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Late Devonian conodonts and event stratigraphy in northwestern Algerian Sahara

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ABSTRACT

Conodonts recovered from the Late Devonian South Marhouma section comprise 5 genera with 31 species (3 undetermined). The fauna establishes the presence of MN Zones 5, undifferentiated 6/7, 8/10 for the Middle Frasnian, the MN Zones 11, 12, 13 for the Upper Frasnian as well as the Early through Late *triangularis* Zones in the basal Famennian. The outcropping lithological succession is one of mostly nodular calcilutites alternating with numerous marly and shaly deposits, which, in the lower and upper part, comprise several dysoxic dark shale intervals. Among these the Upper Kellwasser horizon can be precisely dated and as such the presence of the terminal Frasnian Kellwasser Event is recognized for the first time in Algeria. Both the Middlesex and Rhinestreet Events cannot yet be precisely located, but supposedly occur among the dark shale horizons in the lower part of the section. However, their assignment to a precise level has so far not been established. Though poor in conodont abundance the South Marhouma section provides first evidence of the presence of several Montagne Noire conodont zones within the so far widely unstudied Frasnian of the Ougarta Chain. As such it is considered representative for the northwestern Algerian Saoura region.

1. Introduction

Marine Devonian strata crop out in widespread aulacogene structures on the northern margins of cratonic Gondwana in the Algerian Sahara regions, where the sedimentation characterizes basin and ridge environmental conditions (Wendt et al., 2006). Conodont investigations carried out in the last decade focused mainly on the Saharan central basins because of their richness of hydrocarbon reservoirs (Lüning et al., 2003). In this context the first investigations on conodonts were conducted by Lys and Serre (1957) using faunas from the Adrar-Tenzerouft area in order to locate the Devonian and Carboniferous successions. In the same region, the Hassi-Taibin borehole provided Upper Frasnian conodonts. The Givetian/Frasnian boundary was determined by the first appearance of the conodont *Ancyrodella rotundiloba* in the Ahnet basin (south of Hassi-Taibin) by Remack-Petitot (1960). In contrast, the western basins (Sbaa basin, Timimoun and Ougarta basins) remained poorly studied. Among them the Ougarta Chain, and in particular the Marhouma region yields well exposed fossiliferous Late Devonian sections. Menchikoff (1933) was the first to discover abundant and well-preserved goniatites. These macrofaunas were studied by Petter *in* Alimen et al. (1952) and Petter (1959) who published the first biostratigraphic subdivision for the Late Devonian succession. Casier (1985) studied the ostracods, and Crônier et al. (2013) described Famennian trilobites.

In contrast to much detailed conodont works in the neighboring Tafilalt region (Morocco) (e.g. Belka et al., 1999), in the Marhouma region the first Frasnian conodonts were discovered by Göddertz (1987). Fine-scale conodont based biostratigraphy of the Late Devonian in this region remained hitherto unestablished and the first results are presented in this contribution. These allow, in particular, discussion of the possible presence in the Marhouma section of recognized recurrent environmental perturbations of global importance, often characterized by anoxic events, such as the basal Frasne Event, the Middlesex at MN Zone 5, the Rhinestreet extending from MN Zone 6 to MN Zone 8/10, the Lower Kellwasser and the Upper Kellwasser preceding the Frasnian/Famennian boundary (House, 2002; Walliser, 1996).

2. Geological setting

The Ougarta Chain is part of a Paleozoic aulacogen basin that forms the sedimentary cover of the Panafrican cratonic basement (Fig. 1A). Only superficially affected by hercynian compressional

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movements, it forms part of the North Gondwana epicontinental margin, between the South-Atlas fold to the north and the continental West African craton.

Between the Tafilalt (Morocco) to the west and the Azzel Matti ridge to the southeast (central Sahara of Algeria) *via* the Ougarta basin, the Paleozoic fold belts keep the same NW–SE orientation. The tectonic and structural aspects of this area have been described by Fabre (1976) and Donzeau (1974).

In the region south of Marhouma village, about 30 km ESE of Beni Abbes (district of Bechar, SW Algeria), the Upper Devonian is well exposed (Fig. 1B). In the investigated South Marhouma section (Coordinates: Base N 29°57′31.6″. W 002°06′07.8″ Top N 29°57′37.6″. W 002°06′10.9″) the Late Middle to Early Upper Devonian interval is lithologically subdivided into the Cheffar el Ahmar Formation and the Marhouma Formation (Boumendjel et al., 1997) (Fig. 2).

The upper part of the Cheffar el Ahmar Formation comprises more than 7 m of black to gray shale deposits superseded by 25 m of alternating dark shales and few centimeter-thick micritic limestone layers that yielded some macrofaunas (goniatites: *Mesobeloceras*, orthoceratids and phacopid trilobites) (Fig. 2).

Thirty-two meters above the base of the section (Fig. 2) the Marhouma Formation starts. In its lower part it is composed of beige-pink, micritic nodular limestones with thin-bedded, laminated pelitic marlstones and interbedded siltstones.

The upper part of the section (63–84 m) comprises dark shales with intercalated large diagenetic nodules yielding orthoceratids, goniatites (*Aulatornoceras*, *Manticoceras*) and rare brachiopods. This succession is superseded by shales with trilobite-bearing limestone nodules (member 2 of Crônier et al. (2013)).

3. Presentation of conodont data

The weight of the studied samples varies from 0.1 kg to 1.5 kg (Table 1) and they have been dissolved in formic acid (10%). The insoluble residue has been rinsed through two sieves (1 mm, 100 μm). Residues smaller than 1 mm were dried and handpicked under a stereomicroscope. Among 100 levels treated, only 43 samples yielded conodont elements. Seven hundred and forty-five conodont elements were picked (Table 1). In this paper, the Montagne Noire zonation of Klapper (1989) is used for the Frasnian, while Klapper (2007a) and the Ziegler and Sandberg (1990) standard zonation is used for the Famennian.

Some abbreviations have been used, *Pa* for *Palmatolepis*; *Po* for *Polygnathus*; *Ic* for *Icriodus*; *An* for *Ancyrodella*; *Ag* for *Ancyrognathus*. MHS signifies Marhouma Sud for the figured specimens. All of the collection is stored in the Institut des Sciences de l'Evolution in Université Montpellier 2 (France).

Genus *Ancyrodella* Ulrich and Bassler, 1926.
Type species *Ancyrodella nodosa* Ulrich and Bassler, 1926.
Ancyrodella sp. A.
(Fig. 3, A and B).

Remarks: Our specimen differs from both the early and late forms of *Ancyrodella rotundiloba* by the presence of pointed anterior margins. The thin platform and the weak ornamentation at the posterior part can be assigned to a juvenile element.

Material: One specimen from Cheffar el Ahmar Formation (MH2).

Genus *Ancyrognathus* Branson and Mehl, 1934.
Type species *Ancyrognathus symmetricus* Branson and Mehl, 1934.
Ancyrognathus coeni Klapper, 1990.
(Fig. 3, F and G).
1956 ? *Ancyrognathus* sp. A Hass, pp. 17 and 20, pl. 4, Fig. 1.
1957 ? *Ancyrognathus* sp. A Müller and Müller, p. 1097, pl. 142, Fig. 10.
1989 *Ancyrognathus euglypheus* Coen; Klapper, pl. 4, Figs. 9 and 13.
1990 *Ancyrognathus coeni* Klapper, p. 1010, Figs. 51–55, 81, 84, 87, 88, 810, 811, 814, 91–99 and 916.
1998 *Ancyrognathus coeni* Klapper; Bultynck et al., p. 56, pl. 9, Figs. 9 and 10.

Remarks: The *Ag. coeni* specimens illustrated by Klapper (1990) are characterized by an ornamented platform with large nodes. Our specimen shows thin and smooth nodes slightly visible on the platform margins, therefore suggesting a juvenile specimen. The combination of a short free blade, an acute angle developed between lateral lobes, a carina with high posterior denticles, and a slight concave inner side allows assignment of this specimen to *Ag. coeni*.

Occurrence: Europe (Montagne Noire, Ardennes), North America (Tennessee), Western Australia (Canning Basin), North Africa (Meseta, Tafilalt and Mader platforms).

Range: MN Zone 8 to MN Zone 11.

Material: One specimen from Cheffar el Ahmar Formation (MH13).

Ancyrognathus triangularis Youngquist, 1945.
(Fig. 3, H and I).
1945 *Ancyrognathus triangularis* Youngquist, pp. 356 and 357, pl. 54, Fig. 7.
1989 *Ancyrognathus triangularis* Youngquist; Klapper p. 458, p1. 4, Figs. 6 and 7.
1990 *Ancyrognathus triangularis* Youngquist; Klapper, pp. 1017 and 1019, Figs. 71–77, 79 and 113–1121.
1999 *Ancyrognathus triangularis* Youngquist; Lazreq, p. 61, pl. 5. Figs. 8–10 and 12–18 and pl. 6. Figs. 1 and 2.
2002 *Ancyrognathus triangularis* Youngquist; Valenzuela-Ríos, Gozalo and Padro Alonso, p. 297, Figs. 4 and 5.
2013 *Ancyrognathus triangularis* Youngquist; Savage, p. 9, Figs. 5.18–5.19.

Remarks: The equally obtuse angles between anterior platform and lateral lobes identify the specimens as *Ag. triangularis*. The lectotype illustrated by Youngquist (1945, p. 54, Fig. 7) represents circular lateral lobes, a thin ornamentation with scattered nodes which is slightly interconnected toward the margins. Weakly developed free blade and a moderate convexity of the outer side of the anterior platform characterize this species. While our specimens are characterized by lateral lobes with pointed edges, the strong ornamentation with large separate nodes and a marked convexity (90°), it is similar to the specimen illustrated by Klapper (1990, p. 1019, pl. 11, Fig. 10).

Occurrence: Western Australia (Caning Basin), North Africa (Tafilalt and Mader platforms), Europe (Iberian Chains, Cantabrian Mountains, Montagne Noire, Holy Cross Mountains), North America (Arizona and New Mexico, Iowa), Asia (Timan, Central Hunan at South-Central China).

Range: MN Zone 11 to MN Zone 13.

Material: Two specimens from Marhouma Formation (MH19d), (MH20).

Genus *Palmatolepis* Ulrich and Bassler, 1926.
Type species *Palmatolepis subperlobata* Ulrich and Bassler, 1926.
Palmatolepis bogartensis (Stauffer, 1938).
(Fig. 4, C).
1938 *Nothognathella bogartensis* Stauffer, p. 436, pl. 48, Fig. 30.