

# Discovery of an Early Ordovician conodont fauna in the Salm Group of the Stavelot Inlier, Belgium

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## Abstract

Conodonts have been discovered in two locations in the Lienne Valley near Chevron from low grade metamorphic siliciclastic deposits of the Stavelot Inlier belonging to the Salm Group. The conodont fauna described and illustrated in this paper has been collected from a single fossiliferous horizon within the Otrré Formation, at the transition between the Meuville Member and the Les Plattes Member. This is the first record of a conodont fauna from the Stavelot Inlier in Belgium. It is also of interest for regional stratigraphy, international correlation, as well as for palaeobiogeographic interpretations, because the Salm Group forms an epimetamorphic, comprehensive series of nearly a thousand meters in thickness but is poorly dated.

The biostratigraphical comparisons suggest an Early Ordovician, tentatively latest Tremadocian age for the conodont assemblage, but a basal Arenig age cannot be excluded. The fauna is clearly dominated by typical drepanodiform elements, but there is quite some morphological variation in this small simple cone assemblage from subrectiform (of *Drepanoistodus*?) to reclined and recurved elements. The most common elements belong to *Drepanodus arcuatus* PANDER 1856 ranging from the uppermost Tremadocian up into the lower Darriwilian (= uppermost Arenig). However, there are also a few elements in the fauna from the Salm Group, like some strongly recurved "*Drepanodus*" *recurvatus* SANNEMANN 1955, which are comparable to the latest Tremadocian '*franconicus*' fauna, characteristic for the Frankenwald area. The species diversity is very low which is comparable to the situation in cold water areas of the Mediterranean Province of Gondwana and peri-Gondwana like the Frankenwald region, the Barrandian area and the Montagne Noire.

The discovery of this small conodont fauna enhances our knowledge not only of the chronostratigraphy of the Salm Group, but also of the palaeogeographical situation of the Belgian Ardenne in Early Ordovician times.

**Key-words:** conodont biostratigraphy, palaeogeography, peri-Gondwana.

## Résumé

Une faune à conodontes a été découverte dans deux localités de la vallée de la Lienne à proximité de Chevron dans les dépôts faiblement métamorphiques du Groupe de la Salm du Massif de Stavelot. La faune, décrite et illustrée dans cet article, provient d'un même horizon au sein de la Formation d'Otrré. Cet horizon est situé juste à la limite entre les Membres de Meuville et de Les Plattes. C'est la première fois

qu'une faune à conodontes est trouvée dans le Massif de Stavelot. Son intérêt pour la stratigraphie régionale, pour les corrélations internationales, de même que pour des interprétations paléobiogéographiques est manifeste étant donné que le Groupe de la Salm constitue une série compréhensive épimétamorphique, épaisse de près de 1.000 mètres et mal datée.

Les premières comparaisons biostratigraphiques suggèrent pour l'assemblage un âge Ordovicien Inférieur, peut-être Trémadocien supérieur, quoiqu'un âge Arénig inférieur ne puisse pas être exclu. La faune est typiquement dominée par des éléments drepanodiformes, mais il y a une variation morphologique importante dans ce petit assemblage de cônes simples entre des éléments subrectiformes (*Drepanoistodus*?) à des éléments inclinés et incurvés. Les éléments observés les plus communs appartiennent à l'espèce *Drepanodus arcuatus* PANDER 1856. Cette espèce s'étend stratigraphiquement du Trémadocien supérieur au Darriwilien inférieur (= Arénig supérieur). Il y a aussi dans la faune étudiée quelques éléments de la faune '*franconicus*', caractéristique de la région de Frankenwald, datée du Trémadocien supérieur. La diversité spécifique très faible est comparable à la situation qui existe dans des régions d'eau froide de la Province Méditerranéenne (Gondwana et péri-Gondwana) telles la région de Frankenwald, la région Barrandienne et la Montagne Noire.

La découverte de cette petite faune à conodontes enrichit nos connaissances non seulement de la chronostratigraphie du Groupe de la Salm, mais aussi de la position paléogéographique de l'Ardenne belge à l'Ordovicien Inférieur.

**Mots-clés:** conodontes, biostratigraphie, paléogéographie, péri-Gondwana.

## Introduction

The deposits from the Salm Group (Lower and Middle Ordovician) of the Stavelot Inlier (Belgium) hosting the conodont fauna reported herein are characterized by thick, mostly turbiditic, often strongly folded and faulted strata. Fossils are absent or rare in such comprehensive and disturbed series. Their correlation to the standard chronostratigraphic chart is often problematic. The discovery of fossils, especially of stratigraphically useful groups, therefore is of great importance. The aim of the present paper is to report and describe the exceptional discovery of a conodont fauna in the middle part of the Salm Group. The stratigraphic correlation and palaeobiogeographic aspects of this conodont assemblage, obtained from a coarse-grained greywacke, is discussed. The conodont-bearing level occurs at the transition between the Meuville Member and the Les Plattes Member of the



Otré Formation. It is positioned just a few decimetres below the base of a 70 cm thick manganiferous ore of the Chevron area. The strata containing this manganiferous event, characteristic for the Otré Formation, the middle part of the Salm Group, are entirely devoid of any other determinable fossils.

This is the second record of Ordovician conodonts from Belgium. To date only the Ashgill fauna from the Condroz Inlier was known (TOURNEUR et al., 1993, SARMIENTO & BULTYNCK, 2003) which is low in diversity in

contrast to some highly diverse latest Ordovician faunas from peri-Gondwana and Gondwana (e.g. Thuringia, Sardinia, the Carnic Alps, Spain).

### Geological framework

The regional geology of the Stavelot Inlier (see location at Fig. 1b) was compiled by GEUKENS (1986, 1999) who published maps at a scale of 1/106.000 and 1/125.000. Of

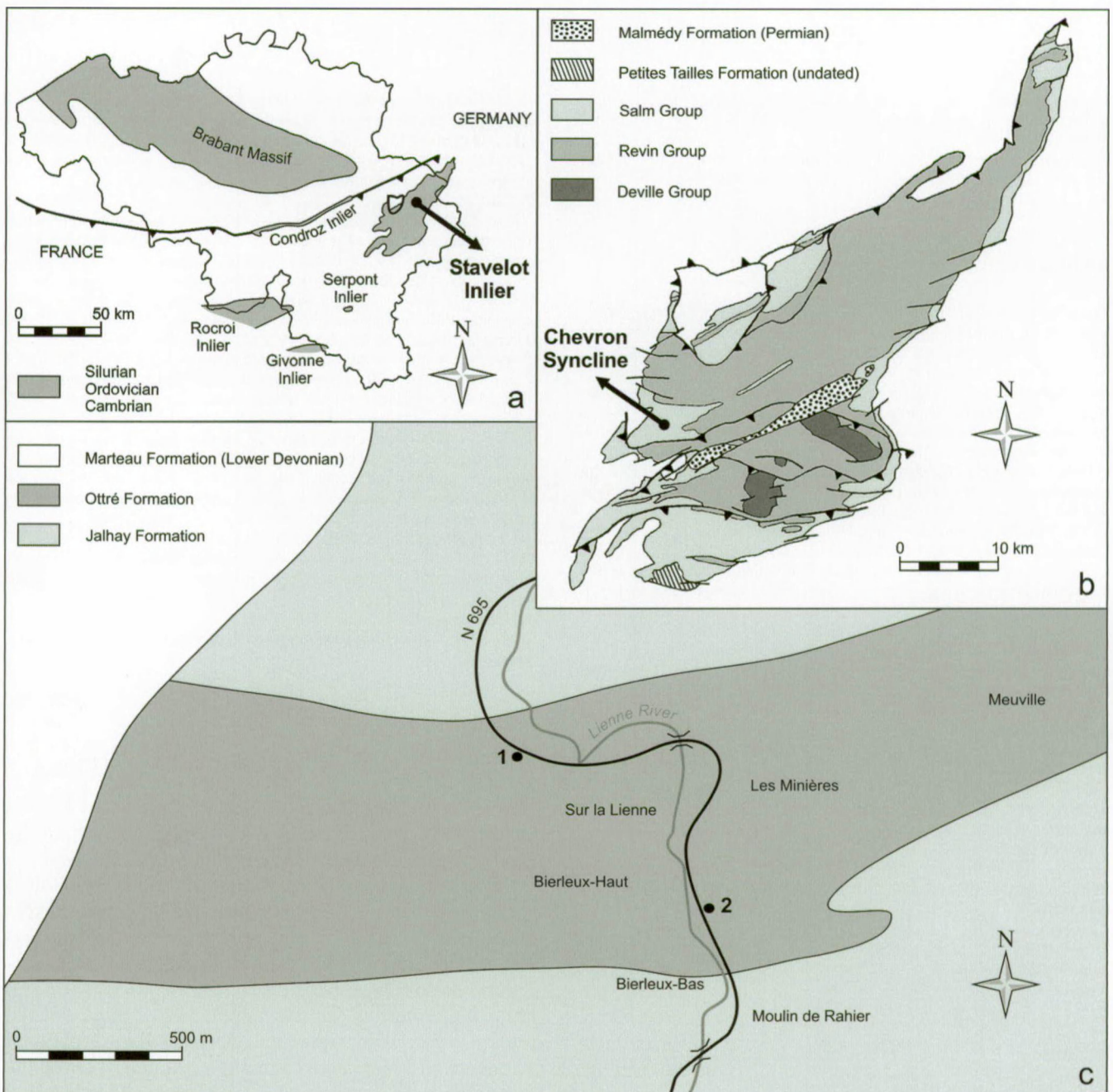


Fig. 1 — a, Stavelot Inlier in the structural scheme of the Belgian Lower Palaeozoic (modified after LALOUX et al., 1996); b, location of the Chevron Syncline and regional geology of the Stavelot Inlier (modified after GEUKENS, 1999); c, location of the two conodont sites in the Otré Formation at the northern and southern flanks of the Chevron Syncline (modified after BREUER, 2002).



special importance for this study is the detailed geological map of the Harzé-La Gleize sheet at a scale of 1/25,000 (ASSELBERGHS & GEUKENS, 1959), which includes the area of the the present topic. This area has been studied for a long time and has been subject of different monographs (DE DYCKER, 1935; FOURMARIER & CALEMBERT, 1941; BERGER, 1965). An entirely cored borehole, the Chevron borehole (GRAULICH, 1966), allowed to recognize its detailed stratigraphy. The Chevron area is characterized by a low grade metamorphism produced at temperatures of about 300 °C and at pressures between 1 and 2 kbar (THEYE, et al., 1996).

The lithostratigraphy of the Stavelot Inlier has recently been reviewed by GEUKENS (1999), formally established by VERNIERS et al. (2002) and comprised three groups, from base to top, the Deville, the Revin and the Salm Groups. Their age, mainly based on acritarch and chitinozoan evidence (VANGUESTAINE, 1992; VERNIERS et al., 2002) is Early Cambrian to lowermost Middle Cambrian for the Deville Group, Middle and Late Cambrian for the Revin Group and Ordovician (Tremadocian to probably Darriwillian) for the Salm Group.

The Salm Group is composed of three formations (the Jalhay, Otré and Bihain Formations) subdivided into members (Fig. 2). The conodont fauna was found in two outcrops within the Lienne Valley, at an horizon corresponding to the transition between the Meuville and Les Plattes Members of the Otré Formation. In this area, the Otré Formation is essentially composed of fine-grained, purplish slate and silty slates. The Meuville Member is 66.3 m thick and consists of silty slates ('quartzophyllades' in the old literature). The Les Plattes Member is shaly and reaches a thickness of at least 130 meters (GRAULICH, 1966). These members were previously called Sm2a and Sm2b (ASSELBERGHS & GEUKENS, 1959; GEUKENS, 1966; GRAULICH, 1966; LAMENS et al., 1986).

The transition between the Meuville and Les Plattes Members is characterized by an about 3.5 meters thick succession (LAMENS, 1985) consisting of an alternation of 1-20 cm thick coarse grained siliciclastic beds with red silstones and shales (LAMENS et al., 1986). The coarser beds are composed of quartz grains, rhodochrosite, hematite, phosphate and rocks fragments in a hematite-rich matrix (BERGER, 1965). Bioclasts (echinoderms, ?oncooids, ?shell fragments) and volcanic rock debris are observed (LAMENS et al., 1986). The rocks can be classified as true greywackes in the sense of BATES & JACKSON (1987).

There is only limited information about the depositional environment of the Otré Formation. According to LAMENS (1986), a relatively deep marine environment is required for the deposition of siliciclastic material and some bioclasts in the Chevron area by turbiditic currents. To the contrary, a lagoonal or tidal flat facies has been suggested for the same unit in the Konzen area, Germany, by VON HOEGEN et al. (1986). During our study, abundant and well preserved trace fossils have been observed in shaly layers interbedded within the coarse grained silici-

clastic beds and a few meters below. According to J.J. ALVARO (pers. comm., 2002) the genera *Arenicolites*, *Treptichnus*, *Torrowangea?* and *Planolites* are present. Further sampling and a more detailed study of this ichnofossil fauna could better specify the depositional history of the investigated strata.

#### Fossil locations, material and methods

Conodonts have been found in two sites (Institut Géographique National's 1:25,000 topographical map: Harzé-La Gleize 49/7-8), marked with numbers 1 (Lamb. Co-ord. X248,275, Y121,475) and 2 (Lamb. Co-ord. X248,845, Y121,000) on Figure 1c. These localities are situated at the northern and southern flanks of the Chevron Syncline. The two sites are situated in small abandoned quarries where manganese ore was mined. The conodonts have been obtained from greywacke beds. These horizons are a few decimeters below the ore layer. The geological context clearly indicates that both sites are in an equivalent lithostratigraphic position. Conodont specimens have been found on the bedding surfaces of the coarse-grained siliciclastic rocks. In association with the conodonts, numerous fragments of phosphatic brachiopod shells and one larger hollow spine, possibly of a trilobite, have been found.

All attempts to dissolve the rock (HOWIE, 1974) without destroying the conodonts were negative. Therefore, the collection consists only of specimens preserved on the bedding planes or on the surfaces of the small splitted rock samples. Thin sections of greywackes made perpendicular to the bedding plane clearly revealed that the conodont specimens were only present in the coarsest

	FORMATION	MEMBER
SALM GROUP	Bihain	Salm-Château
		Ruisseau d'Oneu
	Otré	Colanhan
		Les Plattes
		Meuville
	Jalhay	Lierneux
		Spa
		Solwaster

Fig. 2 — Lithostratigraphic chart of the Salm Group (VERNIERS et al., 2002).



parts of the sequence. The outlines in thin-section perpendicular to the growth axis are symmetrical and sub-symmetrical (e.g. Pl. 1, figs. 11-12, 14, 15) or asymmetrical (Pl. 1, figs. 13, 16). In both cases, the prolongation or the presence of the basal cavity is well defined. The concentric lamellar ultrastructure of the euconodonts is also remarkably well preserved. The original phosphatic matter of the mainly robust conodonts is coloured in red presumably because of the high content of hematite in the host rock (13.6-26.43% of Fe in BERGER, 1965). This is well observed as well in the bedding plane specimens (Pl. 1, figs. 1-10), as in the thin section specimens (Pl. 1, figs. 11-16).

### Discussion of conodont fauna and associated fauna

About 190 conodont specimens have been collected mainly from the locality 1 (Fig. 1c) of the Lienne Valley. Because the specimens observed on the bedding planes have been obtained by splitting the rocks, only a few of them (about two dozens) are complete (e.g. Pl. 1, figs. 3-5, 8, 10), others are preserved as external moulds (about three dozens; e.g. Pl. 1, fig. 2) and most elements display intermediate conditions between those types of preservation exhibiting only parts of the specimens (about 130 fragments; e.g. Pl. 1, figs. 1, 6, 7, 9). However, enough details are observable to describe the general morphology of the exclusively coniform elements. There is an important morphological variation in the small assemblage of coniform elements from subrectiform (of *Drepanoistodus*?) over reclined to recurved.

The major problem in description and interpretation of the material from the Salm Group is not the mostly poor preservation, but the fact that we cannot observe (1) the outline of the basal cavity which makes the interpretation of the element orientation difficult; (2) the symmetry in elements nor any complete ornamentations like in isolated specimens from acid residues. A good example may be an element of *Drepanodus arcuatus* PANDER 1856 (Pl. 1, fig. 9) here interpreted as an erect to proclined M element (according to the notation of LÖFGREN & TOLMACHEVA, 2003). It is less curved like the Sc which are similar in lateral outline, but the problem is that usually these M elements have posteriorly wide open bases which cannot be well examined in the studied material. As material has been split of its lateral side, it is unknown if the element had a carina on that lateral side. Another example is the very robust and strongly recurved element determined as "*Acontiodus*" *franconicus*? SANNE-MANN 1955 (Pl. 1, fig. 8). No basal cavity is visible and therefore, the major problem is the orientation of this element. It closely resembles some of the specimens figured by SANNE-MANN 1955 (Pl. 2, figs. 3, 6), but some features like the lateral keels or a drop-like shape in a section perpendicular to the growth axis of the cusp cannot be observed. However, posteriorly, the lateral side seems to be strongly thickened. In a different orientation, the specimen would fit in lateral outline best with the

strongly recurved Sb elements of *Drepanodus arcuatus* PANDER 1856. However, these elements lack only lateral costae and keels which are present in mature to gerontic Sa elements of the same species (LÖFGREN & TOLMACHEVA, 2003), but these elements are far less recurved. In general, most of the coniform elements found seem to be part of some *Drepanodus* apparatus. The bulk of the elements are recurved S elements, typical drepanodontiforms which are attributed to *Drepanodus* apparatuses (e.g., Pl. 1, figs. 1, 2). However, only few extremely recurved specimens resembling "*D. recurvatus*" SANNE-MANN 1955 have been recovered. Most drepanodontiform elements can be placed into *D. arcuatus* PANDER 1856 and related species together with the typical pipaform and sculponeaform elements. Because the bulk of the recovered material is very robust, many of the large drepanodontiforms look similar to the elements of *D. concavus* (BRANSON & MEHL, 1933). The latter species resembles elements of *Drepanodus arcuatus* PANDER 1856 in many aspects, but, like the similar *Drepanoistodus lucidus* STOUGE and BAGNOLI, it includes hyaline elements in its apparatus and there are also some slight morphological differences in certain element types (see SMITH, 1991). Some of the sculponeaform elements (*Drepanodus* cf. *D. arcuatus*, Pl. 1, fig. 4) have a slightly shorter base than '*Drepanodus*' *sculponea* described by LINDSTRÖM (1955) or the sculponeaform Sc elements of *D. arcuatus* as figured by LÖFGREN & TOLMACHEVA (2003).

Interesting is the general appearance of the only geniculate element (Pl. 1, fig. 5). It is short-based, strongly reclined and is in some respect similar to the form species '*Oistodus*' *selene* described by LINDSTRÖM (1955) and slightly similar to the less reclined M element *Tripodus albanii* STOUGE & BAGNOLI 1988 or to the M element with a much longer base in *Periodon primus* STOUGE & BAGNOLI 1988 (the latter two species are lowermost Arenig taxa, but there are no elements present which would fit in one of those apparatuses). This element has nothing in common with the wide open basal cavities in oistodiforms of the fragile *Diaphorodus* or typical oistodiforms in species of *Paltodus*, *Paroistodus*, *Prioniodus*, and other upper Tremadoc/Lower Arenig taxa. It seems very similar to the M element in *Drepanodus reclinatus* (see LÖFGREN & TOLMACHEVA, 2003).

Several subrectiform elements have been recovered which are clearly not part of any *Drepanodus* apparatus and resemble subrectiform of some early *Drepanoistodus*, but characteristic oistodiform elements of this apparatus are missing. There are few elements which are comparable to pipaform Pb and graciliform M elements of early *Drepanoistodus* species, but this material is often fragmented at the base and hard to interpret. There are two possible explanations for the absence of oistodiform M elements typical for most species of *Drepanoistodus*. On one hand it may be the case that such geniculate elements are absent because the collection is too small, on the other hand some of the badly preserved pipaform elements together with some other drepanodontiforms could belong to an early *Drepanoistodus*? apparatus but cannot



be distinguished from those badly preserved ones of *Drepanodus arcuatus* PANDER 1856. For example, *Drepanoistodus lucidus* STOUGE & BAGNOLI 1988 from Newfoundland has such pipaform elements. However, the apparatus of this lowermost Arenig taxon and its subrectiform elements have a wider and more expanded base.

Despite to these short discussions and examples of faunal elements, comprehensive taxonomic and systematic descriptions of the whole assemblage are not the purpose of this first documentation and will be treated in a separate paper.

Associated with the conodont fauna are fragments of lingulid brachiopods (Pl. 1, fig. 17), possibly *Lingulella* cf. *insons* in LOHEST (1935), of other ornamented phosphatic brachiopod shells (Pl. 1, figs. 19, 20), and one long hollow spine most probably of a trilobite (Pl. 1, fig. 18). The echinoderm fragments and the oncoïds reported by LAMENS et al. (1986) are not observed in the present study. The investigated and illustrated material (rock samples with conodont elements as well as thin sections) is deposited in the collections of the department of Paléobotanique, Paléopalynologie and Micropaléontologie, Université de Liège.

### Biostratigraphy

The fauna is clearly dominated by drepanodiform elements. Hence, the diversity is very low, similar to the situation in other cold water areas of the Mediterranean Province (BERGSTRÖM, 1990) of Gondwana and peri-Gondwana like the Frankenwald region, the Barrandian area and the Montagne Noire. Some elements are clearly considered to have been part of the apparatus of the widespread taxon *Drepanodus arcuatus* PANDER 1856. The bases of the typical Pb (pipaform) elements often have been damaged and only a few such elements are recognized. *D. arcuatus* PANDER 1856 ranges from the latest Tremadocian up into the early Darriwilian (= latest Arenig). However, there are also elements in the fauna from the Salm Group, like some strongly recurved '*D.*' *recurvatus* SANNEMANN 1955, which are comparable to the late Tremadocian '*franconicus*' fauna, characteristic for the Frankenwald area. This is a useful indirect correlation because the '*franconicus*' fauna has been discovered together with taxa of the '*Paroistodus* fauna' in latest Tremadocian strata of the Armorican Massif (LINDSTRÖM, 1976). The '*Paroistodus* fauna' and species typical of the Laurentian '*quadruplicatus* fauna' are known e.g. from the Australian Canning Basin (see LINDSTRÖM, 1976). However, *Colaptoconus quadruplicatus* and other taxa typical for the latter assemblage are characteristic of the Northamerican Fauna D of the 'Low Diversity Interval' which correlates to the even older late Tremadocian *Paltodus deltifer* Zone. Therefore, comparisons to the tropics are not very helpful, and a tentative placement of the Salm assemblage into the latest Tremadocian through earliest Arenig *Paroistodus proteus* Zone seems most reasonable (Fig. 3). However, even when the

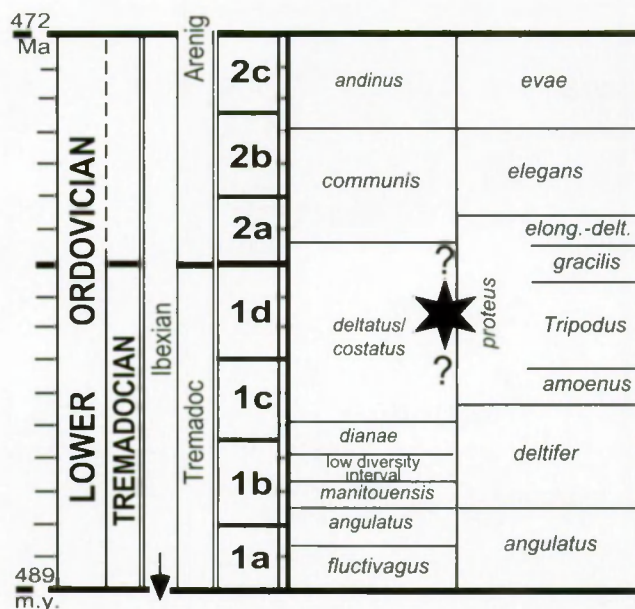


Fig. 3 — Stratigraphic position of the Lower Ordovician conodont fauna from the Salm Group (star) plotted on a chart modified from WEBBY et al. (2004: fig. 2.2).

chronostratigraphic position of the clastic beds in the Otrré Formation comprise the Tremadoc/Arenig boundary, there are no elements found typical for lower Arenig assemblages, e.g. characteristic geniculate elements like the distinctive oistodiform M elements of species of *Paltodus*, *Paroistodus* or *Drepanoistodus*. One must admit, however, that the bases of such elements would probably have fewer chances to be well preserved in such siliciclastic rocks and it cannot be excluded that they represented rare elements within the low diverse assemblage which had no chance to be preserved during deposition.

Finally, our first biostratigraphical comparisons suggest an Early Ordovician, and tentatively a latest Tremadocian age for the assemblage from the Otrré Formation, even when a lowermost Arenig age cannot be excluded (Fig. 3). This preliminary dating does not contradict the generally assumed correlation between the Otrré Formation and the British Arenig (VERNIERS et al., 2002) and the latest Tremadocian age of the uppermost part of the underlying Jalhay Formation dated by acritarchs (VANGUESTAINE & SERVAIS, 2002; BREUER & VANGUESTAINE, 2004).

### Palaeobiogeography

It has been known for some time that Ordovician conodonts do not only represent some biostratigraphically important index taxa but also some very good tools for the solution of palaeogeographic questions because of their pronounced provincialism (e.g. BERGSTRÖM, 1990). Un-



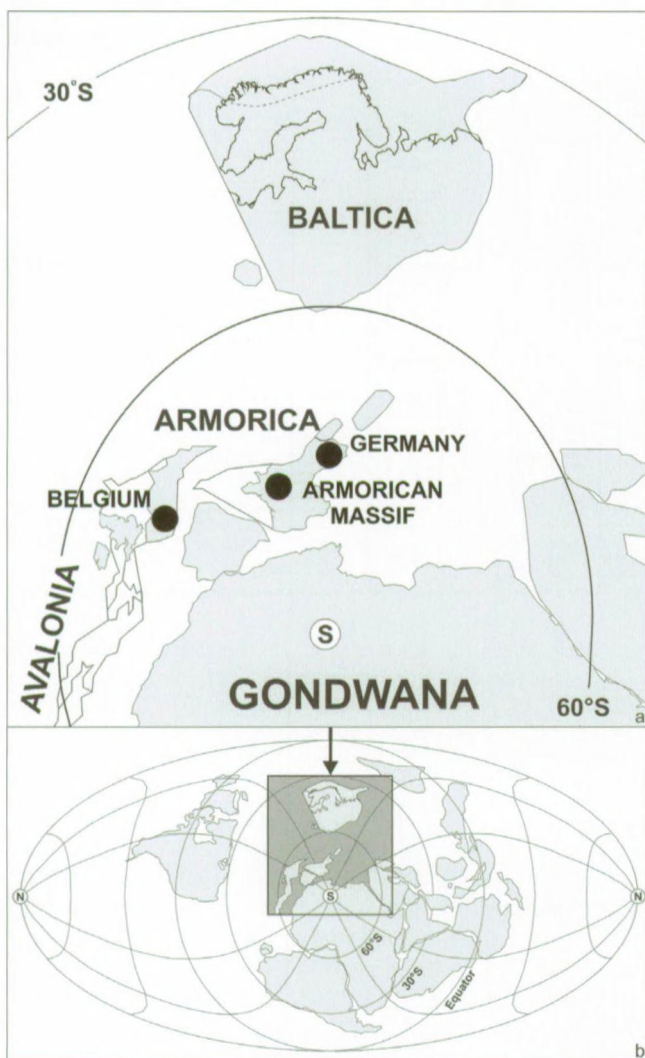


Fig. 4 — a, Lower Ordovician Palaeogeographic reconstruction (modified after SERVAIS & FATKA, 1997); occurrence of the 'franconicus' fauna in the cold water areas of Avalonia and Armorica in the northern peri-Gondwanan region; b, Palaeogeographical map for the Early Ordovician (Arenig) (modified after SERVAIS et al., 1996).

fortunately there is only very limited information about Ordovician conodont faunas and their affinities from the clastic successions of the peri-Gondwana and Gondwana cold water areas. In the well studied areas of carbonate platforms in the Ordovician tropics and subtropics (e.g. Laurentia, Baltica, China, Australia), the faunal affinities are better understood (ZHEN et al. in WEBBY et al., 2000). The associations of Early and Late Ordovician faunas of peri-Gondwana are relatively unknown, except in a few stratigraphic intervals with carbonate sedimentation during a somewhat warmer climatic period like just before the Hirnantian glaciation. This is the reason why this assemblage from the Salm Group is of special importance. Even when such poorly preserved faunas of low diversity without characteristic elements are taxonomically hard to interpret in the sense of multielement taxonomy, we may compare this type of very low diverse

association with time-equivalent faunas from other cold water regions in the Lower Ordovician. In general, the type of material may mainly be compared with cold water taxa from the Baltic Province of the Atlantic Faunal region (BERGSTRÖM, 1990). However, highly diversified faunas flourish during the Tremadocian and Arenig on the Baltic platforms. LINDSTRÖM (1976) suggested a separated Mediterranean Province for the assemblages in the Frankenwald area and the Armorican Massif and BERGSTRÖM (1990) supported the recognition of this distinctive province. Other Gondwana/peri-Gondwana faunas may also belong to this province like the conodonts from Turkey, Montagne Noire, Barrandian area (see KÜPPERS & POHLER, 1992). We suggest that the Early Ordovician fauna from the Otré Formation is well comparable to other coeval and low diverse conodont faunas with Baltic influence from the cooler water environments in the siliciclastic sequences of northern peri-Gondwana (e.g. Frankenwald area, Armorican Massif, Barrandian area).

### Conclusions

- (1) This discovery represents the first record of conodonts from the Salm Group and contributes to improve the limited biostratigraphic information for this siliciclastic succession of the Otré Formation.
- (2) The fauna is tentatively placed in the uppermost Tremadocian because of a) the presence of element types comparable to those of the typical 'franconicus' fauna, b) the presence of subrectiform elements of some early *Drepanoistodus* species without the typical geniculate oistodiform M elements, and c) the lack of any coniforms of 'Arenig' aspect. The age cannot be older than latest Tremadocian because of the acritarch assemblage of latest Tremadocian age described from the uppermost part (the Lierneux Member) of the underlying Jalhay Formation (VANGUESTAINE & SERVAIS, 2002). However, a basal Arenig age cannot be excluded. As noted before, the absence of some typical Arenigian elements could be linked to preservational conditions in the coarse grained host sediment.
- (3) The Early Ordovician faunal association is comparable to other coeval low diverse conodont faunas from the cooler water environments in the siliciclastic peri-Gondwana sequences (e.g. Frankenwald area, Armorican Massif, Barrandian area).

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## References

- ASSELBERGHS, E. & GEUKENS, F., 1959. Carte géologique au 1/25.000, Harzé-La Gleize, 159 et texte explicatif. *Service géologique de Belgique*.
- BATES, R. L. & JACKSON, J. A. (ed.), 1987. Glossary of Geology. Third Edition. *American Geological Institute*, 1-788.
- BERGER, P., 1965. Les dépôts sédimentaires de manganèse de la Lienne inférieure. *Annales de la Société géologique de Belgique*, **88**: 245-268.
- BERGSTRÖM, S. M., 1990. Relations between conodont provincialism and the changing palaeogeography during the Early Paleozoic. In: MCKERROW, W. S. & SCOTSE, C. R. (eds.): *Palaeozoic Palaeogeography and Biogeography. Memoir of the Geological Society, London*, **12**: 105-121.
- BRANSON, E. B. & MEHL, M. G., 1933. Conodont Studies. *Missouri University Studies*, **8**: 1-349.
- BREUER, P., 2002. L'assemblage d'acritarches *messaoudensis-trifidum* et la faune *franconicus* à conodontes dans les formations de Jalhay et d'Ottré, Ordovicien Inférieur du Synclinal de Chevron (Massif de Stavelot, Belgique): biostratigraphie, paléobiogéographie et paléogéographie. MSc thesis, 1-49, 21 pls. University of Liège.
- BREUER, P. & VANGUESTAINE, M., 2004. The latest Tremadocian *messaoudensis-trifidum* acritarch assemblage from the upper part of the Lierneux Member (Salm Group, Stavelot Inlier, Belgium). *Review of Palaeobotany and Palynology*, **130**: 41-58.
- DE DYCKER, R., 1935. La stratigraphie du Salmien supérieur dans la vallée de la Lienne. *Annales de la Société géologique de Belgique*, **58**: 255-262.
- FOURMARIER, P. & CALEMBERT, L., 1941. La stratigraphie du Salmien supérieur de la Lienne. *Bulletin de l'Académie royale de Belgique*, **27**: 505-512.
- GEUKENS, F., 1966. Problème stratigraphique relatif aux planchettes Odeigne-Bihain. *Bulletin de la Société belge de Géologie, Paléontologie et Hydrogéologie*, **74**: 214-219.
- GEUKENS, F., 1986. Commentaire à la carte géologique du Massif de Stavelot. *Aardkundige Mededelingen*, **3**: 15-30.
- GEUKENS, F., 1999. Notes accompagnant une révision de la carte structurale du Massif de Stavelot. *Aardkundige Mededelingen*, **9**: 1-6.
- GRAULICH, J.-M., 1966. Le sondage du Bois des Hovas-Chevron. *Service géologique de Belgique, Professional Paper*, **7**: 1-5.
- HOWIE, F. P. M., 1974. Introduction of thioglycollic acid in preparation of vertebrate fossils. *Curator*, **1**: 159-166.
- KÜPPERS, A. N. & POHLER, S. M. L. 1992. Discovery of the first Early Ordovician conodonts from the Montagne Noire, southern France. In: WEBBY, B. D. & LAURIE, J. R. (eds.): *Global Perspectives on Ordovician Geology*: 487-494; Rotterdam (A.A.Balkema).
- LALOUX, M., DEJONGHE, L., GEUKENS, F., GHYSEL, P. & HANCE, L. (1996). Limbourg-Eupen 43/5-6. Notice explicative. *Carte géologique de Wallonie: 1/25.000, 1-192*.
- LAMENS, J., 1985. Het Salmiaan (Onder-Ordovicium) in het Massief van Stavelot. Unpublished PhD thesis, 1-285. Katholieke Universiteit Leuven.
- LAMENS, J., 1986. Depositional history of Salmian (Lower Ordovician) sediments in Belgium. *Aardkundige Mededelingen*, **3**: 125-138.
- LAMENS, J., GEUKENS, F. & VIAENE, W., 1986. Geological setting and genesis of coticles (spessartine metapelites) in the Lower Ordovician of the Stavelot Massif, Belgium. *Journal of the Geological Society, London*, **143**: 253-258.
- LINDSTRÖM, M. 1955. Conodonts from the lowermost Ordovician strata of South-Central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar*, **76**: 517-604.
- LINDSTRÖM, M. 1976. Conodont palaeogeography of the Ordovician. In: BASSETT, M. G. (ed.): *The Ordovician System: Proceedings of the Palaeontological Association, Symposium, Birmingham, September 1974*: 501-522; Cardiff (Univ. Wales Press & Nat. Mus. Wales).
- LÖFGREN, A. & TOLMACHEVA, T. J., 2003. The occurrence of the conodont *Drepanodus arcuatus* Pander, 1856, and related species from the Ordovician of Baltoscandia. *Paläontologische Zeitschrift*, **77**: 203-221.
- LOHEST, A., 1935. Sur la présence de *Lingulella* cf. *insons* dans le Salmien supérieur et nouveaux gîtes à *Dictyonema flabelliforme* dans la vallée de la Lienne. *Annales de la Société géologique de Belgique*, **58**: 151-152.
- PANDER, C. H., 1856. Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements. *Buchdruckerei der kaiserlichen Akademie der Wissenschaften, St. Petersburg*, 91 p.
- SANNEMANN, D., 1955. Ordovizium und Oberdevon der bayerischen fazies des Frankenwaldes nach Conodontenfunden. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **102**: 1-36.
- SARMIENTO, G. & BULTYNCK, P., 2003. Late Ordovician Conodonts from the Fosses Formation, Condroz Area, Belgium. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **73**: 1-5.
- SERVAIS, T., BROCKE, R. & FATKA, O., 1996. Variability in the Ordovician acritarch *Dicrodiaacrodium*. *Palaeontology*, **39**: 389-405.
- SERVAIS, T. & FATKA, O., 1997. Recognition of the Trans-European Suture Zone (TESZ) by the palaeobiogeographical distribution pattern of early to middle Ordovician acritarchs. *Geological Magazine*, **134**: 617-625.
- SMITH, M. P., 1991. Early Ordovician conodonts of East and North Greenland. *Meddelser om Grønland, Geoscience*, **26**: 1-81.
- STOUGE, S. & BAGNOLI, G., 1988. Early Ordovician Conodonts from Cow Head Peninsula, Western Newfoundland. *Palaeontographia Italica*, **75**: 89-179.
- THEYE, T., SCHREYER, W. & FRANSOLETT, A.-M., 1996. Low-temperature, low-pressure metamorphism of Mn-rich rocks in



the Lienne Syncline (Belgian Ardennes), and the role of carpholite. *Journal of Petrology*, **37**: 767-783.

TOURNEUR, F., VANGUESTAINE, M., BUTTLER, C., MAMET, B., MOURAVIEFF, N., POTY, E. & PREAT, A., 1993. A preliminary study of the Ashgill carbonate beds from the lower part of the Fosses Formation (Condroz, Belgium). *Geological Magazine*, **130**: 673-679.

VANGUESTAINE, M., 1992. Biostratigraphie par acritarches du Cambro-Ordovicien de Belgique et des régions limitrophes: synthèse et perspectives d'avenir. *Annales de la Société géologique de Belgique*, **115**: 1-18.

VANGUESTAINE, M. & SERVAIS, T., 2002. Early Ordovician acritarchs of the Lierneux Member (Stavelot Massif, Belgium): stratigraphy and paleobiogeography. *Bulletin de la Société géologique de France*, **173**: 561-568.

VERNIERS, J., HERBOSCH, A., VANGUESTAINE, M., GEUKENS, F., DELCAMBRE, B., PINGOT, J.-L., BELANGER, I., HENNEBERT, M., DEBACKER, T., SINTUBIN, M. & DE VOS, W., 2002. Cambrian-Ordovician-Silurian lithostratigraphic units (Belgium). In: BULTYNCK, P. & DEJONGHE, L. (eds.): Guide to a Revised Stratigraphic Scale of Belgium. *Geologica Belgica*, **4**: 5-38.

VON HOEGEN, J., LEMME, B., ZIELINSKI, J. & WALTER, R., 1985. Cambrian and Lower Ordovician in the Stavelot-Venn Massif: a model for depositional history. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **171**: 217-235.

WEBBY, B. D., COOPER, R. A., BERGSTRÖM, S. M. & PARIS, F., 2004. Stratigraphic Framework and Time Slices. In: WEBBY,

B. D., DROSER, M. L., PARIS, F. & PERCIVAL, I. G. (eds): Ordovician biodynamics: global patterns of rising biodiversity: 41-47. *Columbia University Press*, Columbia, New York.

WEBBY, B. D., PERCIVAL, I. G., EDGEcombe, G. D., COOPER, R. A., VANDENBERG, A. H. M., PICKETT, J. W., POJETA, J., PLAYFORD, G., WINCHESTER-SEETO, T., YOUNG, G. C., ZHEN, Y. Y., NICOLL R. S., ROSS, J. R. P. & SCHALLREUTER, R., 2000. Ordovician palaeobiogeography of Australasia. In: WRIGHT, A. J., YOUNG, G. C., TALENT, J.A. & LAURIE, J. R. (eds.): Palaeobiogeography of Australasian Faunas and Floras. *Memorior of the Association of Australasian Palaeontologists*, **23**: 63-126.

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### Explanation of Plate 1

Specimens illustrated on figures. 1-10 in lateral view display different morphologies and different modes of preservation of the conodont material from the Otré Formation.

- Figs. 1, 2, 6 — strongly recurved S elements of *Drepanodus* sp. 1 – short base preserved, cusp preserved as an imprint, x 20. 2 – complete mold, x 20. 6 – base and lower part of cusp preserved, upper cusp to tip preserved as an imprint, x 20.
- Fig. 3 — *Drepanodus arcuatus* PANDER 1856, recurved Sa element with a pronounced lateral carina, x 20.
- Fig. 4 — *Drepanodus* cf. *D. arcuatus*, completely preserved sculponeaform Sc element, lateral view, posterior part of base flattened by compaction, x 20.
- Fig. 5 — small geniculate (M?) element, x 40.
- Fig. 7 — reclined to recurved drepanodiform S element, damaged base reflects extension of the basal cavity, x 20.
- Fig. 8 — “*Acontiodus*” *francoicus*? SANNEMANN 1955, strongly recurved element, x 20.
- Fig. 9 — *Drepanodus arcuatus* PANDER 1856, erect to proclined M (?) element, x 20.
- Fig. 10 — *Drepanodus arcuatus* PANDER 1856, large Sa element with damaged base (basal cavity collapsed due to compaction) and a pronounced postero-lateral costa, postero-lateral view, x 20.

Figs. 11-16 are photos of the iron-stained conodont specimens in thin-sections.

- Fig. 11 — section through the uppermost part of the base of a subsymmetrical, laterally compressed coniform element close to the basal tip or through the lower cusp, displaying growth lines parallel and borings (?) mainly perpendicular to the surface of the element, x 134.
- Fig. 12 — section through the cusp of a rounded symmetrical element with sharp anterior and posterior costate edges, faint growth lamellae in the outer part, a concentration of borings (?) in the central part of the cusp and at one of the lateral surfaces, x 152.
- Fig. 13 — section through the base of a slightly asymmetrical, laterally compressed coniform element (black sediment filling the basal cavity), growth lines and boring (?) structures, x 157.
- Fig. 14 — section through the crushed lower base of a laterally compressed coniform element displaying the collapse of the basal cavity and the destruction of the base due to compaction of the coarse-grained clastic sediment, x 137.



- Fig. 15 — section through the cusp of a subsymmetrical (?), laterally compressed coniform element split off on one side by quartz grains (lower left), x 105.
- Fig. 16 — section through a well preserved cusp of an asymmetrical, anteriorly rounded coniform element with a sharp posterior costa, view perpendicular to the growth axis; upper part of the fig. shows well rounded convex outer side of element; growth lamellation well visible; boring structures mainly in the layers of the organic lamellae, x 225.

The fragmented material shown on Figs. 17-20 illustrates the associated fauna.

- Fig. 17 — fragment of a lingulid brachiopod, x 12,5.
- Fig. 18 — long hollow spine most probably of a trilobite, x 15.
- Figs. 19, 20 — fragments of phosphatic brachiopod shells with pitted ornamentation, both x 20.



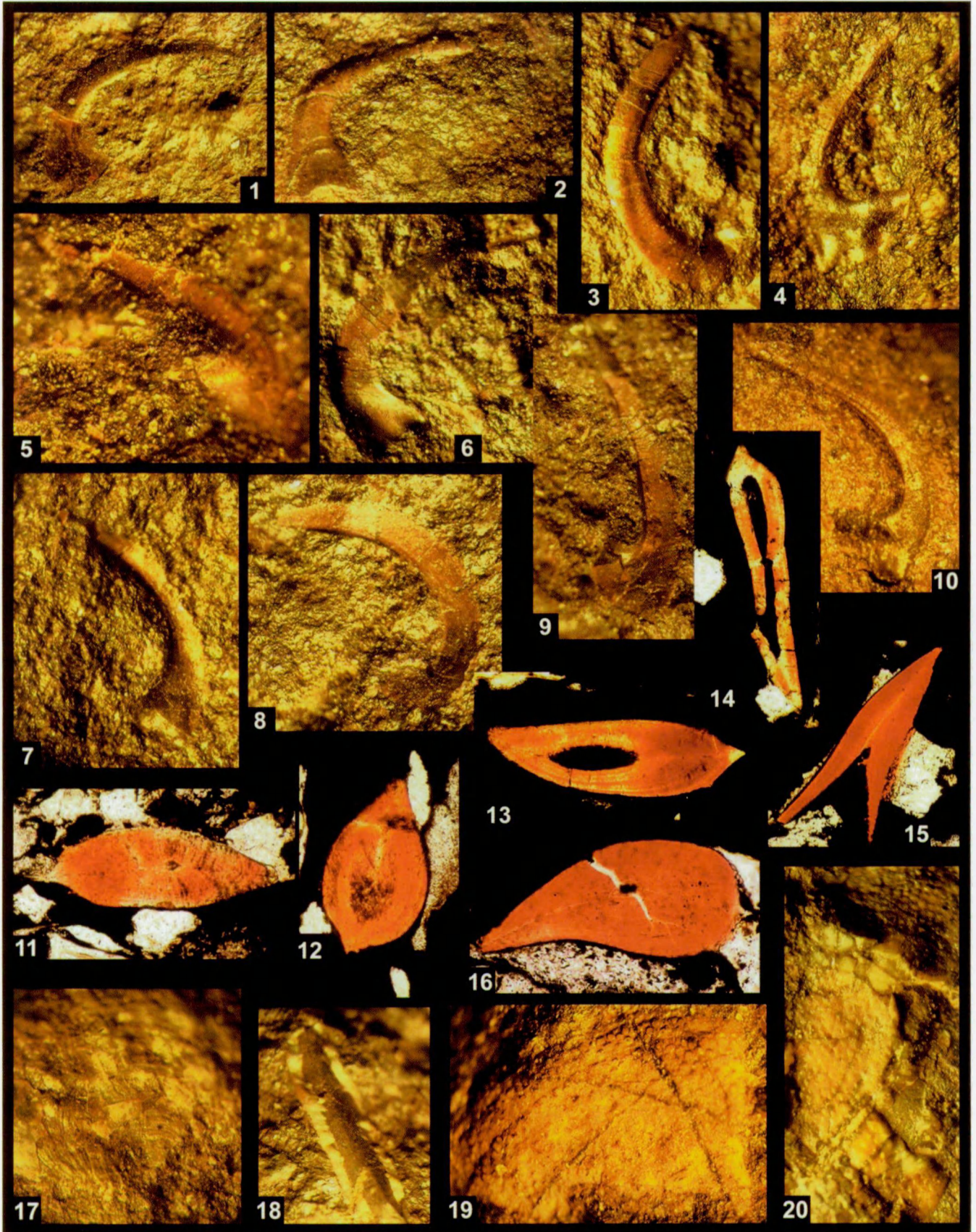


PLATE 1