Devonian and the Carboniferous transgression in the Skoura region, Sub-Meseta Zone, Morocco

Ralph Thomas BECKER[1], Zhor Sarah ABOUSSALAM[1], Ahmed EL HASSANI[2], Lahssen BAIDDER[3], Heiko HÜNEKE[4], Oliver MAYER[4], Pedro CÓZAR[5], Stephan HELLING[1], Konrad SEYFFERT[1] & Andreas MAY[6]

1. Institut für Geologie und Paläontologie, WWU Münster, Corrensstraße 24, D-48149 Münster, Germany
rbecker@uni-muenster.de
2. Hassan II Academy of Science and Technology, Km 4 Avenue Mohammed VI Rabat, Morocco
3. Faculté des Sciences Aïn Chok, BP 5366 Maârif, Casablanca, Morocco
4. Ernst-Moritz-Arndt-Universität Greifswald, Domstr. 11, D-17489 Greifswald, Germany
5. Instituto de Geosciencias, Facultad de Medicina, C/Severo Ochoa 7, Edificio Entrepabellones 7 y 8, Ciudad Universitaria, 28040 Madrid, Spain
6. Friedrich-List-Straße 66, D-59425 Unna, Germany

Fig. 1: View on the Silurian-Devonian cliff below the Taliouine (= Tiliwine) village ca. 30 km N of Ouarzazate (Skoura region, southern foot of High Atlas), with Silurian black shale in the main slope, followed by yellowish weathering Pragian to lower Emsian nodular limestone and more solid cyclic pelagic limestones forming the cliff top (new Imi-n-Tazaght Formation), and greenish Daleje Shale equivalents (new Tizi-n-Ouourti Formation) in the background, below the reddish Permo-Triassic beds.

Abstract. The Sub-Meseta Zone forms the transition between the southern Meseta of the main Variscides and the Anti-Atlas realm. The Skoura region at the southern foot of the High Atlas includes a west-east, discontinuous sequence of Devonian and Lower Carboniferous outcrops, from Tizi-n´Tichka East in the NW of Ouarzazate to Asserhmo in the NE. Based on detailed logging, microfacies, conodont and macrofauna sampling, especially at Taliouine and Tizi n-Ouourti, the regional Devonian litho, bio- and event stratigraphy and facies development is revised. The Lochkovian is marked by a change from unfossiliferous black shales (Lower Member of new Tizi-n-Tichka Formation) to condensed, discontinuous, black, detrital Orthocone Limestones (Upper Member, middle Lochkovian) deposited under strong bottom current influence (contourites). Slumps and a subsequent erosional disconformity mark the regional tectonic episode Sk-TP-1a, followed by a distinctive "Antevariscan"

conglomerate and reworking interval (Sk-TP 1b) that falls in the lower Pragian (Member 1 of new Imi-n-Tazaght Formation). The higher Pragian and lower Emsian are represented by cyclic, coarsening upwards successions of nodular limestones with trilobites and early goniatites (Members 2 and 3). At the top, Member 4 contains a *Mimagoniatites* marker level, partly interbedded within cross-bedded dacryoconarid calcarenites. The global Daleje Event is regionally very pronounced and led to an abrupt change to poorly fossiliferous green silty shales of the new Tizi-n-Ouourti Formation (Lower Member). The anarcestid-rich, nodular Upper Member is only locally well-developed, especially at Tizi-n-Ouourti. It is truncated at the top by the next regional Eovariscan erosion, unconformity, reworking and slumping phase that began in the Eifelian (Sk-TP 2a). The sedimentary record ended locally near the top of the Eifelian (Tizi-n-Ouourti) or a second slumping phase (Sk-TP 2b) began after the top-Eifelian Kačák Event Interval (Member 1 of new Taliouine Formation). The lower Givetian (Member 2) consists of well-bedded to nodular mudstones with some brief reworking episodes (Sk-TP 2c) near the base. The middle Givetian Member 3 includes hypoxic marls with maenioceratid faunas that strongly resemble the succession of the Tata region (Ahrerouch Formation) in the eastern Dra Valley. From the top of the middle to the upper Givetian, a third regional phase of Eovariscan block faulting (Sk-TP 3) caused the intercalation of thick, polymict conglomerate units (Member 4), followed by still poorly known Frasnian strata. Only in the east, the Asserhmo Formation is developed, a thick sequence of polymict conglomerates with reworked Ordovician to upper Famennian pebbles and isolated reef corals. It represents Sk-TP 4 and its origin may correlate with the similar breccia units of the Tinerhir region in the eastern Sub-Meseta Zone. In all of the Skoura region, a significant pre-middle Viséan erosion cut variable into Devonian or even Silurian beds. The oldest Carboniferous beds differ from place to place. At Taliouine, ca. 10 m of very fossiliferous neritic limestones with abundant brachiopods, large euomphalid gastropods, and bryozoans yielded very abundant foraminifers that provide a correlation with the middle Viséan V2a (Cf5α) fauna from Assif n´Tanzouzmine. The Skoura Devonian and Lower Carboniferous records an individual crustal development at the Meseta-Anti-Atlas transition, with lateral facies similarities fluctuating strongly in time, constrained by the repeated synsedimentary tectonic movements.

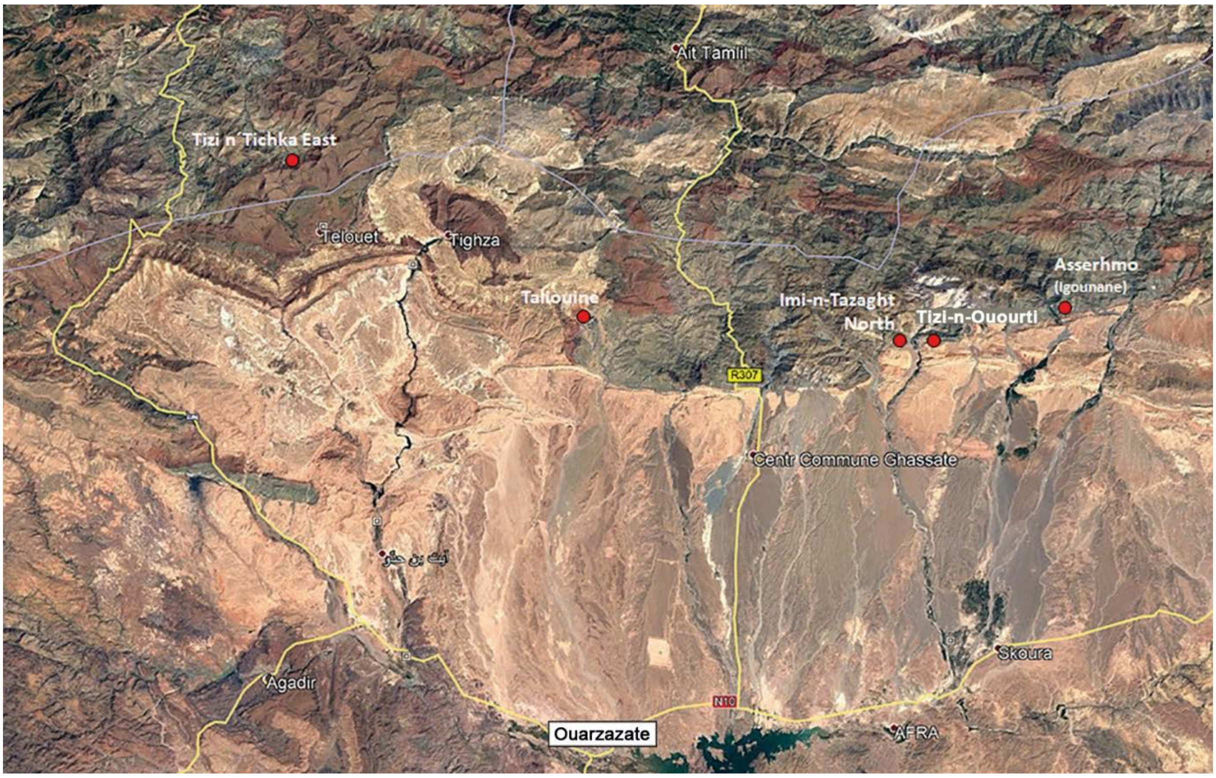

Fig. 2: Google Earth satellite image showing the position of important but each isolated Devonian localities in the wider Skoura region NW to NE of Ouarzazate and at the southern foot of the High Atlas. Separate Devonian and Viséan successions occur at Ait Tamlil in the north (picture width = 100 km).

1. Introduction

The wider Skoura region ("Pays de Skoura") includes from the NW to NE of Ouarzazate a discontinuous series of important Silurian to Lower Carboniferous successions at the southern foot of the High Atlas (Fig. 2), which are well-known since the work by Roch (1939). They represent an intermediate palaeogeographic position between the Anti-Atlas in the south (eastern Dra Valley) and the southern parts of the western Meseta to the NW, such as the Jebilet. The Palaeozoic basement of the High Atlas, including Devonian and Lower Carboniferous strata, is also exposed to the north around Ait Tamlil (e.g., Jenny & Le Marrec 1980; Es-Sadiq et al. 2014; Fig. 2). Apart from mapping, the Skoura region Devonian remained practically unstudied in terms of modern litho-, bio- and chronostratigraphy in the last 50 years, although the early work documented rich faunas (e.g., Termier & Termier 1950c). Our new "pioneer work", with the first bed-by-bed logging, and sampling for microfacies, goniatites and conodonts, concentrated on three successions, from Taliouine (= Twiline or Tiliwine) in the west, via Tizi-n-Ouourti in the middle, to Asserhmo at the eastern end. We studied briefly the Devonian just north of Imi-n-Tazaght and paid a brief visit to the Devonian east of the Tizi-n-Tichka pass, which was included in a preliminary conodont study by Lazreq & Ouanaimi (1998).

Our data enable a new lithostratigraphic subdivision, with six new formations that are partly subdivided into members. In brief, Silurian to Lochkovian black shales and limestones are assigned to the Tizi-n-Tichka Formation (with three members), Pragian to lower Emsian predominant nodular and cyclic limestones make up the Imi-n-Tazaght Formation (type-section at Taliouine, with four members), upper Emsian thick Daleje Shale equivalents (Lower Member) and overlying nodular goniatite limestones (Upper Member) are assigned to the Tizi-n-Ouourti Formation (type-section at Tizi-n-Ouourti), Eifelian to middle Givetian limestones, goniatite marls and overlying conglomerate-marl alternations form the Taliouine Formation (with four members); only locally developed, unsorted, polymict Famennian conglomerates are named as Asserhmo Formation. As previously noted (e.g., Roch 1939; Laville 1980), there are clear facies and thickness differences from west to east. For all new rock units, conodonts, ammonoids, or foraminifers (in the Viséan) provide precise ages, as a base for correlation with Dra Valley and southern Meseta successions (e.g., of the eastern Jebilet). We did not restudy the poorly known Ait Tamlil Devonian, which appears to be generally similar to the Skoura successions. However, Wafik et al. (2017) noted from the Tighmart copper mine, slightly to the north, an anticline with mostly shaly-sandy Devonian strata.

2. Regional tectonic setting

The peculiar importance of the Skoura Devonian and Lower Carboniferous lies in its position near the southern margin of the Variscides. In fact, there are similarities with the Anti-Atlas successions and only the eastern sections, especially Asserhmo, are affected by strong deformation, characterizing the "Domaine oriental" east of the oblique Skoura Fault (Ouanaimi & Petit 1992). Therefore, Pique et al. (1993) placed (most of) the Skoura Palaeozoic on the craton, south of the Atlas Palaeozoic Transform Zone (APTZ), which supposedly caused left lateral displacement in relation to the southern Meseta, which included the Ait Tamlil Devonian at the southern margin.

Hoepffner et al. (2005) introduced a "Southern Zone" of the Moroccan

Hercynides, running from the Tamelelt Inlier in the east to the Skoura Inlier in the west. An eastern continuation of the South Atlas fault was shown to run through the Skoura Palaeozoic, which would explain the west-east difference of tectonic style described by OUANAIMI & PETIT (1992). The model was refined by HOEPFFNER et al. (2006), who placed the Skoura Palaeozoic between the APTZ in the north and the South Moroccan Variscan Front (SMVF) in the south. The terminology was updated by MICHARD et al. (2008, 2010), who proposed the new Sub-Meseta Zone (SMZ, adopted here) to fall between the South Meseta Fault (SMF) in the north, replacing the APTZ, and the not well-defined South Atlas Fault (SAF), replacing the SMVF, in the south. The SMZ continues eastwards to the Tinerhir and Tinejdad regions, where the Devonian is either strongly tectonized or preserved as olistolites (e.g., MICHARD et al. 1982; FERONI et al. 2010; RYTINA et al. 2013). Recent studies showed that the Neoproterozoic basement of the Skoura Palaeozoic bears similarities with the Anti-Atlas successions (e.g., KARAOUI et al. 2019).

Our new data on stratigraphy and facies evolution document that the Skoura Lochkovian to lower Emsian had strong affinities with the eastern Jebilet, that the main upper Emsian was uniform in the whole region, and that after an Eifelian Eovariscan phase, the lower/middle Givetian was a continuation of the eastern Dra Valley. This facies development was terminated by upper Givetian Eovariscan movements as typical for all of the Meseta. The changing pattern in time emphasizes the intermediate structural position. It supports the view (BAIDDER et al. 2008) that there was no major plate tectonic boundary between the Anti-Atlas and southern Meseta in Devonian time. The local limitation of studied outcrops and complex nappe tectonics (e.g., LAVILLE 1980) reflect the post-Hercynian deformation.

3. Research History

GIGOUT (1937): Unpublished thesis on the High Atlas Palaeozoic.

ROCH (1939): Pioneer study on the Palaeozoic in the High Atlas realm (Ait Tamlil and "Pays des Skoura").

ROCH (1950): Brief summary of previous results.

TERMIER & TERMIER (1950c): First illustration of cephalopods from Taliouine and Tizi-n-Ouourti: *Hercoceras mirum* (coiled early nautiloid), *Mimagoniatites "bohemicus"* (aff. or a new species), *"Latanarcestes noeggerathi"* (auct.), *"Werneroceras ruppachense"* (probably a *Sellanarcestes*), "*Anarcestes* cf. *lateseptatus*" (clearly a *Sellanarcestes*), as well as from the Viséan at Tamzerit (*Prolecanites serpentinus*).

PETTER (1959): Description and illustration of ROCH´s *Mimagoniatites bohemicus* from Tizi-n-Ouourti, including a photo of the specimen illustrated as a drawing in TERMIER & TERMIER 1950c [the second specimen is deposited in the Paris Natural History Museum under MHNH.F.R53278].

AMBROGGI et al. (1952): Reference to ROCH´s upper Emsian anarcestid fauna.

HOLLARD (1967): Summary of the Devonian succession, based on unpublished new data by F. DUFFAUD, with an unusual record of a lower Emsian *Mimosphinctes* and a supposed record of Frasnian goniatite shales with "*Koenenites* cf. *lamellosus*" (= upper Givetian *Mzerrebites* record).

HOLLARD (1974): Occurrence of *Anetoceras* (= *Erbenoceras*) in the Skoura Emsian.

LAVILLE (1980): Monographic study on the tectonics of the "Boutonnière de Skoura", including a separation of western and eastern stratigraphic successions.

Fig. 3: View from the west on the thick Silurian black shales (Tizi-n-Tichka Formation, in the center, partly with reddish cover) overlain by a yellowish-weathering band of lower Emsian nodular limestones (Imi-n-Tazaght Formation) east of Tizi-n-Tichka, western end of Skoura Palaeozoic outcrop belt.

CHLUPÁČ & TUREK (1983): Questioning the *Mimag. bohemicus* identification of ROCH´s and PETTER´s Tizi-n-Ouourti specimens.

IZART et al. (1989): Stratigraphy and palaeogeography of the Skoura Viséan, with a new solitary rugose coral, *Caninophyllum skouraense* (nom. corr.).

LAZREQ & OUANAIMI (1998): Conodont data for the Lower Devonian of Tizi-n-Tichka.

OUANAIMI & LAZREQ (2008): Re-illustration of Tizi-n-Tichka section.

BECKER et al. (2015): Brief reference to „Antevariscan“ synsedimentary tectonics in the Lower Devonian of Taliouine.

KLUG (2017): Reference to HOLLARD´s *Mimosphinctes* record.

BECKER & ABOUSSALAM (2019): Reference to the presence of thick Daleje Shale equivalents above a *Mimagoniatites* marker limestone in the Skoura region.

BECKER et al. (2019): Note on the presence of lower Emsian goniatites at Taliouine.

CÓZAR et al. (2020a): Re-sampling and re-dating of the basal Viséan at Assif N´Tanzouzmine S of Taliouine.

BECKER & EL HASSANI (2020): Outline of conducted work in the Skoura region.

4. Devonian of Tizi-n-Tichka

Silurian and lower Devonian strata crop out east of the Tizi-n-Tichka Pass (Figs. 2-3), GPS N31°19´4.06´´, W7°19´19.72´´. Thick (> 200 m) black shales of the new Tizi-n-Tichka Formation form a wide northern slope and grade upwards into alternations with black limestones, Units a-b of LAZREQ & OUANAIMI (1998). Their Unit c consist of ca. 30 m marl-limestone alternation. A conodont fauna with *Caudicriodus postwoschmidti* and *Caud. eolatericresecens* was reported from the middle. However, *Caud. eolatericrescens* is now regarded as based on juveniles of other early icriodids (see DRYGANT & SZARNIAWSKI 2012). Therefore, it is a pity

that the Tizi-n-Tichka specimens were not illustrated. The presence of lower Lochkovian icriodid taxa (MASHKOVA 1970; CORRADINI & CORRIGA 2012) requires confirmation. The massive Unit d represents locally the higher part of the Imi-n-Tazaght Formation (see below). The conodont record of LAZREQ & OUANAIMI (1998), with *Criteriognathus steinhornensis, Caud. sigmoidalis*, and *Eolinguipolygnathus excavatus excavatus*, is in full accord with a position in the ca. middle part of the lower Emsian (see ABOUSSALAM et al. 2015, *steinhornensis* Zone). Distinctive is a local debris flow level (Unit e), followed by ca. 60 m Daleje Shale equivalents (Unit f); the originally reported "Middle Devonian fauna" refers to the upper Emsian, which was widely included in the Eifelian before that stage was refined.

5. Devonian of Taliouine

The Devonian of Taliouine can be seen from the distance as a light-grey band above the mostly Silurian black shales (Fig. 4). The village sits on a solid limestone cliff, the Upper Member of the Imi-n-Tazaght Formation, and on the locally very thick, silty greenish shales of the lower Tizi-n-Ouourti Formation (Figs. 1, 5). We measured and sampled bed-by-bed three sections, the Lochkovian-lower Emsian section in the ravine below the village (Section 1, Figs. 1, 6, GPS N31°15´23.7´´, W6°59´0.89´´), the lower-upper Emsian transition just east of the village, and the Middle Devonian ca. 1.2 km east of village (north of the new 2019 piste leading eastwards).

5.1. Silurian-Lochkovian (new Tizi-n-Tichka Formation)

A thick package (up to 300 m, LAVILLE 1980) of black shale forms the lower part of the slope below Taliouine (Figs. 1, 4), the Tizi-n-Tichka Formation ("Schistes á Graptolites" in ROCH 1939, 1950). The Silurian-Devonian transition must lie within the black shale, followed higher by an "Antevariscan" (BECKER et al. 2015) unconformity. Based on graptolites from eastern sections (WILLEFERT in LAVILLE 1980), the thick main black shales (**Lower Member**) represent the Wenlock-Pridoli.

The Lochkovian to lower Emsian was logged along the western base of the ravine (Fig. 1), with a secondary section in the eastern slope. The **Upper Member** is characterized by an alternation of black shales with laminated, fine-grained, pyritic, partly concretionary limestones, which can be more than 40 cm thick (Bed 4 = G7; Figs. 6, 7.1). Macrofauna is rare apart from a few orthocones. Bed 2 (= G5, Figs. 7.1, 8.2) was sampled without success for conodonts. It is a laminated, dark-grey, argillaceous, microsparitic mudstone with some ostracods, minute calcispheres, very fine shell filaments, dispersed silt grains, and medium-sized, thin mollusk shells, which are embedded convex-up, and which partly cracked due to the overlying sediment load. There is short radiaxial cement growing from shell surfaces. The lamination is caused by variations in dark organic matter and thin, light-grey layers of recrystallized calcisiltite. The microfacies represents a deep, subphotic, anoxic (non-bioturbated), overall hostile shelf basin facies, deposited under mostly calm conditions. The thin calcisiltite bands represent short episodes of increased turbulence and decreased influx and preservation of organic matter.

The top of the member (Beds 6a-8 = G9-10, Figs. 6, 7.2) is characterized by irregularly bedded black limestones with detrital layers and with abundant orthocones (Beds 6b = middle G9 and 8 = upper G10), which filled an erosional relief above black mud-wackestone (Figs. 7.3, 8.3). HOLLARD (1967) noted for his black Lochkovian "Unit a" bivalves (*Panenka, "Lunulicardium"*).

Fig. 4: View on the Taliouine Devonian from the distance in the south, easily marked by the light-grey upper cliff of the lower Emsian Imi-n-Tazaght Formation below intensively red Permo-Triassic beds.

Fig. 5: Thick, poorly fossiliferous, greenish, silty Daleje Shale equivalents (Lower Member of Tizi-n-Ouourti Formation) exposed at the NE end of Taliouine village, locally intersected by Permo-Triassic redbeds.

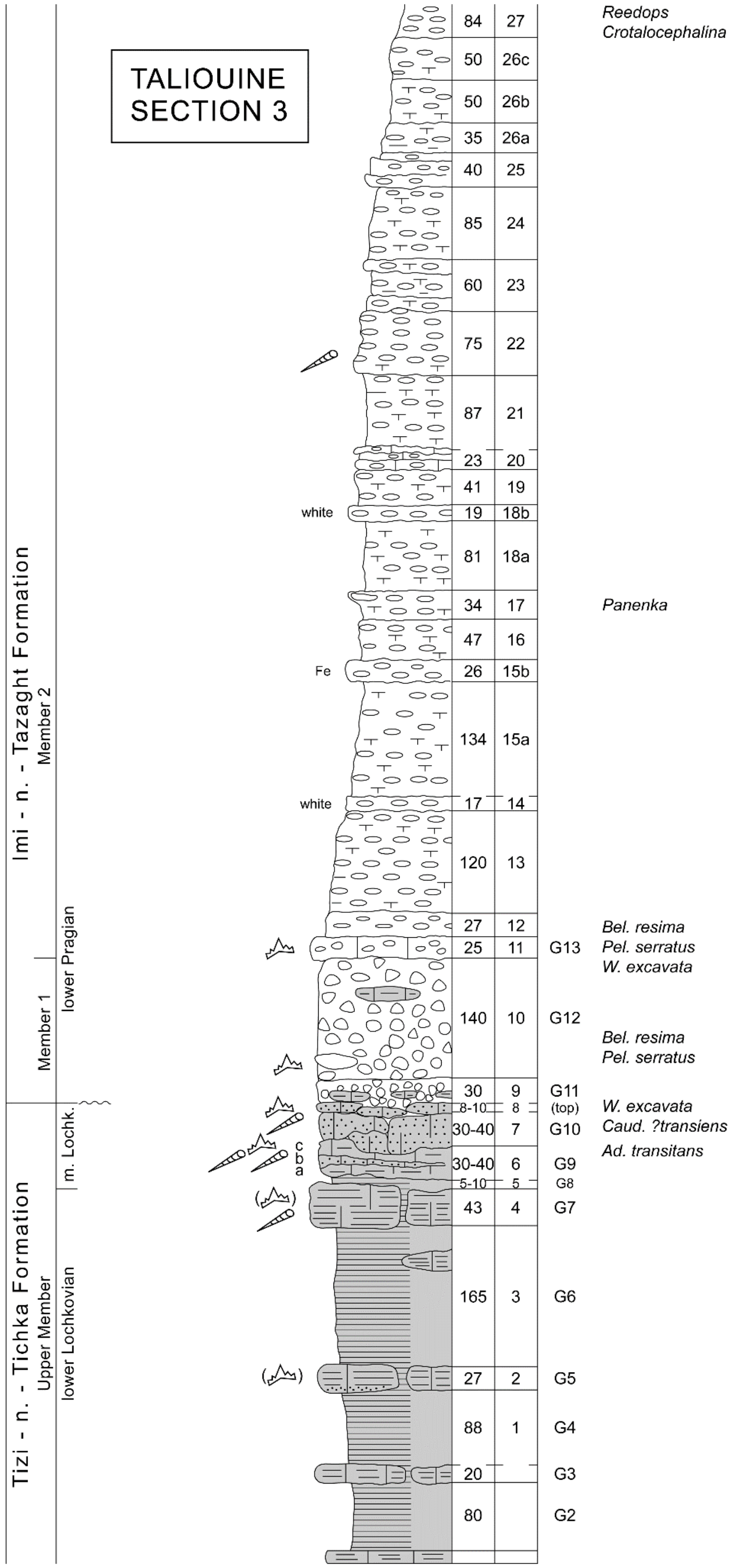

Fig. 6: Lithological succession, position of conodont samples and macrofauna in Taliouine Section 1 (Lochkovian to Pragian part) below Taliouine village (see Fig. 1). G2-13 = independent bed numbering of Greifwald Group.

Fig. 7: Field photos of the Upper Member of the Tizi-n-Tichka Formation at Taliouine, Section 1. **1.** Concretionary black limestones (Beds 0 and 2 = G3 and G5) intercalated between unfossiliferous black shale; white alum salt deriving from pyrite weathering; **2.** Concretion within Bed 3 (= G6) and the condensed, irregularly bedded top of the member (Beds G7-G10); **3.** Detail of Bed G9, showing internally (above the painted numbers) the sharp truncation of dark micrite by a bioclastic layer with abundant orthocones; **4.** Large *Deiroceras* embedded in marl between equivalents of Bed G9 (below, at hammer) and thin, lenticularly bedded bioclastic limestones of Bed G10; **5.** Excavated giant, corroded *Deiroceras* from 4., with an original total length around 1 m, high pyrite content weathered to orange-brown limonite/goethite (on future display in the Geomuseum Münster).

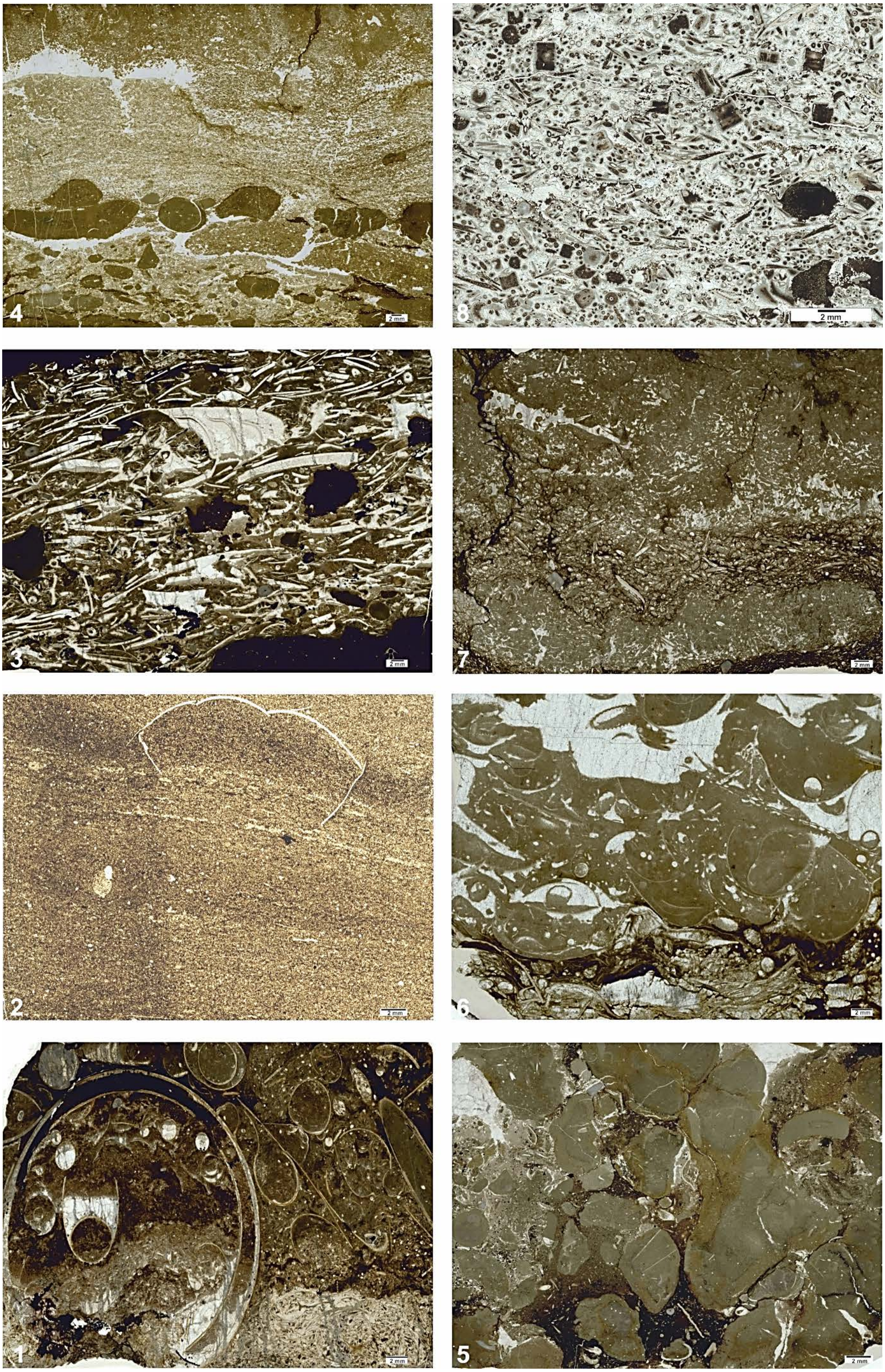
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Fig. 8: Microfacies of Lower Devonian limestones at Taliouine Section 1. **1.** Sparitic rudstone with orthocone and crinoid debris at the base, truncated by an undulating unconformity and overlain by orthocone floatstone with current orientation of variably sized specimens (slightly oblique to the thin-section plane), cone-in-cone stacking, geopetal orthosparite fillings, bivalved ostracods, and a matrix changing from bioclastic pack-grainstone at the base to organic-rich, dark, micritic wackestone at the top, Bed G10 on east slope of the ravine (top Tizi-n-Tichka Formation, Upper Member); **2.** Dark-grey (photo lightened in order to display details), argillaceous, laminated, microsparitic mudstone, with layers variably rich in dark C_{org}, minor dispersed silt content, thin (light) recrystallized calcisiltite layers, and isolated, partly broken (by sediment load), thin-shelled mollusk shells in convex-up position, Bed 2 (= G5), west side of ravine; **3.** Black, organic-rich mudstone (lower right corner) unconformably overlain by cephalopod rudstone, with mostly fractured and planar, current-oriented orthocones, variably sized, angular to torn black mudstone intraclasts reworked from below, small-sized crinoid debris, ostracods, and a dense micrite matrix, Bed 8 (= upper G10), top of Tizi-n-Tichka Formation, west side of ravine; **4.** Poorly sorted, conglomeratic, inversely graded intraclast float-rudstone with subangular to subrounded, partly flat mud-wackestone pebbles at the base, swimming in wacke-packstone matrix with styliolinids and ostracods, overlain by cross-laminated wacke-grainstone, and finally by bioturbated wackestone, Bed 9 = G11, base of Imi-n-Tazaght Formation (Member 1), west side of ravine; **5.** Coarse conglomerate, poorly sorted, non-graded intraclast rudstone with angular to rounded pebbles consisting of bioturbated pelagic mud-wacke-packstone with styliolinids and shell filaments, sitting in a variable matrix of bio-intraclast pack-grainstone with crinoid and trilobite debris, styliolinids, and shell fragments, which was locally washed out or impregnated by dark ferro-manganese minerals; note the concentric weathering of larger pebbles, Bed 10 = G12, Member 1 of Imi-n-Tazaght Formation; **6.** Rudstone with wavy-bedded, mollusk debris sitting in organic-rich wackestone or sparite matrix, overlain by bioturbated mollusk floatstone with ostracodes and dense micrite matrix, with geopetal filling of bioclast interspaces and orthocones by blocky, late diagenetic orthosparite, Bed 27, lower half of Member 2 of Imi-n-Tazaght Formation; **7.** Alternating, flaser-bedded, bioturbated nowakiid wacke- and packstone with minor crinoid debris and micrite matrix that has partly been washed out; the thin packstone layer shows cone-in-cone stacking, current-orientations, and lies above an undulating erosional surface, indicating episodic winnowing and reworking within a contour-current regime, base of Member 3 of Imi-n.-Tazaght Formation; **8.** Styliolinid-crinoid grainstone with ferro-manganese impregnations of clasts and bimodal orientation of the sand-sized cones (from left to right and normal to the thin-section plane), caused by deep-marine bottom currents during peak-flow conditions, Taliouine Section 2, top of Member 4 of Imi-n-Tazaght Formation (see Fig. 17.5).

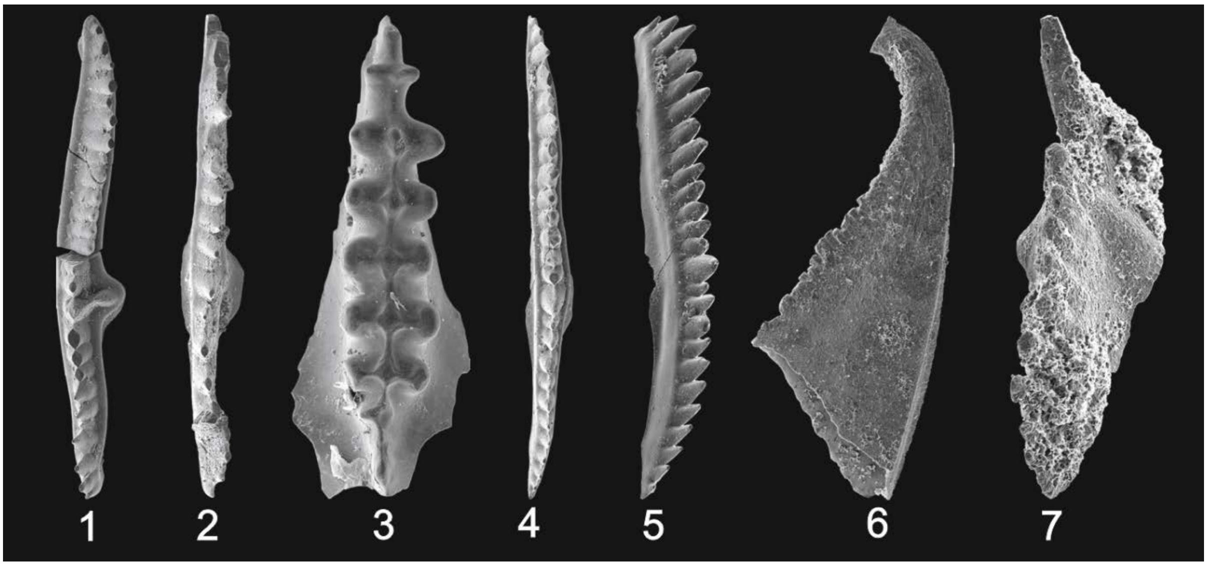


Fig. 9: Lochkovian and Pragian conodonts from Taliouine Section 1; GMM B4C.2.149-154. **1.** *Wurmiella* aff. *wurmi*, with well-defined, small side node, eastern slope, upper Bed G10, x 25; **2.** *Wurmiella wurmi*, eastern slope, upper Bed G10, x 45; **3.** *Caudicriodus ?transiens*, identified due to the number of rows with distinctive nodes and the gently widening basal cavity, posterior part broken off, Bed 8 (= upper G10), x 60; **4-5.** *W. wurmi*, Bed 8 (= upper G10), x 35; **6.** *Belodella resima*, Bed 9 (= G11), x 45; **7**. *Pelekysgnathus serratus*, Bed 9 (= G11), x 65.

Some of the orthocones reached a length of more than 1 m (Fig. 7.5). A longitudinal section (Fig. 10) of one of the giants proved that it belongs to the actinoceratid *Deiroceras hollardi* KRÖGER, 2008. In the Tafilalt, it characterizes a basal Emsian marker unit, the *Deiroceras* Limestone (see ABOUSSALAM et al. 2015), but the widespread genus is known to have a much lower range, down into the Ordovician. For Tafilalt *Deir. hollardi* sizes > 1.5 or even > 2.5 m have been documented or calculated; but from the lower Emsian, not from the Lochkovian (POHLE & KLUG 2018).

Fig. 10: Longitudinal section through the annuli-cyrtochoanitic siphuncle of the actinoceratid *Deiroceras hollardi* from the top of the Tizi-n-Tichka Formation at Taliouine Section 1, picture width 4 cm; GMM B6C.54.190.

A conodont sample from Bed 6c (= upper G9) yielded a single *Ancyrodelloides transitans* (Fig. 11.1), the index species of the middle Lochkovian *transitans* Zone (e.g., CORRADINI & CORRIGA 2012). The species is known from black orthocone limestones of both the Meseta (Oued Cherrat, BECKER et al. 2020a) and the eastern Dra Valley (LAZREQ & OUANAIMI 1998). Associated are broken *Wurmiella* and a probably new pelekysgnathid provisionally identified as *Pel.* n. sp. aff. *elongatus* (Figs. 11.2-3; see taxonomic appendix). Typical *Pel. elongatus* occur in the middle Lochkovian of Spain (e.g., CARLS & GANDL 1969; GARCÍA-LÓPEZ et al. 2002) and Bohemia (e.g., SLAVÍK et al. 2012), which agrees with the age of our specimens.

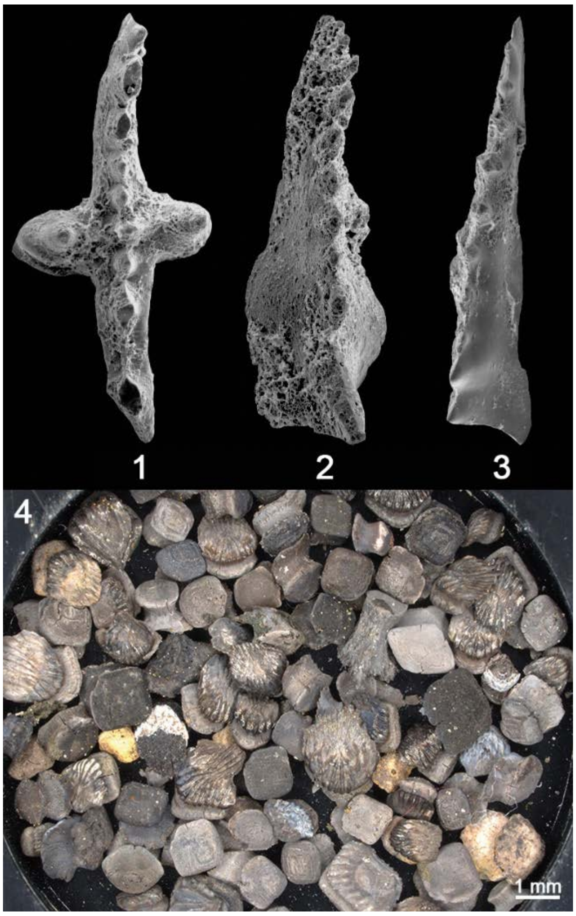


Fig. 11: Conodonts and fish scales from the top Tizi-n-Tichka Formation at Taliouine Section 1. **1.** *Ancyrodelloides transitans*, upper view, Bed 6c (= upper G9), GMM B4C.2.155, x 60; **2-3.** *Pelekysgnathus* n. sp. aff. *elongatus*, two specimens (GMM B4C.2.156-157) with upper and slightly oblique views, Bed 6c (= upper G9), x 60 and x 65; **4.** View on one of five microfossil slides filled with rhombic acanthodian scales (GMM A1C.5.2, Bed 8 (= upper G10).

In Bed 8 (= upper G10), there is a strange, elsewhere unknown (at least in pelagic facies) sudden mass influx of rhombic acanthodian

scales (Fig. 11.4). Acanthodian scales are not a normal element of black cephalopod limestones and their scales are even rare in the lower Emsian, where the large-sized *Machaeracanthus* can be common, for example in the Tafilalt (LEHMAN 1976, 1977; KLUG et al. 2008) but also at Tizi-n-Ouourti (see below). The *Machaeracanthus* scales look very different than the ones from Bed 8 but the taxonomic position of that genus is doubtful. Associated conodonts of Bed 8 (upper G10) are *Wurmiella "excavata"* auct. (10 specimens), *W. wurmi* (Figs. 9.4-5), and a *Caudicriodus ?transiens*. (Fig. 9.3). On the eastern side of the ravine, just above the marl with a giant *Deiroceras* (Fig. 7.5), detrital limestones of Bed G10 produced *W.* aff. *wurmi* (Fig. 9.1) and also *W. wurmi* (10 specimens excluding fragments).

Whilst *Caud. transiens* occurs around the lower-middle Lochkovian boundary, *W. wurmi* ranges throughout the middle-upper Lochkovian (e.g., CORRADINI & CORRIGA 2012). The absence of typical upper Lochkovian species in two samples suggests that the top of the Tizi-n-Tichka Formation is not younger than the middle Lochkovian.

The microfacies of Bed 8 = top G10 (Fig. 8.3) is complex. At the base, there is organic-rich, black, pelagic mudstone with minute calcispheres or, laterally, black ostracod wacke-packstone, mostly with single-valved ostracod debris, and with the fragment of a small-sized tabulate coral. This unit is truncated by unsorted and non-graded orthocone float-rudstone with dense, light-grey micrite matrix, deposited during a high-energy depositional event. It transported mostly crushed (Fig. 8.3) and recrystallized orthocone shells of variable size, some with dark micrite, some with orthosparite filling, small-sized crinoid ossicles, ostracods, trilobite fragments, dacryoconarids, the acanthodian scales, and intraclasts. The latter are black mudstones or middle-grey microsparitic limestones derived from below. There is finely dispersed pyrite that sometimes impregnated shells.

The top of Bed G10 on the other side of the ravine has a similar, complex microfacies (Fig. 8.1) but the orthocones are partly better preserved. A high current regime led to cone-in-cone stacking and parallel orientations. At the base, there is a rudstone composed of orthocone debris, with ostracods, crinoid ossicles, rare trilobite fragments, and largely washed out micrite matrix. Above an undulating unconformity, an orthocone floatstone follows. Right above the erosional surface, the matrix is bioturbated, organic-rich ostracod-shell debris packstone with partly preserved micrite matrix. The latter persisted in the middle part, grading upwards into black, very organic-rich wackestone with ostracods, crinoids, and calcispheres. The filling of the orthocones is also variable, ranging from geopetal orthosparite filling to middle-grey wackestone with ostracods and abundant fine pyrite dispersed in dense micrite matrix, microsparitic wackestone, to bioturbated wackestone with styliolinids. This variability suggests that cephalopods were washed together from different sources.

The erosive unconformities within the beds, erosion of unconsolidated intraclasts and fossils from variable underlying units, planar to wavy deposition of coarse shell debris without removing the micrite matrix, and the lack of sorting or grading point to reworking followed by gravity-induced rapid sedimentation from turbulent density flows. This is supported by the irregular bedding and slumping (Fig. 13.3), as evidence for syndepositional seismic activity ("Antevarican" phase, BECKER et al. 2015).

5.2. Pragian to lower Emsian (new **Imi-n-Tazaght Formation**)

Pragian to lower Emsian nodular limestones are assigned to the new Imi-n-

Tazaght Formation, which is subdivided into four members. The name stems from the village in the upper, eastern reaches of the Oued Tagraga, between localities Imi-n-Tazaght North and Tizi-n-Ouourti (Fig. 2), which both have good outcrops of the formation. However, we select Taliouine as the type locality, where we have logged bed-by-bed the complete formation and where Member 1 at the base is best developed. The main part of the formation is bioturbated (nodular to flaser-bedded) and strongly cyclic (Figs. 6, 13), representing perhaps Milankovitch cyclicity controlled alternations of carbonate versus clay/marl deposition. Faunas are shallow pelagic, with benthos consisting of trace fossils, various trilobites and *Panenka* bivalves, with often large orthocones and rare goniatites as nekton, and abundant dacryoconarids as calcareous plankton. Despite this, the conodont record is extremely sparse. Coarsening upwards is indicated by a trend towards thicker interbeds of pack- and grainstone within the cyclic-bedded limestones.

5.2.1. Conglomeratic Member 1

Member 1 of the Imi-n-Tazaght Formation consists of two beds (Beds 9-10 = G11-12, 1.7 m, Fig. 6) of yellowish to light grey weathering, poorly sorted, non-graded conglomerate (Figs. 8.1, 12, 13.1). Pebbles are a few mm to ca. 10 cm large, subangular to subrounded, partly flat (Fig. 8.4). Bed 9 (= G11) shows a complete grading upwards from sudden intraclast redeposition to background "pelagic rain" accumulation (Fig. 12). In the lower third, up to 4 cm large pebbles of mud-wackestone with styliolinids, shell filaments, and some ostracods float in a fine matrix of wacke-packstone with ostracods, styliolinids, subordinate crinoid debris and shell filaments, interrupted by sparite fenestrae that also fill large interspaces between pebbles. In the upper part of the conglomeratic interval, the micrite has been washed out more strongly and there is debris from trilobites, crinoids, mollusks, ostracods, as well as fine intraclasts. A single small clast consists of *Rectangulina*, a small-sized algal colony of uncertain affinities that is typical for pelagic limestones (e.g., House et al. 2000; Becker et al. 2016).

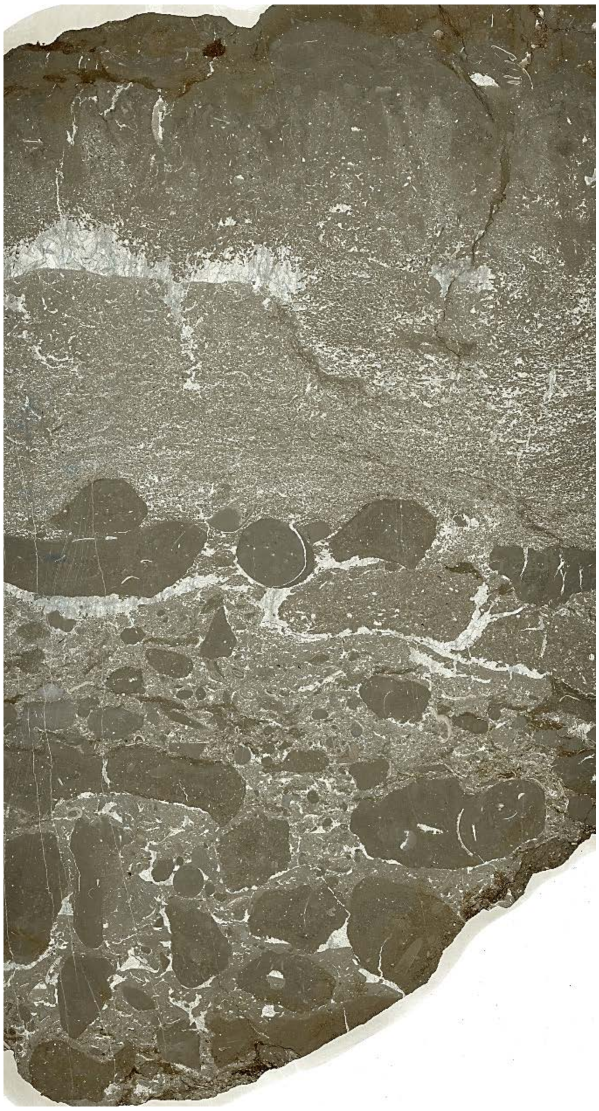


Fig. 12: Complete thin-section and depositional sequence of the lower conglomerate (Bed 9 = G11) at the base of the Imi-n-Tazaght Formation (Member 1) at Taliouine Section 1. Unsorted and non-graded conglomerate (intraclast floatstone) with dacryoconarid mud-wackestone pebbles, increasing washing out of the micrite matrix and sparite replacement, overlain by wavy-laminated styliolinid grainstone with *Stromatactis*, grading into styliolinid wackestone and bioturbated mudstone at the top, the normal pelagic background sediment; picture width 6 cm.

The conglomeratic interval is overlain by wavy-laminated, fine-grained peloid-styliolinid grainstone indicating decreasing but persisting bottom current energy. Intercalated typical *Stromatactis* near the top indicate interruption phases. Above these, there is a gradual transition into wacke- to mudstones with decreasing amounts of styliolinids, ostracods, shell filaments, and increasing bioturbation and flaser-bedding at the top. Along diagenetic dissolution seams microsparitization proceeded.

The conglomerate microfacies of Bed 10 (= G12) is different (Fig. 8.5). Subrounded to subangular, rarely well-rounded pebbles show no sorting or grading. The clasts consist mostly (ca. 80 %) of poorly-preserved, middle-grey, bioturbated styliolinid wacke-packstone with shell filaments and rare ostracods. Subordinate are middle-grey mud-floatstones with few styliolinids and rare orthocones or large mollusk fragments. Rather peculiar are concentric seams of very fine pyrite, a diagenetic feature that obviously postdated early lithification and pre-dated the redeposition. The matrix is rather heterogeneous, ranging from blocky orthosparite to light-/middle-grey bio-/intraclast packstone with debris of crinoids, styliolinids, trilobites, and mollusks. As diagenetic features, there are abundant idiomorphic pyrites and microsparitization. In some parts with dacryoconarids and calcispheres, there is a massive impregnation by ferro-manganese minerals.

In both beds there are subordinate reworked black mudstone clasts of variable size from the underlying upper Tizi-n-Tichka Formation (Fig. 13.2). The dominant clasts made of light- to middle-grey mud- to packstone pebbles prove that the organic-rich, hypoxic Tizi-n-Tichka facies was originally overlain by oxic pelagic facies. Conodonts date them as lower Pragian, based on rare *Pelekysgnathus serratus* (Fig. 8.7) and *Belodella resima* (Fig. 8.6) from the base of Bed 10 (= base G12). The first is the index species of the *serratus* Zone recognized in the lower Pragian of Bohemia (SLAVÍK 2004). It is possible that the marked facies change was caused by the global regression at the Lochkovian-Pragian boundary (e.g., TALENT et al. 1993; WALLISER 1996; BECKER et al. 2020a). However, it seems that the upper Lochkovian is missing in the Skoura region. Since we do not know whether our *Pel. serratus* came from pebbles or the conglomerate matrix, the reworking and re-sedimentation occurred either low or ca. in the middle of the Pragian. The lack of sorting, strong size contrast between pebble size and fine matrix, and the polymict pebble composition suggest deposition from two submarine density flow events. They reflect a re-activation of the fault zone that previously caused the top middle Lochkovian slumping. Block faulting of Pragian age is not common in the Meseta or Anti-Atlas.

5.2.2. Nodular Member 2

Member 2 consists of 47.5 m, cyclic, yellowish to light-grey, marly nodular shales and limestone with abundant orthocones (especially in the lower part, Fig. 13.4), pelagic bivalves (mostly *Panenka*, Fig. 15.2), trilobites (Fig. 14), and pyritic intervals marked by white sulfate weathering minerals (Figs. 6, 13.1). ROCH (1939, 1950) misleadingly called the unit “Calcaires du Ludlow”. HOLLARD (1967) recognized it as Unit b (“marno-calcaires grumeleux à tentaculites”, with phacopids), and LAVILLE (1980) used the term “marno-calcaires beige”. A basal more solid nodular limestone (Bed 11 = G13; Fig. 6) yielded four *Pel. serratus*, associated with *Wurmiella “excavata”* auct. (12 specimens), and *Belodella resima* (two specimens). This suggests that the member begins higher in the lower Pragian, probably directly after the conglomerate deposition.

Fig. 13: Field photos of the Lochkovian-Pragian transition at Taliouine Section 1. **1.** Truncation of the top of the Tizi-n-Tichka Formation by the coarse-grained Eovariscan conglomerate at the base of the Imi-n-Tazaght Formation (Member 1), main section, west side of the ravine; **2.** Large slab of black limestone within the conglomerate, reworked from the top Tizi-n-Tichka Formation; **3.** Poorly preserved giant orthocone with moderately dense septal spacing and large apical angle (unlike as in *Deiroceras*) from upper Pragian nodular limestones (lower part of Member 2 of Imi-n-Tazaght Formation); **4.** Eastern slope of the ravine, showing slumping of the Upper Member of the Tizi-n-Tichka Formation, followed by the layer of large *Deiroceras* (of Fig. 5.4) and subsequent, thin- to wavy-bedded black limestones (Bed G10) that are sharply overlain by the coarse Pragian conglomerate (Member 1 of Tizi-n-Tazaght Formation).

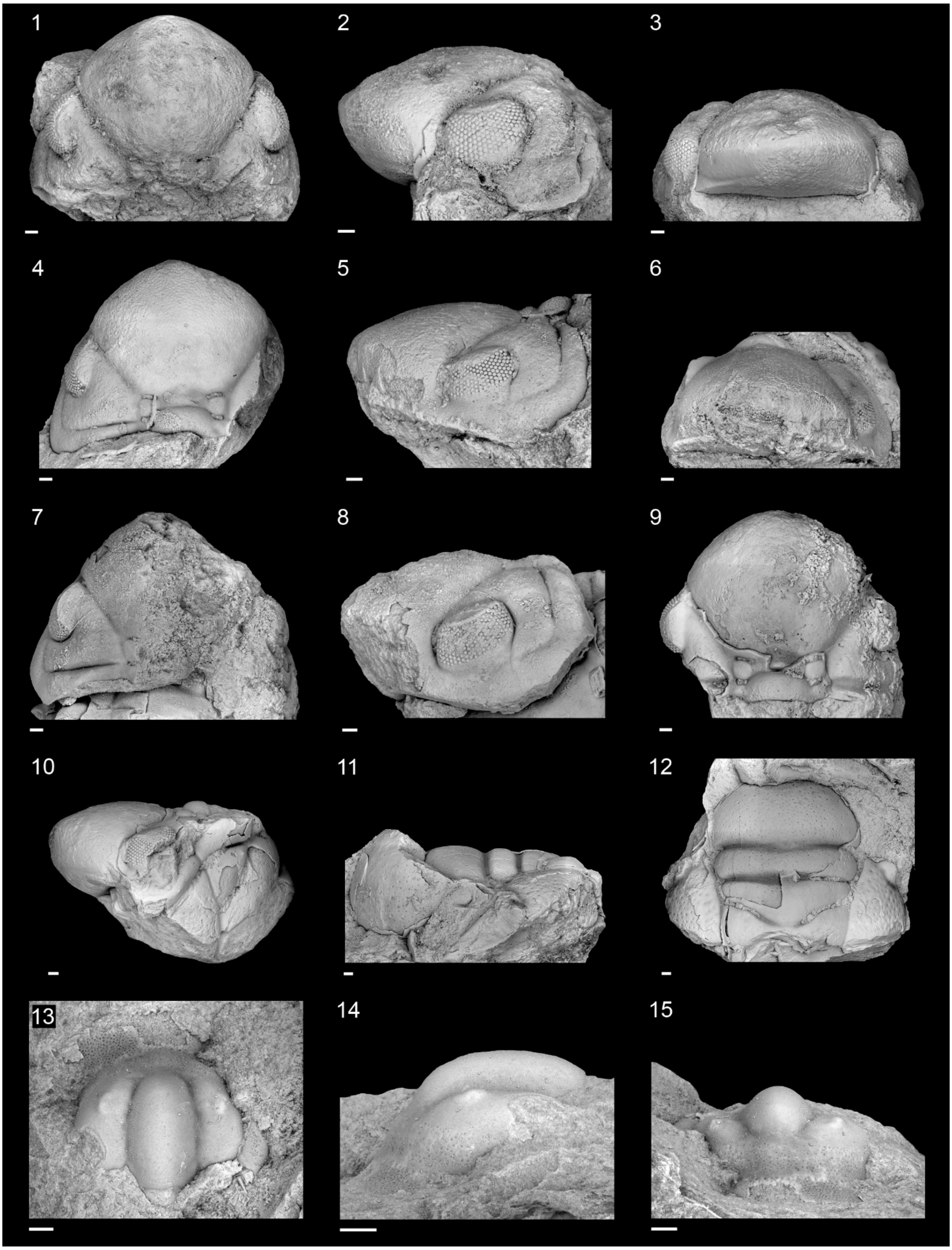


Fig. 14: Trilobites from the Pragian (loose from the higher part of Member 2 of Imi-n-Tazaght Formation, Section at Taliouine; scale bar = 1 mm. **1-3.** *Reedops* cf. *cephalotes hamlagdadianus* ALBERTI, 1983, GMM B7A.12.1; **4-6.** *Reedops* n. sp., GMM B7A.12.2; **7-8.** *R.* cf. *maurulus* ALBERTI, 1970, GMM B7A.12.3; **9-10.** Nodule with *R.* cf. *cephalotes hamlagdadianus* (GMM B7A.12.4) and *Cheirurus (Crotalocephalina)* sp. aff. *gibbus auster* ALBERTI, 1970 (GMM B7A.12.5); **11-12.** *Cheirurus (Crotalocephalina)*? sp., GMM B7A.12.6; **13-15.** *Harpes* sp., GMM B7A.12.7.

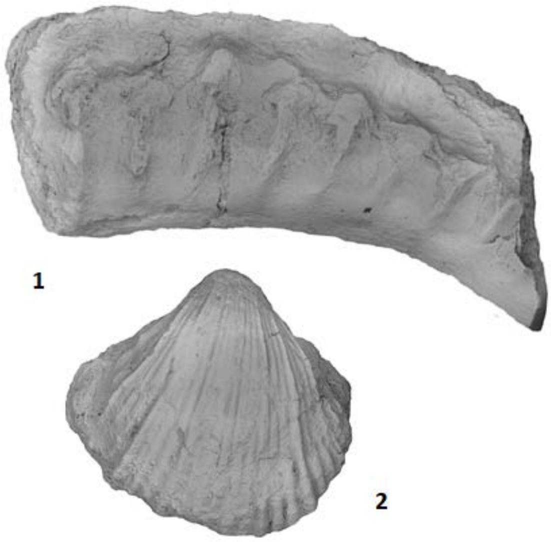


Fig. 15: Mollusk molds from the Imi-n-Tazaght Formation at Taliouine Section 1. **1.** Fragment of last gyroconic whorl of an *Erbenoceras advolvens*, Bed G177, leg.O. Mayer, lower Emsian, lower part of Member 3, GMM B6C54.191. **2.** Small-sized *Panenka* sp. with uneven sharp ribbing, Member 2, Bed 40, upper Pragian, GMM B6A.37.2.

The interval from Beds 27 to 42 yielded various trilobites. There are three species of phacopids, *Reedops* cf. *cephalotes hamlagdadianus* (Figs. 14.1-3, 9-10), *Reedops* n. sp. (Figs. 14.4-6), and *R.* cf. *maurulus* (Figs. 14.7-8). The first is a typical Pragian form of the Tafilalt (Alberti 1983), the third a Pragian species of the Rabat-Tiflet Zone (Alberti 1970). Cheirurids, such as *Ch. (Crotalocephalina) gibbus*, are typically associated (Alberti 1970); the subspecies identification of the Taliouine representative (Figs. 14.9-12) is not clear. The incomplete *Harpes* (Figs. 14.13-15) is an interesting record because the Pragian Harpetida of Morocco are still insufficiently known. In terms of lithology and trilobite assemblages, there are similarities of the Taliouine trilobite levels with the Pragian *Reedops* Limestone of Hassi Nebech in the eastern Tafilalt (Becker & Aboussalam 2015, p. 114).

The loose teicherticeratid collected from around Bed 27 is much younger and was probably derived from above. *Teicherticeras* is rare in Morocco but has been recorded from LD III-C (De Baets et al. 2010; Aboussalam et al. 2015). The position of the Pragian/Emsian boundary is currently placed roughly at the top of Member 2.

Fig. 16: Strongly cyclic Imi-n-Tazaght Formation in the northern end of the ravine of Taliouine Section 1, with Lahssen Baidder and Ahmed El Hassani for scale, the latter sitting on beds with large orthocones.

Fig. 17: Bimodal current orientation of large orthocones at the top of Member 3 of the Imi-n-Tazeght Formation just east of Taliouine village.

The microfacies of Bed 27 shows that long episodes of calm pelagic sedimentation were occasionally interrupted by periods with weak bottom-currents (contourites). High-energy conditions resulted in the fragmentation of mollusks, forming rudstones of recrystallized shells, and with subordinate trilobite debris. The matrix is organic-rich micrite with calcispheres or sparite. The overlying mollusk

floatstone (Fig. 8.6) is characterized by abundant geopetal orthosparite fillings of shells or interspaces and a dense micrite matrix with ribbed nowakiids, fine shell filaments, ostracods, and trilobites.

5.2.3. Cyclic Member 3

This unit was called in ROCH (1939, 1950) as "Calcaires eifeliens", in HOLLARD (1967) as "calcaires bleus á entroques et polypiers, terminus par des calcaires à *Panenka*, and marnes et marno-calcaires à tentaculites avec un banc lie-de-vin" (Units c-d), and in LAVILLE (1980) as "calcaire à entroques – Emsien". The thickness is in the range of 20-25 m (Figs. 1, 16). Typical are light-grey, strongly cyclic, flaser-bedded, bioturbated bioclastic limestones that are poor in macrofauna in the main cliff. Well-exposed bedding planes covered by bimodally oriented large orthocones (Fig. 17) or *Panenka* are typical at the top, just east of the village. The cyclicity is caused by subtle variations in the carbonate mud/skeletal grain ratio.

A conodont sample from the member base yielded *Caudicriodus celtibericus*, which ranges from the upper Pragian into upper parts of the lower Emsian (*inversus* Zone, ABOUSSALAM et al. 2015). The whorl fragment of a subadult *Erbenoceras advolvens* was collected in-situ in Bed G177 (Fig. 15.1), laterally to the main ravine, from a nodular interval in the lower part of Member 3. The species ranges in the lower Emsian from LD III-B to C (e.g., KLUG 2001; DE BAETS et al. 2010; BECKER et al. 2019).

The microfacies of the basal bed (Fig. 8.7) shows nowakiid wackestone with shell filaments, interrupted by sharply bounded layers of nowakiid packstone with cone-in-cone stacking, bimodal current alignments, and a minor amount of crinoid debris. The dense, middle-grey micrite matrix has partly been washed out, creating small sparite fenestrae. In comparison to Bed 27 (mollusk rudstone), the cyclic occurrence of nowakiid packstone layers, which show a systematic thickening upwards, indicate increasing bottom-current intensity. The increase of bottom currents prevented the settling of clay and coincides with a regressive phase, which is in accord with the eustatic trend high in the lower Emsian (e.g., BECKER et al. 2020a).

5.2.4. Member 4

The ca. 5 m thick Member 4 was not separated by ROCH (1939, 1950) from Member 3 but recognized as Unit e ("calcaires à *Panenka*") by HOLLARD (1967). It includes two subunits. A lower nodular limestone exposed in Section 2 (Fig. 18.1) contains abundant *Mimagoniatites* (Fig. 18.2), orthocones, *Pananeka* mass occurrences (Figs. 18.3), and current-related shell hash beds with cladochonid tabulate corals, small orthids, crinoid debris, styliolinids, and striatostyliolinids. The microfacies of Bed A (Fig. 19) is a flaser-bedded, strongly bioturbated/intercalated mixture of dark dacryoconarid (mostly nowakiids) and light-grey mollusk debris wacke-packstone with rare gastropods.

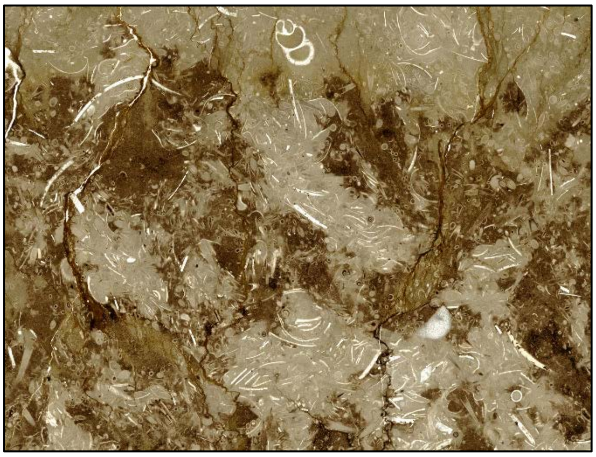


Fig. 19: Microfacies of the lower part of Section Taliouine 2, Bed A (lower subunit of Member 4 of Tizi-n-Ouourti Formation): strongly bioturbated (mixed) wacke-packstone, variably with abundant dacryoconarids and high C_{org}, or shell filaments and a gastropod (picture width = 32 mm).

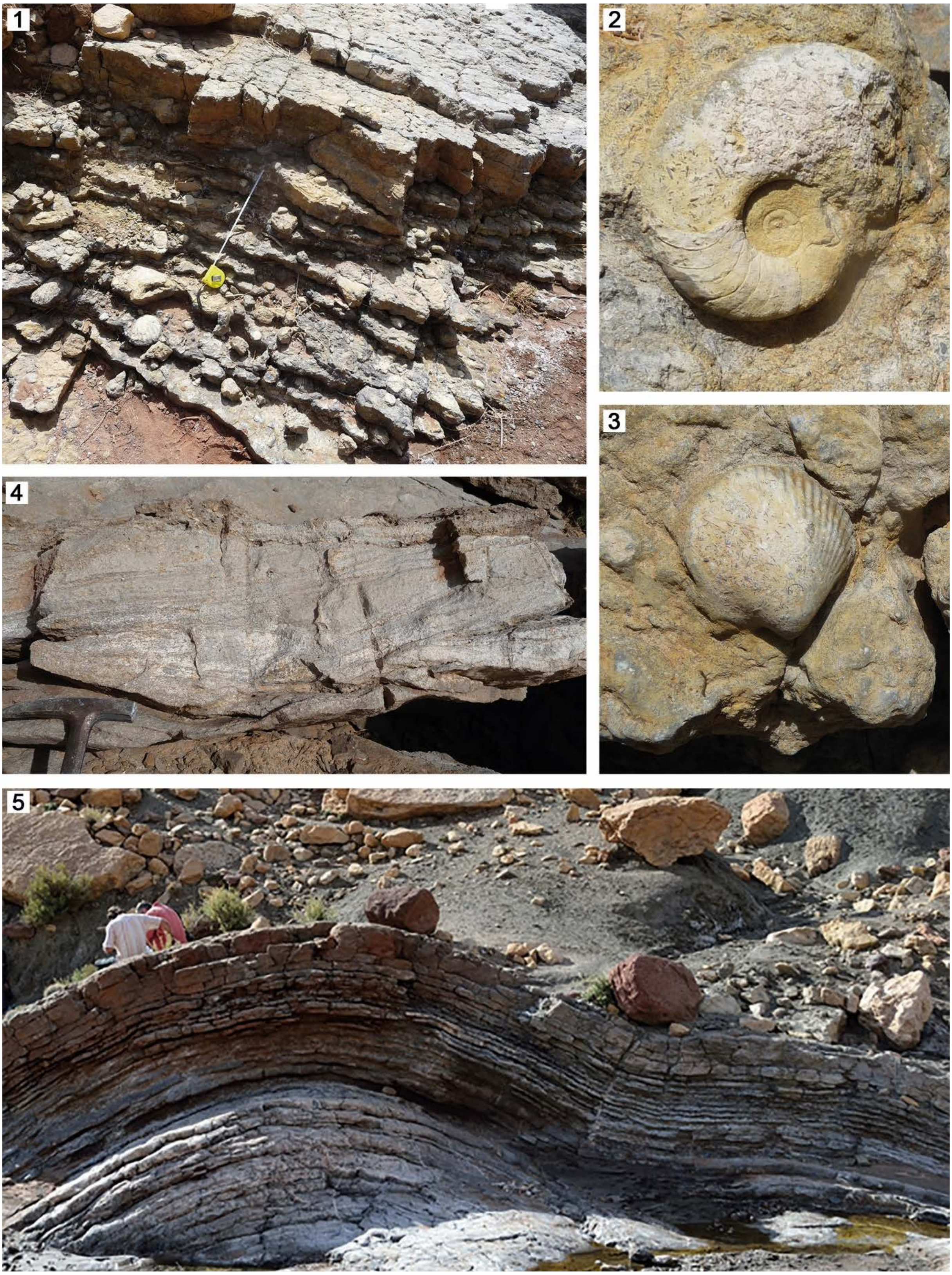


Fig. 18: Field photos of Member 4 of the Imi-n-Tazaght Formation. **1.** Thin-bedded, very fossiliferous nodular limestones of Section 2, lower subunit with goniatites; **2.** *Mimagoniatites* sp., strongly compressed species, in-situ from thin Bed E, ca. at the end of the measuring stick in 1., 4 cm diameter, GMM B6C.54.192; **3.** Locally abundant finely ribbed species of *Panenka* from the same bed, length = 3 cm, GMM B6A.37.2; **4.** Cross-bedded styliolinid grainstone (contourite) from the upper subunit east of Section 2; **5.** "Folding" of the top part of the Imi-n-Tazaght Formation and Member 4 normal to the overall Variscan folding, perhaps caused by buckling adjacent to normal faults and against the soft overlying shales of the basal Tizi-n-Ouourti Formation.

The *Mimagoniatites* was assigned by HOLLARD (1967) to *Mim*. cf. *zorgensis* but our specimens suggest that it is a different, strongly compressed species, not *Mim. fecundus*, the valid senior synonym of *Mim. zorgensis* (CHLUPÁC & TUREK 1983). *Mimagoniatites* defines genozone LD III-D near the top of the lower Emsian (BECKER & HOUSE 1994). In the Anti-Atlas, a late lower Emsian epibole of the genus can be found from the Tafilalt Platform to the eastern (JANSEN et al. 2004a) and western Dra Valley (BECKER et al. 2008; BECKER & ABOUSSALAM 2011; ABOUSSALAM et al. 2015). Within Member 4, F. DUFFAUD found the first North African *Mimosphinctes* (recorded by HOLLARD 1967) but the specimen has never been figured or described (see KLUG 2017), and its whereabouts are unknown. *Mimosphinctes* is the index genus of LD III-E (BECKER & HOUSE 2000d). Therefore, Member 4 comprises the complete LD III-D/E interval, as the *Mimagoniatites* Limestone of the eastern Anti-Atlas (BECKER et al. 2019). Despite the pelagic facies, a conodont sample was barren, which fits the poor Tafilalt conodont record of the same interval (ABOUSSALAM et al. 2015). The top bed of the short Section 2 shows again numerous large, current-oriented orthocones.

Following the beds on strike to the east, to the small oued that feeds the ravine of Section 1, there are good exposures of the top of the formation and member (upper subunit). It is characterized by cross-bedded dacryoconarid grainstones (Fig. 18.4), which represent calcarenitic contourite deposits formed at conditions of vigorous bottom currents. A conodont sample from the top limestones of Fig. 18.5 was, again, barren. The microfacies shows a nowakiid grainstone with a minor amount of crinoid, mollusks, and trilobite debris (Fig. 9.8). There is fine syntaxial cement growth around nowakiid cross-sections while crinoid pieces are surrounded by rim cements. Deep impregnation or coating by ferro-manganese minerals is very common. The main matrix is late diagenetic blocky orthosparite.

Towards the east, normal faults cause an upslope repetition of the succession. The upper subunit forms wide gentle “folds” (Fig. 18.5) with axes normal to the direction of the regional Variscan folds. These are interpreted to have resulted from buckling associated with the normal faulting. The overlying green shales provided no rheological resistance to the seismic energy; the folds, but not the faults, continue in the shale unit.

5.3. Upper Emsian (new **Tizi-n-Ouourti Formation**)

All upper Emsian strata are assigned to the Tizi-n-Ouourti Formation, which is well exposed at the name-giving type locality (see below). At Taliouine, the thickness is considerably higher but the upper part is incomplete and strongly affected by Eovariscan synsedimentary movements and slumping.

5.3.1. Lower Member (greenish shale)

The limestones of the Imi-n-Tazaght Formation are sharply overlain by dark-grey to greenish-grey, silty, poorly fossiliferous, resistant shales (Figs. 18.5, 20), the Lower Member of the Tizi-n-Ouourti Formation. It forms rather steep slopes and can be seen from the distance as a lithostratigraphic marker (Fig. 1). Rare fossils are preserved as siderite nodules, which suggest eutrophic and hypoxic conditions. There are incomplete orthocones and a solitary rugose coral (deep-water type), which do not provide a biostratigraphic age. According to the sketch in LAVILLE (1980), a thickness in the scale of 300 m can be assumed (see the same value given for Unit g of HOLLARD 1967). ROCH (1939, 1950) noted the lack of fossils but called the unit “Schistes eifeliens”. It has to be recalled that upper

Emsian strata where still included in the Eifelian at his time. Based on the faunas from right below and above, there is no doubt that the Lower Member is an equivalent of the Bohemian Daleje Shales and especially of the lithologically similar lower member of the Amerboh Formation of the Tafilalt (e.g., BECKER et al. 2013, 2018a: Unit K).

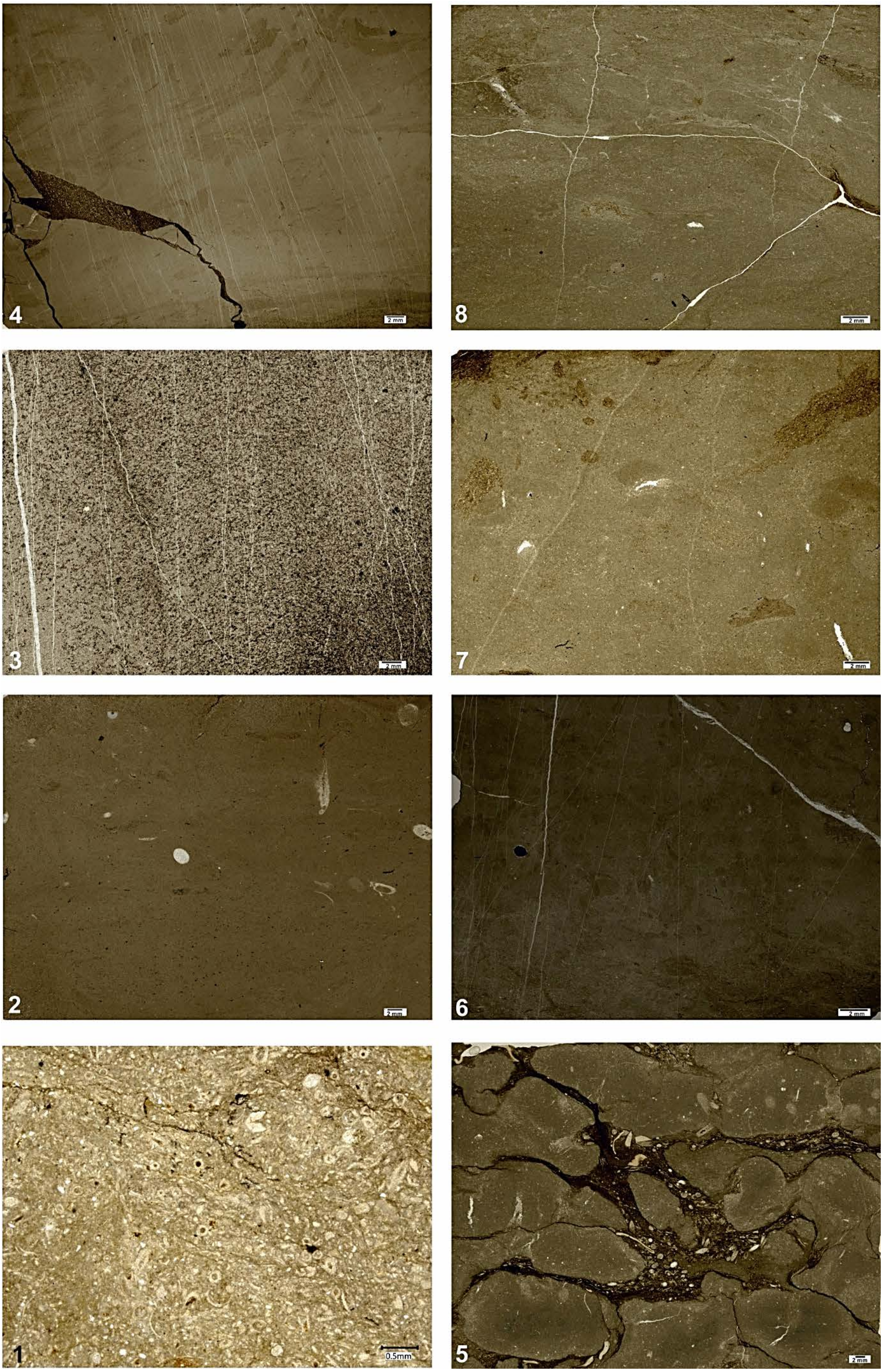
Fig. 20: Thick succession of almost unfossiliferous green, silty shales forming the Lower Member of the Tizi-n-Ouourti Formation ca. 600 m east of Taliouine.

5.3.2. Upper Member (Anarcestid Limestone olistolites)

The shales of the Lower Member become gradually dark-grey. Our Section 3 lies in a narrow ravine starting from the new piste to the east, ca. 1.2 km northeast from the last houses of Taliouine village (at N31°16´00.64´´, W6°58´41.89´´). On the northeastern ravine side, numerous small blocks of light- or dark-grey limestone and isolated fossils (olistolites) lie without any orientation in the upper part of the Tizi-n-Ouourti Formation and form a slump unit, the Upper Member. In the middle part of the steep southwestern slope, there is a large, internally bedded glide block of upper Emsian limestone. A conodont sample from its middle part yielded ten specimens of *Linguipolygnathus bultyncki*, an alternative index species of the *serotinus* Zone, which is also more frequent than the nominal zonal species in the eastern Anti-Atlas (ABOUSSALAM et al. 2015). The suite of loosely collected macrofossils adds to the similarity with the *Anarcestes* Limestone of the Tafilalt and *Sellanarcestes*-rich limestones (LD IV-D_1, *An. crassus* Subzone) of the Dra Valley (BECKER et al. 2004c, 2004d; EBBIGHAUSEN et al. 2004, 2011):

"Latanarcestes noeggerathi" auct. (Figs. 20.5-6; see TERMIER & TERMIER 1950c, pl. 145, figs. 4-6; possibly = *An.* cf. *subnautilinus* in ROCH 1939)
Sellanarcestes wenkenbachi
Sellanarcestes applanatus (Figs. 20.1-2; probably = *An.* cf. *lateseptatus* and *An.* cf. *crispus* in ROCH 1939, = *Werneroceras ruppachense* in TERMIER & TERMIER 1950c, pl. 145, figs. 15-16, = *An.* cf. *lateseptatus* on pl. 146, fig. 1)
Anarcestes simulans
Anarcestes crassus
Achguigites tafilaltensis
Panenka div. sp. (Fig. 20.7)
large orthocones (Figs. 20.3-4, *Temperoceras*)
solitary Rugosa
phacopid trilobites (poorly preserved)

Fig. 21: Representative macrofauna from the upper Emsian of Taliouine, Section 3, all figures in natural size. **1-2.** Mature *Sellanarcestes applanatus*, lateral and adoral views, body chamber occupying the full last whorl, leg. A. El Hassani, GMM B6C.54.193; **3.** Large orthocone with central siphuncle, lateral view GMM B6C.54.194; **4.** Septal view of a very similar second fragment, GMM B6C.54.195; **5-6** "*Latanarcestes noeggerathi*" auct., lateral and ventral views, GMM B6C.54.196; **7.** Large *Panenka* sp., GMM B6A.37.4.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5
2 mm

Fig. 22: Microfacies of carbonates from Talioúine Section 3, partly enlightened in order to display details. **1.** Bioturbated, recrystallized dacryoconarid wacke-packstone with shell filaments and thickly encrusted nowakiids, upper Emsian glide block in the SE slope of Talioúine Section 3 (enlightened); **2.** Pelagic mudstone with rare shell filaments, crinoid ossicle, and a sparite-filled orthocone, Bed 4; **3.** Strongly recrystallized (microsparitic) and organic-rich mudstone, almost without fossils, Bed 5 (enlightened); **4.** Mudstone with discrete burrows filled by darker carbonate mud, Bed 9 (enlightened); **5.** Nodular "conglomerate" (intraclast rudstone formed by in-situ brecciation), with subrounded mudstone pebbles and interspaces invaded by coarser-grained wacke-packstone matrix with ostracods and other bioclasts, impregnated by ferro-manganese minerals, Bed 17; **6.** Dark brownish-grey, organic-rich, bioturbated mudstone, Bed 28a (enlightened); **7.** Light-grey bioturbated mudstone with distinctive burrows in the upper part, filled by darker, more organic-rich mud, Bed 39b; **8.** Middle-grey, bioturbated, partly flaser-bedded mudstone, Bed 44c.

Talioúine Section 3																
conodont zones	*serot.*	*hemiansatus*			*timorensis*								*rhen./varcus to ansatus*			
Bed and sample no.	U. Ems	4	7	9	15	17	28a	39b	44a	46	55	67	71	81	kgl1	kgl2
L. bultyncki	10															
L. linguiformis		1			13	6			0.5			4	2	3		4
L. weddigei		1														
Po. hemiansatus		1			4											
Linguipolygnathus sp.			0.5							0.5						
Po. pseudofoliatus				3	11											
I. cf. *difficilis*					4											
I. obliquimarginatus						3	1	1?								
Po. parawebbi									0.5			1			1	
Po. timorensis												2	1			1
I. regularicrescens												1?			2	
Po. varcus															1	2
Po. rhenanus															1	
I. difficilis															2	
Bel. resima															2	
Oz. plana																1
total conodonts	10	3	1	3	32	9	1	1	1	1	0	8	3	3	9	9

Tab. 1: Conodont ranges in the upper Emsian to middle Givetian at Talioúine Section 3.

ROCH (1939) added a pleurotomariid gastropod and the early nautiloid *Hercoceras mirum*, which is better known from the upper Emsian of Bohemia (TUREK 2007). The microfacies of the middle part of the large glide block is a dark-grey, bioturbated dacryoconarid wacke-packstone with some mollusk filaments, crinoid debris, and rare bryozoan fragments (Fig. 21.1). Recrystallization led to a poor preservation of many bioclasts. Ribbed nowakiids are encrusted by thick cement and show no current orientation. The environment was a eutrophic, calm, pelagic carbonate ramp.

5.4. Eifelian/Givetian (new Talioúine Formation)

The unfossiliferous black alum shales at the base of Section 3 are thought to represent the global Kačak Event Interval since the directly overlying limestones defining the base of the Talioúine Formation yielded *Polygnathus hemiansatus*, the basal Givetian index species. It enters just above the main event interval in the Jebel Mech Irdane GSSP of the Tafilalt (e.g., WALLISER et al. 1995; WALLISER & BULTYNCK 2011).

5.4.1 Member 1 (black limestones)

Member 1 is the lower part of Unit h of HOLLARD (1967). It is characterized by medium-bedded, partly chaotically arranged (slumped, with angular unconformities, Fig 23), argillaceous, black limestones (Beds 2-9, Fig. 26). The reworking of middle upper Emsian anarcestid limestones and the subsequent absence (by erosion or non-deposition) of top-Emsian to lower Eifelian limestones suggests that a local third interval of Eovariscan seismic activity occurred in the higher Eifelian. This is supported by evidence from Tizi-n-Ouourti (see below). The next regional block faulting phase causing the slumping began just above the Eifelian-Givetian boundary. Accordingly, the slumped and lenticular Bed 4 yielded *Po. hemiansatus* (Fig. 27.3) in association with *Linguipolygnathus* (e.g., *L. weddigei,* Fig. 27.3). Bed 4 is a poorly fossiliferous mudstone (Fig. 22.2) with only a few small crinoid ossicles, rare ostracods, and a sparite-filled small orthocone. It is increasingly microsparitic (recrystallized) in the upper part. A few dacryoconarids show syntaxial fine cement growths into the organic-rich matrix.

In the overlying Bed 5, the recrystallization is even stronger and the fossil content even poorer (Fig. 22.3). The lack of lamination is distinctive. Bed 7 yielded only a fragmentary linguipolygnathid, Bed 9 *Po. pseudofoliatus*, a species that ranges in the Anti-Atlas from the middle Eifelian into the Givetian (BELKA et al. 1987). While the base of Bed 9 is laminated, the main part shows irregular evidence of burrowing, with darker mud filling of feeding traces (Fig. 22.4).

5.4.2 Member 2 (oxic pelagic mudstones)

Member 2 (upper Unit h of HOLLARD 1967) starts with Bed 13 (Fig. 26) and is defined by light-grey limestones that are partly argillaceous (especially in the upper part) and that alternate with levels of nodular shale (e.g., Beds 29, 37, 40, 42-43) and, near the top, shale/marl (Beds 56, 61). Macrofauna is poor, with the exception of reworked shells, including trilobites, at the top of Bed 17. The total thickness is 11.2 m.

Fig. 23: Irregular bedding indicative of strong slumping of detrital basal Givetian limestones embedded in black alum shale at the base of Section Taliouine 3 (base Taliouine Formation); white color from weathered pyrite.

A limestone from ca. 1.5 m above the section base, collected during reconnaissance a year before the bed-by-bed logging (ca. Bed 15), yielded the name-giving marker species (Fig. 27.8), *Po. pseudofoliatus* (Figs. 27.9-10), *L. linguiformis* (Fig. 27.7), and an icriodid that is close to *I. difficilis* (Fig. 27.6). True *difficilis* indicate a younger, middle Givetian position (BULTYNCK 1987; GOUWY & BULTYNCK 2002). The microfacies of the bed is complex (Fig. 24, enlightened), with evidence for reworking and synsedimentary tectonics. From base to top the following subunits are recognizable:

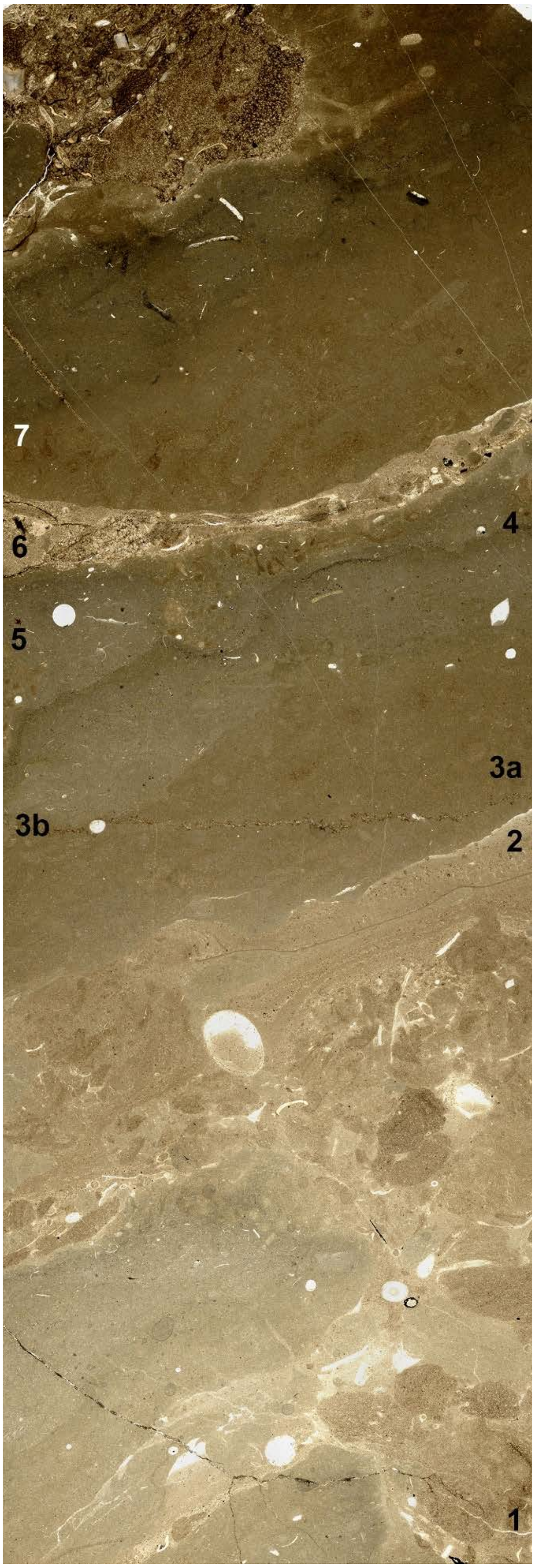
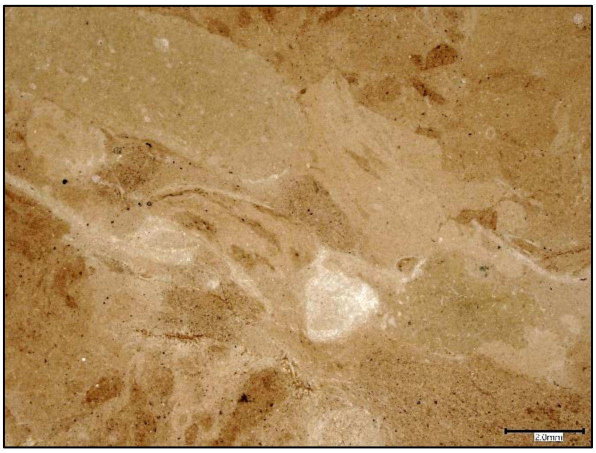


Fig. 24: Complex microfacies of Bed 15, ca. 1.5 m above the base of Member 2 of the Taliouine Section 3.

1. Ca. 10 cm conglomerate with unsorted, non-graded, partly flat pebbles reaching 5 cm or more, consisting variably of middle-grey mudstone with a few shell filaments or some orthocones, or slightly darker but smaller, subrounded pebbles consisting of microsparitic mudstone. The matrix ranges from lighter-grey microsparitic mudstone to floatstone with crinoid ossicles, dacryoconarids (showing syntaxial, radially growing cements), and sparite-filled orthocones. The top is formed by a laminated, slightly peloidal mudstone.
2. Undulating, sharp discontinuity surface marked by a laterally fading sparite seam.
3. Ca. 2 cm non-laminated mudstone with single bivalved ostracods (3a) and a minor discontinuity (3b) within.
4. Third undulating discontinuity surface marked by a seam of fine, dispersed pyrite/hematite.
5. Ca. 0.5-1 cm slightly coarser and peloidal mudstone with shell filaments, orthocones and burrows coming partly from the top.
6. Crack filled above an undulating discontinuity by strongly recrystallized bio-intraclast wacke-packstone with debris from mollusks, trilobites, crinoids, and some dacryoconarids.
7. Ca. 7 cm large pebble of mudstone with burrows (Fig. 25).
8. Erosional truncation, followed by recrystallized bioclastic wacke-packstone similar as in 4. The trilobite debris is rather thin-shelled.

The strongly polyphase deposition suggests the interruption of generally calm, deep shelf mudstone facies by four different high-energy events. The first originated from a debris flow and formed the unsorted and polymict mudclast conglomerate (Fig. 25.1). The weaker second event led to scouring on the seafloor and a sedimentary break marked by the sparite seam (Fig. 24). The third also caused scouring, but during increasingly anoxic conditions, causing an alignment by minute pyrite aggregates. The fourth was caused by a stronger bottom current moving and embedding a large, bioturbated mudclast in a coarse-grained, detrital layer.

2



1

Fig. 25: Microfacies details of Fig. 24. **1.** Partly flat mudstone pebbles in the lower part of the conglomeratic debris flow Unit 1; **2.** Details of the abundant trace fossils (burrows) below and above unconformities 4 and 5/6 (both photos enlightened).

Bed 17 represents superficially a second, nodular weathering "conglomerate" (Fig. 22.5). A sparse conodont fauna with *Icriodus obliquimarginatus* (Figs. 27.11-12), an alternative basal Givetian marker species, and *L. linguiformis* suggests a position just slightly higher in the *hemiansatus* Zone. At the base, there is a layer of wavy-laminated microsparitic mudstone. Above, the thin-section suggests an in-situ brecciated pelagic mudstone with rare shell filaments, ostracods, and nowakiids. Interspaces between the 1 to 20 mm large, subrounded clasts were invaded by a much coarser wacke-packstone matrix with abundant ostracods, dacryoconarids, trilobite and crinoid debris. During diagenesis, there was recrystallization, impregnation by ferro-manganese minerals, and the forming of dissolution seams at clast contacts. The lithology of Bed 17 is explained by synsedimentary seismic activity triggering brecciation and resedimentation that brought in bioclastic calcareous sand, which invaded opened interspaces and which also formed the locally unique, fossiliferous, bioclastic bed top.

The main part of Member 2 consists of mudstones that are very unfossiliferous, apart from burrows, even in thin-section (Bed 28a, Fig. 22.6, Bed 39b, Fig. 22.7, Bed 44c, Fig. 22.8; Bed 51, Fig. 29.1, Bed 60). There are very rare dacryoconarids and shell filaments. Flaser-bedding is caused by different degrees of microsparitization and the diagenetic overprinting of bioturbation (Bed 60). Well-defined burrows are filled by darker, organic-rich microsparite (Bed 39b, Fig. 22.7). Some beds are silty (Bed 60). In Bed 67, a nodular, bioturbated mudstone with very fine shell filaments, including a thin trilobite piece, is under- and overlain by wavy-laminated, flaser-bedded silty mudstones with rare crinoid debris and dacryoconarids. This succession indicates fluctuating currents, either distal turbidites or contourites. The general setting was the same as before, a subphotic pelagic ramp below the main habitat of ammonoids, trilobites, and other deeper-water benthic fauna.

Conodont faunas are sparse (Tab. 1) and include *I. obliquimarginatus* from Bed 39 (Fig. 27.13), *Po. parawebbi*, a species ranging from the upper Eifelian to the lower Givetian (BELKA et al. 1987), and *L. linguiformis* from Bed 44c (Fig. 27.14). A slightly richer fauna comes from the top of Member 2 (Bed 67), with *Po. parawebbi* (Fig. 27.16), *Po. timorensis* (Fig. 27.17), marker of the lower Givetian *timorensis* Zone, and *I. regularicrescens* (Fig. 27.15).

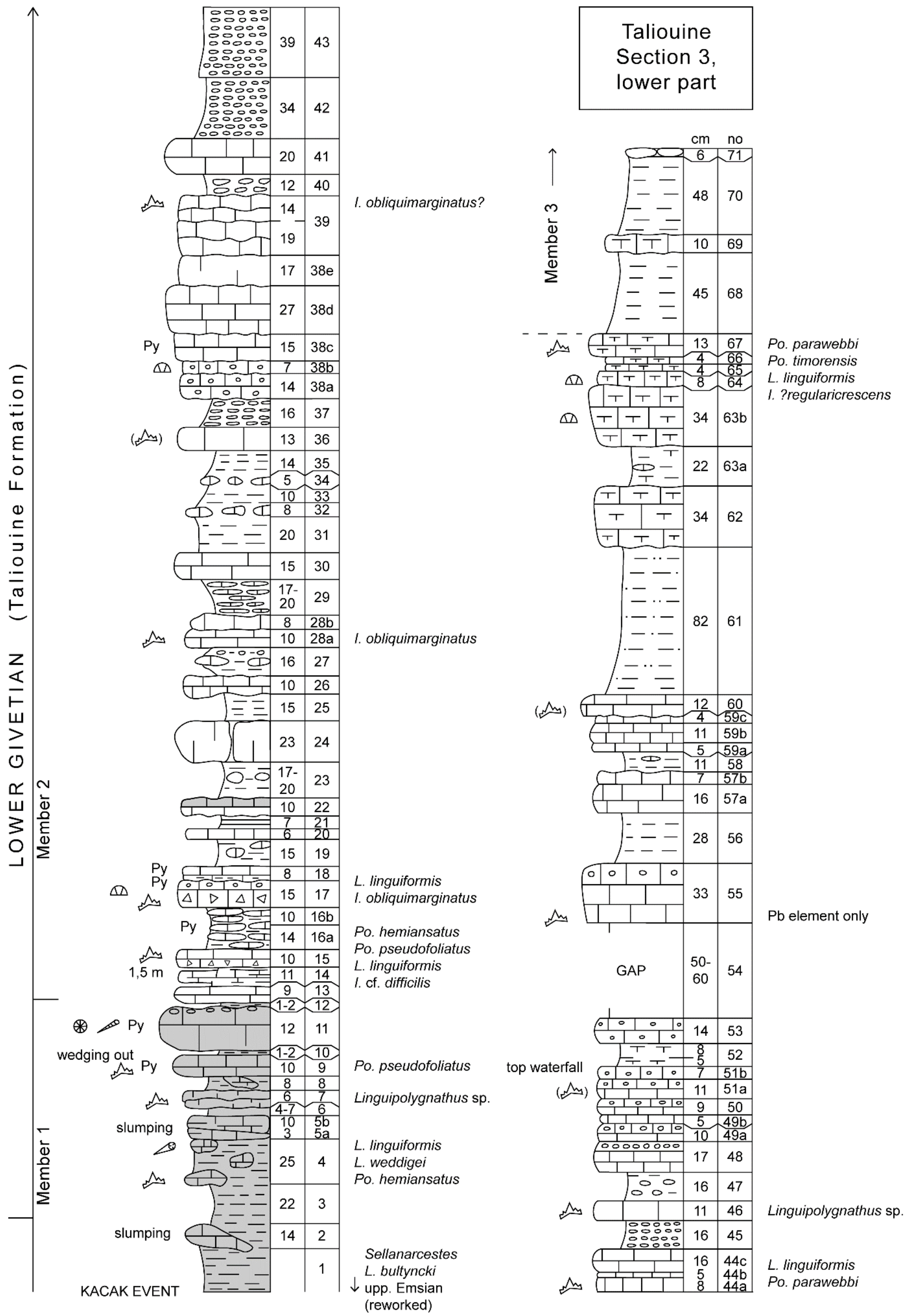


Fig. 26: Lithological and faunal succession of upper Eifelian to lower Givetian part of Taliouine Section 3, showing the position of conodont samples (see Tab. 1); Py = pyrite.

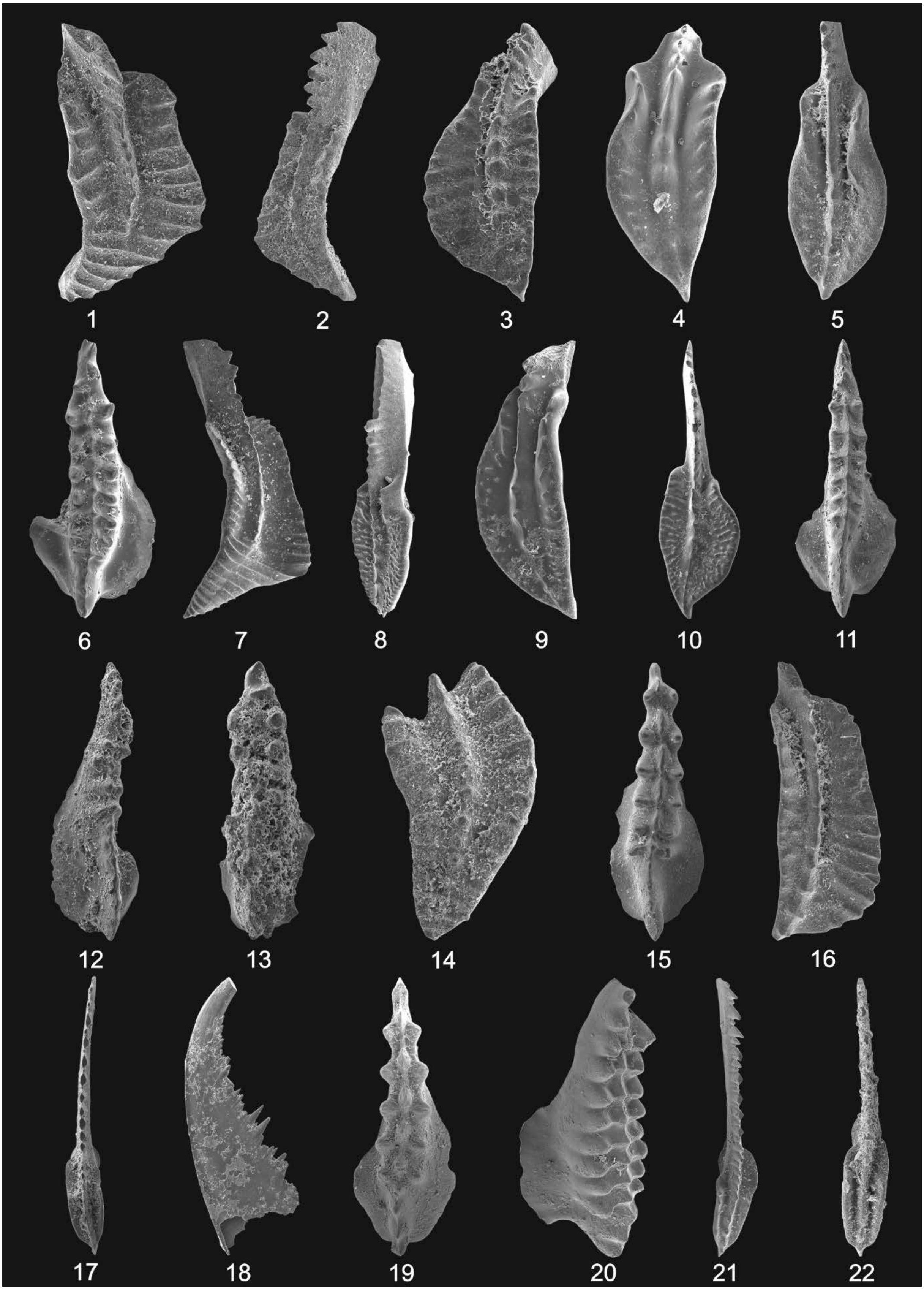


Fig. 27: Conodonts from Taliouine Section 3; GMM B4C.2.158-179. **1-2.** *Linguipolygnathus bultyncki*, upper part of upper Emsian glide block on the SW slope of the ravine, x 60 and x 55; **3.** *L. weddigei*, Bed 4, x 60; **4.** *Polygnathus hemiansatus*, Bed 4, x 80; **5.** *Po. pseudofoliatus*, Bed 9, x 70; **6.** *Icriodus* cf. *difficilis*, Bed 15, x 40; **7.** *L. linguiformis*, Bed 15, x 30; **8.** *Po. hemiansatus*, Bed 15, x 25; **9-10.** *Po. pseudofoliatus*, Bed 15, x 55 and x 25; **11-12.** *I. obliquimarginatus*, Bed 17, x 35; **13.** *I. obliquimarginatus*, Bed 39, x 60; **14.** *Po. parawebbi*, Bed 44c,

x 55; **15.** *I. regularicrescens*, Bed 67, x 65; **16.** *Po. parawebbi*, Bed 67, x 80; **17.** *Po. timorensis*, Bed 67, x 30; **18.** *Belodella resima*, Conglomerate 1, x 40; **19.** *I. difficilis*, Conglomerate 1, x 65; **20.** *I. regularicrescens*, Conglomerate 1, x 35; **21.** *Po. rhenanus*, Conglomerate 1, x 40; **22.** *Po. varcus*, Conglomerate 1, x 60.

5.4.3. Member 3 (goniatite shale/marl)

Member 3 is defined by the dominance of marls and hypoxic goniatite shales above the last compact sequence of limestone beds. It was recognized by HOLLARD (1967) as 70 m thick Unit i: "schistes à *Koenenites* cf. *lamellosus* puis calcaires à "Orthoceres" et tentaculites". A supposed Frasnian age is probably based on the mid-identification of the homoeomorphic upper Givetian genus *Mzerrebites* as lower Frasnian *Koenenites*. Intercalated argillaceous mudstones are very conodont-poor, with *L. linguiformis* and *Po. timorensis* in Bed 71. The first was also found in Bed 83; both species occur widely in the middle Givetian (e.g., ABOUSSALAM 2003; ABOUSSALAM & BECKER 2011). In the Givetian conodont biofacies model of NARKIEWICZ et al. (2016), *Linguipolygnathus* is especially abundant in outer shelf settings and pelagic platforms. More precise ages are provided by the ammonoid succession. The total thickness is in the scale of 60-70 m but the significant amount of scree from above enabled bed-by-bed logging only in lower ca. 38 m (Fig. 28). We attempted to trace Bed 70 laterally, but doubt that Bed 71 in the two partial sections (Figs. 26, 28) is the same bed. However, the correlation error appears to be small. In the upper lateral section (Fig. 28), Bed 71 is rather peculiar because of its internal, marked angular unconformity between burrowed laminated, silty mudstone (Fig. 29.2). This was either caused by slumping or we are dealing with the cross-section of structures of a large trace fossil, such as *Zoophycos*.

The microfacies of the subordinate higher limestone beds strongly resembles that in higher parts of Member 2 (see Bed 81, Fig. 29.3 in comparison to Fig. 29.1). The macrofauna is diverse but not abundant, often small-sized, and requires a tedious sampling effort. There is a remarkable admixture of pelagic (goniatites, orthocones, deeper-water solitary Rugosa) and neritic fauna (large-eyed phacopids, reefal corals, bryozoans, spiriferids), as it has been described from the Tata region of the eastern Dra Valley (BECKER et al. 2004b; EBBIGHAUSEN et al. 2007; SCHWERMANN 2011). This suggests a shallower setting than for Member 2 despite the higher amount of shale/marl. Fauna is either preserved as goethitic moulds (many mollusks), indicating hypoxic conditions, or in light-grey pelagic limestone, where all mollusks lack their shell. The currently known complete fauna is as follows:

*Agoniatites meridionalis** (Figs. 30.9-10)
*Agoniatites costulatus**
Sellagoniatites waldschmidti (Figs. 30.1-2)
*Sobolewia virginiana** (Figs. 30.11-12)
Maenioceras sp. indet.*
*Afromaenioceras crassum**
Afromaenioceras n. sp. A (more involute than *Afro. crassum*, close to *Afromaenioceras* n. sp. sensu BECKER et al. 2004b)*
Afromaenioceras n. sp. B (umbilicus wide, pachyconic, with more advanced sutures than in *Afro. crassum*; Figs. 30.13-14)
Afromaenioceras n. sp. C* (= *Bensaidites* n. sp. of KORN & KLUG 2002 and *Maenioceras* n. sp. II of BECKER et al. 2004b)
Wedekindella n. sp.* (sensu BECKER et al. 2004b, with concave umbilical wall; Figs. 30.7-8)
*"Trevoneites" assessi** (Figs. 30.3-4)
"Phoenixites" n. sp. 1* (sensu BECKER et al. 2004a and ABOUSSALAM & BECKER 2011; strongly compressed at very small size and with punctiform umbilicus, Figs. 30.5-6)
?*Lobobactrites* sp.* (compressed fragment)
?Bactrites declivis
orthocones indet*
Naticopsis sp.*

?Goniphilus sp. (species without ribbing)
other gastropods*
"Palaeonucula" sp.
?sponge
Dig. (Digonophyllum.) sp. (Fig. 32.7)
Laccophyllum sp.
Argutastrea (Argutastrea) hullensis hullensis (flat, 13 cm large colony, Bed 86, Figs. 32.1-2)
Heliolites intermedius* (Fig. 32.4)
*Thamnopora** *irregularis* (Bed 82, Fig. 32.8)
Favosites sp. (Fig. 32.3)
tabulate coral colony with square cross-section
Thomasaria (Mzerrebiella) bultyncki (see García-Alcalde & El Hassani 2020)*
?Adolfia sp. (Fig. 30.21)
terebratulid brachiopods
fenestellid and other bryozoans
crinoid stem pieces*
Geesops? sp. (Figs. 31.1-3)
Chotecops? sp. 1 (Fig. 31.7)
Chotecops? sp. 2 (Figs. 31.8-9)
Gerastos sp. aff. *izius* (Figs. 31.4-5)
proetid pygidium (Fig. 31.6)
wood pieces

All taxa/faunal groups marked by an * occur in contemporaneous beds of the Tata region (Bensaîd 1974; Becker et al. 2004a, Aboussalam et al. 2004; Aboussalam & Becker 2004). The faunal similarity is very large, both in the goniatites and benthic assemblages. However, there is one distinctive difference, which gives an important relationship with the Tafilalt: the entry of *Sellagoniatites* in Beds 70-72. The genus is missing in the Dra Valley and enters in the Tafilalt in the Lower/Middle *Sellagoniatites* Beds, which encompass the Upper *pumilio* Event beds at the base of the *ansatus* Zone (ca. in the middle of the middle Givetian; Becker et al. 2004b; Aboussalam & Becker 2011). The *Sell. waldschmidti* Zone forms the upper part of MD II-C. Equivalent strata are overlain in the Tata region by the *Agoniatites* Beds with *Agon. meridionalis*, which also characterizes Beds 70-79 at Taliouine Section 3. It is remarkable that the two widespread *pumilio* Event beds (e.g., Lottmann 1990) do not occur locally.

Heliolites intermedius was first described by Le Maître (1947) from lower Givetian reef limestone of Morocco. It was found jointly with *Thamnopora* in the lower middle Givetian Upper *Maenioceras* Beds of Oued Mzerreb (Schwermannn 2011). *Heliolites* and *Thamnopora* are both known as pioneer reefal-type corals, ranging in low numbers into muddy and dysphotic settings, for example at the base of Givetian biostromes of the northern Maïder (Stichling 2013). Another "pelagic occurrence" of Givetian *Thamnopora* is in the marly facies of the Lower Marker Bed of the Tafilalt Basin at Hassi Nebech (Bockwinkel et al. 2013). *Thamnopora irregularis* is a long-ranging Emsian to Givetian species (May 1993b). Heliolitids were in principle tolerant to a high detrital influx, which caused growth interruptions, but relied on sediment removal by episodic currents (Król et al. 2021). The possibly new tabulate coral occurs abundantly in a single Givetian locality of the southern Tafilalt (Amessoui Syncline).

Argutastrea (Arg.) hullensis hullensis was described by Hill (1954) from the lower Frasnian of the far distant Canning Basin, Western Australia (see revision by Brownlaw & Jell 2008). However, very similar forms, e.g., *Arg. tenuiseptata* Coen-Aubert & Lütte, 1990, are known from the Givetian of Europe, which were re-assigned as a subspecies to *Arg. (Arg.) hullensis* by May (1993a). The unusual presence of *Argutastrea* in middle Givetian pelagic goniatite facies was first noted by Aboussalam (2003, fig.15; identification by S. Schröder) in the Tafilalt Basin at Hassi Nebech. There is a middle Frasnian equivalent of colonial rugose corals in deep, subphotic facies, the *Hexagonaria* Bed of Oued Mzerreb, (Becker et al. 2004b), which yielded *Hex. buxutiensis*, a species from the Frasnian of the Ardennes.

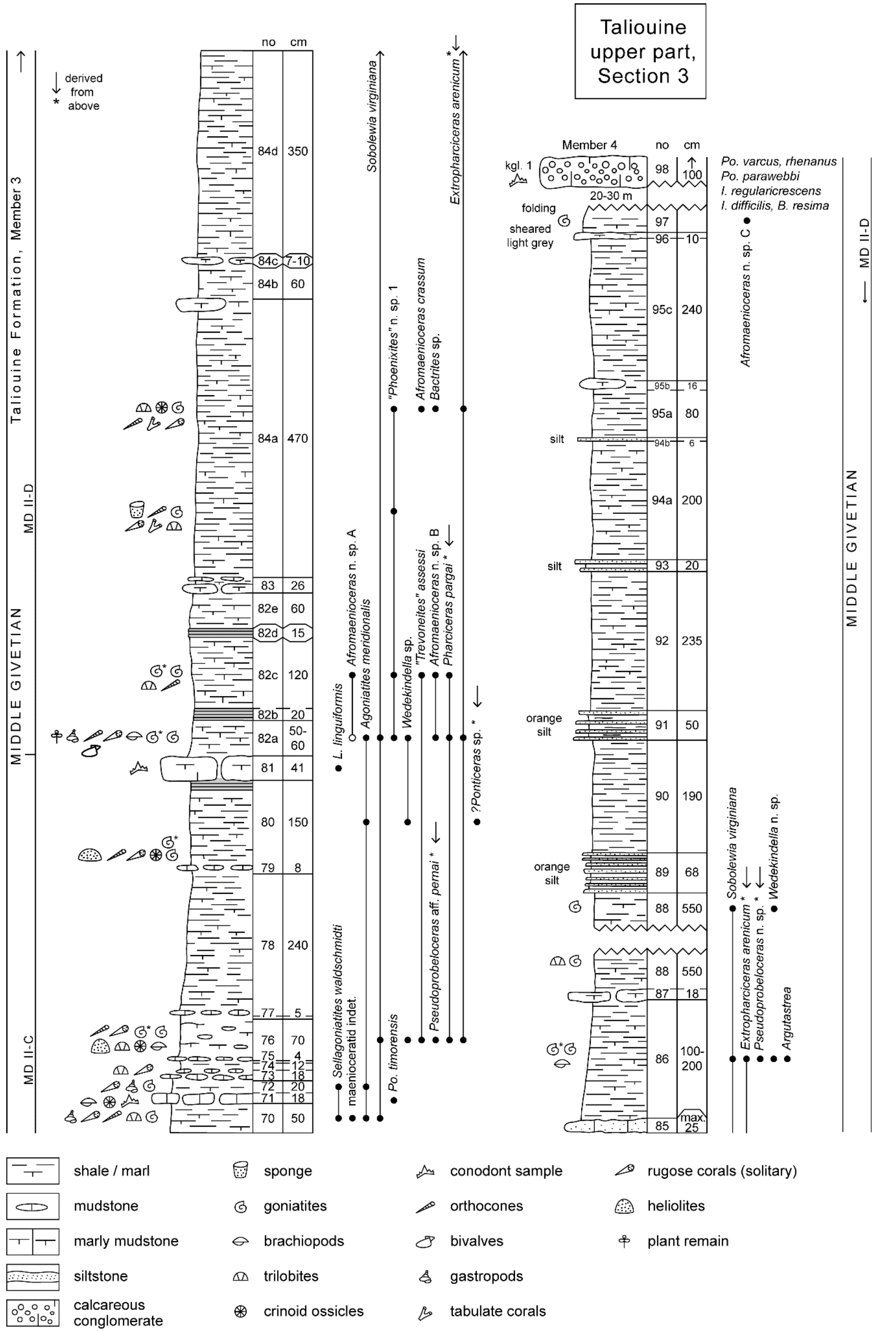


Fig. 28: Lithological and faunal succession of middle Givetian part of Taliouine Section 3, showing the position of conodont samples (see Tab. 1) and ammonoid faunas, including upper Givetian specimens derived from above.

Afromaenioceras, the index genus of MD II-D, enters in Bed 82a (Fig. 28). We correlate the thick sequence of Beds 75 to 88 with the pre-Taghanic *Maenioceras* Marl of the Tafilalt (ABOUSSALAM & BECKER 2011), which shares the presence of "*Phoenixites*" (strongly compressed tornoceratids with slightly open umbilicus and weak traces of ventrolateral furrows), *Wedekindella, Sobolewia, Agoniatites,* and of the *"Trevoneites" assessi* Group. The latter represents a new genus of the Parodiceratinae that closes the umbilicus at maturity, unlike as in true *Trevoneites*. The figured *Sobolewia* displays some randomly distributed "Housean Pits" on the flanks (Fig. 30.11). They are of unusually variable size (the largest occur at the last two septa) and do not conform with the even larger few pits illustrated by DE BAETS et al. (2011, fig. 5) on the surface of Algerian sobolewiids. In our specimen, there are intermediates between Types 1 and 2 sensu DE BAETS et al. (2011).

Five Beds (76, 82a, 82c, 84a, 86) yielded loose upper Givetian goniatites that are in complete disagreement with the rest of the fauna; they must have been washed down from above. We found three taxa, *Pharciceras pargai* juv. (Figs. 30.15-16), *Extropharciceras* cf. *arenicum* (nine fragments), and *Pseudoprobeloceras* aff. *pernai* (Figs. 30.17-18, more strongly ribbed than *pernai* and with weak ventrolateral double furrows, unlike as in *Ps. costulatum*). While *Ph. pargai* is typical for MD III-C (BOCKWINKEL et al. 2009), *Pseudoprobeloceras* is an index genus of MD III-D (BECKER & HOUSE 1994b, 2000a, 2000d). Since we did not observe any upper Givetian goniatites in the upper 20-30 m of Member 3 (Fig. 28), we assume that they derive from Member 4, from marls between the conglomerates higher up in the steep slope.

The local position of the Taghanic Crisis interval at the middle/upper Givetian boundary is currently unclear. The orange-weathering siltstones in the upper part of Member 3 (Beds 89, 91, 93, 94b; Fig. 28) indicate a polyphase shallowing trend but above, we could not locate the top middle Givetian (Upper Tully level) *Mzerrebites juvenocostatus-Atlantoceras* fauna (MD III-A), which is so characteristic for the Tata region (BENSAID 1974; BECKER et al. 2004b; ABOUSSALAM et al. 2004). However, HOLLARD (1967) probably recorded *Mzerrebites* as the homoeomorphic, lower Frasnian genus *Koenenites*.

Rather low in the succession, in Bed 70, we collected each a small and a median-sized, incomplete spiriferid with a single rib within the narrow sulcus, ribs right at each sulcus margin, undivided lateral ribs, and poorly preserved traces of undulating growth lamellae (Fig. 30.21). We preliminarily identify it as *?Adolfia* (wr. comm. U. JANSEN, April 2021), which previously has been questionably recorded from the Givetian of the Western Sahara (SCHEMM-GREGORY 2011, p. 10). The top-Emsian *?Adolfia* described by GOURVENNEC (2018) from the Algerian part of the Tindouf Basin has much coarser ribs. In general, the genus had a global distribution. For a reliable identification, the shell ornament of our specimens is too poorly preserved. There are some morphological similarities with *Vandercammenina*, which is not known from the Givetian. GOURVENNEC (2018) suggested that the *Vandercammenina-Cyrtospirifer* transition took place from the Eifelian to the Givetian and one may suspect that our specimens are part of this lineage.

The trilobite fauna includes a relative of the proetid *Gerastos izius*, which was described from the lower Givetian of the northern Maïder (GIBB & CHATTERTON 2010). The proetid pygidium may have belonged to the same form. The three phacopids are not well

preserved but appear to represent taxa that have not yet been documented from Morocco. The two forms with smooth cephala agree with the genus *Chotecops*, which ranges from the upper Emsian to upper Givetian. In the Tafilalt, it is so far only known from the lower Eifelian of Hamar Laghdad (ALBERTI 1983) and the top-Eifelian of Jebel Mech Irdane (FEIST & ORTH 2000). The species with strongly ornamented cephalon is difficult to place generically. There are similarities with the Emsian *Morocops*. Among described Givetian genera, *Geesops* is closest.

5.4.4. Conglomeratic Member 4

Member 4 includes three main conglomerate beds separated by poorly exposed marls that are mostly covered by Carboniferous limestone scree from above. Conglomerate 1 (Figs. 29.4, 33.1) consists of unsorted, non-graded subangular to subrounded clasts with stylolithic and partly ferromanganese-stained compaction contacts, and a peloidal mudstone in the interspaces that has widely been washed out and replaced by sparite. There are four types of clasts:

1. Middle-grey, slightly bioturbated mudstones with a few dacryoconarids and shell filaments.
2. Slightly lighter middle-grey mudstones with calcispheres.
3. Partly laminated, brownish peloidal mudstones.
4. Isolated crinoid ossicles, rugose (*Thamnophyllum*, Fig. 32.5), and tabulate corals (*Platyaxum*, Figs. 32.6).

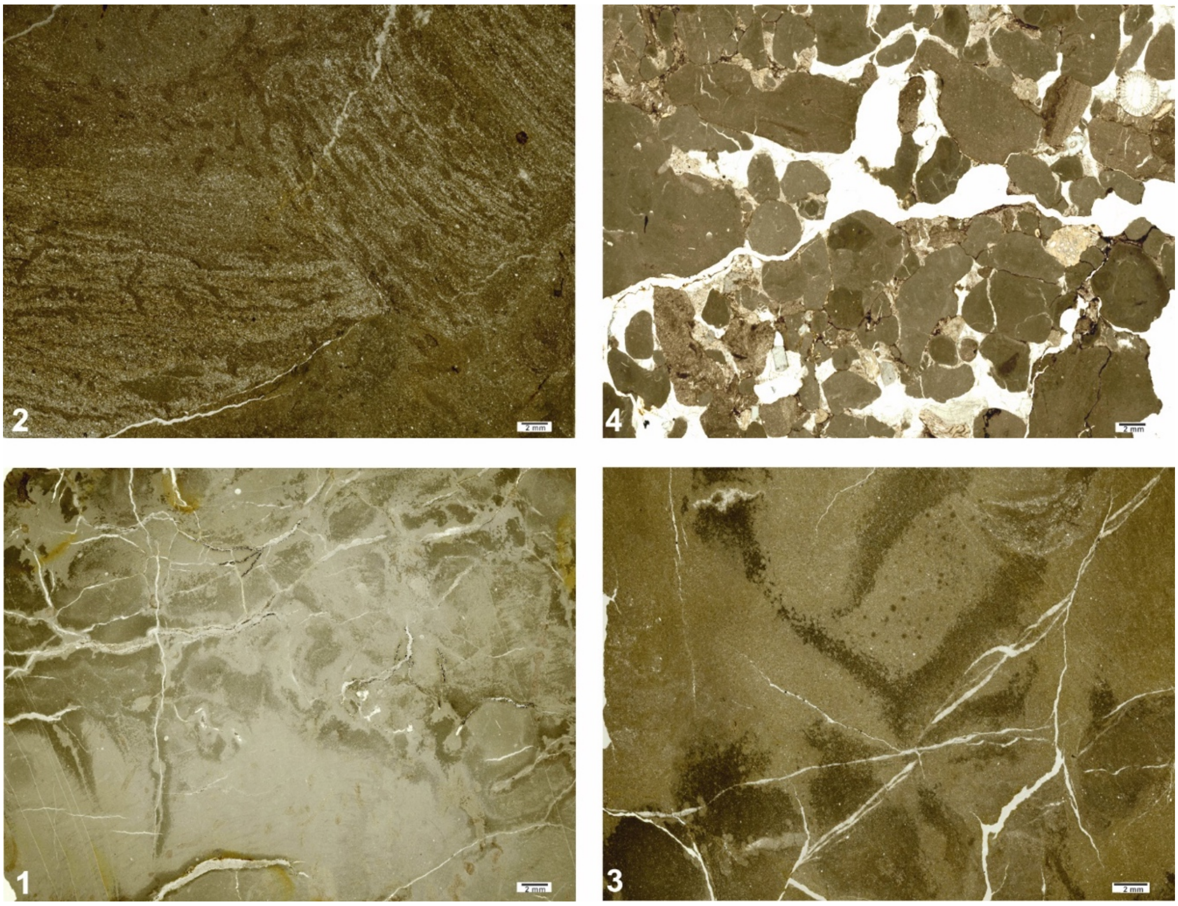


Fig. 29: Microfacies of limestones in Member 3 and 4 of the Taliouine Formation, Taliouine Section 3. **1.** Almost unfossiliferous mudstone, with numerous calcite veins and associated variable late diagenetic microsparitization causing a strongly patchy-cloudy pattern, Bed 51; **2.** Internal angular unconformity (55°) between laminated and burrowed, silty mudstone, within Bed 71 (enlightened), possibly structures of a large trace fossil, such as *Zoophycos*; **3.** Almost unfossiliferous mudstone overprinted by patchy diagenetic recrystallization, Bed 81; **4.** Conglomerate 1 of Member 4, an unsorted and non-graded extraclast rudstone with subangular to subrounded mud-wackestone pebbles, often in stylolithic contact, including isolated corals, and with a matrix of unsorted fine clasts or white sparite.

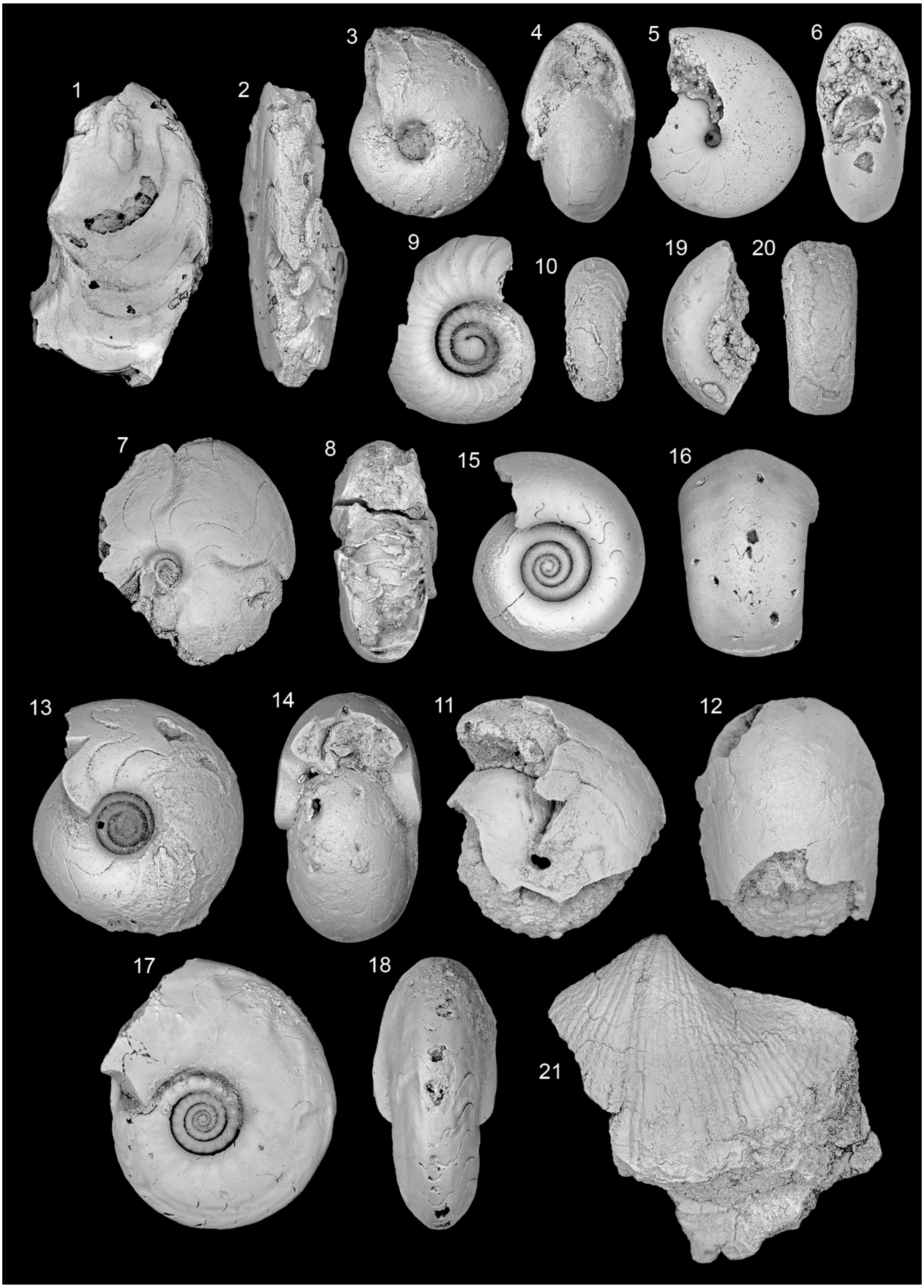


Fig. 30: Goniatites (GMM B6C.54.197-206) and a brachiopod from the middle/upper Givetian of Taliouine Section 3. **1-2.** *Sellagoniatites waldschmidti*, whorl fragment with typical sutures, Bed 72, x 1.5; **3-4.** *"Trevoneites" assessi*, Bed 76, x 5; **5-6.** *"Phoenixites"* n. sp. 1, showing the open umbilicus, juvenile shell compression, and incipient ventrolateral furrows, Bed 82c, x 5; **7-8.** *Wedekindella* n. sp. sensu BECKER et al. (2004b), incomplete specimen showing the typical, furrowed, concave umbilical wall, Bed 88, x 3; **9-10.**

Agoniatites meridionalis juv., Bed 82a, x 5; **11-12.** *Sobolewia virginiana*, incomplete, with a few small, lateral Housean pits, Bed 88, x 3; **13-14.** *Afromaenioceras* n. sp. B, with wide umbilicus, advanced sutures, and ventral Housean pits, Bed 82c, x 3; **15-16.** *Pharciceras pargai* juv., with incipient broad ventral keel, collected loose from Bed 76, x 5; **17-18.** *Pseudoprobeloceras* aff. *pernai*, collected by S. STICHLING loose from Bed 76, x 4; 19-20. *?Ponticeras* sp., whorl fragment with gephuroceratid ventral sutures, collected loose from Bed 80, x 5; **21.** *?Adolfia* sp., Bed 70, SMF 102136, x 2.5.

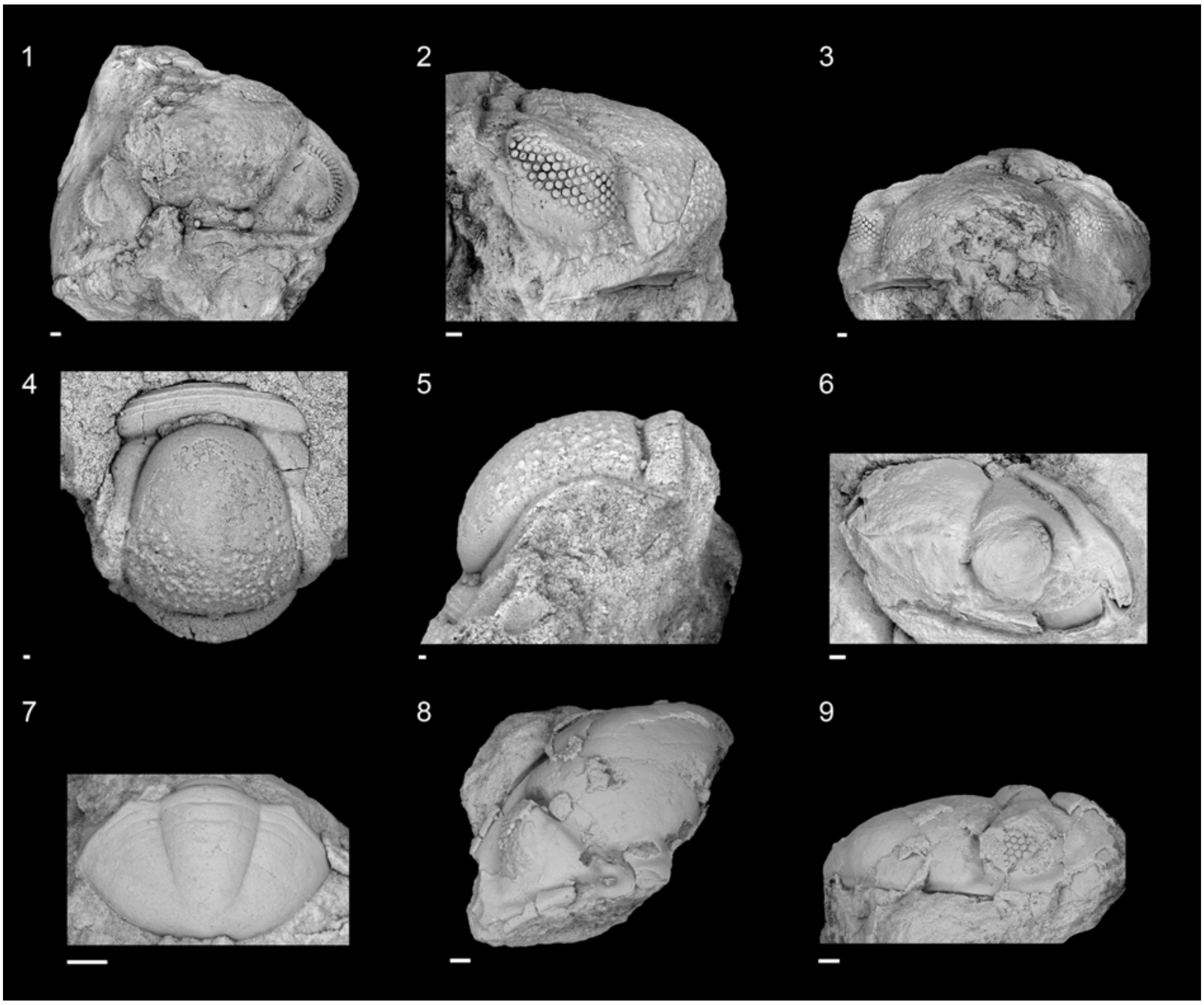


Fig. 31: Trilobites from the middle Givetian Member 3 of the Taliouine Formation, Taliouine Section 3; scale bar = 1mm. **1-3.** *Geesops*? sp., Bed 82, GMM B7A.12.8; **4-5.** *Gerastos* sp. aff. *izius* GIBB & CHATTERTON, 2010, Bed 84, GMM B7A.12.9; **6.** *Chotecops?* sp. 1, loose, GMM B7A.12.10; **7.** Proetid pygidium, Bed 82, GMM B7A.12.11; **8-9.** *Chotecops?* sp. 2, ca. Bed 88, GMM B7A.12.12.

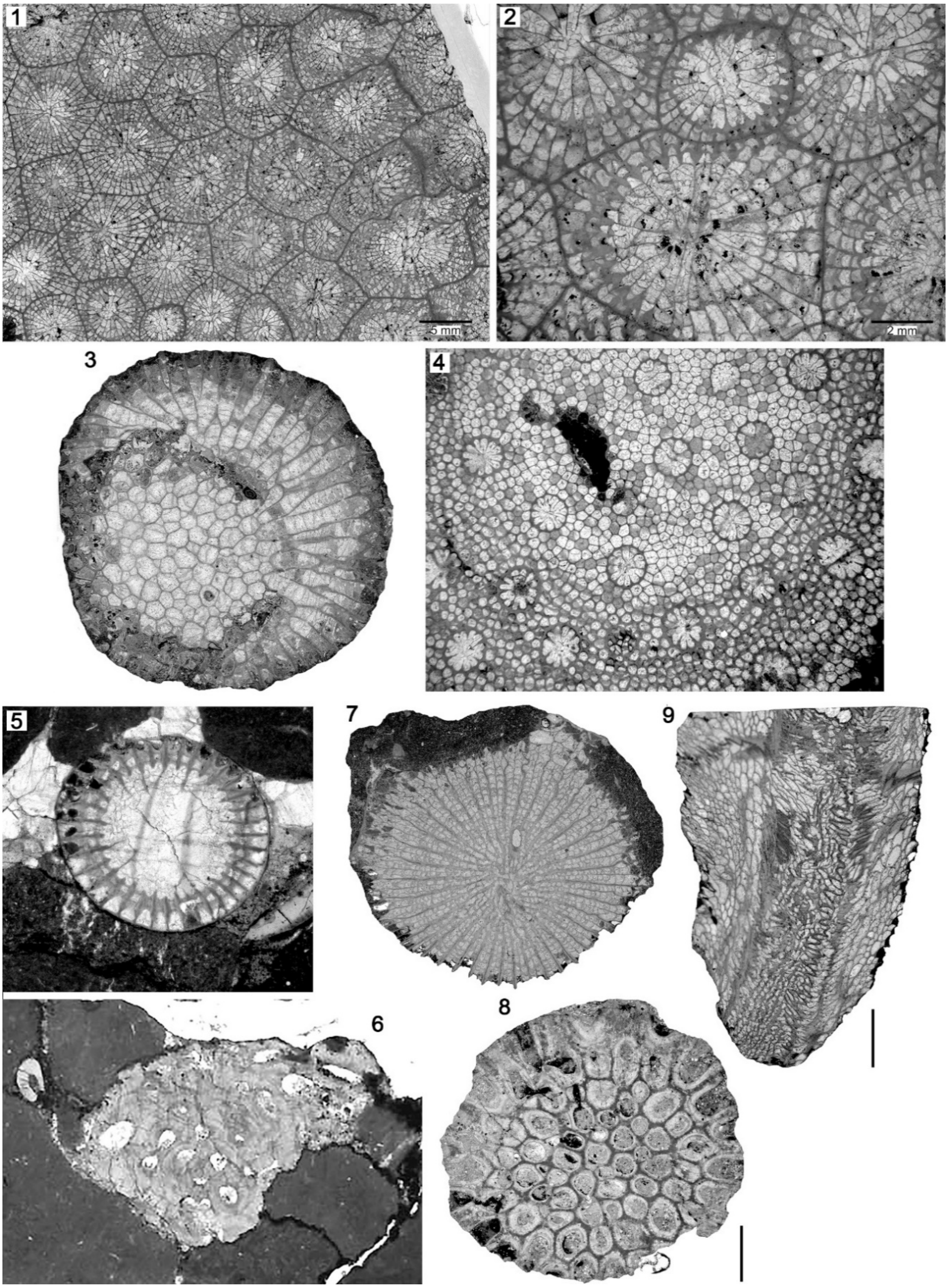


Fig. 32: Middle Givetian corals from Taliouine Section 3, GMM B2C.57.4-10. **1-2.** *Argutastrea (Arg.) hullensis hullensis*, overview and detailed polypar morphology, Bed 86, higher Member 3; **3.** *Favosites* sp., loose from Member 3, 27 mm colony diameter; **4.** *Heliolites intermedius*, loose from Member 3, picture width 14 mm; **5.** *Thamnophyllum* sp., Conglomerate 1, Member 4, 5.3 mm diameter; **6.** *Platyaxum* sp., oblique section; Conglomerate 1, Member 4, oblique colony length 6.8 mm; **7, 9.** *Digonophyllum (Digonophyllum)* sp., cross-section, 26 mm diameter, and longitudinal section, scale bar = 5 mm, Member 3, loose specimen (normally a shallow-water form, not one of the German species); **8.** *Thamnopora irregularis*, cross-section, Member 3, Bed 82, scale bar = 2 mm.

1

2

Fig. 33. The conglomeratic Member 4 at Taliouine Section 3. **1.** Details of Conglomerate 1, with mostly angular and small-sized pebbles in close, partly stylolithic contact; **2.** Overview of massive Conglomerate 2, with large-sized subrounded pebbles in the scale of 10-40 cm diameter.

The limestone clasts were probably all derived from Member 2, which must have been uplifted and eroded after lithification at a near-by fault scarp. Support for post-lithification reworking comes from sparite-filled veins that end at clast margins. The crinoids and corals lived just before or at the time of redeposition since they form isolated bioclasts and were reworked without surrounding sediment. There are only lower/middle Givetian conodonts, such as *Po. parawebbi, Po. varcus* (Fig. 27.22), *Po. rhenanus* (Fig. 27.21), *I. difficilis* (Fig. 27.19), and *I. regularicrescens* (Fig. 27.20). Consequently, we assign Conglomerate 1 to the first main Eovariscan episode that affected all the Meseta, starting high in the middle Givetian (Becker et al. 2015). Deposition occurred by rockfall at an active fault scarp.

Conglomerate 2 follows after ca. 8 m of light-grey marl, is up to 5 m thick, and forms a steep cliff in the slope (Fig. 33.2). It is also a rockfall deposit but with much larger clasts. Again, it yielded only lower/middle Givetian conodonts: *Po. varcus, Po. timorensis*, *L. linguiformis*, and *"Ozarkodina" plana* (Tab. 1). Conglomerate 3 is ca. 3.5 m thick and follows after another ca. 8-10 m thick, poorly exposed interval. It has not been sampled for conodonts but is believed to belong to the same synsedimentary tectonic episode; by fault uplift the youngest strata are eroded first and, therefore, should be found in the first reworking unit (Conglomerate 1).

Conglomerate 3 is overlain by ca. 20 m of poorly exposed bioclastic and marly limestone alternating with marls. There is indirect evidence for a Frasnian succession: From Bed 80 we collected a small-sized, loose, goniatite fragment (Figs. 30.23-24) that combines a widely evolute, depressed conch with a manticoceratid suture. It is probably a juvenile ponticeratid, which indicates the local presence of an upper Frasnian goniatite shale interval (see Boudouda goniatite chapter, this volume). In addition, we collected a middle grey, coarse crinoidal limestone block with fragmented auloporid corals and an atrypid, a brachiopod group that died out with the top-Frasnian Upper Kellwasser Event. This record fits the recognition of a Frasnian detrital limestone in the section log of Laville (1980) and the discovery of reworked Frasnian brachiopod limestone at Asserhmo (see below). Further studies are in progress.

Fig. 34: View on the thick Silurian to strongly cyclic lower Emsian succession at Tizi-n-Ouourti from just north of Imi-n-Tazaght. Access to the section is from the south along the valley behind the mountain on the right.

6. Devonian at Imi-n-Tazaght North

The Lower Devonian crops out on the hill just west of the piste that winds (after a sharp left turn) from Imi-n-Tazaght (= Imi n´Tarzat) to the north (Fig. 2). As noted by ROCH (1939), there are Silurian black and greenish-grey shales (Tizi-n-Tichka Formation) but just at the road we did not observe embedded limestones with orthocones, bivalves, or gastropods mentioned by him. To the west, the succession is cut off by a normal fault. The Lochkovian-Pragian boundary is locally marked by an unconformity and sedimentary gap spanning ca. the middle Lochkovian to middle Pragian. Member 1 of the Imi-n-Tazaght Formation is characterized by two solid marker limestones that dip steeply to the south. The first, brownish weathering, bioclastic marker bed is characterized by large *stromatactis* filled by white orthosparite or (in the middle part) by invading, strongly recrystallized dacryoconarid wackestone grading into shell filament packstone. The *Stromatactis* are underlain by poorly fossiliferous, non-bioturbated mudstone layers. The main microfacies (Fig. 35.1) is a flaser-bedded, bioturbated wacke-packstone with abundant crinoids, mollusk debris of very variable size, ostracods, gastropods (pleurotomariaceans), and orthocones, partly with geopetal filling. The matrix is micritic but there are thin packstone layers with small-sized shell debris, caused by winnowing due to the periodic influence of bottom currents. The environment was a moderately shallow carbonate ramp with episodic microbial growth. We assume that the calcimicrobes grew in a dysphotic environment since there is no evidence for euphotic organisms. However, the setting was shallower than at Taliouine. Iron-manganese impregnations of some shells and dissolution seams are diagenetic features.

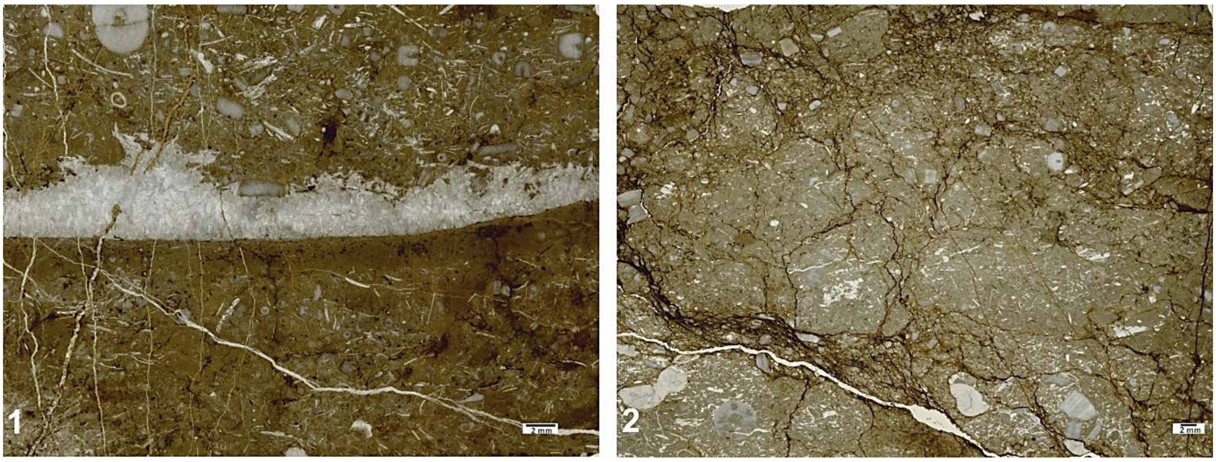


Fig. 35: Microfacies of Pragian/Emsian limestones from Imi-n-Tazaght North. **1.** Bioclastic, microbial, bioturbated packstone with abundant shell filaments, crinoid ossicles/debris, ostracods, and large, sparite-filled *Stromatactis*, underlain by micritic mudstone layers, upper part of *Stromatactis* Bed, base of the Lower Member of Imi-n-Tazaght Formation; **2.** Flaser-bedded, bioclastic, bioturbated wacke-packstone with abundant crinoid remains, shell filaments, dacryoconarids (mostly nowakiids), and many pressure solution seams, Member 3 of Imi-n-Tazaght Formation.

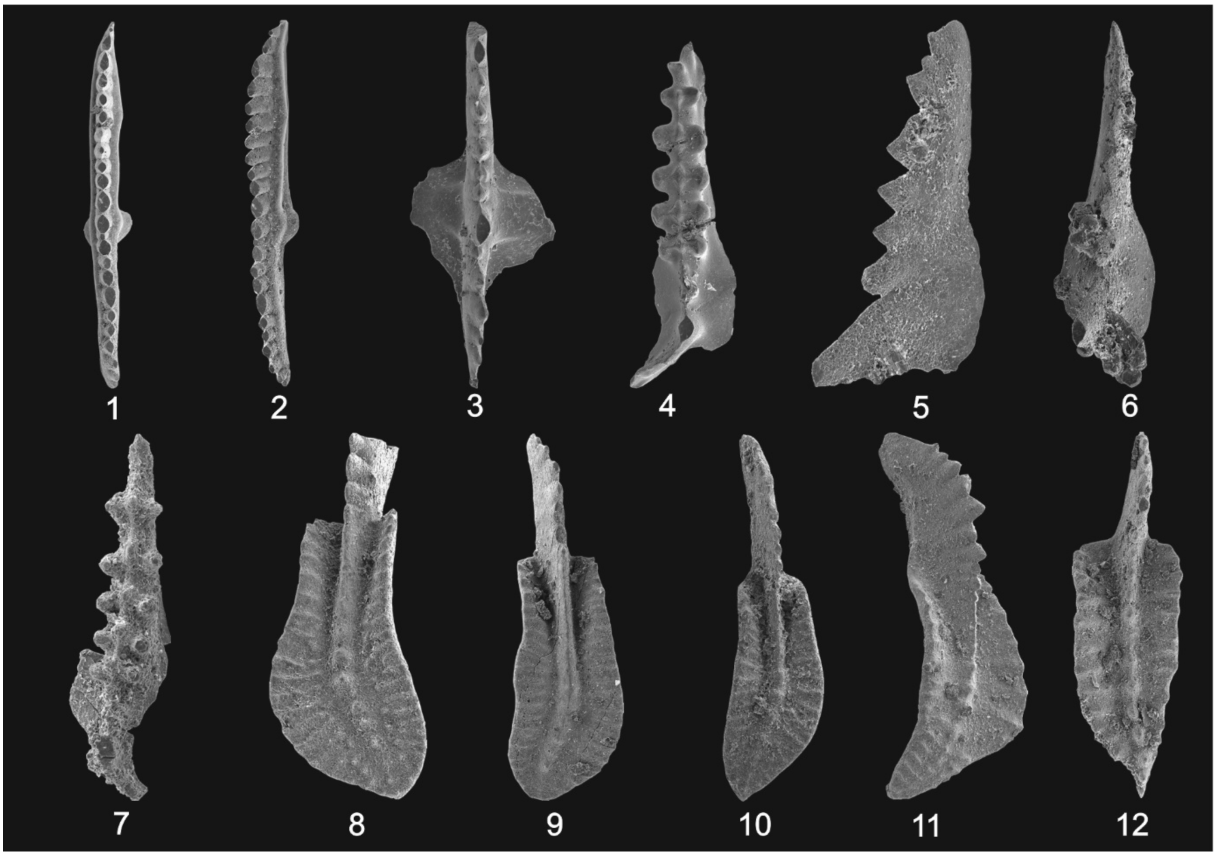


Fig. 36: Conodonts from the Lower Devonian of Imi-n-Tazaght North (1-6 from basal *Stromatactis* Bed of Imi-n-Tazaght Formation, 7 from Member 3 of that formation) and the upper Eifelian of Tizi-n-Ouourti (Bed G50a, kockeli Zone); GMM B4C.2.180-189. **1-2.** *Wurmiella wurmi*, x 35; **3.** *Criteriognathus miae*, x 80; **4.** *Caudicriodus celtibericus*, x 60; **5-6.** *Pelekysgnathus serratus*, x 95; **7.** *Caud. curvicauda*, x 95; **8.** *Polygnathus amphora*, x 50; **9.** *Po. costatus*, x 40; **10.** *Po. parawebbi*, x 45; **11.** *Linguipolygnathus pinguis*, x 35; **12.** *Po. praetrigonicus*, x 50.

The dominance of spathognathodids is in accord with a moderately deep setting. We found *Wurmiella wurmi* (14 specimens, Figs. 36.1-2), a single *Criteriognathus miae* (Fig. 36.3), two *Caudicriodus celtibericus* (Fig. 36.4), and a *Pelekysgnathus serratus* (Figs. 36.5-6). In Bohemia, *Caud. celtibericus* and the oldest *Crit. miae* overlap for a brief interval early in the upper Pragian with the youngest *Pel. serratus*, for example at Mramorka (SLAVÍK 2004). In our opinion, the FAD of *celtibericus* should define the *celtibericus* Zone, not the LAD of *Pel. serratus*. *Wurmiella wurmi* is known to range into the lower Pragian (e.g., SLAVÍK & HLADIL 2004) but has not been recorded from upper Pragian levels with *Caud. celtibericus*. However, this may be based on taxonomic problems. *Wurmiella wurmi* cannot be confused with the Pa element that is widely but incorrectly included in the highly problematical (see MURPHY et al. 2004) multi-element species *W. excavata*. This un-named form has fewer denticles on its shorter blade (see ROOPNARINE et al. 2004) but is not identical with *"Ozarkodina" simplex*, the assumed Pa element of the Silurian *W. excavata* s. str. (see REXROAD & CRAIG 1971). MAWSON & TALENT (1994) illustrated as *W. excavata* a specimen from Victoria, Australia, jointly with *Crit. miae*, that has only a few denticles less than our specimens. Since we have no evidence for extreme condensation in the *Stromatactis* Bed, we accept a range extension of *W. wurmi* into early parts of the upper Pragian, where the morphology and variability of specimens called *W. excavata* (e.g., 1400 specimens mentioned by SLAVÍK 2004) requires documentation.

The second prominent bed is a solid, grey, oxygenated Orthocone Limestone, which has not been sampled for conodonts. It is overlain by a mostly covered interval of light-grey nodular limestone, the basal part of Member 2 of the Imi-n-Tazaght Formation.

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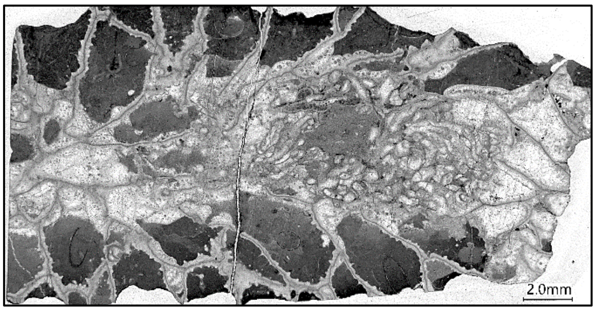

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Fig. 37: Pragian and lower Emsian at Imi-n-Tazaght North. **1.** Very large-sized and slender orthocone (?*Deiroceras*) cut and displaced by a later calcite vein, Orthocone Limestone, lower part of Member 2 of Imi-n-Tazaght Formation; **2.** Vertically bedded nodular

Member 2 with mass occurrences of small orthocones; **3.** Longitudinal section through a *Michelinia* sp., Member 2, GMM B2C, 57.11; **4.** Thin- to medium-bedded, slightly overturned, solid, crinoidal limestones of Member 3 at the top of the section, with L. BAIDDER for scale and the northern houses of Imi-n-Tazaght in the background.

A local special feature is a second prominent Orthocone Limestone with straight nautiloids reaching originally almost a meter in length (Fig. 37.1). The main part of the nodular Member 2 contains 10-15 cm thick layers that are extremely rich in smaller-sized orthocones (Fig. 37.2). Associated are a few trilobites, such as the Pragian *Cheirurus* (*Crotalocephalina*). *Panenka* is locally rare while there are common crinoid stem pieces. Rare branches of tabulate corals (*Michelinia* sp., Fig. 37.3) suggest a slightly shallower ramp setting than at Taliouine. *Michelinia* (including its likely synonym *Praemichelinia*, MAY 2006) is not common but globally widespread in the Lower Devonian. For example, it is known from the Pragian of the Armorican Massif (e.g., LAFUSTE & PLUSQUELLEC 1980), from the basal Emsian of the Dra Valley (PLUSQUELLEC in DE BAETS et al. 2010), the upper Emsian of Spain (MAY 2006; FERNÁNDEZ-MARTÍNEZ & PLUSQUELLEC 2006), and southern Algeria (e.g., LE MAÎTRE 1952; BOUMENDJEL et al. 1996).

The prominent, ca. 1.5 m thick, thin- to medium-bedded, light-grey crinoidal limestones of Member 3 (Fig. 37.4) begin above a sharp base. In the middle, we found a nodule of more than 10 cm diameter surrounded almost completely by a branching auloporid coral. A conodont sample from the base of Member 3 yielded two specimens of *Caud. curvicauda* (Fig. 36.7). The species ranges in the Tafilalt from the upper Pragian into the basal Emsian. Therefore, the base of the member is taken as the approximate Emsian base. Dissolution in acetic acid produced also fragments of *Machaeracanthus* spines. This somewhat problematical acanthodian is common in the basal Emsian of the Anti-Atlas (e.g., KLUG et al. 2008; BECKER et al. 2018a).

The microfacies of the conodont sample block fluctuates between bioturbated nowakiid-crinoid packstone with many shell filaments and dense micrite matrix, somewhat coarser, more crinoid-rich packstone with partly washed out matrix, and nowakiid wackestone. There are geopetal fillings and cone-in-cone stacking of some dacryoconarids. This indicates small variations of bottom current strength on the upper parts of a pelagic ramp. The dominant crinoid debris, lack of cephalopods, and presence of tabulate corals suggests the proximity of a shallower environment with crinoid forests. Fe-M-mineralizations follow dissolution seams that produce flaser-bedding. The top of Member 3 is slightly overturned (Fig. 37.3) and ends at a steep cliff, which follows a fault. Higher strata are lacking at Imi-n-Tazaght North (ROCH 1939).

7. Devonian of Tizi-n-Ouourti

The Tizi-n-Ouourti section was called by ROCH (1939) the most distinctive section of the Skoura Devonian. He gave a faunal list for the “Eifelian”, which in fact refers to the locally very fossiliferous upper Emsian strata (see LAVILLE 1980). The section can be reached from the piste leading from Toundout in the east to Imi-n-Tazaght in the west, much closer to the latter (Fig. 34). It requires a short walk along the northwards leading oued filled with Silurian black shale debris, which is, therefore, easy to recognize. Our measured section lies at N31°17'21.99", W6°39'43.74".

7.1. Lochkovian to lower Emsian

The Silurian black shales (Tizi-n-Tichka Formation, Field Unit A) are well exposed in

the lower slope of the section (Figs. 34, 38.1). There are unfossiliferous siderite (Fig. 38.3) and partly large black limestone concretions (Fig. 38.2), as in the Upper Member of Taliouine. The environment was anoxic. We did not note orthocone-rich limestones but the bedding is also irregular, suggesting slumping (Fig. 38.4). At the top there is a conglomerate/slump bed, which represents Member 1 of the Imi-n-Tazaght Formation. A conodont sample was unfortunately barren.

Member 2 (Field Unit B, 1° in ROCH 1939, fig. 21) is a ca. 15 m thick succession of cyclic and variably resistant (Figs. 34, 38.4), yellowish weathering marly, nodular limestone with orthocones, *Panenka*, phacopids, and dacryoconarids. The thickness is higher than at Imi-n-Tazaght to the west. We have not yet logged or sampled it locally.

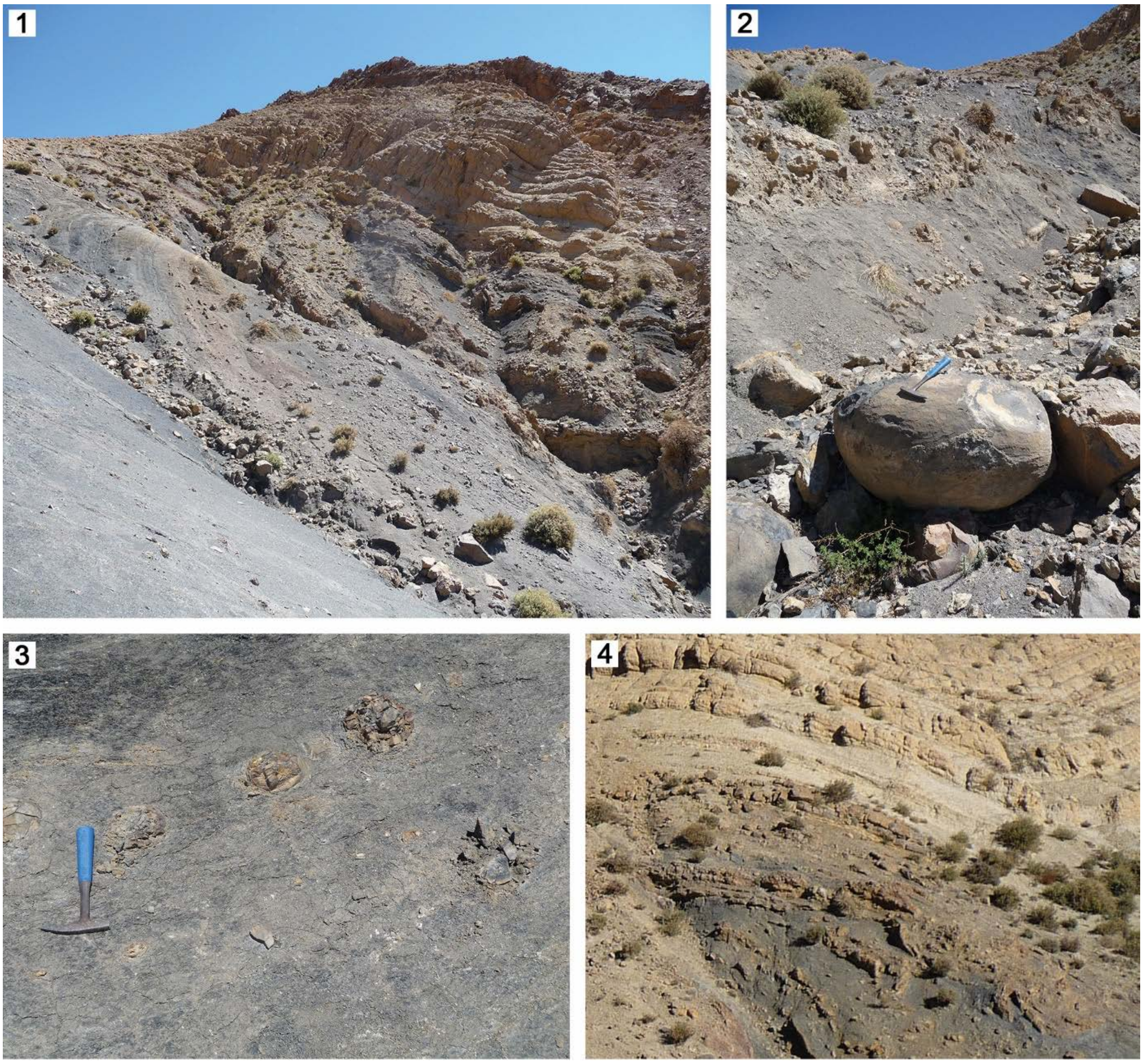

Fig. 38: Field photos of the Lochkovian to lower Emsian at Tizi-n-Ouourti. **1.** Overview of succession from the Silurian black shales (Tizi-n-Tichka Formation, Lower Member) to the thick cliff-forming, lower Emsian limestones of the Imi-n-Tazaght Formation; **2.** Large limestone concretion in the Lower Member; **3.** Isolated large siderite concretions in the Lower Member of the Tizi-n-Tichka Formation; **4.** Slumped, irregular bedding of the Upper Member, followed by a conglomerate/slump bed at the top, and then by the yellowish-grey weathering, well-bedded and cyclic nodular limestones of Member 2 of the Imi-n-Tazaght Formation.

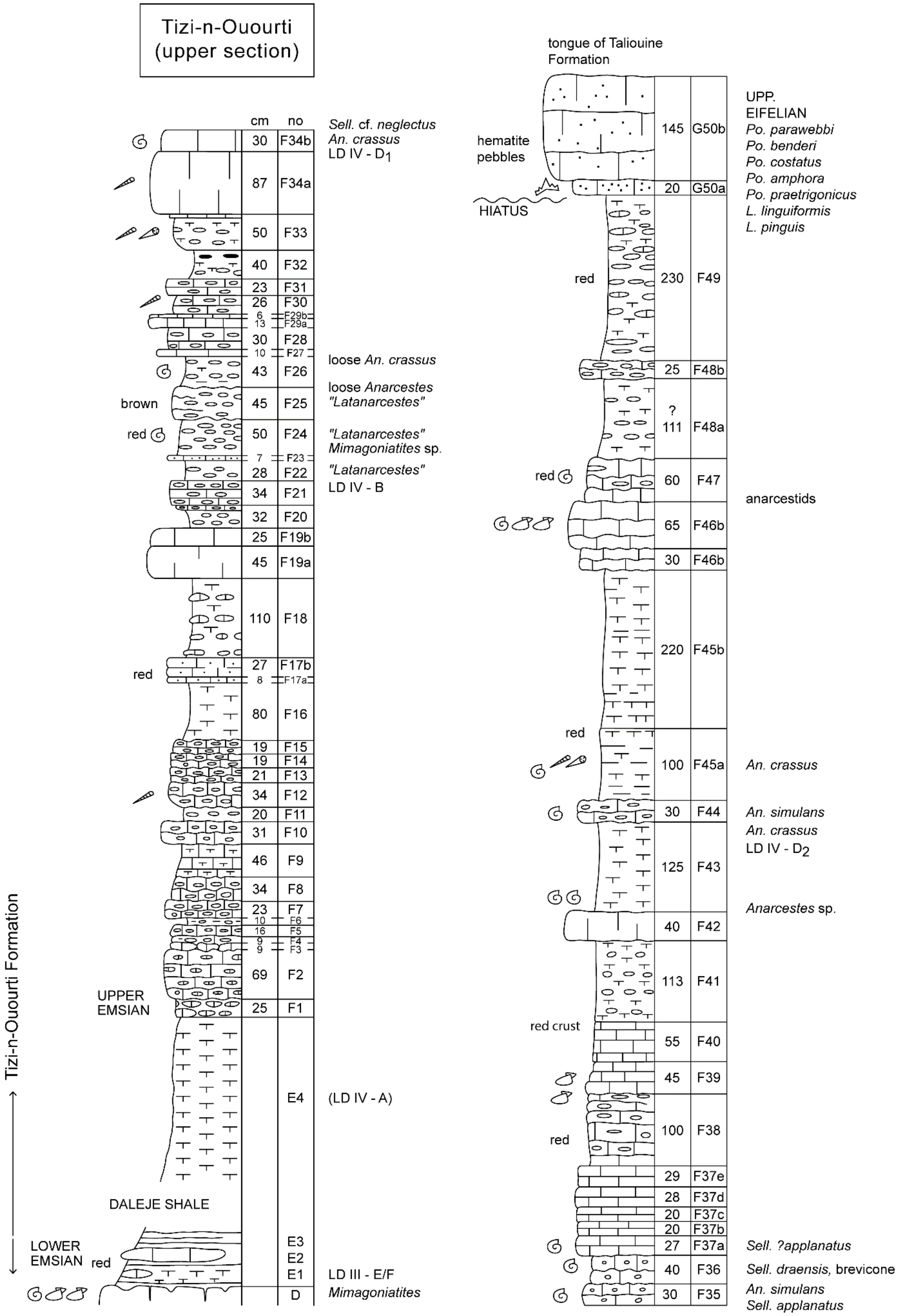

Fig. 39: Sedimentary and faunal sequence of the upper Emsian (Tizi-n-Ouourti Formation) to Eifelian (tongue of lower Taliouine Formation) at Tizi-n-Ouourti.

Fig. 40: Backside (southern flank of mountain) of the lower cliff at Tizi-n-Ouourti with the top of the lower Emsian on the left (Member 4 of Imi-n-Tazaght Formation), locally moderately thick Daleje Shale equivalents (Lower Member of type Tizi-n-Ouourti Formation), and cyclic, nodular anarcestid limestones (Upper Member), erosionally capped by a thin upper Eifelian limestone unit (tongue of Talioune Formation) on the right.

Member 3 (Field Unit C, blue limestone with crinoids and corals in ROCH 1939 = lower 2°) forms the main lower cliff (Fig. 34) composed of brownish-grey weathering bioclastic limestones. It has been logged in detail by the Greifswald Group but results are still forthcoming. Member 4 (Unit D) forms a sequence of very fossiliferous limestones with masses of *Panenka* and *Mimagoniatites* sp. (Fig. 41) on the steep dipping, southern backside (Fig. 40). At least some larger *Mimagoniatites* have wider whorls than at Taliouine.

7.2. Upper Emsian (Tizi-n-Ouourti Formation)

The *Panenka-Mimagoniatites* marker bed at the top of the Imi-n-Tazaght Formation ends with an upper discontinuity surface formed during an interval of current-induced sediment starvation and non-deposition. It is followed by the type succession of the Tizi-n-Ouourti Formation.

Fig. 41: Squashed *Mimagoniatites* sp. from the top of Member 4 at Tizi-n-Ouourti, GMM B6C.54.207.

Unit E, the ca. 10 m thick Lower Member (3° in Roch 1939), begins with dacryoconarid-rich marls with limestone concretions (Bed E1, Fig. 39), followed by a red shale (Bed E2) and large, flat, up to 15 cm thick, unfossiliferous concretions (Bed E3). The main part (Bed E4) consist of greenish-grey to whitish weathering shales and marls without macrofauna. The ca. 30 m thick Upper Member (4° in Roch 1939) begins with 6 m of light-grey to brownish weathering, thin-bedded nodular limestone and nodular shale (Beds F1-18) with poor macrofauna (rare orthocones). The ca. 35 cm thick, prominent Bed 17 is a detrital wacke-grainstone with dacryoconarids deposited under the episodic influence of bottom currents. The next marker unit is the ca. 70 cm thick Bed 19 (Fig. 39).

The first goniatite faunas enter in the nodular package of Beds F22 to F26 (base of 5° in Roch 1939). Bed F23 is a thin bioclastic bed (dacryoconarid packstone). Bed F24 is distinctive due to its red to violet nodules. Apart from one large *Mimagoniatites* (Figs. 42.11-12) all goniatites collected in-situ belong to "*Latanarcestes noeggerathi*" auct., which defines in the northern Maïder (Stichling 2013) and Dra Valley (Becker et al. 2004d; Ebbighausen et al. 2011) the first anarcestid zone (LD IV-B) of the upper Emsian (see also Becker & House 1994b). In the Dra Valley, the "*noeggerathi*" Zone correlates with higher parts of the *Icriodus fusiformis* Zone (Weddige in Jansen et al. 2004b; Aboussalam et al. 2015).

The preservation of all Tizi-n-Ouourti goniatites is moderate at best (Fig. 42). Shells have been dissolved, corrosion by diagenetic dissolution is common, and many moulds show elliptical deformation, which prevent precise shell parameter measurements. Large orthocones and solitary rugose occur in Beds F30-33 and in the massive, almost 1.2 m thick marker bed F34 that forms a second cliff top. In its upper part, there are in-situ *Sellanarcestes* and *Anarcestes*, which prove that zone LD IV-D_1 (sensu Becker & House 1994b) has been reached. In the Anti-Atlas conodont succession, this is the level of the *Linguipolygnathus bultyncki* Zone, which correlates internationally with the *serotinus* Zone (Aboussalam et al. 2015). Abundant *Anarcestes-Sellanarcestes* assemblages continue in overlying nodular beds (Beds F35-37, Fig. 39). Bed F38 is another reddish unit with large *Panenka*. The top of the limestone-dominated part of the member ends with a red crust at the top of Bed F40, an indicator of a short-termed interval of non-deposition. Above, thick marl and nodular marl units dominate on the (southern) back slope. In the lower part, the 40 cm thick Bed 42 is a good marker for orientation. Beds F43 to F47 yielded only *Anarcestes*, associated with orthocones, solitary Rugosa, and *Panenka*. The disappearance of *Sellanarcestes* defines the base of MD IV-D_2 (Becker & House 1994b), which falls in the Tafilalt in the middle of the *L. cooperi* Subzone (Aboussalam et al. 2015). There are three reddish intervals in the upper part of the Tizi-n-Ouourti Formation, a red marl at the top of Bed F45a, reddish nodules with *Anarcestes* of Bed F47, and red nodules in the middle of Bed F49. Since the red intervals do not follow changes from marl to nodular and solid limestone, and since they are laterally not consistent, they represent a superimposed feature, perhaps the circulation of iron-enriched pore water coming from the overlying post-Variscan redbeds.

The upper Emsian fauna of Tizi-n-Ouourti is as follows (bivalve identifications by M. G. Waterlot in Roch (1939):

"*Latanarcestes noeggerathi*" auct. (Figs. 42.1-2)
Sellanarcestes draensis (Figs. 42.3-4)
Sellanarcestes applanatus (Figs. 42.13-14)
Sellanarcestes cf. *neglectus*
Sellanarcestes aff. *neglectus* (Figs. 42.5-6)

Anarcestes simulans (Figs. 42.7-8)
Anarcestes crassus (Figs. 42.9-10)
Mimagoniatites bohemicus (see TERMIER & TERMIER 1950c)
Mimagoniatites sp. (Figs. 42.11-12)
?Pseudendoplectoceras tazaghtense n. sp. (Fig. 55.1), Bed F36
?Pseud. rochi n. sp. (Fig. 55.2), Bed F26
various orthocones
Panenka erosa
Panenka obtusa
Panenka pulchra
Panenka cf. *subtilis*
Panenka cf. *intermittens*
styliolinids and nowakiids
crinoid stems and ossicles
Favosites sp.
Cladochonus sp. (growing on goniatites)
solitary Rugosa (at least two species)
Linguipolygnathus bultyncki
Linguipolygnathus cooperi cooperi
Linguipolygnathus mawsonae

As in the Dra Valley and Tafilalt, non-corroded anarcestids show the wide-spread "Housean Pits" (Type 1, Figs. 42.3-4) resulting from endoparasitism (e.g., DE BAETS et al. 2011). *Sellanarcestes draensis* underlines the faunal similarity with the Tata region (EBBIGHAUSEN et al. 2011), where *An. crassus* is also a common form.

7.3. Eifelian (Taliouine Formation)

The Emsian/Eifelian boundary at Tizi-n-Ouourti is marked by a disconformity and long hiatus, ranging from the top-Emsian to the middle part of the upper Eifelian. There is a 20 cm thick, brownish weathering crinoidal limestone with sharp base (Bed G50a, Fig. 39), followed by a 145 cm thick, massive bed (Bed G50b) with abundant hematite nodules. Both represent a short tongue of the Taliouine Formation, but in very different facies. The lower unit yielded various Eifelian conodonts: *Polygnathus parawebbi* (Fig. 36.10, 2 specimens), *Po. benderi* (two specimens), *Po. amphora* (Fig. 36.8, 15 specimens), *Po. costatus* (Fig. 36.9, nine specimens), *Po. praetrigonicus* (Fig. 36.12, four specimens), *Linguipolygnathus linguiformis* (nine specimens), and a single *L. pinguis* (Fig. 36.11). *Polygnathus parawebbi* enters in the upper part of the *pseudofoliatus* Subzone (of the *costatus* Zone, "middle" Eifelian) but is more typical from the upper Eifelian *kockelianus* Zone on (BELKA et al. 1997; GOUWY & BULTYNCK 2002). The upper part of the latter zone is the type-level of *Po. amphora* (WALLISER & BULTYNCK 2011), the locally dominant species. Normally, it should not overlap with some of the other taxa: *L. pinguis* and *Po. praetrigonicus* range typically within the lower Eifelian from the *partitus* Zone through most of the *costatus* Zone. Based on graphic correlation, GOUWY & BULTYNCK (2002) suggested that *Po. costatus* may overlap with *Tortodus kockelianus*, but not with *Po. amphora* (see WALLISER & BULTYNCK 2011). *Polygnathus benderi* was so far not known from Morocco; in Germany it occurs from the "upper part of the *costatus* Zone" (*pseudofoliatus* Subzone) to the *australis* Zone (WEDDIGE 1977). As a consequence, the fauna from Bed G50a represents a mixed assemblage, with lower (*costatus* Zone) and top-Eifelian species. The local pure polygnathid biofacies indicates deep neritic to shallow pelagic deposition. It is peculiar since *Tortodus* (s.str.) is normally a common genus in the Moroccan upper Eifelian. The hiatus, reworking and faunal mixing occurred during the same regionally distinctive Eovariscan tectonic interval that caused the slumping and shedding of upper Emsian glide blocks and small olistolites at Taliouine. The Tizi-n-Ouourti section belonged to a more stable upper part of the carbonate ramp, where deposition became very episodic and incomplete. ROCH (1939, fig. 21) assigned overlying strata to the Cretaceous, overthrusted by Liassic limestones.

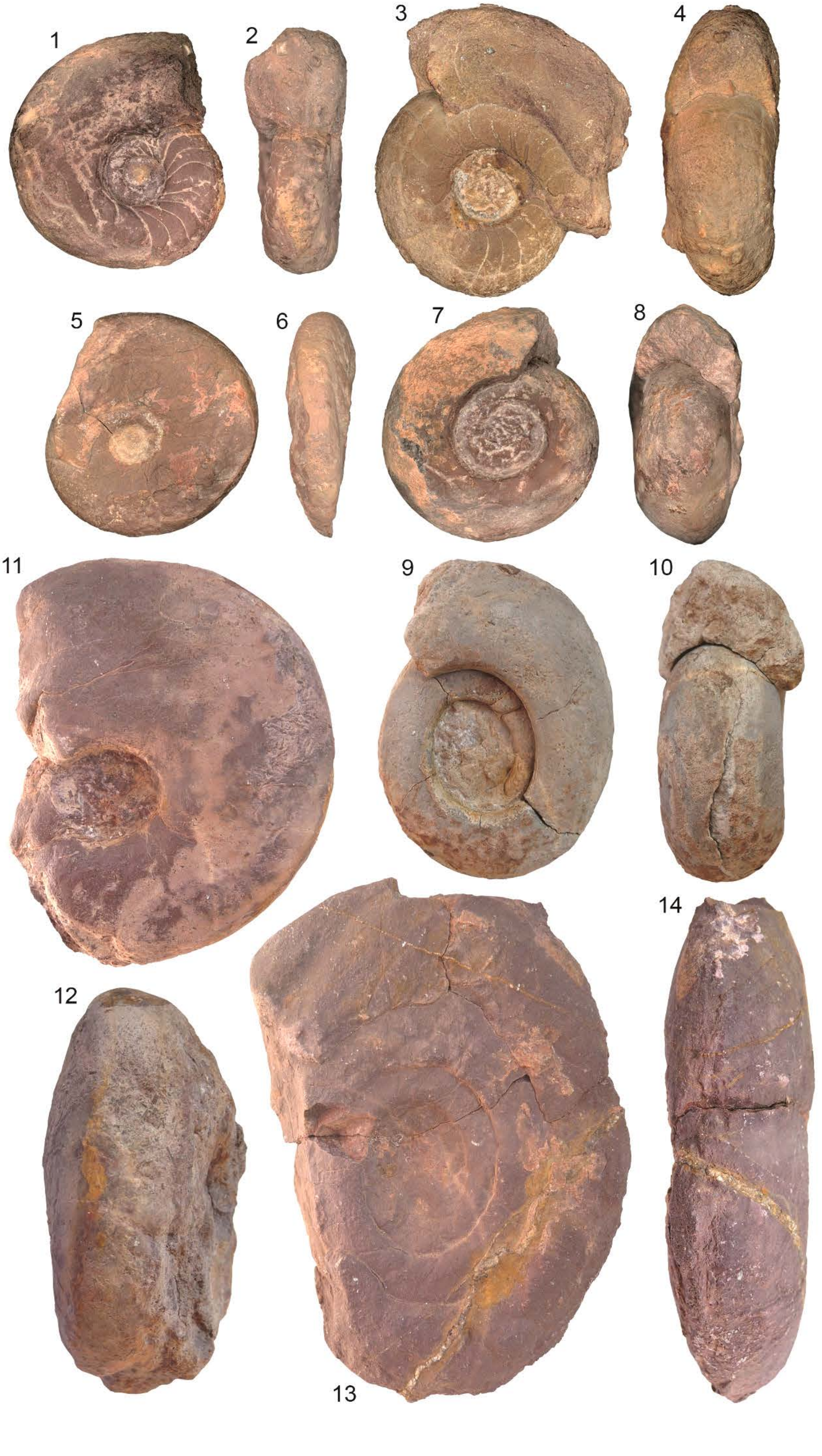
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Fig. 42: Goniatites from the Upper Member of the Tizi-n-Ouourti Formation (upper Emsian) in the type section; GMM B6C.54.208-214. **1-2.** "*Latanarcestes noeggerathi*" auct., lateral and adoral views, Bed F24, x 1; **3-4.** *Sellanarcestes draensis*, showing the typical, rather narrow umbilicus of median stages, and a ventrolateral row of elongated Housean Pits, lateral and adoral views, Bed F36, x 1.3; **5-6.** *Sell.* aff. *neglectus*, too involute and compressed for typical *neglectus*, lateral and ventral views, loose, x 1.5; **7-8.** *Anarcestes simulans*, lateral and adoral views, Bed F45, x 1; **9-10.** *An. crassus*, lateral and adoral views, Bed F44, x 1; **11-12.** *Mimagoniatites* sp., with relatively low whorl expansion rate, possibly caused by distortion, Bed F24, x 1; **13-14.** *Sell. applanatus*, lateral and ventral views, Bed F42, loose, x 1.

Fig. 43: View from the water reservoir on the two lateral Lower Devonian sections Asserhmo West (in the background) and Asserhmo East, at the foot of the foreground slope, with the cliff-building solid limestones of Members 3/4 of the Imi-n-Tazaght Formation for orientation. The winding dirt road runs in the Silurian black shales of the Tizi-n-Tichka Formation.

8. Devonian at Asserhmo

The Devonian of Asserhmo can be reached by following the winding road from Toundout to the NE and taking a piste to the left after crossing a major oued filled by shale. The piste joins after ca. one km the oued, then branches, where the right oued leading to the north should be used. After less than a km, a winding piste branches off to the left (west), leading uphill and, after passing some houses, eventually reaches the hill with the local water reservoir on the top. Fig. 43 shows the view from there onto the two adjacent Lower Devonian sections below, to the west. Note that the piste ends within the settlement (background of Fig. 43) and cannot be used for a circuit.

8.1. Silurian/Lower Devonian

The Silurian to lower Emsian succession follows closely the general lithostratigraphy of the Skoura Palaeozoic but thicknesses are much reduced (only ca. 15 m for the complete Pragian/lower Emsian, 10-20 m according to LAVILLE 1980, p. 98). This suggests either a

more proximal platform/ramp setting at Asserhmo and/or the influence of different subsidence. Significant for the regional tectonic model is the locally strong, cleavage-type, dense fracturing, which even affected rather massive limestones (Figs. 45.2-3). OUANAIMI & PETIT (1992) drew attention to this different tectonic style and postulated an oblique Skoura Fault, which delimited an "Domaine oriental" (with Asserhmo) from the much less deformed "Domaine central" (Tizi-n-Tichka to Tizi-n-Ouourti). The fact that different Variscan tectonic styles cross a uniform Lower Devonian sedimentary basin shows that the regional deformation types do not characterize different original terrains. The contrasting tectonics of the Skoura region is consistent with the model that the Meseta and Anti-Atlas were lying close to each other in the Devonian (e.g., BAIDDER et al. 2008), with a rather variable overprint during the later main Variscan orogeny.

8.1.1. Asserhmo West

The western small Lower Devonian cliff of Asserhmo (N31°19'46.35", W6°33'24.18") was logged bed-by-bed in two parts (Fig. 44). The Pragian Member 2 of the Imi-n-Tazaght Formation (low hill at the piste, left column) consists of ca. 11 m exposed cyclic nodular shales and limestones with abundant orthocones, *Panenka*, and dacryoconarids. Unlike as in the western sections, no trilobites were observed. Member 3 begins with thin- to medium bedded solid limestones (main cliff, right column), followed by detrital limestone, and a massive, 3.6 m thick limestone unit (Beds 6-7), which is possibly cut off in the south by a fault. Bed 5 (right column) is a flaser-bedded, slightly reddish, bioturbated bioclastic packstone with many dacryoconarids (styliolinids and subordinate nowakiids), ostracods, crinoid ossicles and fragments, some orthocones, abundant small shell filaments, and micrite matrix that was partly washed out (Fig. 46.1). It represents a shallow pelagic ramp below the storm wave base but under the influence of bottom currents. As typical for the strong regional tectonic overprint, there are many cracks filled with sparite and secondary black iron minerals. The conodont fauna is sparse (Tab. 2), with *Criteriognathus miae* (Fig. 47.1) and *Latericriodus bilatericrescens*. The latter species confirms a basal Emsian age (*bilatericrescens* Zone, see ABOUSSALAM et al. 2015). In the plain at its southern base, follow black shales, which may represent the Daleje Shale equivalents (Lower Member of Tizi-n-Ouourti Formation).

8.1.2. Asserhmo East

Below the eastern cliff (Fig. 43), the Silurian to basal Devonian black shales of the Tizi-n-Tichka Formation crop out in the small valley but the transition to the nodular marls of the lower Imi-n-Tazaght Formation (Member 2) is covered; based on changing bedding directions, a minor fault cannot be excluded. Member 3 is equally massive as at the adjacent western section and Member 4 is easily accessible on the southern side of the cliff (Fig. 45). It consists of densely fractured, solid bioclastic limestone with masses of *Panenka* shells covering in convex-up position the top surface. Since there are no bivalved shells, these were not preserved in living position but were transported by bottom-currents. The microfacies (Fig. 46.2) shows within the bed a flaser-bedded alternation of styliolinid wackestone and styliolinid-bivalve packstone with few crinoid ossicles, thick *Panenka* fragments, poor orientation but very frequent cone-in-cone stacking of the dacryoconarids, and very fine, light-grey micrite matrix. The diagenesis introduced iron mineralizations and microsparitization at pressure solution seams. There are several *Mimagoniatites* sp. (the compressed form known from Taliouine) on

the top surface, indicating LD III-D high in the lower Emsian. The monospecific conodont fauna consists of abundant *Crit. steinhornensis* (Tab. 2, *steinhornensis* Zone). The complete absence of polygnathids resembles the Anti-Atlas *Mimagoniatites* Beds (ABOUSSALAM et al. 2015) and suggests a shallow pelagic setting.

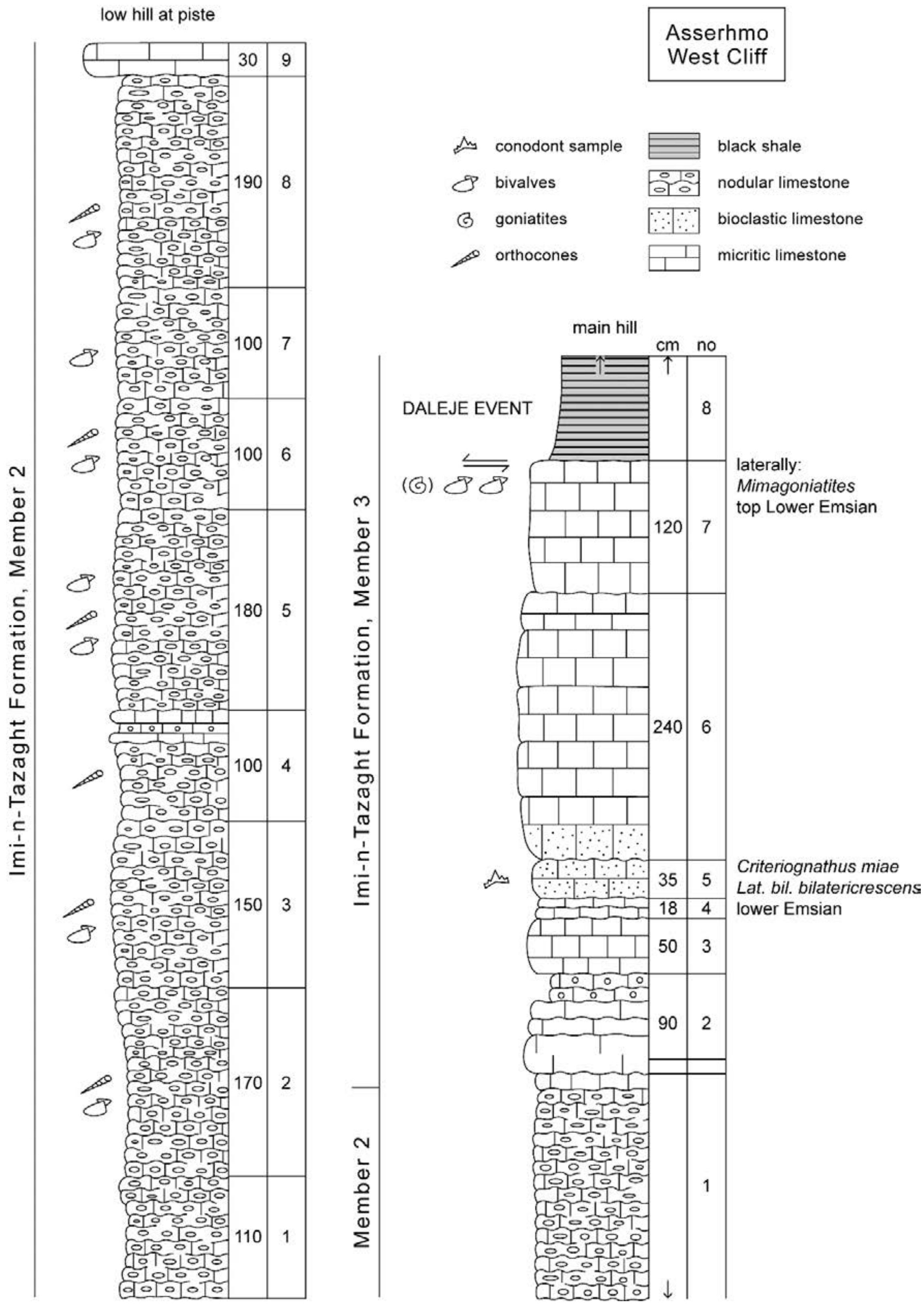

Fig. 44: Lithological log and faunal record at section Asserhmo West.

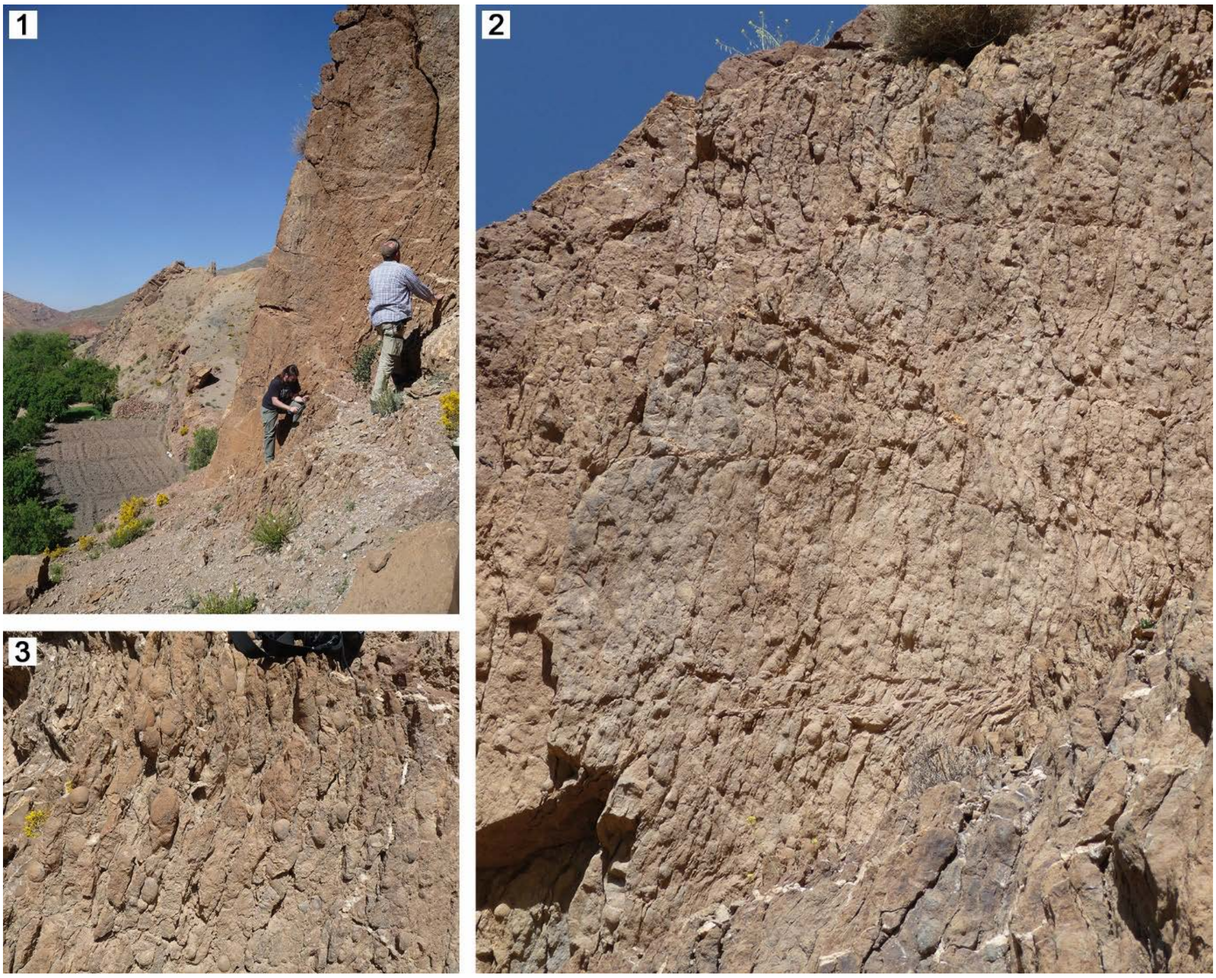

Fig. 45: Top of Imi-n-Tazaght Formation (top Member 4) at Asserhmo East. **1.** Overview of the steep cliff, with S. HELLING and H. HÜNEKE for scale, and with Asserhmo West in the background; **2-3.** *Panenka* mass occurrence and strong, undulating, cleavage-type, dense fracturing of the solid limestones.

On the adjacent hill to the east, below the water reservoir, the ca. 60 m thick Daleje Shale equivalents (Lower Member of Tizi-n-Ouourti Formation) seem to lie directly on the Silurian black shales but the poor outcrop situation does not rule out a fault contact.

8.2. Asserhmo Formation

The new formation is defined as a succession of conglomerates, silt- and sandstones, and subordinate fine, detrital limestones. The upper part of the hill below and at the water reservoir is formed by a 3-5 m thick conglomerate unit (**Lower Member**) (Fig. 48.1), followed on the eastern backside by up to 50 m fine-grained siliciclastics (**Upper Member**; compare description in LAVILLE 1980).

8.2.1. Lower Member

At the base, there is a 25 cm thick interval with two beds of solid, fine detrital, dark-grey limestone. The upper, platy bed is a completely unfossiliferous, slightly wavy laminated, microsparitic and dolomitic mudstone with thin, oblique calcite veins (Fig. 46.3). Conodont sampling was not successful. It represents the distal part of a hostile pelagic shelf basin receiving very fine-grained carbonate detritus. Separated by a dark shale interval, a 8-10 cm thick first conglomerate follow, marked by macroscopically distinctive, flat but well-rounded, black pebbles reaching ca. 2 cm maximum size. It yielded no conodonts. In thin-section (Fig. 46.4), it is a rudstone with abundant, rounded black ferromanganese, brownish, goethized or

limonitized, and smaller, red hematite pebbles. The majority of the diverse limestone pebbles is also rounded, strongly affected by variable recrystallization, dolomitization, iron mineral impregnation at the margins or along fractures, and pressure solution contacts. As far as the original microfacies is preserved, there are light- and dark-grey mudstones, light-grey nowakiid packstones, black dacryoconarid-orthocone wackestones, and black orthocone-gastropod floatstones with micritic matrix and poorly preserved dacryoconarids. Subordinate are fine sand- and siltstones. There is almost no matrix in the clast interspaces. We suggest distal rockfall deposition at the lower slope of a fault scarp, where uplifted Lower Paleozoic to Middle Devonian strata were subject to a long interval of erosion and reworking in an agitated coastal setting before sediment overload at the upper slope and/or seismic activity triggered a small avalanche.

The timing of events can be better deduced from the higher, more fossiliferous conglomerates, which follow above 33 cm of laminated black shale, the background facies of a normally quiet basin. The ca. 1.2 m thick lower unit of the main conglomerate begins with a second layer of small-sized (1-3 cm) pebbles, which shows an irregular, erosive base. There is inverse grading towards the middle part (clast size increasing up to 20 cm), reverting into normal grading at the top. Well-rounded Ordovician quartz pebbles are very common (Fig. 48.2). In the subsequent 60 cm, there are subrounded to subangular, yellowish to reddish weathering limestone clasts (Fig. 48.3).

Asserhmo conodont samples							
age	**low. Emsian**	***steinhorn*. Zone**	**m. Lochk.**	**MN 10/11**	**Givet.**	**upp. Fam.**	
bed and sample no.	**West - Bed 5**	**East - top Mbr. 4**	**Orth. Lst.**	**brach lst.**	**coral lst.**	**cgl. 1**	**cgl. 2**
Bi. spinulicostatus M1						2	
Bi. aculeatus aculeatus						1	
Bi. costatus M2						1	
Neo. communis cf. *yazikovi*						3	
Neo. communis communis						6	
Pseud. primus primus						1	
Lat. claudiae?						1	
Crit. miae	2						
Crit. steinhornensis		27					
Lat. bilatericrescens	1						
Ancyrodelloides transitans			3				
Pa. hassi				5			
Po. ?webbi				1			
Po. aff. *paradecorosus*				1?			
Avign. decorosus				1			
L. linguiformis					1?		
L. zieglerianus							1
Br. ampla							2
Bi. stabilis stabilis							1
Sc. velifer leptus					1		1
total conodonts identified	**3**	**27**	**1**	**8**	**2**	**15**	**5**

Tab. 2: Conodonts from the Lower Devonian, from individual clasts, and conglomerate bulk samples at Asserhmo.

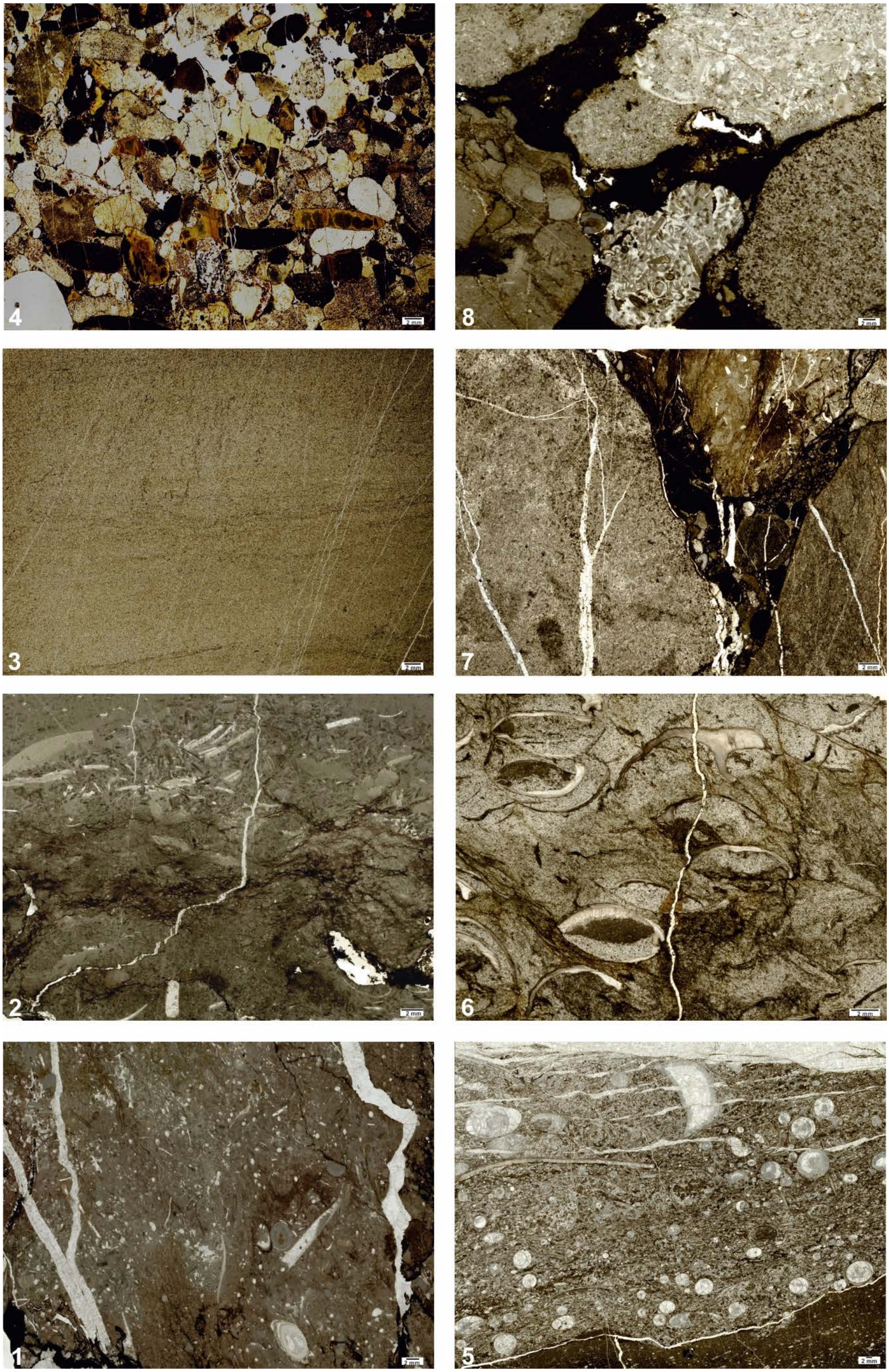
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Fig. 46: Microfacies of thin-sections from Asserhmo. **1.** Bioturbated wacke-packstone with abundant dacryoconarids, ostracods, orthocones, fine mollusk filaments, and crinoid debris, embedded in fine micritic matrix that is locally washed out, Asserhmo-West, Bed 5, basal Member 3 of Imi-n-Tazaght Formation (right column in Fig. 43); **2.** Alternation of dacryoconarid wackestone, bivalve-dacryoconarid packstone with rare crinoid ossicles, and recrystallized flaser-bedded intervals with diagenetic iron mineralizations, top of Imi-Tazaght Formation (Member 4, *Panenka* Bed with *Mimagoniatites*); **3.** Dark, unfossiliferous, microsparitic and dolomitic, laminated mudstone, base of the Lower Member of the Asserhmo Formation; **4.** Fine-grained conglomerate low in the Asserhmo Formation, a poorly sorted, strongly polymict extraclast rudstone with often well-rounded pebbles of black ferromanganese mineralization, brownish goethite/limonite, and whitish to brownish recrystallized and dolomitized, variable pelagic limestones; **5.** Black, laminated, organic-rich dacryoconarid wackestone with abundant ostracods (at the base), disconformably overlain (above the thin, diagenetic sparite seam) by an unsorted, non-graded, partly laminated, organic-rich orthocone floatstone with sparite-filled, current-orientated (almost normal to the thin-section plain) longi-orthocones, large mollusk filaments, and a bioclastic, peloidal grain-packstone matrix; at the top with a sparite-filled crack, large pebble from main conglomerate, middle Lochkovian; **6.** Recrystallized (pseudosparitic), flaser-bedded, bioturbated brachiopod floatstone with ferromanganese coating of some shells and bivalved or convex-up, current-controlled brachiopod embedding; shell filling partly by matrix, partly geopetal, pebble in main conglomerate, middle Frasnian; **7.** Unsorted extraclast rudstone with angular to subrounded larger pebbles of dolomitized, middle- to dark-grey, peloidal, bioturbated mudstone with several generations of calcite veins, dolomitic, originally light-grey, bioclastic wacke-packstone with dacryoconarids, abundant mollusk debris (upper right), and small-sized, iron-mineralized finer clasts including black ferromanganese pebbles, microsparitic mudstone, and isolated crinoid ossicles, coral-bearing main conglomerate; **8.** Extraclast rudstone with subrounded to subangular clasts of light-grey nowakiid grainstone with cone-in-cone stacking (lower center), middle- to dark-grey dolomitized mudstone (lower right, center, and upper left), light-grey, poorly sorted crinoid grainstone with ostracods (upper right), and brecciated mudstone (lower left), surrounded by iron-mineralized matrix that coated the clasts, upper part of main conglomerate.

The subsequent conglomerate at the terrace of the building is coarse, extremely polymict (Fig. 48.5), without any sorting or grading, and with isolated corals sitting between quartzite or limestone pebbles (Fig. 48.4). It represents the deposits at a higher part of the palaeoslope, originating from a sequence of rockfall events caused probably by repeated seismic activity. The strong mixing of clasts of very different age and provenance requires a common source, probably from a larger high-energy, coastal environment prior to their gravitational downslope transport. Since there is a difference between the rounding of older siliciclastic (Cambro-Ordovician) and younger (Devonian) limestone clasts (e.g., Figs. 48.2 and 48.4), recycling of the first is likely. The exposure and reworking time of the lithified Devonian limestones was much shorter than for the resistant quartzite pebbles. A survey of the clasts spectrum, their faunas and ages, adopting notes by LAVILLE (1980), gave the following results:

1. Well-rounded, mostly brownish to dark-grey, thin-bedded Ordovician quartzites (Figs. 46.4, 48.1 and 48.4).
2. Well-rounded, small-sized, flat, black ferromanganese pebbles (Figs. 46.4, 6 and 46.7, 48.4; probably Lower Paleozoic in age).
3. Red hematite clasts (Fig. 46.4).
4. Completely recrystallized, light-grey to brownish, variably dolomitic or goethitic limestones.
5. Unfossiliferous silt- and fine sandstone.
6. Dark-grey, laminated limestone poor in macrofauna: organic-rich mudstone or wackestone with dacryoconarids and partly dominant ostracods, sometimes with orthocones, with micritic or microsparitic matrix (Fig. 46.5; reworked from the upper Tizi-n-Tichka Formation).
7. Dolomitized or microsparitic, bioturbated, sometimes peloidal grey mudstone with sparite-filled veins ending at the clast margins, as evidence for full lithification and tectonic overprint (healing of fractures) before reworking and redeposition (Figs. 46.7-8).

8. Black Orthocone Limestone (Fig. 46.5): Unsorted, non-graded, partly laminated, organic-rich orthocone float-rudstone with mostly sparite-filled, rarely geopetal, current-orientated orthocones, large mollusk fragments, and a bioclastic (fine shell debris, abundant ostracodes, subordinate dacryoconarids), peloidal grain-packstone matrix. Matrix partly micritic, partly sparitic (washed out). Conodonts include the middle Lochkovian index species *Ancyrodelloides transitans* (Fig. 47.3; see VALENZUELA-RÍOS et al. 2015), possible *Wurmiella* fragments, and many ramiforms. Early stages of the orthocones are longiconic, with very low apical angles, and with hemisphaeric protoconch, as in Sphaerorthoceratidae (Orthoceratida, Neocephalopoda) (reworked from the top Tizi-n-Tichka Formation).
9. Dark-grey, bioturbated orthocone-gastropod floatstone with micritic matrix and poorly preserved dacryoconarids (?Lochkovian).
10. Flaser-bedded to nodular, light- to middle-grey limestone poor in macrofauna: bioturbated dacryoconarid wacke- or packstone with mollusk debris (Figs. 46.6-7) or grainstone with current-controlled washing out of the micritic matrix and nowakiid cone-in-cone stacking (Fig. 46.8). Such clasts are probably the source of rare Pragian conodonts, such as *Latericriodus ?claudiae* (Tab. 2; reworked from the Imi-n-Tazaght Formation).
11. Light- to middle-grey, unfossiliferous bioturbated mudstone, often recrystallized or dolomitic (probably reworked from Givetian Taliouine Formation).
12. Crinoidal limestone with *Panenka* (reworked from top Imi-n-Tazaght Formation).
13. Light- or middle-grey, fine detrital/crinoidal limestone: poorly sorted crinoidal packstone with ostracods and mostly washed out micrite matrix (Fig. 46.8), partly darker due to secondary iron impregnations (possibly reworked from Middle Devonian Taliouine Formation that, however, has no local outcrop).
14. Encrinite: coarse crinoid rudstone with ossicles and stem pieces (probable provenance as 13.).
15. Brecciated mudstone (Fig. 46.8), indication for seismic activity before the exhumation.
16. Flaser-bedded brachiopod limestone (Fig. 46.6): Recrystallized (pseudosparitic), bioturbated brachiopod floatstone with ferromanganese coating of some shells and bivalved or convex-up, current-controlled embedding. Complete shells are filled by a mixture of matrix and geopetal sparite. Conodonts include an encrusted *Avignathus decorosus* (Fig. 47.4), incomplete probable *Polygnathus webbi* (Fig. 47.6), *Po.* aff. *paradecorosus* (Fig. 47.5) with unusually wide platform, and five *Palmatolepis hassi* (Fig. 47.7). The first species enters at the top of the middle Frasnian (e.g., KLAPPER 1997), where it was found in griotte facies of the Tata region (BECKER et al. 2004a, 2004b). The palmatolepid dominance is not typical for brachiopod limestone and suggests a deep neritic setting, near the storm wave base. The top middle/upper Frasnian brachiopod limestone probably correlates with the atrypid block collected at Taliouine. It proves that a Frasnian carbonate ramp existed once, but in the Asserhmo region this was completely destroyed by Eovariscan uplift and erosion.
17. Isolated crinoid ossicles (Fig. 47.7) and corals, such as *Parastriatopora* (Figs. 49.1-2), *Alveolites* (Figs. 49.3-4), *Heliolites*, and phillipsastreids. *Parastriatopora* is a widely distributed genus in the Silurian to Emsian (e.g., MAY 2005). Its presence as isolated clast is unusual since we did not observe corals in the Pragian/lower Emsian at Asserhmo West and East. This suggests a more distant source, where the coral must have been freed from marl, not from lithified limestone. The partly large alveolitid colonies are unlikely to have been derived from the Lower Devonian. The group is characteristic for neritic to biostromal facies, which does not occur in the Skoura Lower Devonian. Based on an associated Middle Devonian linguipolygnathid (Tab. 2, coral limestone sample), the alveolitids probably derived from a local reefal facies of the Givetian Taliouine Formation. This is supported by the phillipsastreids (see *Prismatophyllum* of LAVILLE 1980), which occur in the Givetian/Frasnian, while *Heliolites* is not known above the Givetian.

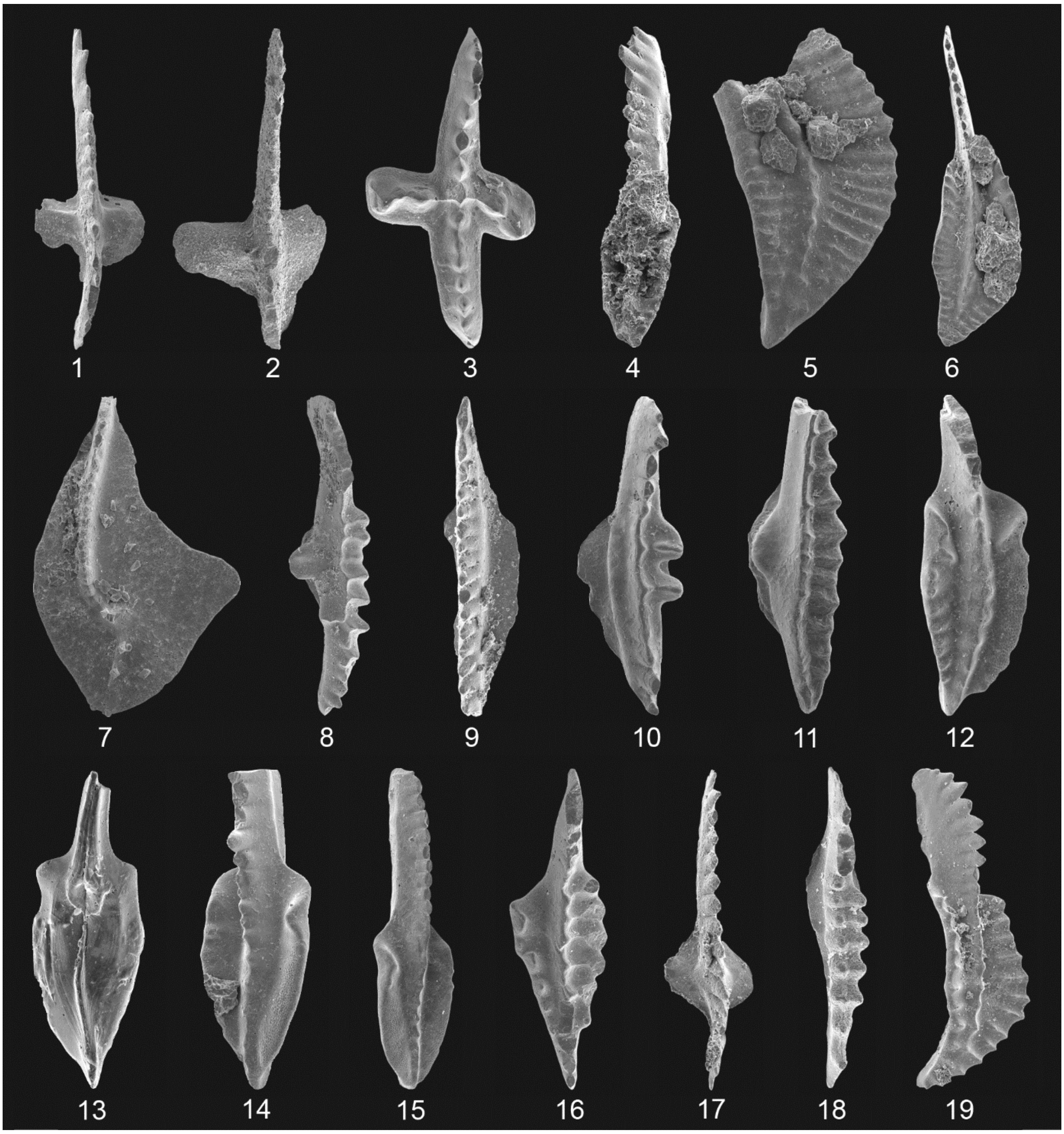

Fig. 47: Conodonts from the Lower Devonian, from individual clasts and conglomerate bulk samples at Asserhmo; GMM B4C.2.190-207. **1.** *Criteriognathus miae*, Asserhmo West, Bed 5, x 65; **2.** *Crit. steinhornensis* (early form), Asserhmo East, top of Imi-n-Tazaght Formation, x 60; **3.** *Ancyrodelloides transitans*, unusual morphotype with downlapping side lobe, pebble of black Orthocone Limestone, middle part of main conglomerate, x 40; **4.** *Avignathus decorosus*, encrusted, brachiopod limestone pebble, x 65; **5.** *Polygnathus ?webbi*, incomplete, brachiopod limestone pebble, x 45; **6.** *Po*. aff. *paradecorosus*, with atypically wide platform, brachiopod limestone pebble, x 55; **7.** *Palmatolepis hassi*, brachiopod limestone pebble, x 60; **8.** *Bispathodus spinulicostatus* M1, with side node on a left platform extension, as in the type material (ZIEGLER et al. 1974), conglomerate bulk sample 1, x 35; **9.** *Bi. stabilis stabilis*, conglomerate bulk sample 2, x 65; **10.** *Bi. aculeatus aculeatus*, transitional from *Bi. bispathodus*, with posterior extended basal cavity, conglomerate bulk sample 1, x 60; **11.** *Bi. costatus* M2, conglomerate bulk sample 1, x 60, **12-14.** *Neopolygnathus communis* cf. *yazikovi*, 12-13 = strongly ribbed morphotype, x 65, 14 = variant with ribbing on one side only, x 60, both from conglomerate bulk sample 1; **15.** *Neo. communis communis*, with distinctive collar, conglomerate bulk sample 1, x 45; **16.** *Pseudopolygnathus primus primus* M3, conglomerate bulk sample 1, x 50; **17.** *Branmehla ampla*, conglomerate bulk sample 2, x 65; **18.** *Scaphignathus velifer leptus*, conglomerate bulk sample 2, x 65; **19.** *Linguipolygnathus zieglerianus*, conglomerate bulk sample 2, x 50.

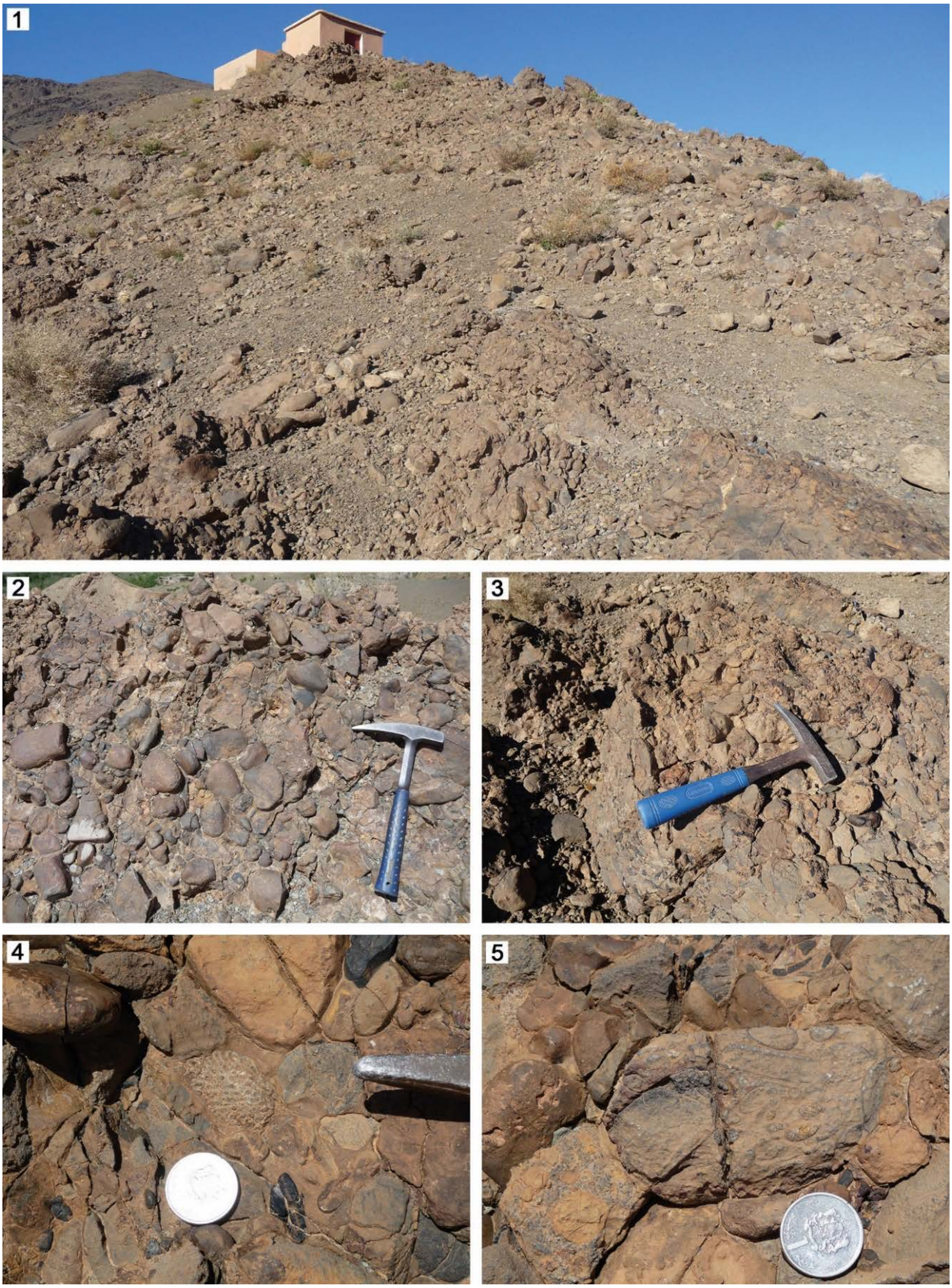

Fig. 48: Field photos of the conglomeratic Asserhmo Formation. **1.** Section overview, with the small water reservoir building (2 m high) at the top; **2.** Details of lower part of main conglomerate dominated by well-rounded Ordovician quartzite pebbles; **3.** Middle part of main conglomerate dominated by subangular clasts of yellowish to reddish-weathering limestone; **4.** Details of upper part of conglomerate, showing the embedding of a tabulate coral between unsorted, polymict, rounded to angular clasts; **5.** Large subrounded pebble of orthocone limestone in unsorted upper part of Asserhmo Formatio, with almost no matrix between the polymict clasts (coin = 24 mm).

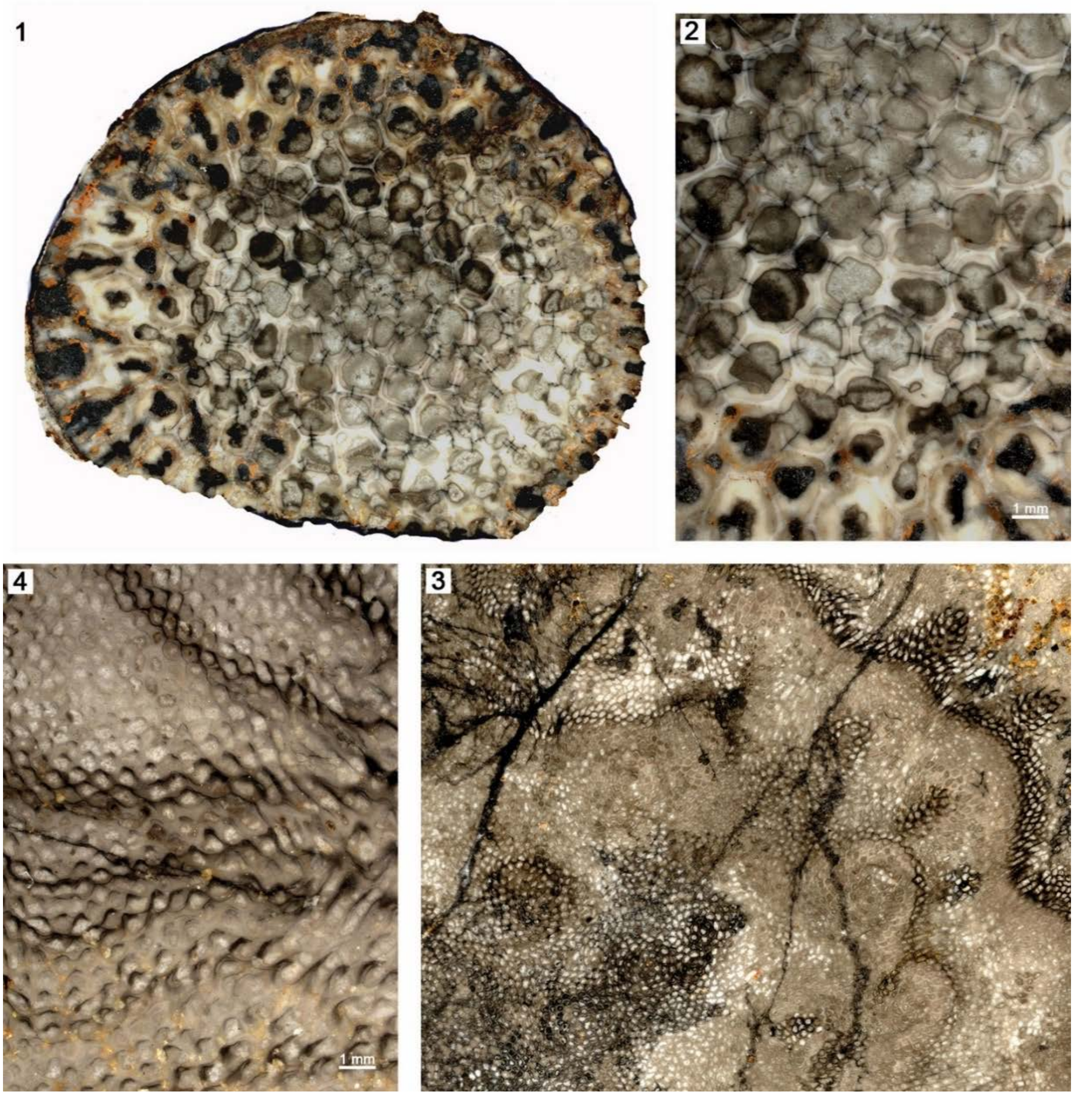

Fig. 49: Isolated tabulate corals from the upper part of the Lower Member of the Asserhmo Formation (scale = 1 mm). **1-2.** *Parastriatopora* sp., colony diameter 2.5 cm, GMM B2C.57.12; 3-4. *Alveolites* sp., picture width of 3. = 4.5 cm, GMM B2C.57.13.

19. Abundant dark-grey mudstone with rare crinoid debris and fine detrital limestone, resembling the two beds at the base of the Lower Member. This is perhaps the origin of relatively diverse middle/upper Famennian conodonts collected from two conglomerate bulk samples (Tab. 2). Sample "Conglomerate 1" from the base of the main part yielded *Bispathodus spinulicostatus* M1 (Fig. 47.8), *Bi. costatus* M2 (Fig. 47.11), *Bi. aculeatus aculeatus* (Fig. 47.10, transitional from *Bi. bispathodus* due to its long basal cavity), *Pseudopolygnathus primus primus* M3 (Fig. 47.16), *Neopolygnathus communis communis* (Fig. 47.15), and *Neo*. *communis* cf. *yazikovi*. (Figs. 47.12-14; see taxonomic paragraph). *Bispathodus costatus* defines the upper Famennian (higher UD V) *costatus* Subzone of Hartenfels (2011) or *costatus* Zone sensu Spalletta et al. (2017). All other species could come from the same interval (for *Ps. primus primus* M3 see Hartenfels & Becker 2016b) but a Pragian clast (see Tab. 2) was part of the same block. The "Conglomerate 2" sample produced *Bi. stabilis stabilis* (Fig. 47.9), *Branmehla ampla* (Fig.47.10), and *Scaphignathus velifer leptus* (Fig. 47.17). The first defines in the scheme of Hartenfels (2011) a zone that is equivalent to the (Lower) *expansa* Zone of the palmatolepid succession, high in UD IV. The second ranges from the middle Famennian *utahensis* Zone (former

Upper *marginifera* Zone) to the basal *aculeatus aculeatus* Zone (basal UD V; HARTERNFELS 2011). *Scaphignathus velifer leptus* is known from the *utahensis* to the *styriacus* Zones (UD III to middle UD IV). Therefore, the Famennian assemblage is mixed (middle/upper part of UD IV, possibly also UD III) and older than the one from upper Famennian clasts of "Conglomerate 1". Clasts in the sample with alveolitids yielded a second *Sc. velifer leptus*. A pebble within "Conglomerate 2" yielded the basal Eifelian (e.g., BELKA et al. 1987) *Linguipolygnathus zieglerianus* (Fig. 47.18) and a poorly preserved scolecodont. None of the Skoura outcrops yielded so far any in-situ conodonts of the *partitus* Zone.

The conglomerate clast spectrum and conodonts prove that not only the typical Skoura Lower and Middle Devonian known from the outcrops was subject to uplift and reworking, but also a Givetian to Frasnian neritic ramp/platform and ?middle to upper Famennian pelagic limestones. The latter are completely unknown from the studied Skoura localities. The conglomerates, therefore, provide unique windows into the whole Upper Devonian facies development of the region. It is likely that the current lack of lower and undoubted middle Famennian conodonts reflects only the so far limited sampling. Alternatively, there was an upper Famennian transgression, ca. at the level of the *Annulata* Events (see HARTENFELS 2011 and HARTENFELS & BECKER 2016a). There is currently no local evidence for uppermost Famennian and lower/middle Tournaisian strata.

8.2.2. Upper Member

The Upper Member of the Asserhmo Formation occupies the eastern slope of the water reservoir hill. It consists of brownish weathering, fresh dark-grey, silty slates and platy, laminated, micaceous, well-sorted fine sandstones without fossils. There is potential for future palynomorph dating, which could prove a supposed (upper) Tournaisian age. LAVILLE (1980) included the Upper Member in the Devonian, below an Upper Viséan unconformity, but his interpretation was not based on any faunal data.

1

2

Fig. 50: Field photos of the Viséan at Taliouine Section 3. **1.** Steep upper slope, showing a thick package of greenish-grey shale partly covered and overlain at the top by resistant, very fossiliferous bioclastic limestone; **2.** Loose slab of crinoidal limestone with one of the locally very characteristic, large euomphalid gastropods (67 mm max. diameter).

9. Viséan at Taliouine

Previous authors described the laterally rather variable lithology of transgressive Viséan beds in the Skoura region (ROCH 1939, 1950; LAVILLE 1980; IZART et al. 1989). We examined only the succession in the upper

slope of Taliouine Section 3 and collected spot samples.

As discussed above, the ca. 20 m thick alternation of shale, marl, and bioclastic limestones overlying the conglomeratic Member 4 of the Taliouine Formation has been assigned by LAVILLE (1980) to the Frasnian. It is followed by ca. 30 m of greenish-grey, poorly fossiliferous shale (Fig. 50.1) of currently unknown age. The top of the steep hill is formed by a ca. 10 m thick cliff of Lower Carboniferous, very fossiliferous limestones with solitary Rugosa (Fig. 52), abundant brachiopods (spiriferids, Fig. 51, strophomenids, productids), large bryozoan colonies (partly > 10 cm), and, locally especially distinctive, large euomphalid gastropods (Fig. 50.2). This is the “Calcaires viséens” of ROCH (1939, 1950) and the “calcaire jaunes et lumachelle calcaire” of LAVILLE (1980), which was also briefly described by IZART et al. (1989, p. 68).

Thin-sections revealed an abundance (thousands of specimens) of foraminifera (Fig. 53). Assemblages are predominantly composed of typical taxa of the upper part of the early Viséan, including *Archaediscus* ex gr. *stilus*, *A. koktjubensis*, *Archaediscus* spp. at *involutus* stage, *Archaediscus* spp. transitional forms between the *involutus* and *concavus* stages, *Endothyra* spp., *Eoparastaffella florigena*, *E. macdermoti*, *Eotextularia diversa*, *Glomodiscus oblongus*, *G. rigens*, *Nodosarchaediscus* spp., *Plectogyranopsis ampla*, *P. moraviae*, *Pseudotaxis eominima*, *Omphalotis frequentata*, *O. chariessa*, *Tetrataxis* spp., *Uralodiscus rotundus*, and *U. elongatus*. However, rarely, *Archaediscus* at *concavus* stage (*A. krestovnikovi* and *A. moelleri*), *Endothyranopsis compressa,* and *Omphalotis minima* also occur.

The latter species indicate Cfm2 (upper Cf5α) in the middle part of the middle Viséan (top-Arundian; e.g., CÓZAR et al. 2020a, fig. 1). Associated are “algospongia”, such as *Kamaena*, and the problematical dasycladacean *Koninckopora inflata*. The environment was a storm-ridden, euphotic carbonate ramp. There are close similarities with the microfossil assemblage from Assif n´Tanzouzmine ca. 4 km to the SSE (IZART et al. 1989; CÓZAR et al. 2020a). The combined evidence of both sections suggests for the west-central Skoura region a hiatus that spans the Famennian to lower Viséan. At Asserhmo in the east (see above), it was shorter, including possibly only the top Tournaisian and lower Viséan. At Taliouine, the middle Viséan limestones are overlain on the northern backside of the hill by a thick package of greenish-grey silty shales. Based on goniatites mentioned by ROCH (1939), they are of upper Viséan age and indicate transgression, as typical for the Meseta.

Fig. 51: Spiriferid with exfoliated upper shell (preventing generic identification) from the middle Viséan bioclastic limestone at Taliouine, Section 3, GMM B5B.16.14.

10. Regional comparisons of facies and tectonic developments

The regional palaeogeography and reconstruction of synsedimentary structural history of the Skoura Devonian requires stratigraphically tuned comparisons with the allochthonous eastern Jebilet to the NW (see Jebilet chapter), the eastern Dra Valley in the S/SW (e.g., HOLLARD 1978; BECKER et al. 2004a, 2004b; JANSEN et al. 2004), and the

Tinerhir region in the east (e.g., HINDERMEYER 1954, 1955; SCHIAVO et al. 2007; RYTINA et al. 2013), which also belonged to the Sub-Meseta Zone (SMZ, MICHARD et al. 2008, 2010). Figure 54 correlates the principle Devonian successions of Taliouine, Tizi-n-Ouourti and Asserhmo with the Jaidet and Tata successions. For the Foum Zguid region, knowledge of the Middle/Upper Devonian is currently too incomplete; the Lower Devonian resembles the Tata region. The Ait Tamlil Devonian of the High Atlas (JENNY & MARREC 1980) seems to include similarities with the Skoura region, but lacks modern biostratigraphic and microfacies data.

Fig. 52: Representative thin-section of the middle Viséan limestones at Taliouine Section 3, a non-sorted and non-graded brachiopod-crinoid-coral floatstone with well-sorted bioclastic pack-grainstone matrix, representing a current-swept, neritic carbonate platform setting.

Fig. 53: Representative foraminifer-rich thin-section of the middle Viséan limestone (bioclastic grainstone) at the top of Taliouine Section 3.

10.1. Lower Devonian

The Silurian-Devonian transition of the Skoura region belongs to a deep and anoxic (hemi)pelagic shale basin. The Lower Member of the Tizi-n-Tichka Formation correlates with the main part of the Jebel Smaha Formation at Jaïdet and black shales of Ait Tamlil (Unit 8). The whole region is characterized by the lack of *Scyphocrinites* limestones, which are so characteristic for the eastern Anti-Atlas (e.g., HAUDE et al. 2014) and many Meseta regions (e.g., RÉGNAULT 1985). In the western Dra Valley, there was a very different, neritic, mixed siliciclastic-carbonatic facies (Lmhaifid Formation), characteristic for the cratonic shallow NW Gondwana shelf.

The slumped and strongly current-influenced middle Lochkovian Orthocone Limestones of the Skoura region (Upper Member of Tizi-n-Tichka Formation) has no equivalent in the Jebilet or Anti-Atlas. But interestingly, an only slightly older orthocone rudstone with *Ancyrodelloides carlsi* was found as reworked clast in the Taourirt n´Khellil breccia of the eastern Sub-Meseta Zone (RYTINA et al. 2013). The middle Lochkovian first "Skoura synsedimentary tectonic phase" (Sk-TP 1a), culminating in the upper Lochkovian to lower Pragian hiatus, seems to be a characteristic tectono-sedimentary feature of that zone.

Regionally, the "Antevariscan" movements continued ca. to the "middle" Pragian (conglomeratic Member 1 of Imi-n-Tazaght Formation at Taliouine, Sk-TP 1b). Probably as a consequence of the global Lochkovian-Pragian boundary regression, the anoxic and organic-rich facies had disappeared throughout the region and gave way to oxic pelagic mud-wackestones. These were then eroded and redeposited by seismically induced debris flows, together with reworked lower/middle Lochkovian black limestone clasts. Locally (Imi-n-Tazaght North), the higher Pragian began with a unique, condensed, microbial (*stromatactis*), deep neritic or shallow pelagic (dysphotic) limestone. There was a trend of reduced accumulation rates and more shallow ramp settings from west to east. But in the upper Pragian, the Skoura region shows a uniform oxic, nodular, shallow pelagic facies with bioclastic contourites, partly giant orthocones, and abundant *Panenka* bivalves. This Member 2 of the Imi-n-Tazaght Formation corresponds closely to the griotte of the Middle Member of the Jaïdet Formation, and of Units 10/11 at Ait Tamlil (JENNY & MARREC 1980). The Pragian sedimentary history of the eastern Dra Valley differed fundamentally, being characterized by the neritic Rich 1 and 2 cycles (Oued-el-Mdâouer and Merzâ-Akhsai Formations; e.g., HOLLARD 1978; BECKER et al. 2004a; JANSEN et al. 2004).

The Pragian-Emsian transition of the Skoura region correlates roughly with the boundary of Members 2 and 3 of the Imi-n-Tazaght Formation. There was a regional regressive trend towards less argillaceous, more current-influenced limestones. The overall setting remained shallow pelagic but we cannot recognize the transgressive pulse of the basal Emsian *atopus* Event, which is so characteristic in the Tafilalt (*Devonobactrites* Shale with F1 fauna, e.g., KLUG et al. 2008; ABOUSSALAM et al. 2015) and in the Foum Zguid region (DE BAETS et al. 2010: F1 fauna from the base of the Mdâouer-el-Kbír Formation). In this respect, the Skoura and Jaïdet successions are similar.

Our new *Erbenoceras* record from Taliouine may represent the next younger Chebbi Event level, which is marked in the Tafilalt by the rapid deepening of the *Metabactrites-Erbenoceras* Shale (e.g., ABOUSSALAM et al. 2015; F2 level of KLUG et al. 2008). Based on dacryoconarid dating, *Erbenoceras* occurs at the same time in the

northern Maïder (Jebel Issimour, PLODOWSKI et al. 2000). In the eastern Dra Valley, it appears in the middle part of the Lower Member of the Mdâouer-el-Kbír Formation; (HOLLARD 1963a, 1978; BULTYNCK & HOLLARD 1980: conodont Fauna II, *bilatericrescens* Zone). At Jaïdet, a more nodular griotte facies without early goniatites but with common iron mineralizations (Middle Member of Jaïdet Formation) continued in the lower Emsian. By contrast, the possibly correlative Unit 12 of Ait Tamlil is siliciclastic.

The lower Emsian of the eastern Dra Valley terminates the shallowing upwards Rich 3 cycle (Mdâouer-e-Kbír Formation). At its top, a *Mimagoniatites* level was found (JANSEN et al. 2004, 2007). It provides a precise correlation with the top-lower Emsian *Mimagoniatites* Limestone of the Tafilalt (e.g., WALLISER 1991; BULTYNCK & WALLISER 2000; BECKER & ABOUSSALAM 2011), Maïder (top of Bou Tiskaouine Formation, BULTYNCK 1991), and the *Mimagoniatites* level in Member 4 of the Imi-n-Tazaght Formation. The southern Moroccan *Mimagoniatites* bloom and spread has been correlated by BECKER & ABOUSSALAM (2011) with the global Upper Zlíchov Event sensu GARCÍA-ALCALDE (1997). In the Devonian of Ait Tamlil, the detrital, prominent Tassawt Limestone (Units 13/14, JENNY & MARREC 1980) may be a time-equivalent, which needs to be corroborated by biostratigraphical data.

Throughout the Skoura Devonian, the basal upper Emsian Daleje Event is sharp and marked by a fundamental sedimentary change, from fossiliferous, oxic, current-controlled bioclastic limestone to hypoxic silty, hostile shale. The facies break is very similar as in the eastern Anti-Atlas (northern Maïder: base Er Remlia Formation, BULTYNCK 1985; Tafilalt: Unit K, base Amerboh Formation, e.g., BECKER & HOUSE 1994b; BULTYNCK & HOLLARD 2000; BECKER et al. 2018a). However, it is very indistinctive in the eastern Dra Valley succession (ABOUSSALAM et al. 2015) and has not been found in the eastern Jebilet. At Ait Tamlil, greenish to black siltstones (Unit 15) overlying the Tassawt Limestone may represent Daleje Shale equivalents.

The rather uniform development of nodular to flaser-bedded, upper Emsian anarcestid limestones throughout the southern Meseta (eastern Jebilet: Upper Member of Jaïdet Formation)), Sub-Meseta (Skoura: Upper Member of Tizi-n-Ouourti Formation), and Anti-Atlas regions (western Dra Valley to Tafilalt) is intriguing. It suggests a long interval (*bultyncki/serotinus* to *patulus* Zones) of calm, condensed, oligotrophic, pelagic facies with almost identical faunas and without much seismic activity.

10.2. Middle Devonian

The upper Emsian “goniatite garden” episode was abruptly terminated in the lower Eifelian by Eovariscan block tectonics (Sk-TP 2) causing uplift, reworking of the upper Emsian, slumping, and unconformities on the Skoura side (Taliouine, Tizi-n-Ouorti). On the Jebilet side (Lower Member of El Kahla Formation), it led to sudden subsidence and the formation of a siliciclastic and eutrophic basin. A coincident gradual deepening initiated in the Foum Zguid and Tata regions (eastern Dra Valley) a change from condensed limestones to basinal marls with lower Eifelian goniatites (Upper Member of Timrhanrhart Formation, BECKER et al. 2004a). Pyritic (secondarily goethitic) faunas and blooms of minute brachiopods occurred during maximum flooding, the level of the global Choteč Event (BECKER et al. 2004a, 2004b; EBBIGHAUSEN et al. 2011).

Due to the very incomplete, episodic record of Eifelian sediment and conodonts, the Choteč Event cannot be recognized in the Skoura region. Currently, a single reworked

conodont from Asserhmo (*Linguipolygnathus zieglerianus*) testifies that deeper-water sedimentation continued at least locally in the basal Eifelian. At Taliouine, black shales between slumped upper Emsian olistolites and glide blocks (Sk-TP 2a) and slumped basal Givetian limestones (Sk-TP 2b) are taken as a regional expression of the top-Eifelian Kačák Event. At Tizi-n-Ouourti, the sedimentary record ends earlier (with the *kockelianus* Zone), after uplift first caused a long, top-Emsian-"middle" Eifelian hiatus, followed by a regionally unique, shallow, crinoidal-conglomeratic facies. In the Tata region, the Middle Devonian sedimentation was continuous, with cephalopod limestones ("*vanuxemi* Beds" of the Ahrerich Member occurring at the Eifelian-Givetian transition.

The Eifelian tectonic interval of the Skoura region lasted with interruptions into the basal Givetian (Member 1 and basal Member 2 of Taliouine Formation; Sk-TP 2c). Evidence are polymict mudclast conglomerates and in-situ-brecciation of mudstones triggered by seismic events. There are no facies similarities any more with the Jaïdet succession (Upper Member of El Kahla Formation), nor with the lower Givetian of the Tata region (goniatite marls of the upper Ahrerich and lower Oued Mzerreb Members of the Ahrerouch Formation, BECKER et al. 2004a). The reworked Givetian of the Tinerhir region (RYTINA et al. 2013) and northern Maïder (e.g., KAZMIERCZAK & SCHRÖDER 1999; FRÖHLICH 2003, STICHLING 2013) was biostromal. Surprisingly, close faunal and facies ties with the Tata succession were re-established in the seismically quiet lower part of the middle Givetian. Member 3 of the Taliouine Formation resembles the upper Oued Mzerreb and Tiguisselt Members of the Ahrerouch Formation, especially concerning the admixture of dominant goniatite and subordinate neritic faunas. In detail, the marker units of Oued Mzerreb (BECKER et al. 2004b) are not developed and the absence of the *pumilio* Events (LOTTMANN 1990) at Taliouine is distinctive. Apart from the presence of *Sellagoniatites*, the faunas and strata of the Tafilalt Platform and Maïder Basin are not similar. However, far in the SE, the middle Givetian of the Tafilalt Basin (Hassi Nebech) shows some identical faunas in goniatite marls (e.g., *Argutastrea, Afromaenioceras*, and other goniatites; ABOUSSALAM 2003).

The next major block faulting, uplift, reworking and redeposition episode (Sk-TP 3) manifested in the massive and polymict conglomerates of Member 4 of the Taliouine Formation. This development severely interrupted the eastern Dra Valley link. The Taliouine conglomerates represent the first major Eovarican phase in the middle/upper Givetian that characterizes most of the Meseta (BECKER et al. 2015). It is also well-developed (as flat pebble breccias) in an allochthonous Devonian block between Tinerhir and Tinejdad (Section Bou Tisdafine Southeast, TALIH et al. in prep.), in the eastern continuation of the Sub-Meseta Zone. The same seismic events caused megaslumps, breccias, biostrome extinctions, and eventually the top middle Givetian unconformity of the northern Maider (e.g., KAZMIERCZAK & SCHRÖDER 1999; FRÖHLICH 2003; STICHLING 2013). Therefore, there was a pattern of upper Givetian synsedimentary tectonic movements ranging from the Meseta through the Sub-Meseta Zone into the cratonic Anti-Atlas, but, somehow, sparing the Dra Valley.

In the Skoura region, the upper Givetian seismic events were sedimentologically distinctive but episodic, and interrupted a persisting outer shelf, hypoxic goniatite shale facies. Interestingly, the faunas with pharciceratids and pseudoprobeloceratids have no equivalent in the Tata region, where there is a gap of goniatite faunas between the

top-middle Givetian (*Juvenocostatus* Beds, Tiguisselt Member) and higher middle Frasnian (*Naplesites* Beds, Lower Member of Anoû Smaira Formation, BECKER et al. 2004a, 2004b). The closest similar, but much richer assemblages are from the NW Maïder (BOCKWINKEL et al. 2015).

10.3. Upper Devonian

It should be re-emphasized that the supposed Skoura Frasnian with *Koenenites* in HOLLARD (1967) represents most likely top-middle Givetian goniatite shale with *Mzerrebites* as in the Tata region (*Juvenocostatus* Beds). The true Upper Devonian sedimentary and faunal record of the Skoura region is currently very scarce and incomplete, and mostly based on isolated and reworked blocks. This hampers regional comparisons but the data available are sufficient to state that there was a rather unique facies development.

The middle/upper Frasnian neritic brachiopod limestones of Taliouine and Asserhmo have no pendant in all of the southern or eastern Meseta, nor in the eastern Sub-Meseta Zone or Dra Valley (pelagic goniatite beds of higher Anoû Smaira Formation). The next closest occurrences are poorly studied Frasnian brachiopod limestones from the northern Maïder (DROT & HOLLARD 1967; new collection from the Bou Dib area). In the Taourirt n´Khellil breccia east of Tinerhir, the Frasnian is only represented by Kellwasser Limestone clasts (new record).

The upper Famennian pelagic conodont faunas of the main Asserhmo conglomerate have also no pendant in the southern Meseta (Rehamna, Jebilet) or Dra Valley (siliciclastic Lemgairinat Formation). Again, the next closest occurrence is in the northern Maïder, more specifically around the Jebel Rheris (FRÖHLICH 2004 and new data). However, lower/middle Famennian pelagic conodonts were found very recently in the central Jebilet (Sarhlef Formation, LAZREQ et al. 2021) and it is likely that a mostly siliciclastic Jebilet Basin persisted throughout the Famennian.

The Asserhmo Formation shows overall similarities with the Taourirt n´Khellil Formation (RYTINA et al. 2013; HARTENFELS et al. 2013). It is possible that both originated by seismically triggered rockfall along active fault scarps during the same Eovariscan episode (Sk-TP 4). In the Tinerhir region, the breccia units lie at the base of thick greenish shales and siltstones (Ait Yalla Formation, SCHIAVO et al. 2007), which yielded HINDERMEYER (1954) some upper Tournaisian goniatites. The timing of Sk-TP-4 is constrained below its base by our reworked clasts of the *costatus* Zone (Famennian V). This leaves the uppermost Famennian (UD VI) to middle Tournaisian interval. The latter is known for strong seismic activity in the eastern Anti-Atlas (e.g., KAISER et al. 2011, 2013; TAHIRI et al. 2013).

10.4. Summary

In summary, the Skoura Devonian records distinctive crustal developments at the Meseta-Anti-Atlas transition, with variable facies similarities fluctuating in time, and constrained by four regional phases of synsedimentary tectonics (middle Lochkovian to lower Pragian, Eifelian to basal Givetian, upper Givetian, top-Famennian or middle Tournaisian). It was followed by a fifth episode, resulting in a regional unconformity below a middle Viséan shallow shelf succession.

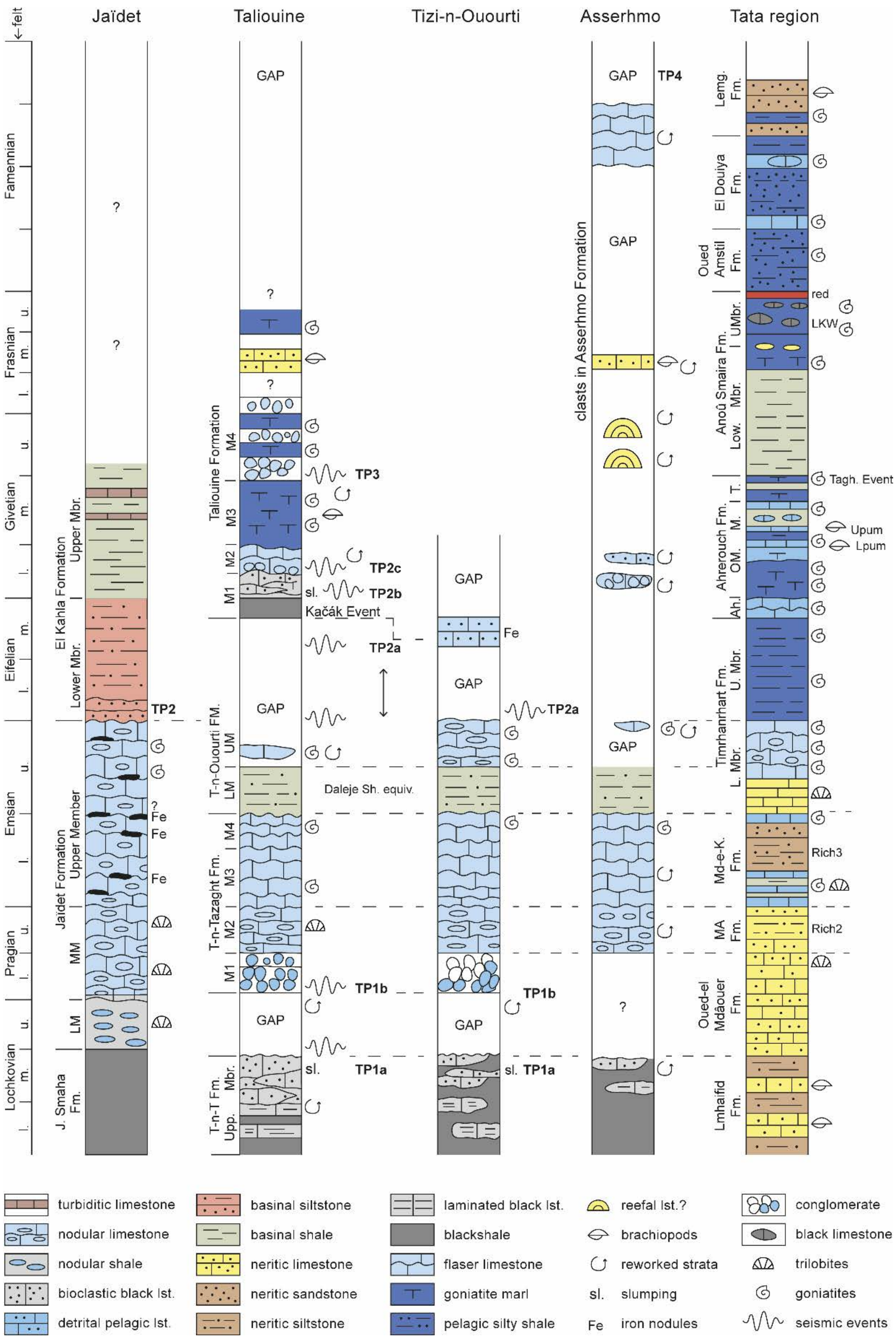

Fig. 54: Correlation of Devonian facies developments in the eastern Jebilet (Jaïdet), Skoura region (Taliouine, Tizi-n-Ouorti, Asserhmo), and eastern Dra Valley (Tata region, BECKER et al. 2004a, 2004b; JANSEN et al. 2004); l. = lower, m. = middle, u. = upper (informal substages); LM = Low. Mbr. = Lower Member, MM = Middle Member, UM = Upp. Mbr. = Upper Member, M1-M4 = Members 1-4, T-n-T Fm. = Tizi-n-Tichka Formation, MA Fm. = Merzâ Akhsai Formation, Md-e-K. Fm. = Mdâouer-el-Kbír Formation, A. = Arherich Member, OMz. M. = Oued Mzerreb Member, T. = Tiguisselt Member, Lemg. Fm. = Lemgairinat Formation, TP 1-4 = tectonic phases of Skoura region, Lpum/U pum = Lower and Upper pumilio Events, LKW = Lower Kellwasser Limestone.

11. Taxonomic notes

11.1. Cephalopods (LA & RTB)

Order Discosorida FLOWER in FLOWER und KUMMEL, 1950
Family Phragmoceratidae MILLER, 1877
Genus *?Pseudendoplectoceras*

***?Pseudendoplectoceras tazaghtense* AFHÜPPE & BECKER n. sp.**
Fig. 55.1a-e

Derivation of name: After the village Imi-n-Tazaght just west of the type locality.

Holotype: GMM B6C.54.155, Geomuseum Münster.

Type locality and level: Tizi-n-Ouourti, Bed F36, upper Emsian, *Anarcestes simulans* Zone, LD IV-D_1.

Diagnosis: Short, small, endogastric, cyrtoconic brevicone with a compressed cross-section. Longitudinal profile ventrally slightly concave, convex in living chamber, dorsally convex, laterally slightly convex. Sutures apparently straight. Siphuncle marginal, with adnation area at adoral ends on dorsal side. Septal necks dorsally cyrtochoanitic and without bullettes. Connecting rings slightly thickened. Chamber deposits with trigonal cross-section on dorsal side of the siphuncle between siphuncular segments and septa.

Description: The specimen consists of part of the living chamber and the last six chambers of the phragmocone. The aperture is not preserved. The shell is weathered, creating some inaccuracies of measurements. The preserved shell is ca. 3.2 cm long, with a maximum diameter of ca. 3.3 cm located 0.5 cm from the last septum within the living chamber. The cross-section at the adapical end is slightly compressed and becomes more distinctly compressed towards the adoral end (ovality = 0.82 – 0.88). The body chamber is short cyrto-breviconic, without evidence of torticonic coiling. The longitudinal conch profile of the ventral side is first slightly concave (Fig. 55.1a) and eventually becomes convex in the living chamber. On the dorsal side, the profile is always convex, laterally it is slightly convex. Due to the surface weathering, sutures are somewhat difficult to discern, but appear to be straight. The chambers are between 3.4 and 3.8 mm long (length/diameter ratio = 0.10 – 0.13) and expand with an angle of 41° (vertically) and 42° (horizontally). The siphuncle is marginal on the internal side of the curvature (siphuncle diameter/chamber diameter = 0.11 – 0.17); therefore, the coiling is endogastric. The siphuncular segments are not particularly inflated, but have an adnation area at their adoral ends on the outer dorsal side. The septal necks are cyrtochoanitic and very short on the dorsal side but not preserved on the ventral (inner) side, where they must have been positioned very close to the dissolved shell wall. The connecting rings are slightly thickened; bullettes are not visible. On the dorsal side of the siphuncle, deposits have been formed within the chamber in the area between the connecting ring and the septum, which have a trigonal cross-section.

Discussion: The knowledge of Lower Devonian Discosorida of Morocco is very restricted and with every new record, the discovery of new taxa can be expected, especially from regions and strata that have never or hardly been sampled for nautiloids. The new species, which is a rare form, resembles *Pseudendoplectoceras lahcani* KRÖGER, 2008 from the Pragian of the southern Tafilalt, the type-species of the genus, in the shape of the siphuncular segments and the chamber deposits as well as in the thickened connecting rings. Both the endogastric coiling and the thickened connecting rings are typical for the Discosorida. Our form differs in the lack of slight torticonic (trochoceroid) coiling,

absence of visible bullettes, which questions the generic affinity, and the more compressed cross-section of the shell. Also, *?Ps. tazaghtense* has short cyrtochoanitic septal necks on the dorsal side of the siphuncle, which are thought to be recumbent in *Ps. lahcani*. The much older (middle Silurian) *Endoplectoceras* FOERSTE, 1926 and *Protophragmoceras* HYATT in ZITTEL, 1900 have more evenly inflated siphuncular segments and more strongly curved shells. *Phragmoceras* BRODERIP in SOWERBY in MURCHINSON, 1839 generally contains much larger species with a relatively large siphuncle, lateral lobes, and thickened connecting rings. Since only the imperfectly preserved holotype is available, we refrain from placing the undoubtedly new species in a new genus.

?*Pseudendoplectoceras rochi* AFHÜPPE & BECKER n. sp.

Fig. 55.2a-e

Derivation of name: In honor of the French geologist Eduard ROCH, who first explored the Devonian geology of the Skoura region.

Holotype: GMM B6C.54.156, Geomuseum Münster.

Type locality and level: Tizi-n-Ouourti, Bed F26, upper Emsian, "*Latanarcestes noeggerathi*" Zone, UD IV-B.

Diagnosis: Small, endogastric, cyrtoconic brevicone with (sub) circular cross-section. Ventral longitudinal profile first concave, convex in the living chamber, dorsal profile convex throughout ontogeny, lateral profiles straight, convex in the living chamber. Sutures straight. Siphuncle strictly marginal on inner side of shell curvature. Siphuncular segments with adnation area at their adoral ends, but not at the adapical end. Septal necks on dorsal side short, cyrtochoanitic, with bullettes, adventrally ortho- or (sub-)orthochoanitic. Chamber deposits with trigonal cross-section on dorsal side of siphuncle between siphuncular segments and septa.

Description: The specimen consists of a partially preserved living chamber and the last seven chambers of the phragmocone. The aperture is not preserved. The preserved shell is 4 cm in length, with a maximum diameter of about 2.5 cm located 0.4 cm from the last septum within the living chamber. The cross-section is circular to very weakly compressed at the adapical and adoral ends. The shell is short cyrto-breviconic and endogastrically curved, obviously not torticonic. The longitudinal profile of the ventral side is concave and becomes convex from the third chamber before the living chamber. The dorsal side is convex in profile throughout. The lateral sides are straight and convex from the third chamber before the living chamber. As far as the weathered surface allows to say, the sutures are straight. Phragmocone chambers are 2.5 - 3.5 mm long (length/diameter ratio = 0.10 – 0.16); the shell expands in the phragmocone with about 43° (vertically) and 31° (horizontally). The siphuncle lies strictly marginal on the internal side (siphuncle diameter/chamber diameter = 0.11 – 0.17). The siphuncular segments are more inflated on their dorsal (outer) side towards the aperture than towards the apex, forming an adnation area at their adoral end. The inner ventral side of the siphuncle and the septal necks are not well preserved. On the dorsal side, the latter seem to be short and cyrtochoanitic, on the ventral side ortho- or suborthochoanitic. On the dorsal side, bullettes are not particularly pronounced. Within the chamber, in the area between the connecting ring and the septum, deposits with a trigonal cross-section were formed.

Discussion: ?*Pseudendoplectoceras rochi* n. sp. resembles the older *Ps. lahcani* in the shape of the siphuncular segments, the bullettes, the chamber deposits, and the cross-section of the shell. However, there is a

difference in the non-thickened connecting rings and in the cyrto- or (sub-)orthochoanitic septal necks, which are supposed to be recumbent in *P. lahcani*. However, they appear to be rather strongly cyrtochoanitic in the illustrations in KRÖGER (2008, pl. 16). Furthermore, a trochoceroid curling is not visible in ?*P. rochi*, but the shell is not complete. The conch curvature is stronger and the expansion angle smaller in *P. lahcani*. For the differences to related genera see under *?Ps. tazaghtense* n. sp. This slightly younger species does not display the bullettes of *?Ps. rochi* n. sp. and is markedly compressed.

11.2. Conodonts (RTB & ZSA)

***Wurmiella* aff. *wurmi* (BISCHOFF & SANNEMANN, 1958)**

Fig. 9.1

Description: Blade of GMM B4C.2.149 very long and elongate, slightly sinuous, bordered along the entire length by a well-defined margin, with 15 low, dense standing anterior teeth, a central larger tooth above the small and asymmetric basal cavity, and eight low posterior teeth that become more free-standing towards the end. Basal cavity extension on the right side bears a single denticle connected with the central tooth.

Discussion: The blade-type, denticulation, and asymmetric small cavity agree closely with the type material of *W. wurmi* from Franconia, Germany. However, the side denticle sitting on the asymmetric cavity extension is distinctive. It does not seem to be a pathological feature. Similar side nodes are known from much older (top-Silurian) specimens assigned to *"Ozarkodina" eosteinhornensis* (e.g., CORRADINI & CORRIGA 2012), which type material, however, does not show such a feature (see WALLISER 1964). The *eosteinhornensis* Group differs anyway in much shorter blades with much fewer denticles.

There is no documentation of a similar specimen from the middle Lochkovian but ROOPNARINE et al. (2004) mentioned an "alpha morphotype with a denticle developed on the blade shoulder" from the contemporaneous Windmill Limestone of Nevada. Since there is currently only one specimen from Taliouine, we keep it in open nomenclature.

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

Figs. 10.2-3

Description: Two pelekysgnathids (GMM B7A.12.156-157) from the top of the Tizi-n-Tichka Formation on the eastern of the ravine below Taliouine differ from all named species of the genus. Only one is well-preserved, the second is encrusted. The blade is narrow and elongate, widening slightly and gradually posteriorly. The lower margin is straight, bending sharply downwards under the most posterior tooth. From the anterior end, eight to nine triangular denticles gain very slightly in height, followed by two much larger, upright, also triangular teeth. There is no platform, only rounded shoulders around the two posterior teeth. The basal cavity is very narrow and deep, widening gradually towards the posterior end.

Discussion: The only named similar Lower Devonian pelekysgnathid is *Pel. elongatus*, which has a wider posterior cavity and denticles of alternating size before the posterior main teeth. Our new form is not identical with *Pel.* aff. *elongatus* from the Lochkovian of Jaidet (see eastern Jebilet chapter, this volume). With respect to the limited and incomplete material available, and since the variability of Lochkovian *Pelekysgnathus* is not sufficiently known, we apply open nomenclature until further sampling.

Occurrence: Restricted to the middle Lochkovian *transitans* Zone of Taliouine.

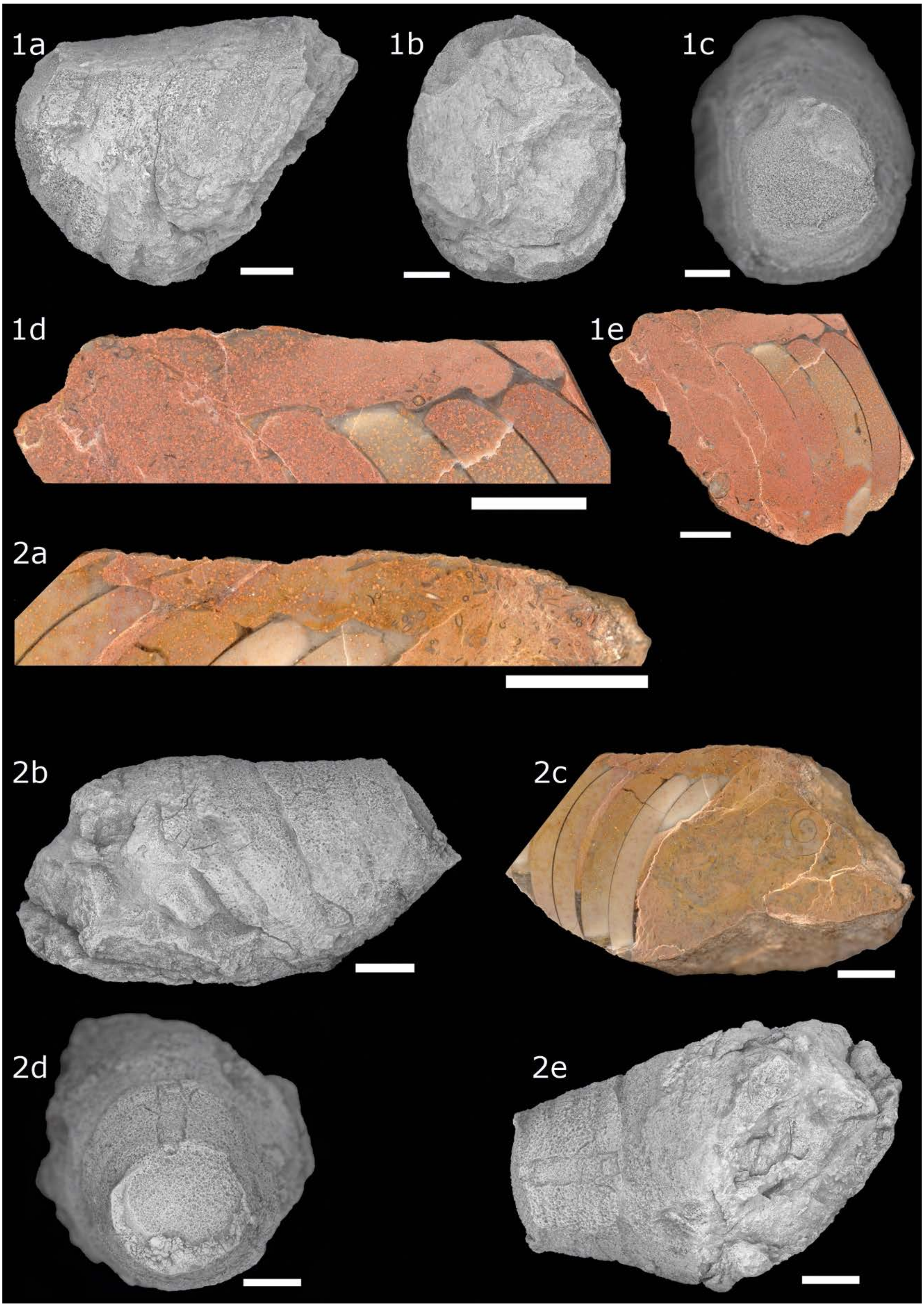

Fig. 55: New Discosorida from the upper Emsian of Tizi-n-Ouourti; scale bars = 5 mm, venter always at the top (apart from 2e). **1.** ?*Pseudendoplectoceras tazaghtense* n. sp., GMM B6C.54.155, a = lateral view, b = apertural view showing compressed cross-section, c = apical view, d = longitudinal section of siphuncle (aperture to the left), e = complete longitudinal section; **2.** *?Pseud. rochi* n. sp., GMM B6C.54.156, a = longitudinal cross-section of siphuncle (aperture to the right), b = lateral view, c = complete longitudinal section, 2 = apical view showing circular cross-section, e = dorsal view with strictly marginal (internal) siphuncle.

***Neopolygnathus communis* cf. *yazikovi* IZOKH in IZOKH & YAZIKOV, 2017**
Figs. 47.12-15

1959 e.p. *Polygnathus communis* HASS: pl. 49, fig. 11 [only]
2017 cf. *Neopolygnathus communis yazikovi* IZOKH (in IZOKH & YAZIKOV): 229, pl. 1, figs. 5-14
2020 *Neopolygnathus* cf. *communis communis* PARZIVI et al.: pl. 2, figs. 24a-b

Description: Free blade with more than 10 low denticles standing in close contact, almost as long as the slightly curved or subsymmetric, subtriangular platform (Fig. 47.15), which is widest near the anterior end. The variably slightly curved or near-straight carina consists of strongly molten denticles that extend slightly beyond the posterior platform end. The anterior platform is always smooth, with a short collar formed on both sides by distinctive margin folds, followed posteriorly by distinctive, slightly irregular (Fig. 47.12) ribbing, often only on one side (Fig. 47.14). The adcarinal troughs are deep and wide. The aboral side displays a small, shallow pit under anterior platform, followed by a shallow depression (Fig. 47.13).

Discussion: In upper Famennian *Neo. communis communis*, the platform is always completely smooth (see Fig. 47.15), mostly curved, and an anterior collar is variably present on one or both sides. The posterior carina extends variably shortly beyond the platform or it may end earlier (see types of BRANSON & MEHL 1934 or the illustrated population of KONONOVA & WEYER 2013, pl. 10). Not in the syntypes (no lectotype has been selected!), but in many other supposedly conspecific specimens, the adcarinal troughs may be narrow and bordered by upturned, sometimes bolstered, smooth margins (e.g., DRUCE 1969; HARTENFELS 2011; HARTENFELS & BECKER 2016a). Clearly, there are several morphotypes within the subspecies (see JI & ZIEGLER 1993; VORONTZOVA 1996), including the invalid *Neo. communis quadratus* WANG, 1989 (a homonym, see BECKER 2012), and *Neo. klapperianus* (ASHOURI, 2006: based on a juvenile); but none agrees with our specimens. “Morphotype 1” sensu JI & ZIEGLER (1993) and GHOLAMALIAN (2005) does not belong to *Neo. communis* but is closely related to the lower Famennian *Neo. osbakensis, Neo. vorontzovae* and *Neo. huijunae* (see WEDDIGE 1984, KUZ´MIN 1996, and WANG et al. 2016); the short free blade is distinctive for the group.

Our specimens do not agree with any named Famennian neopolygnathid. In the curved *Neo. communis dentatus* (DRUCE, 1969), the anterior platform margin is raised and ribbed, especially on the inner side, and, therefore, the rather fine carina sits much lower than the margins. In the Australian *Neo. collinsoni* (DRUCE, 1969), a marked, anterior rostrum with nodes is delimited by a constriction from the main platform, and the aboral depression is narrow and much deeper. There are slight similarities of our material with *Neo. communis lectus* KONONOVA in BUSHMINA & KONONOVA (1981), in which, however, the posterior carina is distinctively short, consisting of a fining row of nodes. *Neopolygnathus communis renatae* CORRADINI, BARCA & SPALETTA, 2003 is characterized by single nodes and short ridges on both sides of anterior platform margin. The platform tends to be constricted, a feature that is extreme in *Neo. margaretae* KONONOVA & WEYER (2013). In *Neo. depressus* (METZGER, 1989), the aboral depression is very deep, and the holotype shows on the left anterior side a row of strong nodes pointing outwards. *Neopolygnathus mugodzharicus* GAGIEV, KONONOVA & PAZUKHIN, 1987 is characterized by high, trigonal margins with some nodes.

Neopolygnathus seminudus (KUZ´MIN, 1992), originally described from Kazachstan, is characterized by marginal ribs that are

restricted to the posterior platform. *Neopolygnathus mutabilis* (KHALYMBADZHA, SHINKARYOV & GATOVSKY, 1991), also from the Famennian of Kazakhstan, can be distinguished because of its stronger curvature, finer carina, and different anterior platform, which is variably smooth or serrated, but without a collar. In the lower Famennian *Polygnathus tichonovitchi* KUZ´MIN & MELNIKOVA, 1991, a possible *Neopolygnathus*, the curvature and the ribbing are stronger and there are no anterior margin folds forming a collar, but spine-like protrusions of ribs. All three *communis* subspecies named by SAVAGE (2013) from NW Thailand are different and characterized by flat platforms. Only *Neo. communis namdipensis* is ribbed, but along the wide median and posterior platform margins.

Other Famennian species, such as *Neo. fibula* HARTENFELS & BECKER, 2016a, display nodes and transverse ridges on the inner parts of the anterior platform. The species belongs to the group around *Neo. carina*, which radiates and is most common in the Tournaisian (e.g., LIPNJAGOW in KOZITSKAYA et al. 1978: *Neo. communis stylensis*; NI 1984: *Neo. communis porcatus*; NIGMADZHANOV 1986: *Neo. tschatkalicus*; QIN et al. 1988: *Neo. shangmiaobeiensis*; MATYJA et al. 2001: *Neo. discurrocostatus*; XIA & CHEN 2004: *Neo. communis gancaohuensis*; QIE et al. 2014: *Neo. communis longanensis*; PLOTITSYN & ZHURAVLEV 2017: *Neo. crucesignatis*). The *communis* Group continued in parallel, leading to forms with very deep "second pit", as in *Neo. burtensis* (DRUCE, 1969).

A neopolygnathid that resembles the Asserhmo form has been described by IZOKH (in IZOKH & YAZIKOV 2013) from the upper Tournaisian of northern Siberia (lower reaches of Lena River) as *Neo. communis yazikovi*. It shares with the Asserhmo specimens the anterior platform collar, rather variable ribbing, and a rather weak aboral depression. In most specimens, the free blade is broken off but it may be shorter than in our material. Another minor difference is that the carina tends to have better defined denticles. A probably conspecific specimen has been figured long ago as *Po. communis* by HASS (1959) from the lower Tournaisian of Texas. PARVIZI et al. (2020) figured recently another similar specimen from the upper Famennian *costatus* Zone of the Alborz Mountain in northern Iran, which is likely the same level as our material. The Carboniferous *Neo. talassicus* NIGMADZHANOV, 1986 is much more strongly ribbed, with merged nodes forming a longitudinal ridge on both sides of the anterior platform, not at its margin; there is no collar. In the lower Tournaisian *Neo. nodosarius*, ribs are also very strong, at least on one side, producing a denticulate outer margin. Specimens from the top-middle Tournaisian of Missouri, identified by CHAUFFE & GUZMAN (1997) as *Po.* aff. *collinsoni*, possess a collar, but have wider, asymmetric platforms with variable, partly very strong ribbing, especially in the posterior half, and additional nodes of the inner platform, along the adcarinal troughs. The Tournaisian *Neo. adola* (COOPER, 1939), placed in synonymy with *Neo. communis* by CHAUFFE & GUZMAN (1997), is characterized by a nodose collar, the lack of posterior ribs, and deeper and narrower adcarinal troughs than in our Asserhmo form.

There are two possibilities: either there are homoemorphic ribbed neopolygnathids with anterior platform collar in the upper Famennian and lower to upper Tournaisian, or there was a long-ranging but only episodically occurring subspecies that survived the global Hangenberg Crisis at the Devonian-Carboniferous Boundary. Since our material from reworked pebbles is not suitable to solve this question, we assign it with a cf. to the Tournaisian *Neo. communis yazikovi.*

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