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Catalogue of the types and illustrated specimens recovered from the 'black marble' of Denée, a marine conservation-Lagerstätte from the Mississippian of southern Belgium

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ABSTRACT. The Viséan 'black marble' of Denée is one of the best preserved Mississippian fossil assemblages. This Lagerstätte is famous for the exceptional preservation of several groups of macro-organisms (fishes, echinoids, graptolites). However, only a part of the fauna has received attention from specialists and most of the phyla may benefit from a modern revision based on new investigative techniques such as 3D imagery and CT-scanning. Almost all the specimens illustrated in the literature have been traced and we present here a comprehensive catalogue of this material. Representatives of several minor groups are photographically illustrated for the first time as well as five emblematic specimens of the styracopterid genus *Benedenius* (Pisces). For purposes of nomenclatural formality, the lectotypes of *Benedenius deneensis* Traquair (in de Koninck, 1878), *B. soreili* Fraipont, 1890, *Oligoporus soreili* Fraipont, 1904, *Taeniaster? fournieri* Fraipont, 1904, and *Scaphiocrinus longicaudatus* Fraipont, 1904 are here selected.

KEYWORDS: Carboniferous, Lower Viséan, Molignée Formation, conservation Lagerstätte, fishes, invertebrates.

1. Introduction

The discovery of a well-preserved chondrostean fish by Hubert Thomson, a quarryman from Denée (Anhée, Namur province, Belgium) (Fig. 1), in 1866 (Van Beneden, 1867, 1871; Henrard, 1951) within the Moliniacian (Viséan) 'black marble' of Denée, a black coloured limestone, was the first of a long series of astonishing findings, which contributed to the fame of the locality among the palaeontological community. For example, Jackson (1929, p. 6) pointed out that 'the Denée locality is not only remarkable for the number of genera and species of Echini found there, but also for the number of individual specimens of certain species that have been found'. Moreover, Kier (1962, p. 1) reported that the locality of Denée includes the 'largest echinoids known, fossil or recent'. However, Soreil (1895) highlighted the scarcity of the fossils.

Most of the studies dedicated to the macrofauna from this particular level were published between 1871 and 1941 (e.g. Fraipont, 1904; Woodward, 1924; Van Straelen, 1926; Delépine, 1928; Fournier & Pruvost, 1928; Demanet, 1929; Jackson, 1929; Ubaghs, 1941). After Ubaghs' publication, these faunas received scant attention from the palaeontological community despite their great scientific value (Kier, 1962; Maisey, 2008). This is partly due to the difficulties in collecting new specimens as most of the quarries have been disused since the 1940^{ths} and/or are flooded (Henrard, 1951). Nevertheless, in the meanwhile, great progress has been made in the understanding of the palaeoenvironment and sedimentological framework of the 'black marble' of Denée (Mamet, 1964; Overlau, 1966; Hance, 1988; Hance et al., 1994, 2001; Lees, 1997; Poty et al., 2002; Mottequin, 2004, 2008; Devuyst et al., 2005).

The aim of this paper is to provide for the first time a comprehensive list of the types and illustrated specimens as well as ichnofossils and unusual sedimentary structures (e.g. skip marks; see Mottequin & Poty, 2011) recovered from the 'black marble' of Denée and to document, if possible, their provenance and position within the sedimentary succession. Moreover, several groups of macroorganisms such as gastropods and conularids, that were known only from list of species (Fournier & Kaisin, 1929) are illustrated here for the first time in order to provide a better account of the diversity and the mode of preservation.

2. Geological and geographical setting

2.1. Lithostratigraphical and palaeoenvironmental context

The 'black marble' of Denée is now included in the Molignée Formation of Early Viséan age (Moliniacian; Mississippian Foraminifer Zone MFZ 9 to MFZ 10 according to Devuyst & Hance in Poty et al., 2006) (Fig. 2). This formation (*c.* 60 m thick) consists of a succession of thin-bedded, commonly laminated black limestones (the typical 'black marble' facies) which alternate with thick-bedded, dark-grey limestones ('thick beds') (e.g. Mamet, 1964; Mottequin, 2004, 2008) (Figs 2-3).

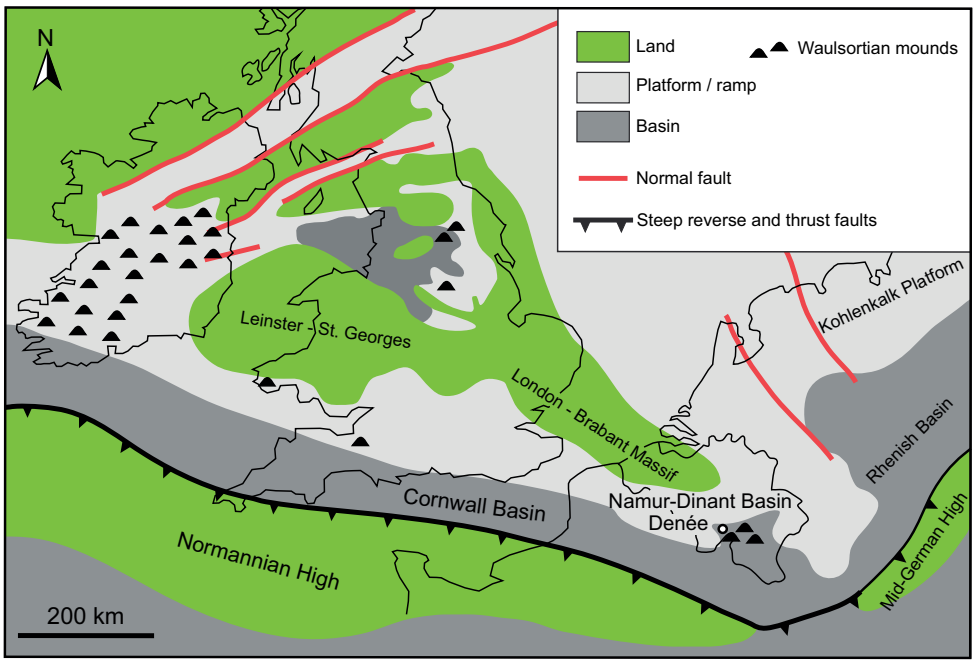

Figure 1. General context of Lower Carboniferous sedimentation in north-western Europe showing the distribution of emergent areas and Waulsortian mounds at the end of the Tournaisian (modified from Ziegler, 1990, and Devuyst & Dehantschutter, 2007).

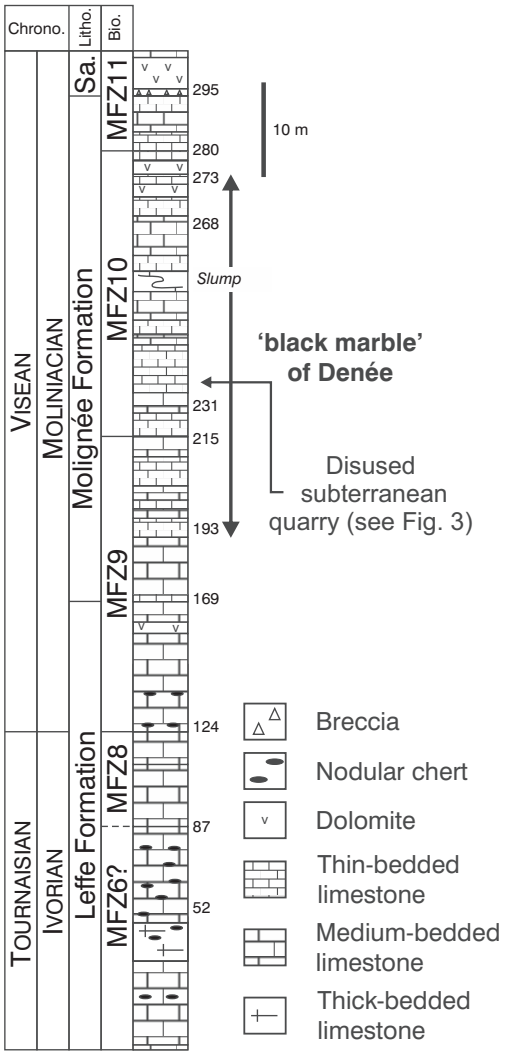

Figure 2. Partial log of the Salet road section (stratotype of the Molignée and Salet formations) (modified from Poty et al., 2006) (see also Fig. 3). Bio. = Biostratigraphy; Chrono. = chronostratigraphy; Litho. = lithostratigraphy; MFZ = Mississippian Foraminifer Zones of Devuyst & Hance (in Poty et al., 2006). Bed numbers are those of Overlau (1966).

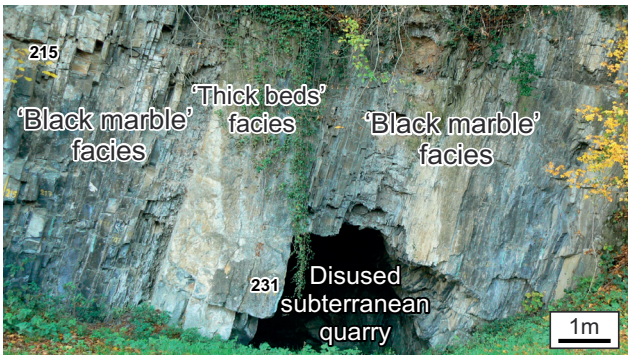

Figure 3. The Molignée Formation in its stratotype (Salet road section) showing the alternating thicker bedded ('thick beds') and thinner bedded ('black marble') units (see also Fig. 2). The beds are overturned and their numbering is that of Overlau (1966) (modified from Mottequin, 2008).

It developed in a confined intra-platform basin (central part of the Dinant sedimentation area [DSA]) located south of the Brabant Massif (Fig. 1), which was progressively filled by distal calcareous turbidites originating from the southward prograding shelf (e.g. Hance, 1988; Hance et al., 2001; Mottequin, 2008) (Figs 4-5). This basin was bordered to the south by a discontinuous barrier of Waulsortian mudmounds built against a major synsedimentary fault separating the DSA from the southern Avesnois sedimentation area (e.g. Hance et al., 2001; Pirotte, 2006 [see Mottequin, 2008, fig. 3]). The alternations of laminated and bioturbated lithofacies occurring within the Molignée Formation implies that the palaeoenvironment recorded several anoxic to dysoxic periods alternating with more oxygenated ones due to sea-level fluctuations of low magnitude (Mottequin, 2008). This periodic confinement of the central part of the DSA took place during a third-order sequence characterized by a low sea level, namely sequence 5 of Hance et al. (2001) (Fig. 5). Low oxygen concentrations are also suggested by the existence of organisms characteristic of dysaerobic facies such as the bivalves of the 'paper pecten' morphotype (e.g. Allison et al., 1995) and the remarkable preservation of the benthic and nektonic macrofauna (Mottequin, 2008).

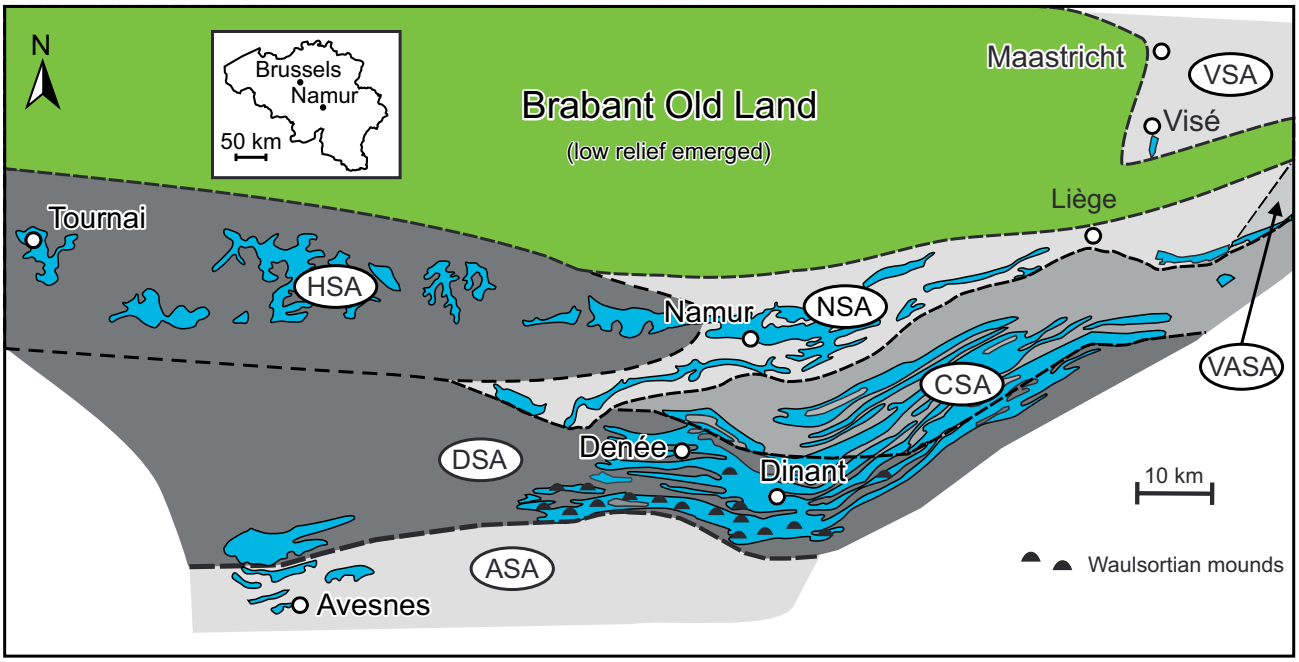

Figure 4. Late Tournaisian sedimentation areas in the Namur-Dinant Basin (not palinspastically restored; modified from Hance et al., 2001). ASA = Avesnois sedimentation area; CSA = Condroz sedimentation area; DSA = Dinant sedimentation area; HSA = Hainaut sedimentation area; NSA = Namur sedimentation area; VASA = Vesdre-Aachen sedimentation area; VSA = Visé sedimentation area.

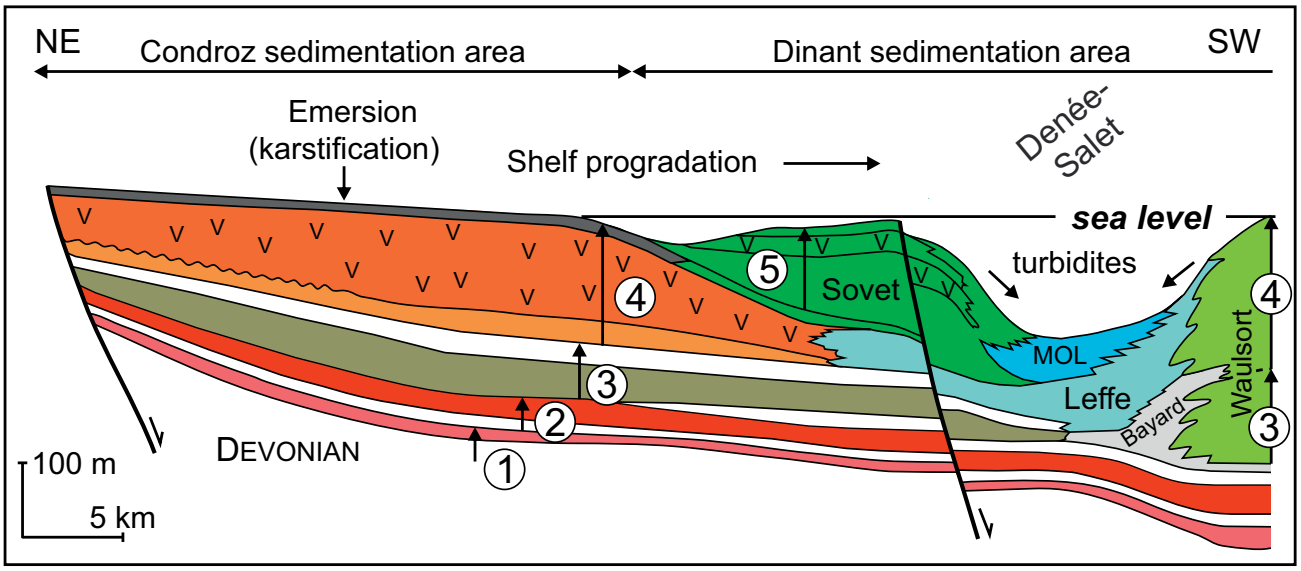

Figure 5. The Condroz sedimentation area (CSA) and the Dinant sedimentation area (DSA) during the third-order sequence 5 of Hance et al. (2001) – their other sequences are represented by the black arrows (modified from Hance et al., 2001).

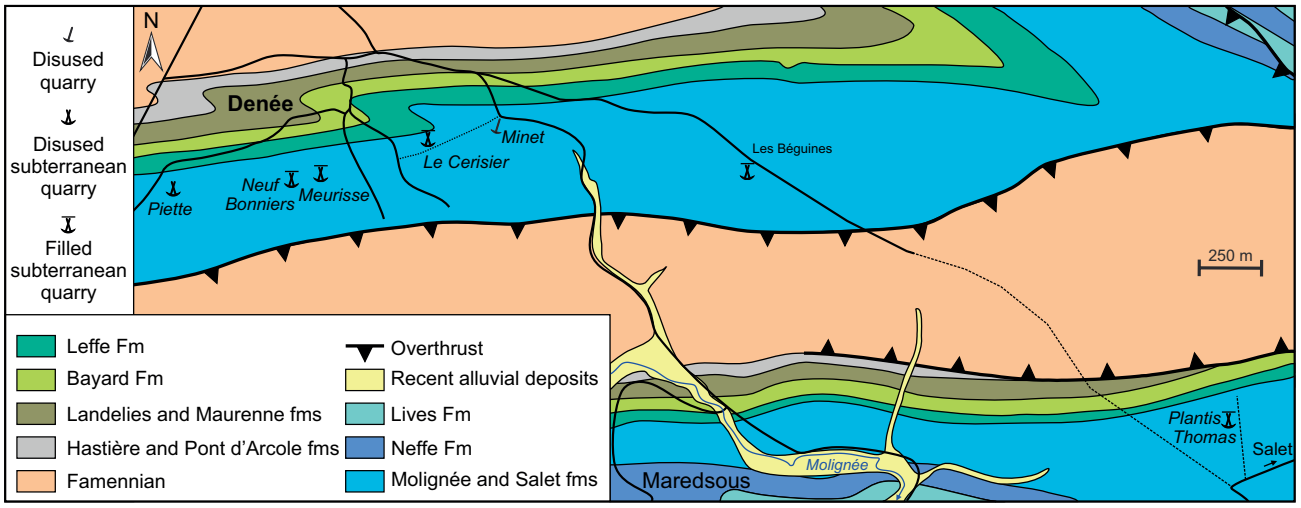

Figure 6. Simplified geological map of the Denée area (modified from Delcambre & Pingot, 2004, and Delcambre & Pingot, in press) with location of the quarries that yielded most of the macrofossils (according to Fournier & Pruvost, 1928, and unpublished notes of Fournier housed at the Centre Grégoire Fournier of Maredsous Abbey).

2.2. The quarries of the Denée area

Most of the fossils were collected in the Denée area (Fig. 6) at the end of the 19th century and at the beginning of the 20th century by quarrymen when the 'black marble' was intensively and manually quarried. Most of the excavations were subterranean and some of them went down to more than 60 m in depth and were more than 100 m long (Marote, 1923; Fournier & Pruvost, 1928). The geological context of these quarries has been recently revised by Delcambre & Pingot (2004), and Delcambre & Pingot (in press). A comprehensive list of the quarries was published by Mamet (1964). Among them, the Le Cerisier, Meurisse and Piette quarries, located around the village of Denée, yielded most of the material (Fig. 6) according to the unpublished catalogue of Dom Grégoire Fournier housed at the Maredsous Abbey. The Plantis Thomas quarry can also be added to this list as it yielded a specimen of the rare styracopterid *Benedenius*.

As is generally the case with old collections, the origin of the specimens is usually not known with precision, despite numerous pieces of information gathered by G. Fournier, except for some fossils which on their label mention the quarried level (e.g. 'La Veine', Les Drîs'). We can reasonably suspect that the bulk of the specimens were collected at Denée, from the exploited levels figured by Fournier (in Fournier & Pruvost, 1928) (Fig. 7).

3. Catalogue of the type and illustrated specimens

The bulk of the material recovered from the 'black marble' of Denée was gathered by Dom Grégoire Fournier (1863-1931) (Kaisin, 1932), who amassed *c.* 1200 specimens from 1888 to about 1927 thanks to the expertise of several quarrymen, notably Alexis and Désiré Moreau from Denée (Fournier & Pruvost, 1928; Henrard, 1951). According to Jackson (1929, p. 72), the possession of very large echinoids such as *Proterocidaris gigantea* de Koninck, 1882 and the other species found in Denée, 'should make the Musée de Maredsous (the former name of the Centre Grégoire Fournier) a Mecca for all lovers of Echini'. This invaluable collection is housed at the Maredsous Abbey (Centre Grégoire Fournier [CGF]). The collection deposited at the University of Liège (ULg) consists of specimens collected by Gustave Soreil (*c.* 1880) and Dom Grégoire Fournier (Jackson, 1929; Henrard, 1951). The collections of the Royal Belgian Institute of Natural Sciences (Brussels) (IRScNB) include specimens collected notably by Edouard Dupont as well as numerous plaster casts of the specimens deposited at the Centre Grégoire Fournier. Some specimens donated to R. T. Jackson by G. Fournier are curated at the Museum of Comparative Zoology of the Harvard University (MCZ).

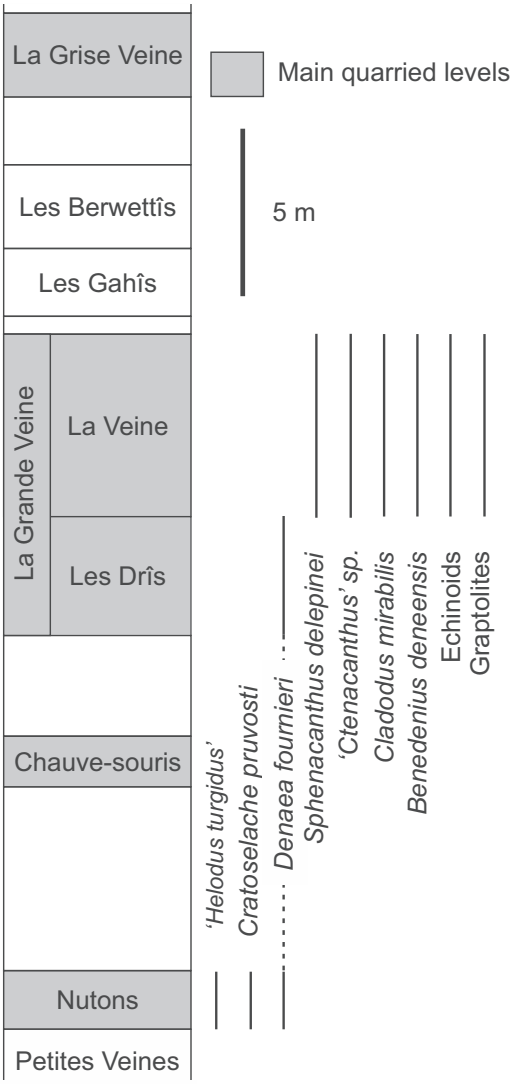

Figure 7. Distribution of fish and some iconic invertebrates within the 'black marble' of Denée (Molignée Formation) as exposed in the quarries of the Denée area (modified from Fournier in Fournier & Pruvost, 1928).

We here mainly focus on the types and the illustrated specimens. Particular sedimentary structures (skip marks), some of them, only known from drawings or poor photographs, are re-illustrated. We have also figured some rare, but unidentified specimens in order to show the diversity of the fauna.

Most of the invertebrate phyla strongly need to be revised and/or studied for the first time, as the last comprehensive list of the faunas dates back to Fournier & Kaisin (1929)! Many specimens are still unidentified and rank among the *incertae sedis* awaiting study based on modern investigative techniques.

3.1. Fishes

CGF 3 (Fig. 8A): *Benedenius deneensis* Traquair in Boulenger (1899, pl. 9) and Henrard (1951, unnumbered figure); Denée, Les Neuf Bonniers quarry.

CGF 4 (Fig. 9A): *Benedenius deneensis* Traquair in Boulenger (1899, pl. 10, figs 1-4); Denée, Demaret or Meurisse quarry.

CGF 5 (Fig. 9B): *Benedenius deneensis* Traquair in Boulenger (1902, without illustration); Salet, Plantis Thomas quarry.

IRScNB P 01261 (counterpart CGF 1) (Fig. 8B): *Palaeoniscus* de Denée in Van Beneden (1871, pl. 4); lectotype of *Benedenius deneensis* Traquair, 1878 in (Traquair in de Koninck, 1878, pl. 2), Traquair (1879, pl. 3, fig. 17), Boulenger (1899, pl. 10, fig. 5), Groessens (in Dupuis et al., 1993, fig. 19.4), Groessens (1994, fig. 2), and Mottequin (2009, fig. 7A); Denée (the specimen was found in 1866, but its precise origin is unknown).

ULg 6136 (Fig. 8C): lectotype here selected of *Benedenius soreili* Fraipont, 1890 in Fraipont (1890, pl. 5); Denée, Les Neuf Bonniers quarry.

CGF 33 (not 233 as incorrectly reported by Pruvost in Fournier & Pruvost, 1928): holotype of *Cratoselache pruvosti* Woodward, 1924 (unnumbered plate) and Pruvost (in Fournier & Pruvost, 1928, pl. 6); Denée, Le Cerisier quarry, Les Nutons.

CGF 34 (not 234 as incorrectly reported by Pruvost in Fournier & Pruvost, 1928): *Cladodus mirabilis* Agassiz in Pruvost (in Fournier & Pruvost, 1928, pl. 5, fig. 2); Denée, Les Béguines quarry, Grande Veine or Les Gahîs.

CGF 35 (not 230 as incorrectly reported by Pruvost in Fournier & Pruvost, 1928) (Fig. 10A): '*Helodus turgidus* Agassiz' in Pruvost (in Fournier & Pruvost, 1928, p. 22, not illustrated); Denée, Le Cerisier quarry, Les Nutons.

CGF 36 (not 236 as incorrectly reported by Pruvost in Fournier & Pruvost, 1928) (Fig. 10B): *'Ctenacanthus'* sp. in Pruvost (Fournier & Pruvost, 1928, p. 21, not illustrated); Denée, Grande Veine.

CGF 40 (not 240 as incorrectly reported by Pruvost in Fournier & Pruvost, 1928, and Ivanov & Derycke, 2005): holotype of *Sphenacanthus delepinei* Pruvost (in Fournier & Pruvost, 1928, pl. 5, fig. 1-1a) and Ivanov & Derycke (2005, fig. 1J-P); Denée, Meurisse quarry, Les Drîs.

Remarks. According to Fournier & Pruvost (1928), most of the specimens (23) assigned to *Denaea fournieri* were collected before 1890 at the Le Cerisier quarry (Les Nutons) but eleven additional ones were recovered from the Meurisse quarry (Les Drîs) after the publication of Fournier & Pruvost (1922).

CGF 201 (Fig. 10C): holotype of *Denaea fournieri* Pruvost (in Fournier & Pruvost, 1922) in Fournier & Pruvost (1928, pl. 1, pl. 4, figs 2, 6, 7, 9, 10), Ivanov & Derycke (2005, fig. 1A-I), and Maisey (2008, fig. 2A); Denée.

CGF 202: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 2, fig. 2), Maisey (2008, fig. 2F); Denée.

CGF 203: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 4, fig. 5, 11, pl. 5, fig. 3); Denée.

CGF 205: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 2, fig. 1); Denée.

CGF 209: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 5, fig. 4); Denée.

CGF 212: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 4, fig. 4); Denée.

CGF 214: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 4, fig. 3); Denée.

CGF 215: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 3, fig. 2); Denée.

CGF 216: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 4, fig. 8); Denée.

CGF 217: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 4, fig. 1); Denée.

CGF 218: *D. fournieri* Pruvost in Fournier & Pruvost (1928, pl. 3, fig. 1); Denée.

CGF 219: *D. fournieri* Pruvost in Maisey (2008, fig. 2B); Denée.

CGF 208: *D. fournieri* Pruvost in Maisey (2008, fig. 2D); Denée.

CGF 224: *D. fournieri* Pruvost in Maisey (2008, fig. 2E); Denée.

3.2. Echinoderms

3.2.1. Crinoids

CGF 44 (Fig. 11C): *Scaphiocrinus longicaudatus* Fraipont, 1904; Denée, Le Cerisier quarry, Les Nutons.

CGF 49 (Fig. 11B): undetermined crinoid; Denée, Grande Veine.

CGF 51 (Fig. 13B): undetermined crinoid; Denée.

CGF 191 (Fig. 11A, D): Denée, Meurisse quarry, La Veine.

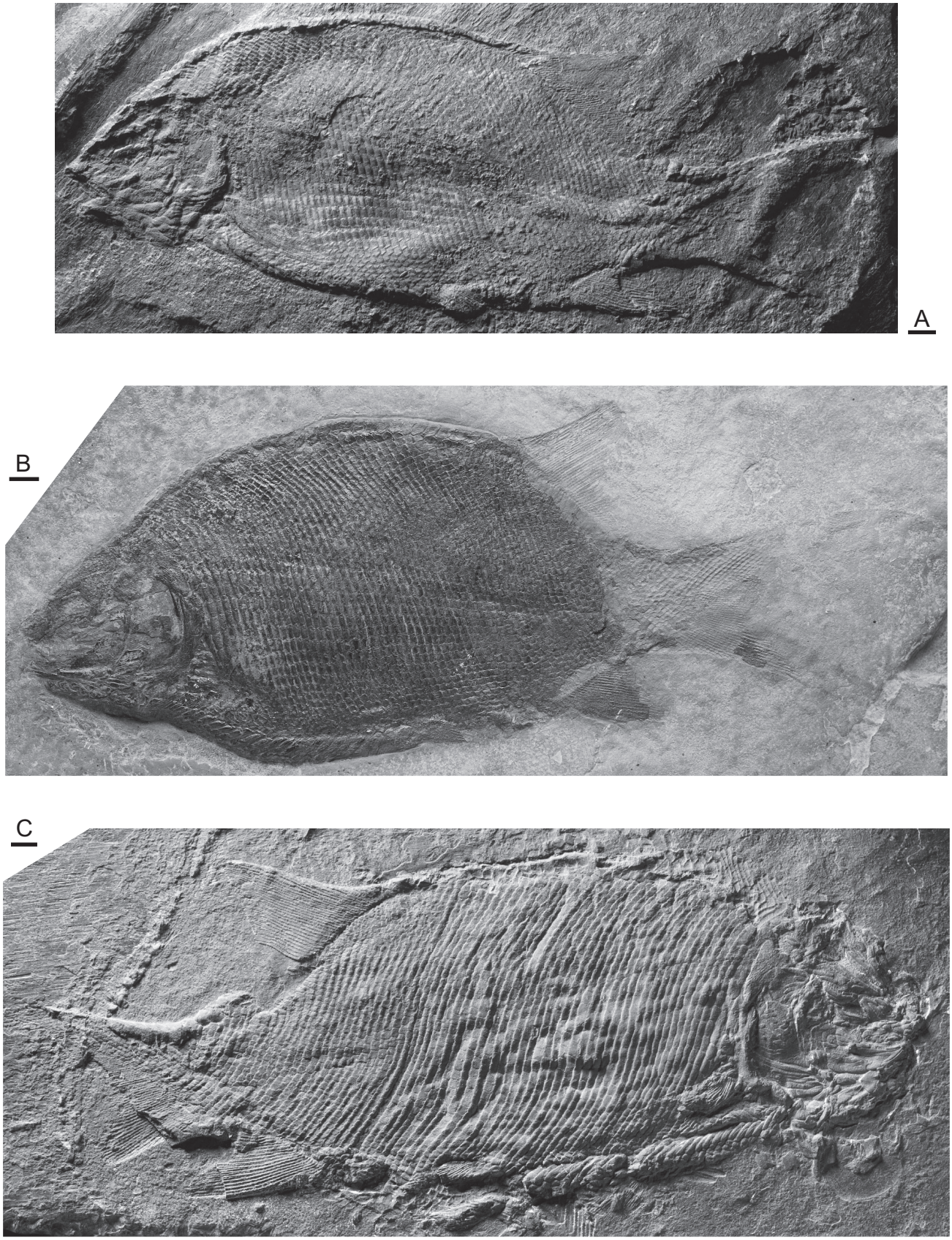

Figure 8. A-B. *Benedenius deneensis* Traquair (in de Koninck, 1878), Molignée Formation. A. CGF 3, Denée, Les Neuf Bonniers quarry. B. Lectotype, IRScNB P 01261, Denée, accurate origin unknown. C. *Benedenius soreili* Fraipont, 1890, lectotype, ULg 6136, Denée, Les Neufs Bonniers quarry. Scale bars: 10 mm.

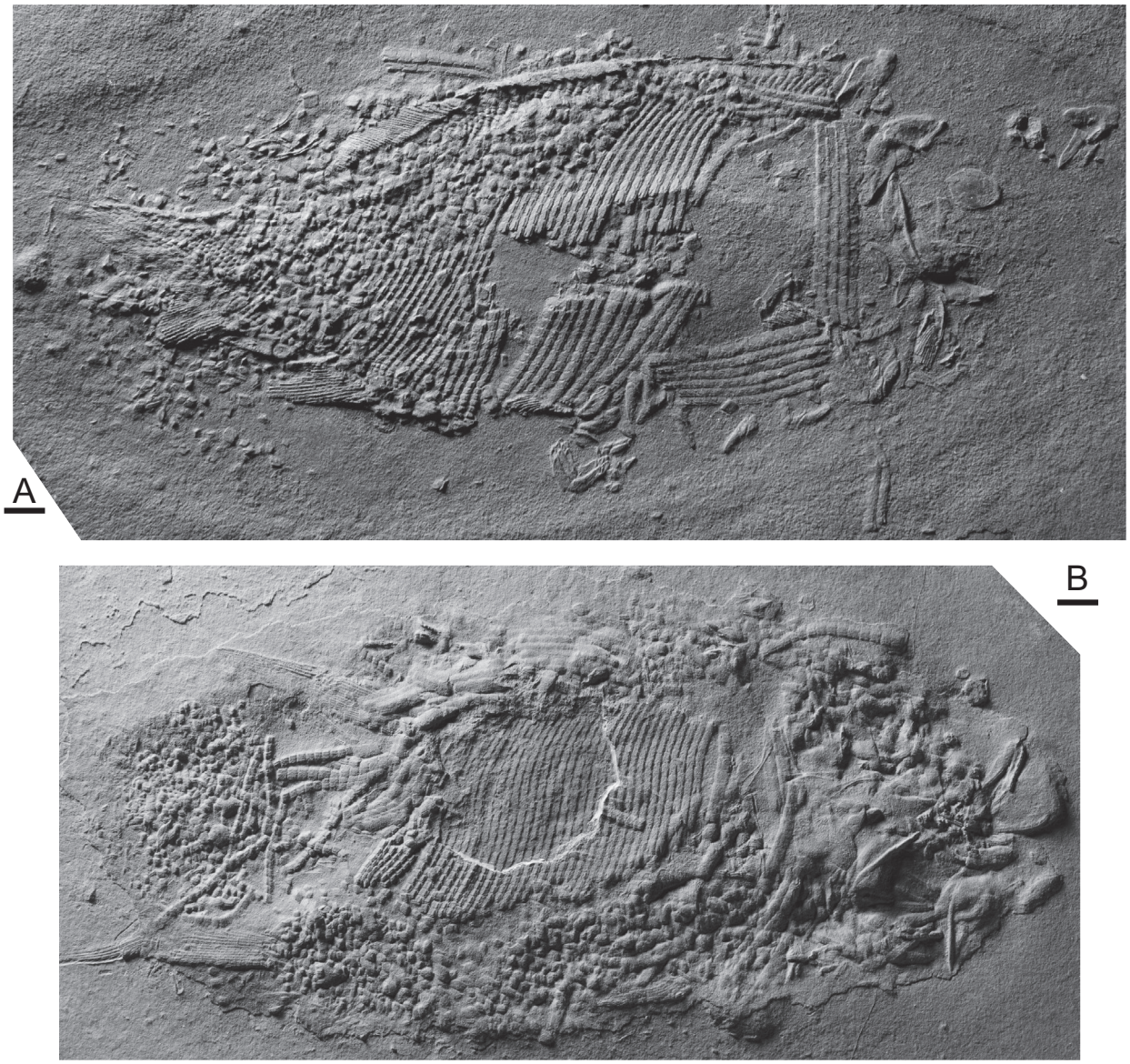

Figure 9. A-B. *Benedenius deneensis* Traquair (in de Koninck, 1878), Molignée Formation. A. CGF 4, Denée, Meurisse quarry. B. CGF 5, Salet, Plantis Thomas quarry. Scale bars: 10 mm.

ULg 11,219: lectotype (here selected) of *Scaphiocrinus longicaudatus* Fraipont, 1904 in Fraipont (1904, pl. 1, fig. 1); *Graphiocrinus longicaudatus* in Mottequin (2009, fig. 6F); Denée.

ULg 11,220: *Scaphiocrinus longicaudatus* Fraipont, 1904 in Fraipont (1904, pl. 1, fig. 2); Denée, Minet quarry, Les Nutons.

3.2.2. Echinoids

CGF 69: *Archaeocidaris wervekei* Tornsquist in Fraipont (1904, pl. 1, fig. 7); Denée.

CGF 70: *Archaeocidaris wervekei* Tornsquist in Fraipont (1904, pl. 1, fig. 6); Denée.

CGF 71: paratype of *Perischodomus fraiponti* Jackson, 1929 in Jackson (1929, pl. 5, fig. 4); *Proterocidaris gigantea* de Koninck, 1882 in Kier (1962, pp. 3, 8); Denée, Meurisse quarry, Les Drîs.

CGF 72: *Rhoechinus elegans* (M'Coy) in Fraipont (1904, pl. 2, fig. 9); *Palaeechinus elegans* M'Coy in Jackson (1929, pl. 2, fig. 17); *Proterocidaris gigantea* de Koninck, 1882 in Kier (1962, pl. 4, fig. B); Denée.

CGF 73: *Palaeechinus elegans* M'Coy in Jackson (1929, pl. 2, fig. 18); Denée.

CGF 74: *Palaechinus lacazei* Julien in Fraipont (1904, pl. 2, fig. 4); Denée, Grande Veine.

CGF 75: *Palaechinus lacazei* Julien (?) in Fraipont (1904, pl. 2, fig. 3); Denée, Grande Veine.

CGF 76: *Palaechinus lacazei* Julien (?) in Fraipont (1904, pl. 1, fig. 8); Denée, Grande Veine.

CGF 78: holotype of *Perischodomus fraiponti* Jackson, 1929 in Jackson (1929, pl. 5, fig. 3) and Henrard (1951, unnumbered figure); *Proterocidaris gigantea* de Koninck, 1882 in Kier (1962, pp. 3, 8); Denée, Piette quarry, Grande Veine.

CGF 81: *Palaechinus lacazei* Julien (?) in Fraipont (1904, pl. 2, fig. 6); *Perischodomus fraiponti* Jackson, 1929 in Jackson (1929, p. 50); Denée.

CGF 94: *Maccoya sphaerica* (M'Coy) in Jackson (1929, pl. 3, fig. 1); Denée.

CGF 100: *Archaeocidaris wervekei* Tornsquist in Jackson (1929, pl. 1, fig. 7); Denée.

CGF 101: holotype of *Lepidechinus belgicus* Jackson, 1929 in Jackson (1929, pl. 5, fig. 1); Denée.

CGF 123: *Lovenechinus lacazei* (Julien) in Jackson (1929, pl. 3, fig. 4); *Palaeoechinus elegans* in Groessens (1994, pl. 7, unnumbered figure); Denée, Meurisse quarry.

CGF 125: *Oligoporus soreili* Fraipont, 1904 in Fraipont (1904, pl. 4, fig. 2)*; Proterocidaris giganteus* de Koninck, 1882 in Jackson (1912, pl. 65, fig. 3, pl. 67, figs 6-7); *P. gigantea* in Jackson (1929, text-fig. 8); Denée.

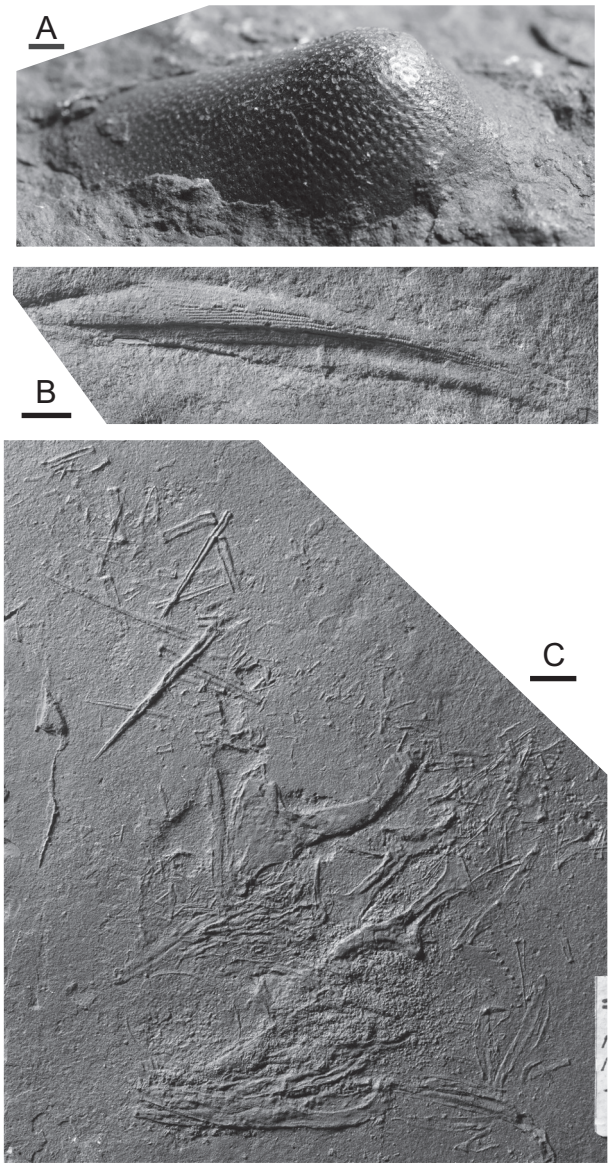

Figure 10. A. *Helodus turgidus* Agassiz *fide* Pruvost (in Fournier & Pruvost, 1928), Denée, Le Cerisier quarry, Les Nutons. B. *'Ctenacanthus'* sp., Denée, Grande Veine. C. *Denaea fournieri* Pruvost (in Fournier & Pruvost, 1922), holotype, CGF 201, Denée, most probably from Le Cerisier quarry, Les Drîs. Scale bars: 10 mm, except A (1 mm).

CGF 127: *Proterocidaris gigantea* de Koninck, 1882 in Jackson (1929, pl. 7), Mortensen (1935, p. 71, fig. 43), Groessens (in Dupuis et al., 1993, fig. 19.3 [?]), and Groessens (1994, pl. 6); Denée.

CGF 138: *Lovenechinus anglicus* Jackson, 1929 in Jackson (1929, pl. 4, fig. 1); Denée.

CGF 140: holotype of *Fournierechinus deneensis* Jackson, 1929 in Jackson (1929, pl. 9); Denée, probably from Les Drîs.

CGF 141: paratype of *Fournierechinus deneensis* Jackson, 1929 in Jackson (1929, pl. 10, fig. 2) and Mortensen (1935, p. 72, fig. 44); Denée.

CGF 142: paratype of *Fournierechinus deneensis* Jackson, 1929 in Jackson (1929, pl. 10, fig. 1) and Mottequin (2009, fig. 6D); *Proterocidaris deneensis* in Kier (1962, text-figs 5-6, pls 5-6); Denée.

CGF 147: holotype of *Deneechinus tenuispinus* Jackson, 1929 in Jackson (1929, pl. 1, fig. 11) and Mortensen (1935, p. 63, fig. 34); Denée, Piette quarry, Grande Veine.

CGF 151: *Proterocidaris gigantea* de Koninck, 1882 in Jackson (1929, pl. 8, fig. 1); Denée.

IRScNB a7386: paratype of *Lepidechinus belgicus* Jackson, 1929 in Jackson (1929, pl. 5, fig. 2); Denée, Piette quarry.

IRScNB a7388: *Proterocidaris gigantea* de Koninck, 1882 in Jackson (1929, pl. 8, fig. 2); Denée, Piette quarry.

IRScNB a7383: *Lovenechinus lacazei* (Julien) in Jackson (1929, pl. 3, figs 2-3) and Maillieux (1933, pl. 9, fig. 132); Denée.

MCZ 3330: *Proterocidaris gigantea* de Koninck, 1882 in Kier (1962, text-figs 1-2, pls 1-2) and Kier (1966, fig. 224.1a, b); Denée.

ULg 11,221 (not traced!): *Archaeocidaris urii* (Fleming) in Fraipont (1904, pl. 1, fig. 5).

ULg 11,222: *Palaechinus lacazei* Julien in Fraipont (1904, pl. 2, fig. 2); Denée.

ULg 11,225: *Palaechinus lacazei* Julien in Fraipont (1904, pl. 2, fig. 5); Denée.

ULg 11,226: *Palaechinus* sp. in Fraipont (1904, pl. 2, fig. 8); *Lovenechinus lacazei* (Julien) in Kier (1962, text-figs 7-9, pl. 4, fig. A); Denée.

ULg 11,227: *Palaechinus konincki* Julien in Fraipont (1904, pl. 3, fig. 1); *Palaeechinus? regnyiensis* Jackson, 1929 (? *pro P. regnyi* Jackson, 1912) in Jackson (1929, p. 38); Denée.

ULg 11,228 (Fig. 12A): lectotype (here selected) of *Oligoporus soreili* Fraipont, 1904 in Fraipont (1904, pl. 3, fig. 2); Denée.

ULg 11,230: *Oligoporus soreili* Fraipont, 1904 in Fraipont (1904, pl. 5, fig. 1); *Proterocidaris giganteus* de Koninck, 1882 in Jackson (1912, pl. 67, fig. 4); *P. gigantea* in Jackson (1929, text-fig. 9); Denée.

ULg 11,231: *Oligoporus soreili* Fraipont, 1904 in Fraipont (1904, pl. 5, fig. 2); *Proterocidaris giganteus* de Koninck, 1882 in Jackson (1912, pl. 67, fig. 5); *P. gigantea* in Jackson (1929, text-fig. 10); Denée.

ULg 11,239: *Oligoporus soreili* Fraipont, 1904 in Fraipont (1904, pl. 4, fig. 1); Denée.

ULg 11,541: *Palaechinus* sp. in Fraipont (1904, pl. 2, fig. 7); Denée.

ULg 35,400: *Proterocidaris gigantea* de Koninck, 1882 in Kier (1962, text-fig. 3, pl. 3) and Mottequin (2009, fig. 7C); Denée.

ULg 2014-02-10/1: *Palaechinus lacazei* Julien in Fraipont (1904, pl. 2, fig. 1); Denée.

3.2.3. Ophiuroids

CGF 67 (Fig. 12C): lectotype (here selected) of *Taeniaster? fournieri* Fraipont, 1904 in Fraipont (1904, pl. 1, fig. 4), Groessens (1994, pl. 7, unnumbered figure), and Mottequin (2009, fig. 6E); Denée, Les Neuf Bonniers quarry.

CGF 68 (Fig. 12B): *Taeniaster? fournieri* Fraipont, 1904 in Fraipont (1904, pl. 1, fig. 3); Denée, Les Neuf Bonniers quarry.

ULg 30,795 (Fig. 12D): undetermined ophiuroid; Denée.

3.3. Brachiopods

CGF 51 (Fig. 13B): unidentified productide; Denée.

CGF 307: *Productus mesolobus* (Phillips) in Delépine (1928, pl. 3, fig. 25); *Productus semireticulatus* in Groessens (1994, pl. 7, unnumbered figure); Salet, La Veine (?).

CGF 320: *Productus mesolobus* (Phillips) in Delépine (1928, pl. 3, fig. 24); Denée.

CGF 322: *Productus mesolobus* (Phillips) in Delépine (1928, pl. 3, fig. 23); Denée.

CGF 329: *Productus* semiréticulé (*sic*) in Delépine (1928, pl. 2, fig. 17); Denée.

CGF 331: *Productus (Pustula) interruptus* Thomas in Delépine (1928, pl. 3, fig. 32); Denée.

CGF 336: *Productus (Pustula) interruptus* Thomas in Delépine (1928, pl. 3, fig. 30); Denée, Minet quarry, Les Berwettis.

CGF 341: *Productus pyxidiformis* de Koninck in Delépine (1928, pl. 6, fig. 70); Denée.

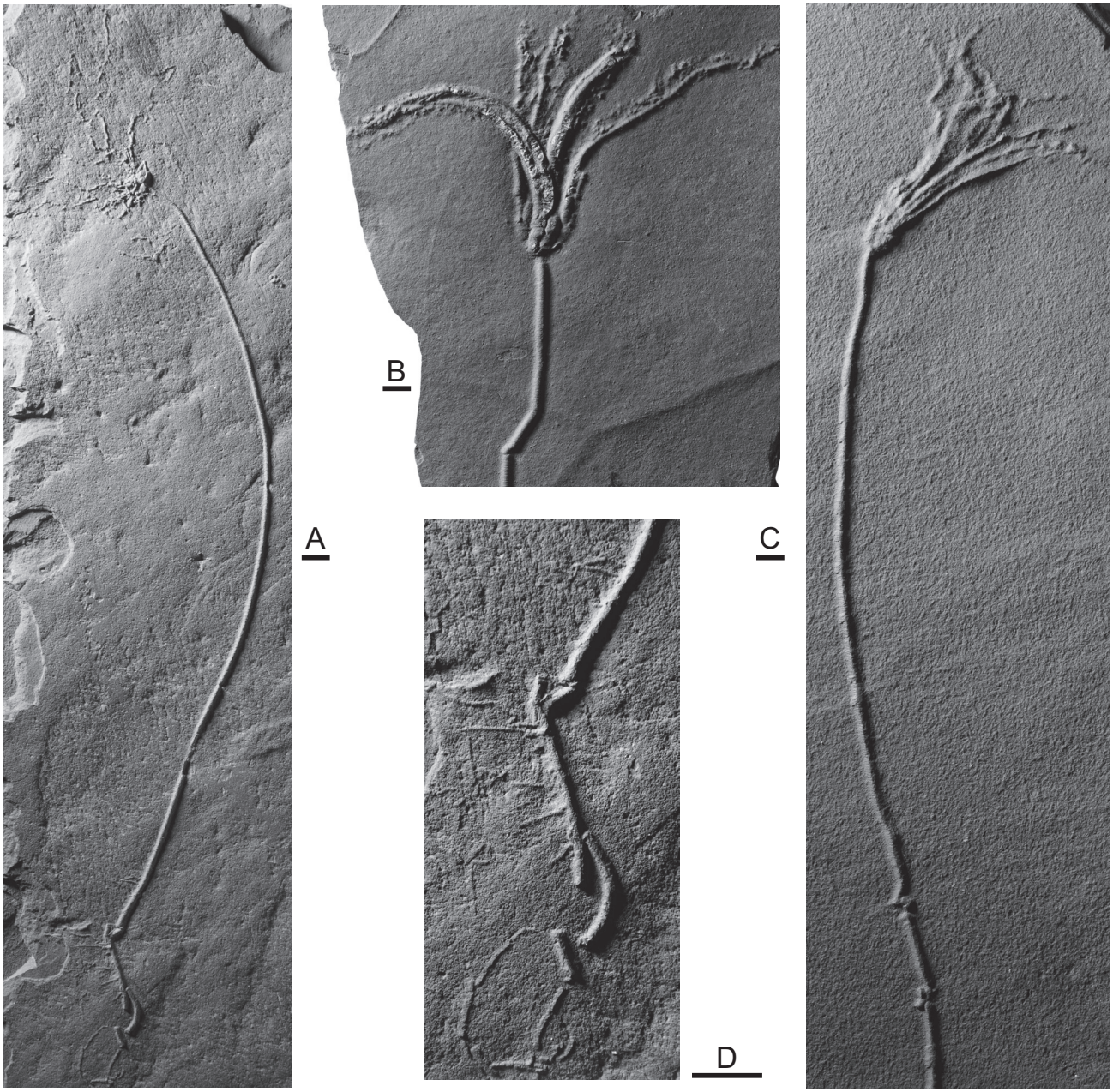

Figure 11. Crinoids from the Molignée Formation. A, D. Complete undetermined crinoids with close-up of the holdfast, Denée, Meurisse quarry, La Veine, CGF 191. B. Undetermined crinoid, Denée, Grande Veine, CGF 49. C. *Scaphiocrinus longicaudatus* Fraipont, 1904, CGF 44, Denée, Le Cerisier quarry, Les Nutons. Scale bars: 10 mm.

CGF 350: *Productus semireticulatus* (Martin) forme *crassispinus* in Delépine (1928, pl. 3, fig. 21); *Productus semireticulatus* in Maillieux (1933, pl. 8, fig. 133); Salet.

CGF 373: *Productus corrugatus* M'Coy in Delépine (1928, pl. 6, fig. 68); Denée.

CGF 386: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 42); Denée.

CGF 406: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 38); Denée.

CGF 408: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 41); Denée.

CGF 409: *Productus semireticulatus* (Martin) forme *crassispinus* Delépine, 1928 in Delépine (1928, pl. 2, fig. 13) and Groessens (in Dupuis et al., fig. 19.2); Denée.

CGF 410: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 39); Denée.

CGF 411: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 40); Denée.

CGF 412: *Productus corrugatus* M'Coy in Delépine (1928, pl. 4, fig. 46); Denée.

CGF 417: *Productus corrugatus* M'Coy in Delépine (1928, pl. 4, fig. 45); Denée.

CGF 431: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 44); Denée.

CGF 446: *Productus cora* d'Orbigny in Delépine (1928, pl. 4, fig. 43); Denée.

CGF 470: *Spirifer bisulcatus* Sowerby in Delépine (1928, pl. 6, fig. 75); Denée.

CGF 472: *Productus concinnus* Sowerby in Delépine (1928, pl. 2, fig. 12); Denée, Grande Veine.

CGF 522: *Productus* aff. *semireticulatus* (Martin) forme *ramispinus* Delépine, 1928 in Delépine (1928, pl. 1, fig. 1); Denée.

CGF 523 (Fig. 13A): *Productus* aff. *semireticulatus* (Martin) (? forme *ramispinus*) in Delépine (1928, pl. 2, fig. 15); Denée.

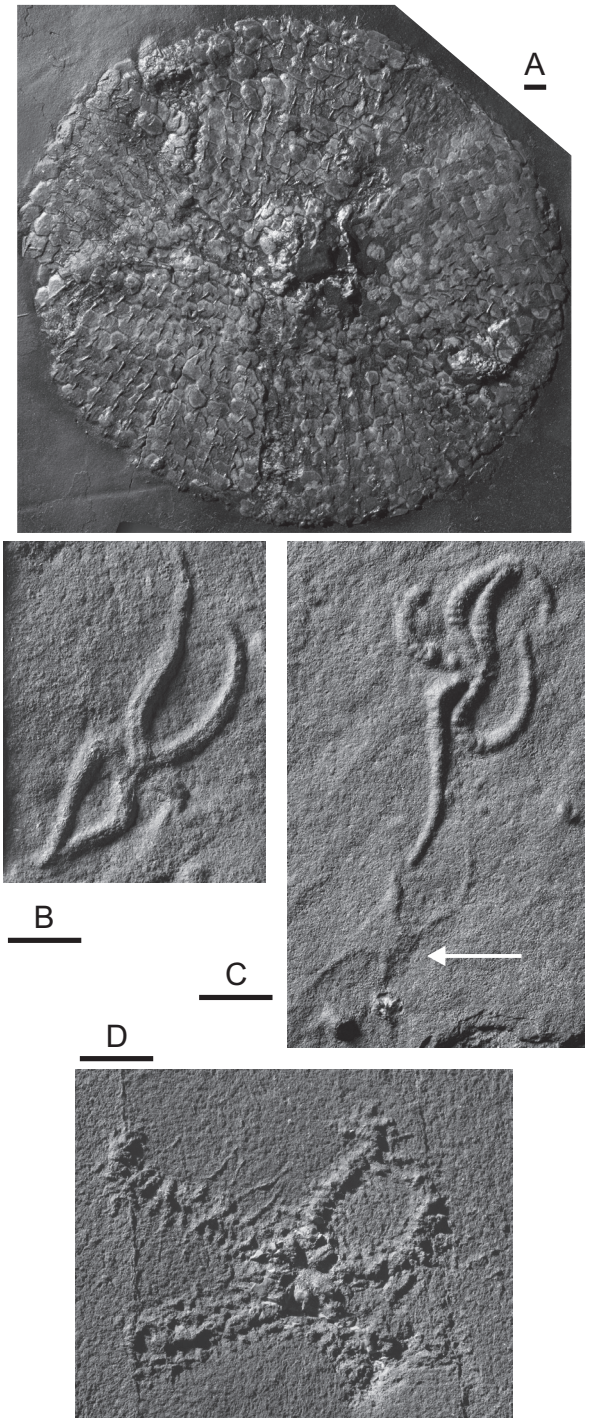

Figure 12. Echinoderms from the Molignée Formation. A. *Proterocidaris gigantea* de Koninck, 1882, ULg 11,228, lectotype of *Oligoporus soreili* Fraipont, 1904. B-C. *Taeniaster? fournieri* Fraipont, 1904, Denée, Les Neuf Bonniers quarry. B. CGF 68. C. CGF 67, lectotype, the arrow indicates the presence of a trace left by the animal before its death. D. undertermined ophiuroid, ULg 30,795. Scale bars: 10 mm.

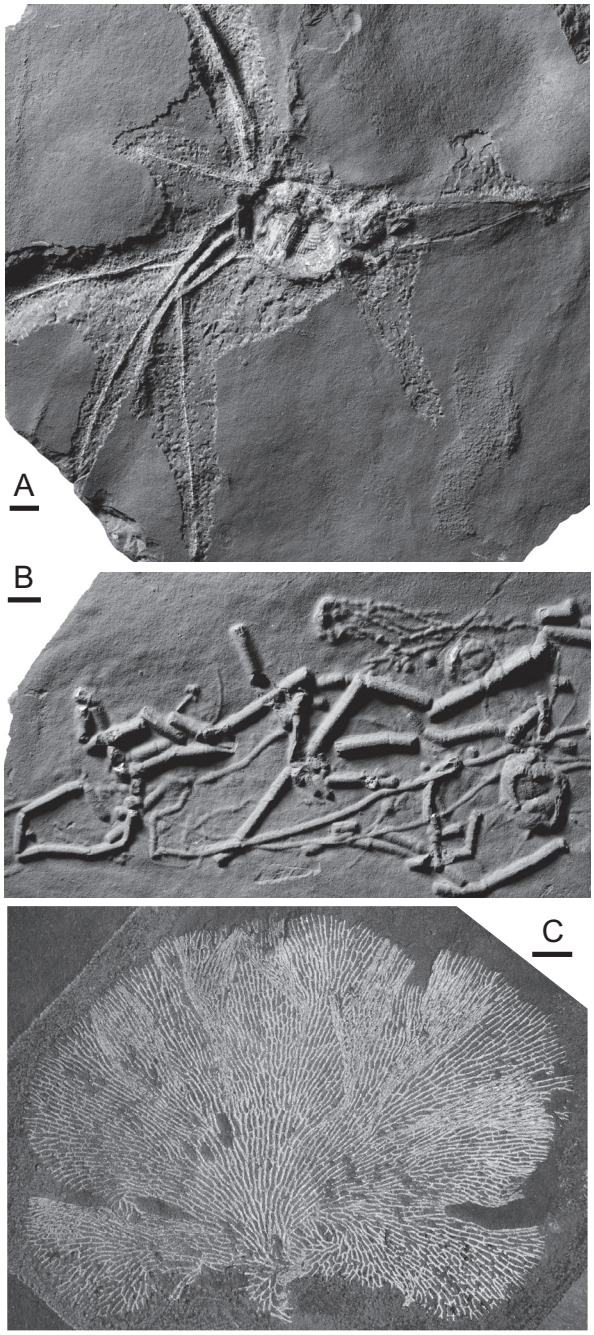

Figure 13. Brachiopods, crinoids and graptolite from the Molignée Formation in Denée. A. Undertermined productide with long ventral spines exceptionally preserved, CGF 523. B. Partly articulated undetermined crinoids and productide with ventral spines preserved, CGF 51. C. *Ptiograptus fournieri* Ubaghs, 1941, holotype, CGF 702. Scale bars: 10 mm.

CGF 525: *Productus* aff. *semireticulatus* (Martin) forme *ramispinus* in Delépine (1928, pl. 2, fig. 16); Denée.

CGF 528: *Productus* aff. *semireticulatus* (Martin) forme *ramispinus* Delépine, 1928 in Delépine (1928, pl. 1, fig. 2) and Groessens (in Dupuis et al., 1993, fig. 19.1), unidentified productid brachiopods in Mottequin (2009, fig. 7K); Denée.

3.4. Molluscs

3.4.1. Cephalopods

CGF (not traced): *Nomismoceras vittigerum* (Phillips) in Delépine (1940, pl. 5, fig. 29); Denée.

CGF 252 (Fig. 14C): undetermined goniatite; Denée, Piette quarry, Grande Veine.

CGF 262 (Fig. 14D): undetermined orthoconic cephalopod; Denée.

CGF 274 (Fig. 14F): undetermined orthoconic cephalopod; Denée, Grande Veine.

CGF 278 (Fig. 14B): undetermined goniatite; Denée.

CGF 284 (Fig. 14E): undetermined goniatite; Denée, Grande Veine.

CGF 289 (Fig. 14A): undetermined goniatite; Denée.

CGF 603: *Nomismoceras frechi* Schmidt in Delépine (1940, pl. 5, fig. 32); Denée.

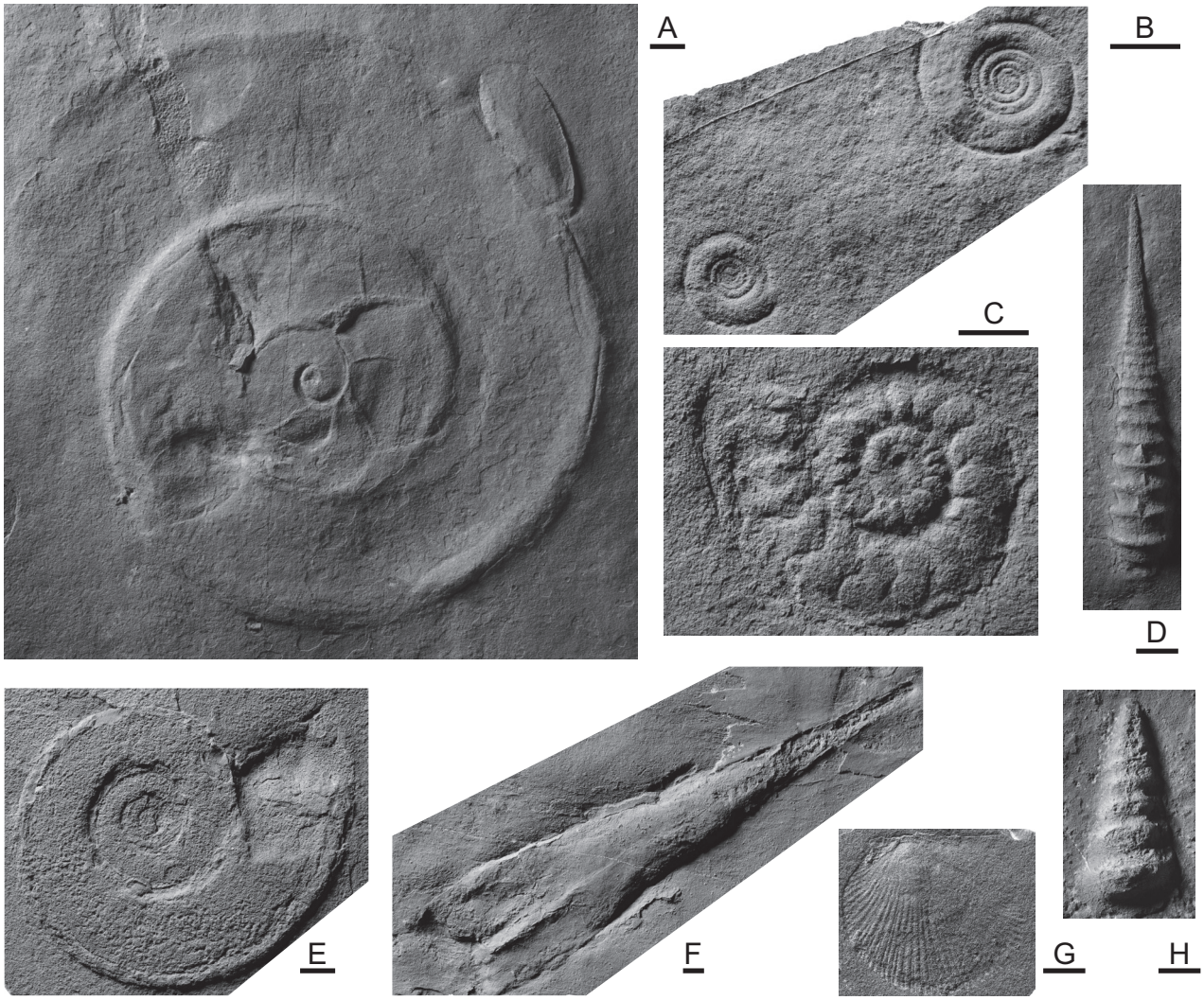

Figure 14. A-H. Molluscs from the Molignée Formation in Denée. A-C, E. Undetermined goniatite. A. CGF 289. B. CGF 278. C. CGF 252, Piette quarry, Grande Veine. E. CGF 284, Grande Veine. D, F. Undetermined orthoconic cephalopods. D. CGF 262. F. CGF 274, Grande Veine. G. '*Pterinopecten' radiatus* (Phillips, 1836), left valve, CGF 652. H. Undetermined gastropod, CGF 614. Scale bars: 10 mm.

3.4.2. Pelecypods

CGF 646: *Pterinopecten dumontianus* (de Koninck) in Demanet (1929, pl. 2, fig. 8); '*Pterinopecten' dumontianus* (de Koninck) in Mottequin (2009, fig. 7K [right]); Denée.

CGF 649: *Pterinopecten dumontianus* (de Koninck) in Demanet (1929, pl. 2, fig. 10); Denée.

CGF 652 (Fig. 14G): *Pterinopecten radiatus* (Phillips) in Demanet (1929, pl. 2, fig. 13); Denée.

CGF 654: *Pterinopecten radiatus* (Phillips) in Demanet (1929, pl. 2, fig. 12); Denée.

CGF 660: *Pterinopecten dumontianus* (de Koninck) in Demanet (1929, pl. 2, fig. 9); '*Pterinopecten' dumontianus* (de Koninck) in Mottequin (2009, fig. 7K [left]); Denée.

CGF 680: *Aviculopecten stellaris* (Phillips) in Demanet (1929, pl. 2, fig. 6); Denée.

CGF 682: *Pterinopecten radiatus* (Phillips) in Demanet (1929, pl. 2, fig. 14); Denée.

CGF 686: *Aviculopecten stellaris* (Phillips) in Demanet (1929, pl. 2, fig. 7); Denée.

IRScNB a5773: *Pterinopecten dumontianus* (de Koninck) in Demanet (1929, pl. 2, fig. 11); Denée, Meurisse quarry.

ULg 11,244: *Pseudamusium anisotum* (Phillips) in Demanet (1929, pl. 2, fig. 16); Denée.

ULg 2014-02-03/1: slab with a 'paper pecten' in Mottequin (2004, pl. 4, fig. C); Maredret-Station (see Mottequin, 2004, fig. 6).

3.4.3. Gastropods

CGF 614 (Fig. 14H): undetermined gastropod; Denée.

3.5. Corals

CGF 1021: *Caninophyllum* sp. (det. E. Poty) in Mottequin (2000, pl. 12, fig. 1); Denée.

ULg 2014-02-10/2: *Caninophyllum* sp. (det. E. Poty) in Mottequin (2000, pl. 12, fig. 1, 2004, pl. 3, fig. C, 2009, fig. 7I); Denée.

ULg 2014-02-10/3: '*Caninia* du type *patula*' in Salée (1911, fig. 1); Denée.

Not traced: '*Caninia* du type *patula*' in Salée (1911, fig. 2); Denée.

3.6. Conularids

CGF 633 (Fig. 15A): Denée, Les Cerisiers quarry.

3.7. Sponges

ULg 2014-02-03/2: slab with 'paper pecten' in Mottequin (2004, pl. 4, fig. C) with a sponge showing long spicules, close to representatives of the genus *Belemnospongia* (Mottequin, 2008, p. 201); Maredret-Station (see Mottequin, 2004, fig. 6).

CGF 1100: sponge (?) in Mottequin (2000, pl. 13, fig. 2); Denée, Meurisse quarry, top of La Veine.

CGF 819 (Fig. 16A): cf. *Phyllothallus* sp. in Mottequin (2000, p. 13, fig. 1); this may be a non-rigid sponge similar to that illustrated by Dietl & Schweigert (2004, pl. 2, fig. 1); Denée, Meurisse quarry.

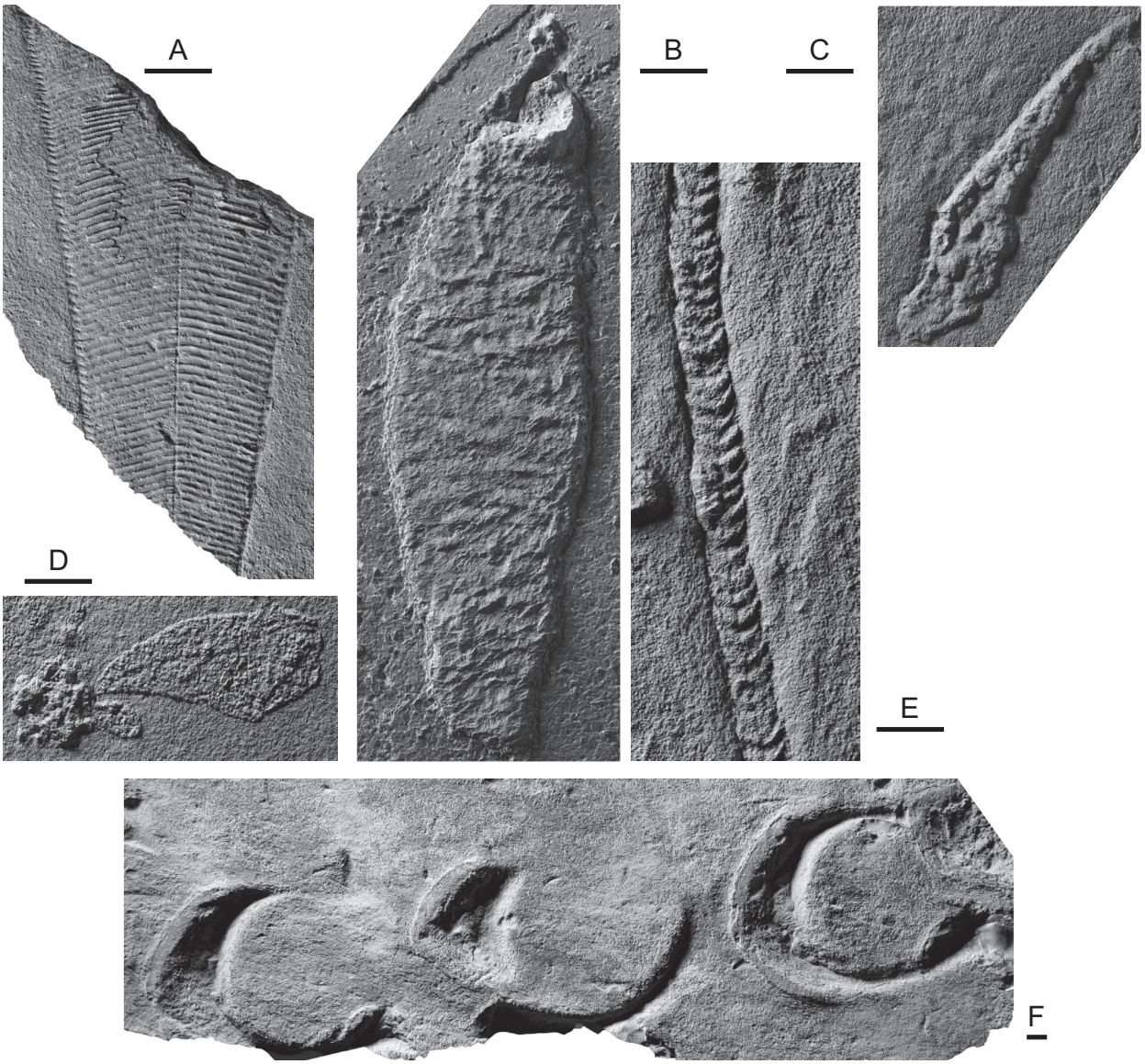

Figure 15. A. Undetermined conularid, CGF 633, Denée, Les Cerisiers quarry. B-D. Incertae sedis. B. this enigmatic fossil was tentatively identified as a holothurian by Kaisin (1926), CGF 759, Denée. C. *Incertae sedis*, CGF 801, Denée. D. *Incertae sedis*, CGF 763, Denée. E. Repichnia, CGF 778, Denée. F. Skip marks probably made by a gastropod shell, CGF 847, Denée. Scale bars: 10 mm.

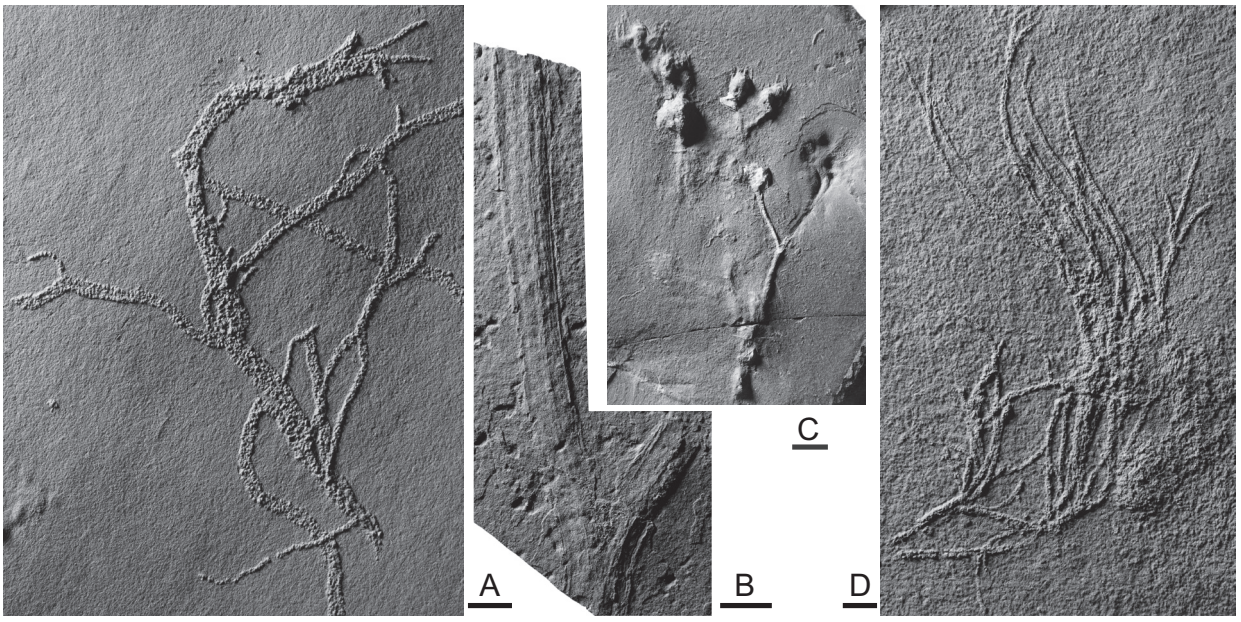

Figure 16. A. Probably a non-rigid sponge, CGF 8198, Denée, Meurisse quarry. B. Undertermined plant axis, Denée, Meurisse quarry, Les Drîs. C. Undetermined spermatophyte fertile branching system, CGF 770, Denée, La Veine. D. Most probably a non-calcareous alga, CGF 771, Denée, La Veine. Scale bars: 10 mm.

3.8. Graptolites

CGF 701: *'Dendrograptus'* sp. 1 in Ubaghs (1941, pl. 2, fig. 9); Denée.

CGF 702 (Fig. 13C): holotype of *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 5, fig. 18) and Henrard (1951, unnumbered figure); Denée.

CGF 704: *'Dendrograptus'* sp. 2 in Ubaghs (1941, pl. 1, fig. 4); Denée, Les Drîs.

CGF 706: paratype of *Dictyonema ultimum* in Ubaghs (1941, pl. 3, fig. 11); Denée, La Grande Veine.

CGF 708: holotype of *Dictyonema ultimum* Ubaghs, 1941 in Ubaghs (1941, pl. 3, fig. 10); Denée.

CGF 710: paratype of *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 2, fig. 8); Denée.

CGF 714: *Dictyonema fraiponti* Ubaghs, 1941 in Ubaghs (1941, pl. 1, fig. 1), Groessens (in Dupuis et al., 1993, fig. 19.5) and Mottequin (2009, fig. 6H); Denée, Piette quarry, La Veine.

CGF 724: holotype of *Dictyonema fraiponti* Ubaghs, 1941 in Ubaghs (1941, pl. 4, fig. 16); Denée.

CGF 725: holotype of *Desmograptus crassus* Ubaghs, 1941 in Ubaghs (1941, pl. 3, fig. 14); Denée, Meurisse quarry, Les Drîs.

CGF 1192: *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 5, fig. 19); Denée.

IRScNB a7671: *Dictyonema fraiponti* Ubaghs, 1941 in Ubaghs (1941, pl. 4, fig. 15); Denée, Piette quarry, La Veine.

IRScNB a7672A: *Dictyonema fraiponti* Ubaghs, 1941 in Ubaghs (1941, pl. 4, fig. 17); Denée, Meurisse quarry.

IRScNB a7672B: *Desmograptus* sp. in Ubaghs (1941, pl. 5, fig. 20); Denée.

ULg 11,280: paratype of *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 1, fig. 2); Denée.

ULg 11,281: paratype of *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 2, fig. 7), Groessens (in Dupuis et al., fig. 19.6), Groessens (1994, fig. 1), and Mottequin (2009, fig. 7G); Denée.

ULg 11,282: *Ptiograptus fournieri* Ubaghs, 1941 in Ubaghs (1941, pl. 1 fig. 3); Denée.

3.9. Incertae sedis

CGF 759 (Fig. 15B): holothurian (?) (see Kaisin, 1926) in Mottequin (2000, pl. 11, fig. 1); Denée.

CGF 1120: crustacean (?) in Mottequin (2000, pl. 11, fig. 2); Denée.

CGF 763 (Fig. 15D): *incertae sedis* (holothurian?) in Mottequin (2000, pl. 12, fig. 3, 2004, pl. 4, fig. B); Denée.

CGF 801 (Fig. 15C): *incertae sedis* in Mottequin (2000, p. 13, fig. 3); Denée.

CGF 798: worm (?) in Mottequin (2000, pl. 14, fig. 1); Denée.

CGF 873: worm (?) in Mottequin (2000, pl. 14, fig. 2); Denée.

3.10. Plants

CGF 769 (Fig. 16B): This fossil consists of a dichotomous axis showing clear longitudinal striation. No other characteristic feature could be observed. It has been determined as *Archaeosigillaria* by Renier (unpublished data). The latter genus has recently been revised by Berry and Edwards (1997). It is characterized by lycopodiaceous stems covered with spirally arranged hexagonal leaf bases. None of these characters are present in the present plant fragment. We think this axis is impossible to determine with precision. Denée, Meurisse quarry, Les Drîs.

CGF 770 (Fig. 16C): This fossil has been identified as *Tristichia*? sp. (det. M. Fairon-Demaret) in Mottequin (2000, pl. 12, fig. 4, 2004, pl. 3, fig. D). The genus name *Tristichia* corresponds to anatomically preserved three-ribbed protosteles presenting papilionoid leaf traces (Long, 1961). The lack of anatomical details in the present material thus invalidates this identification. The occurrence of a bidimensional dichotomous branching system distally bearing cupulate structures is however reminiscent of earliest seed plant organisation but a more detailed analysis is necessary in order to clarify its affinities. We will thus refer to this material as 'undetermined spermatophyte fertile branching system'. Denée, La Veine.

CGF 771 (Fig. 16D): This fossil consists of a long slender axe that all seem to arise from the same zone. The branching pattern is not very clear. Considering the morphology of the specimen, it very likely corresponds to a fossil non calcareous alga. Further investigations are necessary to clarify its affinities. Denée, La Veine.

3.11. Ichnofossils

CGF 754: *Medusina boulengeri* Van Straelen, 1926 in Van Stralen (1926, figs 1-2) and Groessens (1994, pl. 7, unnumbered figure); '*Medusina' boulangeri* (sic) Van Straelen in Harrington & Moore (1956, fig. 129.6) and Groessens (in Dupuis et al., 1993, fig. 19.7a-19.7b). This specimen is probably a burrow (for discussion, see Mottequin, 2004, p. 5); Denée, Piette quarry.

CGF 773: 'empreinte néréitiforme' in Carpentier (1913, pl. 11, fig. 1); Denée.

CGF 778 (Fig. 15E): repichnia, Denée.

CGF 787: 'empreinte néréitiforme' in Carpentier (1913, pl. 11, fig. 2); Denée.

CGF 887: *Zoophycos* sp. in Mottequin (2000, pl. 17, fig. 1); Denée.

CGF 1117: repichnia in Mottequin (2000, pl. 15, fig. 1); Denée, Meurisse quarry, Les Drîs.

ULg 30,016: 'empreinte néréitiforme' in Fraipont (1911, pl. 3); Denée.

ULg 30,088: pascichnia in Mottequin (2000, pl. 16, fig. 1); Denée.

3.12. Skip and groove marks

CGF 825: groove marks in Mottequin (2000, pl. 22, fig. 1); Denée, Piette quarry.

CGF 847 (Fig. 15F): skip marks probably made by a gastropod shell in Mottequin (2000, pl. 20, fig. 1); Denée.

CGF 906: skip mark moulds in Mottequin (2000, pl. 21, fig. 1); Denée, Meurisse quarry.

CGF 1132: skip mark moulds produced by a broken cephalopod shell in Mottequin (2000, pl. 19, fig. 1, 2004, pl. 4, fig. A); Denée, Meurisse quarry, La Veine.

ULg 30,082: skip mark moulds in Mottequin (2000, pl. 18, fig. 1); Denée.

4. Perspectives

This catalogue rather than representing the last word constitutes the first step of a complete reassessment of the Denée "black marble" diverse fauna. This assemblage constitutes an invaluable window on Mississippian environments. The occurrence in the same beds of exquisitely preserved vertebrates and invertebrates as well as the presence of ichnofossils and indications of soft bodied organisms are in our opinion crucial to the reconstruction of past ecological conditions.

5. Acknowledgments

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