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DEVONIAN AMMONOIDS FROM THE APPALACHIANS AND THEIR BEARING ON INTERNATIONAL ZONATION AND CORRELATION

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With 10 plates and 12 text-figures

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ABSTRACT. New ammonoid records from eastern North America are described as part of a sequence of thirty successive faunas recognized especially in the Middle and Upper Devonian. Most of these assemblages occur in the New York succession, but those occurring elsewhere are integrated with that succession as far as evidence allows. Critical ammonoid sequences in North Africa and Europe are described for the pre-Famennian Devonian. This enables comments to be made on the correlation of the America faunas.

Anarcestes is described from New York. From the pre-Tioga Bentonite Onondaga Limestone equivalents in Virginia and West Virginia, two goniatite faunas are distinguished, an earlier with abundant agoniatitids, including *Agoniatites oliveri* sp. nov., and a later fauna with *Foordites buttsi*. From near Salem, Virginia, a rich barytized fauna is described with *Cabrieroceras plebeiforme*, *Agoniatites*, and *Holzapfeloceras croyi* sp. nov. which is thought to correlate with the *Werneroceras* Bed of New York, and with the *Cabrieroceras*-bearing levels of Morocco, Algeria, the Montagne Noire, Czechoslovakia, and the Rhenish Schiefergebirge which, in those areas, is usually taken to mark the basal Givetian. Higher Givetian faunas in the Appalachians include levels with *Maenioceras*, *Sobolewia*, and tornoceratids. From West Virginia are described *Koenenites lamellosus kirchgasseri* subsp. nov., *Lobotornoceras hassoni* sp. nov., *Epitornoceras*, and ?*Pharciceras* from horizons thought to be equivalent to pre-Genundewa strata in New York. This fauna is thought to correlate with European early Frasnian horizons. Faunas at approximately the Genundewa level including *Probeloceras* and *Manticoceras* are recognized in West Virginia. A fauna with *Platyclymenia*, *Cyrtoclymenia*, and *Sporadoceras* is reported from Lorain County, Ohio, and a higher level with *Cymaclymenia* is described from the same area. These comprise the first records of clymenids from eastern North America.

A Middle Devonian silicified fauna with *Cabrieroceras* is described from Nevada and compared with the eastern Middle Devonian faunas. A specimen of *Tornoceras* is described which is the first Devonian goniatite recorded from Bolivia.

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INTRODUCTION

THE purpose of this paper is to describe the sequence of goniatite faunas which has been established in a preliminary study of the Devonian of the Appalachians, both from collections made especially by Dr. C. G. Tillman and Dr. W. A. Oliver Jr. and those made by the author. Advantage is taken to describe some new material from equivalent levels in New York, Ohio, Nevada, and a single specimen from South America. These faunas are compared with the successions known in the Old World.

Goniatite zonation of the Middle Devonian especially is greatly in need of stratigraphic refinement. European faunas, whilst historically famous, are mostly from scattered localities and the stratigraphical relations of them is to a large measure vague, either because facies changes make correlations and the establishment of sequences difficult, or because of tectonic complications, or because of lack of modern description of the faunas. The published zonations (for example, House 1962, p. 250) represent little more than a convenient consensus, without the rigorous and systematically collected sequences which form the basis for the published Upper Devonian zonation.

Eastern North America offers particular advantages in this situation since the Devonian succession is reasonably unambiguous, especially in New York, at least in comparison with Europe. However, all is not straightforward, partly as a result of the loss of convenient stratigraphical markers passing southward down the Appalachians, and partly because the whole area differs from Europe in not having provided a number of genera common in the Old World. Southward, however, an increasingly European and African aspect is apparent in the Appalachian goniatite faunas.

This preliminary review is intended to draw attention to the sequence of goniatite faunas present in West Virginia and Virginia and to comment on correlations with the standard New York sequence (text-figs. 1 and 2). Correlation of these faunas, in turn, with those of Europe is greatly bedevilled by the mixed usages and misusages of terms which have developed over the last ten or so years so that semantic confusion has now replaced the general consensus of agreement on definition which would have been acceptable to most in the 1950s.

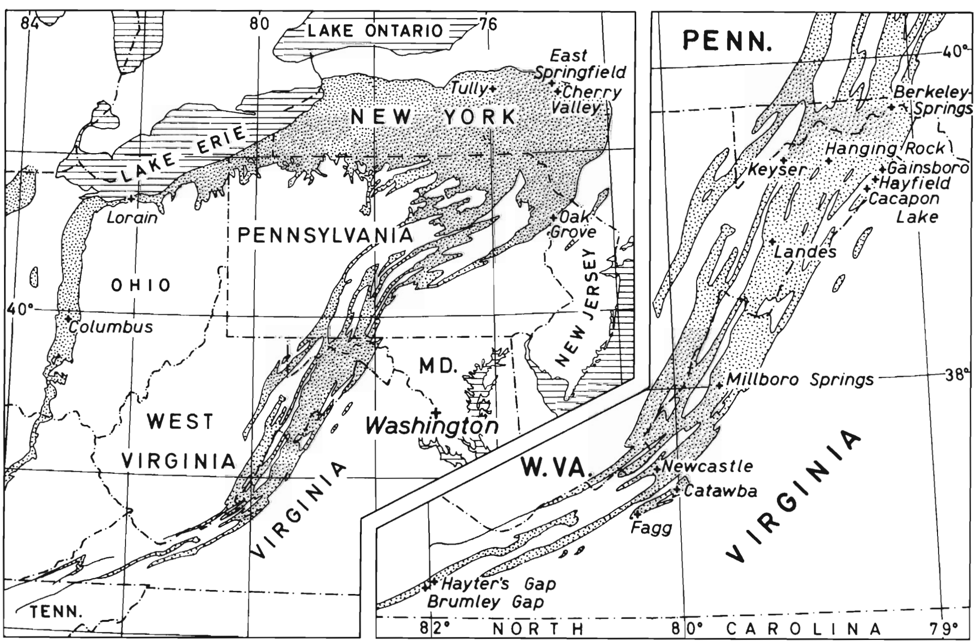
Schemes of goniatite zonation, as with schemes using other groups of fossils, are misleading to the uninitiated. Goniatites tend to occur in horizons separated by strata without them. The term 'goniatite band' has been widely used in English literature to emphasize this. 'Zones' therefore may comprise single bands, or groups of bands, between which there is no evidence at all of a goniatite fauna. This pattern is well illustrated in the eastern North American Devonian. There is every reason to expect that some of the horizons here recognized will contribute to the detailed correlation of the mid and early Upper Devonian in the Appalachians in the way in which similar bands have been of use elsewhere.

Abbreviations. The following abbreviations are used throughout the text for museum collections where the specimens referred to are located: AMNH, American Museum of Natural History, New York; Berl. Mus., Museum for Naturkunde, Berlin; CUPL, Cornell University, Paleontology Laboratory; IGS, Institute of Geological Sciences, London; NYSM, New York State Museum, Albany, New York; Senck. Mus., Museum of the Senckenbergische Naturforschende Gesellschaft, Frankfurt am Main, Germany; Sedgw. Mus., Sedgwick Museum, Cambridge; SUI, Iowa State University Geology Department Collection, Iowa City; UCLA, Geological Sciences Department Collection, University of California at Los Angeles, California; USNM, U.S. National Museum of Natural History, Washington, D.C.; Wies. Mus., Museum der Stadt, Wiesbaden, Germany.

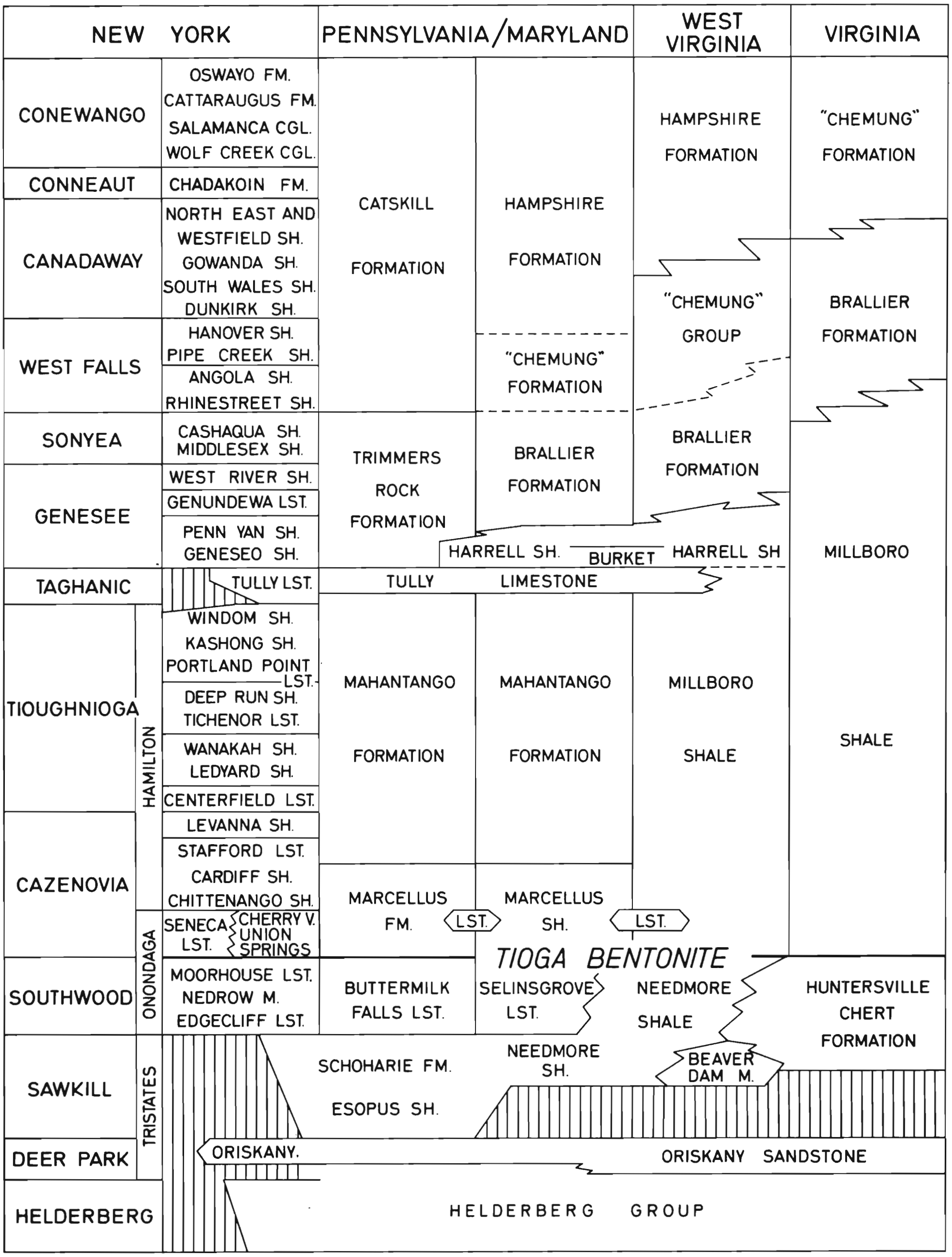
Measurements of specimens are given in millimetres and the following abbreviations of dimensions are used throughout: D, diameter; WW, whorl width; WH, whorl height; Wh, distance from the ventral crest of one whorl to the ventral crest of the preceding whorl; UW, width of umbilicus; R, radius from the centre of the umbilicus to the venter.

THE AMMONOID SEQUENCE IN THE APPALACHIAN DEVONIAN

The stratigraphical relations of the Devonian in eastern North America have been reviewed by Oliver *et al.* (1969 and in Oswald 1968) and more recently by Oliver (1976). The accompanying illustration (text-fig. 2) summarizes the main features of the facies relationships between New York (Rickard 1964, 1975) and Virginia and West Virginia (Dennison 1961, 1971). The problems in correlation southwards from New York results, for the Middle Devonian, from the passage into the Needmore and Millboro Shales which give a monotonous shale sequence with hardly any convenient lithological marker horizons apart from the Tioga Bentonite which separates these units. Thus the precise stratigraphical distinctions of the New York Middle Devonian established by Cooper (1930, 1933) and Oliver (1954, 1956*a*) are lost southwards.



TEXT-FIG. 1. Maps showing the distribution of Devonian rocks in eastern North America and the position of localities mentioned in the text.



TEXT-FIG. 2. Diagram showing the standard Devonian rock succession of New York State (based on Rickard 1975) and the supposed correlatives in the Appalachian area (based on Oliver *et al.* 1969, and sources quoted in text).

The same is true for the Upper Devonian. Southwards the upper part of the Millboro Shale is in places Upper Devonian, and the detailed divisions of the New York sequence are lost southward in the shales and siltstones of the Harrell and Brallier Formations, and in the process the New York marker bands are lost, or at least have not yet been identified.

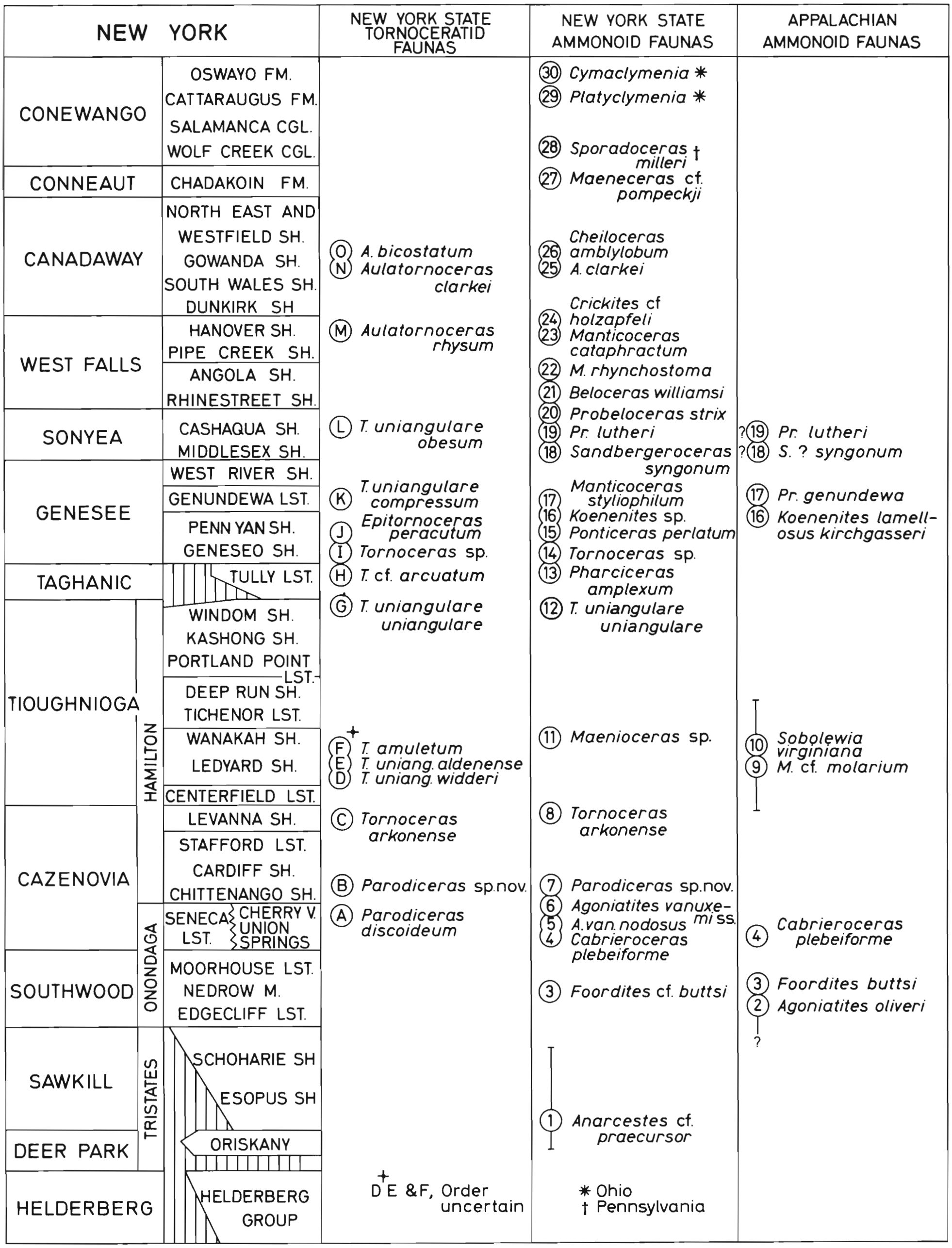
In such a situation faunal marker horizons become very significant. It would appear that some of the goniatite bands recognized here may provide the key to precise documentation of facies and thickness changes and hence palaeogeographical and palaeocological relations in the Appalachian area where the geology is in any case rendered more complex by folding and thrusting.

The goniatite sequence which is given below has mostly been pieced together from separate localities, and the evidence for the stratigraphical order is given. It is convenient to number (text-fig. 3) and discuss the faunas in relation to the better-known New York succession, and to add new details of the type sequence where appropriate. It should be stressed that these numbers are given for ease of reference only. For convenience, names of common goniatites in the bands are used as name indices, but this should not be construed as indicating a definitive zonation. Until the relations with New York are better understood this would be premature. The level of the critical goniatite faunas, related as far as possible to the New York sequence is indicated in text-fig. 3. This is based on an earlier general survey (House 1962, 1968) and a study of the tornoceratid succession (House 1965*a*). Kirchgasser (1975) has reviewed parts of the early Upper Devonian succession. The ranges of some of the critical species related to the New York succession is illustrated in text-fig. 4, but since this is a collative diagram, reference should be made to the text for details of the evidence on which it is based.

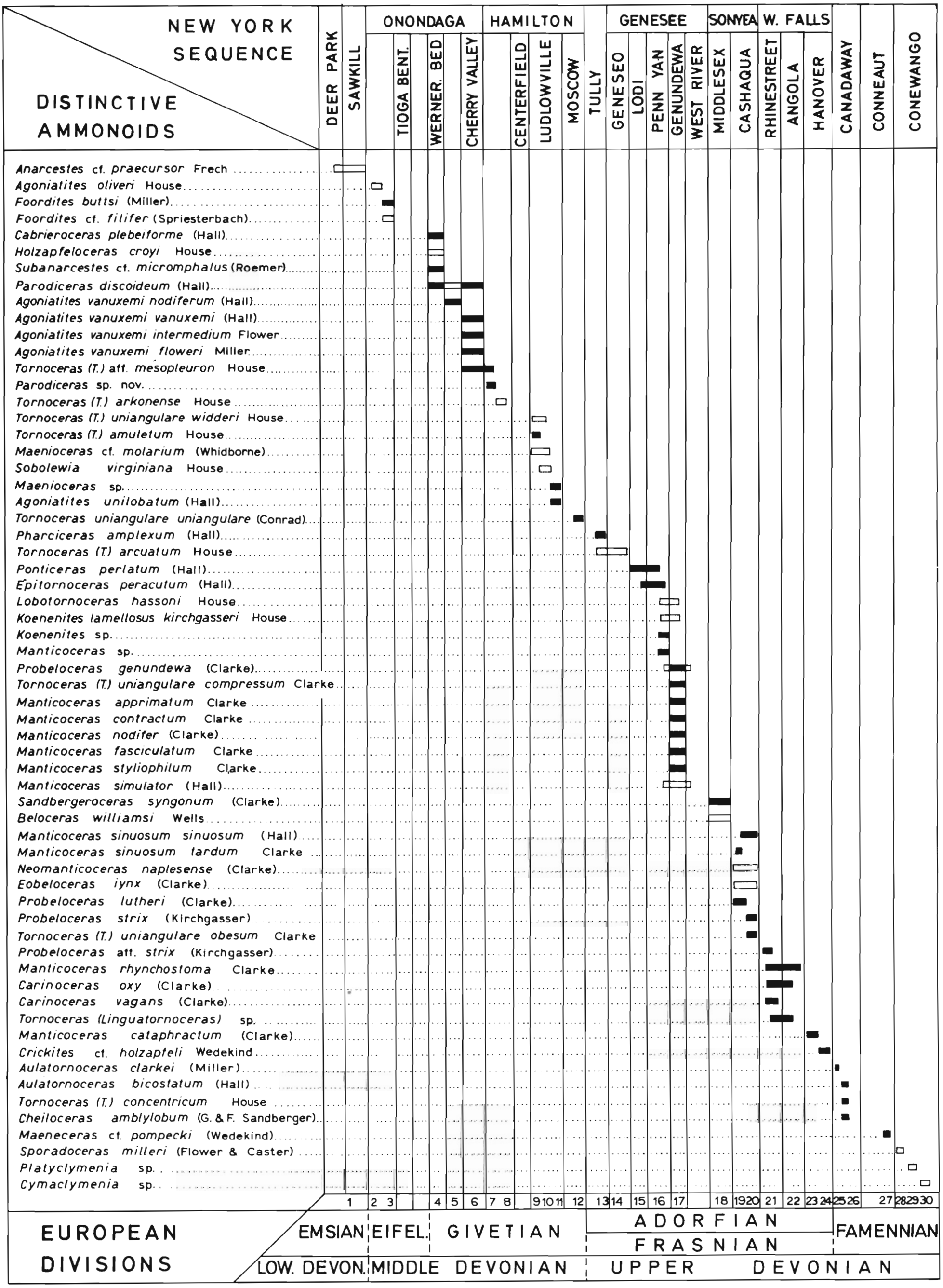
1. *Anarcestes* cf. *praecursor* (Barrande). The earliest goniatite so far known from eastern North America appears to be a specimen collected by H. S. Williams from central New York and given by him the manuscript name *Goniatites oriskania*. He gave the horizon as the Oriskany Sandstone, and that was repeated in a reference to the specimen recently (House 1975, p. 271). But both W. A. Oliver and G. Klapper have suggested that sands up to the early Onondaga might be a possible source. Erben (1966 and earlier) has only recorded anarcestids from the Emsian and younger strata in Europe. The current reference of the Oriskany to the Siegenian cannot be questioned until the source is finally settled. Nothing similar has been found in the Appalachians.

2. *Agoniatites oliveri* House n. sp. (see p. 25). This, and closely related agoniatitids with slow whorl expansion, are common in the Needmore Shale and equivalents above beds referred to the Oriskany Sandstone in northern Virginia and West Virginia. At a quarry on the west side of Route 522, 1·1 km (0·7 miles) north-west of Gainsboro and south-east of Back Creek, Frederick County, Virginia, they occur at levels between 9 and 15 m above the local Oriskany. This locality was noted by Butts (1940, p. 307) and the interval seems to lie in the upper part of the lower unit shown in the section given by Dennison (1961, p. 57, pl. 3, sheet A, locality VI).

The fauna also occurs near Capon Lake (or Springs), in a quarry on the south-east side of Baker Mountain, 0·8 km (0·5 miles) south-west of the turning to Capon Lake,



TEXT-FIG. 3. Diagram showing the stratigraphical occurrence of Devonian goniatite faunas in eastern North America (based on information presented herein, House 1962, 1965*a*, 1968; Kirchgasser 1975).



TEXT-FIG. 4. Range chart of characteristic Devonian goniatites in eastern North America in relation to the New York State sequence. Black bars indicate certain range, open bars indicate uncertain range, either through imprecise correlation with the New York State sequence, or lack of precise documentation of occurrence.

on the west side of Route 259, Hampshire County, West Virgina. Dr. Oliver kindly sent a fauna from here, and others were collected in abundance during a visit in 1972. Here these agoniatitids occur low in the exposed section, and the distance above the Oriskany cannot be great. Sections hereabouts were noted by Woodward (1943, p. 292) and Dennison (1961, pl. 3, sheet B, locality W 5). Dr. Oliver has pointed out that it is not proven that this level may not be pre-Onondaga in age.

East of Keyser, Mineral County, West Virginia, along a farm access track on the north-east side of a stream leading east from O'Neil Gap, west of E. R. Taylor's farm, similar agoniatitids occur at an estimated 29 m above the local Oriskany. The section here was described by Dennison (1955, pp. 32, 118, section 13; 1961, p. 64, locality W 11).

There are other localities for agoniatitids at approximately this level. At Fagg, 8 km (5 miles) south-east of Blacksburg, Montgomery County, Virginia, from the Needmore Shale about 1·5–3·0 m above the Huntersville Chert, comes a specimen here determined as *Agoniatites* aff. *bicanaliculatus* (G. and F. Sandberger). Also there are localities which the writer has not visited at Saumsville, Virginia, including the source of the holotype of *A. oliveri* at Berkeley Springs, West Virginia.

3. *Foordites buttsi* (Miller). Higher in the Needmore Shale, but still below the Tioga Bentonite, occur the first goniatites with a large latero-umbilical saddle. It now seems clear that these are abundant at many localities at levels which post-date the horizons with *A. oliveri* when the faunas are seen in sequence. In Europe *Foordites* extends upwards to the top Givetian, but in eastern North America it has only been found in the early part of its range.

At the quarry north-west of Gainsboro mentioned earlier, *Foordites* occurs about 30 m above the Oriskany. According to the section of Dennison (1961, pl. 3, sheet A), the Tioga Bentonite would be expected some 10 m higher.

In the section along the track east of Keyser, *Foordites* occurs commonly at 9–12 m above the *Agoniatites* horizons. Here again the measurements of Dennison (1961, pl. 3, sheet A, using section W 12) would indicate that the Tioga Bentonite is higher in the section.

The relations of *Foordites* to the Tioga Bentonite can be seen at the Hayfield cross-roads of U.S. Route 50 and Route 60, in Frederick County, Virginia, where *Foordites* occurs in shale exposed on the north-eastern corner of the cross-roads. Dr. Niles Eldredge drew attention to this locality. The Tioga Bentonite is exposed east of the cross-roads on the northern side, and measurements indicate some 30 m between the *Foordites* level and the Tioga metabentonite, which seems rather high, even bearing in mind the thicknesses demonstrated by Dennison. Agoniatitids of the lower fauna were not found here, and the section seems not to go low enough.

The type locality for *F. buttsi* is the highway cut 1·6 km (1 mile) south of Newcastle, Craig County, Virginia (Miller 1938, p. 148). The horizon of the specimen was not recorded precisely. Miller (1938) and Butts (1940, p. 305) give the horizon as Onondaga (that is, Needmore Shale) and Dennison (1961, p. 60, pl. 3, sheet A, locality V 40) has a section which gives a total thickness of pre-Tioga shales as only about 30 m. Again the relations with the *A. oliveri* fauna are not determined, but similar suggestions of local thinning occur near Hanging Rock, Hampshire County, West Virginia, 24 km (15 miles) east of Romney on U.S. Route 50, in an old quarry on the north side of the road 197 m (200 yards) east of North River. Here Miller (1938, p. 148) recorded a specimen collected by G. A. Cooper from about 7·6 m (25 feet) above the Oriskany which he referred to *Tornoceras buttsi*, but which was considered a *Foordites* in a revision (House 1962, p. 253). The writer visited this locality with Dr. Kirchgasser without locating goniatites. This record of *Foordites* is anomalously low, but local dips are high and there is the possibility of either tectonic or original thinning.

The specimen of *Foordites* cf. *buttsi* collected by Oliver (1956*b*, p. 403) from the Nedrow Member of the Onondaga Limestone near East Springfield, Otsego County, New York, came from only 6–10 m below the Tioga Bentonite, thus confirming the place of this fauna near the upper part of the pre-Tioga Bentonite wherever the relationships are clear.

The specimen referred here to cf. *F. filifer* (Spiesterbach) from near Oak Grove, Monroe County, Pennsylvania collected by Dr. Oliver, leaves very much to be desired and is poorly preserved. The level is the upper 15–18 m of the Buttermilk Falls Limestone, but since it has not been located elsewhere the relationship to the *Foordites* faunas are not known.

4. *Cabrieroceras plebeiforme* (Hall). The well-known fauna of the *Werneroceras* Bed (Rickard 1952) near the top of the Union Springs Shale Member of Otsego, Schoharie, and Albany Counties, New York, is the oldest fauna of goniatites known above the Tioga Bentonite. In New York State the fauna includes *C. plebeiforme*, *Subanarcestes* cf. *micromphalus*, and *Parodiceras discoideum* (Hall). This is the only level where *Cabrieroceras* is known in the New York succession (House 1962, 1968).

It is to this level that a remarkable fauna preserved in barytes appears to belong which was collected by Mr. S. Croy of Vinton, Virginia and which was kindly sent for study by Dr. Tillman. The locality is an inactive shale quarry on the south side of Route 311 on the south-eastern slopes of Catawba Mountain, 6·3 km (3·9 miles) north-west of Exit 41 on the Virginia Turnpike (U.S. Route 81), north-west of Salem, Roanoke County, Virginia. Dr. Tillman indicates that the Tioga Bentonite crops out higher up the mountain, stratigraphically below the goniatite bearing level. The Catawba fauna includes *C. plebeiforme*, *P. discoideum*, *Holzapfeloceras croyi* House sp. nov., and *A. vanuxemi* subsp. nov. (Pl. 5, figs. 4, 7, 8). Of the position of this fauna, Lowry and Tillman (*in* Lowry *et al.* 1971, p. 47) have written: 'The beds in this quarry are contorted and offset with respect to those along the highway . . . but it appears to be in the lower part of the Millboro, possibly no more than 100–200 feet [30·5–61·0 m] above the Huntersville Chert.' They comment further that Eubank (1967) had estimated an incomplete Millboro section in the south-east part of the Salem synclinorium to be about 122 m thick, but that elsewhere thicknesses between 9 and 275 m had been recorded by Murphy (1968) and Hazlett, results which are compatible with those noted by Butts (1940, p. 312). In the quarry, a ledge of calcareous beds crosses at about the middle of the quarry face, with large doggers a metre or more across, but these do not yield goniatites. The fauna comes from an underlying layer of smaller concretions, up to 0·4 m across. These are particularly well developed on the south side of the quarry face. The initial fauna was naturally weathered by decalcification into a khaki powder, and this enabled perfect extraction of the barytized cephalopods. Fresh material is more intractable. Tight contortions can be seen in the quarry, which is part of the northern limb of the Salem Synclinorium which rests wholly upon the Pulaski Thrust.

It is tempting to speculate that the levels of large and small concretions here have correlatives with the Cherry Valley Limestone and *Werneroceras* Bed respectively of the New York sequence, but there is no faunal evidence for this.

5, 6. *Agoniatites vanuxemi* (Hall). In New York, from the shales overlying the *Werneroceras* Bed, Flower (1943) described *A. nodiferus* Flower, but this form has not been located elsewhere. The goniatites from the overlying Cherry Valley Limestone in New York are well known. This level has yielded the types of *A. vanuxemi* (Hall) and *P. discoideum* (Hall) (Flower 1943; Rickard 1952). In addition there is *Tornoceras* (*T.*) aff. *mesopleuron* House (1965*a*, p. 90, text-fig. 3C).

Both *Agoniatites* and *Parodiceras* have been widely recorded in the Appalachian area by Butts (1940), Miller (1938), and others. There is no evidence that the forms recorded are from a level which should be correlated with the Cherry Valley Limestone, or that they are from a single band at all. Both genera have longer ranges, and *Agoniatites* extends high in the Hamilton. Unfortunately the agoniatitids have not been studied in detail to see whether they are useful for stratigraphical discrimination.

7. *Parodiceras* sp. nov. and *Tornoceras* (*T.*) aff. *mesopleuron* House (Pl. 9, fig. 5) are here recorded from a level about 18·3 m above the Cherry Valley Limestone in the Chittenango Shale, near Cherry Valley, New York and these constitute a distinctive early Hamilton fauna.

8. *Tornoceras* (*T.*) *arkonense* House. A wide distribution of this species in pre-Centerfield Limestone levels in the Hamilton was recognized when the species was described (House 1965*a*, pp. 91–94). No further information is available.

9. *Maenioceras* cf. *molarium* (Whidborne). This level has so far only been recognized in Washington County, Virginia, in the region between Hayter's Gap and Brumley Gap. The succession here has already been published (House 1962, p. 255; Butts 1940, p. 311). According to Butts, the Goniatite Bed (with *Sobolewia virginiana*) lies about 12·2 m above the Huntersville Chert here, and the maenioceratids occur in the shales for 1·2 m below the Goniatite Bed and in the lower part of the bed itself. Dennison has not recognized the Tioga Bentonite in this area, and the stratigraphical relations have not been established with the other faunas described here. The justification for this placing lies in the mid Givetian nature of the fauna which appears to be later than the *Cabrieroceras* assemblage. It would be very useful if this level could be located in New York State.

10. *Sobolewia virginiana* House. This fauna also is only known at present in Washington County, Virginia in the Hayter's and Brumley Gap area. This Goniatite Bed fauna, with beautifully pyritized goniatites (House 1962) carries *S. virginiana* and *T.* (*T.*) *uniangulare* (Conrad) belonging to the subspecies *widderi* group (House 1965*a*). The latter suggests that correlation may be with levels in New York State above the Centerfield Limestone. Neither goniatite species is helpful in correlation with Europe.

From the Millboro Shale on Route 39 at Millboro Springs, 91 m (100 yards) south of East Stuart Run, and on the north side of a bridge, in Bath County, Virginia, ?*Sobolewia* sp. occurs (USNM 240500), but whether this is to be related to the Hayter's Gap horizon is quite uncertain.

11. *Maenioceras* sp. Although they have yet to be described, attention may be drawn here to a specimen of what appears to be an involute *Maenioceras* located by G. Kloc in the Wanakah Shale of western New York. Agoniatitids at the same level appear to be close to *Goniatites unilobatus* Hall, a form which was tentatively referred to *Sellagoniatites* by House (*in* House and Pedder 1963, p. 511). That assignment seems improbable since Mr. Kloc has demonstrated that no dorsal saddle is present and the form should be referred to *Agoniatites*.

12. *Tornoceras uniangulare uniangulare* (Conrad). The Leicester Pyrite bearing this fauna has been described elsewhere (House 1965*a*). Unfortunately more discriminating elements have not yet been located in this level.

13. *Pharciceras amplexum* (Hall). This goniatite from the West Brook Member of the Tully Limestone of New York (House 1962, p. 272; 1968, p. 1065) has not been recognized in the Appalachian area but is inserted here since this is the fauna which provides the first evidence of the Manticoceras Stufe in New York, the basal levels of which have been taken to define the base of the Upper Devonian in Europe for about eighty years. Comments on the affinities of this form are given in the systematic section. *T.* (*T.*) *arcuatum* House group occur in the West Brook Member also.

14. *Tornoceras* sp. Similarly restricted to New York is a goniatite fauna in the lower part of the Geneseo Shale overlying the Tully Limestone which certainly contains *Tornoceras*, but also has crushed open umbilicate ammonoids with sharply projecting ventro-lateral salients which may well be pharciceratids. These will be described in a forthcoming work with Dr. Kirchgasser.

15. *Ponticeras perlatum* (Hall). A well-known fauna of ponticeratids occurs in the Lodi Limestone and higher levels at least until beds rather below the Genundewa Limestone (House 1962; Kirchgasser 1975). Their distribution will be discussed in a forthcoming work with Dr. Kirchgasser. An analogy with German faunas and Russian Domanik faunas has been drawn (House 1975).

16. *Koenenites lamellosus* (G. and F. Sandberger). A new locality was found, during field work with Dr. Kirchgasser, in a roadside section 3 km (1·9 miles) south of Landes Post Office on the east side of U.S. Route 220, Grant County, West Virginia. The exposure shows styliolinid calcareous nodules and shales in a band 1·2 m thick below a 1·8 m black shale. The fine specimen described later as *K. lamellosus kirchgasseri* subsp. nov. came from one of the nodules. This level is referred to the Tully Limestone by authors writing on this area, but the main grounds for suggesting it is younger in age is that *Koenenites* occurs in New York just below the Genundewa Limestone. There are many small goniatites in the fauna including one (USNM 240493) which shows a suture of *Manticoceras* type, but the possibility that these are inner whorls of *Koenenites* cannot be entirely ruled out at present.

Another fauna was located by Dr. K. O. Hasson and loaned by him for study. This fauna includes ?*Pharciceras galeatum* Wedekind (House 1968, p. 1066), an uncertain determination, and *Epitornoceras peracutum* (Hall). The locality is from beds locally referred to the Tully Limestone from a 3·7 m interval of shales with limestone nodules exposed 0·8 km (0·5 miles) south of Landes Post Office, Grant County, West Virginia, east of U.S. Route 220 and on the farm property of Mrs. Audrey Kesner. Permission for access to this locality was refused on a visit by the author. The correlation of this level can hardly be with the Tully Limestone, whatever the lithological characteristics which led to this assignment. *Epitornoceras* is only known from the upper part of the Geneseo Shale and the Ithaca Formation in New York, all probably pre-Genundewa in age, but well above the Tully (House 1965*a*, p. 119). Since the ?*Pharciceras* could possibly be a *Koenenites*, the faunas considered in this section may be from a similar group, and the correlation would seem best with the strata in New York below the Genundewa where both *Epitornoceras* and *Koenenites* occur. This may be about the level of the Squaw Bay Limestone of Michigan. It is to be hoped that it will prove possible in the future to establish the detailed sequence in the Landes Post Office area, since this is a region where the goniatites are well preserved.

17. *Probeloceras genundewa* (Clarke). A similar group of shales and styliolinid-bearing limestone nodules is exposed discontinuously and poorly on the west side of U.S. Route 220 between 195 and 225 m south of a small bridge 6·6 km (4·1 miles) south of Landes Post Office. The goniatite fauna here, although small in size, is quite profuse, and includes *Probeloceras* cf. *genundewa*, *Ponticeras* aff. *pernai* ((Wedekind), *Lobotornoceras hassoni* House sp. nov., and tornoceratids (USNM 240501–240504) of the type of *T.* (*T.*) *uniangulare compressum* Clarke (Pl. 9, figs. 9, 10) (House 1965*a*, p. 109). This fauna seems about the Genundewa level in the New York succession, but the absence of large manticoceratids suggests it is earlier and it could even predate the faunas with *Koenenites* mentioned earlier, but the abundance of *Probeloceras* suggests it is younger. *Lobotornoceras* is a new record for eastern North America.

Again this locality has locally been referred to the Tully Limestone, but it is clear that it is substantially younger in age than the Tully Limestone in New York.

18. *Sandbergeroceras syngonum* (Clarke). No representatives have yet been found in the Appalachians of goniatites which can unequivocally be referred to the West River and Middlesex Shale Members of the New York succession apart from the uncertain record by Miller (1938, p. 180) of *S.* ?*syngonum* from the Tygart Valley, Randolph County, West Virginia (Tilton 1929, p. 350) which has not been confirmed.

19, 20. *Probeloceras lutheri* (Clarke) and *P. strix* (Kirchgasser). Kirchgasser (1975) has described the occurrence of these species in New York. The Harrell and Brallier Shales at many localities yielded to Butts (1940), Willard (1939), and Prosser and Swartz (1913) in their surveys of the Devonian of the Appalachians, Pennsylvania, and Maryland, many goniatites which they recorded as *Goniatites* or *P. lutheri*. In his revision, Kirchgasser (1975) has restricted *P. lutheri* to the form used originally by Clarke (1885, p. 50, pl. 2, fig. 8; according to Kirchgasser 1975, p. 73, this is USNM 14993), Kirchgasser uses *P. strix* (Kirchgasser) for the form well known as

P. lutheri (*P. strix* is the type species of the now discarded genus *Eidoprobeloceras* Kirchgasser, 1968). Kirchgasser has presented evidence that *P. lutheri* precedes *P. strix* in the Cashaqua Shale in New York and he uses the species as two successive zonal indices.

The occurrence of *Probeloceras* in the Appalachians has not been studied with the attention it deserves. Cursory examination of the shales and siltstones overlying the Millboro Shale at a number of localities yielded the same rather poorly preserved material similar to that figured by Butts (1941, pl. 120, fig. 30) suggesting *P. lutheri* is present, but Kirchgasser (1975, p. 77), who gives some notes on the problem, suggests that other species are also included in the older references to *P. lutheri*. Of particular interest is the way in which, at Hayter's Gap, *P. lutheri* follows a short distance above the *Sobolewia virginiana* Goniatite Bed, suggesting either a stratal gap, or substantial reduction.

Yet higher faunas may well be present in the southern Appalachians and there are a number of records of *Manticoceras* (mostly listed by Miller 1938) which have not been investigated. In New York *Manticoceras* ranges from just before the Genundewa up to the Hanover Shale, so these records cannot be assigned without detailed examination. Now that the sequence in New York is so much better understood it seems that a good deal of clarification of correlation would result from a review of the distribution of *Manticoceras* in the Appalachian area.

For details of the higher faunas of New York indicated on text-fig. 3 reference should be made to earlier works by the author (House 1962, 1965*a*, 1968).

FAUNAS FROM OHIO, NEVADA, AND SOUTH AMERICA

It is convenient to mention in this section some new faunas which have come to light in recent years and to make some comment on older faunas which have a bearing on the successions described from the Appalachians. Essentially therefore this is an addendum to an earlier review (House 1962).

Ohio. Goniatite faunas have been described by Sweet and Miller (1956) from the Columbus Limestone of Ohio. Since the Tioga Bentonite is now thought to intervene between the Columbus Limestone and the overlying Delaware Limestone (Oliver *et al.* 1969), comparison with the sequences established here are of interest. Unfortunately, however, little precise stratigraphical information is available for the known specimens. Furthermore, much of the material which formed the basis for the determinations given by Stauffer (1909, pp. 168, 169) seems to have been lost. The Columbus fauna seems to comprise the following: *Foordites* (?) *eberlei* (Sweet and Miller), *F.* (?) *mithrax* (Hall), *Agoniatites* n. sp. (Sweet and Miller 1956, pl. 94, figs. 1, 2), and *Latanacarcestes* (?) *staufferi* (Sweet and Miller). It should be noted that Stauffer mentions '*Gyroceratites ohioensis* Meek' and '*G. inelegens* Meek' as occurring in both the Columbus and Delaware Limestones, but in the absence of any material or illustrations no significance can be read into this. It should be noted that the forms referred tentatively to *Foordites* have very different sutural patterns than those of the *F. buttsi* type, and that in the absence of ontogenetic data reference to *Foordites* must be speculative.

Quite a new fauna (fauna 29 on text-fig. 3) has been located by Dr. W. J. Hlavin from a level near the base of the Cleveland Shale on the Vermillion River, Lorain County, Ohio. This fauna is not described here, but comprises *Platyclymenia* sp., *Cyrtoclymenia* sp., and *Sporadoceras* sp. There is little doubt that these are representatives of the German Platyclymenia Stufe and, with the notes on *Cymaclymenia* given below, comprise the first records of genuine clymenids in eastern North America. The material is pyritized and additional collecting should enable a full account of the fauna to be published subsequently. Dr. Mackenzie Gordon informs me (in litt.) that he had identified *Platyclymenia* in material earlier submitted by Dr. Hlavin from a locality on Vermillion River subsequently destroyed by the building of a bridge on Interstate Highway 90.

Dr. W. J. Hlavin has also kindly sent for study a most interesting ammonoid assemblage (fauna 30 on text-fig. 3) from the Cleveland Shale, about 1–2 m below the contact with the overlying Bedford Formation, at a locality on the side of Towness Creek, a tributary of Beaver Creek, Lorain County, Ohio, from a horizon about 24 m above the level yielding *Platyclymenia* sp. These crushed ammonoids are preserved as pyritic films often preserving shell ornament and aperture form, but rarely sutures. In view of the state of preservation, and the probability that more material will be forthcoming, systematic descriptions of the fauna are not given here, but the following notes and the accompanying illustrations are intended to draw attention to critical aspects of the fauna.

One specimen (USNM 240494, Pl. 10, figs. 5, 7) shows evidence of a suture which clearly belongs to *Cymaclymenia*, and another (USNM 240495) shows on the lower flanks a similar suture pattern. Several specimens, but especially a large example (USNM 240496, Pl. 10, fig. 6), show convex growth lines and an involute shell with closed umbilicus. These could represent imitoceratids or sporadoceratids, but in the absence of indications of the suture are indeterminable.

The nearest locality yielding *Cymaclymenia* is that described by House (1962) in southern Iowa from the level of the Chonepectus Sandstone, but *Cymaclymenia* is a long-ranging genus in the European Famennian (House, 1971). In Germany *Cymaclymenia* is a long-ranging upper Famennian clymenid and it is recorded (Vöhringer 1960) as ranging up into the Hangenberg Schiefer higher than any other clymenoid genus, but it is not seen in the overlying, *Gattendorfia*-bearing, Hangenberg Kalk which was taken as basal Carboniferous by the Heerlen and Sheffield conferences on the Carboniferous System. Therefore whilst fauna 30 is the youngest ammonoid fauna known in eastern North America, the precise age is not determined.

Nevada. A more extended fauna is described in the systematic section from the locality in the southern Roberts Mountains from which goniatites have already been reported (House 1965*b*). The horizon is the lower *Warrenella kirki* Zone in the McColley Canyon Formation (see Johnson 1971, p. 304). The forms represented are: *Cabrieroceras* aff. *plebeiforme* (Hall), *Agoniatites* aff. *kayseri* (Wedekind), and ?*Sobolewia* sp. Comments on the correlation of this fauna are made later, but the fauna would seem slightly younger than the *Werneroceras* Bed in New York.

Bolivia. Dr. A. J. Boucot has sent for study a single goniatite specimen from Chacoma, La Paz Province, Bolivia, which represents the first Devonian goniatite known from

Bolivia. It is described and figured later and assigned to *Tornoceras* (*T.*) *baldisi* Leanza, that is a species described from Argentina which was the first evidence for Devonian ammonoids at all in South America (Leanza 1968). Dr. P. E. Isaacson, who has been surveying the Chacoma area writes that the specimen was found loose apparently from the Sicasia Formation (?) or possibly the Collpacucha Formation. Leanza referred his material to the Upper Devonian, and this may be the correct assignment, but tornoceratids with the type of growth lines shown by the Chacoma specimen occur in the early Hamilton in New York, and hence a Givetian age seems at least possible.

COMPARISON WITH GONIATITE SEQUENCES IN THE OLD WORLD

Lower Devonian and early Middle Devonian

So far no goniatites unambiguously referable to the Siegenian or Emsian have been described from eastern North America. There are records from Nevada (House 1965*a*, 1965*b*), the Yukon (House and Pedder 1963, p. 509), and in the Canadian Arctic Islands (Erben 1966, p. 656). None of these contribute significantly to problems of correlation around the Lower/Middle Devonian boundary. It is, however, useful to review the evidence of North African and European goniatite faunas of the latest Lower Devonian as well as those of the early Middle Devonian since this helps to stress the contrast with eastern North America. The distribution of the earliest-known goniatite fauna has recently been reviewed by Chlupáč (1976*a*, *b*).

North Africa provides one of the most detailed early goniatite sequences for the Emsian and Eifelian interval, and has been elucidated by Hollard (1974) in southern Morocco. From this work the succession may be summarized as follows.

6. *Cabrieroceras crispiforme* (Kayser)
5. *Werneroceras ougarta* Petter
4. *Pinacites jugleri* (Roemer), *Foordites occultus* (Barrande), *Anarcestes lateseptatus plebeius* (Barrande)
3. *Anarcestes lateseptatus lateseptatus* (Barrande) and '*Anarcestes*' *neglectus* (Barrande)
2. *Sellanarcestes wenkenbachi* (Kayser), *S. tenuior* Walliser, *S. crassior* Walliser, *Latanarcestes noeggerathi* (von Buch) group, *Mimagoniatites tabuliformis* Kullmann, and *Gyroceratites* spp. (both *Gyroceratites* sp. cf. *graçilis* (Bronn) and *G. laevis* (Eichenberg) have been recorded but further investigation is needed (Hollard 1974, p. 59)
1. *Anetoceras* (*Erbenoceras*) *advolvens* (Erben), *Mimagoniatites* sp. cf. *bohemicus* (Barrande), *M. zorgensis* (Roemer), *Mimosphinctes cantabricus* Kullmann and *Mimosphinctes* sp.

Hollard compares fauna 1 with that of the Zlíchovian of Czechoslovakia and, following usual German practice, refers fauna 2 to the late Emsian and faunas 3 and 4 to the Eifelian. The opportunity I have had to see the sequence under Dr. Hollard's guidance has led me to suggest that the goniatites named by Madame Petter (1959) as *W. crispiforme ougarta* from the Sahara have a more arched whorl section and smaller umbilici than the true *Cabrieroceras*, and seem to occur rather earlier. These seem correctly referred to *Werneroceras*. Hollard takes fauna 6 as marking the basal Givetian following German and Czech usage. It should be noted that he convincingly discards suggestions by Sougy (1969) that *P. jugleri* occurs in the 'Lower Couvinien' in Mauritania.

Apart from the sudden entry of the *Cabrieroceras* fauna, there is little comparison between this sequence and that described from eastern North America. Closer ties, especially in the occurrence of *Foordites* and agoniatitids of Eifelian aspect, seem present in Algerian faunas described by Petter (1959), but unfortunately the lack of detailed biostratigraphic record makes comparison difficult. Apart from the absence of *Pinacites* in the Appalachians, the *F. buttsi*, agoniatitid, and other records of the Needmore Shale have a close link with Petter's faunas referred to the late Eifelian.

Germany. Regretfully, the goniatite sequence for the interval here considered is poorly known in the Eifel Mountains. Schmidt (1950) described the four specimens then known from the Eifel. These included *P. jugleri*, from the Ahrdorf Schichten, and *Cabrieroceras* material from an unknown horizon.

In the Rhenish Schiefergebirge, the sequence described by Kayser (1884) from Grube Langscheid, 1200 m south-south-west of the confluence of the Rupbacht and Lahn rivers south of Steinsberg, established the succession (to use modern assignments) of *G. gracilis*, *Anarcestes lateseptatus*, and *P. jugleri* faunas. This was little modified by Wedekind (1917) who recognized a *S. wenkenbachi* (Kayser) fauna as preceding *A. lateseptatus* and he referred the former to the Middle Devonian, but the relations with the *Gyroceratites* sequence were not disentangled. Schmidt (1926), in a review of Middle Devonian zonation, argued that the *S. wenkenbachi* Zone should be referred to the Lower Devonian. The *Gyroceratites* succession was analysed by Walliser (1962). Recently Walliser (1973) has reviewed the late Lower and early Middle Devonian goniatite zonation, but only a preliminary outline has been published which is summarized below. The index letters have been inserted for convenience.

f. *Cabrieroceras crispiforme* (= *rouvillei*)
e. *Pinacites jugleri* with *Werneroceras* and related forms
d. *Anarcestes lateseptatus* with *Pinacites jugleri*
c. *Anarcestes lateseptatus* without *Gyroceratites gracilis*
b. *Gyroceratites gracilis* with *Anarcestes lateseptatus*
a. *Sellanarcestes wenkenbachi*, *S. crassior* Walliser, *S. tenuior* Walliser, with *Gyroceratites laevis*

This sequence is to a large extent a composite of faunal evidence from different localities. That is not to suggest it is not reliable, but that it lacks the authority which faunas taken from a single measured section have. In part these difficulties are due to the fact that the best goniatite faunas come from the schwellen type limestones of the Ballersbacher Kalk, Günteröder Kalk, and Odershäuser Kalk which occur in the eastern part of the Rhenish Schiefergebirge. Unfortunately the goniatite faunas from these are largely based on old records, and there has been little recent revision. The nature of the limestones, frequently lenticular bodies within argillite, makes this difficult, and some limestone lenticles have even been completely quarried away and are no longer available. There are the additional difficulties that the sequences in the limestones are frequently condensed, and hence stratigraphical admixture is apparent in the literature, and the problem that faunas from isolated limestone occurrences cannot be related with stratigraphical precision to the better-known sequences.

Fauna 'a' has as an index *S. wenkenbachi*, and, in his admirable morphological study of *Sellanarcestes*, Walliser (1965) revised the type material of *S. wenkenbachi* and designated a lectotype from Grube Königsberg in the Rubtachthal from among

Kayser's original material (Berl. Mus. *c.* 392) which he stated was from the 'Wissenbacher Schiefer der oberen Kondelgruppe' which he referred to the upper Emsian. In this work Walliser described two new species, *S. tenuior* and *S. crassior*. These were based on material collected around 1900 by Denckmann which were recorded as from the (supposed) Ballersbacher Kalk at Blauer Bruch, near Wildungen; Walliser referred these specimens to the lower Eifelian on the basis of *kockelianus* group conodonts collected by Ziegler in 1956 (Bischoff and Ziegler 1957; Ziegler 1971, p. 11), Ziegler having based his interpretation of the succession on an unpublished report by Pusch dated 1934. It seems highly questionable whether the Eifelian age assignment given for *S. tenuior* and *S. crassior* can be accepted as proven when it is based on such disparate evidence scattered over three-quarters of a century. The Heisdorf/Lauch junction is another of the boundaries mentioned in discussions on the Lower/Middle Devonian boundary. Solle (1972) gave a review of the boundaries and divisions of the Emsian and commented on the goniatite sequence. He indicated that *S. wenkenbachi* ranged from the lower to upper parts of what he correlated with the Kondel Unterstufe in the Wetteldorfer Richtschnitt. Thus *S. wenkenbachi* is known to occur just below the level usually taken as the top of the Emsian. It may well be that *S. tenuior* and *S. crassior* are from a similar level.

Fauna 'b' is really distinguished by the entry of *G. gracilis* and the distinctions between *G. laevis* and *G. gracilis* formed the basis for the Gracilis–Grenze boundary for the Lower/Middle Devonian boundary suggested at the Bonn/Brussels Symposium (Erben 1962*a*, p. 65). Subsequent work by Walliser (1962) clarified the species of *Gyroceratites* involved, but the relations of these to the *Sellanarcestes*/*Anarcestes* faunas seems poorly documented.

Fauna 'c' suffers from the usual difficulties associated with a zone defined by the absence of a fossil. It is unfortunate that details have not been published to justify this.

Fauna 'd' seems to be based on goniatite records from the type section of the Ballersbacher Kalk near Ballersbach. Records include *A. convolutes* (Sandborger) [*sic.*], *A. lateseptatus* (Bayrich), *A. subtuberculatum* (Sandberger), and *P. jugleri* (Wittekindt 1965, p. 625; Ziegler 1971, p. 29), but this is a collation from the literature, and cannot be taken to represent the goniatite fauna without substantial revision and new collecting, but this fauna presumably forms the basis for Walliser's fauna 'd'. Anomalies include the record of '*A. convolutes*', perhaps referring to *Sobolewia* (?) *convoluta* (G. and F. Sandberger) the type material of which was from Wissenbach, or *Holzapfeloceras convolutum* (Holzapfel) from Ense (and hence perhaps from the Günteröder Kalk). The conodont fauna from the Ballersbacher Kalk at Ballersbach is referred to the *corniger* Zone by Wittekindt (1965). Professor Ziegler informs me that the lowest part of the Ballersbacher Kalk at Ballersbach has yielded *Sellanarcestes wenckenbachi*. Klapper (*in* Ziegler 1971, p. 29) reports that the upper 0·36 m carries 'a typical Nedrow member conodont fauna'. The details of this reduced succession still have to be elucidated.

Fauna 'e' appears to represent the Günteröder Kalk fauna. In the type Ballersbacher Kalk section, overlying shales and thin limestones some 5 m thick comprise the 'Zwischenschichten', the lower part of which was referred to the *bidentatus* Zone, and the upper part to the *kockeliana* Zone by Wittekindt. The earlier portion is supposed to be the source of *W. ruppachense*, *F. occultus*, and *P. jugleri* according to inferred placings in Wittekindt's sequence, and determinations by Walliser (*in* Ziegler 1971, p. 29). This would seem to be a typical Jugleri Zone fauna.

Fauna 'f' marks the entry of a distinct goniatite assemblage and corresponds to the Odershaüser Kalk. From this unit Wittekindt (1965, p. 623) recorded *Cabrieroceras rouvillei*, *Agoniatites inconstans*, and *Maenioceras terebratum*. This is the Crispiforme (or Rouvillei) Zone level taken on the orthochronological ammonoid scale as the base of the Givetian. The *M. terebratum* record is anomalous, and in the absence of any published description or illustration of well-located material, impossible to interpret unless it represents a specimen of the early Givetian *Maenioceras* group in which the early whorls are open and the later ones closed, falsely simulating *M. terebratum*. The fauna of the Odershäuser Kalk was described initially by Holzapfel (1895) and was revised by Correns (1923) who determined *C. rouvillei*, *C. karpinskyi*, *A. costulatus*, *A. urfensis*, *Parodiceras inversum*, and others in the fauna. This is the faunal level which is thought to correspond with the main *Cabrieroceras* horizon of Czechoslovakia, the Montagne Noire, North Africa, Virginia, and the *Werneroceras* Bed of New York.

If the base of the Givetian becomes defined internationally at a level corresponding to the break between faunas 'e' and 'f' it will represent a clear-cut faunal definition in goniatite terms over a very wide area. Among other contenders is the Couvinien/Givetian boundary as it is becoming known in the Belgian type areas. The truth is, of course, that the Belgian sections have been so poorly known faunally that they have not been used as a standard for the last century. In the writer's view, the fact that they have become better known in one or two regards in recent years (notably through the work of Bultynck) is no reason for discarding the established German usage, or invalidating the literature of the last century. Posterity is unlikely to appreciate the confusion which would result.

At present, however, the literature is confused by much circular argument from uncertain data. For example, the interpretation of the Blauer Bruch section is instructive. Here the inferred Ballersbacher Kalk and the inferred Günteröder Kalk occur within a 'Kalkige Zwischenschichten'. Convincing correlation of these lithologies with their type localities elsewhere is not established. Yet, on the assumption that the correlations are correct, and the reasonable evidence on conodont grounds that the fauna of the 'Kalkige Zwischenschichten' agrees with that of both the Couvinien Co2c R/IV and the Junkerberg Schichten of the Eifel (Bultynck 1970), Klapper (1971, p. 60) argues that the *Werneroceras* Bed of New York correlates with the upper Eifelian and upper Couvinien rather than with the lowest Givetian (House 1962). It does seem true that the evidence supports correlation of the New York *Werneroceras* Bed with what in Belgium is taken as upper Couvinien, but it is an assumption only that this is the same as what is taken in the Schiefergebirge as upper Eifelian. Since the *Cabrieroceras* fauna is not described from the Blauer Bruch section, the evidence from that section cannot be relevant to the problem. From a goniatite point of view, it is really only the Odershäuser Kalk at Steinbruch Benner (Wittekindt 1965, p. 625) which appears to be where both conodonts and *Cabrieroceras* are described, and the situation there is not without problems. In the first place, the goniatite records are a little ambiguous, and rather old, as pointed out above. Secondly, the *eiflia* Zone conodonts described by Wittekindt cannot be said to come from the same horizon as the goniatites since they were not collected together. Thirdly, it is not convincingly demonstrated that the 'Zwischenschichten'/Odershäuser Kalk boundary is a simple one so that diachroneity cannot be ruled out. Finally, in view of the lack of a continuous section from the highest Eifelian to the upper Middle Devonian anywhere in the Schiefergebirge (Ziegler 1971, p. 12), the matter is hardly likely to be resolved there. But the practice in the Schiefergebirge has been to take the base of the Givet Stufe at the base of the Odershäuser Kalk, and at the entry of the '*C. rouvillei*' fauna. Further work is needed to establish whether this level really does correspond with the entry of *eiflia* Zone conodonts.

The point of this discussion has largely been to show that the conodont evidence cannot at present be taken to preclude the approximate contemporaneity of the *C. plebeiforme/crispiforme* occurrence of New York, Virginia, North Africa, and the Schiefergebirge. There are general grounds why that postulation should be looked at critically however. First, the assumption that *Cabrieroceras* evolved rather suddenly from *Werneroceras* is not supported by the detailed ontogenetic and phylogenetic study the matter deserves. Secondly, the occurrence of a band of strata characterized by a particular goniatite over very wide areas, is not in itself any proof of contemporaneity (although the possibility of *post mortem* drifting in this case may make it more reasonable). Thirdly, the absence of record in eastern North America of the preceding faunas with *Pinacites* and *Werneroceras* (s.s.) might be taken to indicate a change in faunal distribution pattern at about the boundary which might disturb the order of appearance.

Czechoslovakia. The sequence of goniatites in the Devonian of Czechoslovakia is known almost wholly from the revisions of Chlupáč (1957, 1959, 1960, 1968, 1976*a*, *b*; Chlupáč and Turek 1977) for the Lower and Middle Devonian generally, and by Erben (1962*b*, 1964, 1965) especially for the Lower Devonian. The sequence which results is as follows: youngest beds given above.

Sbskro Beds: *Cabrieroceras crispiforme*, *Agoniatites costulatus*, *A. holzapfeli*, *A. fulguralis*, *A. obliquus*, *A. nodiferus*, *Maenioceras* cf. *molarium*, *Holzapfeloceras* sp., ?*Sobolewia* sp., *Kokenia tenuissima*.

Choteč Beds: *Pinacites jugleri*, *P. eminens*, *Foordites occultus*, *F. pinguior*.

Třebetov Beds: *Gyroceratites gracilis*, *Paraphyllites tabuloides*, *P. amoenus*, *Mimagoniatites bohemicus*, *M. fecundus*, *Anarcestes lateseptatus plebeius*, *A. praecursor*, *Latanarcestes neglectus*, *Sellanarcestes* sp., *Pseudobactrites bicarinatus*.

Daleje Beds: *Gyroceratites gracilis*, *G. laevis*, *Mimagoniatites fecundus*, *Paraphyllites amoenus*, *Convoluticeras discordans*, *Bojobactrites ammonitans*, *Pseudobactrites bicarinatus*.

Zlíchov Beds: *Mimosphinctes zlichovense*, *Mimagoniatites fecundus*, *Anetoceras* cf. *hunsrueckianum*, *Palaeogoniatites lituus*, *Convoluticeras discordans*, *Caeleceras praematurum*, *Gyroceratites* cf. *laevis*, *Pseudobactrites bicarinatus*.

The Zlíchovian includes the Zlíchov Beds and perhaps transitional beds above. The Dalejan embraces both the Daleje Beds and Třebetov Beds. The records show that *Anetoceras*, *Palaeogoniatites*, and *Mimagoniatites* enter earliest in the Zlíchov Beds. Chlupáč (1976*a*) has confirmed that the horizon of *Celaeceras* is the Zlíchov, the type locality at Svagerka suggesting the upper part which yields most goniatites. The *Anetoceras* fauna compares well with that of Morocco and other areas. Noticeable rarities in the Czech record include the mimosphinctids, which are known in the Harz, Spain, and North Africa, and also the *Sellanarcestes* group, but it will be noticed that the order of appearance *Anetoceras*, then *Mimosphinctes*, then *Sellanarcestes* reflects the German zonation (text-fig. 12). Carls *et al.* (1972) have argued that the Zlíchov/Daleje Beds boundary corresponds to the German lower/upper Emsian boundary, and they take the base of the Eifel-Stufe at the base of the Lauch Beds of the Eifel which they consider to fall within the Třebetov Beds. Location of *Sellanarcestes* in the Třebetov has helped this correlation.

The Choteč Beds fauna corresponds well with the German fauna 'e' and hence with the *Foordites buttsi* horizons of the Appalachians.

It is the fauna of the early Sbskro (particularly the basal Kačák level) which shows close analogies with the Odershäuser Kalk fauna, and with the *Cabrieroceras*-bearing beds in Morocco. Apart from the *Maenioceras* and *Sobolewia* (?) records this is true also of the *Werneroceras* Bed and Cherry Valley Limestone in New York, if the Czech names are taken, not at their face value, but in terms of the morphology the names imply.

In summary, therefore, any recommendation on levels to be used for the definition of the Lower/Middle Devonian, Emsian/Eifelian, and Emsian/Couvinian boundaries using goniatites cannot but confirm the established German practice and usage notwithstanding the fact that, as for all groups, further detailed work might clarify the matter. That these boundaries may not match the poorly known sections in southern Belgium, and the supposed 'type' sections there, should not be used to discard a framework which has been the foundation for biostratigraphic work for many groups in central Europe, and which has formed the basis for correlation in other continents for most of this century.

Late Middle Devonian and early Upper Devonian

Apart from the absence of certain genera, above the level of the *Werneroceras* Bed in New York, reasonably close affinity occurs in the goniatite faunas of eastern North America with those of the Old World up to the early Famennian when the American record becomes sparse (House 1962, 1973*b*). Detailed consideration of the relations of the bulk of the New York Frasnian equivalents must await the publication of a restudy of the fauna. This account concentrates therefore on the sequence up to about the equivalents of the Genundewa.

North Africa. In Petter's general account of the Saharan goniatites in 1959, little biostratigraphic record was given, and the faunas were compared with the established zonal sequence in Germany rather than forming the basis for the critical establishment of an independent North African succession. This has now to some extent been remedied by the carefully collected record of Hollard (1974) and those of Bensaïd (1973, 1974), the last providing substantially new information.

In his more general review of the goniatite succession in the Tafilalt and Ma'der, Hollard (1974) records *Maenioceras*, *Wedekindella*, and *Agoniatites* at several localities above the main *Cabrieroceras* levels, and refers the localities to the Givetian. At Bou-Dib he records *M. excavatum* (Phillips), using an invalid homonym for the form named by Whidborne (1889, p. 64) as *Goniatites molarius*, that is, the zonal index *M. molarium*, forms conforming to which occur in Virginia (fauna 6 above). Rather higher he records *M. terebratum*, confirming the sequence known elsewhere, but these faunas have not been illustrated or described.

The detailed study by Bensaïd (1974) is a significant contribution to the elucidation of the goniatite sequence about the Middle/Upper Devonian boundary. Combining these new faunas with those already mentioned, the sequence given in the previous section may be extended upwards as follows:

13. *Manticoceras* spp., *Beloceras* cf. *sagittarium* (G. and F. Sandberger), *Neomanticoceras* sp.
12. *Pharciceras applanatum* Bensaïd, *P. kseirense* Petter, *P. taouzense* G. and F. Termier, *Pseudoprobeloceras nebechense* Bensaïd, *Petteroceras errans* (Petter), *Synpharciceras clavilobum* (G. and F. Sandberger), *Beloceras* (?) *disciforme* Bensaïd.
11. *Atlantoceras tataense* Bensaïd, *Maenioceras crassum* Bensaïd, *Keonenites juvenocostata* (Bensaïd), *Pharciceras tridens* (G. and F. Sandberger).
10. *Maenioceras sulcatostriatum* Bensaïd, *M. terebratum* (G. and F. Sandberger).
9. *Maenioceras terebratum* (G. and F. Sandberger), *M. sulcatostriatum* Bensaïd, *Wedekindella brilonense lata* Bensaïd, *Tornoceras* (*T.*) *simplex* (von Buch).
8. *Tornoceras* (*T.*) *simplex* (von Buch), *T.* (*T.*) *westfalicum* (Holzapfel), *Wedekindella brilonense lata* Bensaïd.
7. *Maenioceras* cf. *molarium* (Whidborne), *Wedekindella* sp. *Tornoceras* sp.

Faunas 8–11 Bensaïd described from Oued Mzerreb, and faunas 12 and 13 from Hassi Nebech, and he uses the boundary suggested between them to divide the Frasnian Iα into two faunas, Iα_1 and Iα_2. The boundary between the Middle and Upper Devonian he takes between faunas 10 and 11, that is at the entry of multilobed *Koenenites* and *Pharciceras*. The overlap in range recorded of *Maenioceras* and *Pharciceras* is interesting, but since the latter is thought to have been derived from the former, a population showing both is not unexpected. It is the entry of new forms which marks the main faunal break.

In this sequence there appears to be a gap between faunas 12 and 13. This is the level where the main *Ponticeras* development is to be expected, but Petter (1959) recorded the typical German species, under the name *Probeloceras*, in several localities in the Sahara, so they may either be locally absent, or as yet undetected.

England. The faunas from south-west England comprise assemblages from separate localities, but since the variety of genera represented is great, especially in Middle Devonian, it is appropriate to list these for comparison. Whilst some revisions and additions are given, essentially these faunas have been listed previously by House (1963).

D. *Manticoceras* cf. *intumescens* (Beyrich), *M. cordatum* (G. and F. Sandberger), *Beloceras sagittarium* (G. and F. Sandberger) from Lower Dunscombe.
C. *Koenenites* sp., *Probeloceras forcipiferum* (G. and F. Sandberger), *Tornoceras* (*T.*) sp. nov. from Staverton Wood.
B. *Maenioceras terebratum* (G. and F. Sandberger), *Wedekindella brilonense* (Kayser), *Wedekindella* aff. *brilonense* (Kayser), *Cabrieroceras karpinskyi* (Holzapfel), *Holzapfeloceras* aff. *circumflexiferum* (G. and F. Sandberger), *Sobolewia* aff. *nuciforme* (Whidborne), *Agoniatites costulatus* (d'Archiac and de Verneuil), *Tornoceras* (*T.*) aff. *uniangulare* (Conrad), '*Protornoceras*' *foxi* House, *Aulatornoceras* aff. *sandbergeri* (Foord and Crick) from Trevone and Portquin.
A. *Maenioceras molarium* (Whidborne) and the varieties *apertum* and *intermedium*, *Maenioceras* aff. *decheni* (Kayser), *Agoniatites transitorius* (Phillips), *A. obliquus* (Whidborne), *Wedekindella psittacina* (Whidborne), *Sobolewia nuciforme* (Whidborne), *Tornoceras* (*T.*) sp. from Wolborough.

The faunal distinction between 'B' and 'C' has been taken to mark the Middle/Upper Devonian break. Noteworthy here is the clear distinction of the Molarium Zone ('A'), recognized widely elsewhere under the invalid or junior synonyms of *M. molarium*, *undulatum*, and *excavatum*. At present the *Ponticeras* level is not adequately recognized in south-west England unless it is by the small forms referred to the genus from North Cornwall (Gauss and House 1972).

Germany. Although Germany is regarded as the classic area for the definition of the Devonian ammonoid zones, much revision is still required. In particular most published work has related to the reduced successions of the cephalopodenkalk facies in which precise stratigraphical discrimination is very difficult. Nevertheless for the interval here considered the works of Holzapfel (1882, 1895), and Wedekind (1913*a*, 1917) are fundamental. From the level of the mid Frasnian type Büdesheimer faunas (Clausen 1968, 1969) upwards to the top Famennian, the goniatite sequence is documented in considerable detail, and no comment on that is necessary here. The sequence actually around the contender levels for a Middle/Upper Devonian boundary is not so well described although the fundamental faunal change at the base of the Adorfian, to 1α or Lunulicosta Zone has long been recognized.

The German faunas are very rich and varied, and it serves the present purpose only to list the genera characteristic of the faunal divisions rather than the species involved. For the Upper Maenioceras Stufe, or Terebratum Zone, none of the genera listed are known in the Schiefergebirge to range higher, but all occur earlier in the Middle Devonian, and the Terebratum Zone faunas are really distinguished by characteristic species. For the divisions of the Manticoceras Stufe, those given for the Lunulicosta Zone are, with one exception (*Ponticeras*), diagnostic of the zone, and are not known to occur in the zones above or below. Detailed records of the biostratigraphical occurrence of these are mostly not available. The genera listed for the Cordatum Zone are not known earlier, although several range higher.

Manticoceras Stufe (Iβ/γ), Cordatum Zone
Linguatornoceras, *Lobotornoceras*, ?*Sandbergeroceras*, *Polonoceras*, *Archoceras* (s.s.), *Maternoceras*, *Manticoceras*, *Timanoceras*, *Carinoceras*, *Neomanticoceras*, *Mesobeloceras*, and *Beloceras*.

Manticoceras Stufe (Iα), Lunulicosta Zone.
Epitornoceras, *Pharciceras*, *Synpharciceras*, *Neopharciceras*, *Triainoceras*, *Ponticeras*, *Timanites*, *Koenenites*, and *Hoeninghausia*.

Upper Maenioceras Stufe, Terebratum Zone
Foordites, *Holzapfeloceras*, *Sobolewia*, *Maenioceras*, *Cabrieroceras*, *Werneroceras*, *Agoniatites*, and *Sellagoniatites*.

In a collaborative work with Professor W. Ziegler, the goniatite sequence at Adorf is being restudied, and a more detailed sequence, especially for the Lunulicosta Zone and early Cordatum Zone has now been described (House and Ziegler 1977). The data given above seem unlikely to be changed.

Several factors deserve comment. The Adorf succession, and others of the more goniatite-rich localities of the Schiefergebirge, are extremely reduced. The Adorf succession shows evidence of disconformities within the succession. These successions cannot even be compared for stratigraphical precision with, for example, the New York State sequence, where incredibly precise stratigraphical discrimination is possible. The most precise statements are still those of Wedekind (1913*b*, 1917) and

Matern (1929, 1931), but the faunas from Adorf are still only imprecisely known in relation to the actual beds exposed there. It is to solve this relation that current work is directed. It is already clear that the level taken by conodont workers on the evidence of Paeckelmann (1928) as the Iα and Iβ limestones are misnomers. In part of the succession at Adorf the Iα faunas range well below the so-called Iα limestone, and the Iβ faunas extend above the so-called Iβ limestone. In truth there has been no published justification for these names and they should be discarded as misleading. They have been the cause of the misalignment of the conodont and goniatite zonation which has caused so much confusion over the last fifteen years.

Now the base of Iα, and the sudden introduction of the distinctive Lunulicosta Zone goniatites, has formed the definition of the base of the Adorfian and of the Upper Devonian in the usage consistently adopted in Germany for many years. Essentially this was first very clearly stated by Denckmann (1900, 1901) but there is an older history too. It is to this definition that the biostratigraphical scales using corals, ostracods, and trilobites has been linked. It will be apparent that this level can be fixed in New York if the entry there of *Pharciceras* following the loss of *Agoniatites* is accepted as being the same faunal break (House 1962).

It is still uncertain where in the sequence of southern Belgium and northern France this break occurs. It was previously argued that this lay near the base of the Assise de Fromelennes, but following the recent work on the conodonts of the Assise de Fromelennes by Bultynck (1974) it may lie rather a little above the base, but the evidence is far from clear. However, the Belgian sections have not provided the biostratigraphical scales for other invertebrate groups which have been used internationally, and have, in practice, been of little help in other areas.

Recently (Bouckaert *et al.* 1971) there has been a change in Belgian usage, and an attempt to raise the definition of the Givetian/Frasnian boundary from the base of the Assise de Fromelennes (as used in all standard works on the Belgian Devonian, including the *Lexique* (Waterlot 1957), the *Prodrome* (Fourmarier 1954), and the definitive contributions to the *Calgary Symposium* (Lecompte 1968)) to a level at the base of the Assise de Frasnes (House 1973*a*). Judging by the poor ammonoid evidence (Mouravieff and Bouckaert 1973) and by the new evidence of the relations between the goniatite and conodont scales at Adorf, this boundary must be near the base of the Cordatum Zone, very much higher than any boundary ever used in Germany. In New York the horizon would be near the level of the Genundewa. Recent arguments on the assignment of the Tully (Cooper 1968) have all been based on the assumption of a lower boundary either below the West Brook Member of the Tully (House 1962) or at the base of the Genesee (Cooper 1968), both boundaries which would appear to fall within the lower half of the Assise de Fromelennes, and substantially below the level of the base of the Assise de Frasnes.

SYSTEMATIC DESCRIPTIONS

Suborder AGONIATITINA
Family AGONIATITIDAE Holzapfel, 1899
Genus AGONIATITES Meek, 1877

Type species by original designation *Goniatites expansus* Vanuxem (1842, p. 146, text-fig. 1) (= *G. vanuxemi* Hall 1879, p. 43).

The sequence of agoniatitids in the Middle Devonian of New York and adjacent states is in need of systematic and statistical study. There seems no other area in the world which provides such a detailed succession for this type of analysis. Here only a few notes are given on the sequence. Two forms from equivalents of the Onondaga Limestone are described, and an account is given of a specimen from the Middle Devonian of Nevada.

The outline of a sequence of agoniatitids which is emerging may be summarized as follows (text-fig. 4). The earliest forms found in eastern North America (for example, *A. oliveri* and *Agoniatites* aff. *bicanaliculatus* here described) tend to have slowly expanding whorls and they contrast with those from higher levels in not attaining a large size. Above this, from the *Cabrieroceras*-bearing level at Catawba, is the form referred to here as *A. vanuxemi* subsp. nov. (Pl. 5, figs. 4, 7, 8), an elegant agoniatitid with distinctive doubly lirate growth lines and with no trace of the lateral nodes which characterize *A. nodiferus* Hall from an horizon inferred to be slightly younger from the shales between the *Werneroceras* Bed and the Cherry Valley Limestone in New York (Rickard 1952). Either the presence of nodes or early coarse ribbing distinguishes *A. floweri* Miller (1938, p. 45, pl. 11, figs. 1, 2), *A. vanuxemi* (Hall), and *A. intermedius* Flower (1936, p. 346, pl. 23, fig. 11), all from the overlying Cherry Valley Limestone. Following an earlier suggestion (House 1962, p. 254) the 'species' *floweri*, *nodiferus*, and *intermedius* are probably best regarded as subspecies of *A. vanuxemi* until detailed work on them has been undertaken. Yet another variant, with even coarser ribs on the early whorls than any seen on the types of *A. vanuxemi* which have been examined (AMNH 4416, NYSM 3541–3543), is shown on a specimen (NYSM 12007) from the Cherry Valley Limestone which Professor J. W. Wells has recently sent (Pl. 9, fig. 13). It is too premature to comment on the agoniatitids higher in the Hamilton to which the name *A. vanuxemi* has been applied. As remarked earlier, *Goniatites unilobatus* Hall should probably be referred to *Agoniatites* rather than *Sellagoniatites*.

Agoniatites aff. *bicanaliculatus* (G. Sandberger)

Plate 2, figs. 8, 9

aff. 1851 *Goniatites bicanaliculatus* G. Sandberger, pp. 295, 297, 304, pl. 2, figs. 5, 15; pl. 3, fig. 28.
aff. 1851 *Goniatites bicanaliculatus* G. and F. Sandberger, p. 112, pl. 11, figs. 5*a*–*q*, 6*a*–*f*.

Material. A single laterally crushed internal mould of a phragmocone and early part of a body chamber preserved in grey siltstone (USNM 186166).

Description. Shell form at 13·6 mm diameter indicates a laterally compressed form with flat venter, ventro-lateral furrows with two spiral grooves, and whorls with deep impressed depth and with an open umbilicus. Body chamber and last few camerae show a very weak coarse ribbing on the surface which forms a broad sinus on the flanks and projects sharply orad into the ventro-lateral furrow. Suture with a ventral lobe small and narrow, and a lateral lobe which occupies the whole of the flank.

Remarks. Although crushed, it is clear that the impressed depth is real and hence, despite similarities of ornament with species of *Gyroceratites* (Walliser 1962), the species should be referred to *Agoniatites*. One of the original specimens figured by the Sandberger brothers is reillustrated here (Pl. 2, figs. 10, 11) and it will be seen that this example has a more rotund whorl section, and also that the ventral lobe forms a large and broad V rather than the small lobe shown by the Fagg specimen.

Material and Horizon. Specimen collected by W. D. Lowry and students from the Needmore Shale, about 1·5–3 m above the Huntersville Chert, from a roadside section at Fagg, 8 km (5 miles) east of Blacksburg, West Virginia.

Agoniatites aff. *kayseri* Wedekind

Plate 2, figs. 6, 7

aff. 1917 *Agoniatites kayseri* Wedekind, p. 110, text-fig. 21*c*, pl. 15, fig. 10.
. 1968 *Agoniatites* sp. nov., House, p. 1066.

Material. One silicified and well-preserved specimen (USNM 239851) showing part of the phragmocone and body chamber, and some other fragments which may belong to the same form.

Dimensions.

	D	WW	WH	Wh	UW
USNM 239851	27·7	10·3	17·1	*c.* 10·0	2·3
	16·9	6·6	9·6	*c.* 6·2	*c.* 1·9

Description. Shell form laterally compressed with well-rounded venter and slender whorl outline. Ventro-lateral furrow on the outside of the silicified shell shows double grooves at about 11 mm diameter, but later there is a single groove which continues to the outermost whorl seen but gets progressively weaker. Otherwise there is no trace of ornament and the course of any growth lines is not seen. Suture typically agoniatitid, but the ventral lobe has not been seen. Dorsal lobe deep and broadly rounded.

Remarks. Had more material been available there might have been justification for a new specific name for this form since the quality of preservation is quite exceptional. There are several described species of *Agoniatites* which are similarly slender and smooth surfaced. *A. phillipsi* Wedekind (1917 p. 112, pl. 16, fig. 1) has a wider umbilicus and no ventro-lateral groove. The larger species, *A. roemeri* (Holzapfel 1882, p. 234, pl. 45 (2), fig. 1), differs in the same characters. *A. kayseri* Wedekind (1917, p. 110, text-fig. 21*c*, pl. 15, fig. 10), the holotype of which is refigured here (Pl. 2, figs. 4, 5), is an internal mould, and has similar proportions to the Nevada specimen, but does not show ventro-lateral furrows, at least, not on the internal mould (the dimensions of the holotype of *A. kayseri* are: D = 47·5; WW = 16·0; WH = 26·0; Wh = *c.* 18·0; UW = *c.* 5·0).

Horizon and Locality. Collected by A. J. Boucot and H. K. Erben from the Nevada Formation in the southern Roberts Mountains, Nevada, from an elevation of 2633 m (8640 feet) on the eastern slope of a saddle 152 m (500 feet) north of Hill 8788, approximately 4·8 km (3 miles) west and 4·8 km (3 miles) north of Roberts Creek Ranch, T. 22 N, R. 50 E, Eureka County. See later comments on the horizon under *Cabrieroceras* aff. *plebeiforme*.

Agoniatites oliveri House sp. nov.

Plate 1, figs. 3–7

Material. The Holotype (USNM 239873 figured Pl. 1, figs. 3, 4) and thirty-nine specimens assigned to, or conforming with, the species (USNM 239866–239872, 239874–239878) preserved in grey, yellow, or green mudrock. All the material has been laterally crushed and in some specimens there has been other distortion so that the figures given below are approximate.

Dimensions.

	D	WW	WH	Wh	UW
USNM 239873 (Holotype)	33·2	—	14·5	—	10·6
	16·5	—	7·5	4·7	4·8

Description. The innermost whorls are seen in several specimens (USNM 239866, 239867, 239869–239871) but the protoconch form cannot be discerned. However, even at diameters as little as 5 mm there is a clear impressed depth. Subsequently there is a slow increase in the spire radius. Whorl form over the flanks inferred to be flatly convex and with a weakly developed ventro-lateral furrow. The venter, which seems rounded in the early whorls, is flat or flatly rounded in the largest diameters seen, and the pattern of crushing (for example in USNM 239877, Pl. 1, fig. 6) suggests that the whorl width, at 32 mm diameter, must substantially have exceeded half the whorl height.

At about 5 mm diameter (USNM 239869) raised rectiradiate disjunct lirae cross the flanks and they number about seventeen in a quarter whorl. Later the internal moulds show flexuous biconvex growth lines, sometimes periodically strengthened on the lower flanks, which form a weak salient on the umbilical slopes, and a broad rounded lateral sinus from which the growth lines pass strongly forward to a salient on the ventro-lateral shoulder. Several specimens (Pl. 1, figs. 3, 4 and Pl. 10, fig. 1; the latter is referred to *Agoniatites* cf. *oliveri*) show that the growth line ornament of outer whorls takes the form of disjunct lirae as in the earlier stages.

Remarks. So many of the described species of *Agoniatites* are incompletely known that it is unfortunate that this one is not represented by better material. It seems distinct from previously named forms in the regular and slow expansion of the whorls, the more widely open umbilicus, the absence of ribbing, and the characteristic ornament of growth line lirae. Since the species is so widespread in the early Needmore Shale of the Appalachians it is useful for it to be given a name. It has still to be located in the New York succession.

Horizon and locality. USNM 239873 (the Holotype), 239874*a*, *b* (three specimens) collected by W. A. Oliver Jr. from the Needmore Shale at the Oriskany glass sand quarry, Berkeley Springs, West Virginia, one specimen (USNM 239873) of which is from the upper and two are from the middle zone of J. C. Brower. USNM 239875, 239876*a–c* (four specimens) collected by J. C. Brower from the middle zone of the Needmore Shale at Saumsville, north-east of Winchester, Virginia. USNM 239869–239872*a–u*, 239877, 239878 (twenty-six specimens) from the Needmore Shale exposed low in a quarry on the west side of Route 259 on the south-east side of Baker Mountain, West Virginia. USNM 2398566, 2398567, 2398568*a–c* (five specimens) from a level in the Needmore Shale about 29 m above the Oriskany Sandstone exposed beside a track east of O'Neill Gap, west of E. R. Taylor's farmstead, Mineral County, West Virginia. USNM 239879, 239898 (two specimens) from the lower 12 m above the base of the Needmore Shale in a quarry 90 m south-east of Back Creek, beside Route 522, 1·1 km (0·7 miles) north-west of Gainsboro, Frederick County, Virginia.

Suborder ANARCESTINA
Family ANARCESTIDAE Steinmann, 1890
Genus ANARCESTES Mojsisovics, 1882

Type species by subsequent designation of Foord and Crick (1897, p. 38) *Goniatites plebeius* Barrande.

The sole specimen from New York described below belongs to a type which should be referred to a new genus. The typical representatives of *Anarcestes*, such as *A. plebeius* and *A. lateseptatus* are all widely umbilicate. The *A. praecursor* group, on the other hand, has an umbilicus which is very much more closed, giving the shell quite a different appearance. But the type material of *A. praecursor* (designated by Frech 1897, p. 169 as Barrande 1865, pl. 5, figs. 1–5; pl. 7, figs. 3–9; pl. 30*a*, fig. 9), which has been examined at the Narodni Museum, Prague, is neither well prepared, nor very well localized, and contains a variety of forms, and is at present unsuitable for designation as the type of a genus until further work has been undertaken on it. Material from elsewhere is either poorly preserved, or, as in the case of the New York specimen, lacking meaningful stratigraphical relationship with standard successions. The specimen figured as *A. praecursor* by Bogoslovski (1969, p. 154, pl. 5, fig. 1*a*, *b*) may not belong to the species. For the present, therefore, *Anarcestes* is interpreted in the traditional broad sense.

Anarcestes cf. *praecursor* Frech

Plate 2, figs. 1–3

cf. 1865 *Goniatites plebeius* Barrande (pars), pl. 7, figs. 3, 4, ?5–8.
cf. 1897 *Anarcestes praecursor* Frech, p. 169.
cf. 1963 *Anarcestes* (*Latanarcestes*) cf. *praecursor* House *in* House and Pedder, p. 513, pl. 74, fig. 3.

Material. A single specimen (USNM 62950) preserved as an internal mould in yellow fine sandstone comprising part of a phragmocone and part of a body chamber. Measurements approximate.

Dimensions.

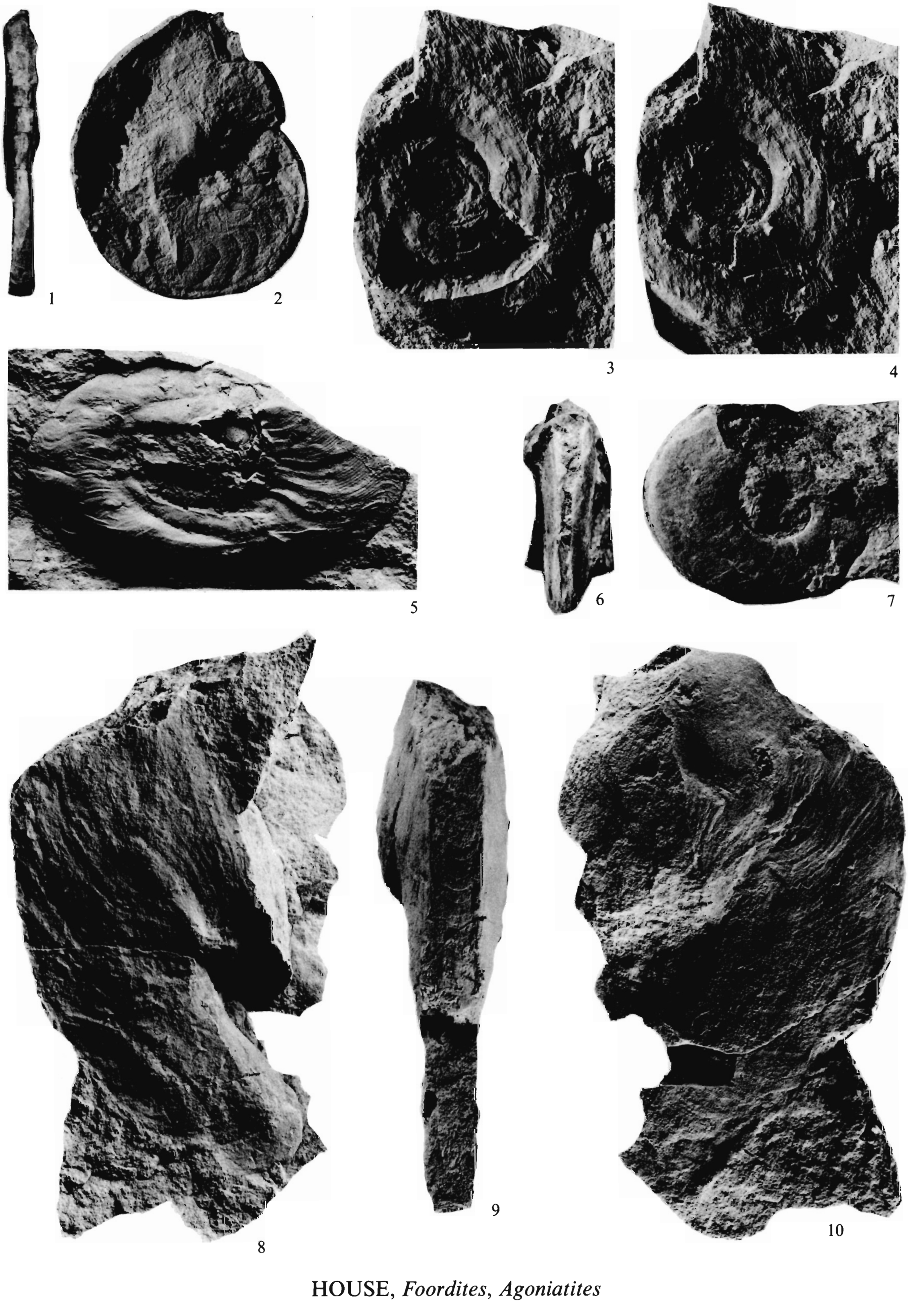
	D	WW	WH	UW
USNM 62950	48·5	19·0	25·0	*c*. 9·8
	22·3	11·0	10·5	4·2

EXPLANATION OF PLATE 1

Figs. 1, 2. *Foordites* sp. Specimen from the Needmore Shale about 130 feet above the local Oriskany Sandstone in a section beside a track east of O'Neill Gap, east of Keyser, West Virginia. USNM 239897, × 1.

Figs. 3–7. *Agoniatites oliveri* House sp. nov. Specimens from the Needmore Shale of Virginia and West Virginia. 3, 4, the Holotype after and before development collected by Dr. W. A. Oliver Jr. from near Berkeley Springs, West Virginia, USNM 239873, × 1·5. 5, Paratype from near Saumsville, Virginia, collected by J. C. Brower, USNM 239875, × 1. 6, 7, paratype from near Capon Lake, West Virginia, USNM 239877, × 1.

Figs. 8–10. *Foordites* cf. *filifer* (Spriesterbach). Specimen from the Buttermilk Falls Formation, 0·7 miles east of Oak Grove, Pennsylvania, USNM 5867-SD (No. 5867), × 1.



HOUSE, *Foordites*, *Agoniatites*

Description. No trace of the shell or surface ornament is preserved. The body chamber shows a well-rounded umbilical wall with flanks convexly converging to a broadly rounded venter. The inner whorl shows a more rotund and rounded whorl section although it is crushed and falsely appears oxyconic owing to this distortion. Poor traces of the suture are seen. The dorsal suture shows on top of the preceding whorl as having a somewhat rectilinear, broad, dorsal lobe. The ventral suture is only seen near the umbilical wall where it passes from a saddle centred on the seam rursiradiately across the lower flanks.

Remarks. This is the earliest goniatite known in eastern North America if the age and locality details are correct. These rest on the impeccable reputation of H. S. Williams. In a previous discussion (House and Pedder 1968) comments on the horizon represented by Barrande's types were given in the light of Chlupáč's revision of the Czech sequence. If the source was from the Třebetov Limestone, then, following Carls *et al.* (1972), the horizon would be regarded as Emsian. But the New York specimen is more slender in cross-section than the specimens of Barrande thought here to be best taken to typify the species.

Horizon and locality. The specimen label records USNM 62950 as having been collected by H. S. Williams from the Oriskany of central New York, and the lithology would support this. On the other hand, W. A. Oliver Jr. and G. Klapper have pointed out in discussion that similar sandstones occur between the Oriskany and early Onondaga in New York and that these younger horizons cannot be entirely ruled out as a source.

Genus CABRIEROCERAS Bogoslovski, 1958

Type species by original designation *Goniatites rouvillei* von Koenen, 1886 (= *G. crispiforme* Kayser, 1879).

Cabrieroceras was distinguished by Bogoslovski (1958, p. 73) from *Werneroceras* because of the wider and more regularly expanding umbilicus and the simpler suture, and the name has been widely used in Europe and North Africa since being introduced. It is argued earlier that specimens from Morocco and Algeria referred to *W. ruppachense ougarta* Petter (1959, p. 101) should probably not be placed in *Cabrieroceras*, and thus defined *Cabrieroceras* becomes diagnostic for the Givetian since it is not known above the Terebratum Zone.

There are several names available for material of the genus. *C. rouvillei* (von Koenen 1886, p. 166, illustrated by Rouville 1887, pl. 7, fig. 6) from the Montagne

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EXPLANATION OF PLATE 2

Figs. 1–3. *Anarcestes* cf. *praecursor* (Frech). Labelled by H. S. Williams 'Oriskany, central New York', USNM 62950, ×1.

Figs. 4, 5. *Agoniatites kayseri* Wedekind. Holotype figured by Wedekind (1917, pl. 15, fig. 10) from the Wissenbacher Schiefer, Wissenbach, Germany. Geol. Pal. Inst. Göttingen, ×1.

Figs. 6, 7. *Agoniatites* aff. *kayseri* Wedekind. Specimen from the Nevada Formation, Roberts Mountains, Nevada. USNM 239851, ×1·3.

Figs. 8, 9. *Agoniatites* aff. *bicanaliculatus* (G. Sandberger). Specimen collected by Dr. W. D. Lowry and students from the Needmore Shale at Fagg, Virginia. USNM 186166, ×3.

Figs. 10, 11. *Agoniatites bicanaliculatus* (G. Sandberger). Specimen figured by G. and F. Sandberger (1851, pl. 11, fig. 5, 5*a*) from the Wissenbacher Schiefer, Wissenbach, Germany. Wies. Mus., ×1.

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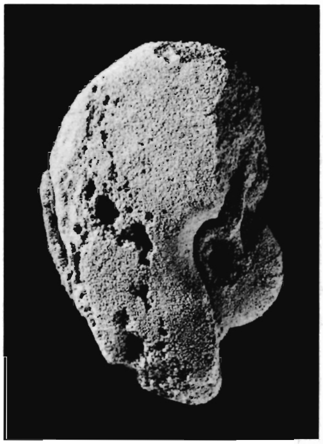

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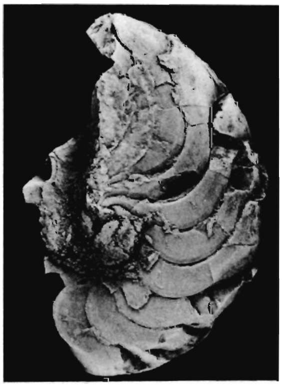

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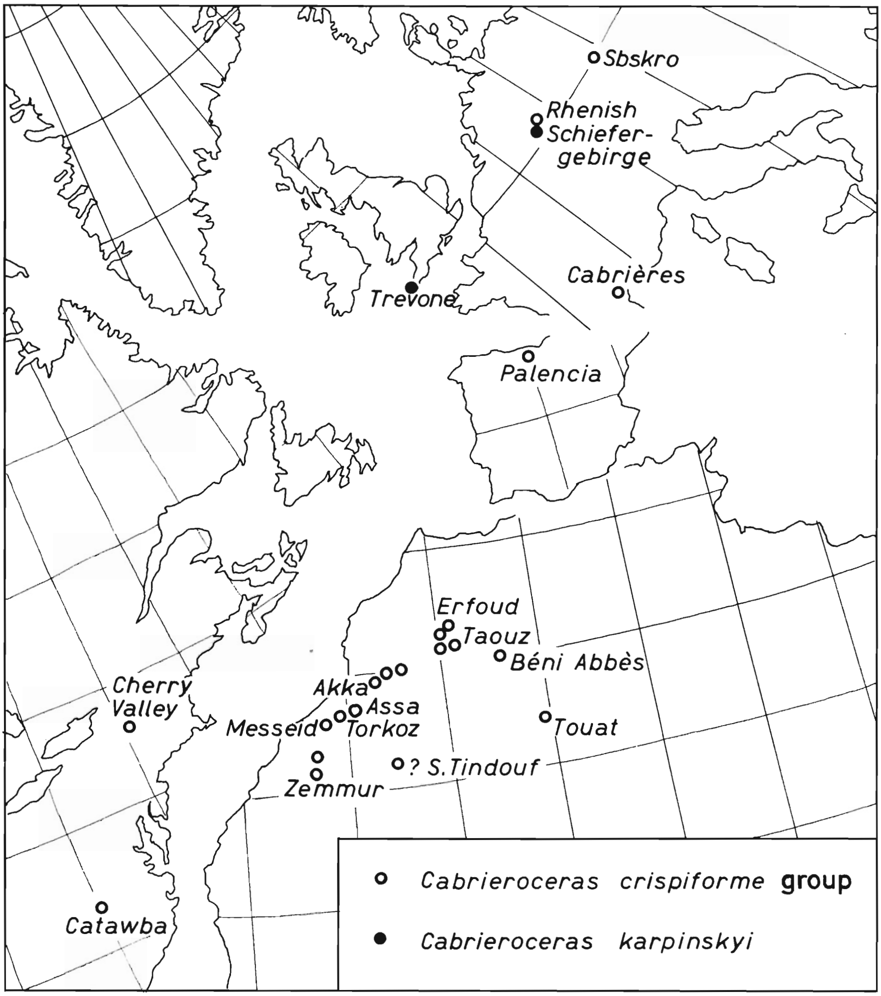
HOUSE, *Anarcestes*, *Agoniatites*

Noire is poorly preserved, but has usually been regarded as a junior synonym of *C. crispiforme* (Kayser 1879, p. 301), the holotype of which came from Schönecken near Prüm, in the Eifel: this specimen is refigured here (Pl. 4, figs. 11, 12). The name *C. crispiforme* has been widely used for the Odershäuser Kalk form, usually taken to mark the early Givetian in the Schiefergebirge, and also in Czechoslovakia (Chlupáč 1976, p. 304). Either as *C. rouvillei* or *C. crispiforme* similar types have been taken to mark the early Givetian in North Africa. There seems no clear way of distinguishing either of these from *C. plebeiforme* (Hall 1879, p. 448) from the New York *Werneroceras* Bed (House 1962) which is thought to be the level of material here described from Virginia. Both *C. plebeiforme* and *C. crispiforme* were named in the same year, and which has priority has not yet been established. However, for present purposes,



TEXT-FIG. 5. Map showing the distribution of records of Middle Devonian *Cabrieroceras* faunas using a convenient reconstruction.

it seems best to use the American name for the forms here described since the stratigraphical placing is more precise than that of the European type material and, with the descriptions given here, the species is far better known.

There is remarkable agreement between the *Cabrieroceras*-bearing level in North Africa and that in eastern North America, and the abundance of the genus at a restricted stratigraphical level makes it likely that they are broadly contemporaneous. This is also the conclusion reached by Burton and Eldredge (1974) based upon their contained trilobite faunas. A map has been prepared (text-fig. 5) showing the distribution of *Cabrieroceras* in Europe, North Africa, and eastern North America. In Czechoslovakia, Germany, and North Africa this fauna of *C. crispiforme* is widely taken to identify the basal Givetian, but international agreement on this is not established. The precise stratigraphical discrimination which is possible in New York should make that succession a serious contender for an international stratotype definition.

At present the only name used for species of *Cabrieroceras* from higher levels in the Givetian is *C. karpinskyi* (Holzapfel 1895, p. 77) but no lectotype has been designated, and the type material is from at least two levels, the Odershäuser Kalk and the ironstone at Martenberg, only the latter being late Givetian in age.

Cabrieroceras plebeiforme (Hall)

Plate 3, figs. 1–12; text-figs. 6, 7*c*

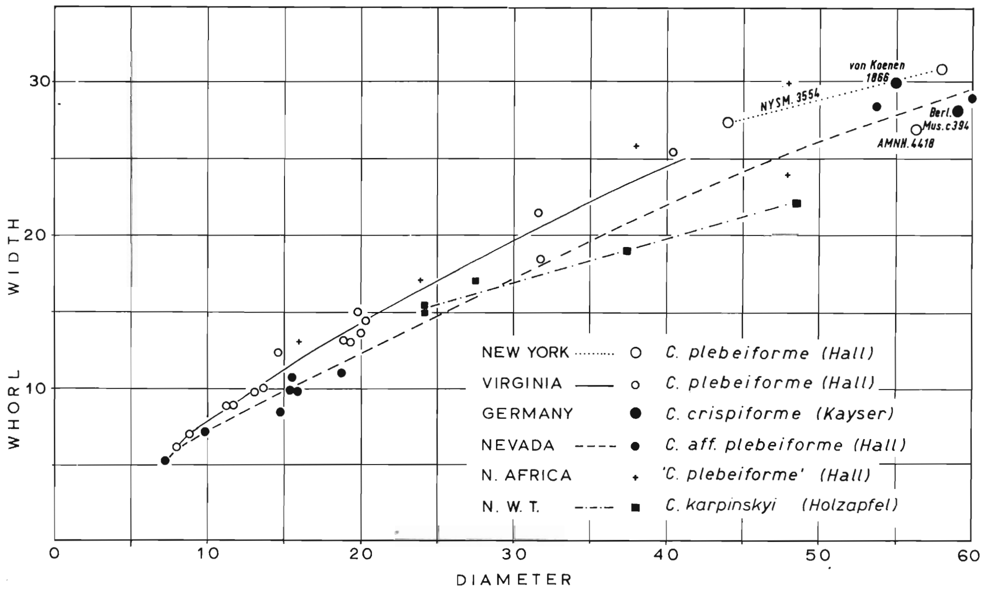
1876 *Porcellia ?rotataria* Hall, p. 16, figs. 25, 26.
1879 *Goniatites plebeiforme* Hall, p. 448, pl. 16, figs. 25, 26; pl. 110, figs. 3–9.
1933 *Werneroceras plebeiforme* Schindewolf, p. 98.
1938 *Werneroceras plebeiforme* Miller, p. 58, pl. 5, figs. 1–6, text-figs. 8, 9.
1962 *Cabrieroceras plebeiforme* House, p. 253, text-fig. 3A, B.
1968 *Cabrieroceras plebeiforme* House, p. 1064.

Material. Twenty-two specimens (USNM 186137–186157, 186161) preserved as barytic shell replacements or crystalline barytic moulds.

Dimensions.

	D max	D	WW	UW
USNM 186137	8·85	8·8	7·0	4·2
USNM 186138	*c.* 8·8	7·9	6·1	3·5
USNM 186139	12·6	11·6	8·9	6·4
USNM 186140	13·4	11·2	8·8	5·8
USNM 186141	13·0	11·2	*c.* 8·8	5·2
USNM 186142	14·8	13·6	*c.* 10·0	6·4
USNM 186143	16·6	14·6	12·3	6·7
USNM 186144	17·4	13·1	9·7	6·6
USNM 186145	18·9	18·8	13·1	9·5
USNM 186146	19·4	19·3	13·0	9·7
USNM 186147	20·0	20·0	13·6	9·3
USNM 186148	20·6	19·8	15·0	10·5
USNM 186149	24·5	20·3	14·4	10·0
USNM 186150	37·0	31·6	*c.* 21·5	15·8
USNM 186151	*c.* 36·0	31·8	18·4	*c.* 16·8
USNM 186152	52·7	40·4	25·5	19·6

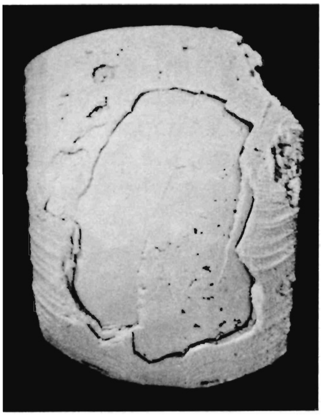
Description. Shell form cadiconic from earliest size seen (7·8 mm USNM 186137), but more ammoniticonic in the first whorl, after which proportions become regular. Whorl form very depressed, reniform up to 40 mm diameter, at which, and later, the whorl height/whorl width ratio increases (USNM 186161) (text-fig. 6). Ornament consists of raised, finely spaced lirae, rursiradiate across the umbilical wall, forming a shallow sinus on the outer portion of the broad venter (where the lirae become subdued), passing forwards to a ventro-lateral salient which is weakly associated with a shallow incipient groove, and passing sharply back to a deep ventral sinus. Nodes develop on the umbilical wall in later whorls and become more prominent on the adult body chamber. Dorsal wrinkle layer well developed on most specimens (text-fig. 7*c*) and seen between 7 and 45 mm diameters formed on top of the preceding whorls. The course is slightly prorsiradiate or rursiradiate from the umbical seam, and is composed of irregular fine discontinuous ridges varying in length from 0·1 mm to ridges which extend continuously over the venter. Frequency from 4 to 6 ridges per mm. The course becomes rectiradiate on the mid venter. The wrinkle layer is



TEXT-FIG. 6. Graph showing dimensions of *Cabrieroceras* specimens from various localities and including the type material of *C. plebeiforme* (Hall) (AMNH 4418), *C. rouvillei* (von Koenen 1886), and *C. crispiforme* (Kayser) (Berl. Mus. c. 394). For details see text.

EXPLANATION OF PLATE 3

Figs. 1–12. *Cabrieroceras plebeiforme* (Hall). Specimens from the Millboro Shale in a quarry on the south side of Route 311 on the south-eastern slopes of Catawba Mountain, west of Salem, Virginia, collected by Mr. S. Croy. 1, 2, USNM 186139, ×3. 3, 5, 12, USNM 186146; 3, 5, ×2, 12, ×4. 4, 6, 7, USNM 186143; 4, ×6, 6, 7, ×2. 8, 9, USNM 186137, ×3. 10, 11, USNM 186156, ×1.



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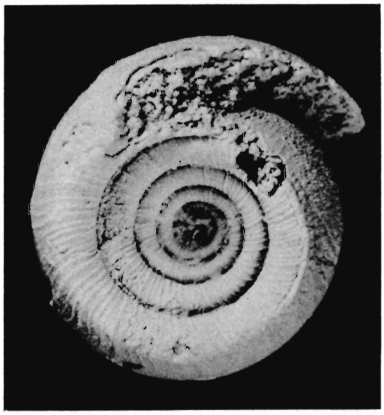

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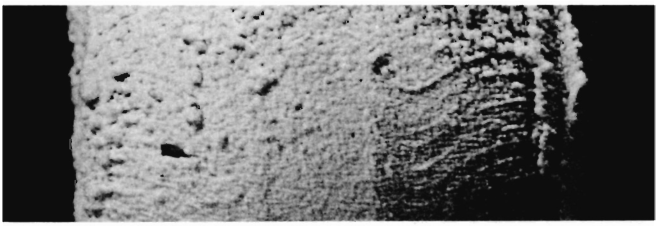

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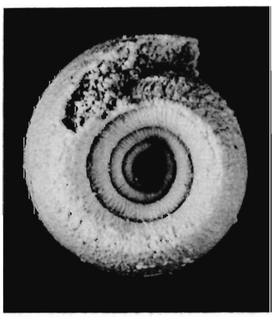

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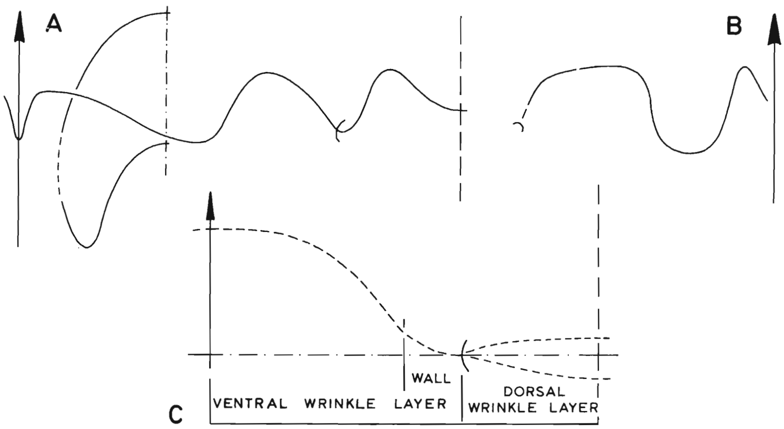
HOUSE, *Cabrieroceras*

seen to pass continuously into the ventral wrinkle layer (USNM 186141) where the course passes forward to form a broad salient centred on the mid venter (on the inside of the replaced shell). The suture consists throughout of a V-shaped ventral lobe, the suture passing almost rectilinearly towards a saddle on the umbilical shoulder and thence to a weak lobe on the umbilical wall. The dorsal lobe is broad and shallow.



TEXT-FIG. 7. Illustrations of *Holzapfeloceras*, *Epitornoceras*, and *Cabrieroceras*. A, *H. croyi* House sp. nov., whorl section, and suture (composite drawing) at about 14 mm diameter based on the Holotype, USNM 186160, from the lower part of the Millboro Shale in a quarry on the south-eastern slopes of Catawba Mountain, Virginia, ×3. B, *E. aff. peracutum* (Hall). Suture based on USNM 186052 from near Landes Post Office, West Virginia, ×1·33. C, *C. plebeiforme* (Hall). Course of the wrinkle layer mainly based on USNM 186149 from the lower part of the Millboro Shale in a quarry on the south-eastern slopes of Catawba Mountain, Virginia, ×3.

Remarks. The measurements given here give more detail of this species than is known for the European material. What comparisons can be made with other material is illustrated in text-fig. 6. It should be borne in mind that Old World material is mostly represented by internal moulds, and that from Virginia and Nevada by shells replaced either by silica or barytes the measurements of which refer to the outside of the shell. The close agreement of the Virginia material to that from New York is the basis for the firm specific assignment to the New York species. The consistent trend to a lower whorl width to diameter ratio for the Nevada and North West Territories is the main reason for giving those other assignments.

Horizon and locality. The best material (USNM 186137–186157, 186161) was found by Mr. S. Croy of Vinton, Virginia, in a quarry on the south side of Virginia Route 311, on the south-eastern slope of Catawba Mountain, at an horizon considered by Tillman (*in* Lowry *et al.* 1971, p. 47) to be 'in the lower part of the Millboro [Shale] possibly no more than 100–200 feet [30·5–61·0 m] above the Huntersville Chert'.

Cabrieroceras aff. *plebeiforme* (Hall)

Plate 4, figs. 1–8, 13, 14

1965*b* *Cabrieroceras* aff. *crispiforme* (Kayser) House, p. 339, pl. 32, figs. 1, 3–5.
1968 *Cabrieroceras* aff. *crispiforme* House, p. 1066.

Material. Twenty specimens (USNM Loc. 10807, 239853–239863, 239864*a–d*, 239865*a–c*, 240499) mostly preserved as siliceous shell replacements in a micritic matrix, many incomplete. Early whorls are included in a small group of nucleii (USNM Loc. 10807) from the same locality, and there are two further poorly preserved specimens (USNM 240499).

Dimensions.

	D max	D	WW	UW
USNM 239853	20·0	58·0	*c.* 29·0	28·8
USNM 239854	—	53·7	28·4	26·8
USNM 239855	19·7	15·8	9·8	7·4
USNM 239856	—	15·4	10·8	7·7
USNM 239857	—	14·7	8·5	7·1
USNM 239858	—	12·8	9·3	6·2
USNM 239859	—	9·8	7·2	4·8
USNM 239860	—	7·2	5·3	2·8

Description. Shell form cadiconic in earliest whorls measurable (USNM 239860). General subsequent shell proportions indicated in text-fig. 6. Whorl form depressed through ontogeny but the venter becomes more highly arched, and the whorl height/whorl width ratio increases in the outer whorls of the largest specimens seen. Ornament of fine raised lirae seen on the umbilical walls is slightly rursiradiate in the early whorls but becomes more markedly so later in one specimen (USNM 239861, Pl. 4, fig. 2) in which there are periodic bullate nodes. But no signs of nodes are seen on the larger specimens available. The suture (seen on USNM 239856, Pl. 4, fig. 8) shows a small but deep ventral lobe; the lateral suture slopes forward to a saddle centred on the umbilical shoulder, and then back to a small, rounded lobe on the umbilical wall. The dorsal suture forms a broad and shallow lobe between the seams.

Remarks. This fauna enables a description given earlier (House 1965*b*) to be complemented. The earlier material (UCLA W28–59) was from the same locality, but only three specimens in the middle-size range were present. The course of the growth-line striae now appears to be a less reliable character than supposed earlier now that more material has been examined. The fauna differs from the Virginian fauna described here especially in the whorl width/diameter ontogenetic pattern (text-fig. 6), the whorl width being systematically lower for a given diameter. Also there is no evidence for the development of umbilical nodes in the outer whorls as is seen both on Virginian and New York specimens of *C. plebeiforme*.

The question now arises—what is the distinction, if any, which can be made with *C. karpinskyi* (Holzapfel 1895, p. 77, pl. 3, figs. 15–20), a cotype of which was figured by House and Pedder (1963, pl. 72, figs. 5, 6, 8). Statistical data of the specimens from the North West Territories is included in text-fig. 6, and illustrates how the whorl width/diameter ratio is yet lower again. Furthermore, the later whorls of forms referred to *C. karpinskyi* approach WW = WH. On balance, therefore, the Nevadan specimens seem closer to *C. plebeiforme*, but have some characteristics of *C. karpinskyi*. The fauna thus may be slightly younger than the *Werneroceras* Bed level. In the absence of maenioceratids in the fauna no more precise placing within the Givetian can be suggested.

Horizon and locality. This collection was assembled by H. K. Erben and A. J. Boucot in 1965 (USNM Loc. 10807). The locality was given as the same as that for the earlier fauna (House 1965), that is, from the Nevada Formation about midway in the section between the '*Stringocephalus*' level above and the '*Spirifer* *pinyonensis*' Zone below, from an elevation of 2633 m (8640 feet) on the eastern slope of a saddle 152 m (500 feet) north of Hill 8788, approximately 4·8 km (3 miles) west and 4·8 km (3 miles) north of Roberts Creek Ranch, T. 22 N, R. 50 E, southern Roberts Mountains (Roberts Creek Mountains Quadrangle), Eureka County, Nevada. The *Eurekospirifer pinyonensis* Zone is referred by Johnson (1970, p. 59) to the Emsian, and in present terminology it falls within the McColley Canyon Formation (Johnson 1971, p. 304). The *Cabrieoroceras* fauna occurs within the overlying Denay Limestone in the lower *Warrenella kirki* Zone. Johnson supports the reference of this level to the Givetian on the basis of brachiopod and conodont evidence (loc. cit.).

Family PINACITIDAE Hyatt, 1900

This family at present has been taken to include a rather miscellaneous group of primitive goniatites in which the adult lateral lobe is derived during ontogeny from an early subumbilical lobe and which possess one or two adult umbilical lobes and a mid dorsal lobe (in some with a median saddle developing within it). *Pinacites*, the name-giver, is rather distinct from other members and is best restricted to oxyconic forms with small umbilici and angular saddles. Bogoslovski's (1958, p. 64) reference of *Maenioceras* to a separate family seems well accepted.

There is some confusion surrounding the genera *Parodicerellum*, *Foordites*, *Wedekindella*, and *Holzapfeloceras*. Only the first three were recognized by Bogoslovski (1969, pp. 175, 6), and with *Pinacites*, *Wedekindella*, and *Pseudofoordites* these comprised the genera he referred to the family (Hyatt's spelling as Pinnacitidae was corrected by Schindewolf (1933), but the family authorship remains Hyatt's (Hyatt *in* Zittel-Eastman 1900, p. 550) rather than Schindewolf's as given by Bogoslovski).

Parodicerellum Strand (1929, p. 9) was proposed as a replacement genus for *Parodiceras* Wedekind (1917, pp. 107, 115) which was preoccupied by *Parodiceras* Hyatt (1884, p. 319). Hence, under Article 67(i) of the *Code*, the type species must be *P. brilonense* Kayser as clearly designated by Wedekind (1917), that is, *Goniatites retrosus* var. *brilonensis* Kayser (1872, p. 664, pl. 25, fig. 2*a*–*e*; the holotype was refigured by House and Pedder 1963, pl. 73, fig. 2). But Schindewolf (1928, p. 311) had already proposed *Wedekindella* as a replacement for *Parodiceras* Wedekind. Therefore *Parodicerellum* is an objective junior synonym of *Wedekindella* and is not available as a genus in the way that Bogoslovski (1969, p. 175) has used it.

This leaves the genera *Foordites* Wedekind (1917, p. 113: type species by original designation *Aphyllites occultus platypleura* Frech, 1889, p. 242, the original figures to which this referred are reillustrated here in text-fig. 8) and *Holzapfeloceras* (Miller 1932, p. 330: type species by original designation *Tornoceras convolutum* Holzapfel,

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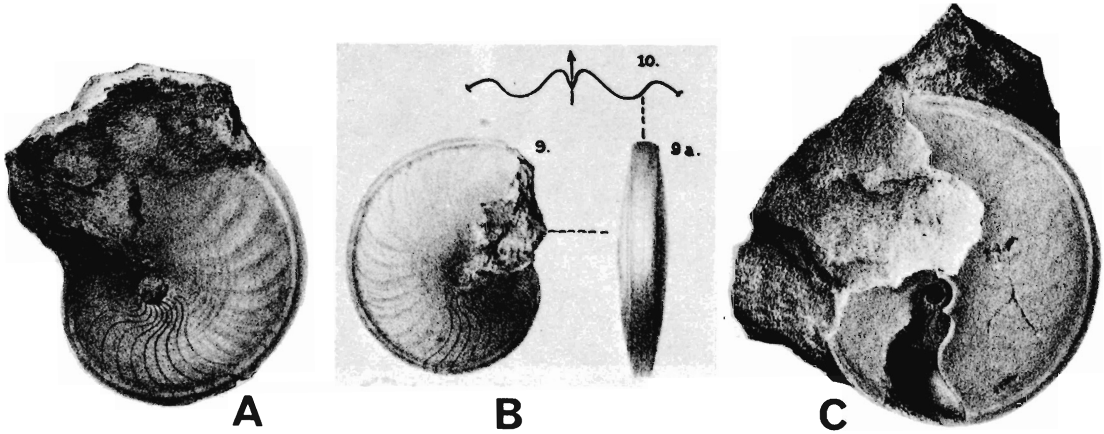
EXPLANATION OF PLATE 4

Figs. 1–8, 13, 14. *Cabrieroceras* aff. *plebeiforme* (Hall). All from the Nevada Formation, southern Roberts Mountain, Nevada. 1, 2, USNM 239861, ×1·5. 3, 4, USNM 239854, ×2. 5, 6, USNM 239858, ×2. 7, 8, USNM 239856, ×1·5. 13, 14, USNM 239857, ×1·5.

Figs. 9, 10. ?*Sobolewia* sp. From the same locality and horizon. USNM 239852, ×1.

Figs. 11, 12. *Cabrieroceras crispiforme* (Kayser). Holotype figured by Kayser (1879, pl. 5, fig. 1) from Schönecken, Eifel, Germany. Specimen prepared by Professor O. H. Walliser. Berl. Mus. c. 394, ×1.

HOUSE, *Cabrieroceras*, ?*Sobolewia*



TEXT-FIG. 8. *Foordites platypleura* (Frech). Reproductions of the type figures designated by Frech. A, Kayser 1884, pl. 5, fig. 8. B, Kayser 1884, pl. 5, figs. 9, 10 (both from Grube Langsheid). C, Kayser 1884, pl. 6, fig. 10 (from Grumbacher Teich).

1895, p. 88, pl. 4, figs. 1–3: one of Holzapfel's specimens is refigured here, Pl. 9, figs. 11, 12, and this specimen is designated lectotype of the species). The sutural characteristics of *Foordites* and *Holzapfeloceras* were shown to be similar by Schindewolf (1933, pp. 99–103) and both show a migration of the early subumbilical lobe to a lateral position in the adult, thus often producing homoeomorphy with *Tornoceras* (Schindewolf 1933; Petter 1955).

Species included within *Foordites* are typically laterally compressed, flat-sided, with a narrowly rounded or tabular venter and, in the type species, with ventrolateral furrows. *Holzapfeloceras* includes species which are subglobular to well rounded, with small umbilici and often with ventro-lateral furrows. Few would put great weight on this distinction, especially since the types of *Holzapfeloceras* are small and possibly immature. *Holzapfeloceras* and *Foordites* may therefore be regarded as generically distinct (following Schindewolf) or regarded as synonyms (as did Petter 1955). It seems, however, that the goniatites which are similar to the type species of *Foordites* are restricted to the late Anarcestes Stufe (or approximately late Eifelian), particularly those which also have small latero-umbilical lobes. It may, therefore, be useful to continue to recognize the distinction since it may have stratigraphical value.

Genus FOORDITES Wedekind, 1917

Type species by original designation *Aphyllites occultus platypleura* Frech 1889, p. 242, *nom. nov. pro* Kayser 1884, pl. 5, figs. 8–10; pl. 6, fig. 10: reillustrated here in text-fig. 8.

Foordites buttsi (Miller)

1938 *Tornoceras* (*Tornoceras*) *buttsi* Miller pp. 147, 148, text-fig. 31, pl. 33, fig. 1.
1940 *Tornoceras buttsi* Butts, p. 305.
cf. 1956*b* *Tornoceras* cf. *T. buttsi* Oliver, p. 404, text-fig. 1*a*, *b*.
1962 *Foordites buttsi* House, p. 253.
1964 *Foordites buttsi* Rickard (chart).
1968 *Foordites buttsi* House, p. 1064.

Material. The holotype (USNM 92247). Specimen crushed flat, composed of styliolinid-rich shale.

Description. Only a few additional notes need complement the account given by Miller (1938, p. 147). The holotype is 65 mm in diameter with an open umbilicus about 6 mm wide. The body chamber occupies about the last one-sixth whorl. The suture shows a small V-shaped ventral lobe, a forwardly projecting narrow ventro-lateral saddle, a broad and rounded lateral lobe, and an arched latero-umbilical saddle which is narrow and asymmetric; the earlier sutures seen (at 48 mm diameter) show a sub-triangular form of this saddle, but it is seen to become more rounded and symmetrical. The last sutures are approximated.

Remarks. The type species of the genus has a much smaller latero-umbilical saddle, but otherwise there is reasonable agreement in shell form so far as the crushed Virginian specimen allows comparison. Petter noted a general resemblance between this species and *F. djemeli* Petter (1955), but her material was mostly smaller although one specimen at a diameter of 40 mm had an umbilical width of 4 mm.

Much material has been referred to *Foordites* from Virginia and West Virginia in a preceding section, but none of this is particularly well preserved. One specimen (Pl. 1, figs. 1, 2) seems to have had a tabular venter.

Horizon and locality. The holotype is from a highway cut 1·6 km (one mile) south of Newcastle, Virginia. It was recorded as from the Onondaga, but this would refer to the Needmore Shale in present terminology.

Foordites cf. *filifer* (Spriesterbach)

Plate 1, figs. 8–10

cf. 1935 *Paraphyllites filifer* Spriesterbach, p. 521, pl. 50, figs. 2, 3.

Remarks. The single specimen available (USNM 5867-SD) is illustrated sufficiently well for description to be unnecessary. It is very close indeed to Spriesterbach's figures, but the subumbilical lobe is not convincingly shown, and this may be due to distortion. Spriesterbach referred his specimen to the genus *Paraphyllites*, but the type species of that genus, *Goniatites tabuloides* Barrande (1865, p. 34, pl. 4, figs. 1–12) shows a narrowly rounded venter rather than a clearly tabular venter. It is thought here to agree better with the type material of *Foordites*, and it conforms with the late Eifelian group with a reduced latero-umbilical saddle.

Horizon and locality. The specimen, USNM 5867-SD (No. 5867) collected by Dr. W. A. Oliver Jr. from 1·1 km (0·7 miles) east of Oak Grove, and 12·8 km (8 miles) north-east of East Stroudsberg, on Route U.S. 209, Bushkill Quadrangle, Pennsylvania, from the upper, non-cherty part of the Buttermilk Falls (upper 15–18 m) and a metre or so above a bed with *Eodevonaria.*

Genus HOLZAPFELOCERAS Miller, 1932

Type species by original designation *T. convolutum* Holzapfel 1895.

This genus is used here to comprise species close to *Foordites* but with a well-rounded, often subglobular outline, with a smaller umbilicus, usually without ventro-lateral furrows, and with a larger latero-umbilical saddle. The type material of two poorly illustrated German species is illustrated here, that is, the type species *H. convolutum* (Pl. 6, figs. 1, 2) and *H. denckmanni* (Holzapfel) (Pl. 9, figs. 1, 2, 11, 12). In view of the growth line pattern, reference of the latter to *Sobolewia* seems mistaken.

Holzapfeloceras croyi House sp. nov.

Plate 5, figs. 2, 3, 5, 6; Plate 6, figs. 5, 6; text-fig. 7A

Material. Four specimens (USNM 186158–186160, 186162) preserved as barytic replacements, only one (USNM 186162) including part of the body chamber. USNM 186160 (figured Pl. 5, figs. 5, 6) is designated holotype.

Dimensions.

	D	WW	WH	Wh
USNM 186159	18·8	9·3	11·9	4·9
USNM 186158	18·3	—	10·4	*c.* 6·0
USNM 186160 (Holotype)	14·0	7·7	8·2	4·6
USNM 186162	12·6	—	7·3	3·2
	8·9	5·2	—	—

Description. Involute with closed umbilicus, venter well rounded with ovate cross-section (text-fig. 7A) and maximum width low on the flanks. No evidence of surface ornament. Suture (text-fig. 7A) with a narrow V-shaped ventral lobe, a narrow ventro-lateral saddle passing steeply down to a rounded V-shaped lateral lobe at about the mid flanks: latero-umbilical saddle highly arched, slightly asymmetrical. Dorsal suture with a deep dorsal lobe and an arched asymmetrical subumbilical saddle: umbilical lobe centred on the seam. The holotype (USNM 186160) shows sutural approximation.

Remarks. Critical ontogenetic evidence is lacking, and the reference to *Holzapfeloceras*, rather than *Tornoceras* is based on the distinctive form of the suture, especially of the latero-umbilical saddle. But, as will be seen from comparison with the type species, *H. convolutum* (Pl. 6, figs. 1, 2), it differs in several respects from the type species, and also forms such as *H. denckmanni* (Pl. 9, figs. 11, 12) which are referred to *Holzapfeloceras*, rather than *Sobolewia* because of their well-developed biconvex growth lines.

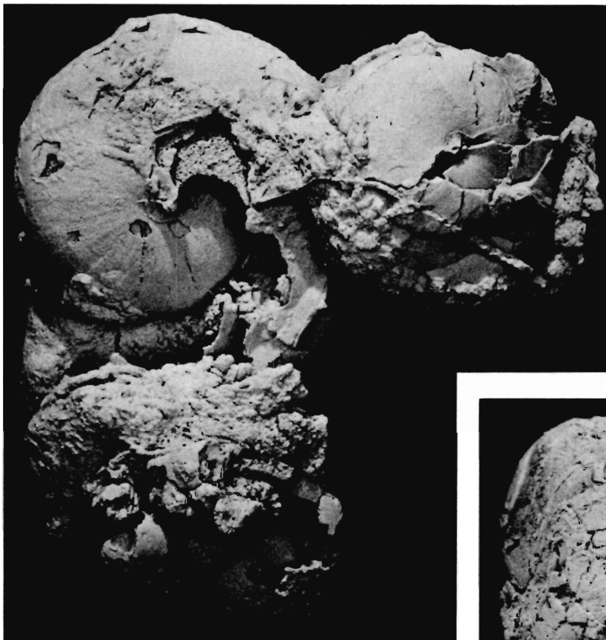
Horizon and locality. These specimens were found by Mr. Croy of Vinton, Virginia, in a quarry on the south side of Virginia Route 311 on the south-eastern slope of Catawba Mountain. The horizon is considered by Tillman (*in* Lowry *et al.* 1971, p. 47) to be in the lower part of the Millboro [Shale] possibly no more than 30–61 m above the Huntersville Chert.

EXPLANATION OF PLATE 5

Figs. 1, 8. *Parodiceras discoideum* (Hall). Two (upper) specimens in a block from the Millboro Shale in a quarry on the south-eastern slopes of Catawba Mountain on the south side of Route 311, west of Salem, Virginia, collected by Mr. S. Croy. USNM 186152, ×1.

Figs. 2, 3, 5, 6. *Holzapfeloceras croyi* House sp. nov. From the same locality and horizon. 2, 3, USNM 186159, ×2. 5, 6, the Holotype, USNM 186160, ×3.

Figs. 4, 7, 8. *Agoniatites vanuxemi* subsp. nov. From the same block as fig. 1. USNM 186152. 4, ×2·5. 7, 8, ×1.



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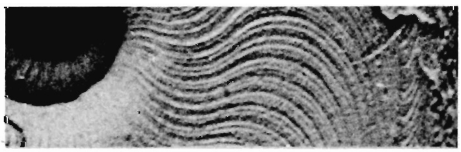

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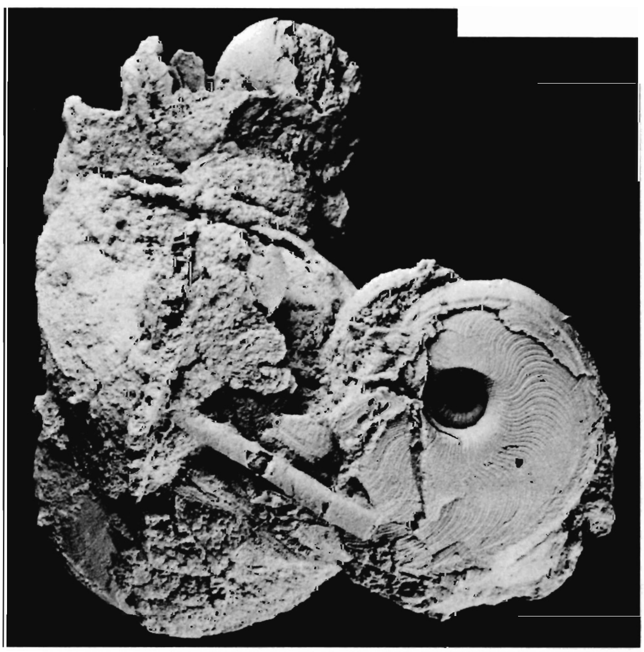

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HOUSE, *Parodiceras*, *Holzapfeloceras*, *Agoniatites*

Family PROLOBITIDAE Wedekind, 1913*a*
Genus SOBOLEWIA, Wedekind, 1917

Type species by original designation (Wedekind, 1917, p. 155) *Goniatites cancellata* d'Archiac and de Verneuil (1842, p. 339, pl. 25, fig. 6*a*, *b*).

The placing of *Sobolewia* in the Prolobitidae unites this genus with genera otherwise known only from the early Famennian. There are no morphological criteria which would justify separation, but the absence of any record from the intervening Frasnian is surprising.

?*Sobolewia* sp.

Plate 4, figs. 9, 10

Material. A single specimen (USNM 239852) with part of the body chamber and phragmocone preserved.

Dimensions.

	D	WW	WH	Wh	UW
USNM 239852	38·3	25·0	*c.* 17·7	8·4	*c.* 7·3

Remarks. The limited characteristics of the specimen may be seen from the photographs. Growth lines form a narrowly rounded sinus on the outer part of the umbilical shoulder. Evidence on the flanks suggests that the major growth-line pattern is convex. These observations do not enable ready comparison with the known species of *Sobolewia* discussed by Schmidt (1950) and House (1962), but the general proportions of the cross-section are not unlike those of the specimen figured as *Sobolenia* aff. *denckmanni* by Schmidt (1950, fig. 5*b*), particularly in the open umbilicus. But at least one of the original specimens of *G. denckmanni* (Holzapfel 1895, pl. 3, fig. 24*b*, that is, Berl. Mus. c. 347) differs in showing ventro-lateral furrows, strongly biconvex growth lines at 19 mm diameter, and a closed umbilicus: it is here referred to *Holzapfeloceras*.

Material and horizon. From the same horizon and locality as *Cabrieroceras* aff. *plebeiforme* given above.

EXPLANATION OF PLATE 6

Figs. 1, 2. *Holzapfeloceras convolutum* (Holzapfel). Specimen figured by Holzapfel (1895, pl. 4, fig. 2*a*, *b*) here designated Lectotype. From Ense, near Wildungen, Germany, Berl. Mus. c. 351, ×3.

Figs. 3, 4. ?*Pharciceras galeatum* Wedekind. Specimen collected by Dr. K. O. Hasson from near Landes Post Office, West Virginia. USNM 186054, ×1·5.

Figs. 5, 6. *Holzapfeloceras croyi* House sp. nov. From the lower part of the Millboro Shale in a quarry on the south side of Route 311 on the south-eastern slopes of Catawba Mountain, west of Salem, Virginia, collected by Mr. S. Croy. USNM 186158, ×3.

Figs. 7, 8, 11, 12. *Epitornoceras* aff. *peracutum* (Hall). Specimen collected by Dr. K. O. Hasson from a locality near Landes Post Office, West Virginia. USNM 186052, ×1.

Figs. 9, 10. *Tornoceras* (*T.*) cf. *baldisi* Leanza. Specimen collected loose, perhaps from the Sicasica Formation or possibly Collpacuchu Formation, at Chacoma, La Paz Province, Bolivia. USNM 239899, ×2.


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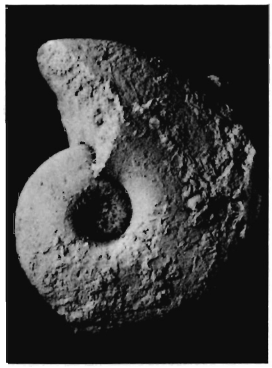
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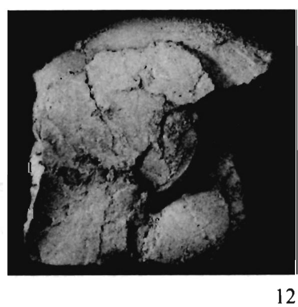
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HOUSE, Devonian Ammonoids

Suborder GEPHUROCERATINA
Family GEPHUROCERATIDAE Frech, 1897
Genus MANTICOCERAS Hyatt, 1884

Type species by original designation *Goniatites simulator* Hall 1874, p. 2; 1876, pl. 69, figs. 1, 2; pl. 74, fig. 8.

?*Manticoceras* sp.

Plate 9, figs. 6, 7; text-fig. 11D

Material. Three specimens (USNM 240492, 240493, 240498) preserved in dark grey styliolinid limestone with phragmocone partially preserved in crystalline calcite.

Dimensions.

	D	WW	WH	Wh	UW	R
USNM 240492	22·7	6·8	10·2	8·6	4·2	13·4
	14·9	5·1	7·1	5·0	—	9·2
USNM 240493	15·8	5·3	7·3	—	4·4	—

Description. Laterally compressed, open umbilicate form with slender whorl section with maximum whorl width low on the flanks which converge convexly towards a well-rounded venter. Growth lines pass orad across the umbilical slopes to a salient low of the flanks and thence pass convexly apicad to a broad-rounded sinus on the flanks and to a rounded salient on the outer flanks and to a deep ventral sinus. Suture as illustrated in text-fig. 11D.

Remarks. This material seems too slender to be the inner whorls of *Koenenites* which occurs in approximately the same level. Reference to *Manticoceras* depends on the presence of an umbilical lobe and on the course of the growth lines, but the dorsal suture has not been seen.

Horizon and locality. Both specimens are from a concretion in the Harrell Shale on the west side of U.S. Route 220, 198 m south of a small bridge 6·6 km (4·1 miles) south of Landes Post Office, West Virginia. Two other specimens (USNM 239890*a*, *b*) from a cutting 3 km (1·9 miles) south of Landes Post Office may belong here also.

Genus PROBELOCERAS Clarke, 1898

Type species by original designation *Goniatites lutheri* Clarke (1885, p. 50, pl. 2, fig. 8).

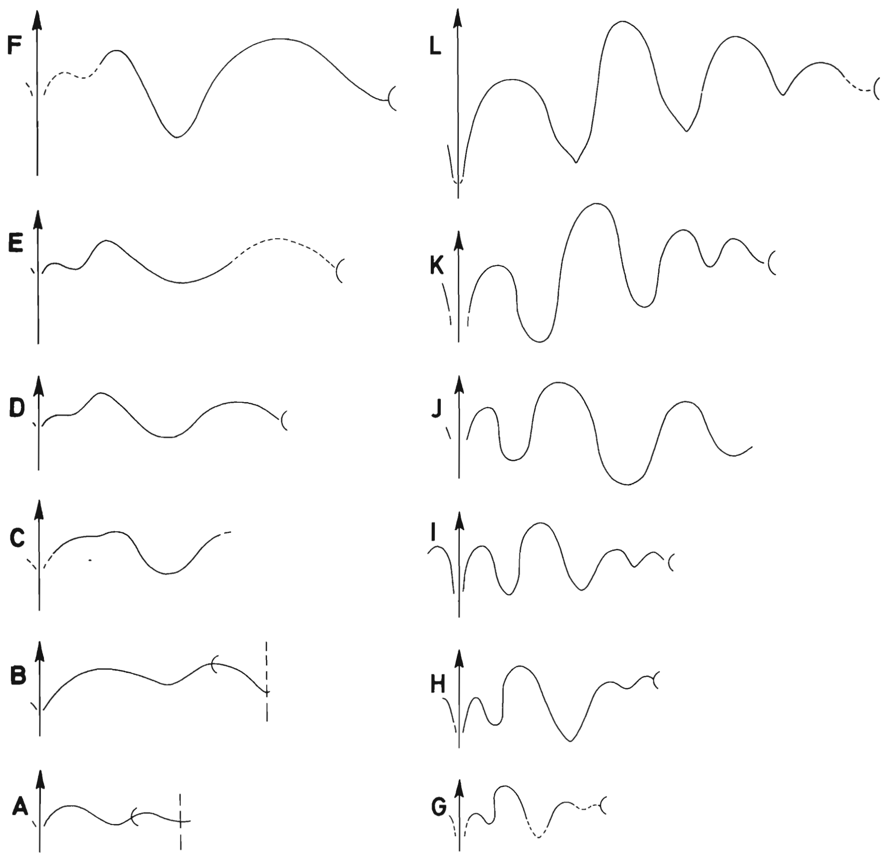
A detailed review of the New York Frasnian representatives of this genus has been given by Kirchgasser (1975). It should be noted that Kirchgasser, in locating the original specimen on which Clarke based the type species, has shown that *Probeloceras lutheri* as used by Clarke in 1898 is a distinct species for which he has coined the name *P. strix* (the type species of *Eidoprobeloceras* Kirchgasser, 1968, a genus now considered a synonym of *Probeloceras*).

Probeloceras cf. *genundewa* (Clarke)

Plate 8, figs. 1, 2, 12–17; text-fig. 10

(For synonomy of *P. genundewa* see Kirchgasser 1975, p. 77).

Material. Sixteen specimens (USNM 239880–239886, 239887*a–i*) preserved in a dark-grey styliolinid limestone and from a single nodule.



TEXT-FIG. 9. A–F, sutural diagrams illustrating the early ontogeny of *Maenioceras*. A–E, based on specimens from the Terebratum Zone at Pentonwarra Point, Trevone, and Portquin, North Cornwall. F, based on IGS 7117 from Wolborough, South Devon. A, the fourth suture. B, suture at 1·6 mm diameter, both based on Sedgw. Mus. H 9933 from Trevone, $\times$ 50. C, suture at 8·5 mm diameter based on Sedgw. Mus. H 9934 from Trevone, $\times$ 12·5. D, suture at 8 mm diameter. E, suture at 12 mm diameter, both based on IGS 1570, from Portquin (sutures reversed for comparison), $\times$ 12·5. For locality details see House 1963. G–L, sutural diagrams of *Pharciceras* spp. from New York and Germany.

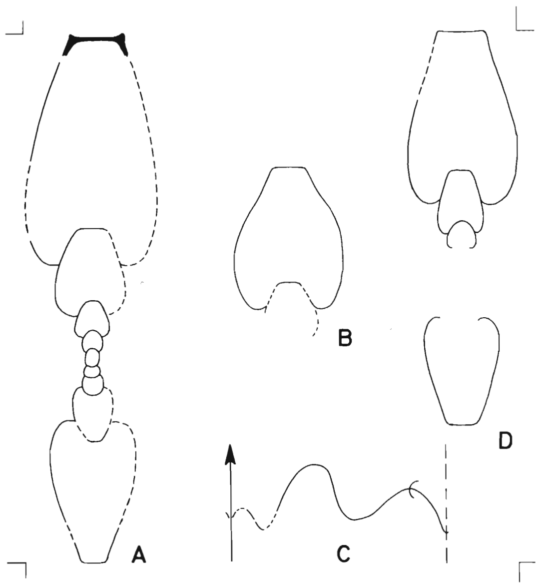
G–I, *P. amplexum* (Hall), sutures based on specimens from the Tully Limestone, New York. G, the Holotype from near Lodi Landing, Seneca Lake, NYSM 3729, $\times$ 3·3. H, specimen from June's Quarry, Tully, USNM 143014, $\times$ 3·3. I, specimen from same locality, suture drawn by W. M. Furnish, SUI 37052, $\times$ 3·3. J, K, *P. tridens* (G. and F. Sandberger), sutures enlarged from the original figures of G. and F. Sandberger (1849–1856, pl. 4, fig. 2*e*; pl. 9, fig. 2*b*) from Germany, the sutures of the types were developed by abrasion which has resulted in a rounding of the lobes. L, *P. tridens* (G. and F. Sandberger), suture of a specimen from the Untere *Pharciceras*-Lage of Kullmann and Ziegler (1970, p. 74) in the Martenberg section at Adorf (now Diemelsee), Germany, Sedgw. Mus. H 9935, $\times$ 1·5.

Dimensions.

	D	WW	WH	Wh	UW	R
USNM 239880	14·8	3·5	6·0	5·0	4·1	8·3
	8·7	2·3	3·8	3·2	2·8	5·6
	5·7	1·9	1·9	—	1·9	3·5
USNM 239881	10·1	2·9	4·6	3·7	3·0	—
	6·7	2·0	2·9	—	2·3	—
USNM 239882	11·2	2·9	5·2	—	—	—
	7·6	2·2	2·9	2·3	3·5	—
	1·7	0·7	0·5	—	0·8	—
USNM 239883	11·6	3·2	5·6	—	—	—
USNM 239884	11·4	3·3	5·3	—	3·0	—
USNM 239885	13·0	3·5	5·9	—	3·3	—
USNM 239886	11·0	3·1	5·0	—	2·9	—

Description. Protoconch seen in two specimens (USNM 239882, 239886) ranges in width from 0·6 to 0·7 and in diameter from 0·53 to 0·57 mm: form somewhat ellipsoidal with a faint constriction three-quarters of a whorl from the proseptum position. Early whorls serpenticonic with little impressed depth. By 5 mm diameter a flattened band has developed on the venter, and by 6 mm diameter whorl width and whorl height are approximately equal; thereafter whorl height always exceeds width, the whorl section becoming progressively flask-shaped (text-fig. 10). On testate specimens, in the outer whorls, spiral flares form on either side of the flattened, slightly concave venter, but internal moulds may show no sign of either the flares or of a concavity.

Growth lines, seen as raised lirae, are convex on the protoconch, but the point at which they become biconvex, as in the adult, has not been determined. Typically in



TEXT-FIG. 10. *Probeloceras* cf. *genundewa* (Clarke). Specimens from south of Landes Post Office, Grant County, West Virginia. A, cross-section at 14·8 mm diameter of USNM 239880, ×5. B, C, cross-section and suture at whorl height of 2·9 mm of USNM 239882, ×6·7. D, cross-section at 10·1 mm diameter of USNM 239881, ×5.

the adult (USNM 239881) growth lines show a slight salient on the umbilical shoulder and pass back to form a broadly rounded sinus on the mid flanks and forward to a salient centred just outside of the ventro-lateral flares. The ventral sinus is U-shaped. Occasionally there is evidence of periodic swellings along the ventro-lateral salient (Pl. 8, figs. 1, 17). The suture has not been examined in many specimens owing to the frequently recrystalized interior, but it appears to be typical for the *P. genundewa* group (see text-fig. 10C) in showing non-angularity of the lobes and rounded elements generally. No trace has been seen of an incipient umbilical lobe dorsal of the seam.

Remarks. In view of the discussion given by Kirchgasser (1975, p. 81) little comment need be made here. The details given above for *P. genundewa* type material complements that given by Kirchgasser for *P. lutheri* and *P. strix* from higher horizons in the New York sequence. It would seem to follow from the comparison that the correlation of the material from West Virginia is about the level of the New York Genundewa.

Material and locality. All specimens are from a nodule found within beds referred to the Harrell Shale on the west side of U.S. Route 220, 200 m south of a bridge 6·6 km (4·1 miles) south of Landes Post Office, Grant County, West Virginia. According to details kindly provided by Dr. K. O. Hasson, this locality falls within the division mapped as Genesee on the 1923 map of the geology of Grant County. A block containing other specimens of this and other species in the fauna is registered as USNM 240506.

Genus *Koenenites* Wedekind, 1913*b*

Type species by the subsequent designation of Wedekind (1917, p. 126) *Goniatites lamellosus* G. and F. Sandberger (1851, p. 85; 1850, pl. 8, fig. 1).

Koenenites lamellosus kirchgasseri, House, subsp. nov.

Plate 7, figs. 4, 6; text-fig. 11C

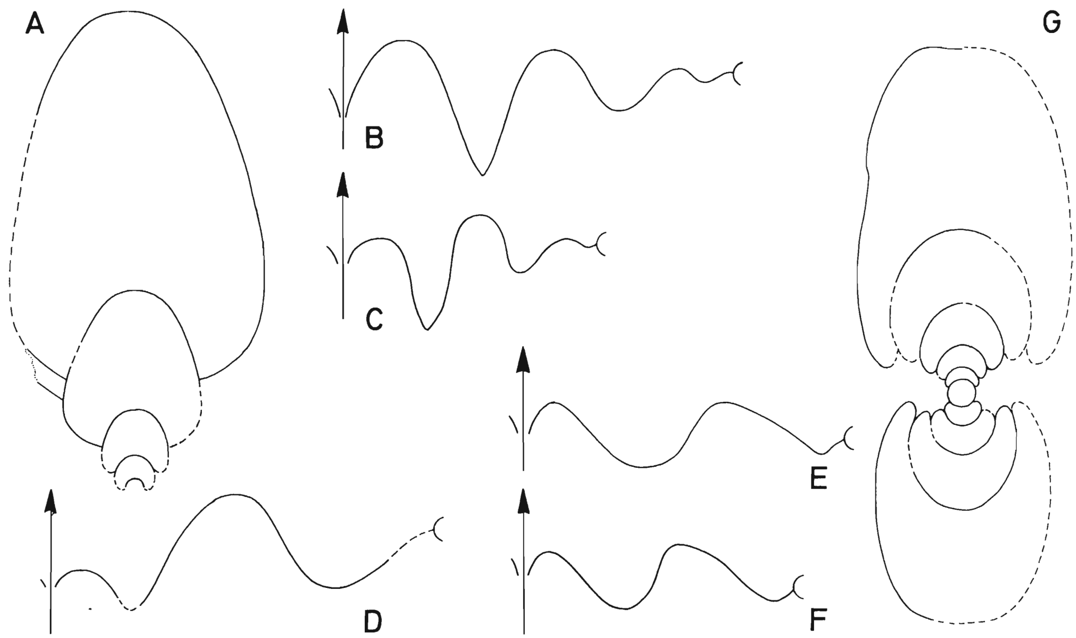
Material. One well-preserved, partially testate specimen preserved in grey micrite showing the phragmocone and part of the body chamber.

Dimensions.

	D	WW	WH	UW
Holotype USNM 239888	48·0	14·0	21·8*	12·0

* Including shell on one side only.

Description. Laterally compressed and open umbilicate. Whorl section, at early part of body chamber, widest on the low flanks and sloping convexly and gently to the seam: the sides converge to a narrowly rounded venter with feint furrows on either side, 4·8 mm apart at 48·0 mm diameter. Ornament well seen on outside of shell forming a shallow salient on the sloping wall, and a broad lateral sinus centred on the mid flanks. Growth lines shown by strong periodic raised lirae numbering eight in 10 mm on the mid flanks at 48·0 mm diameter. On the internal mould, trace of growth lines is only weakly shown on the low and mid flanks but they become more prominent approaching the ventro-lateral salient on the outer flanks. The crest of this salient lies below the ventro-lateral furrow. Ventral sinus poorly shown on the mould over the venter. The form of the suture is here shown diagrammatically (text-fig. 11C).



TEXT-FIG. 11. *Koenenites*, *Ponticeras*, and *Lobotornoceras* from West Virginia. A, B, *K.* sp., cross-section, and suture (reversed for comparison) at 15 mm whorl height, based on a specimen collected by Dr. K. O. Hasson from near Landes Post Office, USNM 239889, ×3·3. C, *K. lamellosus kirchgasseri* House subsp. nov., suture of Holotype based on a specimen collected by Dr. W. T. Kirchgasser from 1·9 miles south of Landes Post Office, USNM 239888, ×5. D, ?*Manticoceras* sp., suture at 14·4 mm based on a specimen from 6·6 km (4·1 miles) south of Landes Post Office, USNM 240492, ×6·7. E–G, *L. hassoni* House sp. nov., from the same locality 4·2 miles south of Landes Post Office. E, suture of the Holotype at 5·8 mm whorl height based on USNM 239891, ×6·6. F, suture (reversed for comparison) at 7·8 mm diameter based on USNM 239892, ×6·6. G, cross-section based on USNM 239893, ×6·4.

Remarks. Matern (1931, pl. 2, fig. 1) wrongly chose a neotype for this species (Senck. Mus. XI. 329a). This was invalid since the original specimens of the Sandberger brothers were, and are, extant in the Wies. Mus.: their dimensions are:

		D	WW	WH	UW
G. and F. Sandberger	Fig. 1	68·0	*c.* 16·5	33·3	13·4
1850, pl. 8	Fig. 1*f*	41·3	13·6	18·6	9·2
	Fig. 1*b*	40·5	13·5	17·7	12·0
	Fig. 1*c*	38·0	11·5	16·3	9·7
Senck. Mus. XI. 329a		*c.* 62·0	15·0	30·8	14·6

EXPLANATION OF PLATE 7

Figs. 1, 2. ?*Pharciceras galeatum* Wedekind. Specimen collected by Dr. K. O. Hasson from near Landes Post Office, West Virginia. USNM 186056, ×1.

Figs. 3, 5. *Koenenites lamellosus* (G. and F. Sandberger). Specimens figured by G. and F. Sandberger (1850, pl. 8, fig. 1), from Oberscheld, Germany. 3, ×1; 5, specimen here designated Lectotype Wies. Mus. ×2.

Figs. 4, 6. *Koenenites lamellosus kirchgasseri* House subsp. nov. Specimen collected by Dr. W. T. Kirchgasser from 1·9 miles south of Landes Post Office, West Virginia. The Holotype, USNM 239888, ×1·5.

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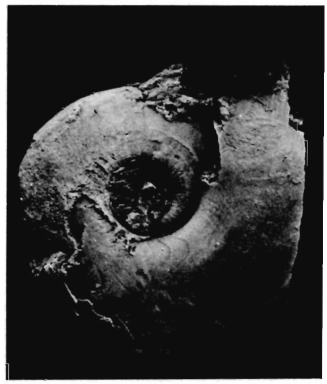

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HOUSE, ?*Pharciceras*, *Koenenites*

From these figures it will be seen that the over-all proportions of the new subspecies agree with the German type material. The diagnostic difference lies in the frequency of the lateral growth-line lirae. In the specimen figured by G. and F. Sandberger (1850, pl. 8, fig. 1) lirae number about fifteen in 10 mm on the mid flanks and are not prominent. In the West Virginia specimen their frequency is about half as great, and they are prominent. The large lateral lobe of the new subspecies is more lingulate and less triangular than in the German material (knowledge of the suture in the type material is based on G. and F. Sandberger 1850, pl. 8, fig. 1*c*, *d*).

Horizon and locality. This specimen was collected by Dr. W. T. Kirchgasser with the writer from a nodule bed 0·6–1·2 m below a 0·6 m bed of black shale exposed in a roadside section on the east side of Route 220, 3 km (1·9 miles) south of Landes Post Office, West Virginia. This level is referred to the Tully of the local lithostratigraphy but is probably younger than the New York Tully. In New York *Koenenites* is only known just below, and possibly just above the Genundewa Limestone. Some fragments from the matrix of the specimen described subsequently as ?*Pharciceras galeatum* may be referred to ?*Koenenites* sp. (USNM 239889, 239890).

Family PHARCICERATIDAE Hyatt, 1900

It was suggested in 1968, (House, 1968, p. 1063) that the Pharciceratidae were descended from *Maenioceras*. This is also the conclusion of Bensaïd (1973). It seems appropriate to give the evidence from Cornish specimens on which this suggestion was made and illustrations showing the early ontogeny of *Maenioceras* are given here (text-fig. 9).

Although the later stages in the development of *Maenioceras* have been described and figured by several writers, this is the first time that the earliest stages have been illustrated and therefore fresh light can be shed on the origin and affinities of the genus. Various opinions on the matter have been expressed in the past. Thus Foord and Crick (1897, p. 121), following Holzapfel (1895, p. 106), state of *M. terebratum* that 'Young shells have the suture line of *Agoniatites*' and that 'the development of the suture line points to a descent from *Agoniatites*'. Schindewolf, on the other hand,

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EXPLANATION OF PLATE 8

Figs. 1, 2, 12–17. *Probeloceras* cf. *genundewa* (Clarke). Specimens from 6·6 km (4·1 miles) south of Landes Post Office, West Virginia. 1, 2, USNM 239886, ×2. 12, 13, USNM 239881, ×1·5. 14, 15, USNM 239880, ×1·5. 16, 17, USNM 239885, ×1·5.

Figs. 3–5. *Parodiceras discoideum* (Hall). Specimen from the *Werneroceras* Bed, south side of Route 20, near Cherry Valley, New York State. NYSM 12008, ×1·5.

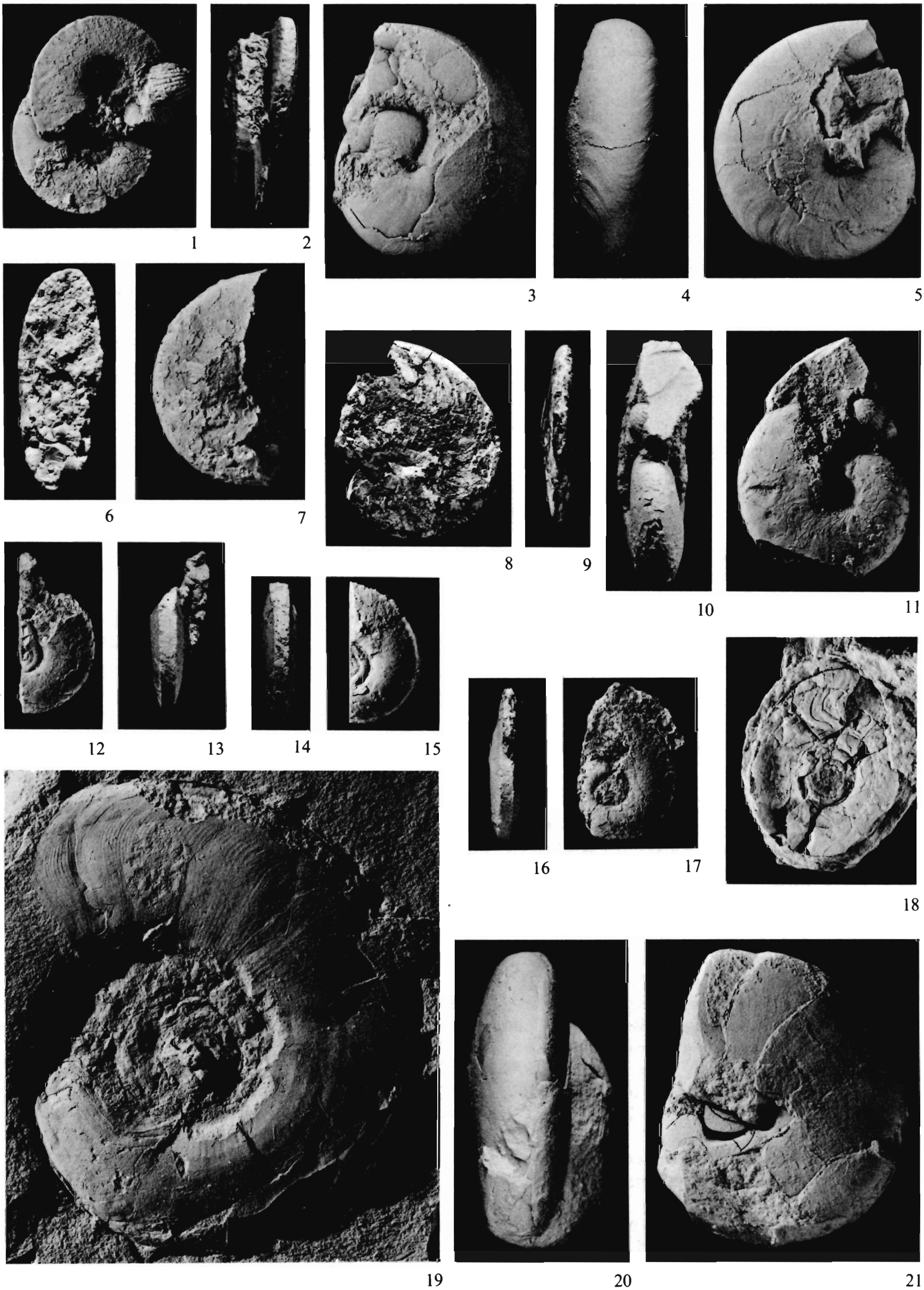
Figs. 6, 7, 10, 11. *Lobotornoceras hassoni* House sp. nov. Specimens from 6·6 km (4·1 miles) south of Landes Post Office, West Virginia. 6, 7, a Paratype, USNM 239893, ×3. 10, 11, the Holotype, USNM 239891, ×2.

Figs. 8, 9. *Foordites* sp. Specimen collected by Dr. N. Eldredge from the Needmore Shale at the Hayfield cross-road, Frederick County, Virginia, AMNH 35985, ×1.

Fig. 18. *Agoniatites* cf. *oliveri* House sp. nov. Specimen from the Needmore Shale from near Capon Lake, West Virginia. USNM 239878, ×1.

Fig. 19. *Parodiceras* sp. nov. Specimen from the Chittenango Shale, 2·7 miles north-west of Cherry Valley, New York. NYSM 12006, ×1.

Figs. 20, 21. *Tornoceras* (*T.*) sp. Specimen from the Romney Shale on Knobley Mountain road, 8 miles south-west of Short Gap, Cumberland, Maryland USNM 239900, ×1.



HOUSE, Devonian Ammonoids

without giving any evidence, derives the genus from *Anarcestes* via *Foordites* (Schindewolf, 1933, p. 88).

The important distinction, as elucidated by Schindewolf, between the Agoniatitidae and Anarcestidae (as used by him), is that in the former the lateral lobe of the adult is formed from a laterally placed lobe in the earliest stages whereas in the Anarcestidae, whilst the 'lateral' lobe of the adult may be lateral or subumbilical in position, it is always subumbilical at first (Schindewolf, 1954, p. 223). As illustrated here (text-fig. 9A–F), in the Cornish specimens of *Maenioceras*, the early subumbilical lobe migrates during ontogeny to a lateral position in the adult, and the adult ventrolateral lobe appears adventitiously (as has long been recognized). The genus therefore has closest affinities with the Anarcestidae.

The group of anarcestids which show ventrad migration of the primary subumbilical lobe during ontogeny includes *Foordites* and Schindewolf considered this to be the ancestor of *Maenioceras*, presumably because of similarities in shell form. But the early stages of *Maenioceras* are more reminiscent of *Cabrieroceras*, and both genera may have a common source.

Genus PHARCICERAS Hyatt, 1884

Type species by the subsequent designation of Wedekind (1917, p. 127). *Goniatites tridens* G. and F. Sandberger (1850, p. 66; 1849, pl. 4, fig. 2*a–e*).

The suture of the type species of *Pharciceras* differs from *Maenioceras* in possessing an additional lateral lobe, making three lobes on the flanks rather than two, one of which is adventitious. Other species included in *Pharciceras* may have more than three lobes on the flanks. *P. lunulicosta*, for example, has five.

EXPLANATION OF PLATE 9

Figs. 1, 2. *Holzapfeloceras ?denckmanni* (Holzapfel). Specimen figured by Holzapfel (1895, pl. 3, fig. 23*a*, *b*) from the 'schwarzen Kalken bei Wildungen', Germany, Berl. Mus. c. 362, ×3.

Figs. 3, 4. *Werneroceras ruppachense* (Kayser). Specimen figured by G. and F. Sandberger (1850, pl. 11, fig. 3*a–d*) here designated Lectotype, from Lerbach or Madfeld, Germany. Wies. Mus., ×2.

Fig. 5. *Tornoceras* (*T.*) aff. *mesopleuron* House. Specimen from the Chittenango Shale, 2·7 miles northwest of Cherry Valley, New York. NYSM 12009, ×1.

Figs. 6, 7. ?*Manticoceras* sp. Specimen from the Harrell Shale, at 6·6 km (4·1 miles) south of Landes Post Office, West Virginia. USNM 240498, ×1·5.

Figs. 8, 14. *Lobotornoceras ausavense* (Steininger). Neotype here designated from the Büdesheimer Schiefer, 250 m south-south-east of Büdesheim Church, Büdesheim, Eifel, Germany. Sedgw. Mus. H 9932, ×6.

Figs. 9, 10. *Tornoceras* (*T.*) *uniangulare compressum* Clarke group. Specimen from 6·6 km (4·1 miles) south of Landes Post Office, West Virginia. USNM 240501, ×2.

Figs. 11, 12. *Holzapfeloceras denckmanni* (Holzapfel). Specimen (here designated Lectotype) figured by Holzapfel (1895, pl. 3, fig. 24*a*, *b*) from the 'schwarzen Kalken mit *Posidonia hians* bei Wildingen'. Berlin. Mus. c. 351, ×2·3.

Fig. 13. *Agoniatites* aff. *vanuxemi* (Hall). Specimen from the Cherry Valley Limestone, Oneida Creek road cut, 2 miles south-west of Munnsville, Madison Co., New York, collected by J. W. Wells (his locality 225). NYSM 12007, ×1·5.

Figs. 15, 16. *Cabrieroceras* aff. *plebeiforme* (Hall). Specimen from the Nevada Formation, southern Roberts Mountain, Nevada. USNM 239854, ×1.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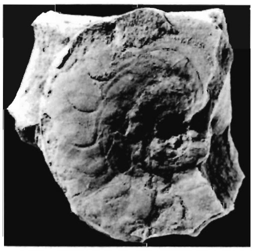
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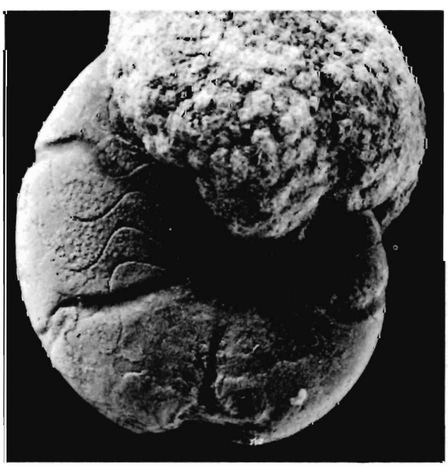
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HOUSE, Devonian Ammonoids

It is convenient now to comment on the relations of *P. amplexum* (Hall) whose affinities with *Pharciceras* have been questioned by Kullman and Ziegler (1970, pp. 81, 82). In an accompanying illustration a series of sutures are given of specimens of *P. amplexum* and *P. tridens* (text-fig. 9G–L). All are united by the simple, deep ventral lobe, the three lobes on the flanks, and an umbilical lobe centred on the seam. Since *P. tridens* is the type of the genus, and pharciceratids with more lobes are also included in *Pharciceras*, whilst one lobe less is characteristic of *Maenioceras*, it is difficult to justify the placing of *amplexum* in a genus other than *Pharciceras*. Nor, as pointed out before (House 1962, p. 273), is whorl shape helpful, since other species of *Pharciceras*, and some of *Maenioceras*, have similar form. Regarding lobe length and form, usually taken as of only specific or subspecific value, it should be noted that the suture of the type specimen of the Sandberger brothers has been developed by abrasion so that the lobes probably appear more rounded than they were. The specimen from the Tully Limestone prepared by W. M. Furnish (text-fig. 9I) is so close to *P. tridens* that one might determine it as conforming to that species rather than to *P. amplexum*.

It may be remarked that the second specimen figured by the Sandberger brothers under the name of the type species has been referred to a new genus and species, *Sphaeropharciceras sandbergerorum* by Bogoslovski (1955, p. 1104). Having examined the type specimen, one cannot but agree with the Sandbergers that it is rather a crushed *P. tridens*.

?*Pharciceras galeatum* Wedekind

Plate 6, figs. 3, 4; Plate 7, figs. 1, 2

Material. Four specimens, USNM 186053–186056, preserved in grey micrite with phragmocones substantially filled with crystalline calcite. Matrix with styliolinids.

Dimensions.

	D	WW	WH	Wh	UW
USNM 186053	*c.* 55·0	17·0	23·0	—	—
USNM 186054	25·9	*c.* 10·0	12·0	9·3	5·3

Description. Open umbilicate, laterally compressed; whorl section of outer whorls greatest at low mid flanks adjacent to the convexly sloping wall down to the seam. Flanks converge ventrad to a well-rounded venter. Growth lines seen on one specimen (USNM 186055) with periodic raised lirae, pass from a lateral sinus forward to a ventro-lateral salient and then sharply back into the ventral sinus. Suture (poorly seen on USNM 186055) shows evidence of a large lateral saddle low on the flanks, a weak lobe on the seam, a dorsal lobe centred on the dorsum, and another between it and the seam.

Remarks. There are similarities between these specimens and that described here as *Koenenites lamellosus kirchgasseri*, but general form, and the sutural evidence seem more suggestive of *P. galeatum* Wedekind (1917, pp. 128, 168, pl. 20, fig. 1) from Oberdevon Iα of Grube Prinzkessel, Germany, as recorded on a previous occasion (House 1968, p. 1067). Further consideration of this will have to await accessibility to the source locality and more material.

Horizon and locality. Specimens collected by Dr. K. O. Hasson and recorded in his M.Sc. thesis as from his Bed 39, from a 3·7 m interval of shale with limestone nodules exposed about 0·8 km (0·5 mile) south of the Landes Post Office, Grant County, West Virginia. This level is currently referred to the Tully of local lithostratigraphy, but there can be little doubt (see discussion of *Epitornoceras*) that the correlation is with higher levels than the Tully in New York.

Suborder GONIATITINA
Family TORNOCERATIDAE Arthaber, 1911
Genus PARODICERAS Hyatt, 1884

Type species by original designation *Goniatites discoideus* Hall (1860, p. 97, text-figs. 3–5).

The type material is thought to have come from the Cherry Valley Limestone near Manlius, New York, and the species is common at this level, and the lithology of the type material is similar. The holotype has recently been refigured (NYSM 4055, House 1965*a*, pl. 5, figs. 29, 30; text-fig. 3A, B).

Parodiceras has not been recorded from the *Werneroceras* Bed before (Rickard 1952), but a tornoceratid, recorded as *Tornoceras*, was noted by Flower (1943, p. 16), and this may well have referred to *P. discoideum*. Also described are barytized specimens from the new Catawba Mountain locality which are thought to come from a correlative of the *Werneroceras* Bed in Virginia.

Parodiceras discoideum (Hall)

Plate 5, figs. 1, 8; Plate 8, figs. 3–5

For synonymy see Miller (1938, p. 144 and House 1965*a*, p. 89).

Material. From west of Cherry Valley, New York, two specimens (NYSM 12008, 12010). From Catawba Mountain three specimens (USNM 186152*a–c*).

Remarks. The better preserved of these specimens show the distinctive growth line form of *P. discoideum* in which the course is flexuous across the flanks with only an extremely shallow lateral sinus. Further specimens from both localities show evidence of periodic strengthening of the growth lines (Pl. 5, fig. 1; Pl. 8, fig. 5) which has been noted also on material from the type horizon (House 1965*a*, pl. 5, fig. 34). What sutural evidence there is supports assignment to this species rather than *T. mesopleuron*.

Horizon and locality. NYSM 12008, 12010 from the *Werneroceras* Bed in a road cutting on the south side of Route 20 west of Cherry Valley, New York, collected by the author. USNM 186152*a–c* from a roadside quarry on the south side of Route 311 on the south-eastern slope of Catawba Mountain, Virginia, and collected by Mr. S. Croy, the horizon of which is thought to be in the lower part of the Millboro Shale, possibly no more than 30–61 m above the Huntersville Chert.

Parodiceras sp. nov.

Plate 8, fig. 19; Plate 10, fig. 8

Material. A single crushed specimen (NYSM 12006) showing a complete body chamber and part of the phragmocone preserved in dark-grey shale.

Description. The specimen has a maximum diameter of 75 mm. It shows the aperture, and the body chamber occupies the last three-quarters of a whorl. The umbilicus appears to be completely closed. Growth lines (Pl. 10, fig. 8) indicate an almost rectiradiate course across the flanks with only the slightest trace of a lateral sinus: on the venter there appears to be a deep sinus. Subdued spiral ridges about 2·3 mm apart are seen on the early body chamber. The suture shows a very large latero-umbilical saddle, but from the lateral lobe to the ventro-lateral region its course seems almost rectiradiate: the course is not seen on the venter.

Remarks. The reference to *Parodiceras* follows from the sutural form and the growth-line pattern, but the specimen differs from *P. discoideum* (see House 1965*a*, p. 89 and the specimen figured here, Pl. 8, figs. 3–5) in being substantially larger than any specimen of that species known, in possessing spiral ornament, and in the gross sutural outline. Indifferent preservation of the only known specimen precludes giving this form a name at present.

Horizon and locality. From a road metal quarry in the Chittenango Shale on the north-east side of a dirt road 4·3 km (2·7 miles) north-west of Cherry Valley, New York, at an elevation of 509 m (1700 feet) and estimated by Dr. L. V. Rickard to lie approximately 18·3 m (60 feet) above the Cherry Valley Limestone.

Genus TORNOCERAS (TORNOCERAS) Hyatt, 1884

Type species by original designation *Goniatites uniangularis* Conrad (1842, p. 268, pl. 16, fig. 4; see House 1965*a*, p. 104).

Tornoceras (*Tornoceras*) cf. *baldisi* Leanza

Plate 6, figs. 9, 10

cf. 1968 *Tornoceras baldisi* Leanza 1968, p. 327, figs. 1–4.

Material. A single specimen (USNM 239899) preserved in iron stained micrite showing part of the body chamber and crushed phragmocene.

Dimensions.

WH	WW	Wh
c. 19·5*	17·8	8·9

Description. The preserved portion of the body chamber shows a stout whorl section with a broad, well-rounded venter with indications that the maximum whorl width lay quite low on the flanks. Ornamentation of fine lirae forms a well-rounded sinus

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EXPLANATION OF PLATE 10

Fig. 1. *Agoniatites* cf. *oliveri* House sp. nov. Specimen from the Needmore Shale in a quarry 0·7 miles north-west of Gainsboro, Virginia. USNM 239879, ×3.

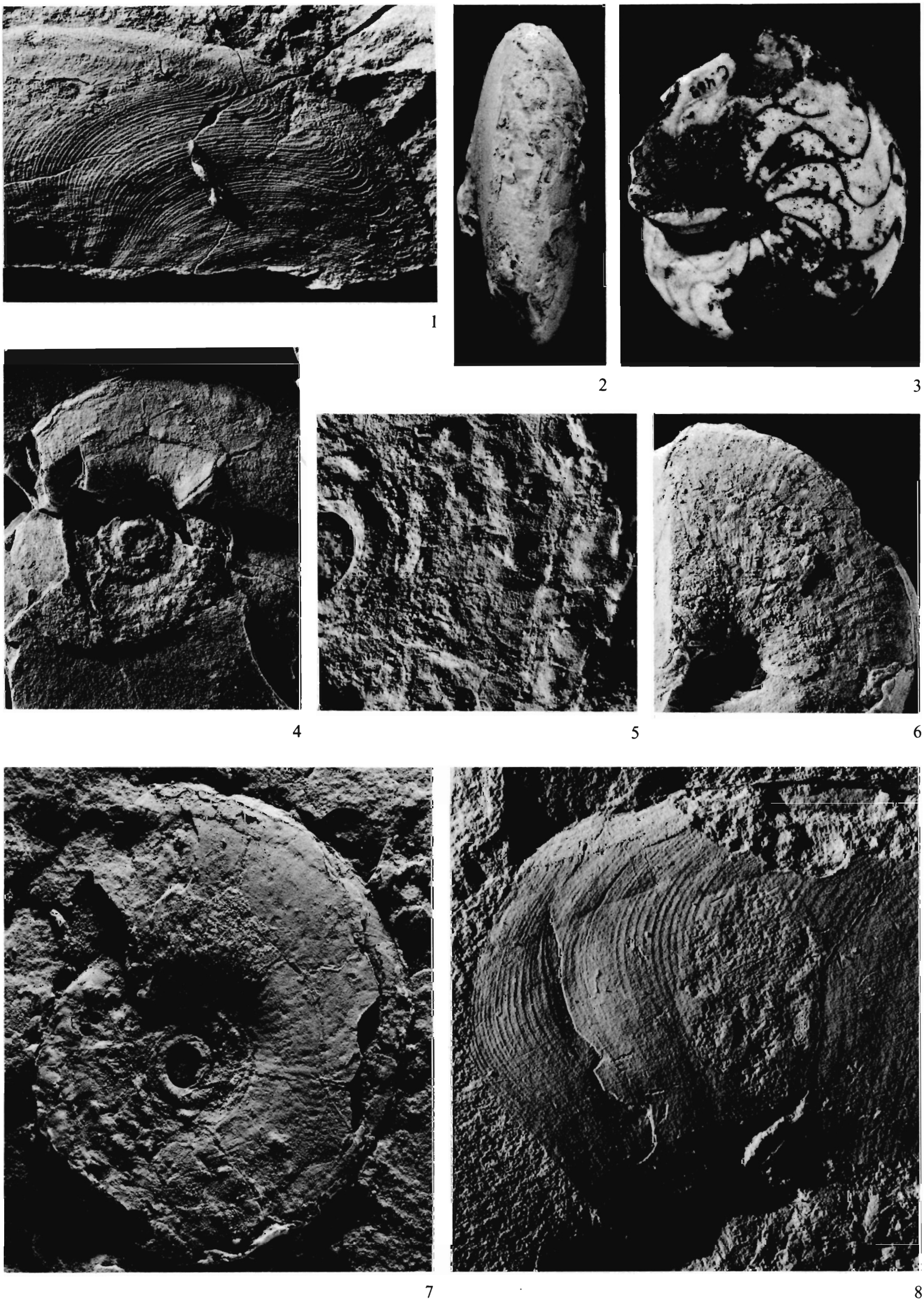
Figs. 2, 3. *Epitornoceras mithracoides* (Frech). One of the syntypes figured by Frech (1887, pl. 2, fig. 1*b*) from the early Upper Devonian of Eibach, Germany, Berl. Mus. c. 469, ×1.

Fig. 4. ?*Cymaclymenia* sp. Specimen from the Cleveland Shale on Towness Creek, Lorain County, Ohio. USNM 240495, ×1·5.

Figs. 5, 7. *Cymaclymenia* sp. from the same locality and horizon. USNM 240494. 5, ×4, 7, ×2.

Fig. 6. Sporadoceratid or imitoceratid indet. Specimen from the same locality and horizon. USNM 240496, ×1.

Fig. 8. *Parodiceras* sp. nov. Specimen from the Chittenango Shale 2·7 miles north-west of Cherry Valley, New York. NYSM 12006, ×2·4.



HOUSE, Devonian Ammonoids

centred on the venter, a scarcely projecting ventro-lateral salient, and a broad shallow sinus on the flanks; course on the lower flanks not seen. The ventral suture seen on the penultimate whorl preserved shows a V-shaped ventral lobe, a narrowly rounded ventro-lateral saddle which slopes sharply down to the lateral lobe: indications only are visible of the latero-umbilical saddle.

Remarks. This is the first Devonian goniatite to be described from Bolivia. Reference to the species described by Leanza from Argentina is based on the sutural form primarily, and since neither the type material, nor the Bolivian specimen is well preserved, the assignment is a tentative one only. Leanza referred his material to the Upper Devonian, but the Middle Devonian (Givetian) cannot be ruled out. Comparison with forms from the early Hamilton seem more reasonable.

Material and horizon. This specimen was submitted for study by Professor A. J. Boucot and it was collected loose by Professor Branisa from near Chacoma, La Paz Province, Bolivia. Dr. P. E. Isaacson, who has been surveying this area, suggests (in litt.) that it could be from the Sicasica Formation (?), or possibly the Collpacuchu Formation.

Genus *Lobotornoceras* Schindewolf, 1936

Type species by original designation *Goniatites ausavensis* Steininger (1853, p. 40, pl. 1, fig. 11).

The distinctive types species (Pl. 9, figs. 8, 14) is laterally compressed at early diameters, and shows prominent lateral constrictions in the adult so that it differs markedly from the other species commonly referred to the genus: these include *L. bicaniculatum* Petter (1959, p. 208, pl. 15, fig. 12) from the Famennian of the Sahara; *L. bilobatum* (Wedekind 1908, p. 579, pl. 39, fig. 35; pl. 40, fig. 8) from the Cheiloceras Stufe, Famennian, of Enkeberg, Germany: *L.* (?) *carnicum* (Gortani 1907, p. 224, pl. 1 (4), fig. 17) probably early Famennian of the Carnic Alps, Italy; *L. delepinei* Clariond MS. (Petter 1959, p. 209, text-fig. 47, pl. 15, fig. 15) from the Famennian ('zone V') of the Sahara; *L. escoti* (Frech 1902*a*, p. 48, text-fig. 13*b*4, pl. 3(2), fig. 19) from the Famennian of the Montagne Noire; and *L. pseudobilobatum* Dybczyński 1913, p. 519, pl. 1, fig. 11; pl. 2, fig. 11) probably from the early Famennian of the Holy Cross Mountains of Poland.

It is incorrectly stated in the literature that the horizon of the type species is the Cheiloceras Stufe at Büdesheim (Wedekind 1917, p. 136; Petter 1959, p. 208; Bogoslovski 1971, p. 77). But as Frech (1902*a*, p. 48) correctly noted the species occurs with the typical mid Frasnian fauna of the Büdesheimer Schiefer, and the type locality is at Büdesheim. In the absence of any trace of Steininger's collection I am designating the specimen here figured (Pl. 9, figs. 8, 14) as a neotype for *L. ausavense* (Steininger). This specimen was obtained from the classical locality with a typical suite of Cordatum Zone goniatites.

The morphological and stratigraphical distinction between the Famennian species of *Lobotornoceras* and the Frasnian type species would have been clear cut were it not for the record here of an early Frasnian *Lobotornoceras* with a form associated with the Famennian species. This may be taken to confirm an earlier observation (House *in* House and Pedder 1963, p. 529) that the two groups are phylogenetically distinct, but it is not proposed here to recognize this taxonomically.

Lobotornoceras hassoni House sp. nov.

Plate 8, figs. 6, 7, 10, 11; text-fig. 11E–G

Material. Six specimens (USNM 239891 (Holotype figured Pl. 8, figs. 10, 11)), 239892–239896, 240505 (Paratypes) preserved in dark-grey styliolinid limestone frequently with the inner whorls preserved in crystalline calcite.

Dimensions.

	D	WW	WH	Wh	UW
USNM 239891	13·5	5·0	7·3	—	0
USNM 239896	7·6	3·6	—	—	0
USNM 239892	7·7	3·3	—	—	0
	8·8	3·4	—	—	0
USNM 239893	11·7	4·0	7·4	3·6	0

Description. Inner whorls not seen except in cross-section (text-fig. 11G) which shows that the first two whorls or so have an open umbilicus. In middle whorls the outline is rotund and whorl section rounded with maximum width near the mid flanks. By 7 mm diameter, or so, the over-all form shows a laterally compressed conch and whorls with a maximum width close to the umbilical shoulder with flanks converging convexly to a well-rounded venter. The growth lines in outer whorls show a salient low on the flanks, and a broadly rounded lateral sinus, but the ventral course has not been observed. The suture (text-fig. 11E, F) shows the diagnostic saddle centred on the umbilical seam even at about 6 mm diameter (USNM 239896); at larger diameters the ventral suture becomes progressively more openly V-shaped. The lateral lobe is broadly rounded, large, and asymmetric. The steep ventrad face to the latero-umbilical saddle makes it markedly asymmetrical. The subumbilical lobe appears to progress from rounded to subacute.

Remarks. This species, named after Dr. K. O. Hasson who first found Frasnian goniatites in the Landes area, is the only species of the genus which has simple *T.* (*T.*) *uniangulare* type asymmetrical lateral lobes and saddle. It differs from *L. ausavense* in being less compressed and not having constrictions. The sutures of Famennian species differ in that the sutural elements in them are more symmetrical and in some cases more angular. *L. pseudobilobatum* differs in having an even more subdued suture.

Horizon and locality. All specimens from a styliolinid limestone nodule from the Harrell Shale on the west side of U.S. Route 220, 200 m south of a small bridge 6·6 km (4·1 miles) south of Landes Post Office, West Virginia.

Genus *Epitornoceras* Frech 1902*a*

Type species by original designation *Goniatites mithracoides* Frech (1887, p. 30, pl. 2, fig. 1)

As currently used this distinctive oxyconic tornoceratid group with acute, or subacute ventro-lateral lobes is restricted to the early Frasnian. In New York *E. peracutum* is limited to the upper part of the Geneseo Shale and the Ithaca Formation in the Ithaca meridian, that is, in equivalents of the upper part of the Lunulicosta Zone. There is no evidence that it ranges as high as equivalents of the Genundewa. The single specimen described here from West Virginia is only the second solid specimen known from North America.

Recently, however, the type material has come to light and will be illustrated and described in a subsequent work (Pl. 10, figs. 2, 3). The source was an ironstone in the lowermost Upper Devonian (Lunulicosta Zone) at Grube Eibach, Oberscheld, Germany (Frech 1902*a*, p. 52, 1902*b*). The material is not so sharply oxyconic, nor the sutural elements so angular as has been inferred from the published figures. The *E. peracutum* form represents a stock which could be derived from *E. mithracoides*.

There is a homoeomorphic group of oxyconic tornoceratids from the Cheiloceras Stufe of the Holy Cross Mountains of Poland and other areas which forms the end member of a series from typical *Tornoceras*. This has been elucidated by Dr. H. Makowski. But these are independently derived from *Tornoceras*. The material from the Canning Basin recorded by Petersen (1975, p. 18) as *E. peracutum* also occurs in the Cheiloceras Stufe and should probably be referred to this later stock which really should be given a separate generic name.

Epitornoceras aff. *peracutum* (Hall)

Plate 6, figs. 7, 8, 11, 12, text-fig. 7B

aff. 1879 *Goniatites peracutus* Hall, pl. 69, fig. 8; pl. 74, fig. 13.
aff. 1965*a* *Epitornoceras peracutum* House, p. 118, pl. 8, fig. 73, text-fig. 13C.

Material. A single specimen (USNM 186052) comprising an incomplete portion of a phragmocone and portion of the body chamber preserved in grey styliolinid-rich mudrock.

Description. Outer whorls approaching oxyconic form, but stout whorled (at D = *c*. 54, WW = *c*. 20·5) with a maximum width low on the flanks. Venter subacute on the internal mould but sharper, and with an incipient keel on the outer surface of the shell replacement. Ornament seen on a portion of the outer surface and comprising growth lines forming a low, broad sinus on the mid flanks which pass forward to a broadly rounded ventro-lateral salient and back to a very deep ventral sinus. Suture as illustrated in text-fig. 7B.

Remarks. This specimen is stouter than the only other solid specimen of *Epitornoceras* known from North America (NYSM 396) from the 'Genesee Shale between Rock Stream and Rock Landing', Seneca Lake (west shore). The exact source of that specimen is not known, but *Epitornoceras* occurs in a two metre prominent calcareous bed near Rock Stream Landing (now Fir Tree Point) at a level thought to correspond to a unit overlying the Lodi Limestone of the eastern side of the lake. The new specimen differs from the Holotype (NYSM 4091) in that the ventro-lateral saddle is less acute, and the lateral lobe less deep. In general proportions it agrees better with the specimen figured by Harris (1899, pl. 6, fig. 35; refigured by House 1965*a*, text-fig. 131) from the Ithaca Formation (CUPL 39652). This would suggest a level high in the Genesee Group as is also indicated by the rest of the material from Landes Post Office.

Locality and horizon. Collected by Dr. K. O. Hasson from Bed 39 (p. 81) of his unpublished M.Sc. Thesis in a 3·7 m interval of shale with limestone nodules exposed 0·8 km (0·5 miles) south of Landes Post Office, Grant County, West Virginia (see previous discussion under ?*Pharciceras galeatum* for details).

CONCLUSIONS AND COMMENTS ON INTERNATIONAL CORRELATION AND SUBDIVISION OF THE DEVONIAN SYSTEM

The correlation proposed between the sequence of thirty ammonoid faunas established in eastern North America and the standard sequence of Germany is illustrated in text-fig. 12. It will be noticed how, even at the present state of investigation, the discrimination of faunas in the American Erian and Senecan is more refined than that so far established for equivalent sequences in Europe. This is related to such factors as the greater thickness, more common stratigraphical markers, and better exposure of the American sequences. In terms of comparison of faunas, greatest congruity between the Old and the New World is found in the Senecan or Frasnian when ammonoid faunas are at their most cosmopolitan, a point which has been made on earlier occasions (House 1962, 1973*b*). Older and younger ammonoids in eastern North America are closely similar to European types, but many genera common in Europe are, as yet, unknown in America. The effect of this is to give a different character to the faunas rather than to raise much doubt on the correlations involved. Since further genera thought not to be present in America are here reported, it is likely that future work will diminish yet more this apparent difference.

Some comments will be made on the broad conclusions on matters of correlation. It is convenient to use what has been the standard German divisions of the Devonian System (text-fig. 12); the only difference is that Chlupáč (1976*a*) is followed in using the international *Anetoceras*, rather than the local *Mimosphinctes*, as the name for the earliest *stufe*. In conclusion some comments will be made on the current status of the main subdivisions of the Devonian System both in Europe and in North America.

Correlation

In the Lower Devonian goniatites are unknown in eastern North America apart from *Anarcestes* cf. *praecursor* described here (fauna 1 of text-figs. 3, 4, 12): the type of this species comes from levels yielding *Sellanarcestes* in Czechoslovakia. There is a fuller record of anetoceratids in western U.S.A. (House 1965*b*), eastern Canada (House and Pedder 1963), and the Arctic Islands (Erben 1966), but the succession of these faunas has not been worked out and detailed correlation is not yet attained using them.

Middle Devonian faunas seem first clearly recognizable with *Agoniatites oliveri* and *Foordites buttsi* in faunas 2 and 3, but the affinity of these seem to be with the middle or upper part of the Anarcestes Stufe of Europe. It should be noted how closely some of the *Foordites* resemble, in suture form, *Pinacites*, but that genus has not yet been recognized in the New World. It has been argued here that the *Cabrieroceras plebeiforme* fauna (4), shown to extend from New York southwards into Virginia, is the correlative of the *C. crispiforme* faunas of North Africa, the Odershauser Kalk of Germany, and the basal Kačák Member of the Sbskro Beds of Czechoslovakia. In the areas mentioned it is used to define the lowest Givetian, and it would form a useful level for the international definition of the basal Givetian. For the later Middle Devonian, the sequences in the Appalachians and in New York (faunas 5–12) give much more faunal and stratigraphical discrimination than do their corresponding

EASTERN NORTH AMERICA			GERMAN DEVONIAN STANDARD			
SERIES	STAGES AND GROUPS	AMMONOID FAUNAS	AMMONOID ZONES	STUFEN	STAGE	
CHAUTAUQUAN	CONEWANGO		*Prionoceras sp.* *Cymaclymenia euryomphala* VIβ *Wocklumeria sphaeroides* VIα *Kalloclymenia subarmata*	*WOCKLUMERIA*	FAMENNIAN	UPPER DEVONIAN
		30 *Cymaclymenia sp.*	Vβ *Gonioclymenia speciosa* Vα *Gonioclymenia hoevelensis*	*CLYMENIA*		
		29 *Platyclymenia sp.* 28 *Sporadoceras milleri*	IV *Platyclymenia annulata* IIIβ *Prolobites delphinus* IIIα *Pseudoclymenia sandbergeri*	*PLATYCLYMENIA*		
	CONNEAUT CANADAWAY	27 *Maeneceras cf. pompeckji* 26 *Cheiloceras amblylobum* 25 *Aulatorn. clarkei*	IIβ *Maeneceras pompeckji* IIα *Cheiloceras curvispina*	*CHEILOCERAS*		
SENECAN	WEST FALLS	24 *Crickites cf. holzapfeli* 23 *Mant. cataphractum* 22 *Manticoceras rhynchostoma*	*Manticoceras sp.* Iδ *Crickites holzapfeli*	*MANTICOCERAS*	FRASNIAN	
	SONYEA	20 *Probeloceras strix* 19 *Prob. lutheri* 18 *Sandbergeroceras syngonum*	Iγ *Manticoceras cordatum*			
	GENESEE	17 *Manticoceras styliophilum* 16 *Koenenites sp.* 15 *Ponticeras perlatum* 14 *Tornoceras sp.*	Iβ Iα *Pharciceras lunulicosta*			
?	TAGHANIC	13 *Pharciceras amplexum*				
ERIAN	TIOUGHNIOGA	12 *Torn. unian. unian.* 11 *Maenioceras sp. virginiana* 9 *Maenioceras cf. molarium*	*Maenioceras terebratum* *Maenioceras molarium*	*MAENIOCERAS*	GIVETIAN	MIDDLE
	CAZENOVIA	8 *Torn. arkonense* 5,6 *Agoniatites vanuxemi* 4 *Cabrieroceras plebeiforme*	*Cabrieroceras crispiforme*			
?	SOUTHWOOD	3 *Foordites buttsi* 2 *Agoniatites oliveri*	*Pinacites jugleri* *Anarcestes lateseptatus*	*ANARCESTES*	EIFELIAN	
ULSTERIAN	SAWKILL DEER PARK	1 *Anarcestes cf. praecursor*	*Sellanarcestes wenkenbachi* *Mimagoniatites zorgensis* *Anetoceras hunsrueckianum*	*ANETOCERAS*	EMSIAN	LOWER
	HELDERBERG				SIEGENIAN	
					GEDINNIAN	

TEXT-FIG. 12. Diagram showing the proposed correlation between the sequence of ammonoid faunas established in eastern North America and the standard sequence of Germany. For comments on the definition of larger divisions see discussion in text.

European sequences. Several common European species are still missing from the New York record, but the recent discovery of *Maenioceras* suggests that time may close gaps that remain. It is still true that the southern Appalachian record has more European affinity than that of New York.

The earliest record of Upper Devonian goniatites (in the German sense of Upper Devonian) is the *Pharciceras amplexum* fauna (13) of the West Brook Member of the Tully Limestone (House 1968). Previously it was thought that conodont evidence suggested this correlation was in error, indeed, should be 'rejected' (Orr and Klapper 1968), but it is now known that what was in error was the correlation between the German conodont sequence with the German goniatite sequence, and the conodont correlation now agrees with the goniatite correlation for the West Brook Member (House and Ziegler 1977). Miscorrelations of a similar sort using conodonts at this level have caused havoc with the literature and correlations in many countries, notably in western U.S.A., Canada, and in Australia in a way which is most regrettable: lack of thorough attention to the macrofossils of the beds from which the initial conodont sequences were described is the cause of this. The detailed sequence of Senecan goniatite faunas (13–24) has been given in outline (House 1968) and the early part of the sequence has been given in more detail (Kirchgasser 1975), and Dr. Kirchgasser and the writer are continuing study of the sequence. What is striking is the affinity of the detailed sequence with the successions in Germany and the Komi A.S.S.R. of Russia. It is clear that the New York sequence is the most detailed goniatite succession known anywhere for the Frasnian time interval. Again there are some European genera missing, particularly pharciceratids other than *Pharciceras*, some distinctive and common manticoceratids, such as *Maternoceras* and *Trimanticoceras*, and there is a great rarity of beloceratids, but the sequence of forms present matches that of the Old World with precision.

Ammonoids from the higher Upper Devonian, the Chautauquan of Ohio, Pennsylvania, and New York (faunas 25–30), continue the European affinity, although records are sparser than in the Senecan, and there are still substantial gaps. However, the records of *Platyclymenia*, *Cyrtoclymenia*, and *Cymaclymenia* given here show that clymenids are not absent from eastern U.S.A. as has been thought. Doubtless further records will come to light in the future. So far as detailed sequence is concerned, Europe still provides the best-known successions. It should be mentioned, however, that the German sequences are mostly of the reduced cephalopodenkalk type from pelagic limestones of *schwellen* environments. The records in eastern North America often occur as part of much thicker sequences, and hence faunas can be discriminated stratigraphically in a way hardly possible in many of the European localities.

Subdivision of the Devonian

During the 1950s there was a broadly agreed consensus on the boundaries between the Lower, Middle, and Upper Devonian in which differences in national usage were minor and of the nature of whether or not the Assise de Bure should be placed in the Lower or the Middle Devonian. It was agreed internationally that the German standard formed the basis of international reference, essentially continuing the priority Sedgwick and Murchison gave in the early part of the last century, but also acknowledging the very real contributions to Devonian biostratigraphy made by German research workers, especially in marine facies. Similarly the German, Belgian, and French stage names (text-fig. 12) were widely used, the only significantly different practice being the use of Couvinien rather than Eifelian, and the combination of the Siegenian and Emsian as the Coblencien by French-speaking writers. Definitions in the type areas were mostly rather exhaustively treated by national authorities in their contributions to the *Lexique Stratigraphique International* and these, and the practice in the type area, formed the basis for reference. All this is not to imply correlations with the type areas were correct but that practice in the type areas was the standard of reference.

Three main factors have led to a deterioration into the present confused situation. First, detailed chronologies using particular fossil groups have been established and it is boundaries defined in terms of these that have been used for the supposed recognition of stages and boundaries even if the chronologies have not been tied into type areas. Secondly, workers in facies other than those of type sections have preferred to correlate their sequences to reference sections in similar facies, even if this means introducing a novel nomenclature and ignoring that which has historic precedence. Thirdly, pressure for 'golden spikes' and formal international definition has already led to a plethora of quite new proposals, many of which pay not the least regard to past usage in type areas: the decision on the Silurian/Devonian boundary which, albeit for good reason, ignored historical priority completely, has seemed to encourage such anarchy. The principle that boundaries should be defined to be widely usable and cause least disturbance to existing literature and historic practice seems to have been lost.

For the Lower Devonian, proposals to discard the standard stages of the Ardennes and Rhine Valley, which are in marine clastic facies, in favour of new stages from the carbonate sequences in Czechoslovakia (Chlupáč 1976*b*) finds much support in western North America. These proposals would ignore the work which has been done over many years tying the marine clastic sequences into the Old Red Sandstone facies, and would make redundant and virtually unusable much past literature. However, on these matters the goniatite evidence contributes little except in so far as certain Emsian faunas are concerned.

For the Lower/Middle Devonian boundary no less than six possible boundaries have been suggested (Chlupáč 1976*b*): these range from a level probably very low in the Emsian to a level at the base of the Jugleri Zone (as shown on text-fig. 12): these proposals carry with them no discussion of the implications for terminology in the clastic marine facies or in the Old Red Sandstone facies. Here, of course, there have been several levels where the Lower/Middle Devonian boundary has been taken in the past in Europe. Surely any new proposals higher or lower than those commonly used in the past should be discounted.

The Eifelian/Givetian boundary is similarly debated, but here the matter seems to resolve into whether German practice is followed (as recommended here) or whether a freshly defined boundary using conodonts in the classic Ardennes sections at the Couvinien/Givetien boundary (Bultynck 1970) is accepted.

Discussion of definition of the Middle/Upper Devonian boundary is greatly bedevilled by the adoption of a level on the conodont scale, thought to correspond to the boundary used here (and shown on text-fig. 12), but which was erroneously placed too high as has been shown by recent work (House and Ziegler 1977). The false boundary has been widely used corresponding with the extensive use of conodonts biostratigraphically. Before the error in the conodont definition was realized the Belgians redefined the base of the Frasnian to what they thought was the more correct level as falsely indicated by conodonts. Essentially possible contendors for this boundary range from the German level as used for the last seventy years (and indicated on text-fig. 12) up to a level at about the Lunulicosta Zone/Cordatum Zone boundary, the latter approximating to the new Belgian definition at the base of the Assise de Frasnes. It will be noted that a level so high is quite at variance with usage in eastern North America and in Russia.

The differences in definition of the Frasnian/Famennian boundary are relatively small in scale, and are unlikely to be the cause of much problem in reaching international agreement (House 1973*a*; House and Ziegler 1977), but the recent destruction of the Senzeille type section introduces difficulties.

Controversy concerning the Devonian/Carboniferous boundary need not be referred to here, apart from pointing out that Belgian and Russian authors have tended not to accept the Gattendorfia Stufe/Wocklumeria Stufe boundary indicated on text-fig. 12, and they have continued to take a boundary at the base of Tn_{1a}, interpreting this as a level within or at the base of the Wocklumeria Stufe.

The American major series divisions (text-fig. 12) have never been seriously used outside North America, and even North American literature has not been wholly stable. The Ulsterian/Erian boundary is taken by Rickard (1975) at the base of the Onondaga, but by Oliver *et al.* (1969) at the Tioga Bentonite (text-fig. 2). There is much to recommend Rickard's definition since then the Ulsterian corresponds almost exactly with the traditional definition of the Lower Devonian. In 1964 Rickard took the base of the Senecan at the base of the Tully and Taghanic, and it will be seen that such a definition agrees well with the traditional definition of the base of the Upper Devonian as taken in Germany (text-fig. 12). Subsequently Oliver *et al.* (1969) have drawn the base of the Senecan at the top of the Taghanic, and in the revised chart for New York, Rickard (1975) follows this: again the 1964 definition of Rickard, or at least one which is at the same level as the European definition would simplify international nomenclature. The base of the Chautauquan seems to agree very closely with the Frasnian/Famennian boundary as defined by conodonts. Typical early Cheiloceras Stufe goniatites are first seen in the Gowanda Shale. All current American literature accepts the Wocklumeria Stufe/Gattendorfia Stufe boundary as marking the top of the Devonian.

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MICHAEL R. HOUSE

Department of Geology
University of Hull
North Humberside HU6 7RX

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