

REVISION OF THE RHENISH LATE VISEAN GONIATITE STRATIGRAPHY

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(3 figures)

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ABSTRACT. The Late Viséan Kulm series of the Rhenish Massif can be subdivided into 15 successive goniatite zones: *hudsoni* Zone, *globostriatum* Zone, *crenistrina* Zone, *fimbriatus* Zone, *spirifer* Zone, *falcatus* Zone, *gracilis* Zone, *spirale* Zone, *rotundum* Zone, *suerlandense* Zone, *poststriatum* Zone, *eisenbergensis* Zone, *liethensis* Zone, *chalicum* Zone, and *novalis* Zone. All are defined by the first occurrence of the nominate species. The new zonation is an advanced version of the German standard goniatite stratigraphy, but allows close correlation to the stratigraphic scheme proposed for the sections in the British Isles. A proposal for a subdivision of the Viséan Stage is presented, using the first entry of the goniatite species *Goniatites hudsoni* Bisat, 1934 as Mid-Viséan boundary. Also, a new proposal for definition of the Viséan-Namurian boundary is given, suggesting that this boundary should be marked with the first entry of *Edmooroceras pseudocoronula* (Bisat, 1950), rather than with *Emstites leion* (Bisat, 1930).

KEYWORDS: Palaeozoic, Carboniferous, Viséan, Germany, Rhenish Massif, ammonoids, biostratigraphy.

RESUME. Révision de la stratigraphie des goniatites du Viséen récent rhénan. Les séries du Culm Viséen supérieur du Massif Rhénan peuvent être divisées en 15 zones successives de goniatites: *hudsoni* Zone, *globostriatum* Zone, *crenistrina* Zone, *fimbriatus* Zone, *spirifer* Zone, *falcatus* Zone, *gracilis* Zone, *spirale* Zone, *rotundum* Zone, *suerlandense* Zone, *poststriatum* Zone, *eisenbergensis* Zone, *liethensis* Zone, *chalicum* Zone, et *novalis* Zone. Toutes sont définies par l'apparition de l'espèce citée. La nouvelle zonation est une version améliorée de la stratigraphie habituelle allemande des goniatites, mais permet une corrélation étroite avec le système stratigraphique proposé pour les sections dans les Iles Britanniques. On propose ici, pour subdiviser l'Étage Viséen, l'apparition des espèces de goniatites *Goniatites hudsoni* Bisat, 1934 comme limite du Viséen moyen. Une nouvelle proposition pour définir la limite du Viséen-Namurien est faite, suggérant que cette limite devrait être marquée par l'apparition de *Edmooroceras pseudocoronula* (Bisat, 1950), plutôt que par celle de *Emstites leion* (Bisat, 1930).

MOTS-CLES: Paléozoïque, Carbonifère, Viséen, Allemagne, Massif Rhénan, ammonoïdes, biostratigraphie.

1. INTRODUCTION

Goniatites are still the best index fossils to subdivide the clastic sequences of the Middle European Kulm series. They are fairly abundant in Flysch-like sequences, in the Posidonia Shales, in limestone turbidites, as well as in autochthonous limestones, allowing correlation of these different sedimentary successions. Goniatites of very similar type can be used as index fossils in a large geographical area, ranging from Ireland in the northwest to the Lublin Basin in the southeast. Consequently, many stratigraphical age determinations of rocks have been achieved with goniatites.

The basis for the Late Viséan goniatite zonation in Germany was formed by Schmidt (1925), using different ornamental types of goniatites to distinguish between the *crenistrina*, *striatus*, and *granosus* zones. This concept has been evolved by Kobold (1933), Haubold (1933), Ruprecht (1937), Kulick (1960), and Nicolaus (1963), resulting in a subdivision of 11 goniatite subzones within the Late Viséan.

During the last two decades, many new outcrops of Late Viséan rocks in the Rhenish Massif have been studied. Among these, the large quarries in the Kulmplattenkalk Formation are the most important (Korn, 1988). In addition, some new road cuts

also enabled the study of Late Visean rocks (Korn, 1990a; Korn, 1993). The information received from these new outcrops makes it necessary to revise the stratigraphical scheme, usually by subdividing some of the former subzones.

The new stratigraphical scheme offered here resembles more closely that introduced for the British Isles (Bisat, 1928; Bisat, 1934; Bisat, 1950; Bisat, 1952; Moore, 1936; Hudson & Cotton, 1945; Riley, 1990a) than the older German subdivision. Therefore, correlation between the Irish, English, Belgium, German, Polish, and Czech sections can be achieved much more easily than before.

2. LOCALITIES

All the localities on which the advanced stratigraphical scheme is founded are situated at the northern margin of the Rhenish Massif, most of them close to the provincial capital Arnsberg (Fig. 1). Kulmplattenkalk sections (Oese, Edelburg, Holzen, Arnsberg, Wicheln, Enkhausen, Wennemen, Berge) as well as Posidonienschiefer sections (In den Dieken, Sundern, Frenkhausen) have been studied, showing principally the same goniatite succession. Besides these important outcrops over long stratigraphic intervals, many small exposures with one or a few different goniatite horizons substantiate the results. Also taken into account are those sections near the eastern margin of the Rhenish Massif (Medebach, Hillershausen, Bömighausen, Rhena), which were intensively investigated by Kulick (1960) and Nicolaus (1963).

The stratigraphical scheme published here is based on the following sections (data source in brackets):

- Schälk (Ruprecht, 1937; Horn, 1960; Korn, 1988)
- Oese (Nicolaus, 1963; Korn, 1988)
- Edelburg (Ruprecht, 1937; Schmidt, 1942; Horn, 1960; Korn, 1988)
- Holzen (Korn, 1988)
- Herdringen (Ruprecht, 1937; Schmidt, 1942; Korn, 1988)
- Wicheln (Korn, 1988)
- Arnsberg (Korn, 1993)
- Enkhausen (Korn, unpublished)
- In den Dieken (Ruprecht, 1937; Schmidt, 1942; Korn, 1988; Korn, unpublished)
- Sundern (Nicolaus, 1963; Korn, 1988)
- Frenkhausen (Ruprecht, 1937; Horn, 1960; Korn, 1988)
- Berge (Ruprecht, 1937; Horn, 1960; Korn, 1988)
- Wennemen (Nicolaus, 1963; Kulick, 1960)
- Eulenspiegel (Korn, 1990a)
- Glenne-Tal (Korn, 1990a)
- Enkenberg (Figge, 1968)
- Medebach (Kulick, 1960; Nicolaus, 1963)
- Hillershausen (Kulick, 1960; Nicolaus, 1963)
- Herborn (Nicolaus, 1963).

3. THE GONIATITE SUCCESSION

Without exceptions, the lower boundaries of all the 17 zones are defined here by the first occurrence of the nominative species. With only a few exceptions, the proposed goniatite zones are characterized by the main occurrence of the index species. The fau-

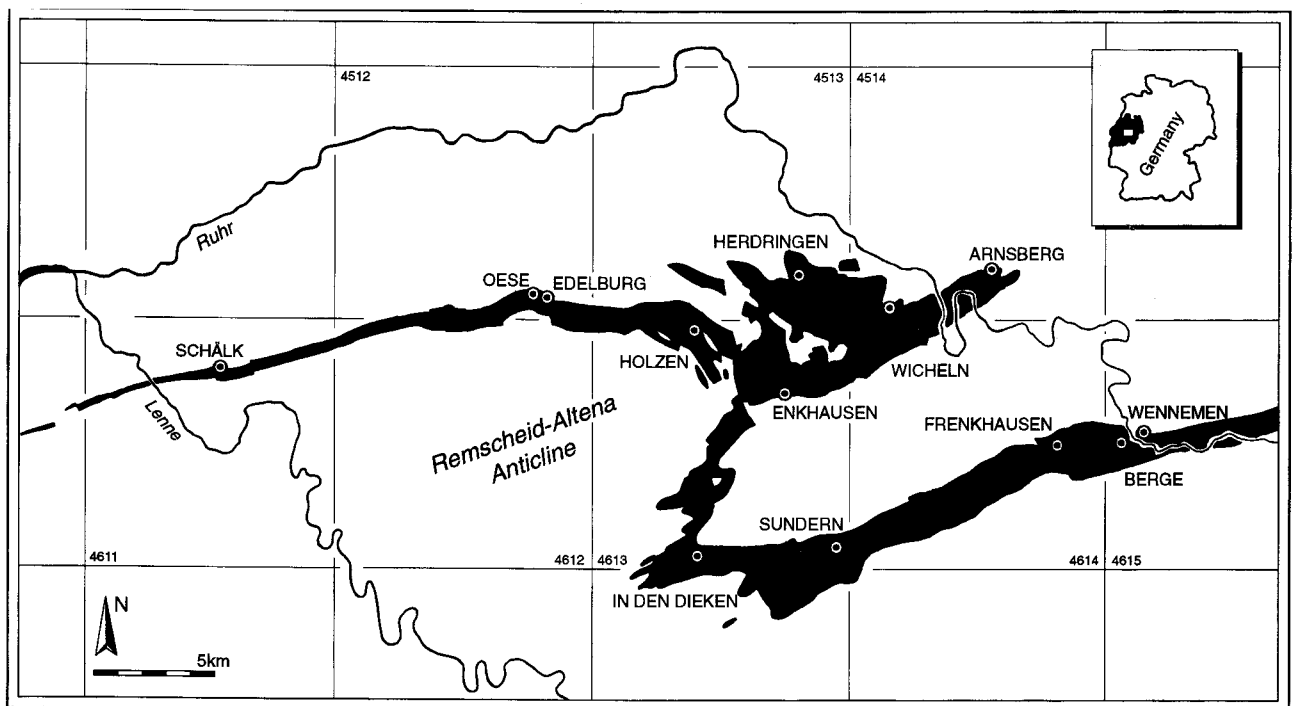


Figure 1. Location of most important sections of Late Visean rocks (black) at the northern margin of the Rhenish Massif.

nal characteristics of the different discriminated zones are as following (Fig. 2):

- *Grimmeri* Zone. In the Rhenish Massif, ammonoid assemblages from the base of the *Goniatites* Stufe are poorly known, and the lower boundary has been defined with the first entry of *Entogonites grimmeri* (Kittl, 1904). Below these beds, there are horizons with *Entogonites nasutus* (Schmidt, 1941), a species that probably gave rise to *E. grimmeri*. Both zones are almost exclusively known by crushed goniatites, not allowing clear determination of other goniatite species. Thus, the exact horizon of *Beyrichoceras mepeli* Schmidt, 1941 is still unclear.

- *Hudsoni* Zone. The last occurrence of *Entogonites grimmeri* is in the so called *Grimmeri* Bed, a distinct index horizon known from many localities in the Rhenish Massif. It is characterized by a huge individual number of this species, together with the entry of *Goniatites hudsoni* Bisat, 1934. Co-occurring ammonoids in the *Grimmeri*-Bed belong to the genera *Girtyoceras*, *Eoglyphioceras*, *Nomismoceras*, *Michiganites*, and probably to *Bollandoceras*. The *hudsoni* Zone is characterized by three index horizons: the *Grimmeri* Bed, the *Pterinopecten* Bed [with abundant occurrence of *Irinoceras latecostatum* (Nicolaus, 1963)] as well as the „Goniatitenknollen“. The latter is only known from sections near the eastern margin of the Rhenish Massif; it yielded a rather well preserved and diverse fauna with *Goniatites hudsoni*, *Girtyoceras moorei* Nicolaus, 1963, *Cowdaleoceras araneum* (Nicolaus, 1963), *Nomismoceras vittiger* (Phillips, 1836), *Nomismoceras* (?) sp., *Eoglyphioceras* sp., *Prolecanites* sp., and *Pronorites* sp. (Nicolaus, 1963; Korn, 1990a). The lower boundary of the *hudsoni* Zone does not fit the boundary between the Goa1 and Goa2 in the sense of Nicolaus (1963), which has been defined at the last occurrence of *Entogonites grimmeri*. For easier correlation with the British Isles (Riley, 1990a), all the newly defined zones are characterized by the first entry of the nominate species. The *hudsoni* Zone therefore has the same duration as the B2a Zone of the new zonation introduced by Riley (1990a) for the British Isles.

- *Globostriatus* Zone. In the Rhenish Massif, this zone is only known from crushed goniatite material, but it is easily recognizable because of its conspicuous index species *Goniatites globostriatus* (Schmidt, 1925). Many of the goniatite species from the preceding zone are still present, such as *Goniatites hudsoni*, *Girtyoceras moorei*, and *Cowdaleoceras araneum*. The *globostriatus* Zone resembles the higher part of the *schmidtianus* Subzone (Goα2) and the lower part of the *crenistrina* Subzone (Goα3) of Nicolaus (1963), and the equivalent of the B2b Zone of the British zonation.

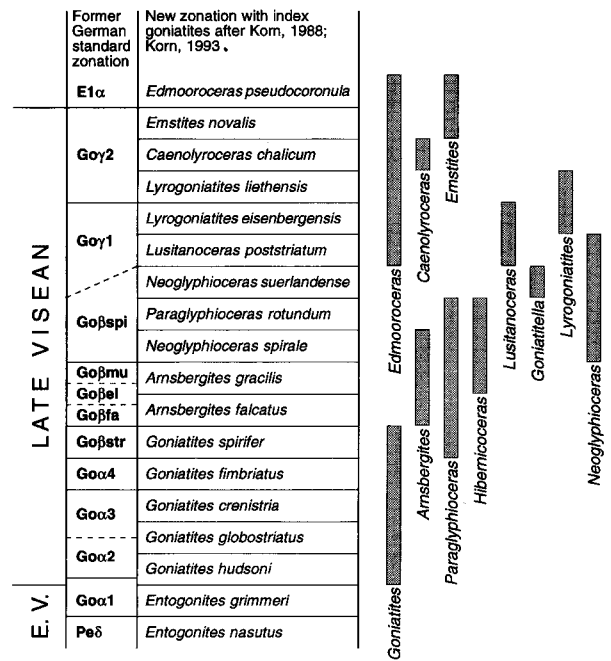


Figure 2. Revised stratigraphic scheme of the Late Visean and correlation with the former German standard zonation. Bars on right side show stratigraphical occurrence of most important goniatite genera.

- *Crenistrina* Zone. *Goniatites globostriatus* is still present in the basal *crenistrina* Zone, but does not occur in the *Crenistrina* Bed, the main index horizon in the Kulm series of the Rhenish Massif. This pale-grey limestone, known from the most of the investigated sections, often is developed as three different limestone beds of 5 to 30cm thickness containing numerous individuals of *Goniatites crenistrina* Phillips, 1836, but only few specimens of *Eoglyphioceras truncatum* (Phillips, 1836), *Pronorites* sp., and *Dimorphoceras* (?) sp. (see Nicolaus, 1963; Korn, 1988; Korn, 1990a). The *crenistrina* Zone in the new sense has a shorter duration than in the sense of Nicolaus (1963) who defined the base of this zone by the extinction of „*Goniatites crenistrina schmidtianus* [= *Goniatites hudsoni*]“, and not by the first entry of *Goniatites crenistrina*.

- *Fimbriatus* Zone. The index species *Goniatites fimbriatus* (Foord & Crick, 1897) has its first occurrence immediately above the *Crenistrina* Bed. In some localities, such as the Herborn section, *Eoglyphioceras truncatum* is much more abundant than *Goniatites fimbriatus* (see Nicolaus, 1963), providing good evidence for the *fimbriatus* Zone. Both the *crenistrina* Zone and the *fimbriatus* Zone together can be correlated with the P1a Zone of the British zonation (Bisat, 1934). The *fimbriatus* Zone coincides with the *intermedius* Subzone (Goα4) of Nicolaus (1963).

- *Spirifer* Zone. *Goniatites fimbriatus* ranges up into the *spirifer* Zone, in which besides *Goniatites spirifer* Roemer, 1850 it is the most abundant goniatite. *Paraglyphioceras* (?) *semistriatum* (Nicolaus, 1963) is also relatively common, but *Paraglyphioceras radiatum* (Hodson & Moore, 1959) is rare in the Rhenish Massif and has not yet been figured in the literature. The *spirifer* Zone has the same duration and boundaries like the *striatus* Subzone (Goßstr) of Kulick (1960) and Nicolaus (1963).

- *Falcatus* Zone. With the entry of *Arnsbergites falcatus* (Roemer, 1850) a change in the goniatite fauna occurs. The genus *Goniatites* is completely replaced by its successors *Arnsbergites* and *Paraglyphioceras*; other genera such as *Girtyoceras* and *Nomismoceras* continue in their occurrence. In the British literature, the *A. falcatus* layer has not been clearly separated from the underlying horizon, both are included in the P1b Zone (Hodson & Moore, 1959). As shown by Korn (1990b), the horizons with *Goniatites spirifer* and *Arnsbergites falcatus* can clearly be separated in Co. Leitrim of Ireland, showing principally the same succession as in the localities in the Rhenish Massif.

- *Gracilis* Zone. Generic composition did not change from the underlying zone, but the genera *Arnsbergites* and *Paraglyphioceras* produced the new species *A. gracilis* Korn, 1988 and *P. rudis* (Moore & Hodson, 1958). *Hibernicoceras* occurs for the first time, and forms an important constituent of the goniatite fauna. The newly defined *gracilis* Zone partly contains the *elegans* Zone of Kobold (1933) and Kulick (1960); a zone that was hardly recognizable. *Paraglyphioceras elegans* (Bisat, 1928) cannot be treated as an index fossil because of taxonomic uncertainties due to very poor preservation of the type (Korn, 1988). Furthermore, its stratigraphic position is uncertain, suggesting that it is stratigraphically slightly older than *Arnsbergites sphaericostriatus* (Bisat, 1924), a close relative to *A. gracilis*. "*Goniatites mucronatus*", which obviously is a *Hibernicoceras* species, is no longer used as index species since in distorted specimens it can only hardly be separated from other species of that genus.

- *Spirale* Zone. Many of the species of the latter zone continue into the *spirale* Zone, which is characterized by the first occurrence of *Neoglyphioceras spirale* (Phillips, 1841). Also appearing in this zone is *Praedaraelites culmiensis* Kobold, 1933, which is very abundant in only one horizon, providing an opportunity for correlations with occurrences in Ireland and Northern England. Less important genera in this zone are *Girtyoceras*, *Pronorites*, and *Nomismoce- ras*. The *spirale* Zone is newly defined here, it has a much shorter duration than in the sense of Kobold

(1933) or Kulick (1960) who also included the next higher horizon within this zone. The British P1c Zone embraces both the *gracilis* Zone and the *spirale* Zone.

- *Rotundum* Zone. With this zone, another remarkable step in the goniatite distribution of the Kulm series is reached. *Arnsbergites* is no longer existing, but *Hibernicoceras* is still present with *H. striatospaericum* (Brüning, 1923), *H. doliolum* Korn, 1988, and *H. ultimum* Korn, 1988. *Paraglyphioceras rotundum* Brüning, 1923 is the most abundant goniatite of this zone, accompanied by *Sulcogirtyoceras burhennei* (Brüning, 1923) and *Girtyoceras brueningianum* (Schmidt, 1925). The *rotundum* Zone resembles the P1d Zone of Hudson & Cotton (1945). "*Goniatites koboldi* Kobold, 1933", the index for the P1d, is a junior synonym of *Paraglyphioceras rotundum* (see Korn, 1988).

- *Suerlandense* Zone. None of the species of the latter zone has been discovered in this horizon, which yielded the newly entering species *Neoglyphioceras suerlandense* Korn, 1988, *N. oculum* Korn, 1988, *Goniatitella agricola* Korn, 1988, *Girtyoceras margaritatum* Korn, 1988, and *G. duekmoerense* Korn, 1988. In the Rhenish Massif, *Sudetoceras* occurs for the first time in this horizon, somewhat later than in Ireland (Moore & Hodson, 1958). At the top of this zone, a lithologic index horizon ("*Actinopteria* Shale") is present in many sections of the Rhenish Massif; it is an alum shale that in some horizons contains many specimens of *Actinopteria persulcata* (McCoy, 1851). Evidence for this zone by goniatites is lacking outside the Rhenish Massif.

- *Poststriatum* Zone. In this zone, the genera *Lusitanoceras* and *Lusitanites* occur for the first time, but it cannot be stated with certainty that they appear in the same level. *Lusitanoceras poststriatum* (Brüning, 1923) and *Lusitanites circularis* Korn, 1988 are the most common goniatites in this zone, but usually they do not occur together on the same bedding surfaces. Additional species are *Sudetoceras crenistriatum* (Bisat, 1928), and members of *Girtyoceras*. The *poststriatum* Zone resembles the British P2a Zone, but specific identification of the collections from Lancashire is required before further reaching conclusions can be made. *Lusitanites clitheroensis* Korn, 1988 (= *Goniatites subcircularis* in Moore, 1936) occurs in a slightly higher level as does *Lusitanoceras granosum* (see Moore, 1936).

- *Eisenbergensis* Zone. Of all the Late Viséan goniatite zones, this one is known from the fewest localities. Only one section is known (Schälk) in which the exact horizon of *Lyrogoniatites eisenbergensis* (Ruprecht, 1937) could be traced with certainty. The

fauna of this horizon also includes *Lusitanoceras postriatum* (see Ruprecht, 1937), as well as *Girtyoceras aedulkei* Korn, 1988. The Zone Goy1 of Ruprecht (1937) includes three of the zones proposed here: *suerlandense*, *poststriatum*, and *eisenbergensis* Zones.

- *Liethensis* Zone. Stratigraphic evidence of this zone is incomplete, but well preserved faunas are known from loose blocks of several localities and the section at the motorway building site near Arnsberg (Korn, 1993). Co-occurring with *Lyrogoniatites liethensis* Korn, 1988 are *Sudeticeras splendens* (Bisat, 1928) and *Kazakhoceras hawkinsi* (Moore, 1930). "*Lyrogoniatites georgiensis*" figured by Calver & Ramsbottom (in Earp *et al.*, 1961) appears to be identical with *Lyrogoniatites liethensis* and allows a correlation of the P2c Zone with the *liethensis* Zone.

- *Chalicum* Zone. The differences of the three species *Lyrogoniatites eisenbergensis* (Ruprecht, 1937), *Lyrogoniatites liethensis* Korn, 1988, and *Caenolyroceras chalicum* Korn, 1988 are hardly recognizable in completely crushed material, and often preclude exact stratigraphic determinations of such specimens. Thus the separation of the latter three zones requires well preserved material, at least showing the constrictions. The *chalicum* Zone, however, is characterized also by the conspicuous species *Cousteauceras costatum* (Ruprecht, 1937), which often accompanies the nominative species. Also, some girtyoceratids such as *Girtyoceras goii* Korn, 1988 and *G. edwinae* Korn, 1988 are restricted to this zone. The *chalicum* Zone may be compared with the horizon that at Dinckley yielded "*Goniatites newsomi* mut β " (Moore, 1936), which presumably is conspecific with *Caenolyroceras chalicum*.

- *Novalis* Zone. With the entry of *Emstites novalis* Korn, 1988, a completely new ammonoid fauna occurs. All the species with coarse spiral ornament disappeared, replaced by the genus *Emstites* displaying a more delicate ornament. This zone is not clearly separated in sections in the British Isles.

- *Pseudocoronula* Zone. All the genera of the latter zone are continuing, but with the newly occurring species *Edmooroceras pseudocoronula* (Bisat, 1950) and *E. tornquisti* (Wolterstorff, 1899). *Emstites schaelkensis* (Brüning, 1923) and *Cousteauceras? involutum* (Horn, 1960) appear a little higher, and are abundant goniatites in this fauna. Although *Emstites leion* (Bisat, 1930), the index goniatite of the basal Namurian, has not been found in the Rhenish Massif, it can be regarded as being very close to *Emstites schaelkensis* because of the striking morphological similarity. Therefore, the *pseudoco-*

ronula Zone can be treated as basal Namurian, correlated with the British E1a Zone.

4. CORRELATION OF THE CENTRAL EUROPEAN STRATIGRAPHY OF THE VISEAN STAGE WITH OTHER REGIONS

A convincing correlation of the Central European sediments of the Late Visean Stage as well as the Visean-Namurian boundary with those of other regions, e.g. the American Midcontinent, North Africa and South Urals has not yet been presented. The fine stratigraphical scheme of the Late Visean which has been developed in Central Europe cannot be applied in the fossiliferous sections of other regions because of several reasons:

- The genus *Goniatites* though widespread, contains stratigraphically different species.
- The genera *Arnsbergites*, *Paraglyphioceras* and *Hibernioceras* are very rare or lacking.
- Some genera such as *Neoglyphioceras* range into a stratigraphically higher position.

The divergent development of goniatite faunas is already remarkable in the *hudsoni*, *globostriatum*, and *crenistria* Zones, of which no real equivalents are known from other areas outside Central Europe. In contrast, faunas which can be regarded as isochronic to the *fimbriatus* and *spirifer* Zones occur in America with *Goniatites multiliratus* (see Gordon, 1962; Gordon, 1965), in Spain with *Goniatites stenumbilicatus* (see Kullmann, 1961), and in the South Urals with *Goniatites crenifalcatum* (see Bogoslovskaya, 1966). All these species display very similar suture lines which suggest an equal developmental stage and thus a similar stratigraphic age.

In the Central European sections, five different goniatite zones are following which are characterized by the genera *Arnsbergites*, *Hibernioceras*, *Paraglyphioceras*, and *Goniatitella*, before *Lusitanoceras* has its first occurrence. It is remarkable that the genus *Goniatites* is lacking in these zones. This striking peculiarity cannot be explained, especially because conch geometry as well as ornament and suture development suggest that *Lusitanoceras* is a direct descendant of *Goniatites*.

Lusitanoceras is a cosmopolitan goniatite genus that occurs with numerous different species in various regions. Close morphological similarity of all the species within this genus suggests that all occur in the same stratigraphic interval. Co-occurring goniatites are usually species of *Neoglyphioceras* and *Lusitanites*. There is no evidence that *Lusitanoceras* and its descendant *Dombarites* have been collected from the same horizon. Information given by Librovich and quoted by Ruzhentsev & Bogoslo-

vskaya (1971) that in the Tyan-Shan *Lusitanoceras orientale* (Librovich, 1940) has been collected together with *Dobarites* may be invalid since that lithological unit is 300m thick.

Interestingly, no members of the family Goniatitidae younger than *Lusitanoceras* could be traced in the central European faunas. *Dobarites*, for instance, which is an extremely common goniatite genus in the faunas of the American Midcontinent, North Africa, the South Urals, and Asia, could not be traced in the Rhenish Massif or the British Isles. *Dobarites* is accompanied by genera such as *Hypergoniatites*, *Neogoniatites*, etc. which also are missing in Central Europe. Goniatite genera which are present in both provinces include *Neoglyphioceras*, *Lusitanoceras*, *Lyrogoniatites*, and *Emstites*, but not a single species is known to occur in both regions. Hence exact stratigraphic correlation is prevented, and only interpretations can be presented, based on goniatite associations with similar species.

The Visean-Namurian boundary of the Russian authors (Ruzhentsev & Bogoslovskaya, 1971) was drawn at the base of the *Hypergoniatites-Ferganoceras* Genozone (Nm1a). This contains a diverse goniatite fauna consisting of more than 25 different genera, of which *Dobarites*, *Hypergoniatites*, *Dobarocanites*, *Neoglyphioceras*, *Lusitanites*, *Platygoniatites* and *Ferganoceras* constitute the majority of the individuals (Ruzhentsev & Bogoslovskaya, 1971). A Central European equivalent of this rich association is not known. Faunal composition, however, suggests that this fauna is slightly younger than the *Lusitanoceras* faunal band, but somewhat older than the beds containing *Emstites* (Fig. 3).

Emstites occurs with the species *E. insolitum* (Ruzhentsev & Bogoslovskaya, 1971) and *E. shimanskyi* (Ruzhentsev & Bogoslovskaya, 1971) in the Russian *Uralopronorites-Cravenoceras* Genozone (Nm1b). *Dobarites*, *Platygoniatites* and *Dobarocanites* are the most abundant associated genera. Because of the entry of *Emstites*, this zone might be correlated with the newly defined *novalis* and *pseudocoronula* Zones around the Central European Visean-Namurian boundary.

5. PROPOSAL FOR A MID-UISEAN BOUNDARY

Within the Visean Stage, two succeeding complexes of ammonoid faunas can easily be distinguished:

- An early faunal complex dominated by genera which were already present in the late Tournaisian, such as *Merocanites*, pericyclids, as well as new components such as *Bollandites*, *Bollandoceras*, *Beyrichoceras*, etc. (Riley, 1990b).

- A late complex consisting of *Goniatites* and its descendants *Arnsbergites*, *Paraglyphioceras*, *Hibernioceras*, *Lusitanoceras*, *Goniatitella*, and *Girtyoceras*, *Prolecanites*, etc. (Korn, 1988; Riley, 1990a; Riley, 1993). Some genera (*Bollandoceras*, *Beyrichoceras*) from the early association continue in the lower part of this complex.

A subdivision of the Visean Stage should respect these faunal differences and also should be drawn at the most conspicuous faunal change. This is at the base of the *hudsoni* Zone [and thus will be defined with the first entry of *Goniatites hudsoni* Bisat, 1934], or at the base of the British B2 Zone, respectively. This boundary is remarkable for the following reasons:

- *Goniatites* appears for the first time with the species *G. hudsoni* [it has to be mentioned here, however, that the phylogenetic origin of the genus *Goniatites* is still unclear].
- *Girtyoceras* has its first entry together with *Goniatites*.

A Mid-Visean boundary with *Goniatites hudsoni* as its index species bears several advantages:

- *Goniatites hudsoni* is a common ammonoid species that is, because of its striking dorsolateral projection of the growth lines, easily recognizable, even in crushed material.
- *Girtyoceras* is an easily determinable goniatite and is fairly common.
- In the Rhenish Massif, this boundary coincides with the famous *Grimmeri*-Bed, a marker horizon that is easily detectable because of the abundant individuals of the conspicuous ammonoid *Entogonites grimmeri* (Kittl, 1904) [this species, however, occurs already in older beds in much less frequency (e.g. sections Oese, Sundern, Medebach, etc., Nicolaus, 1963)].

6. A NEW PROPOSAL FOR THE UISEAN-NAMURIAN BOUNDARY

During the 4th International Congress for the Carboniferous stratigraphy in Heerlen, 1958 it was proposed to define the Visean-Namurian boundary with the first entry of the goniatite species "*Cravenoceras leion* Bisat, 1930" [now *Emstites leion* (Bisat, 1930)] that was thought to occur in different regions isochronically and thus is the best index fossil for this purpose. Later studies (Korn, 1988), however, showed that this assumption was incorrect, and that the boundary defined with *Emstites leion* is accompanied by some difficulties:

- *Emstites leion* appears to be restricted to Northern England, occurrences in other regions are doubtful. Specimens from the Rhenish Massif, formerly determined as *Cravenoceras leion*, are almost exclu-

	RHENISH MASSIF	N. ENGLAND, IRELAND	SOUTH URALS
E1	<i>pseudocoronula</i> Zone	<i>Cravenoceras leion</i> Zone (E1a)	Nm1b1 <i>Uralopronorites-Cravenoceras</i> Genozone
	<i>novalis</i> Zone		Nm1a2
LATE VISEAN	<i>chalicum</i> Zone		<i>Hypergoniatites-Ferganoceras</i> Genozone
	<i>liethensis</i> Zone	<i>Lyrogoniatites georgiensis</i> Zone (P2c)	Nm1a1
	<i>eisenbergensis</i> Zone	<i>Neoglyphioceras subcirculare</i> Zone (P2b)	
	<i>poststriatum</i> Zone	<i>Goniatites granosus</i> Zone (P2a)	
	<i>suerlandense</i> Zone		
	<i>rotundum</i> Zone	<i>Goniatites koboldi</i> Zone (P1d)	

Figure 3. Correlation of the stratigraphical schemes around the Visean-Namurian boundary [N. England and Ireland after Calver & Ramsbottom (1961) and Moore & Hodson (1958), S. Urals after Ruzhentsev & Bogoslovskaya (1971)].

sively belonging to *Emstites schaelkensis* (see Korn, 1988), and specimens from Co. Leitrim of Ireland may all belong to the species *Emstites brandoni* (Palframan, 1984).

- Species of *Emstites* can only be certainly identified in good preservation, and crushed specimens are almost never determinable. Thus many reports of *Emstites leion*, based on distorted specimens, are questionable. In some cases, it might not even clear that these specimens in fact belong to the genus *Emstites*.

A far better index fossil for the definition of the Visean-Namurian boundary is *Edmooroceras pseudocoronula* (Bisat, 1950):

- It is a very abundant goniatite at the Visean-Namurian boundary.
- It is an easily detectable species, of which even crushed specimens can be convincingly determined.

Edmooroceras pseudocoronula is a species that in the Rhenish Massif has its occurrence slightly above the first entry of *Emstites schaelkensis*. At Edelburg, Horn (1960) documented that *Emstites schaelkensis* [*Cravenoceras leion* in his description; „*Goniatites schaelkensis*“ in his description now belongs to *Emstites novalis* (see Korn, 1988)] can be collected about 60cm below the lowest *Edmooroceras pseudocoronula*. Also, Figue (1968) reported the same situation for the Enkenberg section. In a fauna from Schalk, which is extremely rich in solidly preserved individuals, abundant *Emstites schaelkensis* occur here together with less frequent *Emstites novalis* Korn, 1988 and *Edmooroceras wedekindi* (Brüning, 1923). *Edmooroceras pseudocoronula* is absent in this fauna (Korn, 1988). For this section, Horn (1960) also postulated that *Emstites schaelkensis* preceeds *Edmooroceras pseudocoronula*.

In the British Isles, the stratigraphical position of *Edmooroceras pseudocoronula* and co-occurring goniatite species have not yet been perfectly documented. Yates (1962) stated that in Co. Leitrim in Ireland *Edmooroceras pseudocoronula* has its first entry together with „*Cravenoceras leion*“, but since she did not describe or figure distinct specimens from the latter species, the value of this information is limited. The holotype of *Edmooroceras pseudocoronula* was collected at River Ribble in Lancashire, thought to be E1 (Moore, 1936; Moore, 1946; Bisat, 1950), but the only one co-occurring goniatites were „*Paragoniatites tonksi*“ and some dimorphoceratid species. For the statement of Calver & Ramsbottom (in Earp *et al.*, 1961) that this horizon lies above the faunal band that in Light Clough yielded the type specimens of *Emstites leion*, firm evidence is lacking.

It can, however, be assumed that a boundary defined by *Edmooroceras pseudocoronula* is very near to the formerly defined *Emstites leion* level (Fig. 3).

7. CONCLUSIONS

Redefinition and monographic description of the Late Visean goniatites of the Rhenish Massif (Korn, 1988; Korn, 1990a) can be used as the basis for a revision of the goniatite standard zonation that was introduced by Schmidt (1925) and refined by Ruprecht (1937), Kulick (1960), and Nicolaus (1963). The Late Visean Kulm series in the Rhenish Massif contains numerous goniatite specimens which permit a subdivision of this time interval into 15 different goniatite zones. Most of these zones can easily be recognized in many sections at the northern and eastern margin of the Rhenish Massif.

The Late Visean goniatite zonation presented here is based on goniatites of the three families Goniatitidae, Cravenoceratidae, and Neoglyphiocerataidae, primarily supplemented by species of the families Girtyoceratidae and Anthracoceratidae. Other goniatite families such as Prolecanitidae, Daraellitidae, Pronoritidae, Nomismoceratidae, Dimorphoceratidae, and Berkhoceratidae are present but only in a few cases they are useful for stratigraphic purposes.

Application of the proposed zonation is not restricted to the Rhenish Massif; sections from Ireland in the northwest to the Lublin Basin in the east show principally the same succession of faunas. Especially the well-studied sections in Co. Leitrim, Ireland (summarized in Brandon & Hodson, 1984) and in the area of Clitheroe in Lancashire (summarized in Calver & Ramsbottom in Earp *et al.*, 1961) show very close relationships to the Rhenish succession,

promising a further development of a goniatite subdivision that is applicable in Western and Central Europe. Correlation with successions in the American Midcontinent, North Africa, the South Urals, and Asia must remain imperfect because of faunal differences between the provinces.

By means of goniatites it would be reasonable to subdivide the Visean Stage and to use *Goniatites hudsoni* Bisat, 1934 as index fossil of the Mid-Visean boundary. This boundary separates two easily distinguishable faunal complexes, an early one especially dominated by goniatites of the families Pericyclidae and Muensteroceratidae, and a later one in which the families Goniatitidae, Neoglyphiocerataidae, and Cravenoceratidae are predominant.

The present Visean-Namurian boundary with *Emstites leion* (Bisat, 1930) as its index species is very difficult to trace outside of the north of England. It should be replaced by a much better determinable boundary defined by the entry of *Edmooceras pseudocoronula* (Bisat, 1950), which also has a much wider geographic distribution than *Emstites leion*. A boundary with *Edmooceras pseudocoronula* would be more or less at the same stratigraphical position as the old boundary.

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