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MODIFICATION OF THE BRITISH AVONIAN CONODONT ZONATION AND A REAPPRAISAL OF EUROPEAN DINANTIAN CONODONT ZONATION AND CORRELATION (*)

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(1 fig. hors-texte)

RÉSUMÉ

L'auteur passe en revue les principales restrictions que comportait la zonation par conodontes de l'Avonien proposée par Rhodes, Austin et Druce et en discute certaines modifications. Les faunes à conodontes d'autres régions sont parallélisées avec celles de l'Avonien. La zonation par conodontes des séquences européennes est résumée en un schéma uniforme applicable au Dinantien d'Europe.

Treize zones à conodontes sont reconnues. Les corrélations sont explicitées entre les successions du Dinantien d'Europe et l'attention est attirée sur les différences se présentant entre les associations de shelf et celles de bassin. On constate la similitude existant entre la séquence de conodontes viséens de l'Avonien de Grande-Bretagne, celle de l'Osagien supérieur de la vallée du Mississippi, celle du Canada et celle de l'Australie, ce qui confirme la valeur de la zonation avonienne pour les corrélations intercontinentales.

ABSTRACT

The main limitations of the Avonian conodont zonation proposed by Rhodes, Austin & Druce are outlined. Modifications of the zonal scheme are discussed. Conodont faunas from other regions are related to those of the Avonian. Conodont zonation of European sequences is summarized and a uniform zonal scheme emerges, which is applicable to European Dinantian rocks. Thirteen conodont zones are recognized. Correlation between European Dinantian successions is shown. Differences between shelf and basin conodont faunas are emphasized. Similarity between the Viséan sequence of the Avonian of Britain, the upper Osagean of the Mississippi Valley, and the Viséan of Canada and Australia is noted and the value of the Avonian zonation for intercontinental correlation is confirmed.

INTRODUCTION

Rhodes, Austin & Druce (1969) described the conodont sequence present in the type Avonian of the Avon Gorge, England. Additional information was reported from Wales, Shropshire, the North of England and Scotland. The Avonian conodont zonation proposed by the above authors has been criticized by some conodont workers (Ziegler 1971a, Matthews & Butler in press). Research with collaborators since the submission of the 1969 paper has led to modifications of the zonation (see below) and clarification of correlations (see chart). This paper illustrates that the Avonian zonation as modified herein is worthy of retention and application.

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The limitations of the Avonian fauna were appreciated and clearly stated in 1969. The main limitations may be listed as follows :

(a) The sampling in the Avon Gorge (p. 21) was not as refined as that of many sequences in other parts of the world. Certain parts of the sequence were collected in detail, but ideally a bed by bed investigation is necessary.

(b) Certain parts of the sequence did not yield conodonts and other parts yielded small faunas (p. 31, 32).

(c) It was noted (p. 32) and stressed (p. 59) that species of the genus *Siphonodella*, which are used for zonation in other regions were rare in the Avonian collection.

(d) Many conodonts were at the time unique to the Avonian. Particularly was this true of the Lower Avonian K Zone (p. 52).

(e) The distinctive Middle Dinantian genus *Scaliognathus* was not found and alternative reasons for its absence were suggested (p. 57, 65).

(f) Many specimens found in the Avonian sequence had an anomalous range compared with those of other regions (p. 53).

In addition during the writing of the 1969 paper serious difficulty was encountered in correlating the Avonian sequence with those of other countries (Fig. 16 of Rhodes, Austin & Druce, 1969). The difficulties were due to the limited information then available. Information from North America was based largely on the work of Collinson, Scott & Rexroad (1962) and their co-workers. The authors were fortunate in having available the advice and comments of Dr. C. W. Collinson. Subsequent work by Thompson (1967), Thompson & Goebel (1968), Thompson & Fellows (1970) and Sandberg and Klapper (1967) has increased our knowledge of American Mississippian faunas. The record of North American occurrence of *Scaliognathus* may be cited as being important for international correlation. Information from Germany was based on the pioneer studies of Bischoff (1957) and Voges (1959, 1960) and language difficulties were encountered. Dr. Willi Ziegler kindly discussed taxonomic problems with particular reference to the lowest Avonian faunas, which contained forms, which by comparison with Germany suggested a Devonian age. New information is now available from Germany (Wirth 1967, Ziegler 1969) and previous work has been reappraised (Sandberg & Klapper 1967, Meischner 1970 and Ziegler 1971). The Belgian faunas were perhaps the least known. Correlation of the Avonian with Belgium was based on the preliminary results of Conil, Lys and Mauvier (1964). Study of their chart and comparison with the German sequence reveals the conflicting evidence of conodont distribution in these two countries. The work of Groessens (1971) is now available. In 1966 Australian Dinantian conodont sequences were not described in any detail. Australian faunas are now described in detail (Druce, 1969, 1970). Descriptions of Dinantian conodonts from Britain and Ireland were few and brief.

In introducing their section on correlation of the Avonian with Europe and North America Rhodes, Austin & Druce (1969, p. 52) stated « More information is needed from all areas before the present faunal similarities and difficulties can be fully interpreted ». Realizing the limitations of the described conodont sequences a wider investigation of conodont faunas was undertaken. In studying faunas from Britain and Ireland one was aware that other schools were studying conodont sequences in other parts of Britain. The results of the research of British colleagues would it was thought provide necessary information on British Dinantian rocks in areas removed from the Avon Gorge and the North Crop of the South Wales coalfield. The conodont sequences of south-west England, including the Mendips, the

greater part of the North of England and from the neighbourhood of Cork, Ireland have not therefore been investigated by the author. Conodont sequences in these regions are of particular interest and importance for an understanding of the distribution of British Dinantian sequences. It is not surprising that results already published (Varker 1967, Morris 1969, Matthews 1969, 1969a, Matthews & Butler in press) indicate that the faunas of these regions differ from those of the Avonian sequence, nor that they emphasize the limitations of the Avon Gorge faunas.

The Avonian conodont zones proposed in 1969 were related to the coral-brachiopod zones of Vaughan (1905) at their type locality in the Avon Gorge. Conodonts have now also been listed from goniatite horizons in Britain and Ireland. The B-G zones of the goniatite scheme have been investigated with co-workers (Austin 1968a, 1972, Aldridge, Austin & Husri 1968, Austin & Aldridge in preparation). Similarities and differences between conodont faunas of the « coral brachiopod facies » and the « goniatite facies » have been noted and reasons for the distribution suggested. (Aldridge, Austin & Husri, 1968).

Difficulty in recognizing the base of the Dinantian in Britain was mentioned by Austin, Druce, Rhodes and Williams (1970). These authors reported new faunas from Devon below the Dinantian boundary. Continuing work on this problem will be reported shortly, (Austin & Hill in press). Faunas from close to the Tournaisian-Viséan boundary were noted by Austin (1968) and Austin & Aldridge (1969). Morris (1969) generously acknowledged the assistance given him in relating his important Pennine conodont fauna to those of the Avon Gorge. A colleague Hill (1971) has found the elusive *Scaliognathus anchoralis* in a carbonate sequence.

The limitations of the Avonian Viséan sequence were recognized and have been largely overcome by the preliminary results from two sequences in Ireland (Austin, Husri & Conil 1970). The Viséan conodont sequences of Ireland show close similarity with those of Europe and the Avonian faunas show similarities with those described from North America. No other region is known to the writer where Viséan shelf and basin conodont sequences have been established. Isolated Viséan faunas from the North of England (Austin 1968a), have also been reported.

More important however was the realization that it was necessary to understand the sequence of conodonts in the type Dinantian of Belgium. In collaboration with Drs. F. H. T. Rhodes, J. Bouckaert, R. Conil, M. Lys, M. Streel, H. Pirlet and later with Mr. E. Groessens, Mr. G. Chabot and Dr. A. Lees, stratotype and parastratotype sections were sampled and conodonts recovered. Work on these sequences continues. Preliminary results listing faunas from the base of the Tournaisian (Austin et al., 1970) from the Tournaisian/Viséan boundary (Conil et al., 1969) and from the Upper Viséan (Austin & Rhodes 1970) have been published. Sampling of the stratotype sections was at 3 metre intervals, but it enabled Groessens (1971) to make a bed by bed study of critical parts of the sequence.

In collaboration with Dr. Eva Paproth, Dr. D. Stoppel and Dr. W. Ziegler classic sequences in Germany have been revisited and additional topotype material has been collected. Part of Dr. Meischner's conodont collection has been examined. Differences of opinion concerning conodont taxonomy, in particular those of the *Spathognathodus costatus* group are being resolved with Dr. C. Sandberg and Dr. W. Ziegler.

Colleague Dr. E. C. Druce has investigated Australian conodont sequences (Druce 1969, 1970) and his results show that the conodont sequence of Australia is not unlike that of the type Avonian.

In addition to the conodont research collaboration with European specialists of foraminifera and spores has resulted in clarification of critical parts of the stratigraphic sequence in Britain (Austin et al. 1970, Rhodes & Austin 1971, p. 338).

The research reviewed above suggests that the limitations of the Avonian sequence described with others in 1969 were appreciated at the time of publication and that attempts have subsequently been made to overcome the deficiencies. Publication, although often in preliminary form, has made the results of the research available to all other workers. To do so was imperative in order to permit a view expressed in 1968 that « Comparative studies must be made over a wide region in order to appreciate the true significance and importance of new conodont faunas ». (Austin, Aldridge & Husri 1968). In the same paper the view was expressed that « it is important to distinguish real differences between conodont faunas, which are due to differences in stratigraphic distribution of species, and apparent differences, which are none the less real, and which reflect the environment in which the conodont-bearing « animal » lived ». Subsequent conodont studies with collaborators have attempted to separate stratigraphic differences and environmental differences of conodont distribution in the Diantian. Differences between conodont faunas of identical age verified by independent means have been interpreted rather than ignored. (Rhodes & Austin 1971, p. 341). The evolution of conodonts which have been recovered from rocks deposited in both shallow water and deeper water environments has been examined and a picture emerges of faunas which are different in these two depositional regimes. No single conodont zonation will ever be universally applicable and at the same time provide a refined stratigraphy. A Dinantian conodont zonation for Europe is outlined below and its relationship to the Avonian zonation is indicated. No zonation will be better for any region than one defined for use in that region (for example the scheme of Varker 1967) and the greater the detail of the study the greater will be its value.

MODIFICATION OF THE AVONIAN ZONATION OF RHODES, AUSTIN & DRUCE 1969

Continuing research on Avonian conodont faunas has led to modifications of the zones which were proposed by Rhodes, Austin & Druce (1969). The modified zonation is shown on the chart.

The Z Zone fauna of the Avon Gorge is dominated by specimens of the genus *Pseudopolygnathus* (Rhodes, Austin & Druce 1969, p. 32). In the upper part of the Z Zone there is an abundance of a form referred to as *Pseudopolygnathus* cf. *longiposticus*. Below and within this zone of abundance there are small specimens which appear similar to *Polygnathus lacinatus*. According to Rhodes, Austin & Druce (1969, fig. 50) the upper part of the Z Zone on the North Crop sees the appearance of *Polygnathus lacinatus*, followed a little higher in the sequence by *Cavusgnathus* sp. nov. A. No specimens of *Pseudopolygnathus* cf. *longiposticus* are present in the upper part of the Z Zone of the North Crop. Rhodes, Austin & Druce (1969) chose to equate the *P. lacinatus* fauna of the North Crop with the specimens they referred to as *Polygnathus* cf. *lacinatus* from the Avon Gorge (which as mentioned above first appear below *Pseudopolygnathus* cf. *longiposticus* in the Avon Gorge). The *Pseudopolygnathus* cf. *longiposticus* Zone was interpreted as being absent from the North Crop due to an unconformity (see Rhodes, Austin & Druce 1969, p. 42). In following this interpretation the authors were influenced by the study of George (1954) who referred the

beds from which the North Crop *P. lacinatus* specimens came to the Z Zone. Since the publication of the zonation new conodont faunas are available from other regions, which indicate that *Cavusgnathus* sp. nov. A occurs not in the Z Zone, but higher in the sequence within C. Dr. Murray-Mitchell (written communication) is of the opinion that the corals listed and illustrated by George do not necessarily imply a Z age for the beds in question on the North Crop.

The base of the *Polygnathus lacinatus* Zone of the North Crop is now equated with part of the *Gnathodus antetexanus* — *P. lacinatus* Zone of the Avon Gorge. *Polygnathus lacinatus* first appears in the Avon Gorge section in sample Z 32. The base of the *Polygnathus lacinatus* — *Pseudopolygnathus* cf. *longiposticus* Zone is redefined to have its lower limit at the base of Z 32. The zone is characterised by an abundance of *Pseudopolygnathus* cf. *longiposticus* and it extends to the top of the Z Zone in the Avon Gorge (sample Z 38). The overlying *Gnathodus antetexanus* — *Polygnathus lacinatus* Zone is the zone of maximum abundance of *P. lacinatus*. The Zone of *Polygnathus lacinatus* is no longer recognized and the zone of *Spathognathodus costatus* — *Gnathodus delicatus* extends from sample K 18 to sample Z 31 in the Avon Gorge. *Gnathodus delicatus* and *Gnathodus semiglaber* appear in the upper part of the zone in the Avon Gorge.

The second major modification concerns the C_2-D_1 interval. Rhodes, Austin & Druce (1969, p. 43, 44) recognized a zone of *Taphrognathus varians* — *Cavusgnathus* — *Apatognathus* in the Avonian S_2 Subzone. This zone is invalid as the speciemens refered to *T. varians* are small juvenile stages of *Cavusgnathus*. The *Cavusgnathus unicornis* — *Apatognathus*, *Taphrognathus varians* — *Cavusgnathus* — *Apatognathus* and the *Apatognathus geminus* — *Cavusgnathus Zones* erected in 1969 are replaced by a *Cavusgnathus* — *Apatognathus* Zone, which extends from the upper part of the C_2 into the base of the D_2 Subzone in the Avon Gorge (see Austin in press). The fauna mentioned by Rhodes, Austin & Druce (1969, p. 51) from the main Algal Limestone of Roxburghshire is older than the *Cavusgnathus* — *Apatognathus* Zone, as it contains *Taphrognathus*. It is probably representative of part of the Zone of no conodonts recorded from the *Caninia* Dolomite of the Avon Gorge.

A final modification is a lowering of the lower limit of the *Mestognathus beckmanni* — *Gnathodus bilineatus* Zone into the D_1 Subzone. It is emphasized that the three upper Avonian zones are not found in the Avon Gorge section.

EUROPEAN DINANTIAN CONODONT ZONATION AND CORRELATION

Conodont zonations of Dinantian rocks in Europe have been proposed by various authors. It is an appropriate time to review the present knowledge and to evaluate the conodont record. A unified European scheme emerges and this is outlined below and illustrated (Chart 1).

In outlining the scheme one is conscious that it owes a great deal to the patient study of many conodont workers. Bischoff (1957), Voges (1959, 1960), Böger (1962), Meischner (1970), Kock, Leuteritz & Ziegler (1960), Wirth (1967), and Ziegler (1969, 1971) have related conodonts to the cephalopod orthochronology in Germany. Paproth (1969) and Matthews (1971) have clarified some Dinantian palaeontological standards. From Belgium, Conil, Lys & Mauvier (1964), Conil et al. (1969), Bouckaert & Higgins (1963), Groessens (1971), Austin et al. (1970), Pirlet (1968) and Conil et Pirlet 1970 have described faunas of the Classic Dinantian sequence. In Britain Rhodes, Austin & Druce (1969) outlined the sequence of conodont faunas of the

Avonian and Varker (1967) has suggested a scheme for application in the North of England. Matthews (1969, 1969a) and Matthews & Butler (in press) have described British conodont faunas from southwest England and have related their faunas to the conodont zonation of Germany. Austin, Husri & Conil (1970) have suggested a zonal scheme for Irish Dinantian rocks. All the information enables similarities and differences of conodont faunas to be evaluated.

The conodont sequence in Germany is well documented in the Upper Dinantian. The base of the *Gnathodus bilineatus* Zone occurs in the cu 11 α interval of Stratigraphy (Böger 1962) and *Gnathodus nodosus* has its lower limits in the middle of cu 111 β. Meischner (1970). The conodont faunas of the *Gattendorfia* Kalk cu I are also well documented (Voges 1959) and the modified zonation of Ziegler (1971) is adopted. The conodont faunas above the *Gattendorfia* Kalk and below the horizons which yield *Gnathodus bilineatus* are ambiguous in Germany (see Matthews 1971 for detailed discussion). Most workers would agree that there is a zone of *Siphonodella crenulata* near the base. The relationship of the *S. crenulata* Zone to the *Scaliognathus anchoralis* Zone is uncertain. Many reports of the *anchoralis* fauna from Germany are documented from horizons which contain reworked conodonts. (Krebs 1963, 1964; Austin, in press). The true age relationship of the *anchoralis* Zone is therefore in doubt. Conodont faunas which are younger than the *S. anchoralis* Zone and older than the *G. bilineatus* Zone are referred to the *S. anchoralis* — *G. bilineatus* interregnum. The post *S. crenulata* pre *G. bilineatus* faunas are in the opinion of the writer better defined in Belgium.

In Belgium Groessens (1971) has reported that *Siphonodella* has its youngest stratigraphic occurrence in the lowest part of Tn 3a. Within Tn 3a it is possible to recognize the first appearance of *Polygnathus communis carina* followed by *Gnathodus semiglaber*. *Spathognathodus bultyncki* first appears at the base of Tn 3c. It is followed by *Dollymae bouckaerti* and then *Scaliognathus anchoralis*. The base of the Viséan is recognized by the first appearance of *Gnathodus homopunctatus* and, or *Mestognathus beckmanni*. *Gnathodus commutatus* appears within Vlb. Seven conodont zones are therefore recognized in the Tn 3a — Vlb interval of the Belgian stratigraphy. These are older than the *G. bilineatus* Zone and probably younger than the base of the *S. crenulata* Zone of Germany.

Thirteen conodont zones are thus recognized based on the conodont development seen in the conodont sequences of Belgium and Germany. These zones based on the first appearance of species are as follows :

13 *Gnathodus nodosus*
12 *Gnathodus bilineatus*
11 *Gnathodus commutatus*
10 *Gnathodus homopunctatus* — *Mestognathus beckmanni*
9 *Scaliognathus anchoralis*
8 *Dollymae bouckaerti*
7 *Spathognathodus bultyncki*
6 *Gnathodus semiglaber*
5 *Polygnathus communis carina*
4 *Siphonodella crenulata*
3 *Siphonodella* — *Pseudopolygnathus triangulus triangulus*
2 *Siphonodella* — *Pseudopolygnathus triangulus inaequalis*
1 *Siphonodella sulcata* — *Protognathus kockeli*

Zone 2 may be replaced by the *Siphonodella sandbergi* — *Siphonodella duplicata* Zone of Sandberg & Klapper (1967).

This proposal concerning European conodont zonation has the merit of recognizing the base of the Dinantian and the Tournaisian-Viséan boundary as agreed by the Subcommission on Carboniferous stratigraphy. It also includes the German records of the zonally important goniatites with the exception of those from Cu 11 γ Erdbacherkalk. The conodont faunas of this level are interpreted as reworked and because they contain conodonts indicative of a post *anchoralis* age elsewhere it is considered that they should more correctly be assigned to the *S. anchoralis — G. bilineatus* interregnum. This scheme can also be related to the conodont sequences of North America outlined by Collinson, Rexroad and Thompson (1971) with the exception of those of the Keokuk- St. Louis interval of time.

The Gnathodus bilineatus — Scaliognathus anchoralis interregnum of Germany can by definition be recognized in the North American conodont sequence in the interval from the Upper Burlington to the top of the St. Louis. *S. anchoralis* has its youngest stratigraphic occurrence in the *Bactrognathus — Taphrognathus* Zone of the Upper Burlington and *Gnathodus bilineatus* first appears at the base of the Ste. Genevieve. However the conodont faunas of Germany and the Mississippi Valley are very different at this level. The genus *Taphrognathus*, which is characteristic of the lower horizons of this interval in North America has not been recorded from Germany, nor from Belgium. The genus is only known in Europe from Britain (see above p. 527). The genus *Cavusgnathus*, which is characteristic of upper levels of this interval in North America is rare in Germany and in Belgium. The *Gnathodus homopunctatus — Gnathodus commutatus* fauna which is characteristic of this interval in Belgium has not been recognized by Collinson, Rexroad & Thompson (1971), altough Canis (1968), found a similar fauna in Missouri. These differences are interpreted as ecological and infer that conodonts were controlled in their distribution by facies to a greater extent than has been widely recognized. Austin & Barnes (in press) have drawn attention to the relationship between conodont distribution and lithofacies in the Dinantian.

The sequence of conodont faunas as developed in the Avon Gorge and the North Crop of the South Wales Coalfield in Britain, in Australia (Druce 1969, 1970), Canada (Globensky 1967) and in parts of the Mississippi Valley are similar. The Avonian Zonation thus has value for both local and intercontinental correlation. The sequences differ from those of the basin areas of Germany, southwest England and south Ireland. The results of conodont studies of the shelf environment at present in progress in Britain are awaited with interest to see if they confirm the sequence as outlined by Rhodes, Austin & Druce (1969) and modified in this paper.

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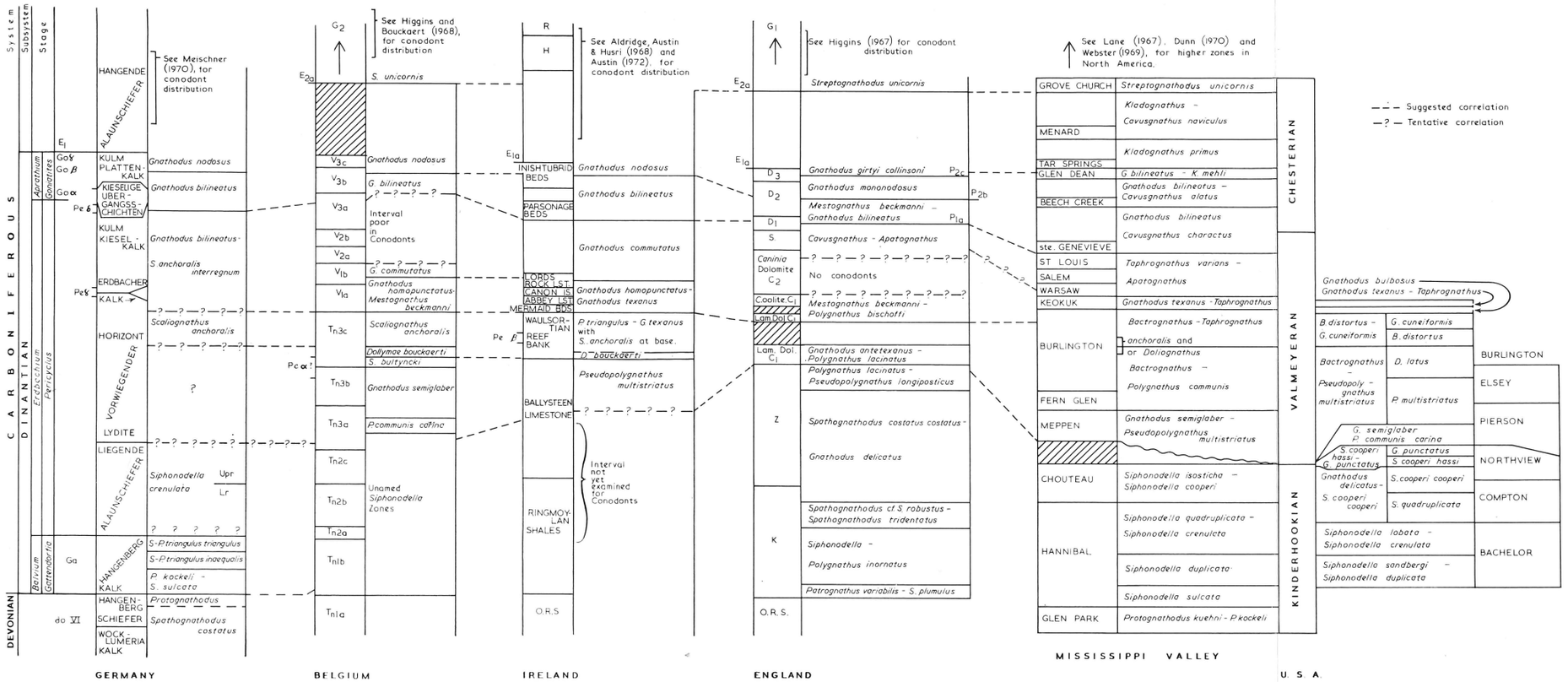

EXPLANATION OF CHART

Conodont zonations of Dinantian rocks in Germany, Belgium, Ireland, England and North America and their correlation. The conodont zonation of Germany is modified after Bischoff (1957), Voges (1959, 1960), Böger (1962), Meischner (1962, 1970) and Ziegler (1969, 1971). The conodont zones of Belgium are based on the studies of Groessens (1971) and Rhodes & Austin (unpublished). The conodont zones of Ireland are modified after Austin, Husri & Conil (1970) and those of England are based on the study of Rhodes, Austin & Druce (1969) as modified herein. North American zonation is after Collinson, Rexroad & Thompson (1971) with the insertion of the range of *anchoralis* and/or *Doliognatus*. The source of goniatite indices is also indicated. Note the *Apatognathus Scalenus-Cavusgnathus* Zone reported from the Upper St. Louis of the Mississippi Valley has been ommitted by error. Tentative Warsaw correlation after Hewitt and Conil (1969).