

**Biostratigraphie des couches
de transition Dévono-Carbonifère et limite entre les deux Systèmes
(Synthèse du groupe de travail sur la limite Dévonien/Carbonifère)**

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Avec 2 tableaux

Summary

The most recent micropalaeontological and palynological data are presented on the problem of the Devonian/Carboniferous boundary. The report emphasizes the correlations provided by the different groups of fossils (Table 1) and it discusses the most useful palaeontological criteria for placing the systemic boundary (Table 2).

New data are as follows:

1) The *pusillites-lepidophytus* spore assemblage has been found in the Etroeungt Limestone at St. Hilaire in the Avesnois (France).

2) The base of the *pusillites-lepidophytus* assemblage in the Hastière section, a typical section of the Tn1a in the Dinant basin near Dinant, is associated with a *costatus* conodont fauna. The position of the PLi spore assemblage at a level higher than base of the *costatus* conodont fauna, already known from the Ourthe Valley, is now confirmed for the Dinant area.

3) The last *Hymenozonotriletes lepidophytus* are found as poorly preserved (reworked ?) specimens below the horizon of a "primitive" *Siphonodella* in the first bed of the Hastière Limestone in the paratotype at Anseremme near Dinant.

4) The *pusillites-lepidophytus* assemblage is associated with an upper *costatus* fauna, near the base of the 150 metres thick section at Seiler (West Germany).

5) A few spores including *H. lepidophytus*, *H. pusillites* and a newly found species similar to *Spinozonotriletes balteatus*, occur in both the Oese and Stockum sections of West Germany. At Oese, these spores are found in ca. 15 metres of sandstone intercalated between the Hangenberg Shales (with a PLs 2 assemblage) and the first Carboniferous limestone (with the succession *Protognathodus* fauna/*Siphonodella sulcata* Zone). At Stockum, they occur with a PLs 3 assemblage, which is associated with the cephalopod *Balvia prorsum* and a *Protognathodus* conodont fauna. Work now in progress indicates that a more suitable basal limit may be found here for what has been called earlier the *trivialis-explanatus* spore assemblage.

6) The Sappington Formation of Wyoming and Montana (U.S.A.) contains a *pusillites-lepidophytus* assemblage with a species content very similar to that of the PLs 2 assemblage found in the Hangenberg Shales. It is associated with "primitive" *Siphonodella* which, in the U.S.A., occurs below the base of the *sulcata* conodont zone.

7) In the Mississippi Valley, the Saverton Shales contain a *pusillites-lepidophytus* assemblage with large specimens of *H. lepidophytus* (C zone), corresponding to the PLi/m assemblage. These are associated with the American *aculeatus* conodont zone. An earlier report of the I.U.G.S. Subcommittee on Carboniferous Stratigraphy (Sheffield 1967) is discussed in the light of these new data, and a proposal is made for placing the Devonian/Carboniferous boundary as near as possible to the presently accepted limit, i.e. at the incoming of *Gattendorfia subinvoluta*, but more closely defined by taking into account the evolution of conodonts (*Siphonodella* lineage or *Protognathodus/Gnathodus* lineage). A stratotype should be selected which contains these conodonts throughout the section.

Introduction

De bonnes corrélations biostratigraphiques au niveau des couches de transition entre le Dévonien et le Carbonifère sont aujourd'hui réalisables entre les faciès littoraux du Nord de la France et de la Belgique et les faciès qualifiés de „bathyaux" en Allemagne.

Ces corrélations sont très précises et pour s'en convaincre, il faut se reporter aux plus récents rapports publiés sur cette question (notamment AUSTIN et al. 1971, PAPROTH & STREEL 1971). En termes très généraux, il est devenu évident que la base du Système Carbonifère sensu Heerlen 1935 se situe dans la séquence sédimentaire carbonatée de quelques mètres qui constitue la partie inférieure du Calcaire d'Hastière (pris ici avec son sens de Formation lithostratigraphique) dans la localité-type du bassin de Dinant, en Belgique. Quant à la base de l'Étage (de la Série ?) Tournaisien dans son acceptation traditionnelle francobelge, incluant les couches d'Etroeungt, elle peut être située, selon la définition qu'en donnent les auteurs, à différents niveaux du Calcaire à *Wocklumeria* dans les coupes classiques de l'Hönnetal en Allemagne.

Ces corrélations sont pressenties depuis quelques années déjà (voir PAPROTH 1964) mais il était bon de les affiner encore avant de passer à une étape plus décisive, celle du choix (définitif) d'une limite acceptée par tous, qui ferait coïncider la base de l'Étage Tournaisien et la base du Système Carbonifère dans

un stratotype possédant les qualités requises d'une coupe de référence internationale. Ce rapport se présentera donc en deux parties:

- dans la première seront recensées les dernières données biostratigraphiques, parfois inédites, accessibles après l'impression des rapports cités plus haut; elles vont toutes dans le sens d'un affinement stratigraphique et d'un élargissement géographique de critères déjà utilisés.
- dans la seconde partie, le problème du choix d'une limite précise acceptable par tous sera discuté et des solutions seront proposées.

Il est apparu que l'étape ultime, la désignation d'un stratotype, dépendait dans une large mesure du choix de cette limite précise et que, par conséquent, elle pouvait être encore différée. Nous croyons d'ailleurs qu'une telle décision doit être prise par une commission élargie groupant des spécialistes du Dévonien et du Carbonifère, ayant par conséquent un statut différent d'un groupe de travail centré essentiellement sur la stratigraphie du Dinantien.

Données biostratigraphiques récentes

Le tableau 1 rassemble de part et d'autre de la zonation détaillée des Céphalopodes, les zonations des principaux groupes fossiles concernés par les corrélations que nous recherchons. Les 14 niveaux biostratigraphiques proposés (n° 1 à XIV, tab. 1) n'ont évidemment pas tous, loin s'en faut, le même poids dans les discussions qui vont suivre. Le tableau 2 reprend les critères principalement utilisés (n° 1 à 13 pour la faune) en mettant l'accent sur leur valeur biostratigraphique en tant qu'approche d'une chronostratigraphie. Ainsi, nous considérons comme particulièrement significatifs, les points d'apparition d'espèces qui se produisent dans une séquence faunistique ou floristique continue dans un même profil. Encore faudrait-il sélectionner parmi ceux-ci, les espèces qui apparaissent dans une séquence où leur position phylogénétique peut être démontrée. D'autre part, les critères de première apparition locale et a fortiori de disparition locale d'une espèce (base et sommet de teilzone) nous paraissent comparativement des données de deuxième choix.

a) Affinement des corrélations biostratigraphiques dans les régions ardenno-rhénanes

Avesnois: Le Calcaire d'Etroeungt à St. Hilaire (AUSTIN et al. 1971: hors-texte 1) contient l'assemblage de spores *pusillites-lepidophytus* supérieur (PLs1). Dans le Calcaire noir d'Avesnelles sus-jacent AUSTIN & RHODES 1971 avaient isolé *Protognathodus kockeli*, un conodonte des zones VIII et IX (tab. 1).

Hastière-Anseremme: La base de la zone *pusillites-lepidophytus* est identifiée dans la coupe de Hastière, sentier des vignes (AUSTIN et al. 1971: hors-texte 1) quelques mètres au-dessus d'une faune à conodontes *costatus* (BOUCKAERT, STREEL & THOREZ 1971). La succession 1/PLi (voir tableau 2) identifiée pour la première fois dans la vallée de l'Ourthe est maintenant confirmée dans la région type d'Hastière-Anseremme.

A Anseremme, quelques spécimens d'*Hymenozonotriletes lepidophytus*, mal conservés et peut-être remaniés, sont présents dans les schistes immédiatement sous-jacents au Calcaire d'Hastière dont le premier banc contient une nouvelle espèce de conodonte, une *Siphonodella* „primitive" (d'après J. BOUCKAERT et CH. SANDBERG, inédit).

Seiler: KOCH, LEUTERITZ & ZIEGLER 1971 ont publié les résultats de l'étude d'une tranchée provisoire effectuée dans la région d'Iserlohn, non loin de l'Hönnetal. L'intérêt de cette étude est double. D'abord, elle met en évidence, pour la première fois dans une même coupe, la succession de conodontes: Faune à *Protognathodus/Siphonodella sulcata* zone. Ensuite, elle montre que les Schistes de Hangenberg peuvent atteindre quelque 150 mètres de puissance, 10 kilomètres à l'ouest d'Oberrödinghausen où ils ont moins de 10 mètres d'épaisseur. La puissance des Schistes de Hangenberg dans la coupe Seiler est établie sur la base de la distance qui sépare les faunes à *Protognathodus* au sommet, des faunes *costatus* supérieur trouvées à la base de la coupe. Nous la confirmons par la découverte de spores de la zone *pusillites-lepidophytus* à la fois dans le haut (Schurf 2 : III 15-54 m à III 17-72 m) et dans le bas de la coupe (Schurf 1 : P.16, obere *costatus* zone et P.6.1). En ce qui concerne le dernier niveau (P.6.1), la corrélation avec les couches de Hemberg proposée par les Ostracodes est en contradiction avec la corrélation par spores puisque la base de la zone *pusillites-lepidophytus* se situe dans la zone à conodontes *costatus* trouvée dans les couches de Dasberg et de Wocklum.

Oese et Stockum: cette coupe récemment levée en détail par E. PAPROTH (inédit) présente un intérêt au moins aussi considérable que la coupe précédente. Elle est située à quelques kilomètres seulement au nord de la coupe classique d'Oberrödinghausen. Les Schistes de Hangenberg y sont épais d'une dizaine de mètres et contiennent des assemblages de spores identiques à ceux décrits dans les sédiments similaires à Oberrödinghausen (PLs2, PAPROTH & STREEL 1971). Une analyse des spores dans 19 échantillons se succédant de 50 en 50 centimètres au-dessus du Calcaire à *Wocklumeria* montre un comportement assez parallèle des assemblages entre Oberrödinghausen et Oese en ce qui concerne l'évolution de la taille moyenne d'*H. lepidophytus* d'un assemblage à l'autre: zone D (interquartile 46 à 61 μ), suivie de la zone E (interquartile 41-46 à 56 μ). A Oese, on peut de plus mettre bien en évi-

dence le retour des zones D et E, en alternance, dans la partie supérieure du profil. Ceci nous paraît confirmer le caractère remanié de ces dépôts (Voir PAPROTH & STREEL 1971).

Contrairement à la coupe d'Oberrödinghausen où le Calcaire de Hangenberg repose directement sur les Schistes de Hangenberg, la coupe d'Oese se singularise par l'intercalation à ce niveau d'une séquence gréseuse de 15 mètres qui contient aussi des spores mais ceux-ci sont beaucoup moins bien conservés. Il est possible néanmoins d'y reconnaître *H. lepidophytus*, *Vallatisporites pusillites*, *Retusotriletes incohatus*, *Baculatisporites fusticulus*, *Corbulispora* sp. et une nouvelle espèce pour les bassins ardenno-rhénans, proche de *Spinozonotriletes balteatus* PLAYFORD. Cette espèce est présente également dans la séquence schisteuse de Stockum (AUSTIN et al. 1971 : hors-texte 1) dans les assemblages PLs3, au-dessus de la lentille carbonatée contenant à la fois la faune de Céphalopodes à *Balvia prorsum* (zone VIII sur le tab. 1) et la faune de Conodontes à *Protognathodus*. A Oese, la transition „Grès de Hangenberg"/„Calcaire de Hangenberg" contient, comme à Seiler, la succession de Conodontes: Faune à *Protognathodus/Siphonodella sulcata* zone.

L'étude palynologique comparée des coupes d'Oese et de Stockum est en cours; elle devrait permettre de mieux définir dans les régions ardenno-rhénanes la transition entre les zones à spores *pusillites-lepidophytus* et *trivialis-explanatus* qui jusqu'ici n'ont jamais été observés en succession dans un même profil dans ces régions.

Les corrélations nouvelles par Conodontes et Spores entre Oberrödinghausen et Oese, d'une part, et entre Oese et Stockum d'autre part, apportent les premières preuves directes de l'existence d'une lacune sédimentaire sous le Calcaire de Hangenberg dans la coupe classique d'Oberrödinghausen.

b) Elargissement géographique des corrélations par Conodontes et Spores

Des corrélations biostratigraphiques simultanées par Conodontes et Spores entre l'Amérique du Nord et l'Ouest de l'Europe sont présentées par SANDBERG, STREEL & SCOTT (sous presse). Elles concernent principalement la position stratigraphique des Formations de Sappington dans le Wyoming et le Montana et de Saverton dans le site classique de la vallée du Mississippi.

Wyoming et Montana: la Formation de Sappington contient un assemblage *pusillites-lepidophytus* dont la liste d'espèces est très similaire à celle de l'assemblage PLs2 contenu dans les Schistes de Hangenberg d'Oberrödinghausen et d'Oese. Cette assemblage est associé à une faune de Conodontes à *Protognathodus* et à *Siphonodella* „primitives", qui, aux Etats Unis, apparaît dans la zone *costatus*.
Vallée du Mississippi: Les Schistes de Saverton con-

tiennent un assemblage *pusillites-lepidophytus* où manquent les *Grandispora echinata*, *Lophozonotriletes rarituberculatus* et *Cristatisporites echinatus* qui caractérisent la zone PLs dans l'ouest des U.S.A. et en Europe. L'étude biométrique de la population d'*H. lepidophytus* situe l'assemblage des Schistes de Saverton dans la zone C près du contact des zones PLi/PLm. Ces schistes contiennent la zone de Conodontes *aculeatus* qui, dans la vallée du Mississippi, se situe en-dessous des faunes à *Protognathodus* qui caractérisent le Calcaire de Louisiane.

Pour terminer l'inventaire des acquisitions récentes sur la biostratigraphie des couches de passage Dévonien-Carbonifère, il convient de signaler que l'assemblage à *Hymenozonotriletes lepidophytus* a été isolé d'une séquence de sédiments continentaux sous-jacente au faciès Pocono en Pennsylvanie (WARG, sous presse). Selon cet auteur, la réduction de taille des populations d'*H. lepidophytus* est sensible de bas en haut de la séquence étudiée.

Au stade de l'élaboration de ce rapport, les informations palynologiques nouvelles présentées par nos collègues soviétiques dans le cadre du IIIe Congrès International de Palynologie à Novosibirsk, ne nous sont pas encore parvenues.

Choix d'une limite de base du Système Carbonifère

Les corrélations entre les coupes classiques des bassins ardenno-rhénans nous paraissent relativement précises et s'appuyant sur des critères à large signification géographique, le moment paraît venu de prendre une décision quant au choix d'une limite qui ne serait plus controversée.

On peut s'en assurer en reprenant phrase par phrase les termes principaux du précédent rapport de la Sous-Commission de Stratigraphie du Carbonifère sur cette question (6e Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield 1967, volume I, 1969, pp. XLIV-XLV):

"The Subcommittee, in discussing the need for a precise separation of Carboniferous and Devonian, recognized the many difficulties that arise from variations and incompatibilities of usage:

"a) an early distinction of the Tournaisian Stage from the Devonian Famennian Stage at the base of what has come to be called Tn1a;"

C'est le fond historique du problème. Il a été analysé en détail par MAMET (1968) dont le travail constitue l'approche la plus complète du problème en dépit du fait que les corrélations stratigraphiques qu'il propose entre les régions franco-belges et l'Allemagne ne correspondent plus aux faits actuellement connus. Par exemple, la corrélation approximative de la base du Tn2a avec la base du Carbonifère sensu Heerlen 1935 (MAMET 1968, fig. 2) repose sur la présence de Clymeniids à la base du Tn2a en Belgique (MAMET, MIKHAILOFF & MORTELMANS 1970,

Première apparition dans une succession	Première apparition locale (base teilzone)	Dernière apparition locale (sommet de la teilzone)	Céphalopodes	Conodontes	Foraminifères	Spores	
12	13				X		<i>Chernyshinella glomiformis</i> Zone
	12			X			"advanced" <i>Siphonodella</i>
	TE					X	<i>trivialis-explanatus</i> Zone
	11		X				<i>Gattendorfia subinvoluta</i> (lower cuI)
10	10			X			<i>Siphonodella sulcata</i> Zone
							(base Carboniferous System Heerlen 1935)
	9			X			"primitive" <i>Siphonodella</i> (SANDBERG, STREEL & SCOTT, in press)
	8			X			<i>Protognathodus</i> Fauna
	PLs3					X	<i>pusillites-lepidophytus</i> Zone, upper 3.
	7		X				<i>Balvia prorsum</i>
	PLs2					X	<i>pusillites-lepidophytus</i> Zone, upper 2.
	6		X				<i>Cymaclymenia euryomphala</i>
PLs1	PLs1					X	<i>pusillites-lepidophytus</i> Zone, upper 1
5	5	5			X		<i>Quasiendothyra kobeitusana</i>
PLm	PLm					X	<i>pusillites-lepidophytus</i> Zone, middle
4			X				<i>Wocklumeria</i> Zone (to VI)
3	3	3		X			<i>costatus ultimus</i> Subzone.
2	2				X		<i>Quasiendothyra communis radiata</i>
PLi	PLi			X		X	<i>pusillites-lepidophytus</i> Zone, lower
1	1						<i>costatus</i> Zone, lower
	VU	VU				X	<i>versabilis-uncatus</i> Zone

Tableau 2. Critères paléontologiques principaux de la limite Dévonien/Carbonifère dans les bassins ardennes-rhéens.

Conodontes seuls et de la situer dans une coupe de référence où non seulement une succession d'assemblages de Conodontes est observée, mais où l'on pourrait désigner l'apparition d'une espèce dans une lignée phylogénétique déterminée. Deux lignées de Conodontes semblent s'y prêter: celle des *Gnathodus* et celle des *Siphonodella*. La recherche d'une telle coupe de référence devrait constituer un objectif prioritaire. Cette coupe devrait en outre com-

prendre des groupes fossiles aussi diversifiés que possible, particulièrement parmi ceux qui ont fait leurs preuves dans les problèmes de corrélations interrégionales. L'importance des spores ne peut être notamment sous-estimée dans la mesure où elles constituent le seul outil de corrélation entre les faciès continentaux et les faciès marins (voir AUSTIN et al. 1971: hors-texte 2).

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Discussion

(Following upon the reading of this report by Dr. M. STREEL on the morning of 22nd August)

SANDBERG, C. A. (comment) - I would like to supplement the statements made by Dr. STREEL with reference to a primitive new Devonian species of *Siphonodella*. Recent conodont investigations have shown that the base of the Carboniferous, as proposed by the 1935 Heerlen Congress, may be recognised by phylogenetic changes within two conodont genera: In *Siphonodella*, from *praesulcata* to *sulcata*, and in *Protognathodus*, from *kockeli* to *kuehni*. The *Siphonodella* lineage has been established in central and western North America and in Germany (in a paper to be read by SANDBERG, STREEL & SCOTT in Krefeld, August 24th, 1971). The primitive *Siphonodella praesulcata* has been recently recognized by Dr. BOUCKAERT in Belgium.

CONIL, R. (reply) - La limite des *Siphonodella* primitive / *S. sulcata* suggérée par M. STREEL paraît la plus opportune puisqu'elle se baserait sur une modification survenant dans un même genre de répartition mondiale et dans un même faciès dans certains pays connus, p.e. la Belgique. Plusieurs *Siphonodella* sont déjà connues dans le calcaire d'Hastière et il faudrait y chercher au dessus des couches à *Siphonodella* primitives, ce que nous n'avons pas fait, pour y découvrir l'apparition des *S. sulcata*. L'ancienne limite Tn 1a/Tn 1b correspondait à un changement brutal de faciès du, soit à une modification paléogéographique (transgression vers le bassin de Namur et les Iles Britanniques), soit un phénomène plus général ayant produit la disparition des *Phacops* et des constructeurs de récifs. La nouvelle limite amènerait la création d'un Fa III formant une certaine unité:

- (1) apparition des *Siphonodella* primitives; (2) apparition et développement de la paroi double des *Quasiendothyra* (conduisant à *Q. kobeitusana*); (3) zone Pl. (spores) de STREEL jusqu'à l'apparition des *S. sulcata*. Cette Fa III correspondrait sensiblement au „Strunien" sensu lato de CONIL & LYS 1964.
- SCHMIDT, H. (comment) — *Protognathodus*-Zone wäre besser zu nennen „meischneri-Zone", denn die Gattung *Protognathodus* enthält auch die Art *kockeli* (mit *Gattendorfia*), neuerdings z. T. „*Siphonodella sulcata*-Zone" genannt.
- GEORGE, T. N. (comment) — Biozones are of the greatest use in Dinantian correlation but in Dinantian classification (to be distinguished from correlation) biozones as concepts must necessarily give place to chronostratigraphical zones. These are in their nature objectively defined, not in terms of fossil associations or evolutionary stages, but as rock units in specified stratotypes that function as permanent standards of reference.
- HAHN, G. (reply) — Die Lebenszeit einer Art (Leitart) ist unabhängig von der Sedimentausbildung an einer oder der anderen Stelle.
- MAMET, B. L. (comment) — Exact correlation of the *Gattendorfia* Stufe with the Tn 1 sequence remains difficult on foraminiferal evidence. The only sequence where we have the presence of abundant endothyrids and ammonoids is Ebersdorf in Poland. In that locality, the *Quasiendothyra kobeitusana* disappear at the end of the *Wocklumeria* Zone and the base of the *Gattendorfia* Zone yields no more *Quasiendothyra*. This fact is in apparent contradiction with the presence of *Quasiendothyra* in Tn 1b in numerous points of the Dinant Synclinorium. It is possible that the Tn 1b would be time-transgressive and up to now correlations have been far more lithostratigraphic than biostratigraphic.
- STREEL, M. (reply) — The occurrence of *Quasiendothyra kobeitusana* together with "advanced" *Siphonodella* in the Velbert Syncline, as reported by CONIL & PAPROTH, proves that the top occurrence of *Q. kobeitusana* may fall within the *Gattendorfia* range and therefore may be facies-controlled elsewhere. Consequently, this limit (top of *Q. kobeitusana* range) cannot be used as an argument in favour of a Tn 1b (or, rather, Hastière Limestone) transgressive unit.
- LECKWIJCK, W. P. VAN (question) — Mr. Chairman, might I inquire whether we are struggling to define a stratoboundary for a region, in this case N.W. Europe, or for all regions of the world, whatever their facies? In my opinion we are not ready to tackle the second problem, if only on account of the very few specialists of other continents among us.
- LAVEINE, J. P. — Il s'agit encore d'une question de principe. Si l'on veut faire abstraction des résultats paléontologiques, point n'est besoin d'avoir une séquence continue et même point n'est besoin d'étudier la séquence, il suffit de placer le doigt en un point et de dire voilà la limite. Ou alors on tient compte de l'ensemble des résultats paléontologiques en un maximum de points et il faut essayer de trouver la limite qui donne les plus de chances d'être rencontrée partout.
- AUSTIN, R. L. (question) — What are our terms of reference? Do we still go by the goniatite zones? Or do we select the section with the most useful fossils?
- GEORGE, T. N. (reply) — Our discussions on the detailed classification of Dinantian and Silesian rocks has hitherto been in a West European context. In dividing the subsystem into series and stages we have perforce rested our analysis on a traditional basis limited by regional facies and regional changes. We have not yet attempted to organize a wider classification to include for instance the rocks of mid- and eastern Europe or of northern Africa. Our decisions are therefore limited in their application, and we make no claim that they are anything but regionally applicable to a part of Europe only. Our stratigraphical units are not put forward as standards of global application, however useful they may be in the future when a global co-ordination is attempted.
- NEVES, R. (reply and comment) — The apparently widespread geographical consistency of the conodont faunas is impressive and provides a useful criterion in determining a convenient position at which to place the base of the Carboniferous. However, in view of the occurrence in many areas of terrestrial or non-marine facies in proximity to the boundary position, I feel that consideration should be given to the change in spore floras which also occurs over this stratigraphic interval and which is also of wide geographic occurrence. Perhaps the change from the *pusillites-lepidophytus* Zone to that of the *trivialis-explanatus* Zone would be a useful criterion to be taken into account in conjunction with the conodont succession (lineage?).
- STREEL, M. (reply) — I agree with Dr. Neves that the spore evidence would be a useful criterion to be taken into account with the conodont data, so as to facilitate placing the lower boundary of the Carboniferous System in non-marine deposits. I did not emphasize this point in my report because, so far, the change from the *pusillites-lepidophytus* Assemblage Zone to the *trivialis-explanatus* Assemblage Zone had never been observed in a continuous marine succession in conjunction with good faunal control.

- Data from discontinuous sections in Belgium proved that this change (a major one which may be in some way related to lithological facies) can serve over a wide area for locating the base of the Carboniferous System with, for instance, about the same accuracy that the top of the *Quasiendothyra kobeitusana* range may provide. A more complete comparative study of the Stockum and Oese sections (which is in progress) will probably improve these data.
- MAMET, B. L. — A stratotype is in existence for the internationally accepted Tournaisian stage for more than a century. Its lower limit does coincide with the first Heerlen convention (1927), but not with the second convention (1935).
- LECKWIJCK, W. P. VAN — I would like to draw a further comparison between our work and that of the I.U.G.S. Committee on the Silurian-Devonian boundary which is built up of both Silurian and Devonian specialists. This committee firstly agreed upon the fact that *Monograptus uniformis*, which has been traced in many and distant parts of the world, would, be a useful tool in the selection of the boundary. The next step was to investigate in many (approximately 15) places in western Europe, eastern Europe, North America, North Africa, the strata lying above and below the first occurrence of *M. uniformis*. This was done by the whole committee, composed of palaeontologists, stratigraphers, sedimentologists of diversified disciplines, and a boundary-stratotype situated in one of the regions visited will be proposed at Montreal, the choice being based on various criteria, viz. not only good possibilities of correlation but also such important characteristics as accessibility, not only of the actual boundary line (or point) but also of a good deal of the overlying and underlying strata, the possibility of preservation in the future, etc. I suggest that a similar committee on the Devonian/Carboniferous boundary be created by I.U.G.S., with both Devonian and Carboniferous specialists and that they be given similar terms of reference.
- ELIAS, M. K. — In the course of my work on the Carboniferous of south-central Oklahoma (sponsored by the geologist CH. W. TOMLINSON), I was obliged to work on both goniatites and conodonts. I concluded that by comparison goniatites proved to be the more effective for stratigraphic purposes. Both groups of organisms are stratigraphically important, but the present state of knowledge of conodonts is far less complete than that of goniatites, and is in greater need of further research than that of the latter. By the way, the goniatites and conodonts are never (or practically so) found together, even if found in the same kind of shale, and not far from each other in stratigraphic sequence. Thus they seem to belong to different facies. Thus the two facies — at present — are recognized only by their faunal contents.
- MATTHEWS, S. C. (reply) — Anyone who has had the opportunity to examine and become familiar with both goniatites and conodonts from the neighbourhood of the Devonian-Carboniferous boundary would admit that conodonts are the better zone-fossils thereabouts.
- MATTHEWS, S. C. (question) — A request for further information on the spores. The Heerlen Congress of 1935 established a goniatite as the means of defining the beginning of the Carboniferous but did not (as has now been seen) adequately provide for recognition of slightly higher and slightly lower horizons. The spores, we now know, offer good possibilities near the Devonian-Carboniferous boundary. Do spores give a good account of slightly earlier and slightly later passages of time?
- STREEL, M. (reply) — The answer would be about the same as that given earlier to Dr. NEVES. In addition, I may say that work in progress on the Oese and Stockum sections will probably provide a fairly accurate limit within the *Protognathodus* fauna range, i. e. below the basal occurrence of *Siphonodella sulcata*. This limit would be of the same kind as that at the base of the *pusillites-lepidophytus* Assemblages Zone, since it would be marked by the first occurrence of a couple of new species within an assemblage which remains mainly unchanged (and which still contains *H. lepidophytus* and *H. pusillites*, for example). Unfortunately, this first occurrence is not likely to be succeeded by a large influx of these new species, as happens with *H. lepidophytus* within the *pusillites-lepidophytus* Zone. For this reason, the base of the post-*lepidophytus* assemblage is not easily traced. Similar attempts to define the base of the post-*lepidophytus* assemblage are being made in Ohio and in the British Isles. All the new data obtained still have to be compared, species by species, with the Russian succession.
- MATTHEWS, S. C. (comment) — If we are to consider historical precedents, we should recognize an oblique admission of Belgian priority in the proposals that were issued from Germany in the 1920's and which were built into the zonal scheme approved by the second Heerlen Congress. H. SCHMIDT's *Protocanites*-Stufe (later named *Gattendorfia*-Stufe) was instituted as the lowest Carboniferous with no further reason than that it seemed to amount to an approximate equivalent of the Belgian Etroeungt.
- RAMSBOTTOM, W. H. C. (comment) — It is a good principle not to change established stratigraphical boundaries unless this is essential. If there is

one thing that is clear from the recent micropalaeontological work it is that the existing boundary at the base of cu I is one which it is possible to correlate over wide areas by means of several fossil groups — especially by conodonts and spores. If this boundary could be maintained it would only remain for a suitable section to be found in which the base could be defined. This might be undertaken by a commission under I.U.G.S. as suggested by Professor VAN LECKWIJCK.

STREEL, M. (reply) — I believe that it is essential to change the biostratigraphic definition of the base of the Carboniferous System, because it has become increasingly difficult to consider the *Wocklumeria/Gattendorfia* succession as an accurate tool for tracing this boundary. An ancestor of *Gattendorfia subinvoluta* is not known immediately below the occurrence of this species in the reference section, and it follows that the first occurrence of *Gattendorfia subinvoluta* in the reference section at Oberrödinghausen, and consequently in all sections, cannot be regarded as marking more than the base of a Teilzone. This point is further emphasized by the probability that this section contains an appreciable gap in sedimentation below the horizon of first occurrence of *Gattendorfia subinvoluta*. Changing the definition in favour of a succession with a full lineage of conodonts found in one and the same, continuous sequence of rocks will certainly be an improvement on the present situation created by the decision taken in Heerlen, 1935.

SANDBERG, C. A. (comment) — Conodont workers are able to use on a world-wide basis the presently accepted Heerlen Congress (1935) resolution to place the base of the Carboniferous at the first appearance of *Gattendorfia subinvoluta* in the German cephalopod succession and based on the section at Oberrödinghausen. This position corresponds approximately to the first appearance of *Siphonodella sulcata* and *Protognathodus kuehni* both in Europe and in North America. In partial answer to Dr. M. K. ELIAS, I would like to state that conodonts are indeed rapidly evolving organisms near the Devonian-Carboniferous boundary and that the time span of individual conodont zones during the Upper Devonian and Lower Carboniferous seems to be in the order of a half million years or less. In answer to Dr. M. STREEL, although I have not yet examined the Belgian succession, I have seen evidence for an unconformity or hiatus at or near the Devonian-Carboniferous boundary in the Hönnetal in Germany and also throughout North America. Perhaps the Belgian succession is indeed continuous. However, we need not be concerned about the necessity for placing the boundary where deposition was

continuous from Devonian into Carboniferous time. If this systemic boundary were everywhere continuous, we would not be sitting here now.

PAPROTH, E. (comment) — Ich teile mit, daß das Profil Oese, von dem schon die Rede war, unter dem Hangenberg-Kalk vollständiger ist, als das Profil Oberrödinghausen: unter dem Hangenberg-Kalk liegen (Hangenberg-)Sandsteine, die jünger sind als die obersten, den Hangenberg-Kalk bei Oberrödinghausen unterlagernden Hangenberg-Schiefer. Die Grenze zwischen der Kalkfolge mit *Siphonodella sulcata* (oben) und dem Sandstein mit ZIEGLER'S „*Protognathodus-Fauna*“ (unten) liegt, ohne Schichtlücke, bei Oese in einer etwa 10 cm mächtigen Bank; das hat W. ZIEGLER kürzlich gezeigt. Die Cephalopoden des Hangenberg-Kalkes von Oese sind noch nicht untersucht. Es sollte festgestellt werden, ob die Schichten der *Siphonodella sulcata*-Zone an ihrer Basis auch die ersten *Gattendorfia subinvoluta* führen.

STREEL, M. (reply) — I believe that the present situation would not be greatly improved if *Gattendorfia subinvoluta* were eventually found with *Siphonodella sulcata* in the section at Oese. Indeed, what we need is an ancestor of *Gattendorfia subinvoluta* to be found, immediately below the first occurrence of this species, in the same section and in rocks of the same facies. The *Protognathodus* fauna and *Siphonodella sulcata* Zone, found in successive strata at Oese, unfortunately represent two different conodont lineages. Changing the biostratigraphic definition of the base of the Carboniferous System in favour of a local boundary between two unrelated taxonomic units seems to offer no essential advantage.

GORDON, M. (comment) — Although the goniatites are of considerable use in zoning the Carboniferous rocks in the United States, they are virtually absent at the Devonian-Carboniferous boundary. Only one specimen of *Wocklumeria* has been found in the United States in a small glass vial in the U.S. National Museum. The only early Carboniferous goniatites that might be classed as *Gattendorfia* are small discoidal forms that have been identified as *Kazakhstania*. The conodonts, on the other hand, are well represented and permit us to recognize the 1935 boundary based on the first appearance of *Gattendorfia subinvoluta* in north-western Europe. Foraminiferal correlation based on *Quasiendothyra* is almost impossible as this genus is practically unknown in North America. The base of the Carboniferous as defined in 1935 is recognizable, at least approximately, in the United States, and is therefore acceptable to workers in this part of the world. Whether it is more honest to define the base

of the Carboniferous on conodont distribution is a matter largely of procedure.

ELIAS, M. K. — Finding of conodonts is burdened by considerable difficulty in collecting. For instance, the important genus *Hindeodella* (a haircomblike conodont) is invariably broken to small fragments worthless for specific identification, when conodonts are obtained by dissolution of limestones — the presently widely used method of obtaining conodonts. Hence, manual collecting of conodonts in shale is still important to attain knowledge of all Carboniferous conodonts. At the time of PANDER, only one Carboniferous conodont was described by him; but recently the importance of conodont studies has become recognised in Soviet Russia, and we may expect to have newly discovered conodont faunas from Russia described and worked out by the next Carboniferous Congress in 1975.

JANSONIUS, J. (question) — Dr. STREEL ended his report with indicating three separate biostratigraphical successions, each approximating the Carboniferous-Devonian boundary. Would Dr. STREEL now indicate the geographical locations where these successions are adequately represented?

STREEL, M. (reply) — (1) The first solution was to move the present limit to a level where a true succession of cephalopod zones would exist in one and the same continuous rock sequence, and to continue defining the base of the Carboniferous System in terms of cephalopod faunas only.

(2) The second solution would be as the first, but taking also the conodont zonation into consideration for the definition of a new boundary. The Oberrödinghausen section is suitable for both solutions, e.g. a new boundary could be chosen at the level of the change from *Balvia acuta* to *Pseudoarietites dorso-planus* which corresponds to the level of the change-over from *Siphonodella sulcata* to *Siphonodella duplicata*. However, it became evident during the present discussion that this conodont succession would not be very accurate as a result of different, somewhat conflicting concepts of the species *Siphonodella duplicata* in different parts of the world.

(3) The third solution was to define a new base in terms of the conodont zonation only. If, for practical reasons, this new base would be chosen as near to the base as selected by the Heerlen Congress of 1935, an accurate limit could be found within the gnathodid lineage or in the *Siphonodella* lineage. We believe that there is a case for selecting a boundary within the *Siphonodella* lineage in the Dinantian type sections of the Dinant region, where the rock

succession appears to be more continuous than elsewhere.

CONIL, R. — Je suggère qu'on demande au groupe de travail de chercher le passage *Siphonodella primitives/S. sulcata* dans diverses régions du monde. On trouverait ainsi les meilleures coupes et on verrait si cette limite est mondiale valable. Parmi les autres limites, ce serait celle qui modifierait le moins celle de 1935; une modification de 99 mètres à la base du „calcaire d'Hastière“ ne ferait peut être qu'une modification de 99 mm ou 99 cm à Oberrödinghausen.

MAMET, B. L. — In order to conciliate the different positions it seems appropriate to propose the following working scheme. On a world-wide basis, the most useful criterion for recognition of the base of the *Gattendorfia* Zone appears to be based on conodonts. Hence the conventional Carboniferous boundary could be recognised on that group. The conodont zone to be selected could be placed in a continuous marine stratotype of the Belgo-French region where the stages were originally described. For instance, the Avesnelles, Walcourt or Anseremme successions appear to be suitable. This would enable us to reconcile the "German" with the "Belgo-French" stratigraphic succession. It is further recommended that the system and stage boundaries be placed at the same level and that the redefinition of the Tournaisian will be necessary.

SANDBERG, C. A. — I would like to restate Dr. STREEL'S proposal and to suggest that the base of the Carboniferous might be placed at the first appearance of *Siphonodella sulcata*. This would correspond approximately to the base of the *Gattendorfia subinvoluta* Zone in the German succession.

The discussion on the Devonian/Carboniferous boundary was continued during the afternoon of 22nd August, at which occasion the following formal proposal was presented by M. STREEL on behalf of R. L. AUSTIN (U.K.), E. PAPROTH and D. STOPPEL (B.R.D.), J. DVORAK (C.S.S.R.), M. LYS (France), C. A. SANDBERG and F. G. POOLE (U.S.A.), J. BOUCKAERT, R. CONIL, B. L. MAMET, G. MORTELMANS, M. STREEL and W. P. VAN LECKWIJCK (Belgium):

(1) We propose that the conventional base of the Carboniferous should, for the time being, continue at the base of the *Gattendorfia subinvoluta* Zone as recommended by the 1935 Heerlen Congress, and that a decision on the stratotype be postponed.

(2) With regard to a working boundary, this should be designated as closely as possible to the base of the *Gattendorfia subinvoluta* Zone on the basis of conodonts in a continuous phylogenetic succession. The evolution of *Siphonodella sulcata* from its Devonian ancestor can

be used on a world-wide basis for correlation and should be taken into consideration when designating the basal boundary of the Carboniferous.

(3) The Devonian-Carboniferous boundary-stratotype should be designated in a continuous marine succession, where the working boundary can be recognized. All other considerations being equal, the stratotype should preferably be designated in the region where the original chronostratigraphic units (stages) were defined.

(4) Coincidence of systemic and stage boundaries is recommended, hence any part of the Tournaisian that falls below the base of the Carboniferous should be redesignated and placed in the Famennian.

(5) We also propose to ask the President of the I.U.G.S. Commission on Stratigraphy to

constitute a Committee on the Devonian/Carboniferous boundary and to charge this Committee to examine the proposed conodont limit in a sufficient number of sections to allow the subsequent selection of a suitable stratotype.

After some discussion by T. N. GEORGE, M. STREEL, J. TH. DUTRO, M. GORDON, W. H. C. RAMSBOTTOM and W. P. VAN LECKWIJCK, the stated proposals were accepted in principle as a desirable basis for consideration by the proposed I.U.G.S. Committee on the Devonian-Carboniferous boundary. The constitution of this Devonian/Carboniferous junction Committee was further discussed on August 24th, and the decision was taken to recommend that Professor T. N. GEORGE and Professor M. STREEL should be included as members of this Committee on behalf of the I.U.G.S. Subcommittee on Carboniferous Stratigraphy.

Comparison between conodont zonation and spore assemblages at the Devonian-Carboniferous boundary in the western and central United States and in Europe¹⁾

By CHARLES A. SANDBERG, MAURICE STREEL and RICHARD A. SCOTT

With 4 figures and 4 plates

Abstract

A new conodont fauna, the *Siphonodella praesulcata* Fauna, occurs in very high Devonian beds in the Sappington Member of the Three Forks Formation in Montana and in the Leatham Formation in Utah. The fauna is dominated by *Siphonodella praesulcata* n. sp., a primitive narrow siphonodellid that ranges from near the base of the Devonian Middle *Spathognathodus costatus* Zone (in Utah) into the basal Carboniferous *S. sulcata* Zone (in the Upper Mississippi Valley). As its recognition is important to the correct placement of the Devonian-Carboniferous boundary based on conodonts, *S. praesulcata* n. sp. is described, illustrated, and discriminated from its descendant, *S. sulcata*, which is redescribed.

Two spore assemblages containing *Hymenozonotriletes lepidophytus* are illustrated from occurrences in very high Devonian beds of the Sappington Member in Montana and from the middle part of the Saverton Shale in Illinois. These are correlated respectively with the PLs 2-3 and PL1 spore assemblages of Streel in Europe. In terms of associated or bracketing conodont faunas, the spore assemblages occur within the *Siphonodella praesulcata* Fauna in Montana and within the *Spathognathodus aculeatus* Zone (equivalent to the Middle to Upper *S. costatus* Zone) in Illinois.

The Devonian-Carboniferous boundary in North America is reevaluated on the basis of the new conodont and spore evidence. The highest part of the Devonian is discerned through conodonts by the presence of either the *Protognathodus* Fauna, generally in calcareous or shaly lithofacies, or the *Siphonodella praesulcata* Fauna, generally in silty lithofacies, and through spores by the presence of *Hymenozonotriletes lepidophytus* spore assemblages. Reportedly younger, possibly basal Carboniferous occurrences of *H. lepidophytus* in the eastern United States do not agree with the North American range nor with the worldwide range of *H. lepidophytus* assemblages and are regarded as reworked or misdated.

The *Siphonodella sulcata* Zone marks the base of the Carboniferous in North America and Europe, and, as defined herein, can probably be used throughout the world. In the western United States,

the *S. sulcata* Zone contains the lowest joint occurrence of *S. sulcata*, *Protognathodus kuehni*, *Pseudopolygnathus dentilineatus*, and *Patrognathus variabilis*. Only *P. variabilis* has not yet been found within this zone in the Upper Mississippi Valley and in Germany. In the Upper Mississippi Valley, the *Protognathodus kuehni* - *P. kockeli* Zone was found to contain *S. sulcata*, and hence this zone is abandoned and included in the *S. sulcata* Zone. The *S. sulcata* - *P. kockeli* Zone in Germany also should be amended to *S. sulcata* Zone. Continued use of *P. kockeli* in the zonal name is misleading as this species is an important constituent of the underlying *Protognathodus* Fauna.

Introduction

Purpose and scope

A new conodont fauna, herein named the *Siphonodella praesulcata* Fauna, is recognized in very high Devonian beds of the Sappington Member of the Three Forks Formation in Montana and of the correlative Leatham Formation in Utah. The fauna is dominated by the oldest known siphonodellid, *Siphonodella praesulcata* n. sp., which is described herein. This primitive new species is described and illustrated from occurrences in the Sappington Member and the Leatham Formation, and in the dually named "Glen Park" Formation of COLLINSON (1961 b, p. 104-105) or "Hamburg oolite" of KOENIG and MARTIN (1961, p. 30) in Missouri. It is also present in the Bonaparte Gulf Basin of northwestern Australia, where it was cited as *Polygnathus* sp. B by DRUCE (1969), and in the Middle *Spathognathodus costatus* Zone in Germany (WILLI ZIEGLER, written commun., Sept. 30, 1969). As *Siphonodella praesulcata* ranges from near the base of the Devonian Middle *S. costatus* Zone into the basal Carboniferous *S. sulcata* Zone, its discrimination from closely similar but generally younger *S. sulcata* is important to the worldwide placement of the Devonian-Carboniferous boundary based on conodonts.

Spore assemblages containing *Hymenozonotriletes lepidophytus* KEDO are illustrated from an occurrence in the Sappington Member in Montana (SANDBERG, 1965, p. N16; SANDBERG and KLAPPER, 1967, p. B8-B10; MACQUEEN and SANDBERG, 1970, p. 49-51) and from the middle part of the Saverton Shale in Illinois (COLLINSON, 1961a, p. 67). The Montana assemblage is

¹⁾ Publication authorized by the Director, U.S. Geological Survey