International definition of Devonian System boundaries

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Introduction

International agreement on the use of terminology is essential for clear understanding, communication and interpretation in the Earth Sciences. From the first Congress of Geologists (later International Geological Congress or IGC) held in Paris in 1878 this was recognised as a major scientific need and committees were set up to achieve this for stratigraphic terminology. In Bologna in 1880 it was recommended that all systems should be divided into three divisions, and the Devonian is still divided into Lower, Middle and Upper Series.

Stage subdivisions have a more complex history and at the 1910 meeting of the IGC in Stockholm deference to the local definition in type areas led to the proposal by M.L. Wagen that there should be a Lexique Stratigraphique Internationale giving precise definition of local terms, and especially those that were by then being adopted internationally. By the London IGC in 1948, however, only one volume (Africa) had appeared. Subsequently, under the direction of Pierre Pruvost and others, many volumes appeared. These follow the precept that “Naturelement pour les termes stratigraphiques ayant leurs stratotypes dans le pays correspondant, un développement plus large est a prévu.” Thus it was hoped that a standard would be established based on local type areas. Such was not to be.

With the increase in precision in methods of international biostratigraphic correlation and dating it gradually became appreciated that system, series and stages names were being used in quite different senses around the world. Even worse that substantial discrepancies existed in the very definition of the top and base of the Devonian. National interests were at stake, for maps had been produced and enormous literature had been linked to one or another contending usages. Different definitions were often used by different specialisms and specialists, and by different countries. Under the mask of an apparently common terminology, the reality was chaos. Something of the disparity of usage is illustrated in Fig. 1. One of the aims of the Commission on Stratigraphy of the International Union of Geological Sciences (IUGS) has been to establish committees to try and reach international agreement on definitions so that acceptance by the IGC could codify accepted standards. This paper recounts the attempts made for the Devonian, and of the Lower, Middle and Upper Series terminology, even if the meaning of the terms has differed.

For the Middle Devonian, the stage names Eifelian and Givetian were used in Germany, but French speakers preferred Couvinien

Major international divisions and criteria for their definition

Fortunately for the Devonian there has been no debate on whether Devonian is the appropriate name for the system. Some Americans hankered after the term Erian, but they never pressed the case. So there has been none of the hassle comparable with Silurian versus Gothlandien, or Mississippian/Pennsylvanian versus Carboniferous.

There has always been a general acceptance of three subdivisions for the Devonian, and of the Lower, Middle and Upper Series terminology, even if the meaning of the terms has differed.

The stage terminology has not been so simple (Fig. 2). The Lower Devonian stages, Gedinnian, Siegenian and Emsian of the Ardennes and Eifel have had wide use in western Europe and elsewhere for clastic sequences. But following the detailed description of the Czech sequences by Ivo Chlupáč, a terminology using Lochkovian, Pragian, Zlichovian, Dalejian for carbonate facies had been widely adopted in western North America, Asia and Australia. Correlation between the terminologies has been in dispute, and the definition of each is not without problems.

Figure 1. Diagram illustrating the new stage and series terminology for the Devonian compared with past usages which differ widely from country to country and author to author.
and Givetien. The definition of each differed significantly. The Upper Devonian was generally agreed to be divided into the Frasnian and Famennian but the diverse definitions of the top of the system, meant that the late Famennian, especially for French speaking geologists, was named the Strunian and referred to the Carboniferous.

The role of priority
In zoological nomenclature the rules of priority have generally served to stabilise taxonomic terminology. Why, it may be asked, does not this hold for stratigraphic terminology? The simplest answer is that entrenched viewpoints are too strong; that when terms were originally applied knowledge was in reality only local and vague; and that the international consensus view is that a compromise should now be agreed to give boundaries of maximum usefulness and which enable global correlation as far as possible. For the base of the Devonian Murchison did in fact define a top for the Silurian in the Welsh borderlands and for the top of the Devonian Sedgwick and Murchison did give a stratotype at Fremington Pill, North Devon. As will be seen below, international decisions were taken to choose other levels and other localities to define these boundaries anew. In many ways this was unfortunate because there is now no role for priority, no focus on a type area and, once change has been decided it becomes easier for a subsequent generation to introduce change again. As was said, "will the traditional view that boundaries are defined by the accepted usage in the place of origin of the term be abandoned until the whole panoply and splendour of an international committee can deliberate and decide on everything?" (House 1978).

Faunal definition
There has been a view that since any boundary could only be correlated by fossils it is only necessary to decide on a zonal boundary and no specification of type locality is necessary. This was expressed especially by Professor O.H. Walliser (McLaren 1977, p. 12) who dissented from the decision on the SiluroDevonian boundary taken in 1968. This view was not accepted by the majority because incorrect and subjective faunal and floral correlation was the cause of much of the problem. A boundary stratotype defines a boundary in space and time using fossils. But once the decision is taken it is the boundary stratotype and not the fossils which defines the boundary. The wisdom of the majority view is shown by the growing development of other means of correlation using magnetostratigraphy, ash bands, Milankovitch rhythmity, and using new studies of different fossils since these can be accommodated once a boundary stratotype is decided.

Global events
In the Devonian it has been increasingly claimed that there are certain levels where sedimentary perturbations can be recognised internationally. The late Frasnian Kellwasser Limestone (or Kellwasser Event) is such and some think this may represent the effects of a bolide impact, or cosmic showers (McLaren 1970, 1982). Other levels have been documented (Walliser 1984: House 1985). There has been a groundcurrent view that if these do represent single ‘bioevents’, or catastrophic events, then they should be used to define stage or series boundaries if at all possible. The reality is more complex. The Frasnian/Famennian boundary, if taken at the base of the Lower triangularis Zone, as recommended by Sandberg and Ziegler, gives rise to problems in the selection of good boundary stratotype because it lies within the perturbations of the Kellwasser Event. Similarly the Devonian/Carboniferous boundary at the base of the sulcata Zone lies within perturbations of the Hangenberg Event. The problems are compounded by the fact that there is no agreement on the cause of the perturbations. Clearly the recommendation to draw a boundary level in such bands was not wise.

Golden spikes
The various committees of the Subcommission on Stratigraphy thus conform to the recommendation that critical boundaries are defined at a single horizon in a single section named the boundary stratotype section. The point represented by the theoretical ‘golden spike’ thus defines the boundary in space and time. In some cases the boundary stratotype has been ratified and accepted. In other cases the faunal level has been decided and proposals are awaited on candidate boundary stratotypes. Nevertheless the formal subdivisions of the Devonian are now established which will be used as an international standard. The implications for south-west England are discussed in that light.

Silurian/Devonian Boundary
The boundary stratotype for the Silurian/Devonian (and Pridolian/Lochkovian) boundary is at Klonk, 35km south-west of Prague. Here the boundary is drawn within Bed 20 where the graptolite zonal index Monograptus uniformis enters: a trilobite guide-fossil, Warburgella rugulosa rugulosa enters shortly above. The conodont guide Icriodus waschmidtii enters a little earlier in other sections (Martinsson 1977; Chlupáč et al. 1972). This level appears to correspond to a level a little below the Psammosteus Limestone of Shropshire, Monmouth and Herefordshire in the Welsh Borders. The level has not been identified clearly in southwest England but Sadler (1973) recognised I. waschmidtii in the Roseland area of South Cornwall and the cruder guide to the late Silurian, Sycophorini, has long been known there. Dineley (1986) reports traquairaspids in South Devon that suggest Lochkovian (Gedinnian) is present so that the Dartmouth Slates include very early Lower Devonian (Fig. 2).

This boundary illustrates well the problems of relying on extinctions to define faunal boundaries. In Britain there had been considerable diversity on which level was to be taken as the base of the Devonian, from levels as low as those recommended by Murchison near the Ludlow Bone Bed to levels at the top of the Devonian (just below the Psammosteus Limestone) where graptolites are last seen (White 1950). In many other parts of the world the extinction of graptolites was taken to mark the close of the Devonian. Then many discoveries disproved this, especially the recognition by Hermann Jaeger that Monograptus hercynicus was associated with Siegenian brachiopods in Thuringia. Now it is known that graptolites range up probably to the Emsian in appropriate facies and that the early disappearance from Britain is due to local facies changes.

A Committee on the Silurian-Devonian Boundary and Lower and Middle Devonian Stratigraphy was established at the 1980 IGC meeting in Copenhagen following recommendations from the 1980 Bonn/Brussels meetings (Erben 1962), itself preceded by a meeting in Prague in 1958 (Svoboda 1960). Professor H.K. Erben and from 1968 Dr D.J. McLaren acted as chairmen. Subsequently meetings were held, either of the committee or related groups and usually with associated publications, at Reims (1964), Calgary (1967), Leningrad/Siberia/Ukraine (1968), Prague (1968), Nevada (1970), Prague (Barrandian) (1970), Morocco (1971) and final recommendations were approved by the IGC at Montreal (1972). All this has been documented by McLaren and others (in Martinsson 1977), and the type area for the underlying late Silurian has been described (Kriz et al. 1986). Thus the final decision was a result of much international co-operation. Study of this boundary level has continued as Project Ecostratigraphy.

Boundaries within the Devonian
Decisions on boundaries within the Devonian will be considered in stratigraphical order using stage boundaries as the key (Fig. 2) but this differs from the order in which they were discussed. Recommendations here have been the responsibility of the Subcommission on Devonian Stratigraphy which was established by IUGS in 1972 and which has worked under the successive chairmanship of Prof. H.K. Erben, Prof. W. Ziegler and Dr. W.A. Oliver, Jr. Meetings of the Subcommission, or meetings of related groups, have been held in Marburg (1973),
It has been agreed that the stage names adopted for the Lower Devonian should be as indicated in Fig. 2. The two old terms Gedinnian and Siegenian correlate very approximately with the Lochkovian and Pragian stages which are much better defined in terms of conodonts, tentaculitids and brachiopods.

**Base of Pragian**

At Calgary (1987) it was decided that this boundary should be selected within the band or interval marked by the first appearance of the conodont *Eognathodus sulcatus* and the tentaculite *Novakia arcuaria* which was said to enter a little higher. This level is slightly below the base of the Praha as defined at present (Fig. 2)
but which would be redefined. Levels as high as the base of the gli·
vernzi Zone and as low as within the pesavis Zone were
considered. The boundary faunas were analysed by Weddige (1987)
for the Prague area who recommended using the entry of E.
sulcatus. A boundary stratotype has still to be decided. In Devon
this boundary is probably within the Dartmouth Slates but, until
some good correlation with non-marine facies is established, it is
unlikely to be recognised with precision.

**Base of Emsian**
The level agreed at Calgary (1987) is a band within the range
of overlap of *pirenaeae* and *Polygnathus dehiscens*. A boundary
stratotype has still to be decided and a final exact level chosen.
Nevertheless the band selected is near the base of the dehiscens
Zone (Fig. 2) and represents a level which may be widely
recognised internationally. In south-west England the level will lie
at a horizon within the Staddon and Meadfoot Beds.

The term Emsian, based on the type Ems Quartzite (Kutscher and
Schmidt 1958), has come to replace Coblenzen relatively recently.
Major difficulties here have been related to problems in correlating
the elastic type sections with carbonate sequences elsewhere in
which conodonts, brachiopods and goniatites are more common.
During initial discussions it was thought likely that Zschokian and
Dulejjan might have replaced Emsian for international acceptance,
and they may still survive as substages. The solution of the
correlation problem has been indirect, taking advantage of Spanish
and other sections which carry both elastic and carbonate faunas
(Carls 1987). It is likely that the new definition will include in the
Pragian most levels with *Acrospirifer primaevus*, *Arduspirifer
arduenensis* and *Hysterolites hystericus* and in the early Emsian
levels with *Acrospirifer fallax*, and *Arduspirifer antecedens* in the
early Emsian but conodont faunas will be critical for the recognition
of the boundary. Goniatites, especially Anetoceras and other genera
seem to enter in the late *dehiscens* Zone. Convenient faunal breaks
for different groups lie at different levels and the consensus is likely
to favour the boundary level which is most readily recognisable
internationally. It is hoped that at the Rennes meeting (1988)
progress will be made towards this.

**Base of Eifelian (and Lower/Middle Devonian Series Boundary)**
In 1979 the Subcommission voted for a level to define the
Lower/Middle Devonian boundary at the lower boundary of the
partitus Zone. In 1981 the Subcommission selected a boundary
stratotype marked by the base of Bed 30 in the Wetteldorf
Richtschnitt in the Eifel Hills of West Germany (Ziegler and Werner
1982, pp. 13-84) and a parastratotype level was chosen in the
Holyne Prastav Quarry southwest of Prague (Chlupáč in Zielger and
Werner 1982, p. 85-96). The exact level of this boundary in the
sequences of south-west England remains to be determined since
detailed conodont work has not been done over the critical
boundaries in South Devon. Nevertheless it seems that it will
closely correspond to the Meadfoot Beds/Daddy Hole Limestone
boundary.

Problems here relate to whether Couvinien or Eifelian should be used
for this stage and whether the boundary should be close to the base
of the former or the latter. In Belgium and Schiste de Bure à *Paraspirifer
cultivirugatus* was placed in the Middle Devonian. In Germany the
Lower/Middle Devonian boundary was drawn at the Heisdorf/Lauch
boundary in the Eifel Hills. Nationalistic and linguistic preferences
dominated the early discussion.

International consideration of this boundary commenced at the 1958
Prague meeting (Svoboda 1960) and 1960 Bonn meeting (Erben
1962) before the establishment of the Subcommission. It formed a
substantial item for debate at other meetings, particularly a meeting
in the Eifel and Ardennes in 1974. Great progress was made towards
conclusion at the 1978 Samarkand meeting (Sokolov and
Rzhonsnitsaya 1982).

**Base of Givetian**
At Calgary (1987) it was agreed that an interval from the base of the
ensensis Zone to the base of the varcus Zone and not excluding the
base of the *obliquimarginatus* Zone (Ziegler 1971) which was
replaced by the ensensis Zone by Weddige (1977) should be the
band for definition of the level for this boundary. The exact level
and stratotype remain to be determined. This time band will
probably fall within the Daddy Hole Limestone since the top of this
unit is marked by 10m of dark limestone at the base of the sea cliffs
at the northern end of Redgate Beach (SX 93576497) which is
referred to the upper *ensensis* Zone (Austin et al. 1985, p. 108) to
within the Walls Hill Limestone. The level outside South Devon is
uncertain.

Many levels were discussed before reaching the present consensus.
The band decided is much higher than that represented by the
international occurence of the goniatite *Cabrieroeceras crispiforme*
which is found, for example, in the upper Union Springs in New
York or the Kakac member in Czechoslovakia (Fig. 2), a level
sometimes called the Otomari Event which had been used to define
this level on the goniatite scale. Goniatites are generally very poorly
known in this part of the Devonian and the molarium Zone, at its
type locality at Woborough, is thought to be within the varcus Zone
(Selwood et al. 1984, p. 174) and presumably the early part of that
zone.

**Base of Frasnian (and Middle/Upper Devonian Series Boundary)**
The decision has been made to define the base of the Frasnian stage
and base of the Upper Devonian within bed 42a at the boundary
stratotype section at Col du Puech de la Suque, near St Nazaire de
Ladarez in the Montagne Noire, southern France (Klapper et al
1987). The level is the base of the Lower asymmetrus Zone in the
conodont zonation. In Devon this level is within the succession in
Barton Quarry (SX91256710), Torquay (Austin et al. 1985, p. 130).
It was this quarry which yielded the corals which led William
Lonsdale to propose the founding of the Devonian System. On the
South Devon coast the level is probably represented by the base of the
Babbacombe Slate near Half Tide Rock (House 1964; Castle
1982). The level is present on the north Cornwall coast where it is at
the base of Bed 151 in the excellent sequence of the Marble Cliff
Beds (SW 891765) near Trevone, North Cornwall (Austin et al.
1985, p. 112, section also illustrated by House and Dineley 1985, p.
302).

In the major review of the Devonian system resulting from the
Calgary meeting of 1967 (Oswald 1968) there was almost
unnecessary use of a base for the Upper Devonian at a level
corresponding to the base of the Assise de Fromelennes (F1) in
southern Belgium and northern France, the base of the Manticoceras
Stufe and lunulicosta Zone, and the base of the Tully in New York
(Fig. 2). In the succeeding twenty years this unanimity has been lost.
The new boundary reflects a chain of incidental mis-correlations
leading to the acceptance of a quite different level. The history of
this boundary has been recounted in detail elsewhere (House 1973,
1982) and need not be repeated here. The salutary lesson is the ease
with which long-standing boundaries and, in this case, boundaries
which have resulted from IUGS committees, can be discarded. So
too can any respect for priority. It must be recognised that once such
action is allowed, it becomes much easier for it to happen again, and
the result is destabilising.

**Base of Famennian**
Decisions were made at the 1987 Calgary meeting to revoke an
earlier decision (made at Montpellier in 1983) that the boundary
level should be the base of the Middle triangularis Zone in favour
of a level at the base of the Lower triangularis Zone. A decision
was made by those present that the stratotype should be a section in
the Montagne Noire above the Comnac Quarry (Feist 1983; Feist
and Flajs 1987). This will require reconsideration since sedimentary
perturbations seem internationally associated with the level chosen
which correspond to later parts of the Kellwasser Event. Aspects of
the history of this boundary have been
reviewed elsewhere (House 1973). So far as south-west England is
concerned the precision of knowledge is not such as to help. The
entry of Cheiloceras, which has been used in the past, is a little
above any of the containing levels. But it seems that Knöhl Wood
(SX85086942), Chudleigh, exposes the best sequence across the

Devonian/Carboniferous Boundary

This boundary is now taken at the level of the base of the conodont
Sulcata Zone. A final recommendation will depend on decisions
taken in May 1988 probably from among boundary stratotype
proposals at Hasselbach (Germany), Drewer (Germany),
Montagne Noire (France), Muhua (China) and Dapoushang (China).
This boundary is only fractionally below the former level at the base
of theGattendorfia subinvoluta Zone level. This boundary has been
generally followed in the British Isles (House et al. 1979) so little
change is required. The former Wockumeria/Gattendorfia boundary
was recognised in North Devon, but the best sequence showing the
new boundary was described from boreholes at Chillaton by
Selwood et al. (1982).

At Heerlen in 1935 the Carboniferous Congress decided to take the
base of the Carboniferous at the entry ofGattendorfia subinvoluta
and the base of the Gattendorfia Genus Zone (or Stufe) using the
reference section at the Oberrödengausen railway cutting in the
Sauerland (Jongmans and Gothan 1937, p. 6). This boundary was
followed in most countries, but French speaking countries, and the
USSR, continued to use a lower boundary at the base of the
Strunian, near the base of the Wockumeria Genus Zone. So
international agreement was not achieved by the Heerlen decision.
Furthermore, increased use of conodonts and spores led to pressure
for a redefinition in terms of groups more widespread than
gnaniates.

The IUGS Working Party on the Devonian-Carboniferous Boundary
was organized in 1976 following discussions in Krefeld (1971) and
in Moscow (1975). The first meetings were held at Bristol and Cork
decision was made to recommend an operational boundary using the
entry of Siphonodella sulcata, a level a little below the entry of
Gattendorfia subinvoluta (Paproth 1980). The search for a stratotype
commenced. Other meetings were at Leeds (1981), the Rhenish
Slate Mountains (1982) and Moscow (1983). By the Madrid
meeting (1983) stratotypes were under consideration at Hasselbach
(Germany) (Becker et al. 1984), Kija (subsequently withdrawn) and
Burchgur (USSR) (later withdrawn) (Barskov et al. 1984) and
Muhua (China) (Hou et al. 1984, 1985). By then it was appreciated
that the new boundary level was recognisable by the entry of
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Conclusions

International efforts to achieve consensus on the use of
stratigraphical terms for the Devonian have resulted in spectacular
increases in knowledge and the recognition of many errors in past
interpretation. The precision with which boundaries can now be
recognised, given appropriate faunal or floral representation, must
be approaching the resolution possible with such methods.

However, most work has been done on the correlation of marine
strata and the whole matter of non-marine strata has hardly been
touched. Because conodonts have been most useful for fine
resolution, microfossils have tended to control decisions, but for
field geologists, macrofossils are often more helpful in enabling
immediate recognition of time levels whilst in the field. Many
previously valuable markers using macrofossils have now gone. In
general it is to be regretted that priority has generally been ignored:
this is because a reasonable aim has been to accord with current
international usage as far as possible. This means that none of the
boundaries recommended is sacrosanct even when they have IUGS
approval. Approved IGC boundaries have been discarded in the past
and can be again. Nevertheless the result of this effort of many
geologists has been to establish the Devonian as one of the best
classified systems and one where substantially international
agreement has been reached on all its constituent subdivisions. This
is a major achievement.

More importantly the way is now open for the analysis of the real
genetical problems of the Devonian within the framework of an
agreed terminology and very refined correlation. Considerable
advances are now to be expected in palaeogeographic and
palaeotectonic reconstructions, in studies of sea-level changes and
of palaeoecological fluctuations through time. A more critical study
of evolutionary changes and the nature of the anoxic 'events' and
other perturbations in the record of the Devonian is now possible.
This will be the genuinely scientific outcome of the work of the
three IUGS subcommittees.

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Devonian-Carboniferous boundary in Guizhou province, South China.


**Note added in proof**

At a meeting of the Working Party on the Devonian-Carboniferous Boundary held in May 1988 a decision was taken to recommend as Global Boundary Stratotype for the Devonian-Carboniferous boundary the section at La Serre in the Montagne Noire described by Flajs and Feist (1988) with the Global Boundary Stratotype Point at the base of their bed 89. Other information is contained in Flajs et al. (1988). This was coupled as a package with the recommendation that two other sections should be regarded as Auxiliary Stratotype Sections, namely Hasselbachtal (Becker et al. 1984; Becker 1988) and Nanbiancun (Yu Chang-Min 1988). The matter was referred to a postal vote when it received a 70% majority vote and the recommendation is now being forwarded to the International Commission on Stratigraphy.

A meeting of the Devonian Subcommission was held at Rennes in August 1988. The base of the Pragian was recommended at the entry of *Eognathus sulcatus* in the Velka Chuchle, near Prague. This is now subject to postal voting. Stratotype sections are being sought for the base of the Emsian within the overlap of *Polygnathus pyreneae* and *P. dehiscens*. For the base of the Givetian it was agreed that attention should be paid to the first occurrence of *Polygnathus hemiansatus* as a guide to this boundary and a stratotype decision would be delayed. On the base of the Famennian the Subcommission reconfirmed its preference for the base of the Lower triangularis Zone to define this: of the several stratotype proposals before it the attending members preferred the E 1 Atrous section in southern Morocco and a further year was allowed to permit more documentation of this to be presented.

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