STEPS TO A STANDARD SILURIAN

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ABSTRACT

Procedures concerning the standardization of the upper and lower boundaries of the Silurian System are briefly reviewed. The Subcommission on Silurian Stratigraphy of IUGS was constituted from an *ad hoc* body in 1974. Since then meetings have been held in various countries and there has been much correspondence. Steps towards a standard, internationally agreed, internal chronostratigraphy for the System are reviewed. Underlying philosophy is relevant to the consideration of other parts of the Standard Chronostratigraphical Scale.

UPPER BOUNDARY OF THE SILURIAN SYSTEM

An important, but somewhat unrepresentative, meeting on the Silurian/Devonian boundary was held in Prague in 1958 (Svoboda, 1960). As more and more modern detailed research followed upon the classic and monumental studies of Barrande it is not surprising that colleagues in Central Europe became dissatisfied with the concept of a Silurian/Devonian boundary elusive in character, and with which they found correlation to be difficult and unrewarding. Nor is it surprising that they looked with more favour upon their own seemingly continuously marine sequence. Thanks above all to the inspiration and energies of Professor H.K. Erben there followed the epic Bonn-Brussels meeting of 1960 (Erben, 1962). One of the most important creative leaps for-

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ward in stratigraphy was made (as I remember it) in a discussion within a small group travelling at the back of a coach during that meeting. It was the realisation that the reason for all our difficulties in correlation might be overcome if it were to be accepted that graptolites do not, in some mystical way, disappear abruptly when one passes from Silurian to Devonian rocks. There followed the long years of activity of the Silurian/Devonian Boundary Committee under the successive Chairmanship of H.K. Erben and D.J. McLaren. Much original work was initiated. What Anders Martinsson subsequently referred to as the 'lost series' of the Silurian System began to find its place in correlation tables. Principles of chronostratigraphical standardization were argued through and are now accepted as of much wider applicability. There were two definite steps in this particular process of standardization involving, first, the selection of an horizon for the base of the Devonian at the base of the *Monograptus uniformis* Biozone and, secondly, the selection of a boundary stratotype ('golden spike') section. In the light of subsequent reference to precedent it is especially important to note that the first of these two steps was inevitably separate in this particular case because correlations had previously been in such grievous error that some kind of compromise over the selection of horizon was essential (Holland,1965; Bouček, Horný, and Chlupáč,1966). The record of work of the Committee, its achievments, and the principles underlying these were summarized by McLaren (*in* Martinsson, 1977) in a volume where there are also many papers on the results achieved in research generated by the existence of this body. The final decision was of course for a boundary stratotype at Klonk in the Barrandian (Prague basin) of Czechoslovakia (Fig. 1). Here at the first

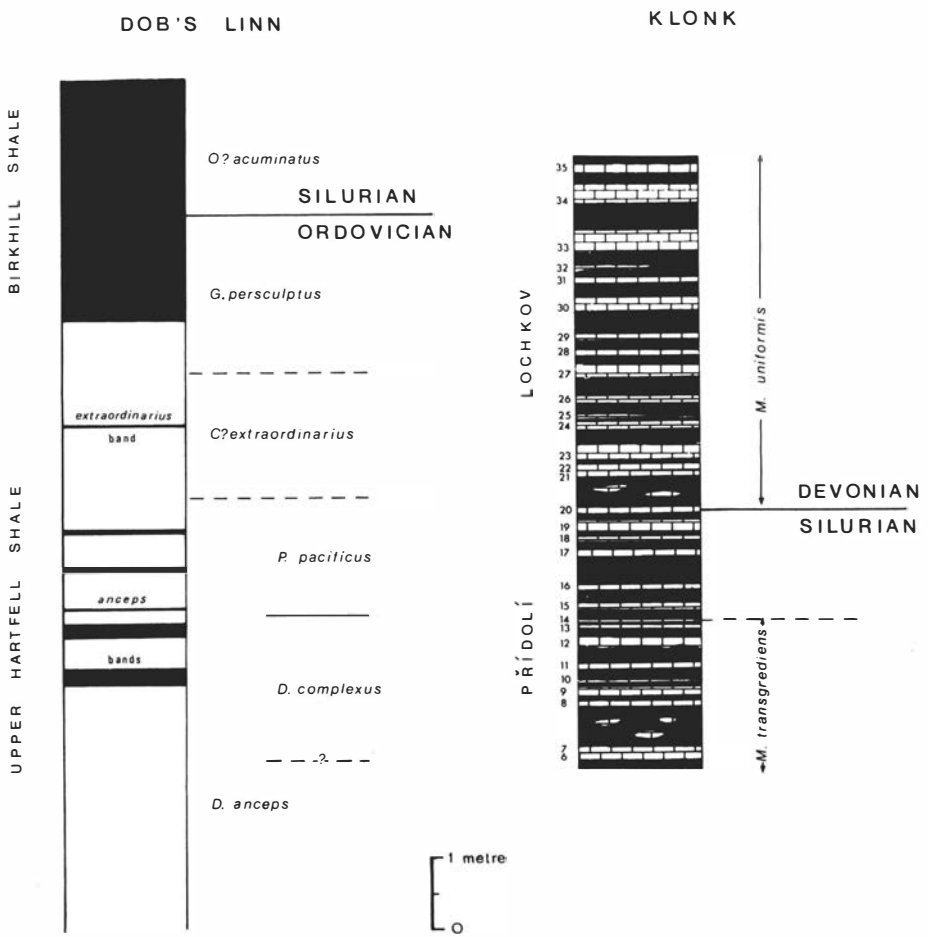

FIGURE 1 Boundary stratotypes for the base of the Silurian System and the base of the Devonian System (modified from J.K. Ingham and Chlupáč, Jaeger, and Zikmundova).

appearance of *Monograptus uniformis* in Bed 20 the standard upper boundary of the Silurian System is now fixed, though strictly of course the function of the boundary stratotype and its marker point refers in more rigid definition to the base of the succeeding Devonian System. Finally, the Silurian/Devonian Boundary Committee in a sense gave birth to the separate Silurian and Devonian Subcommissions of the Commission on Stratigraphy of the International Union of Geological Sciences (IUGS). The consequent continuity of personnel, bringing with it international friendships and the ability to work closely together, has helped immensely in our own work.

LOWER BOUNDARY OF THE SILURIAN SYSTEM

As noted by Alwyn Williams in his introduction to the Geological Society of London's *A Correlation of Ordovician rocks in the British Isles* (Williams *et al.*, 1972), the stratigraphical location of the Ordovician/Silurian boundary has never been in serious dispute. In this case there was certainly no 'lost series'. Finding the uppermost Ordovician and lowest Silurian beds in the type Llandovery area poorly exposed and lacking in diagnostic shelly fossils, Cocks, Toghill, and Ziegler (1970) used Charles Lapworth's classic locality at Dob's Linn in the Southern Uplands of Scotland to define the base of their lowest stage and hence the base of the Llandovery Series. These authors placed it at the base of the *persculptus* Biozone, a biostratigraphical level commonly in use. Undoubtedly there did remain problems of correlation between the graptolitic and shelly facies about this level, notably in relation to the internationally widespread but possibly diachronous *Hirnantia* fauna (see for example Rong Jia-Yu, 1979; Apollonov *et al.*, 1980).

A Working Group on the Ordovician/Silurian Boundary was established during the International Symposium on the Ordovician System held at the University of Birmingham in September 1974. Its Voting Members were nominated by the Ordovician and Silurian Subcommissions. Dr R.B. Rickards was elected Chairman and Dr L.R.M. Cocks Secretary of the Working Group. In 1981 Rickards resigned and the Working Group was placed under the Joint Chairmanship of R.J. Ross Jr and C.H. Holland (respectively Chairmen of the adjacent Subcommissions). During its nine years of existence the Working Group has received over 50 Reports on individual areas and other more general matters, as well as various Circulars. By the time of a joint meeting with the Subcommission on Silurian Stratigraphy (SSS) held in Britain in 1979 it was agreed that only two potential boundary stratotype localities fell into a top category of suitability: Anticosti Island in Canada and Dob's Linn in Scotland.

Members examined the section at Dob's Linn during that meeting. Dr J.K. Ingham of the University of Glasgow has done much to clarify the details of this section (Fig. 1). His discovery of a *Climacograptus extraordinarius* band within the previously supposedly barren beds of the Upper Hartfell Shale, between the top *anceps* band and the base of the Birkhill Shales has increased correlative potential. Apart from the monograph by Elles and Wood (1901-1918), the graptolite fauna at Dob's Linn has more recently been studied by Toghill (1968, 1970) and S.H. Williams has now examined its components in immense detail. Two accounts of the upper Ordovician graptolites are already published (Williams, 1982a, 1982b), the former containing a useful summary of the stratigraphy.

In the summer of 1981 members of the Working Group and of the Silurian Subcommission

visited Anticosti. The arrangements for this superbly conducted meeting were by Professors P.J. Lespérance and C.R. Barnes. Unfortunately, the number of Voting Members of the Working Group present at this meeting was relatively small. The very large island of Anticosti in the St Lawrence estuary now belongs to the Quebec government and is a fishing and hunting reserve. Its small population is concentrated in the settlement of Port-Menier at the western end of the island. Magnificent sea cliff and river sections display a succession of upper Ordovician and lower Silurian rocks with a regional dip of only a few degrees. There is a seemingly continuous carbonate and clastic platform sequence with a range and richness of shelly faunas which impressed everyone who visited the island. Barnes and McCracken (*in* Lespérance, 1981) had suggested a stratotype for the Ordovician/Silurian boundary on the west side of Baie Ellis, itself close to and easily accessible from Port-Menier. The boundary was to be taken within the Ellis Bay Formation where the conodont *Ozarkodina oldhamensis* first makes its appearance. Abundant documentation on the stratigraphy and palaeontology of Anticosti is contained in the two volume guidebook published for the meeting by the Département de Géologie of the Université de Montréal (Lespérance, 1981). Various other publications continue to appear. Petryk (1981) has produced a complete three sheet geological map of the island at a scale of 1 : 100000. McCracken and Barnes (1981) have described the conodont biostratigraphy and palaeoecology of the Ellis Bay Formation. Cocks and Copper (1981) record the presence of a *Hirnantia* fauna at the remote and less well known eastern end of the island.

Both candidates were discussed in detail at meetings of the Ordovician-Silurian Boundary

Working Group held during the International Symposium on the Ordovician System at Oslo in the summer of 1982. A large majority of those present (and of those members present) agreed that a decision should then be taken, and a separated vote of members present gave a clear majority in favour of Anticosti. Since then the matter has been put to formal postal vote by Voting Members of the Working Group, which, in contrast, has resulted in a clear majority for Dob's Linn. Though Anticosti has immense potential as a reference section (see below) Voting Members undoubtedly were influenced by the scarcity of graptolites in the sequence, particularly near the boundary. They also saw real difficulties in correlating the stratotype section throughout the world. To some extent decisions by Subcommissions and Working Groups within the Commission on Stratigraphy depend on the interests of those who happen to be members of these bodies. However, the international structure for decision making is the only one we have and perhaps the best that can be expected. A personal view is that no section is likely to be perfect; that decisions must be made in a reasonably expeditious manner so that fundamental research may continue, unhampered by vagueness of definition and understanding; and above all that once decisions are properly made they should be respected by the geological community.

The stratotype at Dob's Linn having been accepted, there arose the question of horizon within the graptolite sequence. Though the previous use of the base of the *persculptus* Biozone has been widespread, an alternative at the base of the succeeding *acuminatus* Biozone has become increasingly popular. Soviet biostratigraphers have found it to be so (Apollonov *et al.* *in* Oradovskaya and Sobolevskaya, 1979); in their submissions to

the Working Group both J.K. Ingham and H.S. Williams have advocated its use; it has the advantage of leaving the widespread and useful *Hirnantia* fauna unequivocally within the Ordovician. At the time of writing a formal postal vote by Voting Members of the Working Group has resulted in a clear majority in favour of taking the Ordovician/Silurian Boundary, and hence by definition the base of the Silurian System, at the base of the *acuminatus* Biozone in the Dob's Linn section.

These decisions will now be forwarded to the Commission on Stratigraphy in the hope that they may soon be ratified by that body. The preparation of a detailed volume on matters relating to the boundary will then be initiated on the lines of that referred to above for the Silurian/Devonian Boundary. Thus the lower and upper limits of the Silurian System appear to be settled and, in spite of the tendency for geochronometry to reduce the length of the corresponding Silurian Period in terms of radiometrically determined years, Silurian stratigraphers, viewing this moveable feast with a little detachment, still find an impressive extent of often highly fossiliferous rocks requiring the attention of the Subcommission in attempting to achieve an internationally agreed chronostratigraphy within the Silurian System.

SILURIAN SERIES AND STAGES

The Subcommission on Silurian Stratigraphy was constituted from an *ad hoc* body (itself established during the 1972 International Geological Congress in Montreal) at a meeting held in the University of Birmingham during the International Symposium on the Ordovician System of 1974. Its first Chairman was Professor Nils Spjeldnaes and Dr. Francine

Martin has remained throughout as Secretary of the Subcommission. Nils Spjeldnaes was responsible for establishing the final structure of the Subcommission, making sure of appropriately spread national representation among Titular Members and initiating a list of Corresponding Members. There are now sixteen (fifteen since the sad death of Anders Martinsson in July 1983) Titular Members and the Corresponding Membership brings the total list to almost sixty.

In 1976 Professor Spjeldnaes resigned from the Chairmanship and C.H. Holland was elected in his place. At a formal meeting of the Subcommission held during the International Geological Congress in Sydney, Australia in August 1976 it was agreed to embark upon an eight-year programme designed to solve the major problems of Silurian chronostratigraphy. It is most appropriate therefore to report on this programme at the 1984 International Geological Congress in Moscow. Subsequently by the use of questionnaires it was established that there was almost unanimous support for a comprehensive field meeting (with abundant opportunity for formal indoor meetings) to be held in Britain in 1979. This has been referred to already in connection with the work of the Ordovician/Silurian Boundary Working Group. Progress already achieved as a result of this meeting has been summarized in *Episodes* (Holland, 1982). The Subcommission's later field meetings have been held in Anticosti (1981 : see above), the Oslo district (1982), and Podolia (1983).

At their meeting in Britain in 1979 Members of the Subcommission had opportunity to examine sections of Silurian rocks in Wales, the Welsh Borderland, Northern England, and Scotland. The type areas of the Llandovery, Wenlock, and Ludlow Series were all demonstrated as was the base of the Downton Series at Ludlow. Detailed

documentation was provided, particularly in the form of a field guide compiled by M.G. Bassett, L.R.M. Cocks, C.H. Holland, J.K. Ingham, J.D. Lawson, R.B. Rickards, and J.T. Temple.

At Llandovery, O.T. Jones (1925) classified the Llandovery rocks into lettered and numbered divisions, which were later given biostratigraphical significance by Alwyn Williams (1951) and have since been used widely about the world. Cocks *et al.* (1970) provided four stage names: Rhuddanian, Idwian, Fronian, and Telychian. The standard section for the base of the Rhuddanian Stage has already been mentioned. The other definitive sections were within the Llandovery district itself. It is fair to say that members of the Subcommission were unimpressed with the Llandovery district as then demonstrated to them in terms of boundary stratotypes for the basal boundaries of stages within the first series of the Silurian System. Well documented, continuous sections across the boundaries, with appropriate marker points under biostratigraphical control were not clearly available and it was uncertain that all four stages could successfully be correlated internationally. Graptolites appeared not to be abundant.

Discussions on the first series resulted in the decisions that the Subcommission would visit Anticosti during the following year and that, in view of the continuing interest of the Llandovery district as the type area for the series of that name, a British Working Group would investigate it afresh, examining in particular the so called 'northern area' of O.T. Jones (1949), which had remained less well known, but which in fact appeared to offer considerable promise in terms of good sections and graptolitic control.

In the case of the Wenlock Series, Bassett *et al.* (1975) had already published a detailed

modern account of chronostratigraphy, biostratigraphy, and lithostratigraphy, with two stages, the Sheinwoodian and Homerian, properly defined by basal boundary stratotypes, themselves set in the compact, structurally simple, and very well known type Wenlock area. Assurance was given that the sections would be under the care of the Nature Conservancy Council. The two stage names, the basal horizons for the stages (Fig. 2), and the proposed boundary stratotype sections met with approval.

Similarly in the Ludlow anticline, a compact and well known type area had been described in detailed modern terms by Holland *et al.* (1963). Since then an even greater development of forestry roads had increased the potential of this already well exposed and highly fossiliferous sequence (Lawson,1973). After discussion it was concluded that the four stages established by Holland *et al.* (*op. cit.*) were excessive in number. The Bringewoodian Stage was difficult to recognise outside the Welsh Borderland and the Leintwardinian had the extent of only one graptolite biozone (albeit a widely recognisable one). Accordingly it was agreed that these four stages should be paired as two only and that those closely involved in work upon the area should suggest new names for these. The suggestions of Gorstian and Ludfordian Stages (Fig. 2) were subsequently reported (Holland *et al.*, 1980).

At its British meeting the Subcommission also discussed the problem of the fourth series of the Silurian System, which it was agreed should be defined additionally to the Llandovery, Wenlock, and Ludlow. Three candidates presented themselves from which a final choice would be made; the Downton Series of the Welsh Borderland, the Přídolí Series of the Barrandian, and the Skala Series of Podolia. Academician Boris Sokolov, having revealed that the construction

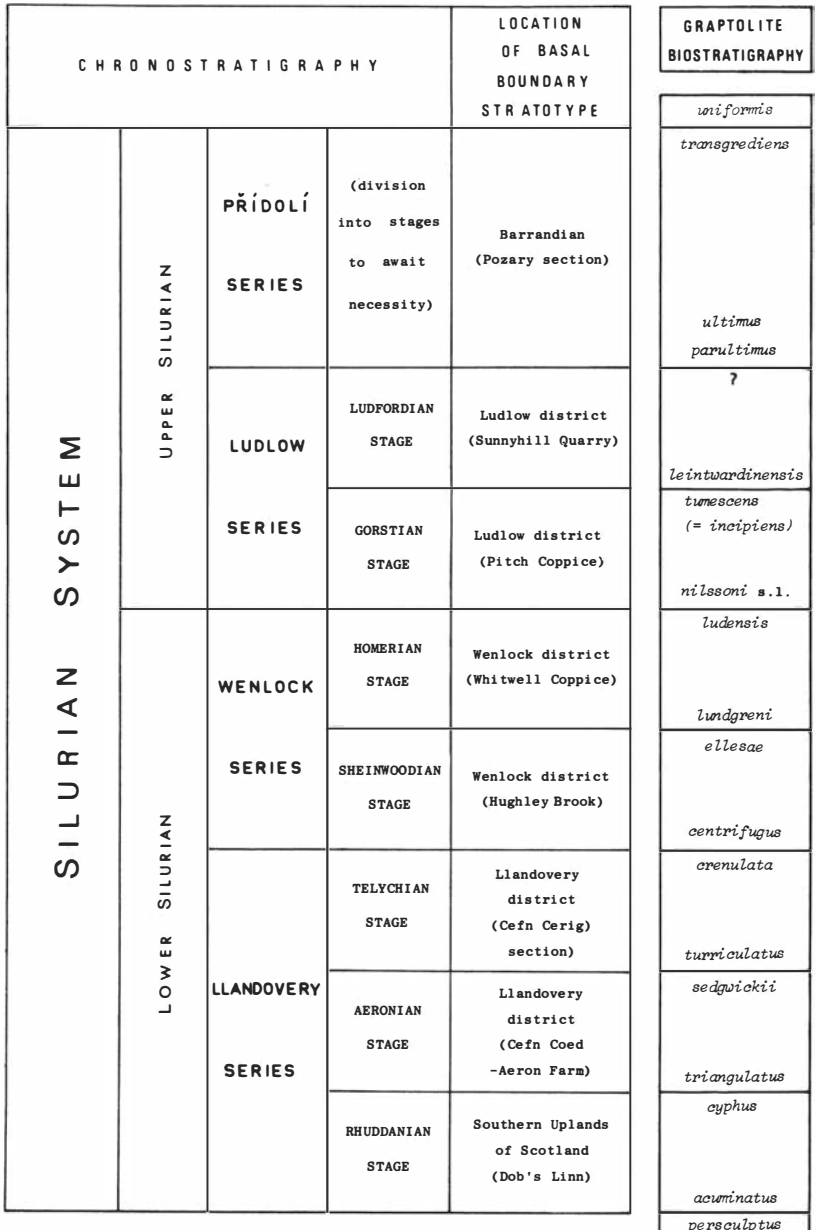
CHRONOSTRATIGRAPHY
LOCATION OF BASAL BOUNDARY STRATOTYPE
GRAPTOLITE BIOSTRATIGRAPHY
SILURIAN SYSTEM
UPPER SILURIAN
LOWER SILURIAN
PŘÍDOLÍ SERIES
(division into stages to await necessity)
Barrandian (Pozary section)
uniformis
transgrediens
ultimus
parultimus
LUDLOW SERIES
LUDFORDIAN STAGE
Ludlow district (Sunnyhill Quarry)
?
leintwardinensis
GORSTIAN STAGE
Ludlow district (Pitch Coppice)
tumescens (= incipiens)
nilssoni s.l.
WENLOCK SERIES
HOMERIAN STAGE
Wenlock district (Whitwell Coppice)
ludensis
lundgreni
SHEINWOODIAN STAGE
Wenlock district (Hughley Brook)
ellesae
centrifugus
LLANDOVERY SERIES
TELYCHIAN STAGE
Llandovery district (Cefn Cerig) section)
crenulata
turriculatus
AERONIAN STAGE
Llandovery district (Cefn Coed -Aeron Farm)
sedgwickii
triangulatus
RHUDDANIAN STAGE
Southern Uplands of Scotland (Dob's Linn)
cyphus
acuminatus
persculptus
Система
Отдел
Ярус

FIGURE 2

of the proposed reservoir in the last of these areas would not eliminate all the good sections of the Skala, invited the Subcommission to examine these rocks at a future meeting in the Ukraine. It was also agreed that opportunity could be made for any members who had not already seen the Downton and Přídolí rocks to do so. The meeting in the Ukraine would allow the occasion to settle the question of the fourth series.

As has remained the practice of the Subcommission, those present at the individual British meeting all took part in discussions, but the proposals on the Wenlock and Ludlow referred to above were subsequently put to postal vote by Titular Members. They were accepted by a substantial majority, recorded in *Lethaia* (Holland, 1980a), and later presented to the Commission on Stratigraphy at its meeting in Paris in August 1980. Professor Anders Martinsson, then Chairman of the Commission, and Dr M.G. Bassett, its Secretary, afterwards circulated documentation and voting papers to all Members of the Commission. The decisions of the Subcommission were ratified without dissent (Martinsson *et al.*, 1981).

The meeting of the Subcommission in Anticosti in 1981 has already been referred to. The Silurian sequence here extends from the base of the System to a level near the top of the Llandovery (or perhaps, it was suggested, Anticostian) Series. Barnes and McCracken (*in* Lespérance, 1981) had informally suggested three stages within the series, to which names had not yet been given. In a subsequent submission to the Subcommission, (dated March 1983), Professor Barnes suggested two stages only to be named the Menierian and Jumpersian. The base of the latter is marked by the first appearance of the conodont *Distomodus staurognathoides*. Rocks of the second stage

are seen along the southern coast of Anticosti Island and along various major rivers in the southern part of the island. Conodonts from this stage have been described by Uyeno and Barnes (1983). The whole sequence in Anticosti maintains the exceptionally good and extensive exposure referred to above in connection with the Ordovician/Silurian boundary. Those fortunate to see these rocks under the guidance of Canadian colleagues found immensely rich shelly faunas in which brachiopods, corals, and trilobites were perhaps especially conspicuous. The microfossils include many ostracodes, conodonts, and acritarchs. Graptolites unfortunately were conspicuous only at the level of the *Monograptus sedgwicki* Biozone, though there are certainly other records (Riva and Petryk *in* Lespérance, 1981).

In conclusion it was agreed that Anticosti certainly provided a potential stratotype area for the first series of the Silurian System. It was also decided that the remaining candidate, the Oslo region, classic in many ways, should be visited in 1982 at a time related to that of the International Symposium on the Ordovician System already mentioned. Arrangements were to be made by Dr David Worsley of the University of Oslo and his active research group. During their 1982 meeting Members of the Subcommission examined various sections, particularly along lake and fjord shorelines, in the three central districts of those eleven into which the Oslo region is divided:Ringerike, Asker, and Oslo itself. The Llandovery rocks here are highly fossiliferous. Though they are structurally more complex than their equivalents in Anticosti, there are no problems in following continuous sections with shelly faunas readily correlatable with those of the type Llandovery area, and hence internationally. Advantageously there are well studied lineages

of *Borealis-Pentamerus-Pentameroides* and of stricklandiids (Baarli and Johnson *in* Worsley, 1982). Graptolites are not so easily seen, but there is considerable potential in the more northerly districts where they have been recently studied by Howe. The volume published for the meeting (Worsley, 1982) contains full lithostratigraphical and biostratigraphical details, together with a synthesis of depositional environments and a field guide.

At a final meeting of the Subcommission in Oslo it was agreed that it would be more reasonable to postpone decision on the first series until a final report had been received from the Working Group concerned with the type Llandovery area. Accordingly it was decided to try to settle the definitions of both first and fourth series at the meeting planned to be held in Podolia in May 1983.

Thus, finally, came the meeting of May 1983 in Podolia, its field excursion based upon the ancient town of Kamenets-Podolsky, which a very few of the foreign participants had previously visited during the historic Silurian/Devonian boundary meeting of 1968. There were two formal indoor sessions in Kiev. The very successful arrangements were by Dr P.D. Tsegelinjuk and his colleagues of the Institute of Geological Sciences in Kiev.

By this time Members had already received a comprehensive submission by L.R.M. Cocks, P.D. Lane, R.B. Rickards, J.T. Temple, and N.H. Woodcock detailing the conclusions of the Working Group on the type Llandovery area. The material is shortly to be published as a *Bulletin of the British Museum Nat. Hist.* A submission on the Oslo region by D. Worsley, R.J. Aldridge, B.G. Baarli, M.P.A. Howe, and M.E. Johnson (dated April 1983) had also been circulated. It recorded additional work in the region and concentrated upon a possible division

of the Llandovery into stages and on the provision of stratotypes. Thirdly, as mentioned already, Professor C.R. Barnes had provided a short submission (dated March 1983) additional to the comprehensive documentation already provided for Anticosti Island.

After very considerable discussion of these three areas a series of informal votes was taken of Titular and Corresponding Members present at the meeting. These indicated by substantial majorities that the first series of the Silurian System should be called Llandovery; that the boundary stratotypes for bases of the second and third of the three stages into which it would be divided should be in the Llandovery area; that the horizons for the bases of these should respectively relate to thebases of the *triangulatus* Biozone and the *turriculatus* Biozone (Fig. 2); and that the boundary stratotype sections for these should be that near Cwm-Coed-Aeron Farm (locality 72 of the Submission by Cocks *et al.*) and the Cefn Cerig road section (locality 162). As there were to be three stages it was agreed that the original names Rhuddanian (its base defined at Dob's Linn) and Telychian (with revised basal horizon) could be used for the first and third of these. The second stage would be named the Aeronian after the locality Cwm-Coed-Aeron mentioned above.

It has frequently been emphasised to the Subcommission that graptolites are not the only stratigraphically useful group of fossils and indeed that their abundance is likely to imply a dearth of other groups. Nevertheless it is not only the graptolite palaeontologists themselves who continue to regard graptolite biostratigraphy as especially useful and accurate in international correlation. Further comment on this point will be made later. Certainly the view appears to have influenced members

in their choice of a stratotypic area for the first series. In seeking to explain the lack of support for Anticosti, it seems also that some of those members who had returned from the island in a state of euphoria, inspired by its beautiful, extensive, and richly fossiliferous sections, had now moved to the view that Anticosti has immense potential for palaeontological and stratigraphical work, but that it is presently very difficult to see its use as a standard with which sections in other regions can reasonably be correlated. Finally, the possible advantage of Anticosti that the boundary stratotype for the base of the Silurian might be in the same place as those for the stages within the first series had now seemingly been lost with the decision to site the former at Dob's Linn. In the case of the lowest series members were undoubtedly choosing between three candidates of a very high standard. That Oslo received only minority support was partly because of the attraction to many members of Llandovery as the historical type area for the Llandovery series.

Before the informal decisions detailed above wereto be put to formal postal vote of Titular Members of the Submission it was agreed that Dr Cocks would provide more detailed photographic and diagrammatic documentation of the two proposed boundary stratotype sections in the Llandovery area and that Dr Worsley would present an altered classification of the Oslo succession in which there would be three stages defined at the same horizons as those proposed for use at Llandovery.

Podolia is an area comparable in some of its geological qualities with Anticosti. Very extensive river cliffs of the Dnestr River and its tributaries show richly fossiliferous Silurian and Lower Devonian clastic and carbonate sequences with extremely simple

structure. Members had already received a detailed submission on the Skala Series (dated 1981) by A.F. Abushik, A. Ya. Berger, T.N. Koren', T.L. Modzalevskaya, O.I. Nikiforova, and N.N. Predtechensky. During the meeting a separate work, *The Silurian of Podolia. The guide to excursion* (Tsegelinjuk *et al.*, 1983), was provided. Using bentonites to correlate the Skala sequence with graptolitic borehole successions elsewhere in Podolia and in Volyn a result had been achieved very different from that provided by Abushik *et al.* It was given lengthy and careful consideration during the meeting but did not find favour. Dr. Tsegelinjuk's view of the scope of the Skala Series was also different from that of the Leningrad group. In practice the Subcommission considered a boundary stratotype for the base of the Skala Series at the base of the Rushkov Formation in the section along the left bank of the Dnestr River near Okopy village (locality 44 of Abushik *et al.*). The Skala is not graptolitic (though most other Silurian fossils groups are present) but in any case correlation of the basal boundary depends upon an occurrence of *Frostiella* sp. 7 m above the base of the formation and of *Frostiella modesta* and *F.* cf. *groenvalliana* 15 to 17 m above the base. The section shows a cyclic development including dolomites. Podolia will always remain an excellent reference area in Wenlock to Lower Devonian stratigraphy but for the present purpose of defining the base of the fourth series of the Silurian System was not regarded as appropriate.

There was, of course, further discussion during the indoor meetings of the Subcommission in Kiev when the other two candidates for the fourth series were also presented and discussed in elaborate detail. A submission on the Downton Series by M.G. Bassett, J.D. Lawson,

and D.E. White (dated 1981) had later been published (Bassett *et al.*, 1982) and followed by a short supplementary submission (dated March 1983). Advocates of the well known Downton area in the Welsh Borderland emphasised that, as the Subcommission had already decided that subdivision of the fourth series into stages was as yet unnecessary, concern lay only with a boundary stratotype for the *base* of the series, its top being already controlled by the agreed base of the Devonian. In this respect the correlative potential of the Ludlow Bone Bed (or more strictly its base) is considerable (Bassett *et al.*, *op. cit.*; Kaljo, 1978). A whole web of biostratigraphical evidence involving ostracodes, vertebrates, graptolites, etc., may be assembled in correlation.

In the end, however, the great majority of Members present favoured the truly marine Přídolí Series of the Barrandian (Prague Basin). Dr Jiří Kříž and his associates (H. Jaeger, F. Paris, H-P. Schönlaub, A. Angelidis, I. Chlupáč, V. Havlíček, M. Krůta, Z. Kukal, J. Marek, R. Prokop, M. Šnajdr, and V. Turek) had prepared a submission (dated March 1983) more detailed, elaborate, and definitive than an earlier version of May 1981. The succession, classic since Barrande's time, is rich in fossils of many groups, though it is fair to say that there has been some reservation about its palynology. It was agreed by informal votes that the name of the fourth Series of the Silurian System should be Přídolí (it is already widely in use), that the basal horizon of this should be the base of the *Monograptus parultimus* Biozone, and that the boundary stratotype section should be that at Pozary fully documented by Kříž *et al.* A remaining problem was the continued use of Přídolí as a formational (lithostratigraphical) term as well as for the series. A number of members expressed

firm reservation about this, but by now Czech colleagues have already agreed to select an alternative formational name.

At the time of writing, then, additional details requested from Drs Cocks and Worsley have been received and a formal postal vote of Titular Members is being conducted concerning the first and fourth series of the Silurian System. It seems reasonable now to be hopeful that international agreement on Silurian chronostratigraphy is in sight.

THE QUESTION OF RANK IN THE CHRONOSTRATIGRAPHICAL HIERARCHY

Ratification by the Commission on Stratigraphy of the formal decisions by the Subcommission on Silurian Stratigraphy concerning the Wenlock and Ludlow *Series* and the *Stages* within these has been referred to above. At its 1979 meeting and subsequently Members agreed to the informal use of 'lower Silurian' and 'upper Silurian' for, respectively, the first plus second and third plus fourth series of the system. This was not a matter for the Commission on Stratigraphy as informal divisions were involved. Clearly such divisions are unlikely to be much needed as correlation with one of our four series or with a range of these will usually be possible. On the occasions when extreme vagueness of correlation or the use of descriptive language requires the terms 'lower' and 'upper' or 'early' and 'late' Silurian, then it is logical that each of these should equate with two of our four series or two of their time equivalents.

However, throughout the deliberations of the Subcommission there has been an underlying, though probably minority, concern about our chronostratigraphical hierarchy which would suggest that divisions such as lower and upper

Silurian should be series, the four divisions Llandovery, Wenlock, Ludlow, and Přídolí should be stages, and the subdivisions within the Llandovery, Wenlock and Ludlow should be lower still in the hierarchy, presumably as substages. This view seems to me to have a varied origin. First, there is in some quarters an obsession with uniformity in stratigraphy. It might, for instance, suit the appetite of the computer better if all systems had series labelled Lower and Upper. But stratigraphy has its roots in the early history of geology. It is too late to expect uniformity of classification and duration of systems. It is true that the Devonian System is likely to have three series, the Lower, Middle, and Upper Devonian, and stages within these. In the Ordovician, however, where the six Series Tremadoc, Arenig, Llanvirn, Llandeilo, Caradoc, and Ashgill are already in wide use where faunal provincialism permits, it is very unlikely that the relevant Subcommission will decide other than upon a total of more than three series, each with its geographical name. And various other varieties of treatment could be quoted throughout the stratigraphical column. Secondly, there is the view more commonly held by European Mesozoic stratigraphers (and itself rooted in the history of the science) that there are only two fundamental units in stratigraphy : the Stage and the Zone, stages being, in effect, bundles of zones. Thirdly, in the Soviet Union the Regional Stage (*Gorizont*), because of the vastness of the territories covered and the variety of their stratigraphy, assumes the importance expected of an international chrono-stratigraphical division such as Wenlock, and thus suggests an equation of rank (Sokolov *et al.*, 1980). In Figure 2 the alternative view of the hierarchical structure with the relevant Soviet terms is added for completeness.

In fact, the matter of hierarchy can probably be left to later deliberations of the Commission on Stratigraphy itself. What matters is agreement upon a set of chronostratigraphical divisions (whatever rank they may eventually be given), with agreed names and diagnoses of each. This we are approaching.

It has been suggested by Dr Hermann Jaeger and others (Jaeger, 1980; Chlupáč *et al.*, 1981) that the Stages presently agreed within the Wenlock and Ludlow are too small in duration and local in applicability to be of international significance. Had this been so they would scarcely have proved acceptable to the Subcommission as a whole. The notion has in any case been opposed by Brouwer (in press) and Holland (1980b). Why should we lose the potential accuracy of correlative statement provided by these divisions? Those for the Wenlock and Ludlow are already in successful international use. I have tried to assess whether the present number of Silurian stages (7 without division of the Přídolí) is unreasonable in comparative terms. I tried to calculate an average of the number of stages currently employed in various parts of the world for other post-Cambrian Palaeozoic systems and for those of the Mesozoic. The figure is approximately ten.

THE ROLE OF THE BOUNDARY STRATOTYPE

I have written elsewhere (Holland, 1978) about the role of the boundary stratotype in chronostratigraphy. The reply to the question as to whether anything more has as yet resulted directly from the placing of the'golden spike' at Klonk beyond that already gained by the selection of the *horizon* for the base of the Devonian System at the base of the *Monograptus uniformis* Biozone may well appear still to be in the negative. I continue to believe that

the importance of the boundary stratotype lies in its role as a future anchor to which all subsequent correlations can be tied, even if new palaeobiological or physical methods become available. An earlier diagram (Holland, 1978, Fig. 3), of which a further refinement is provided in Figure 4 of the present paper, also indicated the philosophical importance of the boundary stratotype as the only place where we actually know (by definition) that time and rock coincide within our classification. Away from this the boundaries we use between chronostratigraphical divisions are *not* lines through time; they are lines through rock which we try to the best of our scientific ability, using all the correlative methods available to us, to relate as closely as possible to synchronism, though we may never know the extent of our accuracy. There has been much discussion in stratigraphy about time *versus* rock. I continue unrepentantly to believe that we hammer our spikes into rock representing time and not into time itself. The selection of boundary stratotypes has also an important by-product in the form of new research generated. This has often been stated in the case of the long road towards the selection of the Silurian/Devonian boundary. It is certainly true in the work of the Subcommission on Silurian Stratigraphy (Fig. 3).

THE ROLE OF PARASTRATOTYPES IN CHRONOSTRATIGRAPHY

All the boundary stratotypes now selected or in process of selection for the internal divisions of the Silurian System are placed in facies sufficiently 'mixed' in character as to allow both graptolitic and shelly faunal correlations. Obviously there are levels at which some features are less satisfactory than others. Thus conodont faunas which are now so

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SUBCOMMISSION on SILURIAN STRATIGRAPHY

The Skala Series
as the fourth Series of the Silurian System

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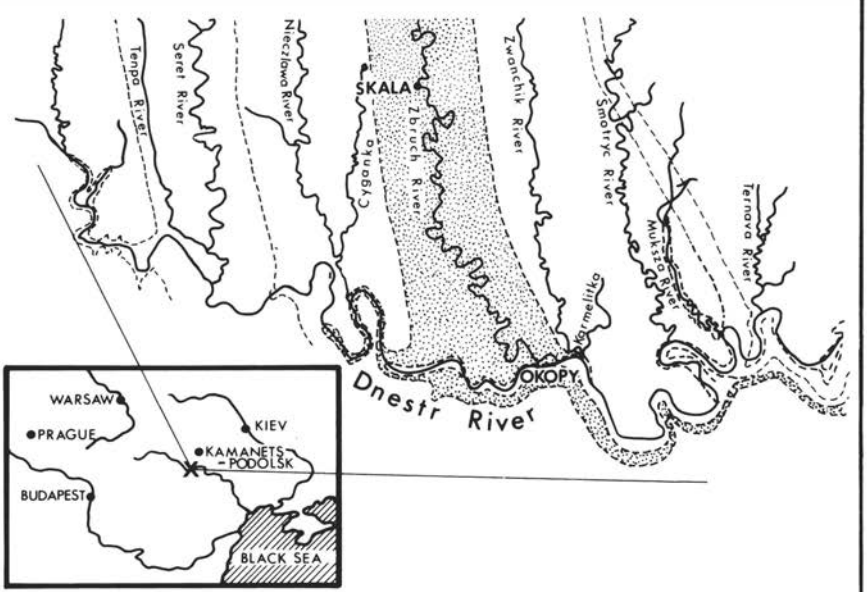

A submission to the Subcommission on Silurian Stratigraphy
December 1981.

FIGURE 3 An example of a submission

useful in Silurian carbonate sequences are not well represented in the type Llandovery. The widespread Old Red Sandstone facies is not represented in the Přídolí. However it remains true that one boundary stratotype cannot represent all facies and thus, for example, emphasis upon graptolitic criteria does neglect the abundance of platform and often carbonate sequences in the world's Silurian. For these reasons the role of the parastratotype is important. It is even more so in the case of the now selected stratotype for the base of the Silurian at Dob's Linn, where correlation must depend almost entirely upon the graptolites.

It is not reasonable to expect the Commission on Stratigraphy presently to handle the matter of parastratotypes in a formal way. There is too much other urgent primary work on hand. It does however seem proper that in the kind of published synthesis which will be produced in a planned book on Silurian chronostratigraphy there will appear detailed description of selected *parastratotypes* which should accompany that of the standard chronostratigraphical stratotypes themselves. I refer, for example to Anticosti and Oslo for the first series of the system, to Podolia and the Downton area for the fourth series. There should be several others such as the Silurian of Gotland, which is classic in itself, exceedingly well known, and so often used as a standard of comparison in other areas of Silurian rocks.

Such parastratotypic areas must of course always play a role *secondary* to that of the boundary stratotype of our internationally agreed standard chronostratigraphy. The latter must remain inviolate. Correlation between the parastratotype and the stratotype itself is of crucial importance if the parastratotype is to play its role in international correlation as a kind of subsidary standard. This is indicated

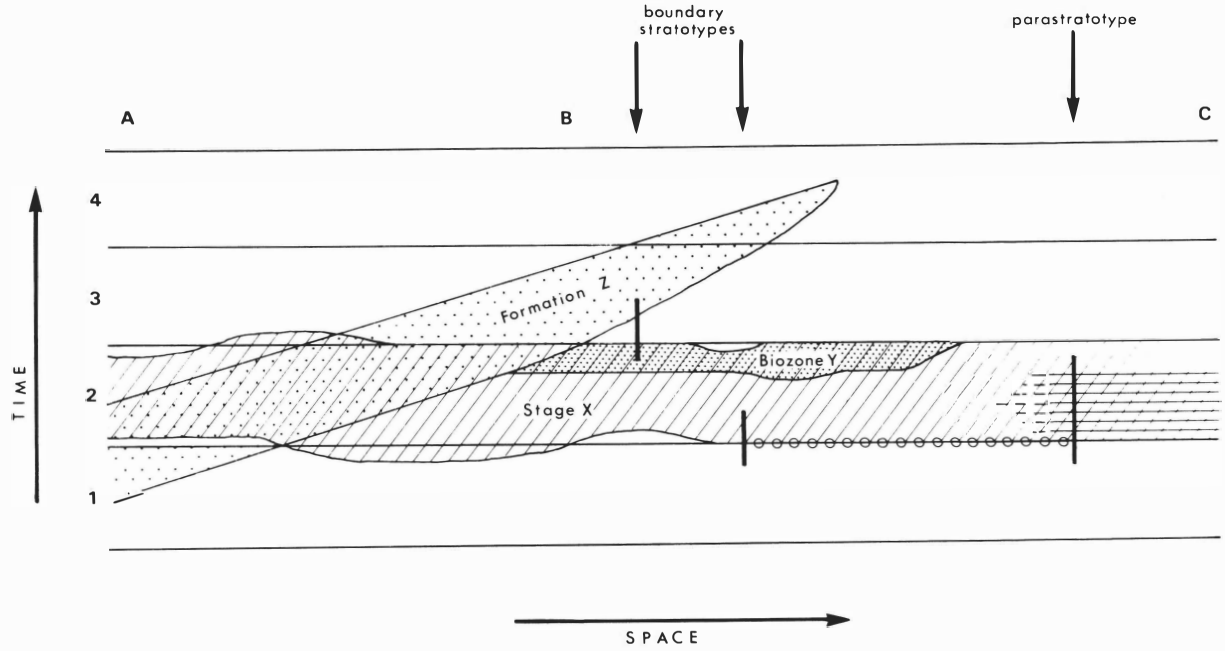

FIGURE 4 Diagrammatic representation of relationships between stratigraphical divisions of different categories. The numbered horizontal divisions indicate the passage of time (see text and Holland, 1978). A parastratotype for the base of the stage (and through its lower and middle parts) is useful in correlation through a different facies.

symbolically in Figure 4 and must be the continuing concern of the Subcommission.

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