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Should the Permian/Triassic boundary be defined by the carbon isotope shift?

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ABSTRACT:

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The authors propose that definition of the Permian-Triassic boundary by the onset of a pronounced negative shift in the carbon isotopic composition of the oceanic carbonate system (recorded presently also in the Meishan section, China) is worth of very serious consideration. Such a definition would this chronostratigraphic boundary to reflecting an important geological event, thus marking a step toward the definition of chronostratigraphic intervals as meaningful units of geological time. Such a definition would permit precise correlation of geographically widely separated geological sections.

INTRODUCTION

The exact stratigraphical position of the Permian-Triassic (=P-T) boundary has been hotly disputed for a long time (*see e.g.* TOZER 1988, TEICHERT 1990, SCHÖNLAUB 1991, SWEET 1992). On the one hand, the base of the Triassic was defined, as early as at the end of the 19th century, as the lower boundary of the *Otoceras woodwardi* Zone (WAAGEN & DIENER 1895). This boundary was, moreover, traditionally correlated with the base of the Werfen Formation in the Alps (DIENER 1912). On the other hand, however, the latter correlation can hardly be regarded as demonstrated and, in fact, the *Otoceras woodwardi* Zone has not yet been unequivocally documented in any section containing undoubted uppermost Permian strata, for example, in Iran or South China (*see e.g.* NAKAZAWA & *al.* 1975, WATERHOUSE 1978, SWEET 1979, YIN & *al.* 1988). It has been quite widely accepted that the most complete transition from the Permian to the Triassic occurs in South Chinese sections (*see e.g.* LIAO 1980, SHENG & *al.* 1984, YIN 1985), although the available stratigraphic data do not rule out the possibility of a minor hiatus encompassing the lowermost Griesbachian (TOZER 1973, 1988; NAKAZAWA & *al.* 1980; DAGYS & DAGYS 1988).

In any event, the position of the P-T boundary in South China has been generally placed at the base of a thin but widely distributed clay layer (YIN & *al.* 1988) of volcanic origin (CLARK & *al.* 1986; but see JINWEN 1989). The exact chronostratigraphic relationship of this boundary to the bases of the *Otoceras woodwardi* Zone and the Werfen Formation, respectively, has so far remained unclear (*see e.g.* DAGYS & DAGYS 1988, DING 1988), although SCHÖNLAUB (1991) suggested, on the basis of a detailed conodont

Antoni HOFFMAN passed away on November the 7th, 1992 study, that the Chinese boundary clay falls somewhere within the Tesero Horizon, which is the lowermost member of the Werfen Formation in the Alps.

Given these difficulties in respect of the definition of this important chronostratigraphic boundary, we suggest in this article that the placement of the P-T boundary should be looked at from a very different perspective. We propose, first, to consider the actual meaning of chronostratiographic boundaries in general, and second, to draw conclusions from recent geochemical studies concerning the P-T transition.

TWO PERSPECTIVES ON CHRONOSTRATIGRAPHIC BOUNDARIES

An accurate time correlation of rocks and geological events is among the main aims of stratigraphy. This aim must indeed be at least partially achieved if we are ever to reconstruct and interpret the history of the Earth and the biosphere, which is the chief task of historical geology and historical biology, respectively. Time correlation of geological strata must, in turn, be based on the recognition of a standard set of reference time planes and on the subsequent deciphering of the relationship of particular strata to those reference time planes, or chronostratigraphic boundaries. There has been a lot of theoretical discussion on the relation of these abstract chronostratigraphic boundaries to real litho- and/or biostratigraphic boundaries that have been established in the field. This issue has been finally clarified with the appearance of the International Stratigraphic Guide (HEDBERG 1976, but *see also* HANCOCK 1977, MURPHY 1977, JOHNSON 1979), and stratigraphers are now largely concerned with the practical problems of time correlation. One theoretical issue that remains open, however, is how to define this basic set of standard reference time planes, or chronostratigraphic boundaries. Once this issue is at least provisionally resolved and the set of chronostratigraphic boundaries is unambiguously defined throughout geological time, stratigraphy will largely comprise analyses of various parti-

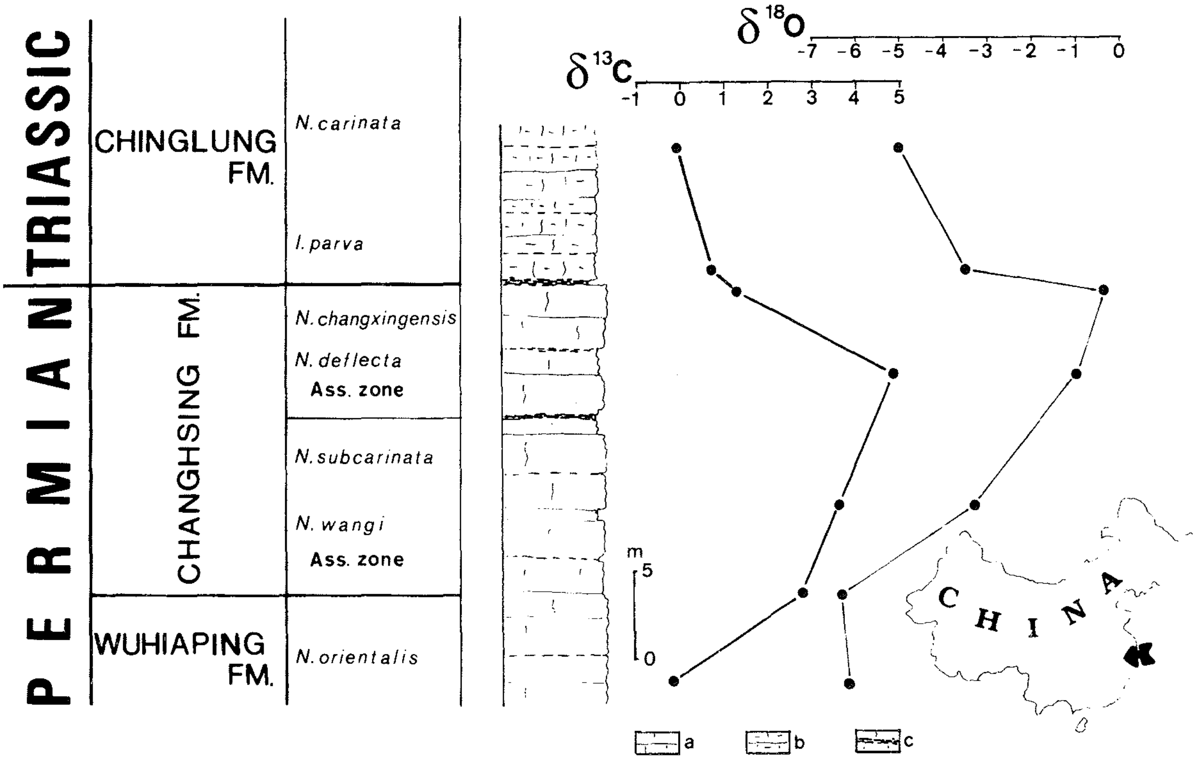

Fig. 1. Stable carbon and oxygen isotope proportions in bulk rock carbonate samples taken at the stratotype section of Changhsingian in Meishan, China. Biostratigraphy after YANG & LI (1992)

cular case studies. In this sense, stratigraphy is inevitably idiographic in scope.

The problem with definition of the basic set of chronostratigraphic boundaries is, fundamentally, the same as the one faced by historians of humankind, although it is, of course, incomparably more complicated owing to the margins of uncertainty being much wider in historical geology than in human history.

In human history, two major approaches have been developed to deal with this problem of definition of the reference time planes. One approach follows from the premise that history is, in fact, nothing but a chronicle of historical events, or a narration that simply enumerates, as precisely and exhaustively as possible, what happened in historical time, without any particular interest in elucidating the causal relationships between those events. In this view, then, narration is a historical explanation (*see e.g.* HÜBNER 1973, 1975; LÜBBE 1973). The standard set of reference time planes, which divide historical time into intervals, may then be entirely arbitrary. Quite obviously, it refers simply to the absolute chronology – in years, centuries, and millennia.

The other approach insists that history is in fact more than merely a chronicle, for it must also involve reconstruction of events as well as their causal interpretation via processes (history as opposed to chronicle, *sensu* WHITE 1965). There is a variety of views as to how this ultimate aim should best be achieved (*see e.g.* DRAY 1957, DANTO 1965, GADAMER 1965). It is often argued, however, that under this approach, all the reference time planes should be meaningful. In other words, they should each correspond to a truly important event in human history. As a matter of fact, it is this particular perspective on human history that justifies the long-standing debates as to whether, for example, the 18th century ended with the French Revolution of 1789 or rather with the Vienna Congress of 1815.

These two contrasting historical approaches to definition of the set of reference time planes are well known also in the field of historical geology, though their distinction is usually disguised under a completely different heading and couched in a different technical language.

The former approach (history as chronicle) tends to regard chronostratigraphic time intervals as divisions (*sensu* HARLAND & *al.* 1972), or meaningless, purely arbitrary segments of geological time (HEDBERG 1976). Ideally, these time intervals should represent years, millennia, or millions of years but the imprecision of radiometric dating commonly makes the usage of such absolute geochronology impossible. Therefore, phyletic events are generally used for this purpose (JOHNSON 1979). They are chosen arbitrarily because no origination of a species can, in principle, be demonstrably more appropriate than any other. At best, one phyletic event may be more easily utilized by stratigraphers than another, though such assessment can usually be made only *a posteriori*. In fact, it seems that a vast majority of discussions concerning the definition of particular chronostratigraphic boundaries (or Global Boundary Stratotype Sections and Points, or GSSPs) focuses solely on stratigraphic utility as the main criterion. This approach might be called the golden spike approach to chronostratigraphic boundaries.

By contrast, the other approach (history as causal interpretation) tends to define chronostratigraphic intervals as units of geological time (*sensu* HARLAND & *al.* 1972), which are meaningful at least in the sense of being delimited by geologically important events. As pointed out by HOFFMAN (1981), this has been the main tenet of the ecostratigraphic paradigm.

It is our contention that history, whether human, biotic, or geological, is indeed best understood as a causal interpretation of events. We should therefore strive to define chronostratigraphic boundaries as a means to recognize geologically meaningful units rather than divisions of geological time – at least at the level of eras and periods – though tradition must be taken into consideration. In other words, we reccomend that the boundaries between eras and periods be defined by geologically and/or biotically important events which occurred as close to the traditionally established boundaries as possible. We further suggest that abiotic events may be better suited than phyletic events for such definitions of major chronostratigraphic boundaries, simply because true phyletic evidence can only hardly be demonstrated in the fossil record. If the rancorous debate on punctuated equilibrium has arrowed at any unequivocal conclusions, it is the recognition that the only kind of phyletic events that can be truly proven in the fossil record are cladogenetic, or branching events. The likelihood of finding such events in palaeontological research, however, is quite low, and to demand that they be located close to the traditionally established stratigraphic boundaries is definitely too much to ask.

We believe that the P-T boundary is a particularly good example to demonstrate the suitability of abiotic geological events for the definition of major chronostratigraphic boundaries.

A PROPOSAL FOR THE P-T BOUNDARY

HOLSER & *al.* (1986) observed that major shifts in $\delta^{13}C$ in the oceanic carbonate system have a tremendous potential as a tool for stratigraphic time correlation. Carbon circulation in the global exosystem of the Earth goes on so rapidly that such shifts must be global in scope, on the one hand, and must achieve this global dimension almost instantaneously in the geological time scale, on the other. HOLSER & *al.* (1986) pointed out that the late Permian pattern in $\delta^{13}C$ includes a very prominent positive anomaly and suggested that both the beginning and the termination of this anomaly could be used for time correlation.

We propose, in turn, to go even further, and to consider the proposition that the P-T boundary could be defined by the onset of the dramatic latest Permian drop in the oceanic $\delta^{13}C$ curve, or by the termination event of HOLSER & *al.* (1986).

We have sampled the stratotype section of the Changhsingian in Meishan, Changxing, China, just 500 m west of the proposed Permian – Triassic GSSP, where stable isotopes were previously studied by BAUD & *al.* (1989). We analysed the obtained carbonate rock samples for stable carbon and oxygen isotopic proportions. The results are shown in Text-fig. 2 as $\delta^{13}C$ and $\delta^{18}O$ relative to the PDB standard.

As clearly shown in the illustration, a conspicuous carbon isotopic drop occurs just below the so-called boundary clay. As noted above, the boundary clay itself can hardly be correlated outside China, with other geological sections that may contain a geological record of the P-T boundary, such as in Kashmir, Iran, the Alps, East Greenland, and West Spitsbergen. By contrast, a prominent carbon isotopic drop has indeed been recorded in a close proximity of the supposed P-T boundary in a large number of these sections (BAUD & *al.* 1989; GRUSZCZYŃSKI & *al.* 1989, 1990; OBERHÄNSLI & *al.* 1989; HOLSER & *al.* 1991). It is our contention that the onset of this negative shift in $\delta^{13}C$ occurred, in fact, simultaneously (on the geological time scale) in all these distant areas, thus providing an excellent means of global-scale time correlation. (We are of course aware that this carbon isotopic shift is only a single stratigraphic marker, while the bulk of correlation must rely, in any case, on further palaeontologic and palaeomagnetic studies.)

A dramatic drop in $\delta^{13}C$ – in fact, by far the single largest event of this kind in the known history of the Earth's exosystem – must have had equally dramatic consequences for the biosphere. As argued by MAŁKOWSKI & *al.* (1989) and HOFFMAN & *al.* (1990), it must have inevitably led to mass extinction. As a matter of fact, the P-T extinction is well known to have been the largest extinction event in the history of the biosphere (RAUP & SEPKOWSKI 1986), although both the rapidity and the causation of this extinction remain highly controversial (*see* HOLSER & MAGARITZ 1987; MAXWELL 1989; ERWIN 1990; HOLSER & *al.* 1991). Therefore, this carbon isotopic shift excellently fits the criteria we have set above for the definition of major chronostratigraphic boundaries.

We are, of course, aware that our proposal does not only mean that an abiotic correlation tool is here assigned priority relative to the standard biostratigraphic tools. Such a definition of the P-T boundary also implies that, contrary to the previous consensus, the *Neogondolella changxingensis – Neogondolella deflecta* conodont assemblage Zone ranges upwards into the lowermost Triassic (it belongs to the Griesbachian according to SWEET 1992). It is to be kept in mind, however, that conodonts were almost unaffected by the P-T extinction and even their apparent reduction in abundance at the so-called boundary clay in South China (CLARK & *al.* 1986) may in fact represent nothing but lateral variation (SWEET 1973, SCHÖNLAUB 1991). Similarly, the so-called mixed-fauna layer (SHENG & *al.* 1984, YIN 1985) would now clearly belong to the lowermost Triassic.

THE STABLE CARBON AND OXYGEN ISOTOPE SHIFTS IN PERMIAN SEAS OF WEST SPITSBERGEN – GLOBAL CHANGE OR DIAGENETIC ARTIFACT?

In 1989 we published a paper (GRUSZCZYŃSKI & *al.* 1989) dealing with an interpretation of $\delta^{13}C$

and $\delta^{18}O$ values for the Productacean brachiopod shells from the Late Permian Kapp Starostin Formation of West Spitsbergen (MAŁKOWSKI 1982). The curves revealed a much larger isotopic event than had been previously recorded (HOLSER & MAGARITZ 1987, BAUD & *al.* 1989). We interpreted this isotopic phenomenon in terms of a fundamental change of the world ocean system and a simultaneous, quantitative change of the components of the Earth exosystem. We additionally presented an hypothetical scenario of biosphere perturbation (GRUSZCZYŃSKI & *al.* 1989, MAŁKOWSKI & *al.* 1989), related to the catastrophic mass extinction at the Palaeozoic- Mesozoic transition. This led us to the erection of a new palaeo-oceanographic model (HOFFMAN & *al.* 1991), condradictionary to the well established "steady state" paradigm.

In 1991, we sent a set of samples to collegues from Texas A&M University, in order to check the $\delta^{13}C$ and $\delta^{18}O$ excursion that we had recorded, using this time mostly brachiopod shells belonging to the oder Spirifrida. Those collegues assumed from the very begining that such a big simultanous negative shift in $\delta^{13}C$ and $\delta^{18}O$ values of 8-10‰ could be the result only of diagenetic alteration (GROSSMAN, *personal communication*).

Quite recently MII & *al.* (1997) have published the results of their investigations. They concentrated almost entirely on showing, by means of cathodoluminesence analyses, that part of the brachiopod samples from Kapp Starostin Formation were diagenetically altered. However, the difference in isotope values for luminescent (altered) and non-luminescent portions of brachiopod shells was in a range of 5‰. Moreover, the whole set of isotope values for the most non-luminescent (unaltered) samples were generally consistent with those published by us (GRUSZCZYŃSKI & *al.* 1989, Fig. 2). Only two brachiopod samples (of which one was luminescent) from the uppermost part of the Kapp Starostin Formation displayed different isotope values from those recorded by us (GRUSZCZYŃSKI & *al.* 1989, Fig. 1). Despite this, MII & *al.* (1997) drew a conclusion supporting their working hypothesis, namely that the results recorded by GRUSZCZYŃSKI & *al.* (1989) had been produced by diagenesis. Such a conclusion is quite surprising, because a shift in isotope values between those reported for the late Permian (Kazanian-Kungurian) by MII & *al.* (1997) and those for the latest Permian (Tatarian) and Early Triassic (HOLSER & MAGARITZ 1987, BAUD & *al.* 1989,

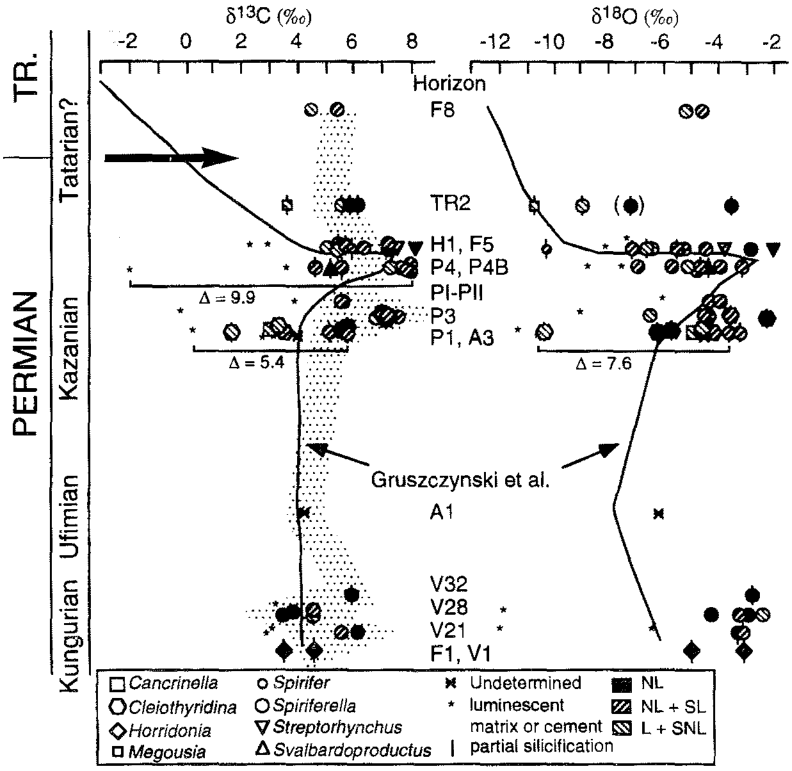

Fig. 2. The composite picture of late Permian isotope event (*after* MII & *al.* 1997) emphasising a question of the switch between two states (shadowed areas) recorded in the both $\delta^{13}C$ and $\delta^{18}O$ age curves; these states are: (i) Kungurian to Kazanian time, characterised by the highest positive isotope values, which is confirmed by MII & *al.* (1997); and (ii) the latest Permian to the earliest Triassic time characterised by isotope values up to 10‰ more negative than for the Kungurian-Kazanian state, which is confirmed by e.g. BAUD & *al.* (1989), GRUSZCZYŃSKI & *al.* (1989, 1990) and neglected by MII & *al.* (1997)

GRUSZCZYŃSKI & *al.* 1990) is around just 10‰. Thus, the authors who estimated that the diagenetical effect was not more than 5‰ (MII & *al.* 1997) should have discussed a bulk of results, and the reasons for the two different isotope states.

MII & *al.* (1997)'s self confidence in neglecting the interpretational potential of their own results relating to the major problem of global geochemical events as reflected by isotope age curves, have caused our strong opposition.

CONCLUSION

We suggest that definition of the P-T boundary by the onset of a dramatic drop in $d^{13}C$ in the oceanic carbonate system, rather than by the appearance of the so-called boundary clay in South China, be given very serious consideration. It has both theoretical and practical advantages. It is advantageous in theory because the boundary between the Paleozoic and Mesozoic eras would then coincide with a major, indeed exceptional, event in the history of the Earth and the biosphere. In practice, the boundary defined in such a way would allow for precise global-scale time correlation by geochemical means, whereas biostratigraphic methods should provide equally good (or poor) resolution as under any other definition.

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