basis of exchange of one conodont species to another. We have to know, would be this boundary to correlates by other fossils. If not, the suggestive boundary is not acceptable.

The resolving of all above mentioned problems could not be realize without of close cooperation between specialists who studied different fossils and different regions. One of the most priority work for the Permian Subcommissions is to organize such kind of cooperative investigations.

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Guidelines for the establishment of global chronostratigraphic standards by the International Commission on Stratigraphy (ICS) (Revised)

by J. Remane, M. G. Bassett, J. W. Cowie, K. H. Gohrbandt, H. R. Lane, O. Michelsen and Wang Naiwen,
with the cooperation of members of ICS

1. INTRODUCTION

The Silurian-Devonian Boundary Committee was the first to put into practice (in 1960) the principle to define chronostratigraphic units by their lower boundary only, which thus becomes automatically the upper boundary of the underlying unit. The Silurian-Devonian boundary-stratotype at Klonk in the Czech Republic was ratified on the 24th International Geological Congress (IGC) at Montreal, 1972. During this process, the Committee developed the principles of chronostratigraphic boundary definition. These "lessons learned" (McLAREN, 1977:23) constituted the basis of the first Guidelines of ICS, where the concept of the Global Standard Stratotype-section and Point (GSSP) was introduced: **"This Boundary Stratotype Section and Point is the designated type of a stratigraphic boundary identified in published form and marked in the section as a specific point in a specific sequence of rock strata and constituting the standard for the definition and recognition of the stratigraphic boundary between two named global stratigraphic (chronostratigraphic) units"** (COWIE et al. 1986:5). This definition is still valid for the Phanerozoic: A GSSP voted by the Full Commission of ICS (the Bureau of ICS and Chairpersons of all ICS Subcommissions, see also BASSETT, 1990) and confirmed by the Executive of the International Union of Geological Sciences (IUGS) represents a ratified boundary definition.

The necessity of a precise Global Chronostratigraphic Scale is obvious. Research on global events means comparison of stratigraphic documents from distant regions - but how can we be sure to deal with the same event throughout, without having a precise and reliable chronostratigraphic scale? The same is true for the establishment of eustatic sea-level curves or the reconstitution of global climatic changes in the past. Progress in these and many other fields of geologic research is only possible if progress is also made in the definition of chronostratigraphic units.

2. AIMS AND PRINCIPLES

2.1. Aims of the Revision

The original Guidelines were issued by the Bureau of ICS (COWIE et al. 1986) and summarized by COWIE (1986) in Episodes, the official publication of IUGS, and by COWIE (1990, 1991). They have guided uniformity of definition for twenty chronostratigraphic boundaries during ten years of successful application. The experience gained in this process has confirmed the basic principles of the original Guidelines. Nevertheless, a cautious revision of the Guidelines appears useful for different reasons:

(1) The Precambrian Subcommission of ICS has proposed a global stratigraphic subdivision for the Proterozoic where boundaries are defined in terms of absolute ages (see sect. 2.2), with entirely new names for the nine Proterozoic systems created on this basis. The resultant new subdivision of the Proterozoic was voted by ICS and ratified by IUGS on the 28th IGC in Washington, 1989; it is thus formalized (and should therefore not have been omitted in the 2nd edition of the ISG).

(2) During the last years, great progress has been made in the field of non-biostratigraphic methods of correlation (See sect. 3.1). These should therefore be given more weight in the choice of boundary levels and type-sections.

(3) Certain problems concerning the philosophy of boundary definition came up repeatedly in recent discussions of GSSP candidates, such as the necessity to respect priority, to have natural boundaries (see sect. 2.4), the rôle of fossils in boundary definition (see sect. 3.1), and the degree to which global correlation has to be exact before defining a boundary (see sect. 2.3).

(4) Since the publication of the original Guidelines (COWIE et al., 1986) important publications on the principles of stratigraphy have appeared, especially the 2nd edition of the International Stratigraphic Guide (ISG) (SALVADOR, 1994), or HARLAND (1992). The position of the Guidelines in this new context had to be clarified.

The rôle of the Guidelines remains, however, unchanged. They regulate the procedures of boundary definition, the selection of an appropriate boundary level, and the corresponding voting procedures (also partly dealt with in art. 3 and 7.1 of the statutes of ICS). They further define the requirements to be fulfilled by the stratotype-section housing the boundary point.

2.2. The Precambrian Standard

The new boundary-type definition, first introduced for the Proterozoic in 1989, was necessitated by the lack of adequate fossils in most of the Precambrian. It is termed herein the **Global Standard Stratigraphic Age (GSSA).** Defining boundaries in terms of absolute ages means that the numerical value of the boundary age is a theoretical postulate independent from the method applied to obtain numerical ages. But, as in the case of boundaries defined by a GSSP, an explicit motivation for the choice of the proposed numerical value should be given, clarifying in the same time its relation to traditional boundary definitions. GSSAs have the same status for boundary definition in the Precambrian as GSSPs have in the Phanerozoic.

2.3. Correlation Precedes Definition

Except for the Precambrian, this principle is still valid. To define a boundary first and then evaluate its potential for long-range correlation (as has been proposed in some cases) will mostly lead to boundary definitions of limited practical value. On the other hand, it would be unrealistic to demand that a given boundary be recognizable all over the world before it can be formally defined. In each case we must find the best possible compromise, otherwise the search for the Holy Grail of the perfect GSSP will never end.

2.4. Priority and Natural Boundaries

Our main task for a number of years will be to develop precise boundary definitions for traditional chronostratigraphic units. Most of them were defined in the last century by their characteristic fossil contents, and their boundaries coincided with spectacular biostratigraphic and lithologic changes. These were "natural" boundaries, in perfect agreement with the catastrophist philosophy of that time. In reality, rapid faunal turnovers are to a certain extent artefacts due to stratigraphic gaps or condensation. Most of the classic type-localities are thus unsuitable for a precise boundary definition: we have to look for new sections where sedimentation is continuous across the boundary interval; but then boundaries will rarely correspond to a lithologic change.

The idea that chronostratigraphic boundaries should always correspond to something "visible" has also led to conflicting regional "definitions" of international chronostratigraphic boundaries, which were adapted to regional lithostratigraphic boundaries of different ages.

There is no formal priority regulation in stratigraphy. In redefining boundaries, priority can therefore be given to the level with the best correlation potential. The redefinition will give us the opportunity to use fossil groups (such as conodonts) and methods of chronocorrelation (such as magnetostratigraphy) which were unknown or poorly developed at the time of the original definition. This does not mean that priority should be totally neglected. Practice considerations will incite us to limit changes to the necessary minimum. If, however, the interregional correlation potential of a traditional boundary does not correspond to the needs of modern stratigraphy, its position has to be changed.

Chronostratigraphic boundaries are conventional boundaries. They are a matter of normative science and can be decided by a majority vote (COWIE et al., 1986). To a certain degree, this principle can be reconciled with the demand for natural boundaries. As stated above, most of the classical boundaries are not clear-cut but correspond to critical biotic and/or climatic transitions. Placing a boundary within such an interval will preserve the advantage of having successive units which are distinguished by their contents. But where exactly the boundary is to be placed, is a matter of convention and practical considerations.

Once a boundary is (re)defined by a GSSP or a GSSA, it should be used in all published figures and tables. Such an obligation will not hinder any authors from expressing their personal opinions.

2.5. Boundary-stratotypes instead of Unit-stratotypes

If chronostratigraphic units were defined by unit-stratotypes, the boundary between two adjacent units would be defined by two separate GSSPs: as upper boundary of the lower unit in one unit-stratotype and as lower boundary of the succeeding unit in the other. The Global Chronostratigraphic Scale must, however, be constituted of strictly contiguous units, without overlaps and with no gaps between them. But there is no method of correlation which would guarantee a perfect isochrony of two separate boundary points, even at a short distance apart (HARLAND, 1992).

This problem was already recognized in the 1st edition of the ISG (HEDBERG, 1976), but unit-stratotypes for chronostratigraphic units were still admitted as an alternative possibility. In the 2nd edition (SALVADOR, 1994), boundary-stratotypes are given a stronger preference, but as a whole, the position remains ambiguous: "Since the only record of geologic time...lies in the rocks themselves, the best standard for a chronostratigraphic unit is a body of rocks formed between two designated instants of geologic time." (SALVADOR 1994: 88).

The Guidelines of ICS are unambiguous: **Chronostratigraphic units of the Phanerozoic Global Standard can only be defined through boundary stratotypes.** Even should the situation arise (e. g. as in the Silurian stratotypes in Britain) that the GSSPs defining the lower and upper boundaries of one and the same unit are located in the same section, this does not imply that the stratigraphic interval and its biota between the two GSSPs represent a unit stratotype.

For several systems, upper and lower boundaries are now defined by GSSPs. Following the choice of the best type-section these are located in distant regions: the base of the Silurian in Scotland, UK; that of the Devonian in the Czech Republic; that of the Carboniferous in the Montagne Noire, France; of the Permian in Kazakhstan; and the base of the Quaternary in Italy.

The lower boundaries of chronostratigraphic units of higher rank (series, systems etc.) are automatically defined by the base of their lowermost stage. In other words: the lower boundary of a system is always also a series and a stage boundary.

A GSSP cannot be compared to the holotype of Zoological Nomenclature; it corresponds rather to a standard of measure in physics (HARLAND, 1992). The use of terms like holostratotype, parastratotype etc. should therefore be avoided (COWIE et al., 1986). If reference sections and points seem necessary in order to give a better understanding of the boundary in another facies or paleobiogeographic context, an auxiliary stratotype point may be defined. Such auxiliary points are subordinate to a GSSP.

3. THE CHOICE OF THE BEST BOUNDARY LEVEL

3.1. Some General Considerations about Chronostratigraphic Methods

Chronostratigraphy and chronocorrelation have been discussed at length in the ISG (SALVADOR, 1994). We may thus limit the following discussion to selected topics which are of particular importance for the choice of the boundary level.

Considerable progress has been made during the last years in developing and in improving methods of non-biostratigraphic chronocorrelation. Some of them are based on geochemical signals, like the famous Ir-spike used as guidance for the definition of the Cretaceous/Paleogene boundary, or on shifts of stable isotopes which should be helpful in the definition of the Permian/Triassic boundary (BAUD et al., 1989).

Reversals of the Earth's magnetic field are important, because they are a worldwide phenomenon and practically instantaneous, thus providing a precise and reliable means of chronocorrelation. Late Jurassic to Recent reversals have been calibrated to the MagneticPolarity Time Scale based on oceanic anomalies (HAILWOOD, 1989).

Geophysical and geochemical events are, however, repetitive and do not allow an unequivocal determination of the age. They need calibration through radioisotopic or biostratigraphic dating. Unfortunately, radioactive isotopes are rarely available where needed so that stratigraphic routine work depends mostly on other methods. But radioisotopic datings are very important for the quantitative calibration of relative ages. Biostratigraphic boundaries, i. e. the boundaries of the material stratigraphic occurrence of species, are diachronous (ISG). This fact has, however, been overstated. A species exists for a finite span of time and is therefore characteristic of a certain geologic interval. In rapidly evolving lineages this may be less than 1 million years, so that most biostratigraphic datings attain a higher degree of resolution than the use of radioisotopes.

The use of fossils for calibrating chronostratigraphic units does not only involve tracing of biostratigraphic boundaries. It is indeed less a matter of correlation than of determining relative ages within a biochronologic standard of reference. Biochronology is the reconstruction of the succession of species in time through the synthesis of local and regional biostratigraphic data (for a recent overview, see REMANE, 1991). The chronostratigraphic reliability of biostratigraphic boundaries can thus be tested by comparing data from different species. In this process, mathematical approaches (Quantitative Stratigraphy) play an increasingly important rôle (GRADSTEIN et al., 1985; GUEX, 1991; MANN & LANE, 1995).

Fossil species depend on the environment and are biogeographically limited. An appropriate choice of wide spread species may diminish but never totally eliminate these shortcomings. Radioactive isotopes do not suffer from these geographical restrictions; but their resolution diminishes with increasing age. Therefore, non-biostratigraphic markers like magnetic reversals and stable isotopes have gained increasing importance in long range lateral correlation.

3.2 The Best Boundary-level

With the above considerations in mind, the correlation potential of any boundary level should be tested through a detailed study of several continuous successions covering the critical interval, if possible on different continents. The most suitable of these sections can then be selected for definition of the GSSP. If two boundary levels of equal correlation potential are available, the better candidate (see chapter 4) will decide the choice of the boundary level.

This implies the integration of data from different facies and paleogeographic provinces in a global synthesis. The perfect GSSP; where all elements of such a synthesis are well represented, will often not be available. Flexibility is therefore necessary in order to make a timely decision.

The boundary definition will normally start from the identification of a level which can be characterized by a marker event of optimal correlation potential. This marker event may be a magnetic reversal, some kind of geochemical or isotopic signal, or the first appearance or last occurrence of a fossil species. However, only the boundary point in the section, the GSSP (COWIE et al., 1986) formally defines the boundary. This means that an occurrence of the primary marker does not automatically determine the boundary. Other markers should therefore be available near the critical level, in order to support *chronostratigraphic correlation in sections* other than the GSSP. If the primary marker is a fossil species, first appearances are generally more reliable than extinction events, especially if the gradual transition between the marker and its ancestor can be observed.

4. REQUIREMENTS FOR A GSSP

The danger of eternalizing the search for the best type-section has already been addressed in sect. 2.2. **The stratotype-section should contain the best possible record of the relevant marker events.** In this sense, the requirements listed below characterize the ideal section. Not all of them can be fulfilled in every case, but the fact that all GSSPs are voted by ICS in accordance with the present Guidelines insures that flexibility will not degenerate to arbitrariness.

4.1. Geological Requirements

4.1.1. **Exposure over an adequate thickness** of sediments is one requirement to guarantee that a sufficient time interval is represented by the section, so that the boundary can also be determined by interpolation, using auxiliary markers close to the boundary.

4.1.2. **Continuous sedimentation:** no gaps, no condensation in proximity of the boundary level.

4.1.3. The **rate of sedimentation** should be sufficient that successive events can be easily separated.

4.1.4. **Absence of synsedimentary and tectonic disturbances.**

4.1.5. **Absence of metamorphism and strong diagenetic alteration** (identification of magnetic and geochemical signals).

4.2. Biostratigraphic Requirements

4.2.1. **Abundance and diversity of well preserved fossils** throughout the critical interval. Diversified biotas will offer the best possibility of precise correlations.

4.2.2. **Absence of vertical facies changes** at or near the boundary. A change of litho or biofacies reflects a change of ecologic conditions which may have controlled the appearance of a given species at the boundary level. A sharp lithofacial change may also correspond to a hiatus. "An obvious boundary should be suspect" (COWIE et al., 1986).

4.2.3. **Favourable facies for long range biostratigraphic correlations;** this will normally correspond to an open marine environment where species with a wide geographic range will be more common than in coastal and continental settings. The latter should therefore be avoided.

4.3. Other Methods

Magnetostratigraphy, sequence stratigraphy, cyclostratigraphy, analysis of stable isotopes should be given due weight in the selection of a GSSP. If a choice has to be made between candidates having more or less the same biostratigraphic qualities, the one offering the better applications of non-biostratigraphic methods should be preferred.

4.3.1. **Radioisotopic dating.** Whenever possible, it is important to achieve direct quantitative calibration (numerical age) of a chronostratigraphic boundary at the GSSP.

4.3.2 **Magnetostratigraphy.** A reproducible magnetic reversal stratigraphy is a desirable requirement in order to know where in the magnetostratigraphic sequence the GSSP is located.

4.3.3. **Chemostratigraphy**, including the study of vertical changes of the proportions of stable isotopes, which may be indicative of global events.

4.3.4. The regional paleogeographical context and the facies relationships of the stratotype-section should be clarified. Knowledge of the sequence stratigraphy will contribute to an understanding of these relations.

4.4. Other Requirements

4.4.1. The GSSP should be indicated by a permanently fixed marker.

4.4.2. Accessibility: Candidate sections in remote regions which can only be visited by organizing costly expeditions should normally be excluded from the selection.

4.4.3. Free access for research to the type-section for all stratigraphers regardless of their nationality.

4.4.4. When making a formal submission to ICS, the concerned Subcommission should try to obtain guarantees from the respective authority concerning free access for research and permanent protection of the site.

5. PROCEDURE FOR THE SUBMISSION OF A GSSP

5.1. Editing of the Submission

Submissions must be prepared in English. In order to provide a clear picture of the qualities of the proposed GSSP candidate, the formal submission to ICS or to the concerned Subcommission should give the following information:
(1) name of the boundary;
(2) indication of the exact location (coordinates) of the stratotype-section on a detailed topographic map or aerial photograph, if possible at a scale not less than 1 : 50.000;
(3) location on a detailed geologic map;
(4) detailed description of the stratotype-section including a litholog and photos of the section, indicating the bed in which the boundary-point is defined and the key-levels for all physical and biostratigraphic markers;
(5) motivation for the choice of the boundary level and the stratotype-section, with a discussion of failed candidates and their ease of intercontinental correlation;
(6) any comparison with former usage should be discussed fully;
(7) discussion of all markers used in the determination of the boundary level;
(8) illustration of important fossils;
(9) results of radioisotopic dating, indicating clearly what method has been used;
(10) results of all votes within the Working Group and the Subcommission.

Note: Within these procedures, only items 1, 6, 7, 9, 10, and the motivation for the choice of the boundary-level are relevant to the establishment of a GSSA.

Following acceptance of the submission within these Guidelines, the Chairperson or the Secretary of ICS will arrange a vote by the Full Commission within a period of no more than 60 days.

5.2. Voting Procedure

In accordance with the ICS statutes, all formal votes must be conducted by postal ballot, giving a deadline of 60 days for the receipt of votes. Voting members (of the Working Group, Subcommission or Full Commission) may vote "YES", "NO", or "ABSTAIN". The last step in the selection of a final candidate for a boundary level and/or a GSSP should always be a vote on one single candidate (COWIE et al., 1986).

In outline, this procedure includes the following steps:
(1) Successive votes of the concerned Working Group leading to the choice of a boundary level and final vote on a single GSSP or GSSA candidate.
(2) If this obtains the statutory majority in the Working Group, vote on the GSSP or GSSA candidate in the respective Subcommission.
(3) In case of a statutory majority, formal submission of the candidate to ICS for vote.
(4) Again, in case of a statutory majority, submission of the GSSP or GSSA candidate to the IUGS Executive Committee for ratification, together with an abstract of the submission, prepared by the responsible ICS body.

ICS should attempt to finalize, within 3 years after IUGS ratification, any remaining official steps for the protection of the site with the authorities of the country where the GSSP is located.

6. REVISION OF A GSSP

A GSSP or GSSA can be changed if a strong demand arises out of research subsequent to its establishment. But in the meantime it will give a stable point of reference. Normally, this stability should be maintained and the practical value of the boundary definition tested for a minimum period of ten years. Revisions for other reasons should be made only in exceptional circumstances, such as:
(1) The permanent destruction or inaccessibility of an established GSSP,
(2) a violation of accepted stratigraphic principles discovered only after the ratification of a GSSP.

7. SELECTED REFERENCES

The 2nd edition of the ISG (SALVADOR, 1994) contains a comprehensive list of publications dealing with the principles and techniques of stratigraphy. The present list of references was therefore limited to papers providing further information on the principles underlying these Guidelines, adding some titles not mentioned in the ISG.

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Conclusion

by J. Remane, Chairman of ICS

The text of the Revised Guidelines as presented above, is the result of a close cooperation between the Bureau and the Subcommissions of ICS. A first provisional draft was prepared by J. Remane, Chairman of ICS, taking into account proposals made by K. H. Gohrbandt, then Secretary General of ICS. A more formal draft was established on this basis by the Bureau of ICS on its meeting at Neuchâtel (Switzerland) in March 1994. This was circulated to all Subcommissions for comments and criticism. That draft was also presented for discussion on the International Symposium on Permian Stratigraphy at Guiyang (China) in September 1994, the 4th International Symposium on Jurassic Stratigraphy at Mendoza (Argentina) in October 1994, and on the 2nd International Symposium on Cretaceous Stratigraphy at Brussels (Belgium) in September 1995. The final version, which incorporated as far as possible oral and written comments received from members of ICS bodies, was worked out on the meeting of the Bureau of ICS at Neuchâtel in April 1996, attended by J. Remane (Chairman), M. G,. Bassett (lst Vice-chairman), O, Michelsen (Secretary General), and H. R. Lane (lst Vice-chairman elect), and was then submitted for vote to the Full Commission of ICS (consisting of the 5 members of the Bureau of ICS and the 16 Chairpersons of ICS Subcommissions).

In this vote, the Revised Guidelines were approved by the Full Commission with an overwhelming majority, with only one opposing vote. The Revised Guidelines have thus become a formal and mandatory document regulating the procedure to be followed in the definition of chronostratigraphic boundaries. The particular importance of this text lies also in the fact that this is the first document on stratigraphic procedures issued by ICS which represents a voted formal agreement.

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Conodont evolutionary lineage and zonation for the Latest Permian-and the Earliest Triassic*

By Wang Cheng-yuan

Abstract

Isarcicella staescheri is a valid species that defines an independent conodont zone between *Hindeodus parvus* and *I. isarcica* Zones. The so-called *H. latidentatus--H. parvus--I. turgida--I. isarcica* lineage proposed by Zhang et al. (1995) should be revised to be the *H. latidentatus--H. parvus--I. staescheri--I. isarcica* evolutionary lineage. The conodont zones for the P/T boundary beds proposed by Zhang et al. (1995) have to be revised also. In the pelagic facies, the conodont zones in ascending order are *Clarkina changxingensis--C. deflecta* Zone- *C. carinata* Zone and *C. planata* Zone. In the shallow water facies, the conodont zones in ascending order are *H. latidentatus* Zone--*H. parvus* Zone--*I. staescheri* Zone--*I. isarcica* Zone and *H. postparvus* Zone.

Key Words: P/T boundary beds, conodont lineage, Zones, *Isarcicella staescheri* Zone

Conodonts are of utmost importance for the Permian--

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