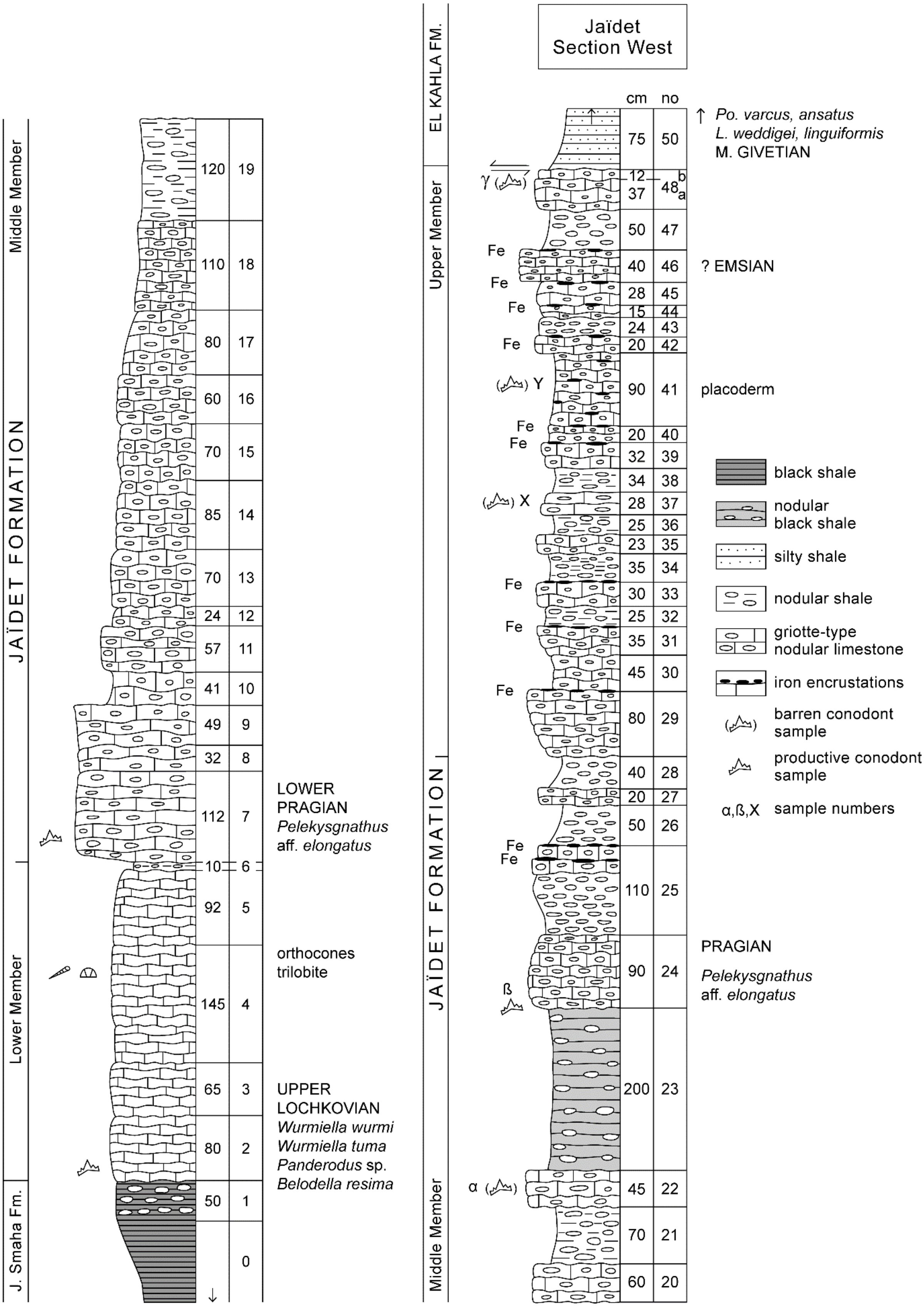


Fig. 7: Lithostratigraphy and position of conodont samples (unproductive levels in brackets) in the Jaïdet Formation of the western limb of Section Jaïdet West.

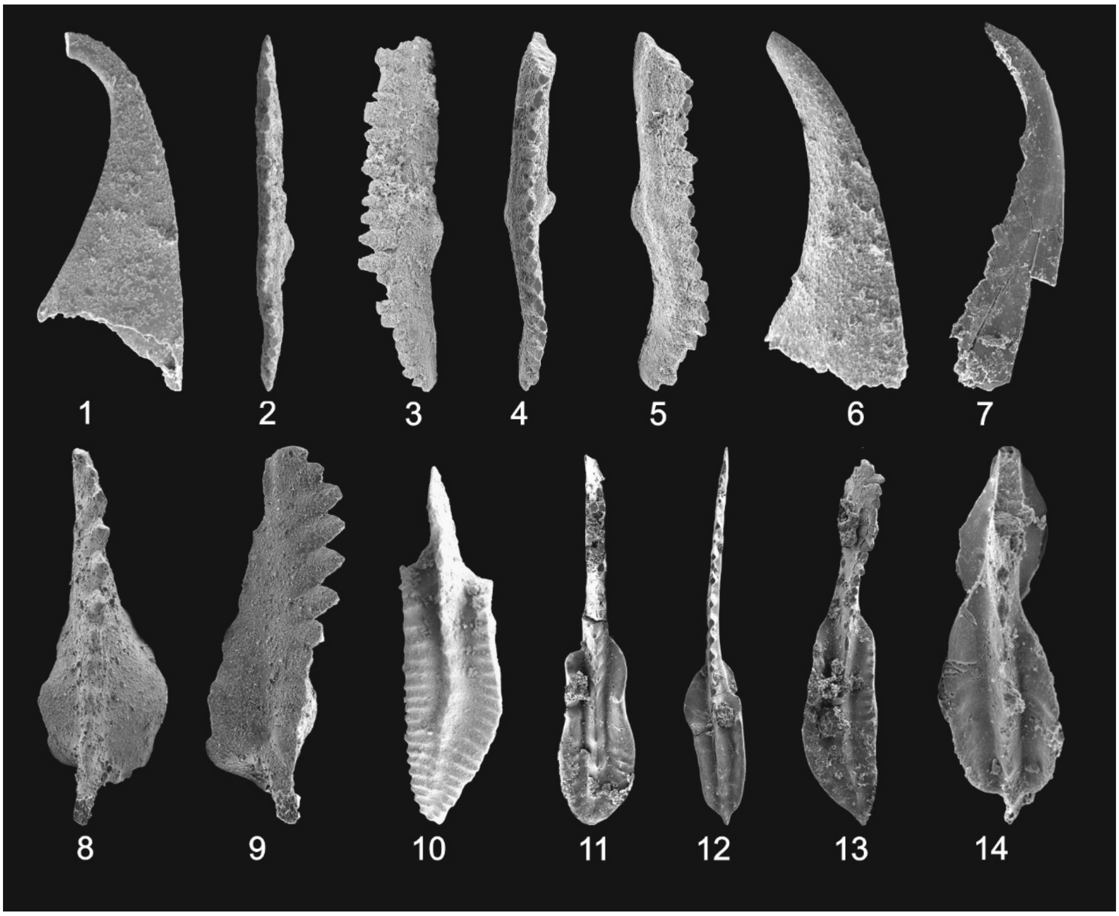


Fig. 8: Lower/Middle Devonian conodonts from the Jaïdet region, 1-6 = base of Lower Member of the Jaïdet Formation (Section Jaïdet West, Bed 2), 8-9 = Middle Member of Jaïdet Formation (Section Jaïdet West, Bed 24), 7 and 11-14 = El Kahla Formation (Section Jaïdet West), 10 = Upper Member of Jaïdet Formation (Section Jaïdet Northwest, main goniatite level); GMM B4C.2.138-148. **1.** and **7.** *Belodella resima*, both x 55; **2-3.** *Wurmiella wurmi*, x 35; **4-5.** *W. tuma*, x 40; **6.** *Panderodus* sp., x 55; **8-9.** *Pelekysgnathus serratus* aff. *elongatus*, x 55; **10.** *Linguipolygnathus cooperi cooperi*, x 30; **11.** *Po. ansatus,* x 55; **12.** *Po. timorensis*, x 55; **13.** *Po. xylus*, x 55; **14**. *Polygnathus varcus*, x 65.

Fig. 9: Microfacies of Section Jaïdet West (western limb). **1.** Bed 2, basal Jaïdet Formation: light-grey, bioturbated, flaser-bedded, microsparitic, slightly dolomitic, bioclastic wackestone with poorly preserved dacryoconarids, ostracods, and small to large idiomorphic pyrite cubes; **2.** Bed 7, basal Middle Member of Jaïdet Formation: middle-grey bioclastic wackestone with nowakiids, ostracodes, and mollusk filaments overlain by dolomitized mudstone with rare crinoid fragments, which also fills an orthocone (upper part) that includes a serially multichambered, sparitic microfossil and pyrite cubes; **3.** Bed 24, upper part of Middle Member: brownish-grey, flaser-bedded and bioturbated wackestone with abundant nowakiids, two-shelled ostracods, mollusk and crinoid debris, and channels of nowakiid packstone; **4.** Bed 37, Upper Member: light-grey, micritic, bioturbated nowakiid wacke- to packstone with a few bivalved ostracods, mollusk filaments, and crinoid ossicles; **5.** Bed 41, Upper Member: massive placoderm bone floating in a flaser-bedded, light- to middle-grey, bioturbated mud-wackestone with mollusk debris and pyrite; **6.** Top of Upper Member: bioturbated nowakiid wacke-packstone with middle- or dark-grey micrite matrix, small orthocones, and partially subparallel orientation of dacryoconarids (lower right corner); **7.** Lower El Kahla Formation: monotonous, bioturbated, light-grey, unfossiliferous, well-sorted siltstone with idiomorphic pyrite; **8.** Upper El Kahla Formation: laminated to cross-bedded, unfossiliferous, silty mudstone.

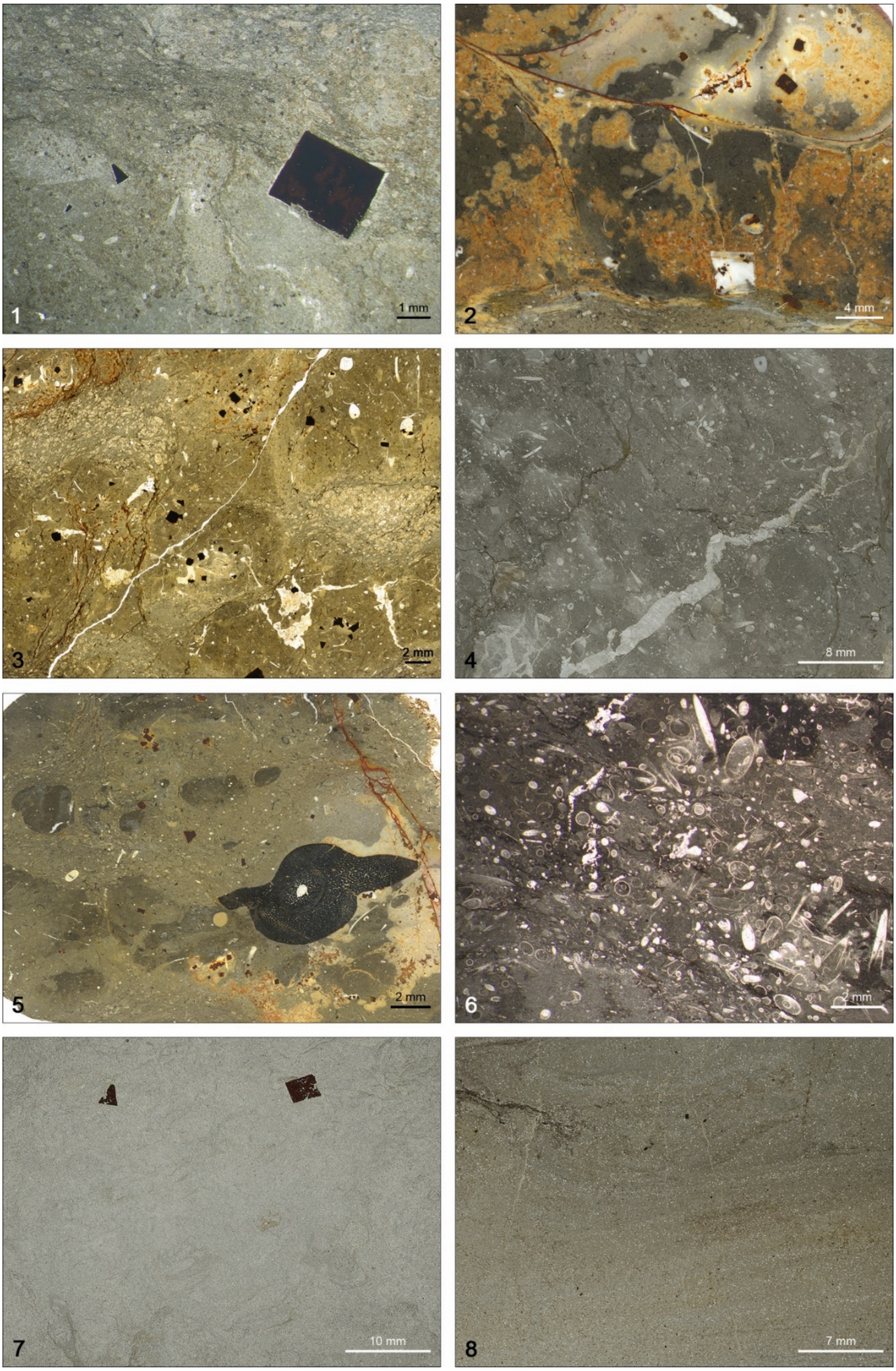

1
1 mm
2
4 mm
3
2 mm
4
8 mm
5
2 mm
6
2 mm
7
10 mm
8
7 mm

Fig. 10: Solid, cliff-forming, orange to beige weathering griotte limestones of the Middle Member of the Jaïdet Formation (Pragian), western limb of Section Jaïdet West, with a hammer and A. EL HASSANI for scale, and the main road in the distance behind him.

In the Bou Marhara succession to the NE, HUVELIN (1977) noted a ca. 50 m thick green shale package with bivalves between the Jebel Smaha and Jaïdet Formations. Based on the local record of a lower Pragian graptolite in the upper Jebel Smaha Formation (*U. thomasi*; see discussion above), the solid, rather condensed nature of the overlying Bou Marhara griotte, with an upper Pragian trilobite record (see below), the best interpretation is that the green shale unit correlates with the lower part of the Middle Member of the Jaïdet Formation of Section Jaïdet West (Fig. 4). It is important that the Jaïdet Formation is currently unknown from the El Kelâa des Srarhna region of the northeastern part of the eastern Jebilet (see HUVELIN 1977).

In the higher part of the Middle Member at Section Jaïdet West, several intervals of grey nodular shale (e.g., Beds 19 and 21) are intercalated. These indicate minor deepening episodes. Especially distinctive is a ca. 2 m thick dark-grey shale with only few limestone nodules (Bed 23). It underlies the more massive Bed 24 with our Sample ß, that yielded a second *Pel.* aff. *elongatus* (Figs. 8.8-8.9). Although it differs morphologically from the *Pel. serratus* Group that is so characteristic for late lower to early upper Pragian strata (e.g., WEDDIGE 1987; SLAVÍK 2004), it can be used as evidence for an age below the top Pragian. HUVELIN (1977) reported accordingly the upper Pragian marker phacopid *Reedops intermedius* from the solid griotte limestones of Douar Oulad-ben Tounsi, as a part of his "F3" fauna of the Bou Marhara Devonian. A second spot with *Odontochile cristata* and *Reedops* was assigned to the lower Emsian but, if the first was correctly identified, a Pragian age was true (see BUDIL et al. 2009). A third spot produced *Reedops, Zlichovaspis*, and the rare asteropygid *Echinopyge*. The first two genera occur both in the Pragian and lower Emsian (e.g., CHLUPÁČ 1977; BUDIL et al. 2009). *Echinopyge* was originally described as an endemic and monospecific genus from the supposed upper Emsian of Bithynia, western Turkey (HAAS 1968). However, the outdated Bithynian Devonian stratigraphy had to be revised. The *Echinopyge* level, the Kurtdoğmus Formation, underlies the Dede Formation, which is famous for its lower Emsian ammonoid fauna (ERBEN 1965). ZIEGLER (1971) recorded *Caudicriodus curvicauda* and *Icriodus angustoides angustoides* from the Kurtdoğmus Formation, which proved a Pragian age, which resolved the contradiction. As a conclusion, Pragian trilobites are common in the Middle Member of the Jaïdet Formation whilst undoubted Emsian species have not yet been found.

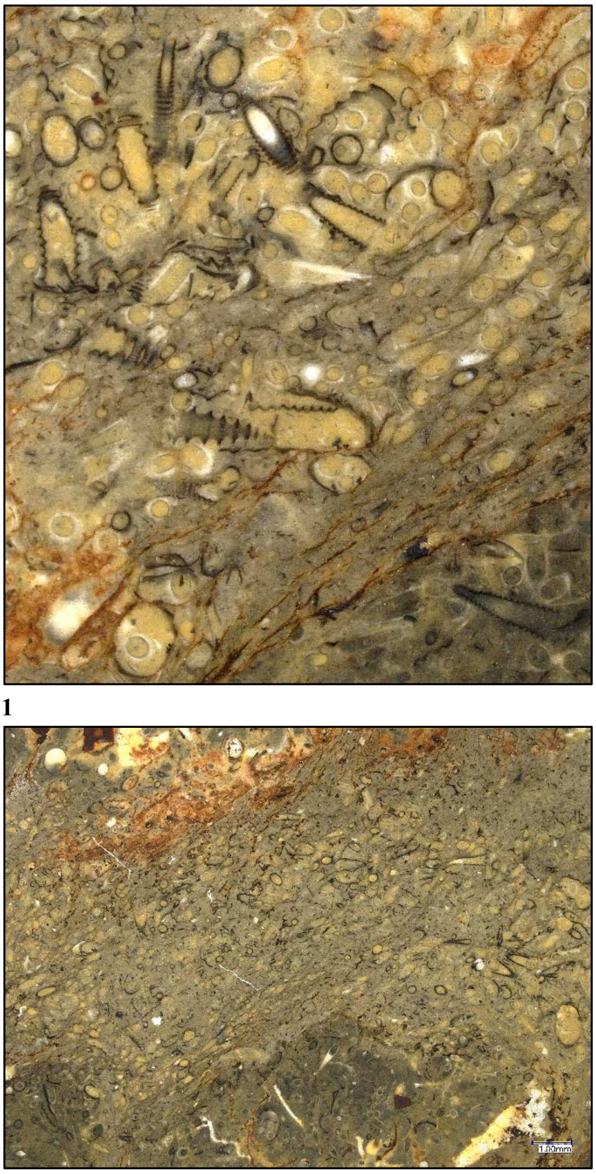


Fig. 11: Details of microfacies of Bed 24. **1.** Well-preserved *Now. (Turkestanella) acuaria* occurring without clear orientation in yellowish wacke-packstone, picture width ca. 3.5 mm; **2.** Channel of nowakiid packstone with partial bottom current orientation.

The microfacies of Bed 24 (Fig. 9.3, 11) is distinctive because of the rather dark and brownish color of the limestone and its high abundance of well-preserved nowakiids (*Now. (T.) acuaria*), either in cloudy wackestone parts without clear orientation of shells (Fig. 11.1), characteristic for the absence of bottom currents, or in channels with coquinas (packstones, Fig. 11.2). The restricted benthos consists of two-shelled ostracods, gastropods, minor mollusk and crinoid debris. This typifies the setting of a pelagic outer shelf carbonate platform or ramp affected episodically by contourites. Sedimentation rates were low and the seafloor was mostly oxic, allowing constant bioturbation by non-shelly benthos.

4.2.3. Upper Member

The Upper Member of the Jaïdet Formation is defined in Section Jaïdet West, western limb, by an increasing amount of iron encrustations (goethite/limonite), often filling burrows. It embraces Beds 29-49, with a thickness of ca. 7.5 m. The solid griotte beds and intercalated nodular shales first form an upper cliff and then continue in the top part of the western backside. Macrofauna is locally very poor. The top of the member and formation is cut off by a fault, as indicated by a change of strike direction. All conodont samples proved to be barren (Fig. 7), which leaves a large uncertainty concerning the age. A lower Emsian age is tentatively assumed for the lower part of the Upper Member. It is rather unusual that outer shelf griotte-type limestones contain no conodonts at all. However, rarity or absence of index forms has also been observed in some Emsian successions of the Anti-Atlas (ABOUSSALAM et al. 2015).

The representative Bed 37 (Fig. 9.4) is a light-grey, micritic nowakiid wacke- to packstone with a few bivalved ostracods, mollusk, crinoid, and trilobite debris. In parts of the thin-section, a subparallel current orientation of the nicely ribbed dacryoconarids can be observed. In Bed 41 (Fig. 9.5), variably light- or middle-grey nodules of fine, bioturbated mud-wackestone with some nowakiids and mollusc debris are surrounded by channel-like nowakiid wacke-packstones. The sample sectioned a massive placoderm bone. At the top, Bed 48 is characterized by bioturbation-controlled

strong lateral and vertical changes of nowakiid abundances (wacke- to packstone) and variably dark, organic-rich or lighter/middle-grey micrite matrix. As below, subparallel orientations and cone-in-cone stacking of dacryoconarids indicate episodic seafloor currents, probably contourites. The macrofauna consists of orthocones with pointed phragomocone apexes (pseudorthoceratids) and a small amount of crinoidal debris. In general, there is a restricted microfacies variability in the Jaïdet Formation.

The eastern limb of the anticline at Jaïdet West shows a reduced thickness for all three members of the Jaïdet Formation. A large, loose block with typical iron encrustations of the Upper Member displays the corroded horizontal section of an anarcestid (Fig. 12; compare HUVELIN 1977, p. 42). It provides firm evidence for an upper Emsian age for the upper part of the Upper Member. However, it is intriguing that no equivalent of the basal upper Emsian Daleje Shales, which is so well developed in the eastern Anti-Atlas (e.g., ABOUSSALAM et al. 2015) and Skoura Devonian (see Skoura chapter), can be recognized in the Jaïdet region.

4.3. Upper Emsian at Section Jaïdet Northwest

A rich upper Emsian goniatite fauna was collected in Section Jaïdet Northwest, situated just north of the main road at the 14 km marker, and just west of a small piste that curves northwards around a school building (GPS N31°52´43,0´´, W7°48´6,6´´). The sections starts with black shales in the north (asumed Jebel Smaha Formation, Fig. 3), followed by ca. 12 m thick, vertically bedded nodular limestones of the Jaïdet Formation exposed in low ridges and cliffs. Anarcestids occur in-situ on bedding planes of the upper ca. 3-4 m. Their preservation on burrowed bedding surfaces is rather poor but two groups are present, possible sellanarcestids with very low whorls (Fig. 13), and possible "*Latanarcestes*" with higher whorls (Fig. 14). Such an association was noted by HUVELIN (1977) from the Bou Marhara Syncline and is typical for the upper Emsian zone LD IV-C of the eastern Anti-Atlas (Maïder), eastern Dra Valley, and Cantabrian Mountains (e.g., BECKER & HOUSE 1994b; EBBIGHAUSEN et al. 2011). However, the poor preservation and restricted number of specimens require to be cautious concerning the precise zone.

Fig. 12: Corroded and iron-stained horizontal cross-section of an upper Emsian anarcestid with typical very low whorls exposed on the surface of a loose block of the Upper Member of the Jaïdet Formation, eastern limb of Section Jaïdet West (scale in cm).

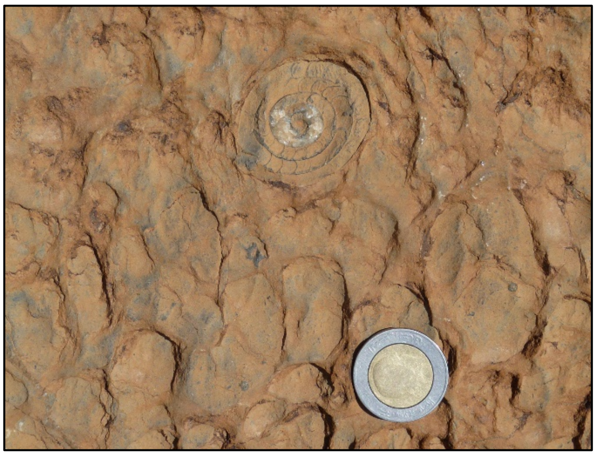


Fig. 13: Corroded anarcestid (probably *Sellanarcestes*) on a strongly bioturbated bedding surface with overprinted *Thalassinoides*-type burrows of the upper Jaïdet Formation at Section Jaïdet Northwest (coin diameter = 25 mm).

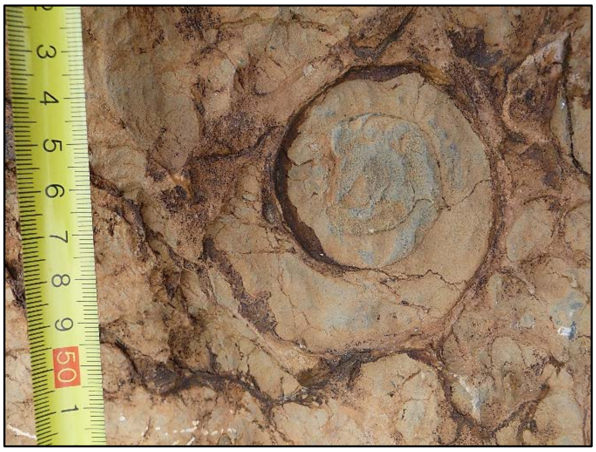


Fig. 14: Corroded different anarcestid with higher whorls (probably "*Latanarcestes*") from the same bedding surface as Fig. 13 (scale in cm).

A much richer fauna weathers out of subsequent less prominent nodular beds on the slope towards the road (Fig. 15). It consists of (bl = black matrix, dg = dark-grey matrix, mg = middle grey matrix, lg = light-grey matrix):

Fig. 15: The most goniatite-rich, more nodular griotte limestones at the top of the Jaïdet Formation of Section Jaïdet Northwest; Stephan EICHHOLT for scale.

"*Latanarcestes noeggerathi*" auct. (common, 55 % of the specimens, Figs. 16.1-4, bl-dg-lg)
Praewerneroceras n. sp. (Fig. 16.5-6, bl)
Sellanarcestes aff. *perfectus* (Fig. 16.7-8, dg-mg)
Sellanarcestes draensis (Fig. 16.11-12, dg)
Sellanarcestes sp. indet. (dg-mg-lg)
Anarcestes cf. *simulans* (lg-ochre)
Anarcestes cf. *crassus* (Fig. 16.9-10, dg-mg)
Achguigites sp. (Fig. 16.13, mg-lg)
orthocones (mg)
Panenka div. sp. (strongly corroded, mg-lg)
phacopid indet.
crinoid stem pieces (dg)
Linguipolygnathus cooperi cooperi (Fig. 8.10)

Again, the preservation is poor. All specimens are corroded, lack any shell remains and inner whorls, and are often laterally distorted. Specimens are variably preserved in black to light-grey or ochre weathering limestone. This indicates that they come from different beds within the several meters thick package. Identifications are based on sutures and rough shell parameters. The specimen identified as *An.* cf. *crassus* (Figs. 16.9-10) is more involute than typical representatives from Bohemia. For *Praewerneroceras* n. sp. (Figs. 16.5-6) and *Sell.* aff. *perfectus* (Figs. 16.7-8) see the taxonomic notes at the end. The specimen identified as *Sell. draensis* (Figs. 16.11-12) agrees with the Tata region types of EBBIGHAUSEN et al. (2011) in the rather narrow umbilicus (32 %) and thick whorls at ca. 30 mm diameter.

The Jaïdet Northwest assemblage resembles closely the faunas from the *An. simulans* and *An. crassus* Zones of Oufrane in the Tata region (LD IV-D). These extend to the upper Emsian of the Skoura region (see Skoura chapter) and to the Tafilalt (KLUG 2002). The form commonly identified as "*Latanarcestes noeggerathi*" (auct.) (Figs. 16.1-4) occurs widely in the eastern to western Anti-Atlas (e.g., BULTYNCK & HOLLARD 1980; BECKER & HOUSE 1994b; KLUG 2002; BECKER et al. 2004d, 2018b) and is most typical for the oldest anarcestid zone. However, it has previously been recorded from younger *Sellanarcestes-Anarcestes* assemblages, e.g., from the western Dra Valley (BECKER et al. 2004d) and Celtiberia, Spain (HOLLARD & HOUSE in BULTYNCK 1979). At Jaïdet Northwest, its dominance in comparison with the two other anarcestid genera is distinctive.

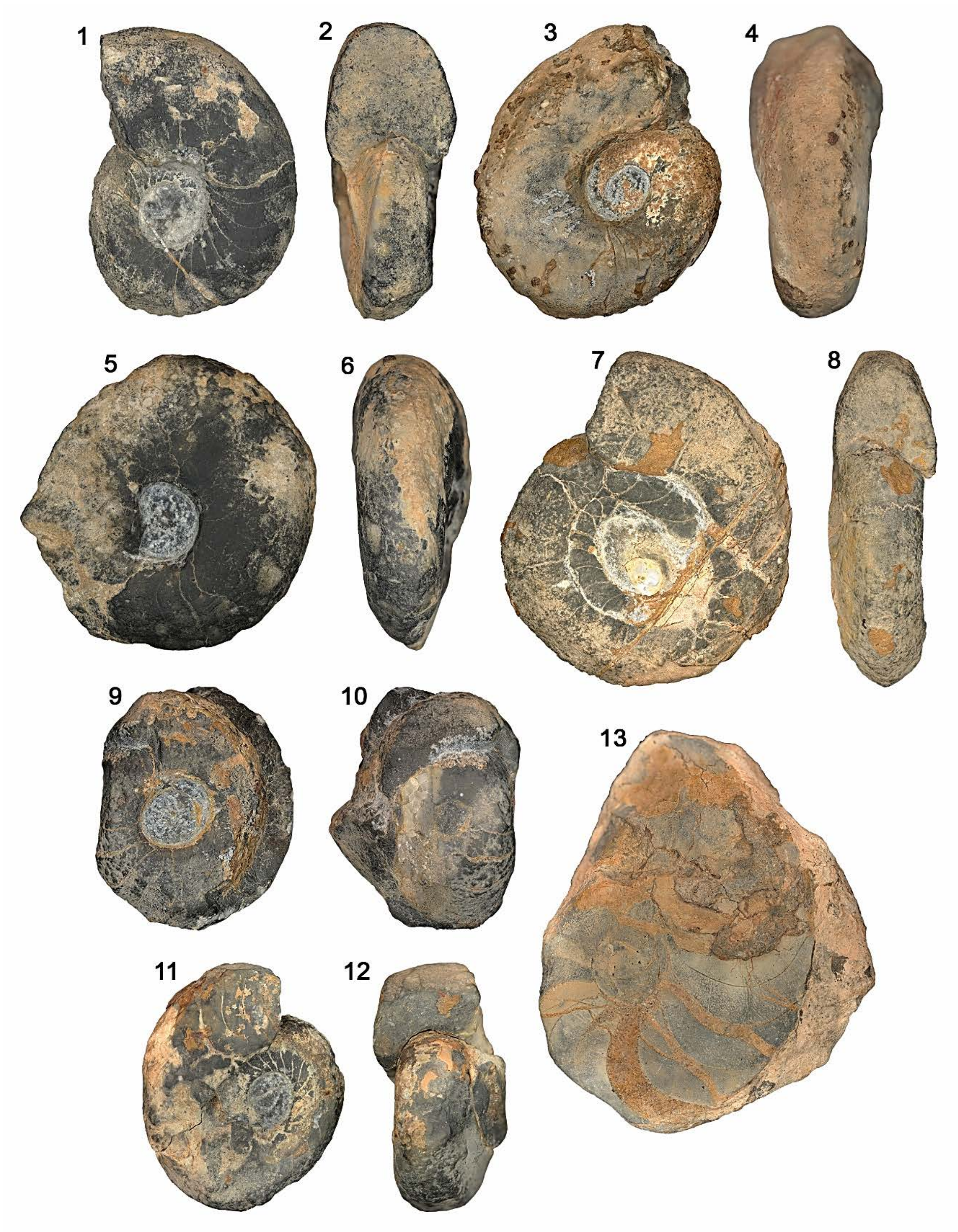


Fig. 16: Upper Emsian goniatites from the top of the Jaïdet Formation at Section Jaïdet Northwest; GMM B6C.54.183-189. **1-4.** "*Latanarcestes noeggerathi*" auct, lateral (1, 3), adoral (2), and ventral views (4), showing elliptical distortion and rather high whorls (with WER > 2.0), x 1; **5-6.** *Praewerneroceras* n. sp., lateral and ventral views, x 1.3; **7-8.** *Sellanarcstes* aff. *pefectus*, lateral and adoral views, showing the moderate whorl overlap and compressed cross-section at maturity, x 1; **9-10.** *Anarcestes* cf. *crassus*, lateral and adoral views of a small specimen, x 1.3; **11-12.** *Sellanarcestes draensis*, lateral and adoral views of a juvenile, x 1.3; **13.** *Achguigites* sp., lateral view of strongly corroded specimen with distinctively different fillings of successive phragmocone chambers by sparite, light-grey micrite, medium-grey micrite, or yellowish weathering micrite, x 1.

Following the original illustration (von BUCH, 1832) and refined knowledge of its type-locality, the true *Lat. noeggerathi* of the southern Rhenish Massif is a very different Eifelian anarcestid that is probably congeneric with *Diallagites* KLUG, 2002. This explains our quotation in inverted commas; a taxonomic revision is inevitable.

Achguigites KLUG, 2002 (Fig. 16.13) is known from the *An. simulans* Zone of the Tafilalt and western Dra Valley (EBBIGHAUSEN et al. 2011). Its occurrence at Jaïdet is, therefore, not surprising. Poorly preserved goniatites were used as conodont sample. We only found the index species of the *cooperi cooperi* Subzone (Fig. 8.14), the level of youngest *Sellanarcestes* in the Tafilalt (ABOUSSALAM et al. 2015).

The upper Emsian pelagic goniatite facies of Jaïdet differs strongly from the Devonian brachiopods and bivalves found by RUSSO (1917; identifications by C. DEPÉRET) in micaceous siltstones and sandy limestones of the Jebel Tekzim, ca. 6 km to the NNE. The quoted "*Spirifer esquerrae*" refers to the type-species of the delthyridoid genus *Boucotiellina* GARCIA-ALCALDE, 2004 (Cyrtiopsidae), which comes from the upper Emsian of León, Cantabrian Mountains. The listed *Orthis beaumonti*, also a Cantabrian species, was subsequently placed in the schizophoriid genus *Pachyschizophoria* JANSEN, 2001, which also occurs typically in the upper Emsian (e.g., JANSEN 2016). In the absence of detailed descriptions or later revisions, the reliability of the original identification is unclear. HUVELIN (1977) noted that dacryoconarid limestones do also occur at the Jebel Tekzim. However, in any case must there have been partly a shallower, neritic Emsian facies in the source region in comparison with the Jaïdet region source. The Carboniferous tectonic transport was heterogeneous, displacing material from different contemporaneous units (neritic facies, pelagic griotte facies, deeper shelf shales) towards the adjacent Jebel Tekzim and Jaïdet regions (in the west) and towards El Kalâa des Srarhna/Jebel Smaha (in the east). This may reflect an original palaeogeographic differentiation in the source region.

4.4. El Kahla Formation (Eifelian/Givetian)

The new El Kahla Formation is introduced for the thick succession of siltstones, fine sandstones, shales and turbiditic limestones that overlie the griotte facies of the Jaïdet Formation. The name is taken from Koudiat El Kahla, ca 1-1.5 km W of Section Jaïdet West, where the formation occupies a wide syncline (Fig. 3).

4.4.1. Lower Member

At Jaïdet West, the non-calcareous "Lutites gréso-micacées verdâtres" of HUVELIN (1977) form a Lower Member. The eastern limb exposes a gradual transition from nodular limestones to solid, yellowish or orange weathering, dark grey calcareous siltstones with abundant trace fossils. Large *Zoophycos* burrows are common (Fig. 17); other bedding surfaces expose deposit feeding fodinichnia resembling *Chondrites targionii* (det. M. BERTLING, Münster; Fig. 18). The producer of *Zoophycos* may have been a polychaete worm (ZHANG & ZHAO 2016) that inhabitated a wide range of marine settings. *Chondrites* is long known to have been adapted to hypoxic facies and often occurs in the deepest bathymetric part of trace fossil successions (BROMLEY & EKDALE 1984), although it also had a wide total palaeoecological range (SEILACHER 2007). Devonian *Zoophycos-Chondrites* co-occurrences are characteristic for low diversity ichnofossil assemblages from grey to dark, organic-rich mudstones of deeper shelf settings, where the size of burrows decreases with oxygenation (SEDORKO et al. 2018). This fits the Jaïdet occurrence. In the southern Tafilalt, large-sized *Zoophycos* are

common in upper Eifelian organic-rich black marls and turbiditic limestones at the Tafilalt Platform margin, which also reflect a hypoxic setting (El Khraouia, BECKER et al. 2013a). There, they also overlie directly condensed nodular limestones. Elsewhere in North Africa, contemporaneous *Zoophycos*-*Chondrites* assemblages characterize the dysoxic Middle Member of the Chefar El Ahmar Formation of the Ougarta region (Algeria; BOUCHEMLA et al. 2020).

The sudden change of ichnofauna at the Jaïdet/El Kahla Formation boundary reflects a break of trophic conditions in the sediment, opening new, intense feeding opportunities. This was probably caused by the significant increase of sedimentation rates, with a rapidly rising influx of fine siliciclastics and associated organic matter. Relationships of *Zoophycos* blooms with early land plant evolution, as proposed by KOTAKE (2014), are unlikely. The Moroccan occurrences predate the "greening of the land" by the spread of trees and forests.

Fig. 17: Bedding surface of orange-beige weathering siltstone of the basal El Kahla Formation with large *Zoophycos* feeding traces, eastern limb of Section Jaïdet West.

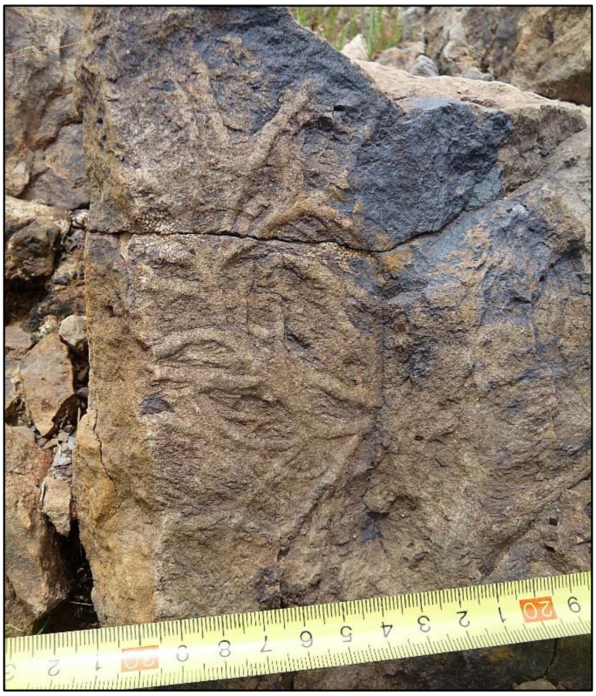


Fig. 18: Complexly branching feeding traces resembling *Chondrites targionii* on a surface of the El Kahla Formation, just above a *Zoophycos* level (to the right), eastern limb of Section Jaïdet West (scale in cm).

On the western limb at Jaïdet West, the main part of the Lower Member (the base is lacking by fault contact) consists of unfossiliferous greenish to dark-grey silty shales and siltstones. A thin-section from higher parts (Fig. 9.7) shows a very monotonous, light-grey facies of well-sorted silt particles with a minor pyrite content, lacking any fossil debris. The seafloor was hostile.

The basal part of the El Kahla Formation includes in the Bou Marhara Syncline (HUVELIN 1977, fig. 18A) a 15-20 m thick "flysch greseux" composed of siltstones/fine sandstones alternating with green shales and "conglomerates" with flat nodules, which are made of dark phosphate and limestones with dacryoconarids ("F5"). The main Lower Member comprises up to 150 m of green shales, which is a higher thickness than at Koudiat El Kahla (50-100 m, HUVELIN 1977, p. 45).

The age of the Lower Member is not really established. The position between the top-Jaïdet Formation levels with upper Emsian goniatites and Givetian limestones (see below) suggests a top Emsian to Eifelian age. A contradiction comes from a lense with the "F7" fauna of Jaïdet (HUVELIN 1977, p. 42). It included various small brachiopods and two trilobite genera (*?Reedops* and *Odontochile*) that normally do not occur above the lower Emsian. The fossiliferous lense was either allochthonous/reworked (possible), the trilobites were incorrectly identified (possible), or the top of the Jaïdet Formation is strongly diachronous within a small area (rather unlikely).

4.4.2. Upper Member

HUVELIN´s "Schistes et calcaires gréseux à Tentaculites" (Jaïdet succession) and lateral "Schistes siliceux polychromes, grés et calcaires gréseux à lits convolutes" (Bou Marhrara Syncline, Kelâa des Srarhna region) are assigned to an Upper Member of the El Kahla Formation. Characteristic are siltstones with intercalated sandy limestones with grading, lamination, cross- and convolute bedding, as typical for turbidites (Fig. 19, thin-section of Fig. 9.8).

At Jaïdet West, the alternation of shales and dark-grey turbidites is ca. 11 m thick but the outcrop ends abruptly on the NW slope of the hill. HUVELIN (1977) suggested a thickness for the complete unit of more than 370 m for the Bou Marhara and of ca. 400 m for Koudiat El Kahla.

The age for the lower part of the member is well constrained by a new conodont fauna from Jaïdet West. It is the richest among our mostly sparse or even unproductive Eastern Jebilet conodont samples, with eight species (specimen numbers in brackets):

Belodella resima (1, Fig. 8.7)
Polygnathus varcus (2, Fig. 8.14)
Polygnathus xylus (4, Fig. 8.13)
Polygnathus ansatus (2, Fig. 8.11)
Polygnathus pseudofoliatus (3)
Polygnathus timorensis (8, Fig. 8.12)
Linguipolygnathus linguiformis (9)
Linguipolygnathus weddigei (1)

Fig. 19: Turbiditic limestone with cross-bedding in the Upper Member of the El Kahla Formation at Section Jaïdet West (scale in cm).

The forth listed species is the index taxon of the middle Givetian *ansatus* Zone (ABOUSSALAM 2003; = former Middle *varcus* Zone). HUVELIN (1977, p. 42) mentioned conodonts in his "F8" fauna from the lower part of the Upper Member in the Jaïdet succession, but gave no details. The corresponding "F6" fauna from the Bou Marhara Syncline (see his fig. 18A) included only *L. linguiformis*, which ranges from the ca. middle Eifelian to the top of the middle Givetian. His "F3" fauna from the Marfa hill SW of Douar Abichat, identified by J. LE FEBRE, included, apart from ramiform elements, *L. linguiformis*, *L.* cf. *mucronata*, "*Po.* cf. *angusticostata*", and "*Po. robusticostata*?". The second species supports an *ansatus* Zone age although there are rare records from the upper part of the underlying *rhenanus-varcus* Zone (BULTYNCK 1987; see discussion in BRETT et al. 2018). The third and fourth species are Eifelian taxa that should not co-occur with *L. mucronatus*. Their cf./? quotations exclude any stratigraphic value.

Currently, there is no record of Eifelian to lower Givetian conodont faunas from the Eastern Jebilet but sampling has not been intensive.

With respect to the high thickness of strata following in the Upper Member the known conodont levels, it is well possible that the clastic El Kahla Formation reached the upper Givetian or Upper Devonian. This has to be clarified by a further search for limestones in higher levels, for example in the core of the Koudiat El Kahla syncline. The recent discovery of Frasnian and lower Famennian strata in the Central Jebilet (LAZREQ et al. 2021) added an incentive for further work.

Fig. 20: Western end of Koudiat Lahmara ca. 1 km east of Jaïdet, with poorly exposed siliciclastics (perhaps upper El Kahla Formation) in the foreground, with S. EICHHOLT for scale, lenticular limestones of the basal Tekzim Formation in the lower slope, and the main crest of “Piton Ouest “ (sensu ANDRÉ 1986; Hill 685) in the back.

5. Carboniferous transgression at Koudiat Lahmara

Studies by HUVELIN (1977), HOLLARD et al. (1977) and ANDRÉ (1986) investigated the Viséan carbonate facies (Tekzim Formation sensu GAILLET 1979) of Koudiat Lahmara, ca. 2-3 km east of Jaïdet (Figs. 3, 20). There are three hills north, northeast, and east of the Ben Brahim settlement (ANDRÉ 1986, fig. 3), just north of the main road. Our sampling focused on “Hill 685” or the “Piton Ouest”, where the laterally discontinuous oldest limestones (see ANDRÉ´s Units 1-4) are exposed on the gentle lower NW slope (Fig. 21). GPS coordinates are N31°52´4.2´´, W7°46´2.0´´. We specifically sampled two oldest lenses for fauna and microfacies. Their contact with underlying shales and siltstones is not exposed and somewhat obscure (Figs. 20, 21). There is no indication for a thrust plane. The geological map of HUVELIN (1972), the hypothetic cross-section of HUVELIN (1977, fig. 32), the discussion in ANDRÉ (1986, fig. 3), and our observations suggest that the lenticular or slumped limestones bodies lie unconformably but without a fault on fine siliciclastics (possibly El Kahla Formation). Laterally, unconformable contacts both with Ordovician quartzites and breccia bearing top parts of the Kharrouba Formation were mapped. The likely interpretation is that the

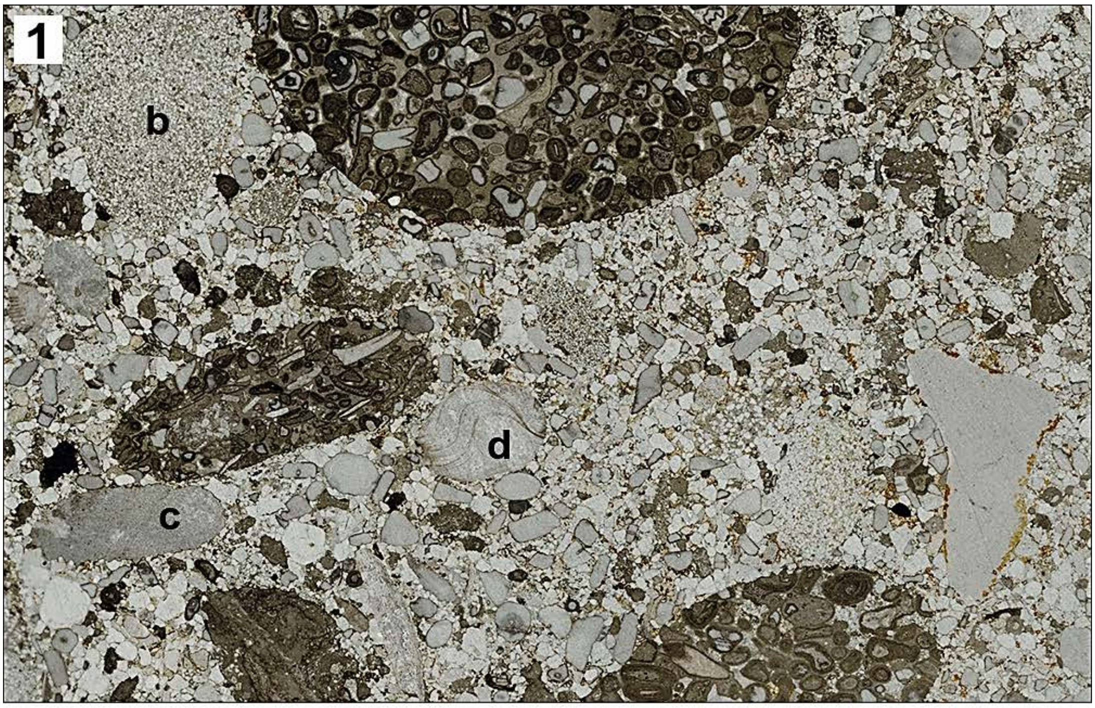
mixed carbonate-siliciclastic to reefal complex of the local Tekzim Formation represents an allochthonous shallow-water klippe/nappe complex that glided together with Ordovician blocks in the final phase into the Kharrouba Flysch basin (compare BEAUCHAMP & IZART 1987). Our irregular limestone blocks could be detached olistolites. A similar situation seems to apply to the Jebel Tekzim (see HUVELIN 1977, fig. 31), where Ordovician and Silurian slices and Devonian carbonate olistolites were shown to lie in Viséan shales, which underlie the type Tekzim Formation limestones. This complex thrusted onto the Kharrouba Flysch or glided into it after breccia formation had started. We have not yet re-studied this outcrop.

Fig. 21: Irregular and lenticular distribution of the oldest limestones of the Tekzim Formation at the western end of Koudiat Lahmara.

The lowest Carboniferous rocks studied by us consist of unsorted and polymict conglomerates with a high content of iron encrustations (Figs. 22.1-2) and cross-bedded, light-grey crinoidal grainstones (Fig. 22.3). The latter are interpreted as tempestites, which accumulated with the conglomerates in a dynamic, transgressive near-shore setting. Reworked material of an older carbonate platform, quartzite and chert pebbles mixed with carbonate and quartz sand during a time of high influx of land-derived iron solutions. ANDRÉ (1986) described the intercalation of limestones and sandstones embedded in fine siliciclastics within his Units 1 and 3-4 while conglomerate was described from Unit 2. We cannot assign our samples specifically to one of his units.

1 2 3

Fig. 22: Limestones of basal Tekzim Formation at the western end of Koudiat Lahmara**. 1.** Alternating and intergraded iron-rich conglomerate and crinoidal limestones; **2.** Details of the conglomerate showing the lack of sorting and grading; **3.** Details of laminated to cross-bedded, tempestitic crinoidal limestones.



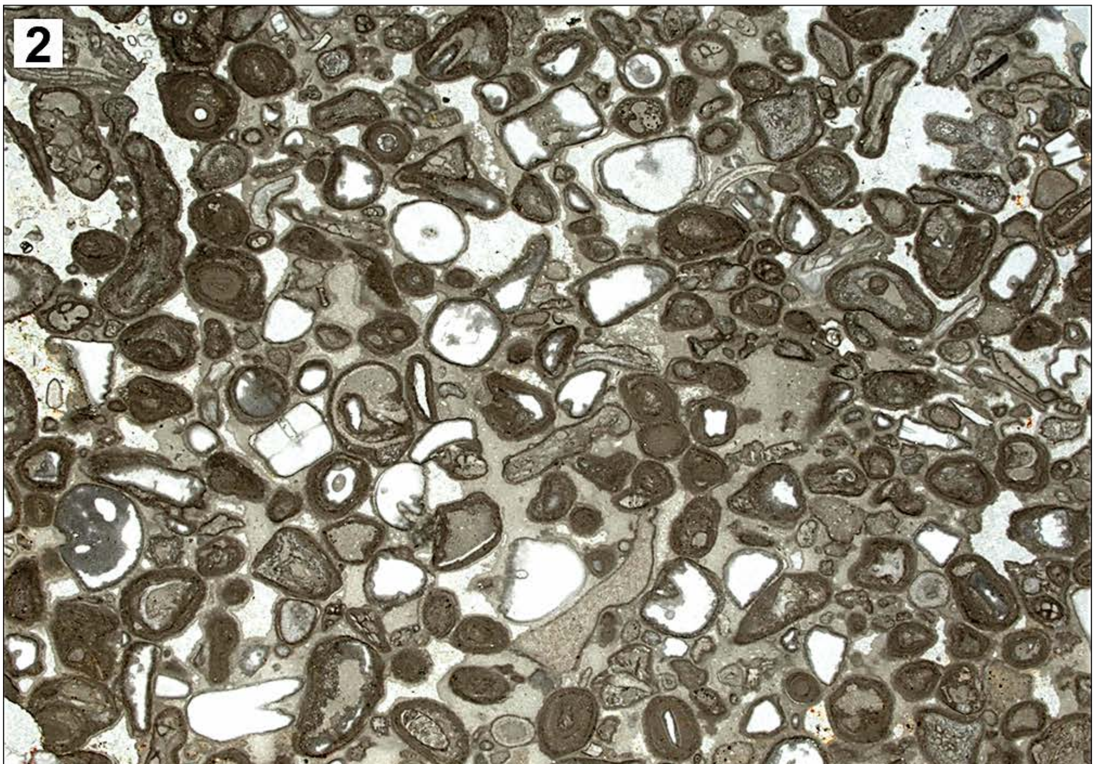


Fig. 23: Microfacies of a conglomerate from the base of the Tekzim Formation at Koudiat Lahmara West. **1.** Overview showing the poor sorting, with four types of pebbles (relative dark coated grain-ooid grainstone with micrite matrix, b = light-grey, fine calcisiltite, c = middle-grey "micrite", d = sparitic fossil fragment) sitting in a matrix of calcisiltite and calcarenite grains, with dominant angular to rounded crinoidal clasts and some darker extraclasts, and sparite between them; picture width = 3 cm; **2.** Details of the calcarenitic coated grain-ooid grainstone, showing the variably thin or thick, dark micrite rims around crinoid pieces, intraclasts, foraminifers, algal and bryozoan fragments and shell pieces, with a dense, partly washed out micrite matrix.

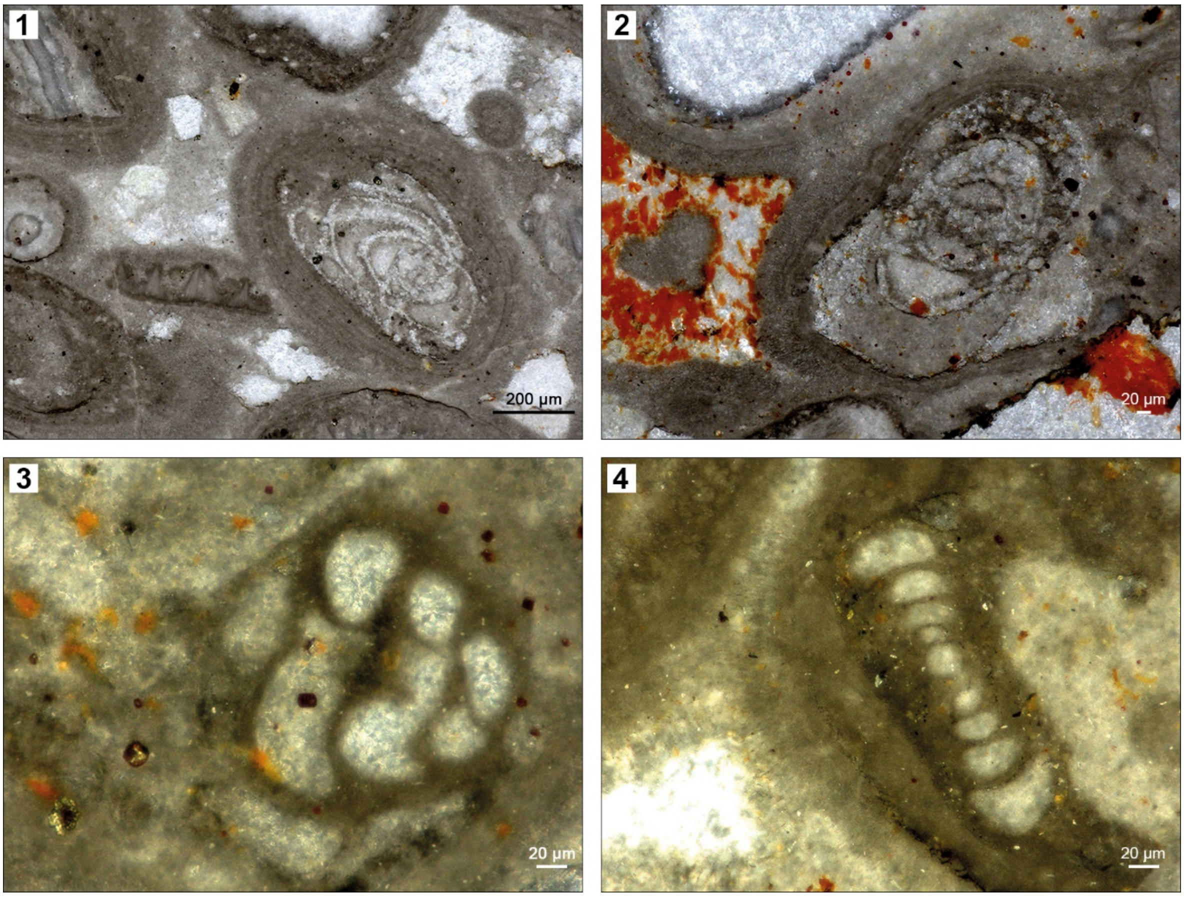


Fig. 24: Coated foraminifers from within oolithic grainstone pebbles in the basal conglomerate at Koudiat Lahmara West. **1.** *Eoparastafella* ex gr. *concinna* (or *Eostaffella radiata*); **2.** *Eoparastafella* ex gr. *florigena*; **3.** *Pseudotaxis* sp. (?*P. sussaicus*); **4.** *Lapparentidiscus* sp.

Thin-sections confirm a rather complex palaeoenvironmental setting with several episodes of reworking and redeposition. As an example for the lowest lenticular limestones, Fig. 23 illustrates a moderately coarse conglomerate. Spherical or flat, well-rounded pebbles of 5-20 mm size float in a poorly sorted calcisiltite to calcarenite (grainstone) matrix with sparite between the grains (Fig. 23.1). Due to compaction, the variably angular (dominant), subrounded or rounded grains are often in stylolithic contact. They consist mostly of crinoid detritus but there are subordinate darker extraclasts, which are small-sized pebble fragments.

Four types of extraclasts can be distinguished: relatively dark coated grain-ooid grainstones, finer, light-grey calcisiltite, sparitic shell fragments, and medium-grey, dense carbonate (probably echinoderm remains). The first type (Fig. 23.2) shows internally a partly washed out very dense and fine micrite matrix and moderately sorted, mostly 0.5 to 2 mm large, rounded to subangular grains with variably thin or thick micrite rims. Apart from ooids, there are coated crinoid ossicles and fragments, encrusted pieces of bryozoans and algae, limestone intraclasts, coated foraminifers, and rare shell filaments. Other pebbles within coarse conglomerate consist of very different, micritic, light-grey, bioturbated mud-wackestone with isolated crinoid ossicles, small brachiopods, and rare gastropods. They represent a calm neritic setting below normal storm wave base.

The conglomerate genesis is reconstructed to have experienced the following phases:

1. A first very shallow to coastal carbonate platform with the adjacent growth of algae, bryozoan colonies, corals, crinoids, shoreline erosion of even older limestone, and deposition of crinoid sand with foraminifers.
2. Erosion of this first platform and first re-deposition, where heterogeneous detrital grains were bored and coated by cyanobacteria, including ooid growth, in a continuing very shallow setting.
3. Re-deposition of the coated grains and ooids in a moderately calm setting together with micrite, which was only partly washed out by bottom turbulence. Laterally, micritic wackestone facies with an in-situ neritic facies prevailed.
4. Lithification of the coated grain limestone and of adjacent micritic wackestones and calcisiltites (minor channel deposits).
5. Second reworking and formation of polymict limestone pebbles in a shallow, high energy environment.
6. Third re-deposition jointly with younger crinoid and pebble debris in an unsorted debris flow (major storm or tsunami deposit) intercalated between shallow-water, crinoidal tempestites.

The age determination has to recognize the reworked nature of foraminifers from within the pebbles/coated grains. They are not very abundant but include at least four taxa: *Eoparastafella* ex gr. *concinna* (or *Eostaffella radiata*, Fig. 24.1), *Eoparastafella* ex gr. *florigena* (Fig. 24.2), *Pseudotaxis* sp. (possibly *Ps. sussaicus;* Fig. 24.3), and *Lapparentidiscus* sp. (Fig. 24.4). This assemblage suggests a lower/middle Viséan age. It represents new indirect evidence for a pre-upper Viséan carbonate platform in the Eastern Jebilet source region, which has been lost by subsequent reworking. Lower/middle Viséan carbonate platforms had a restricted distribution in the Meseta in comparison to the upper Viséan (RODRÍGUEZ et al. 2020; CÓZAR et al. 2020a). The lack of foraminifers in the conglomerate matrix prevents a direct dating of the re-deposition and transgression but it is constrained by the age of the immediately adjacent coral limestones.

Lenses and large blocks of fossiliferous, middle- or dark-grey microbial and detrital coral limestones (Fig. 25) lie also in the lower slope. They may have moved on the slope but ANDRÉ´s section of the Piton Ouest does not show this lithology in the main cliff (only in the distant Piton Nord).

Fig. 25: Field photo of a Viséan biostromal (microbial) limestone slab with the phaceloid rugose coral *Siphonodendron*, basal Tekzim Formation, Koudiat Lahmara West (scale in cm).

Thin-sections (Figs. 26-30) display a close intercalation of different microfacies. Some corals (Fig. 27) are embedded in clotted, micritic, partly brecciated microbial bindstone, partly with sparite-filled fenestral fabrics and sponge spicules (Fig. 30.8). Associations of calcimicrobes and sponges are typical for many microbial limestones. The bindstones are truncated by minor channels (Fig. 27.1, 28) filled with often poorly sorted, intra- and bioclastic packstones (calcisiltites to calcarenites). Bioclasts include crinoid debris, bryozoan fragments, ribbed brachiopod shells, and some foraminifers (Figs. 30.1-7). Typical is orange to reddish Fe dolomite, especially in grain interspaces. Some double-valved brachiopods are filled by the same packstone. Dark-grey pack-

rudstones around other corals (Figs. 26.1, 29.3, 29.6) include coated grains, ooids, rare calcispheres, and micrite matrix.

Many Rugosa are concentrically encrusted by several generations of laminoid microbial fabric (e.g., Figs. 27.1, 27.2), sometimes finally by the attached foraminifer *Tetrataxis* sp. (Fig. 27.2) and by bryozoans (Fig. 27.4). The latter occur as abundant fragments both in the packstones and within brecciated microbial bindstone (Figs. 29.2. and 3). Foraminifers are rather rare in the dark limestones and often poorly preserved. The overall environmental setting was a current- and storm-influenced inner platform within the photic zone. Therefore, conodont sampling was not successful. We found no redeposited Devonian clasts. The microfacies differences between coral matrix from adjacent blocks suggests an original small-scale topography and mixing of material by storm transport. Based on a low number of thin-sections, the fauna is as follows:

Palaeosmilia murchisoni (Figs. 26.1-2)
Axophyllum pseudokirsopianum (Fig. 26.3)
Pareynia sp. (Fig. 27.4)
Siphonodendron irregulare (Fig. 27.1-3)
Multithecopora sp. (Fig. 28)
Auloporida indet. (Fig. 27.3)
Fistulipora parvilabrum (Figs. 29.1-2)
cf. *Ratingella* sp. (Fig. 29.3)
Saffordotaxis cf. *incrassata* (Figs. 29.4-5)
"*Anisotrypa* " sp. (Fig. 29.6)
fenestrate bryozoans
rhabdomesine bryozoans
various brachiopods indet.
Archaediscus convexus (at *concavus* stage, Fig. 30.1)
Pseudoendothyra ornata (Fig. 31.3)
Pseudoendothyra struvei (Figs. 31.1-2)
Ungdarella uralica (Figs. 30.1-3, 6; common)
Omphalotis minima (Fig: 30.4, rare)
Tetraxis sp. (Figs. 27.2, 30.5, rare)
Pseudoammodiscus sp. (Fig. 30.7, rare)
Endothyridae indet.
monaxone sponge spicules (Fig. 30.8)

An upper Viséan age for the pack-rudstone matrix or channels is indicated by the presence of *Pseudoendothyra* and by the locally common *Ungdarella uralica*. The latter is the index species of the Cf6γ1 or lower V3bγ Zone low in the upper Asbian (Cfm7; see Cózar et al. 2020a, fig. 1). This seems to be slightly younger than the Zone 15 age (lower Asbian, V3b, see correlation of Herbig 2006, figs. 4, 6) given by Hollard et al. (1977) for his Sample 7 from Koudiat Lahmara, which also yielded *Pseudoendothyra*. It was taken at the younger southern corner of the ridge. André (1986) recorded additional microfauna from Koudiat Lahmara: *Anatolipora* sp., *Archaediscus, Bruusia, Aoujgalia variabilis*, and *Textularia ribosa*. It was also placed in V3b/Zone 15.

The corals and bryozoans support the foraminifer age. *Palaeosmilia murchisoni* and *Siphonodendron irregulare* are typical corals in the shallow-water upper Viséan of the Moroccan Meseta. In the eastern part of the Western Meseta, they are known from the southern part of the Azrou-Khenifra Basin (Khenifra region: Aretz & Herbig 2010; Somerville et al. 2012, Rodríguez et al. 2012, Said et al. 2013), and from its northeastern termination (Adarouch area: Said et al. 2007, 2011). In the Eastern Meseta, both taxa are known from the Jerada Basin (Aretz 2010). It has to be stressed, however, that both widespread taxa in general have longer ranges. *Palaeosmilia murchisoni* enters at the base of the Viséan (see Semenoff-Tian-Chansky 1974); in Morocco, youngest occurrences have been reported from the lower Bashkirian of the Adarouch area and from south of the Dra Valley in the northern Zag Basin (Rodríguez et al. 2013a, 2013b, 2015). *Siphonodendron irregulare* enters in the middle Viseán (e.g., Poty 1981). South of the Dra Valley it became extinct in the uppermost Brigantian (Rodríguez et al. 2013a), but in the Adarouch

area it continued throughout the Serpukhovian (RODRÍGUEZ et al. 2015, 2016).

Axophyllum pseudokirsopianum was established from the "Djenien" (lower Namurian = Serpukhovian) of the Algerian Sahara (SEMENOFF-TIAN-CHANSKY 1974). In northwestern Africa, it was mentioned from the southeastern Tafilalt (ARETZ et al. 2013) and from the uppermost Viséan (Brigantian) and Serpukhovian of the northern border of the Zag Basin, south of the Dra Valley (RODRÍGUEZ et al. 2013a: "*Axophyllum* ex gr. *pseudokirsopianum*", included in the nominate species by RODRÍGUEZ & SOMERVILLE 2015). The taxon was mentioned with aff.-notation from different localities in the Khenifra-Azrou Basin, eastern Western Meseta (SAID et al. 2013); it was also figured but not described from the Tiouinine reef (RODRÍGUEZ et al. 2012). However, these findings were obviously accepted by RODRÍGUEZ & SOMERVILLE (2015) to belong to the nominate species. Opposed, a single specimen from the Jerada Basin, Eastern Meseta (ARETZ 2010), shows a very extensively developed lonsdaleoid dissepimentarium and remains with doubts (*Axophyllum* aff. *pseudokirsopianum,* see RODRÍGUEZ & SOMERVILLE 2015).

Pareynia, a genus also established by SEMENOFF-TIAN-CHANSKY (1974) from the upper Viséan of the western Algerian Sahara, is rarely reported from Morocco. It was mentioned from the upper Viséan Tiouinine reef south of Khenifra (RODRÍGUEZ et al. 2012) and described from the upper Viséan of the Jerada Basin, Eastern Meseta (ARETZ 2010). *Multithecopora* is an auloporid tabulate coral that is widespread in the upper Visean and occurs up to the Pennsylvanian (e.g., CORONADO & RODRÍGUEZ 2014). In the Western Meseta, it is known from upper Viséan coral reef facies of the Khenifra region (RODRÍGUEZ et al. 2012) and from the Serpukhovian of the Adarouch area (RODRÍGUEZ et al. 2015, 2016). The coral faunula of Koudiat Lahmara consists of taxa known from the Saharan platform and Meseta, but the faunal content, especially of the higher limestone units, needs further investigation.

The Viséan bryozoans of the Meseta have hardly been studied; they are locally rather diverse. The cystoporate *Fistulipora parvilabrum* and cryptostomate *Saffordotaxis incrassata* are both known from the upper Viséan of the Montagne Noire, southern France (Roque Redonde, ERNST et al. 2015a). The incrusting trepostome *Ratingella* is normally an Upper Devonian genus (ERNST et al. 2015b). The morphological similarities of the much younger Koudiat Lahmara specimens are large but a firm identification requires more material. The second trepostome genus, *Anisotrypa*, occurs in the Viséan of China, eastern Europe (Ukraine), and North America, but our material does not fit the described species.

In summary, the new faunal record from coral limestones of the basal Tekzim Formation fits well to the upper Viséan carbonate platforms of other Meseta regions.

Based on correlations in the Rhenish Massif (e.g., HERBIG 2006), a Cf6γ/V3bγ, upper Asbian age gives a rough correlation with the *Goniatites crenistria* level in the adjacent Kharrouba Formation (HUVELIN 1977; HOLLARD et al. 1977). The basal Tekzim Formation at Koudiat Lahmara and the Eastern Jebilet goniatite shale may represent correlative transgressive episodes (Fig. 32). The conglomerates and coral limestones mark the re-onset of deposition after erosion and reworking. In the facies model of GRAHAM (1982a, p. 191), green shales (mudstones) of the upper Kharrouba Formation, which yielded the goniatites in adjacent localities (e.g. at Koudiat Jaïdet, Fig. 3), record an important and rapid transgressive phase.

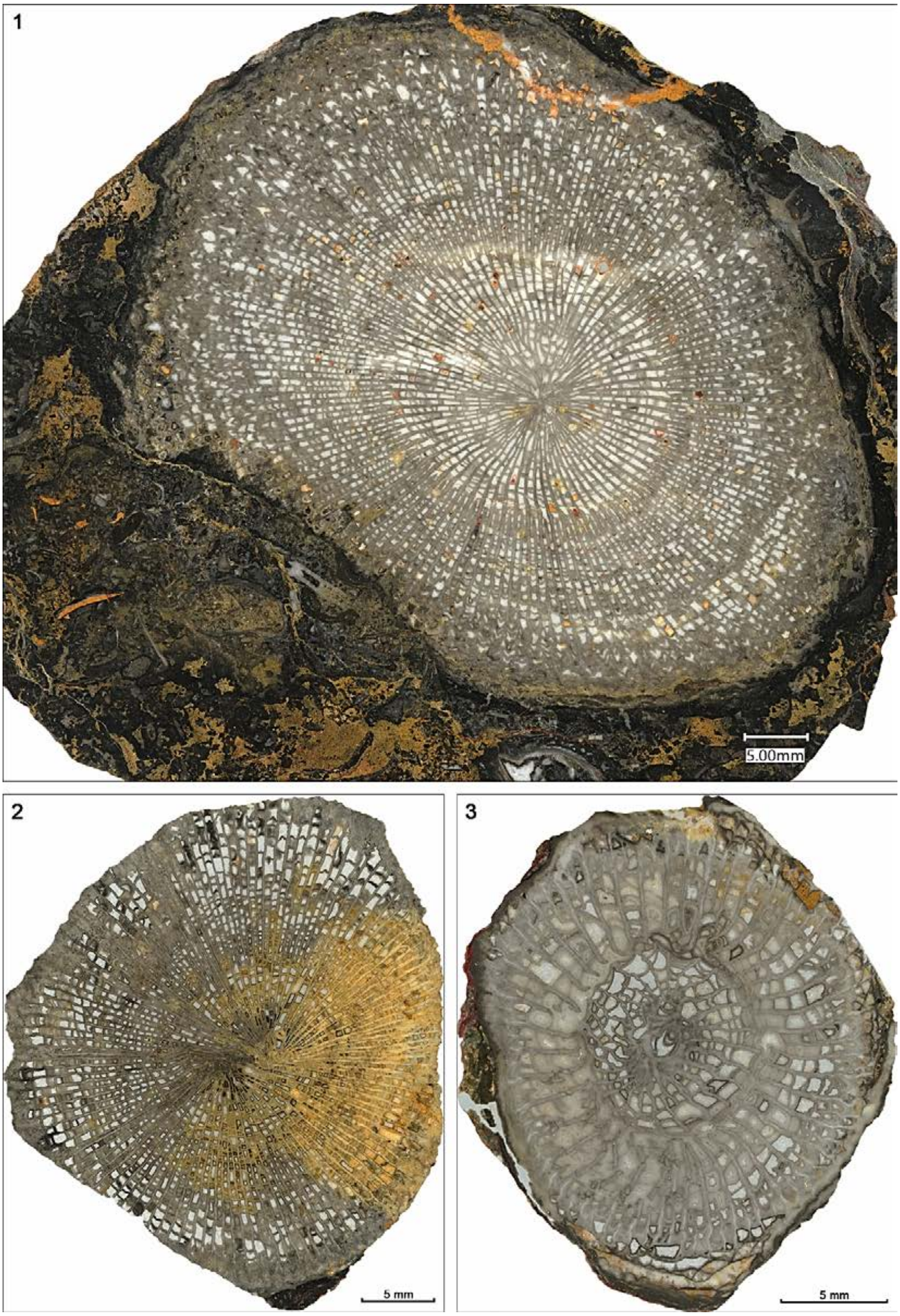


Fig. 26: Solitary rugose corals from the basal Tekzim Formation at the western end of Koudiat Lahmara. **1-2.** *Palaeosmilia murchisoni*; **3.** *Axophyllum pseudokirsopianum.*

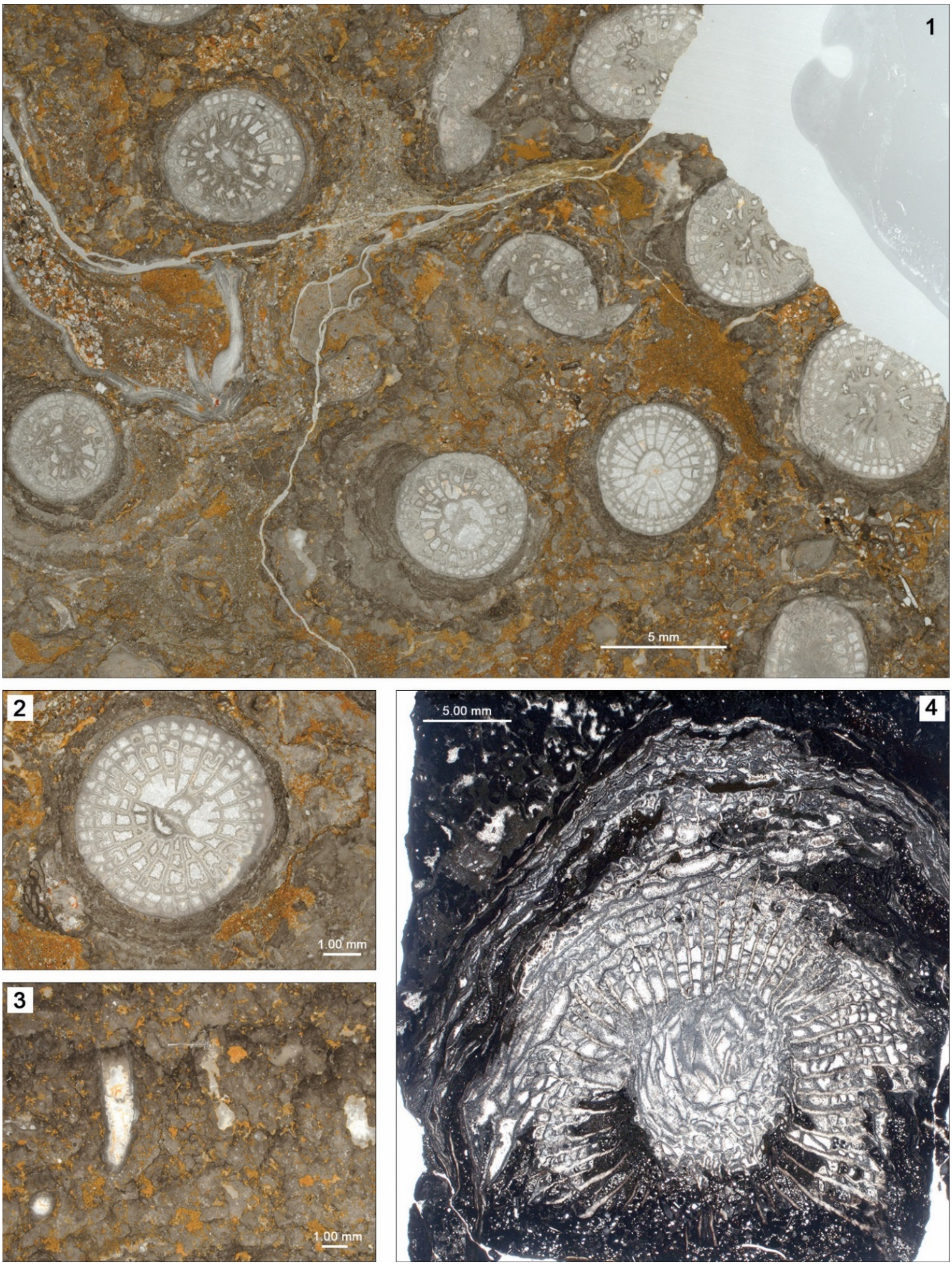


Fig. 27: Phaceloid rugose coral *Siphonodendron irregulare* and microbial fabrics of "*Osagia* type" from near the base of the Tekzim Formation at Koudiat Lahmara West. **1.** Overview of *Siphonodendron* colony embedded in partly brecciated microbialite, truncated by calcarenite channels with fragmentary brachiopods; **2.** Details of a *Siphonodendron* irregular polypar showing strong concentric microbial encrustation and final attachment (lower left) of the foraminifer *Tetrataxis*; **3.** Longitudinal sections of auloporid tabulate coral in growth position within microbial boundstone; **4.** *Pareynia* sp., fragmentary preserved specimen with partly exfoliated outer part of dissepimentarium within organic-rich, microbial boundstone matrix.

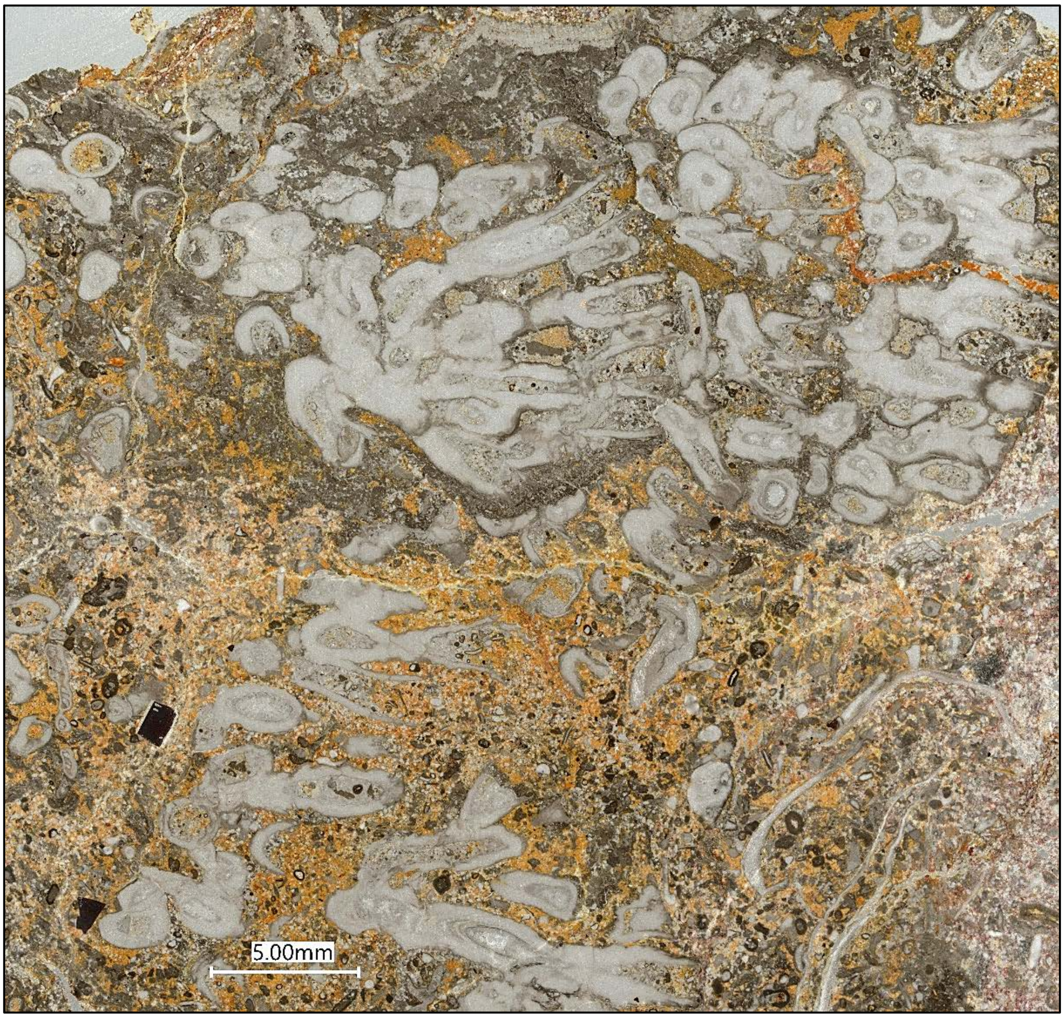


Fig. 28: Auloporid tabulate coral *Multithecopora* from the basal Tekzim Formation at Koudiat Lahmara West partly surrounded by middle-grey microbial limestone or by bioclastic/lithoclastic grainstone, with abundant orange-weathering iron dolomite in interspaces.

It is likely that the thick higher, sandy, crinoidal and eventually biostromal part of the Koudiat Lahmara carbonate platform correlates with the regressive shallow-water limestones near the top of the Kharrouba Formation, e.g., at Koudiat Bourkis. (GRAHAM 1982a, Fig. 3). These were also dated as Cf6γ (IZART et al. 1997: Koudiat Mchih). But the Koudiat Bourkis record of *Climacammina* in HOLLARD et al. (1977) indicates the younger MFZ 15 (upper V3c = Cf6δ, Brigantian; e.g., POTY et al. 2006, CÓZAR & SOMERVILLE 2020). *Climacammina* was also reported from the Jebel Tekzim, which provides a correlation of the type Tekzim Formation and the limestones at Koudiat Bourkis.

The available data contradict the assumption that the Tekzim Formation is generally younger than the Kharrouba Flysch, as shown in DELCHINI et al. (2018). Allochthonous oldest Tekzim limestones are probably time equivalents of higher parts of the Kharrouba Formation. The reworked limestones record an older Carboniferous transgression in the region. In this context, the dating of a limestone in the lower Kharrouba Formation as middle Viséan (ESSEMANI 1988; IZART et al. 1997) should be re-considered (see critical evaluation by CÓZAR et al. 2020a).

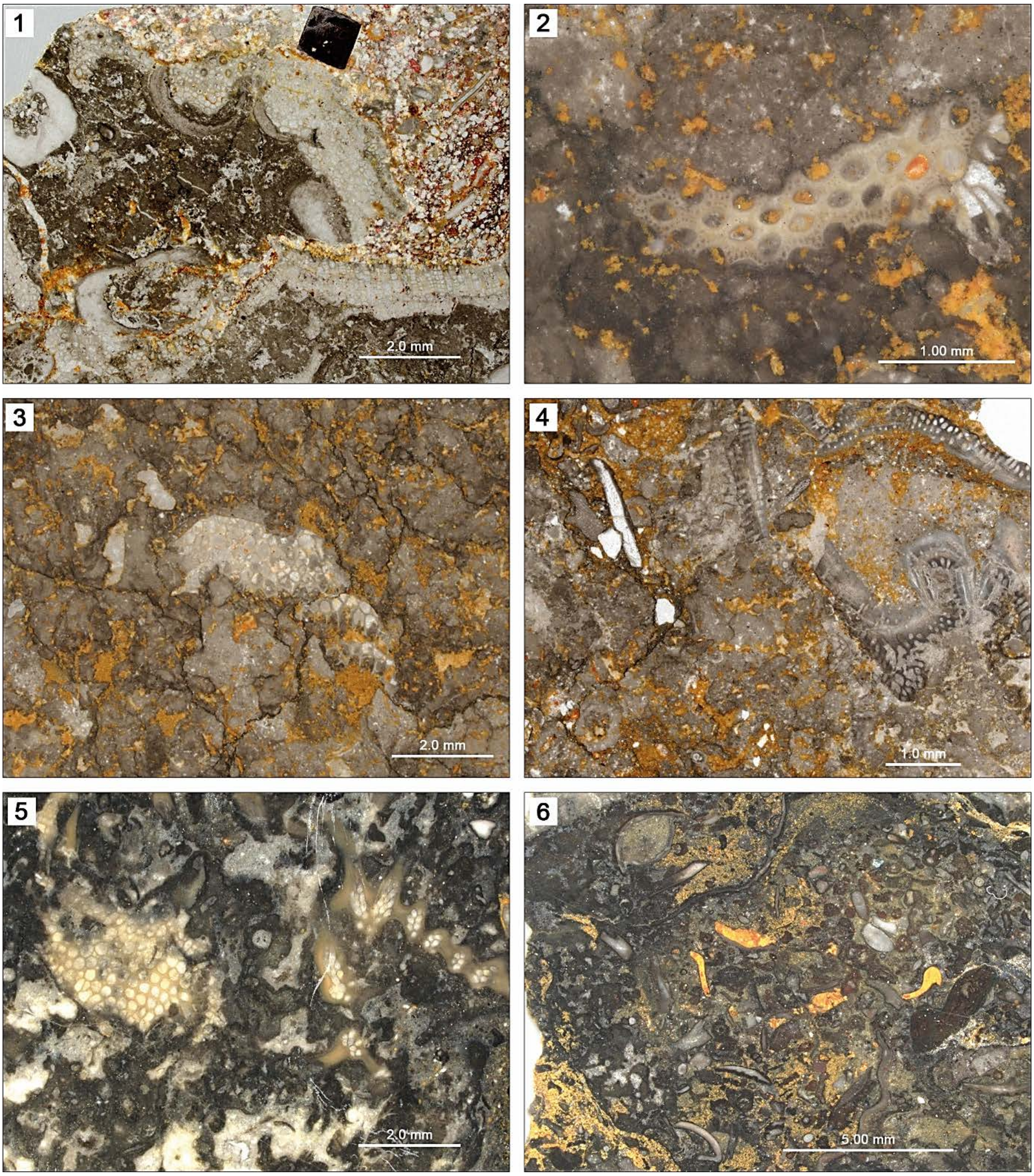


Fig. 29: Bryozoans and microfacies from coral limestone in the basal Tekzim Formation at Koudiat Lahmara West. **1.** *Fistulipora parvilabrum*, partly overgrown by microstromatolites, *Multithecopora* thin-section; **2.** *Saffordotaxis* cf. *incrassata*, *Siphonodendron* thin-section; **3.** ?*Ratingella* sp., *Siphonodendron* thin-section; **4.** Cross-section of unidentified fossil with "punctate" shell arising from a dense, laminated skeletal base, *Siphonodendron* thin-section; **5.** "*Anisotrypa*" sp., bioclastic pack-rudstone around a solitary rugose coral; **6.** Poorly sorted intra- and bioclastic pack-rudstone with micrite matrix, brachiopods, crinoid debris, abundant thick-rimmed coated grains, and secondary, orange-colored dolomitization, matrix around *Palaeosmilia* (see thin-section of Fig. 26.1).

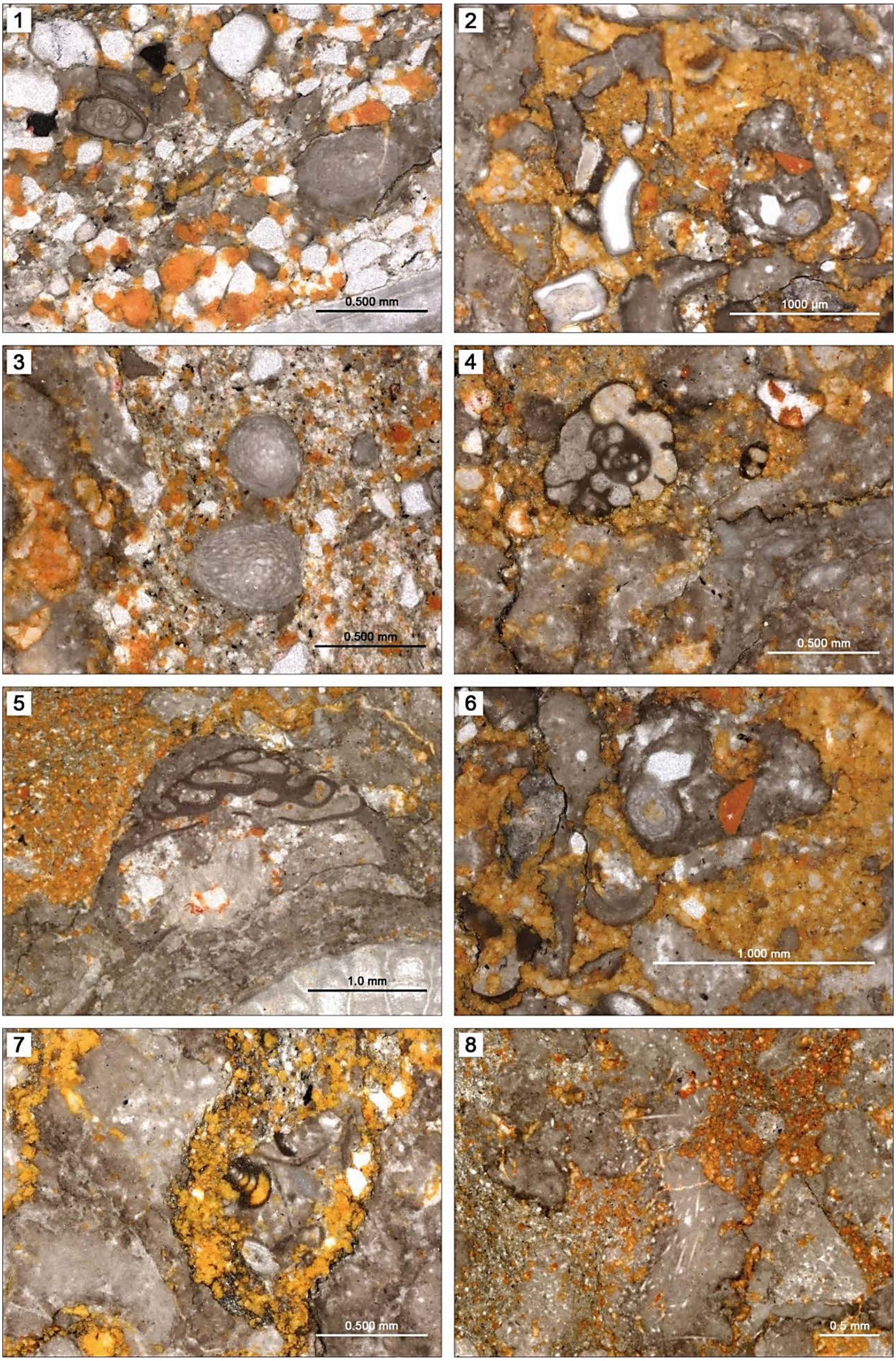


Fig. 30: Foraminifers and sponge spicules from between the *Siphonodendron* colony (Fig. 27.1), basal Tekzim Formation at Koudiat Lahmara West. **1.** *Archaediscus convexus* (at *concavus* stage, left) and *Ungdarella uralica* (right); **2.** *Pseudoendothyra* sp. and *U. uralica* (above); **3.** and **6.** *U. uralica*, illustrating the local abundance of the species, **4.** *Omphalotis minima*, **5.** *Tetraxis* sp., **7.** *Pseudoammodiscus* sp.; **8.** Monaxon spicules in fragmented microbial intraclasts.

6. Palaeogeographic trends and regional comparisons

There are no similarities of the facies developments between the Eastern Jebilet and both the Jebel Ardouz and the northern Rehamna (see Rehamna and Jebel Ardouz chapters). Relationships with the "Azrou-Khenifra Basin" to the east, which currently includes allochthonous nappes and supposed (par)autochthonous outcrops, and the Skoura region in the southeast are discussed in stratigraphic order.

6.1. Lower Devonian

The Lower Devonian of the source region of the Eastern Jebilet nappes was characterized by facies differentiation. The black graptolite shale facies (Jebel Smaha Formation) formed in an anoxic and eutrophic outer shelf basin that stretched over most of NW Gondwana. The anoxia lasted variably until the upper Lochkovian to upper Pragian, if graptolite identifications in HUVELIN (1977) are correct. Equivalent graptolite shales are known from the Mrirt-Ziyar Nappe (e.g., WILLEFERT 1963; FRANCOIS et al. 1986). However, there is so far no record of the megaplanctonic scyphocrinitids in the Eastern Jebilet, which characterize in many other regions the Silurian-Devonian transition (e.g., RÈGNAULT 1985). In the Skoura region (see Skoura chapter), correlative Silurian graptolite shales turn into lower/middle Lochkovian black shale and limestone alternations with giant nautiloids. This different nautiloid facies was terminated by a distinctive, tectonically triggered reworking event that has no match at Jaïdet.

Stepwise regressive trends ended black shale deposition in the Eastern Jebilet source region by improving the ventilation and reducing the accumulation of fine detritus due to bottom turbulence. The overlying condensed nodular shales and limestones of the Jaïdet Formation represent a subphotic outer shelf ramp with pelagic to deep neritic faunas. Especially after the eustatic Lochkovian-Pragian boundary regression, pelagic griotte facies with nowakiid blooms prevailed, but obviously not in the source region of the nappes of the Kelâa des Srarhna region, where only shales are currently known. The Pragian/Emsian transition remained very indistinctive in terms of microfacies, but the macrofauna declined strongly. Rather surprisingly, the transgressive global Daleje Event at the lower/upper Emsian boundary could not be recognized so far in the Eastern Jebilet. Either we have overlooked a shale unit or its sedimentary expression was overprinted by extreme condensation. Such a case was observed by us in the condensed Lower Devonian succession at the Jebel ben Arab northwest of Azrou (new data, see BECKER & EL HASSANI 2020, p. 22). In the Eastern Jebilet, further research is required to solve the Daleje Event question. The upper Emsian is regionally characterized by a marked bloom of pelagic fauna.

In the succession of the Mrirt-Ziyar Nappe, the nodular Submembers A-C of the Anajdam Member (Bou Nebedou Formation; BECKER et al. 2020b) are a close equivalent of the lower/middle Jaïdet Formation. Locally (e.g., at Ziar), there are shale and siltstone intercalations. But Daleje Shale equivalents (Submember D) are recognizable in the Mrirt-Ziar Nappe. Griotte limestone facies returned in the upper Emsian of the Mrirt region but anarcestid faunas are extremely rare there (e.g., AGARD et al. 1958: record from Brouha Akellal). Griotte equivalents of the Jaïdet Formation are also well-developed in the Skoura region, where they show stronger cyclicity. The subsequent green Daleje Shales are very thick at the southern foot of the High Atlas and form a landmark. Especially similar to the Eastern Jebilet are the upper Emsian

"*Latanarcestes*"-*Sellanarcestes*-*Anarcestes* faunas, which are known since ROCH (1939).

6.2. Middle Devonian

The Middle Devonian of the Eastern Jebilet (source region) is characterized by a gradual deepening of the outer shelf basin. A rapid discharge of fine siliciclastics ended the condensed griotte facies. The provenance of this detritus is unclear since the Eifelian of the eastern Dra Valley to the south is characterized by continuing condensed pelagic facies (e.g., EBBIGHAUSEN et al. 2004, 2011). In the Skoura region, there was a marked Eovariscan block faulting and reworking phase starting near the Emsian/Eifelian boundary. Perhaps, the Eastern Jebilet source region belonged to the subsiding northwestern part of the same tilting block. On the uplifted Skoura part, Eifelian erosion and slumping was followed by basal Givetian condensed limestones with some syntectonic conglomerates. Towards the east, in the Azrou-Khenifra region (Mrirt-Ziyar Nappe), the Eifelian is very differently developed. It continues the griotte facies or is missing due to a long time of non-deposition (BECKER et al. 2020b). The transformation of the El Kahla Formation into a Givetian turbiditic, flyschoid basin, therefore, gives a strong palaeogeographic separation from the (eastern) Azrou-Khenifra Basin and southern High Atlas base. However, turbiditic limestones and dark shales indicate better links with the still insufficiently studied (par)autochthonous Middle Devonian outcrops that represent the former shelf basin west of the Azrou and Mrirt-Ziyar nappes (e.g., Bou Khedra, Jebel ben Arab; see BECKER & EL HASSANI 2020).

6.3. Upper Devonian/Tournaisian

Currently there are no rocks of proven Frasnian to Tournaisian age in the Eastern Jebilet. In the Central Jebilet, a partial Frasnian-Famennian range of the Sarhlef Formation was recently shown by LAZREQ et al. (2021). For the hardly studied limestones within the Sidi bou Othmane Formation, there is so far no age control; they may well be of upper Viséan age (see EL HASSANI 1982). Although DELCHINI et al. (2018, p. 3) admit that the stratigraphic relationships between the Sidi bou Othmane and Kharrouba Formations are unclear, they propose that the first underlines the second. This interpretation should be tested by sampling of the metamorphozed limestones. The same applies to an assumed Upper Devonian age for quartz phyllites of the Rhira Formation at the western margin of the Central Jebilet. As mentioned above, we do not rule out that the upper part of the El Kahla Formation falls in the Upper Devonian. In this respect, the discovery of lower Famennian conodonts in metamorphic limestones of the Jbel Gueliz in Marrakech, which lies south of the Central Jebilet (LAZREQ 2017), was intriguing.

A near absence of in-situ Frasnian to Tournaisian strata, resulting from major Eovariscan uplift, reworking and non-deposition, is typical for the Skoura region. In its eastern part, at Asserhmo, there is an extremely polymict Eovariscan conglomerate with reworked Givetian/Frasnian corals, Frasnian brachiopod limestones, and upper Famennian pelagic limestones (see Skoura chapter). Only these clasts preserved the post-sedimentary disrupted, complex Upper Devonian history of that region.

In the Ziyar and Mrirt regions of the southern "Azrou-Khenifra Basin", the upper Givetian to Frasnian are present, but in strongly condensed and incomplete pelagic platform facies (e.g., BECKER et al. 2020b). Unlike as in the Eastern Jebilet, the lower to upper Famennian of Mrirt and Ziyar is well-developed and represented by fossiliferous, thick pelagic griotte facies (e.g., LAZREQ 1992; BECKER & HOUSE 2000c; HÜNEKE

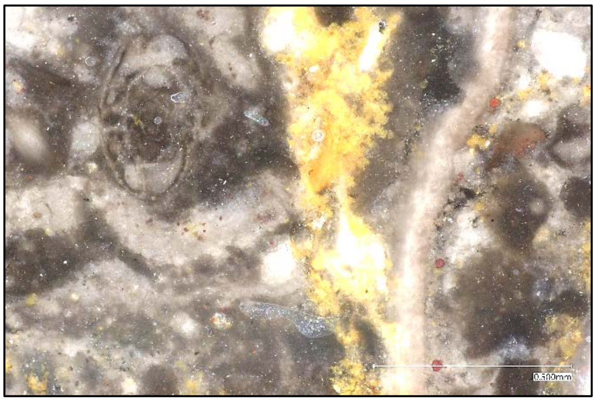
2001). Corresponding rocks can be found as reworked clasts in the upper Viséan olistostrome east of the Jebel Tabainout, which lies west of the Khenifra Nappe (BECKER et al. 2020b). The uppermost Famennian and most of the Tournaisian are lacking or are extremely incomplete in the Mrirt-Ziyar Nappe, due to the next phase of Eovariscan block movements and reworking. Only locally in the (par)autochthonous part of the "Azrou-Khenifra Basin" (Bou Khedra between Mrirt and Azrou, BOUABDEDLLI 1989, HABIBI 1989; localities west of Khenifra, CÓZAR et al. 2020b and RODRÍGUEZ et al. 2020), Carboniferous continuous sedimentation commenced in the upper Tournaisian to basal Viséan.

In summary, there is no good match between the Eifelian to Tournaisian of the Eastern Jebilet, Skoura region and Azrou-Khenifra Basin, which reflects very different synsedimentary block movements.

6.4. Viséan

In the source region of the Eastern Jebilet, a shallow-water carbonate unit existed once in the lower/middle Viséan but it was subsequently destructed by erosion and reworking. Currently, its main record are the reworked pebbles within the younger transgression conglomerate at Koudiat Lahmara. Although the foraminifer record from the reworked pebbles is restricted, there are clear differences to the foraminifers from the matrix of the coral limestones from near the base of the Tekzim Formation. In principle, there are chances to find this "lost lower/middle Viséan platform limestones" as olistolithes within the upper Kharrouba Flysch. The age of the base of the Kharrouba Formation is not yet known. It should be re-considered whether assumed middle Viséan limestones within its lower part (IZART et al. 1997: cf5 (V2b) fauna at Koudiat Kouchina) correlate with the reworked carbonate interval (Fig. 32). CÓZAR et al. (2020a) concluded that the reported faunas are too poor to provide a reliable middle Viséan age. Lower Viséan shallow-water limestones were rare in the Meseta but middle Viséan platform limestones had a moderately wide distribution, e.g., in the autochthonous central-western part of the "Azrou-Khenifra Basin" (Jebel Bouechchot) as well as in the Skoura region (see CÓZAR et al. 2020b).

A main Viséan transgression occurred in the Eastern Jebilet, including the source region of nappes/klippen, in the top lower to upper Asbian. As emphasized above, HOLLARD et al. (1977) provided important evidence for a direct transgression on Lower Devonian strata. Based on records of *Stacheoides* and *Pseudoendothyra*, the age is at least upper Cf6ß (Cfm6, upper V3bß). A slightly younger pulse (*Ungdarella uralica* Zone, Cf6γ1 = lower V3bγ = Cfm7 = upper MFZ 13) is preserved at Koudiat Lahmara by the re-onset of nearshore limestone deposition after the reworking of the older platform. Within the lateral upper Kharrouba Formation, a probably correlative (Fig. 32) transgressive episode is marked by green shales with upper Asbian goniatites. These still require documentation in the light of the recent significant advances in Moroccan upper Viséan goniatite taxonomy and biostratigraphy (KLUG et al. 2006, 2016; KORN et al. 2007; KORN & EBBIGHAUSEN 2008). For example, the oldest goniatites from Sidi Lamine (Khenifra region) were shown by KORN (2017) to include *Goniatites sphaericus*, a slightly younger (top Asbian) species than *Gon. crenistria*. Other goniatites from Sidi Lamine are clearly younger (Brigantian; see DELEPINE 1941 and ROCH 1950; e.g., "*Gon. striatus*") but have not yet been revised.



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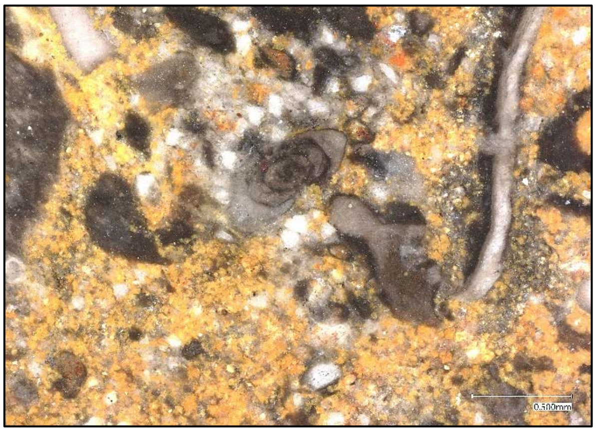

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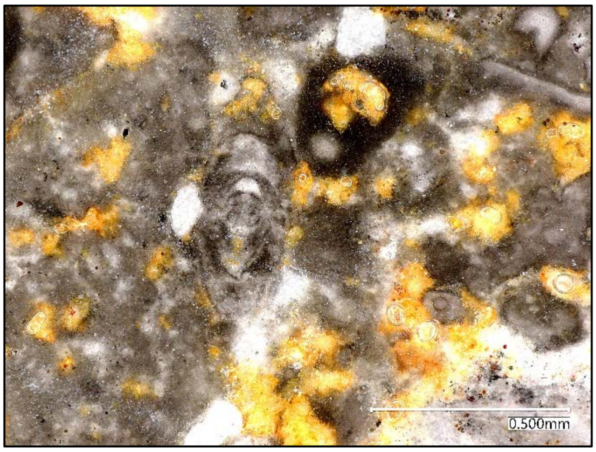

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Fig. 31: Foraminifers from the matrix around a *Palaeosmilia* (1-2; see Fig. 26.1) or *Multithecopora* (3, see Fig. 28), basal Tekzim Formation at the western end of Koudiat Lahmara. **1-2.** *Pseudoendothyra struvei;* **3.** *Pseudoendothyra ornata*.

It is tempting to compare the microbial coral limestones and the subsequent thick Tekzim Formation described by ANDRÉ (1986) with the upper Viséan coral-bearing shoals and build-ups of the Khenifra region (ARETZ & HERBIG 2010; SOMERVILLE et al. 2012; RODRÍGUEZ et al. 2012; SAID et al. 2013). However, the latter were ecologically and taxonomically more diverse and started to grow slightly later (?upper Asbian to Brigantian; SAID et al. 2013) as part of a deepening succession. In the Haouz region south of Marrakech (El Moussira), there was only a crinoidal to microbial shoal without corals at the time (ABOUSSALAM et al. 2017). In the Skoura region, the stratigraphy and facies development of the upper Viséan is still poorly studied (e.g., LAVILLE 1980). Since ROCH (1939), upper Viséan goniatites are known from greenish to black shales, which may correlate with the Eastern Jebilet goniatite shales. But, again, their fauna was never documented.

Since we studied only locally the initial transgression, we will not comment on the higher upper Viséan-Serpukhovian sedimentary, magmatic and structural evolution of the Kharrouba Flysch basin and its palaeogeographic relationships within the Jebilet and beyond in the Western Meseta (for this see HUVELIN 1977; BEAUCHAMP & IZART 1987; BEAUCHAMP et al. 1989; IZART et al. 1997, 2017; ESSAIFI et al. 2003; BAMOUMEN et al. 2008; DELCHINI et al. 2018; CÓZAR et al. 2020a).

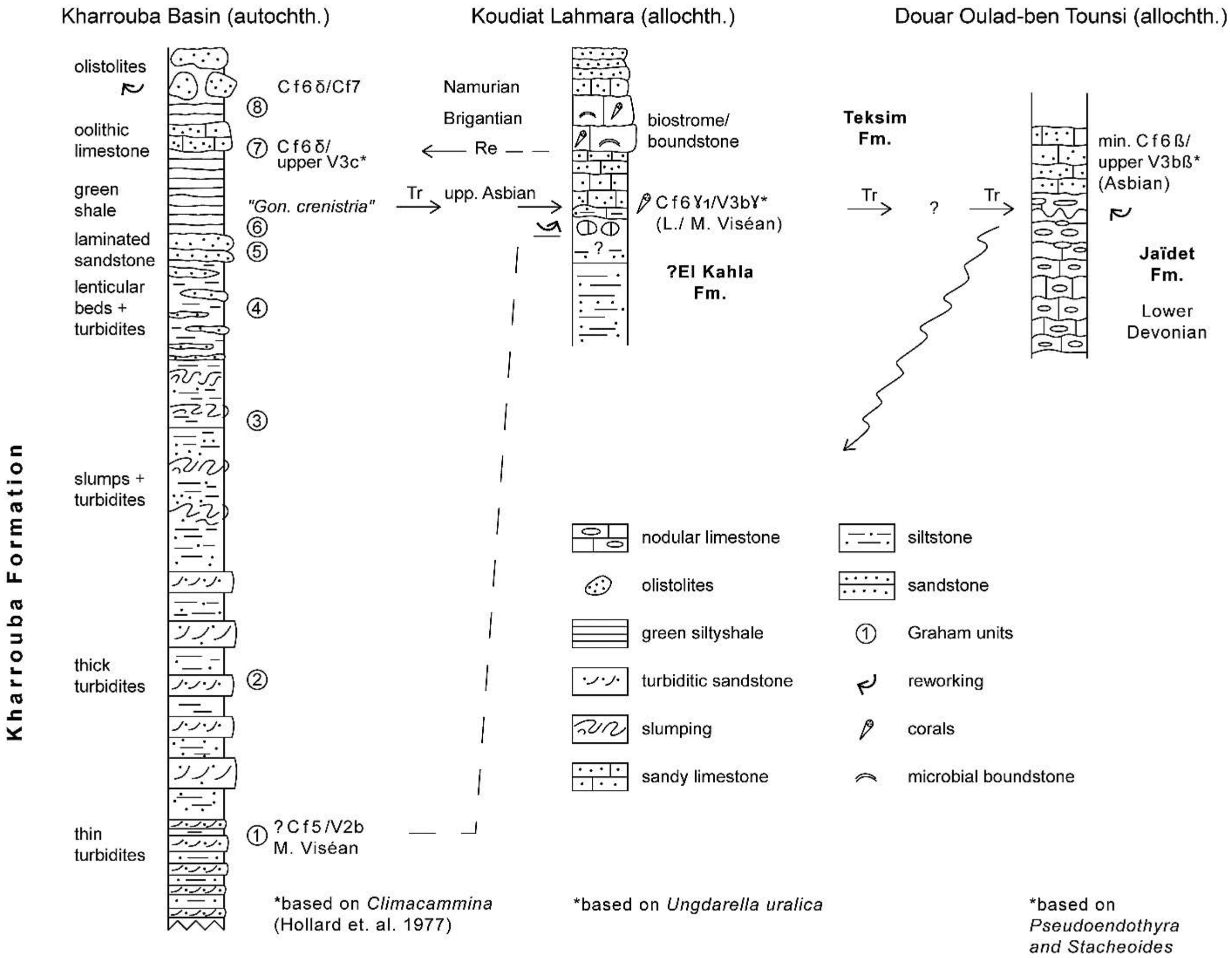

Fig. 32: Sketch (not to scale of thicknesses or absolute time) illustrating the currently assumed correlation between Viséan successions of the Kharrouba Flysch (e.g., Koudiat Mchich/Koudiat Bourkis, see GRAHAM 1982a and IZART et al. 1997), Koudiat Lahmara, and the locality 1.5 km ESE of Douar Oulad-ben Tounsi of HOLLARD et al. (1977).

7. Taxonomic notes

7.1. Ammonoids (RTB)

***Praewerneroceras* n. sp.**

Figs. 16.5-6

Description: A single goniatite (GMM B6C.54.185) from the top nodular limestones at Jaïdet Northwest, incompletely preserved in dark-grey micrite, is convolute, compressed, with gently rounded flanks, and narrowly rounded venter. Sutures consist of a shallow L-lobe on the lower flanks, a wide, low, asymmetric saddle on the mid- and outer flanks, and a narrow, diverging E-lobe. The umbilical wall is short and steep. The preserved part of the body chamber occupies ca. the last half whorl. The phragmocone is crushed on one side.

Conch parameters: Diameter (dm) 36 mm, whorl height (wh) ca. 11.5 mm, whorl width (ww) ca. 14 mm, umbilical width (uw) ca. 10 mm; wh/dm = ca. 0.32, uw/dm = 0.28, ww/dm = 0.39, ww/wh = ca. 0.9.

Discussion: The specimen differs from all named upper Emsian species by the combination of a compressed conch, convolute coiling, and *Anarcestes*-type outer sutures with subumbilical L-lobe and wide external saddle. The only similar genus is *Praewerneroceras*, which type-species from the upper Emsian of Bohemia, *Prae. suchomastense* CHLUPÂČ & TUREK, 1983, has much thicker whorls. The basal upper Emsian

Prae. hollardi BECKER & HOUSE, 1994b from the Tafilalt, which may not be con-generic (compare KLUG 2002), is characterized by very shallow outer sutures. The new specimen may represent a form that is intermediate from "*Lat. noeggerathi*" auct., which is also compressed and convolute, but which differs by higher whorl expansion and its wide L-lobe that occupies in the associated Jaïdet specimens all of the flank (see Figs. 16.1-4). With respect to the poor preservation, open nomenclature is applied until more material becomes available, and until further revision of early anarcestids from southern Morocco.

Occurrence: Restricted to the upper Emsian of Jaidet.

***Sellanarcestes* aff. *perfectus* CHLUPÂČ & TUREK, 1983**

Figs. 16.7-8

Discussion: A few corroded sellanarcestid from Jaïdet Northwest (e.g., the figured GMM B6C.54.186) are rather evolute (uw/dm = ca. 0.45) and compressed (ww/dm = ca. 0.30, ww/wh = ca. 0.90 at 54 mm dm), with a rather high whorl expansion rate (WER = 1.7). They are morphologically intermediate between *Sell. draensis* (with always lower WER ratios) and *Sell. neglectus* (with mature uw/dm < 0.40 and ww/dm < 0.30; see CHLUPÂČ & TUREK, 1983 for the type population and EBBIGHAUSEN et al. 2011 for Dra Valley representatives). *Sellanarcestes ebbighauseni* KLUG, 2002 from the Tafilalt, *Sell. cognatus* CHLUPÂČ & TUREK, 1983, and *Sell. applanatus* (= *tenuior*, see EBBIGHAUSEN et al. 2011) also keep very low WER ratios throughout ontogeny. The Bohemian *Sell. certus* CHLUPÂČ & TUREK, 1983 is always thicker (ww/dm between 0.40 and 0.44 at the same size). The conch of *Sell. perfectus* CHLUPÂČ & TUREK, 1983 resembles *Sell. neglectus* but the original description includes a few specimens (L19337 and L19325, CHLUPÂČ & TUREK, 1983, tab. 28) with wider umbilicus and compressed cross-section at maturity. Since typical *Sell. perfectus* have more strongly embracing whorls, the form from Jaïdet Northwest is identified as *Sell.* aff. *perfectus*.

Occurrence: Upper Emsian of Bohemia and the eastern Jebilet.

7.2. Conodonts (RTB & ZSA)

***Pelekysgnathus* aff. *elongatus* CARLS & GANDL, 1969**

Figs. 8-9

Discussion: The Spanish holotype of *Pel. elongatus* is characterized by two main, inclined posterior teeth and six much smaller and lower, anterior teeth. Paratypes may possess only a single posterior tooth and seven alternating very small or moderately large triangular teeth. In our specimens (e.g., the figured GMM B4C.2.143), the main tooth is directed posteriorly and followed by up to 11 teeth that form a convex, cockscomb type pattern, with the largest and highest teeth located ca. a third from the anterior end. A similar convex pattern, but with shorter free denticle ends, was illustrated by WEYANT et al. (2010) in a *Pel.* aff. *elongatus* from the basal Pragian of the Armorican Massif (L´Armorique Formation).

It is likely that the Jaïdet specimens represent a distinctive taxon but since the variability of Lochkovian/Pragian pelekysgnathids is not well established and since we have only two specimens that are not well-preserved, we keep them in open nomenclature. Further sampling may provide better material. The Pragian *Pel. serratus* Group differs has fewer teeth (ca. six) and a marked, deep incision separating the posterior main tooth.

Occurrence: Restricted to the Pragian of the eastern Jebilet.

7.3. Rugose corals (by H-GH)

***Pareynia* sp.**
Fig. 27.4

Description: The single, slightly oblique cut transverse section is fragmentary preserved. The alar diameter is about 35 mm, the diameter of the tabularium about 22 mm, and the diameter of the axial structure about 9.3 mm. There are 50 quite thick major septa; minor septa are short. The partly exfoliated, extensive lonsdaleoid dissepimentarium comprises almost half of the corallite diameter. External narrow, naotic dissepiments are internally replaced by large, but still narrow lonsdaleoid dissepiments. The typical axophylloid, irregular axial structure is without visible median plate.

Discussion: Only two upper Viséan species were recognized by SEMENOFF-TIAN-CHANSKY (1974): *Par. splendens* (type species) and *Par. gangamophylloides*. RODRÍGUEZ & SOMERVILLE (2015) added a third, smaller species, *Par. Viacrucense,* from the lower Serpukhovian (Pendleian) of southwestern Spain. The present specimen approaches the holotype of *Pareynia splendens densa* (SEMENOFF-TIAN-CHANSKY 1974, pl. 64, fig.1), but clearly differs from *Par. splendens* from the Jerada basin with predominantly large, globose lonsdaleoid dissepiments (ARETZ 2010). The fragmentary preservation of our specimen excludes specific determination. However, it has to be stressed that, as elsewhere, the genus occurs in microbial dominated buildup facies (ARETZ 2010).

Occurrence: Upper Visean of Algeria and Morocco (Western and Eastern Meseta), lower Serpukhovian (Pendleian) of southwestern Spain (RODRÍGUEZ & SOMERVILLE 2015), upper Viséan of Belgium (DENAYER et al. 2011); China (fide RODRÍGUEZ & SOMERVILLE 2015).

***Axophyllum pseudokirsopianum* SEMENOFF-TIAN-CHANSKY, 1974**
Fig. 26.3

Description: The specimen from Koudiat Lahmara has an alar diameter of 20 mm, narrow, inconspicuous dissepimentarium with few isolated lonsdaleioid dissepiments, wide tabularium, and large axial structure, 8.5 mm in diameter. The axial structure is dominated by long septal lamellae; a median plate is inconspicuous. The axial structure is separated from the tabularium by an inner wall composed of thickened dissepiments, and the tabularium from the dissepimentarium by a thin stereoplasmatic thickening. The only partially preserved epitheca is thick (0.5-0.6 mm). 42 major septa; minor septa are short to long, continuing ¼ to ¾ through the tabellarium.

Discussion: The specimen shows the typical features of the species. The transverse section is almost identical to the paratype material of "*Axophyllum pseudokirsopianum* nov. sp. forma *media*" in SEMENOFF-TIAN-CHANSKY (1974, pl. 57, fig. 3). It is also very similar to the description in HERBIG (1986) and a specimen figured in RODRÍGUEZ & SOMERVILLE (2015, fig. 15g), though in our transverse section the median plate is almost not discernable and lonsdaleoid dissepiments are less developed.

Occurrence: Upper Viséan to Serpukhovian of Algeria and Morocco (Western Meseta, Anti-Atlas: Tafilalt, Zag Basin; aff. Eastern Meseta), uppermost Viséan (Brigantian) of southwestern Spain (RODRÍGUEZ & SOMERVILLE 2015), upper Viséan of the Malagides/Betic Cordillera (HERBIG 1986), upper Viséan of Belgium and Britain (see RODRÍGUEZ & SOMERVILLE 2015).

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