New data on occurrences of the Devonian rugose coral Calceola in Belgium

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**Recommended Citation**

Wright, Anthony J.; Coen-Aubert, M; Bultynck, P; and van Viersen, A P.: New data on occurrences of the Devonian rugose coral Calceola in Belgium 2010, 121-129.  
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Abstract
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Keywords
Devonian, Eifelian, Givetian, rugose corals, Calceola, operculum, Belgium, GeoQUEST

Disciplines
Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

This journal article is available at Research Online: https://ro.uow.edu.au/scipapers/632
New data on occurrences of the Devonian rugose coral Calceola in Belgium

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Keywords: Devonian, Eifelian, Givetian, rugose corals, Calceola, operculum, Belgium.

THE BIZARRE and distinctive rugose coral genus Calceola Lamarck, 1799 has been one of the best known and easily recognisable Devonian fossils, and is widely distributed through western Europe, North Africa, southern China and eastern Australia in particular. Indeed, its palaeogeographic distribution suggests that the genus was largely a Gondwanan faunal element.

Most of the well preserved material of this genus is from the Eifel region of Germany, where it has been studied since the introduction of the type species Calceola sandalina by Linné (1771) and where its range is from late Emsian (late Early Devonian: Werner 1968) through the Eifelian and into the Givetian (Richter 1928; Lotze 1928). It ranges from the Emsian into the late Eifelian of Poland (Pajchlowa 1957; Malec 2005; Malec & Turnau 1997) and occurs in the late Eifelian of Moravia (Galle & Ficner 2004). In eastern Australia good occurrences of C. sandalina are known from the late Emsian of New South Wales (Wright, unpublished data) into the early to middle Givetian of north Queensland (Zhen & Jell 1996). The range of the genus in Belgium has formerly been considered to be Couvinian; according to the definition of the base of the Middle Devonian (=base of Eifelian), it ranges from uppermost Emsian to lowermost Givetian. Bultynck & Hollevoet (1999, fig. 2) showed that the genus ranged into the early Givetian.

Pedder (in Pedder & Feist 1998, p. 969) stated that C. sandalina first appears in the “Lower Emsian dehiscens Zone (kitabicus Zone of Yolkin et al. 1994) of Eastern Australia”; elsewhere in the same paper (p. 973) he cited “three probable Pragian occurrences in Australia … (being) … the Tabberabberra Formation of Victoria, … the Martins Wells Limestone of the Broken River Embayment, Queensland” and “… the Mount Etna Limestone” (also of Queensland). More recent data allow re-evaluation of these possible Pragian occurrences of Calceola. The Victorian material referred to by Pedder is presumably Rhizophyllum calceoloides Talent, 1963; this species was referred by Wright (2001) to Chakeola, a Lochkovian to Emsian genus. The other two occurrences cannot yet be assigned with certainty to Calceola as calceoloid coral opercula from the two localities have not been described. Jell et al. (in Withnall et al. 1988, fig. 71) and Webby & Zhen (2008, fig. 2) ascribed a late Lochkovian to early Pragian age to the Martins Wells Limestone Member of the Shield Creek Formation in the Broken River region of north Queensland. The Mount Etna Limestone is mid-Pragian (John Talent, pers. comm. 2009). As previously suggested by Wright (2001), the
Emsian *Calceola sinensis* Mansuy, 1908 from northern Vietnam should also be assigned to *Chakeola*. Thus, there is no proven pre-Emsian representative of *Calceola*.

It has been known from the recognition of the Devonian System by Sedgwick & Murchison in the years 1836-1838 (see Rudwick 1979, 1985 for references) and, in particular, from the subsequent works of Murchison, Sowerby, Phillips and Lonsdale, that the development of Eifelian (early Middle Devonian) strata in Germany, Belgium and France is quite similar, although not identical (Dineley 1984, p. 4-5, figs 4.2, 4.6). Nevertheless, given the abundance and the numerous studies and illustrations of German *Calceola* from the Eifel region in particular, it would be expected that the presence of the genus in Belgium would have been established beyond doubt. Certainly, the Eifelian strata of Belgium and the Eifel region of Germany are characterised by similar faunas, including what has been referred to *Calceola* in both countries. The occurrence of *Calceola* in Germany has been established for almost 250 years, but it is the purpose of this paper to illustrate, for the first time, undoubted *Calceola* from Belgium. Further, although *Calceola* has been widely reported from France (e.g. Barrois 1886; Le Maitre 1934; Pedder in Pedder & Feist 1998), the only good *Calceola* operculum yet illustrated from France is that by Collin (1927, pl. 11, fig. 3).

Despite the numerous listings of *Calceola* from Belgium by Maillieux (1913a, b), Maillieux & Demanet (1929), Lecompte (1960) and Bultynck & Hollevoet (1999), the only illustrations of Belgian *Calceola* known to us are those by Tsien (1969) and, possibly, an idealised drawing of a specimen of indeterminate origin by Maillieux (1933) in a publication on Belgian geology. Tsien (1969, pp. 135-139, pl. 50, fig. 12; pl. 51, figs 11-17; text-figs 30.1-30.3) described “*Calceola sandalina* (Linné) *forma sandalina* (Linné) comb. nov.”, “*Calceola sandalina* (Linné) *forma alta* Richter comb. nov.” and “*Calceola sandalina* (Linné) *forma angulatissima* Tsien nov. *forma*”; his illustrations were of thin sections and non-diagnostic external views of corallites. This situation has considerable implications as Wright (2006, 2007) asserted that, in the Calceolidae, the septal structures developed on the inner surface of the operculum are of fundamental taxonomic significance at the generic level. Indeed, genera such as *Richterola* Wright, 2006, *Savageola* Wright, 2006 and *Chakeola* Wright, 2001 can be distinguished from *Calceola* only with data from well preserved opercula. Therefore it seemed useful to try to study Belgian opercula to establish their morphology, and thus the genus, of the material.

Herein, we illustrate especially the inner surface of Belgian opercula in order to establish the generic and specific identity of these corals. One of us (M. C-A.) located two good opercula, as well as samples of the more common corallites, including some with attached opercula, in collections from Couvin (Fig. 1). Other material from Wellin and Resteigne (Fig. 1) from the collections of one of us (A. P. V.) includes corallites and good opercula. The quality of the available Belgian material is perhaps not as...
elegant (nor does it appear to be as abundant) as the Eifel material; this may be explained by the Belgian material being somewhat more tectonised than the Eifel material as well as, possibly, by the absence in Belgium of favourable sedimentary facies.

In a comprehensive assessment of correlation of the Devonian strata in the Ardennes (Bultynck [Figure 2]. Calceola sandalina (Linné, 1771), all from Hanonet Formation, La Couvinoise Quarry, Couvin, Belgium. A-C, IRScNB a12694, collection P. Bultynck G1 (14OP), operculum in internal, external and oblique views respectively. D-E, IRScNB a12695, collection E. Maillieux IG 10319OP, operculum in internal and external views. Median structure in D is mostly adhesive, not skeletal material. F-H, IRScNB a12696, collection E. Maillieux IG 5911 (673), corallite with operculum in: F, counter view; G, cardinal view; and H, enlargement of F showing, on right side, major and minor septal ridges diverging from alar fossula. I, IRScNB a12697, collection E. Maillieux IG 10319SP, corallite showing calyx. All scale bars 5 mm.
et al. 2000, p. 97, 99, 101, fig. 7), the range of *C. sandalina* was stated to be from the middle part (late Emsian) of the Eau Noire Formation through the Hanonet Formation (latest Eifelian to early Givetian) into the base of the Trois-Fontaines Formation (early Givetian).

**LOCATIONS OF BELGIAN MATERIAL**

**Material from La Couvinoise quarry, Couvin**

All the investigated material from the Couvin area comes from the active La Couvinoise quarry (Fig. 1), which was formerly known in the literature as the Haine or Colard quarry (outcrop Couvin 8708). This quarry is excavated in the Hanonet Formation (former Co2d of Maillieux & Demanet 1929) and in the base of the overlying Trois-Fontaines Formation. According to Bultynck & Hollevoet (1999, fig. 2), who collected their specimens bed by bed, *C. sandalina* occurs throughout the Hanonet Formation and ranges up into the very base of the Trois-Fontaines Formation, being common to abundant in strata G to I described by Bultynck & Hollevoet from the lower part of the Hanonet Formation. One specimen of *Polygnathus hemiansatus* was recovered by Bultynck & Hollevoet (1999) from beds at the top of stratum D, which is 42 m below the traditional Couvinian-Givetian boundary which corresponds to the boundary between the Hanonet and Trois-Fontaines Formations. So the operculum IRScNB a 12694 (Fig. 2A-C) and the two (unfigured) corallites [G1 (14A and 14B)] from stratum G of Bultynck & Hollevoet (1999) belong to the basal Givetian *Polygnathus hemiansatus* conodont Zone. Overall, the material of *C. sandalina* from La Couvinoise quarry comes from the top of the Eifelian in the *P. ensensis* Zone to the base of the Givetian in the *P. hemiansatus* Zone.

**Material from Wellin and Resteigne**

The Hanonet Formation with corallites and opercula of *Calceola* is exposed to the east of Givet at the localities of Pondrôme, Wellin and Resteigne in the southern part of the Dinant Basin (Fig.1) where it was investigated by Coen-Aubert (1996, 1997, 1998, 2008). In the Resteigne quarry, Coen-Aubert (1996, p. 20 and log of fig. 3) observed *Calceola* in the coralline limestones from the very base of the Hanonet Formation and in the argillaceous limestones from its middle part up to about 29 m below the boundary with the Trois-Fontaines Formation. The base of the Hanonet Formation is probably late Eifelian whereas the Eifelian-Givetian boundary lies higher in the Formation. Six specimens from Wellin and Resteigne were available for study.

Two specimens, one corallite in hard matrix and one small corallite with attached operculum (Fig. 2J) were collected by A.P.V. from the base of the Hanonet Formation at this outcrop at Resteigne.

Four additional specimens from Wellin were purchased from collectors by APV. Because identical specimens with detailed locality information are present in other private collections, it is probable that they come from the active Fond des Vaux West quarry which was investigated by Coen-Aubert (1990, 2008) among others. For a long time the upper part of the Hanonet Formation has been well exposed in this quarry and *Calceola* from this locality should be early Givetian. This material is slightly dolomitic and filled with loose argillaceous sandy sediment (in the case of corallites) and includes: one operculum (Fig. 3A-B), two corallites (Fig. 3C-D) and one corallite with its operculum slightly displaced (Fig. 3E-G).

**SYSTEMATIC PALEONTOLOGY**

Collections are stored in the Institut royal des Sciences naturelles de Belgique at Bruxelles, Belgium (IRScNB), the Naturhistorisch Museum Maastricht, the Netherlands (NHMM) and the Paleontological Research Institute in Ithaca, New York, USA (PRI ER).

Some terminology is adopted for convenience and accuracy of description from the customary brachiopod usage. Length is measured normal to the hingeline (the line of contact of operculum and corallite; and the attitude of the posterior (=counter) face of the operculum is best described using the terminology for the brachiopod interarea. Following Wright (2001) the term KOF is used for the counter opercular face and, following Wright (this volume) KEF is used to denote the external counter face of the corallite.

**Family CALCEOLIDAE**

**Remarks.** Weyer (1996) pointed out that this family name has priority over Goniophyllidae Dybowski, 1873; according to Lafuste & Semenoff-Tian-Chansky (1968), Termier & Termier (1948) had already assigned *Calceola* to Calceolidae Lindström, 1883, a junior synonym of Calceolidae King, 1846.

**Calceola** Lamarck, 1799

**Type species.** *Anomia sandalium* (sic) Linné in Gmelin, 1790, p. 3349 (= *A. sandalinum* Linné, 1771, p. 547). A neotype was selected by Richter (1928, p. 173, fig. 1a-b).
Remarks. Pedder in Pedder & Feist (1998) provided a comprehensive synonymy for this species. Taxonomic problems arise with this species, particularly because Richter (1916, 1928), Tsien (1969) and Lotze (1928), in particular, erected several subspecies based almost entirely on the apical angle of the corallite. It has been asserted (Wright 2001, 2006, 2007) that the morphology of the operculum is far more important as a generic and specific discriminator.

**Calceola sandalina** (Linne, 1771) (Figs 2-3)

Figure 3. *Calceola sandalina* (Linne, 1771). A-G, from Wellin, probably Hanonet Formation, Fond des Vaux West quarry. A-B, IRScNB a12698, collection A.P. van Viersen WEL1, internal and external views of operculum. C, IRScNB a12699, collection A.P. van Viersen WEL2, larger corallite, cardinal view showing calyx and septa. D, IRScNB a12700, collection A.P. van Viersen WEL3, smaller corallite showing calyx and septa on counter face. E-G, IRScNB a12701, Collection A.P. van Viersen WEL4, corallite with displaced operculum in (E) counter view, (F) cardinal view and (G), enlarged view of proximal region of cardinal face showing *Clionolithes* traces. H, from Resteigne quarry, IRScNB a12702, Collection A.P. van Viersen RES 1, small corallite with operculum. All scale bars 5 mm.
The net result of the latter point of view is that previous records of Calceola must be suspect unless the internal features of the operculum have been documented; until now no C. sandalina opercula from Belgium have been illustrated.

Material. Hanonet Formation, late Eifelian to early Givetian. Couvin material, all from La Couvinoise Quarry, five specimens (IRScNB a12694-12697) and one specimen from PRI, ER 630. Wellin material, four specimens IRScNB a12698-12701, probably also from the Hanonet Formation, probably from the active Fond des Vaux West quarry. Resteigne material, two specimens (IRScNB a12702, NHMM 2009088) from the Hanonet Formation, Resteigne quarry.

Description. Corallite typically slipper-shaped, with apical angle of as little as 20° and up to 80° at maturity; up to 35 mm wide, maximum length (measured normal to hingeline) 30 mm. Septa faintly visible on both exterior of cardinal face; external counter surface shows growth lines, with prominent median ridge (trace of counter septum). Septal traces seen on the KEF of one worn (slightly etched?) specimen as fine grooves (Fig. 2F, H); on this specimen there are several fine ridges in the median ridge, suggesting a compound nature of this septum. The same corallite shows clearly, externally at the corner of the KEF, the trace of the alar septum and associated septal insertion (Fig. 2H), where septa recently inserted in the alar fossula first make a slight angle to the alar septum but rapidly become parallel to earlier septa on the KEF. Examples of the trace Clionolithes are well preserved on the external cardinal face (Fig. 3F-G).

Operculum semiovate in outline, with prominent growth lines which are semi-circular in early growth stage and transversely semiovate in late growth stage; epifauna often prominent (Figs 2B, 3B), normally on external surface. Posterior face continuous with counter face of corallite, with juvenile section slightly tilted forward. Outer surface gently convex except for slightly raised and tilted proximal area, which is caused by the change in slope of the interarea through ontogeny. Inner surface very slightly concave overall, with lateral extremities slightly raised relative to median edge; a low convex area extends from more or less in front of the hingeline to about 12 mm from posterior edge (Fig. 2C), on both sides of the median septum which extends to outer edge. Five to six septal blades; about 34 septa (major plus minor septa) developed around the edge, about half of which are minor septa inserted outside the more convex proximal part of the inner surface of the operculum. Major septa more or less radially arranged from median ridge to innermost septal blade, but lateral to that they tend to be curved laterally and outermost septa are almost sigmoidal. Median septum incompletely preserved, bifurcates posteriorly forming the pit for articulation (Fig. 2A) with the distal tip of the median septum of the corallite; the two ridges enclosing the pit extend posteriorly to form the central ridge on the ‘interarea’ of the operculum. Immediately inside the posterior edge of the operculum an incomplete row of low rounded knobs is developed above a low sloping surface (Fig. 2A, C).

Dimensions. See table 1 for dimensions including apical angles of corallites.

Remarks. No attempt is made here to subdivide
the collections from Couvin, Wellin and Resteigne into separate taxa; indeed they appear conspecific. As far as present knowledge will allow, it is identical with ‘typical’ specimens of *C. sandalina* from Germany, representative material of which has been illustrated and discussed elsewhere (Richter 1928, 1929; Lotze 1928; Birenheide 1974; Wright this volume). However, even at the species level, identification is complicated because the neotype of *C. sandalina* selected by Richter (1928) does not allow determination of the critical morphological aspects of the operculum; there is even less value in attempting identification to the subspecific level until the status of the infraspecific taxa is clarified. The currently held broad concept of *C. sandalina* is followed here.

One specimen (Fig. 3D) shows a marked increase in the angle subtended by the corners of the KEF, increasing from 20° to 57° (Table 1) whereas at least one other specimen (Fig. 2F) shows a decrease in the same angle from 68° to 50° (Table 1). This is at least in part a manifestation of the way in which these corners are curved; it certainly does highlight the difficulty measuring this parameter and the limits of using such measurements in calceoloid taxonomy.

Several Belgian specimens show interesting details. One exposes the calyx and shows not only desmocyte scars and septal insertion (best seen in the weathered region of the calyx) but also shows quite clearly the location of the alar fossulae and the associated ridges on the counter side of the corner of the corallite (Fig. 2I); these ridges associated with the alar fossulae are also well developed on one of the Wellin specimens (Fig. 3C). As noted above, IRScNB a 12696 (Fig. 2F-H) shows not only major and minor septal traces on the KOF but, much more importantly, septal insertion adjacent to the alar septum at the edge of the KOF.

In conclusion, *Calceola sandalina* from late Eifelian and early Givetian strata of the Hanonet Formation in the Couvin, Wellin and Resteigne areas of Belgium is described and illustrated. In the Couvin area of Belgium, *Calceola* ranges from the late Emsian part of the Eau Noire Formation and the late Eifelian to early Givetian Hanonet Formation into the early Givetian Trois-Fontaines Formation (Bultynck & Hollevoet 1999, fig. 2, p. 6; Bultynck et al. 2000, p. 97, 101, fig. 5, fig. 7).

ACKNOWLEDGEMENTS

We are most grateful to the following: Dr Chris Hollevoet collected important *in situ* material at the La Couvinoise quarry at Couvin; Dr Tim Palmer gave valuable advice on trace fossils; Harald Prescher (Kerpen) and Jules Snellings (Wellen) assisted with discussions on the age of the Wellin occurrence; Dr Jim Sorauf (Florida) helped us borrow material collected by him from Belgium, held by the Paleontological Research Institute in Ithaca, New York; Dr Judith Nagel-Myers arranged the loan of this Sorauf material; Professor John Talent advised on the ages of the Martins Well and Mount Etna occurrences. Comments on the manuscript by Arnošt Galle and Tomas Wrzolek have been most beneficial. AJW acknowledges the use of facilities in the School of Earth and Environmental Sciences, University of Wollongong, and thanks the Linnean Society of NSW for the award of the Linnean Macleay Fellowship for 2006-7-8-9-10.

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WEBBY, B.D. & ZHEN, Y.Y., 2008. Devonian


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