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AN *EOCANITES* FAUNA FROM THE EARLY CARBONIFEROUS OF CHILE AND ITS PALAEOGEOGRAPHIC IMPLICATIONS

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(4 figures and 1 plate)

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ABSTRACT. A goniatite fauna is described from the Zorritas Formation of the Sierra de Almeida, Antofagasta, Chile which includes the genera *Eocanites* and several species of prionoceratids including *Gattendorfia*. A new species, *Eocanites sernageominus* is described. Faunas are assigned to the earliest Carboniferous (lower Tournaisian). The locality is west of the axial ridge of the Andes. Comments are made on the distribution of *Eocanites* internationally. The bearing records do not support the claimed Devonian-Carboniferous unconformity for this area and they indicate that no ice cap was present.

KEY-WORDS: *Eocanites*, *Gattendorfia*, Carboniferous, Tournaisian, Chile, Zorritas Formation.

RESUMÉ. Une faune de goniatites est décrite dans la formation de Zorritas, Sierra de Almeida, Antofagasta, Chili. Elle comprend le genre *Eocanites* et quelques espèces des prionoceratides y compris *Gattendorfia*. Une espèce nouvelle, *Eocanites sernageominus* est décrite. Les goniatites sont attribuées au Carbonifère Inférieur (Tournaisian inférieur). La localité est située à l'ouest de la chaîne axiale des Andes. Le problème de la distribution internationale d'*Eocanites* est discuté. La discordance Devonien-Carbonifère en Amérique du Sud, et les propositions concernant l'existence d'une calotte glaciaire à cette période dans la region, sont revus.

MOTS-CLES: *Eocanites*, *Gattendorfia*, Carbonifère, Tournaisien, Chili, Formation de Zorritas.

1. INTRODUCTION

The fauna of twenty-seven goniatite specimens which is here described was kindly sent for determination by Prof. A. J. Boucot of Oregon State University. It had been collected by Profs H. Niemeyer and C. Breitkreuz from the Sierra de Almeida, about 70 km south of the SW end of the Atacama Desert, about 69°35' West, 24°30' South. The fauna is consistent with a late *Gattendorfia* Stufe, earliest Carboniferous age, for a level in the Zorritas Formation. The useful stratigraphical tie which the fauna provides has already been included in more general studies by Breitkreuz (1986) and Bahlburg *et al.* (1987) who have provided a review of evidence for the development of the Palaeozoic basin indicated in northern Chile between latitudes 21°-27° south of the equator and in NW Argentina. This account is intended to give a more specific account of the goniatite fauna and to illustrate critical elements which it contains but comments are also made on the bearing of the fauna on the claimed Devonian-Carboniferous unconformity in southern South America (López-Gamundi & Rossello, 1993) and of the possibility for a polar ice-cap in South America at this time (Caputo, 1985).

2. LOCALITY AND MATERIAL

The locality of the faunas described here is about 215 km east of Antofagasta, Chile, to the south of the Salar de Atacama and east of the Salar de Punta Negra, along an outcrop from 15 km NW to 16 km SW of Co. Guanaqueros, which is in the southern part of the Sierra de Almeida, 21 km SSW of Monturaqui, in eastern Chile some six or so km from the border with Argentinia (Fig. 1 A, B). The location numbers on the specimens refer to three localities of Profs Niemeyer and Breitkreuz, C, D and E, with the area prefix Z. All these sections at locality B of Isaacson *et al.* (1985) and are in the Quebrada Zorras (Fig. 1B). A composite section has been published by Bahlburg *et al.* (1987, fig. 3) which shows the level

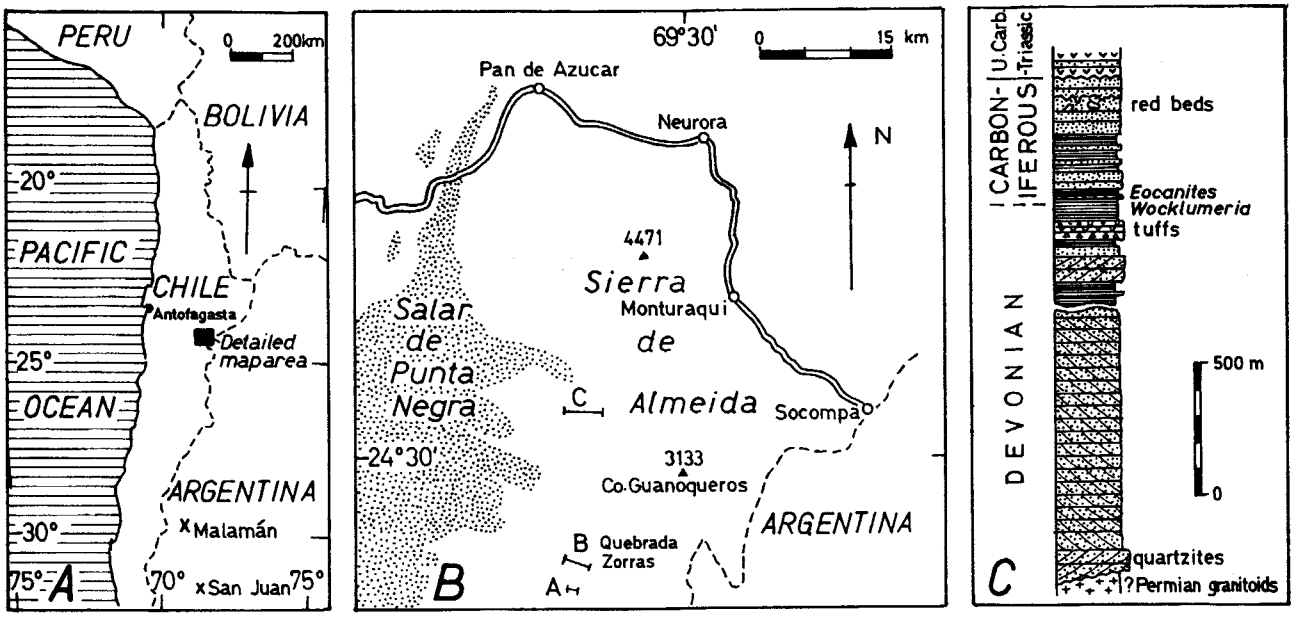

Figure 1. Diagrams showing the location from which the *Eocanites* fauna has been collected. A, Indicating position of locality in northern Chile and showing the location of B. B, a detailed locality map based on diagrams in Isaacson *et al.* (1985). The fauna comes from section C at Quebrada Zorras. C, a stratigraphical column for the locality based on a diagram in Bahlburg *et al.* (1987) showing the level of the *Eocanites* fauna.

of the *Eocanites* fauna (Fig. 1C). The column given refers to an identification of *Wocklumeria*, but that genus is not present in the collections available for study and according to Kullmann (1993) the record was a field determination. The column shows the Devonian - Carboniferous boundary to lie within pelites about 60 m above a group of tuffs and epiclastics with clastics entering about 30 m higher. All the material is consistent with collection as nodules within shales, perhaps silty shales. Usually body chambers are preserved solid but the earlier phragmocones are crushed or were not collected.

The complete collection has been presented to the National Museum of Natural History, Washington, D.C. to which the USNM collection numbers refer.

3. SYSTEMATIC DESCRIPTIONS

Superfamily Prolecanitaceae, Hyatt, 1884
Family Prolecanitidae Hyatt, 1884
Subfamily Eocanitinae Weyer, 1972
Genus *Eocanites* Librovitch, 1957

Type species by original designation of Librovitch 1957, *Protocanites supradevonicus* Schindewolf (1926).

Eocanites sernageominus House, sp. nov.
Pl. 1, Figs 8-12, Text-fig. 2C

DERIVATION OF NAME. After the acronym for the Servicio Nacional de Geologia y Mineria, Casilla, Chile, whose staff have contributed so much to regional geology of the area.

MATERIAL. The holotype and only known specimen is preserved within a nodule is available (USNM 486283; labelled Z-C-12) which shows only a portion of the body chamber and the last two septa preserved solid (Pl. 1, Figs 10-12). An external mould of the earlier phragmocone is preserved within the nodule, enabling a three-dimensional cast to be prepared (Pl. 1, figs 8,9) which includes the very posterior part of the body chamber.

DIAGNOSIS. A species of *Eocanites* with simple convexly rursiradiate growth lines, without biconvexity, with a slightly swollen ventral lobe.

DESCRIPTION. At maximum diameter measurable of 28.3 mm, at the penultimate septum, whorl width is 8 mm, whorl height is 7.6 mm, and the umbilical width is 13.7 mm; on the latex mould at 21.4 mm diameter, whorl width is 7.1 mm, whorl height is 6.7 mm and umbilical width is 9.7 mm. Shell evolute, with body chamber perhaps less than half a whorl. Whorl section rounded (Text-fig. 2C) with shallow impressed depth. Growth lines convexly rursiradiate across the flanks with a broad shallow sinus over the venter towards the end of the phragmocone, but with a slight forward projection on the umbilical slopes in earlier stages. Suture (Text-Fig. 2C) with lanceolate, slightly swollen, ventral lobe, inferred rounded first lateral saddle, first lateral lobe lanceolate with pinched termination and perhaps slightly swollen, second lateral lobe on the inner flank rounded, V-shaped, with a broad, slightly asymmetric (steeper ventrad) saddle to the third lateral lobe with the seam on the dorsad slope; a deep V-shaped umbilical lobe and a deep and narrowly swollen lanceolate mid dosal lobe with a narrow digitiform saddle in between.

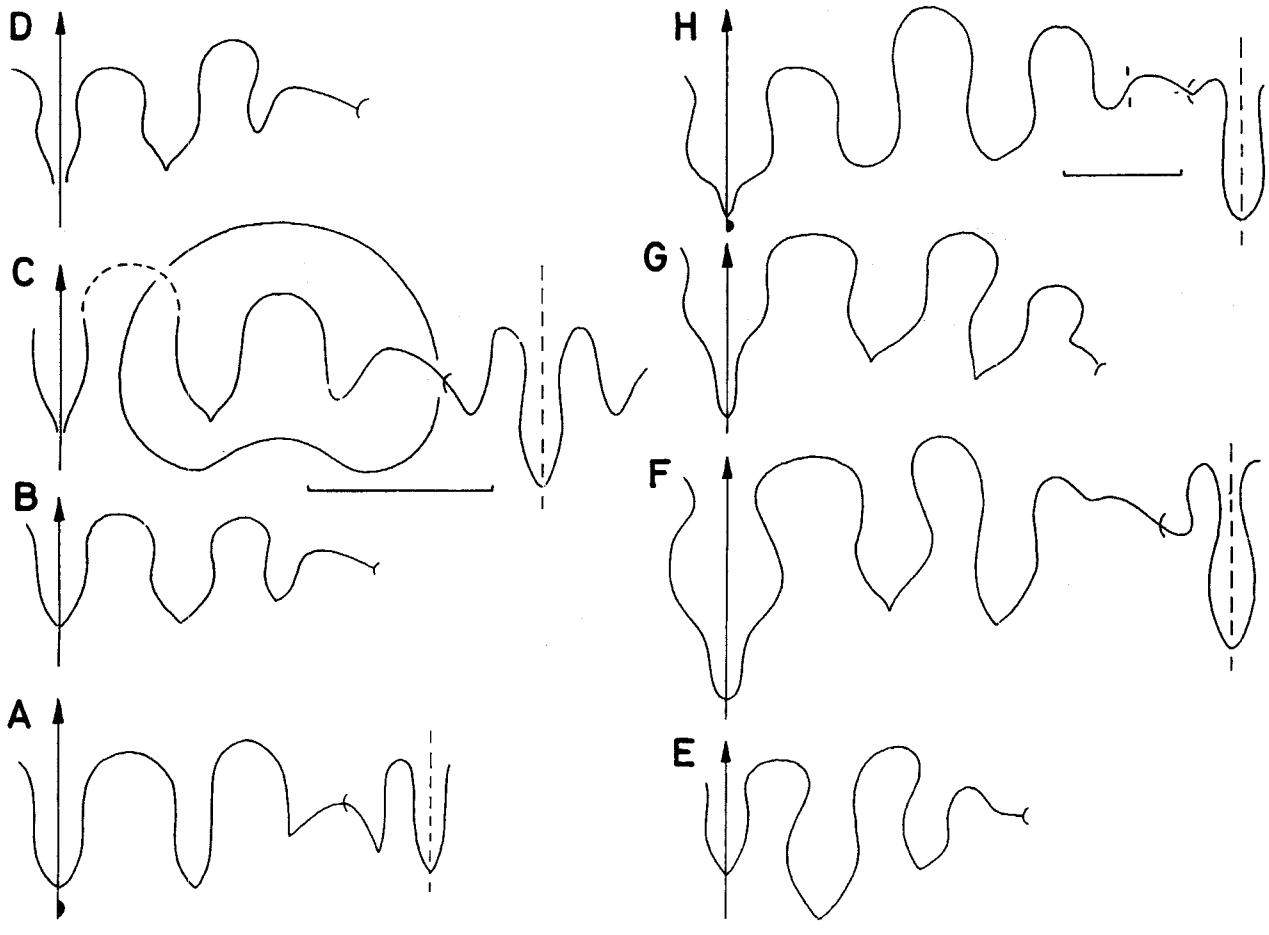

Figure 2. Sutures of Prolecanitidae.
A. *«Protocanites» gurleyi* (Smith). Suture of the holotype based on Miller & Collinson (1951, Text-fig. 12). Specimen from the Northview Shale, Chouteau Formation, at Cedar Gap, Missouri, U.S.A. X 4.8.
B. *Eocanites supradevonicus supradevonicus* (Schindewolf). Revised suture by Korn (1994, p.81) of a specimen figured by Vöhringer (1960) at a whorl height of 6.5 mm. Specimen from the Hangenberg Limestone, Bed 2, at Oberrödinghausen, Germany. X 4.1.
C. *Eocanites sernageominus* House sp. nov. Suture of the holotype and whorl cross section at 28 mm diameter. Scale of 5 mm. From the Zorritas Formation near the southern end of the Sierra de Almeida, Chile. USNM 486283, X 5.2.
D. *Eocanites wangyounensis* Ruan & He. Suture of the holotype based on Ruan & He (1974, Pl. 119, Fig. 6; also figured Ruan 1981, Text-fig. 62a). ca. X 3.6.
E, *Michiganites algarbiensis* (Pruvost). Suture of the holotype based on Pruvost (1914, Text-fig. 1) from north of Bordelete, Portugal. Enlarged.
F. *Michiganites marshallensis* (Winchell). Suture from Miller & Garner (1955, p. 156, Text-fig. 16A). Enlarged.
G. *Michiganites scalibrinii* (Antelo)[= *australis* Antelo 1969). Suture of the holotype based on Antelo (1969, Text-fig. 2A] from the base of the Malimán Formation at Malimán Arriba, Argentina. Enlarged.
H. *Michiganites greenei* (Miller). Reversed suture of the holotype, based on American Museum of Natural History, New York No. 2539. Labelled as from the «Knobstone Formation» (New Providence Shale), New Albany, Indiana, U.S.A. Scale of one millimetre, X 16.2.

COMPARISON. There are some twenty-four named species or subspecies of *Eocanites*, but only *Eo. wangyouensis* shows a similarly swollen ventral lobe: according to the revision by Korn (1994) of Vörhinger's specimen named *Eo. supradevonicus supradevonicus* that species has a significantly more swollen ventral lobe: Schindewolf's holotype of that species is, however, unrevised. The orginal spelling of the species by Ruan & He 1974, p. 239 was *wangyouensis*, but this was changed by Ruan (1981, p. 96, *et seq.*) to *wangyuensis*. Transliteration anomalies are normally grounds for a «justified emendation» under the ICZN *Rules*, but it is not clear that this applies in this case, and I am indebted to J. Kullmann and D. Korn for their opinion that it does not, so the original spelling is used here. In the many forms described by Ruan (1981) the ventral lobes are parallel-sided or slightly V-shaped. Another species (or, more probably, subspecies) showing a slight swelling of the ventral lobe is *Eoc. retiolus* Ruan (1981, p. 97), but these all differ from *Eo. sernageominus* in not having the regular convexly rursiradiate ornament of growth lines. Species currently refered to *Eocanites* show very similar general shell growth characters (Fig. 3).

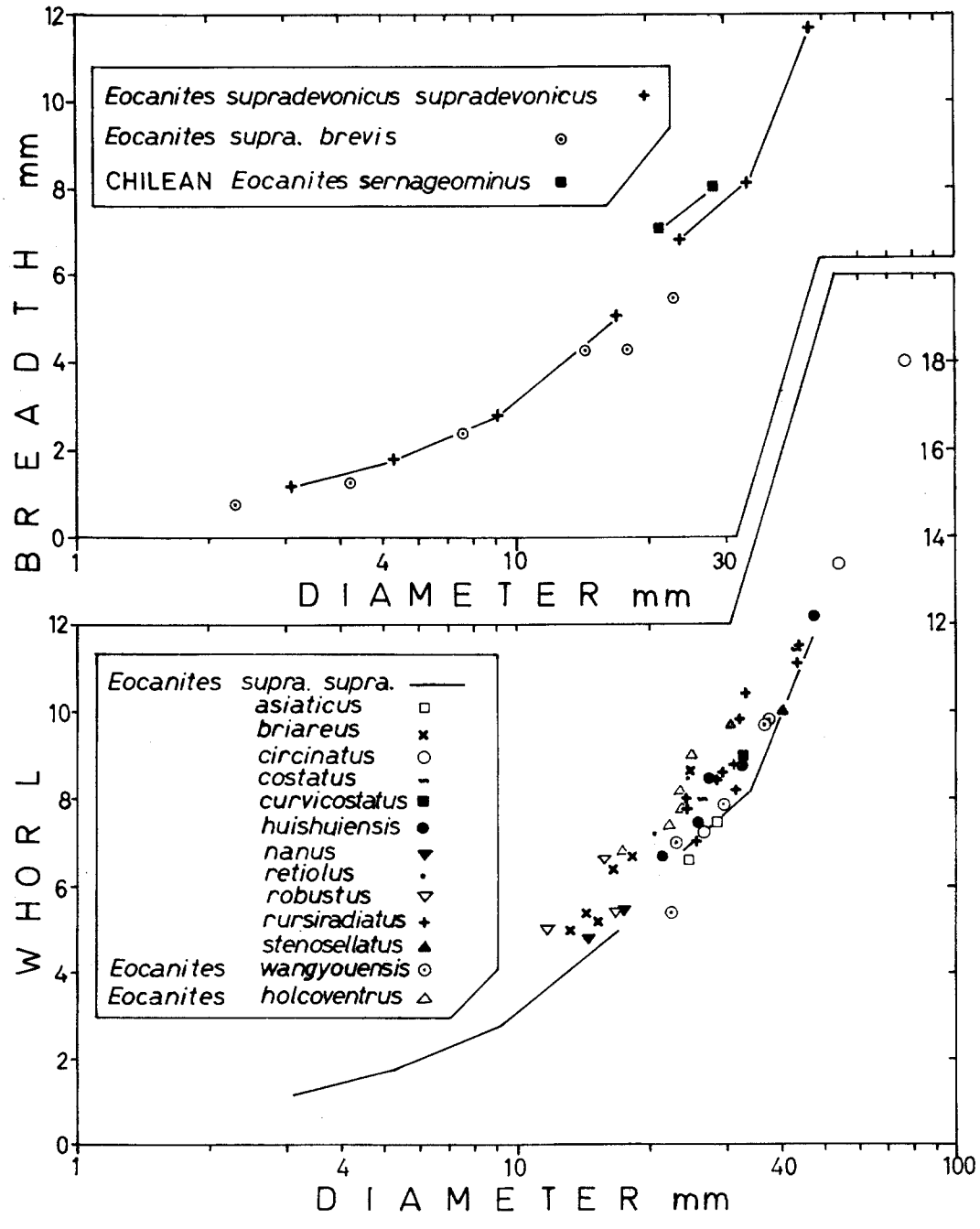

Figure 3. Diagram showing statistical data for *Eocanites*. Data from German material taken from Vöhringer (1960) and showing the relation to the Chilean *Eocanites sernageominus*.

4. COMMENTS ON EVOLUTION

The major papers of Weyer form a starting point for consideration of evolution in the early Prolecanitidae (Weyer 1965, 1972a,b), a group characterized by an evolute shell with early whorls serpenticonic. Weyer suggested that three lines radiated from *Eocanites supradevonicus* type. The first of these established a V-shaped ventral lobe (Protocanitinae) and showed proliferation of umbilical lobes. A second line (Eocanitinae, probably the root stock for all three) kept the ventral lobe rather parallel-sided and also proliferated umbilical lobes. A third line (Prolecanitinae) is characterized by a swollen, and in later members, short ventral lobe, and again by the proliferation of umbilical lobes.

It is the Prolecanitinae which is the direction indicated by *Eoc. sernageominus*. Fig. 2 shows a morphological series of sutures hypothetically linking *Eoc. supradevonicus* with *Michiganites*, in the view of Weyer (1972b), the earliest member of the Prolecanitinae. *Michiganites* is characterised by three lobes on the flanks, whilst *Eocanites* has only two. Use of lateral lobe number in this way has proved useful in the Prolecanitidae as a whole and, if

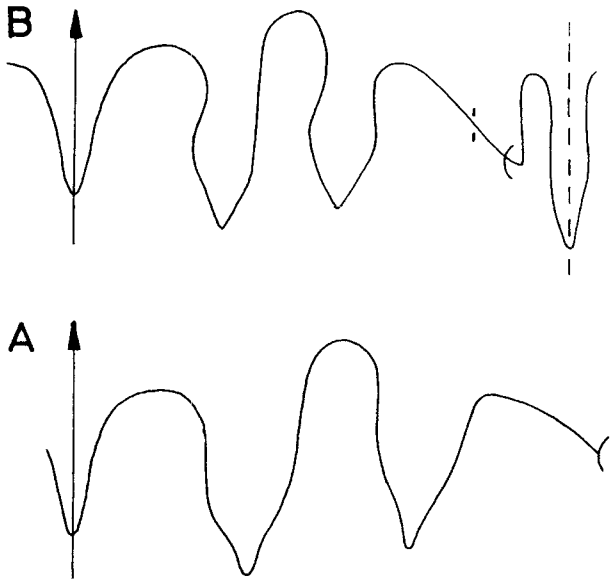

Figure 4. Sutures of *Prolecanites lyoni* (Meek & Worthen).
A. Suture, drawn by the author, of a specimen figured by Hall (1879, Pl. 72, Figs 1,2) in the American Museum of Natural History, New York, from Rockford, Indiana, U.S.A., X 2.
B. Sutural diagram from Gordon (1986, p. 15) of a specimen from the Chainman Shale, Elko Co., Nevada, U.S.A. X 1.5.

followed here, the forms such as *Eoc. sernageominus* and *Eoc. wangyouensis*, start the morphological series towards *Michiganites algarbiensis* (Pruvost, 1914, specific name sometimes spelt *algarviensis*) from Portugal, in which an incipient additional umbilical lobe is seen (Fig. 2E) and the type species of *Michiganites* (Ruzhencev in Bogoslovskiy, *et al.*, 1962, p. 348), *Mich. marshallensis* (Fig. 2F). Forms with the three lateral lobes very well developed include *Michiganites scalabrinii* (Antelo 1970 = *australis* Antelo 1969 *non Prolecanites australis* Delépine 1941) and *Mich. greenei* (Miller 1894), the holotype of which is refigured here (Fig. 2H, Pl. 1, fig. 5), based on drawings and a photograph by the author of the original in the American Museum of Natural History, New York. It is interesting that *Mich. scalabrinii* is recorded from 10.5 km NE of Malamán, San Juan Province, Argentina (Fig. 1A), only 600 km away from the locality for *Eoc. sernageominus*.

The main problem remains, as usual for the Tournaisian, the lack of detailed and stratigraphically known successive faunas of goniatites, especially in the mid Tournaisian. The rich Chinese faunas of Ruan (1981) carry no detailed stratigraphic record. The author has many reservations on the proliferation of specific names in *Eocanites* based on slight sutural differences alone. As indicated by the many illustrations of the sutures of the American *Protocanites lyoni* (Meek & Worthen, 1860) in the literature (for example, Miller, 1956; Miller & Collinson, 1950; Furnish, Miller & Youngquist, 1955; Gordon, 1986) and herein (Fig. 4). Although it might seem that forms with a swollen ventral lobe, such as illustrated by Gordon (1986, Figs 5-2-5), should seem more properly assigned to *Eocanites*, Campbell *et al.* (1983 p. 111; Campbell & Engel, 1963) have indicated that the early stages of Australian *Protocanites* are variable, and often the ventral lobe is swollen. Indeed *Prolecanites* may be derived from *Eocanites* by the simplification of the ventral lobe in the adult. Many «species» of *Eocanites* should be relegated to subspecies, at least until they are involved in a biostratigraphy: some species, on the other hand, are clearly discrete, especially those listed by Weyer (1972b, p. 322) and *Eo. holcoventrus* (Ruan, 1981).

It would seem that *Eo. sernageominus* would be expected to be younger than the majority of typical *Eocanites* known from the *Gattendorfia*-Stufe faunas which were described in the masterly account of the Hangenberg Limestone by Vöhringer (1960). A possible exception is *Eocanites* n. sp. A (Weyer, 1965, p. 458, Pl. 8, Fig. 4a-c, Text-fig. 3) which has a somewhat similar suture but without the swollen ventral lobe, and a different and deeper swollen second lateral lobe on the inner flanks, and quite different ornament.

In a paper reviewing Lower Carboniferous zonation in Argentina (Azcuy *et al.* 1990), following González (1985), a «*Protocanites* fauna» is distinguished as a late Tournaisian Zone, the editor noting (Azcuy *et al.* 1990, p. 208) that the name-giver should be assigned to *Michiganites*.

Superfamily Prionocerataceae, Hyatt, 1884
Family Prionoceratidae, Hyatt, 1884
Subfamily Prionoceratinae, Hyatt, 1884

Twenty-six specimens are available which are prionoceratids. Scarcely any show sutures or phragmocone and they are preserved solid as parts of the body chambers which often show ornament but never evidence of early stages, so detailed determination is not possible. There are three separate collections, Z-D-8j (USNM 486284-286289; numbered 2-12), Z-D-8h (USNM 486290a-g; numbered 13-19) and Z-21 (USNM 486291a-h; numbered 20-27) and comments will be made on each fauna separately.

Z-D-8j

There are ten specimens from this level but only three tentative names are given to members of the fauna:

(a) *Gattendorfia* cf. *molaris* Vöhringer. A single specimen (USNM 486284; No. 7) with only part of the body chamber preserved and showing clearly

the wide, open umbilicus ofthe genus (Pl. 1, Figs. 3,4). At 16 mm diameter the whorl width is 7.1 mm. No sign of the suture is seen. There are probably four constrictions in the last whorl which follow the growth lines being prorsiradiate over the flanks to a rounded salient and a linguiform ventral sinus. The type specimen of the species is from Bed 3c in the Hangenberg Limestone of the Hönnetal, Germany, but it is recorded as ranging up to the top of the exposed *patens* Subzone, the highest level in the *Gattendorfia* Stufe examined by Vöhringer (1960, p.158).

(b) ?*Streeliceras* cf. *heterolobatum* (Vöhringer). Three specimens may be assigned here (USNM 486285-7; Nos. 2,3,8) but none show sutures. The figured specimen (USNM 486285, Pl. 1, Figs 1,2) is the best preserved. This species was made the type species of a new subgenus of *Acutimitoceras*, named *Streeliceras,* by Becker (1995), but the diagnostic feature of the genus, the short ventral lobe, is not shown by any of the specimens. The writer takes the view that *Acutimitoceras* should be restricted only to those oxyconic forms which Librovitch intended to be included within the genus.

(c) ?*Rectimitoceras* sp. A single crushed specimen of part of a body chamber, showing no suture (USNM 486288; No. 5, figured Pl. 1, Figs 6,7) has growth lines and traces of constrictions which conform to Schindewolf's original use of the genus *Imitoceras*, now restricted for younger Carboniferous forms, for which the genus *Rectimitoceras* is applied by Becker (1995).

(d) Other specimens are really not determinable (USNM 486289a-f). One (USNM 486289a; No. 9) has fine convex lirae reminiscent of the specimen figured by Schmidt (1924, Pl. 8, Fig. 1) as «*I. infracarbonicus*». Another specimen has the whorl form of «*I. trochiforme*» (Vöhringer) which Korn (*in* Korn *et al.*, 1994; Korn, 1994, p. 59) refers to the genus *Nicimitoceras* Korn 1993.

Z-D-8h

There are seven specimens (USNM 486290a-g) from this level which are not specifically determinable. These are poorly preserved and none show sutures. Two (USNM 486290a,b;Nos, 14, 15) show the shell form and growth lines of *Nicimit. trochiforme.* Another specimen (USNM 486290c; No. 17) has the shell form of «*Imit. globosum*» Schindewolf (1951, p. 46-48).

Z-21

There are eight specimens in this collection (USNM 486291a-h) all of which are very poorly preserved, without sutures or evidence of early stages but they are consistent with being prionoceratids. One specimen (USNM 48629a; No. 20) shows rather flat flanks converging rapidly to a well-rounded venter.

5. DISCUSSION

5.1. AGE

The faunas as a whole are consistent with a *Gattendorfia* Stufe age, but probably high in the division. Particularly critical forms are the *Eocanites sernageominus* and *Gattendorfia* cf. *molaris.* The former is rather more advanced than any described by Vöhringer (1960) from the Hangenberg Limestone of Germany, which is the best succession known anywhere. *Gatt. molaris* is recorded throughout the upper *subinvoluta* Zone and *crassa* Zone in the records of Vöhringer (1960, p. 177). The other prionoceratids do not suggest anything different.

However, it is the absence of typical later Tournaisian genera, such as *Protocanites, Kazakhstania*, *Prodromites*, *Muensteroceras* and pericyclids which confirms that the fauna should be assigned to the late *Gattendorfia* Stufe. It is of interest that the geographically nearest form, *Michiganites scalabrinii*, from San Juan Province, Argentina (Antelo 1969, 1970), already has the extra umbilical lobe of *Michiganites* and must be presumed to be significantly younger than *Eo. sernageominus.*

In the scheme of Kullmann *et al.* (1990, p. 127) this division is the earliest recognized in the Carboniferous which they refer to «Tournaisian Tn 1b», that is the earliest Tournaisian following the revision of the Devonian-Carboniferous boundary.

Becker (1993a), by contrast, has documented the Lower - Middle Tournaisian boundary goniatite break in some detail. Attention to this break had already been drawn by Matthews (1970, 1971). Becker associates the disappearance of the typical *Gattendorfia* Stufe (cu I) faunas to the transgressive black shale of the Lower Alum Shale, that is, the Lower Alum Shale Event (Becker, 1993a,b).

5.2. DISTRIBUTION OF *GATTENDORFIA* STUFE FAUNAS

This new Chilean record, and the nomenclatorial revisions, extend still farther the known range of *Eocanites*, examples of which are known to be widespread in North America, Europe and Asia. The distribution of the genus has been summarised by Becker (1993a).

5.3. PALAEOGEOGRAPHIC IMPLICATIONS

The area of northern Chile which includes the Sierra de Almeida and adjacent NW Argentina has been recognised in recent years to be the site of a discrete Palaeozoic basin (Breitkreuz, 1986; Bahlburg *et al.*, 1987). Although west of the central cordillera of the Andes it is considered that the region has been part of the South American margin since at least the Late Precambrian. The Zorritas Formation, comprising about 2,700 m of Devonian to early Carboniferous, lies unconformably on early rocks which were folded during the Late Ordovician Oclóyic Orogeny, an orgeny which may have been caused by the collision of either the allochthonous Arequipa Terrane or eastern Laurentia (Bahlburg, 1994). Any collision of a microplate «Chilenia» would lie south of the area of concern here and has been suggested to dock between 29° and 34° south according to López-Gamundi and Rossello (1993).

The Lower Carboniferous of the Sierra de Almeida and the Rio Blanco Basin, of NW San Juan and western La Rioja provinces of adjacent Argentina, have been interpreted as indicative of a transgression from the 'Pacific' into western Argentina, and the fauna has been termed «Malimánian» (González, 1994), and characterized by a «*Protocanites-Rossirhynchus*» Assemblage (formerly *Protocanites* fauna of González 1985); but as remarked above, the goniatite is better refered to *Michiganites* (W. Manger in Azcuy *et al.*, 1990) and the Assemblage renamed. The recognition of an earlier *Gattendorfia* assemblage would seem reasonable.

So far as the late Devonian glaciation of South America is concerned (Caputo 1985), Becker (1993a) has pointed out that the Bolivian records of mid-Famennian sporadoceratids (Babin *et al.*, 1991) indicate warm water and not proximity to an ice cap. Loboziak *et al.* (1992), on spore evidence, moved the date of the suggested glacial deposits in the Parnaíba Basin to equivalents of the Hangenberg Event level at the Devonian-Carboniferous boundary. But if account is taken of the record of *Wocklumeria* (Bahlburg *et al.*, 1987) in north Chile, and the late *Gattendorfia* Stufe age assigned here to the Sierra de Almeida faunas, as well as the probably later occurrence of *Michiganites* in adjacent San Juan Province of Argentina, any ice cap must be significantly distant geographically at those times, or even stratigraphically younger. This supposes that current views on the assignment of the goniatite areas to the South American continent of the time are correct (Bahlburg, 1994).

The suggestion that South America shows a significant Devonian-Carboniferous unconformity (López-Gamundi and Rossello, 1993) may apply to the Ventana fold belt and other areas. But this clearly did not apply to the Sierra de Almeida and the Rio Blanco Basin area discussed here. However, the igneous activity at about this level in western Gondwanaland seems well-documented, and finds analogies in the Marrakesh area of Morocco (Piqué *et al.*, 1993; Leblanc, 1993), and even the Rio Tinto area of Spain (Boulter, 1993), although the relationships of these events are at present quite unknown.

6. ACKNOWLEDGEMENTS

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ADDENDA AND CORRIGENDA

In the paper by the author in *Annales de la Science géologique de Belgique*, T. 115, fasc. 2, p. 574 the explanation of Plate 3 was incomplete. The following should be added:

Figs. 8-11. Gen. nov. *prorsum* (Schmidt). 8-10, MRH 1395, X 6. 11, MRH D 1276, X 6.

The MRH collection referred to will be presented to the University of Oxford palaeontological collections.

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Plate 1

Ammonoids from the Lower Carboniferous of Chile and the U.S.A.

1, 2. ?*Streeliceras* cf. *heterolobatum* (Vöhringer). Lateral and ventral views of a specimen from the Zorritas Formation, Sierra de Almeida, Chile. USNM 486285, X 3.

3,4. *Gattendorfia* cf. *molaris* Vöhringer. Ventral and lateral views of a specimen from the Zorritas Formation, Sierra de Almeida, Chile. USNM 486284, X 3.

5. *Michiganites greenei* (Miller). The holotype of the species from the «Knobstone Formation» (New Providence Shale), New Albany, Indiana, U.S.A. American Museum of Natural History, New York No. 2539, X 5.9

6,7. ?*Rectimitoceras* sp. Lateral and ventral views of a specimen from the Zorritas Formation, Sierra de Almeida, Chile. USNM 486288, X 3.

8-12. *Eocanites sernageominus* House sp. nov. Views of the holotype from the Zorritas Formation, Sierra de Almeida, Chile. 8,9, latex mould of the exterior of the shell; 10-12, lateral and oblique views showing the shell form and sutures. USNM 486283, X 2.


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