The Search for a Paleozoic-Mesozoic Boundary Stratotype

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With 2 Figures

Summary

The Paleozoic-Mesozoic boundary is a major erosional break in most marine sequences. Relatively complete sections in Tethyan regions frequently lack physical evidence of subaerial erosion but even here there is a striking paleontological contrast in whole faunas at the era boundary evidently marking a concise event in earth history. The best known and most appropriate sections for consideration as era-boundary stratotypes occur along the Araxes River between Transcaucasus and Iran, in the Salt Range of Pakistan, and in Guryul Ravine, Kashmir. It is suggested here that the outcrops of the three regions be regarded as a composite stratotype for a provisional world standard. No single area is adequate for the purpose. The exact boundary to be selected should lie above the ranges of all of the Permian species of marine invertebrates: that is, at the limit between *Ophiceras* and *Gyronites* zones. In this choice the distinction between the two erathems can be based on the simultaneous termination of a diverse Paleozoic fauna which does not extend into the *Gyronites* zone.

Major Stratigraphic Units

Many valid generalizations about Paleozoic and Mesozoic biostratigraphy were empirically established nearly a century and a half ago. When John Phillips, William Smith's nephew, named the Mesozoic Era and expanded Sedgwick's Paleozoic to include what we now know as Permian (Phillips, 1840/41), leading European biostratigraphers could already readily distinguish between Permian and Triassic marine faunas by their characteristic assemblages (fig. 1).

Phillips's erathem boundaries were based on mass extinctions confirmed by subsequent work (Newell, 1967a). Other impressive mass extinctions occur at the

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top of the Triassic and elsewhere in the geologic column, as at the upper limits of biomeres (PALMER, 1965). It is interesting to speculate on what treatment PHILLIPS would have given these biologic events had he been in possession of present-day knowledge.

The empirical data of D'ORBIGNY, PHILLIPS, and others, underscored the discreteness of biological events — migration and extinction — events which punctuate the geologic record of life. Many well-studied fossil zones do not clearly show a simple ancestor-descendant relationship. Scattered phylogenies tie consecutive zones together, but the origins of many assemblages remain unknown, as though they had been suddenly created. The sudden appearance of a fauna or flora may mark a world-wide event but the chronometric significance of such an event should be cross-checked and tested against independent evidence.
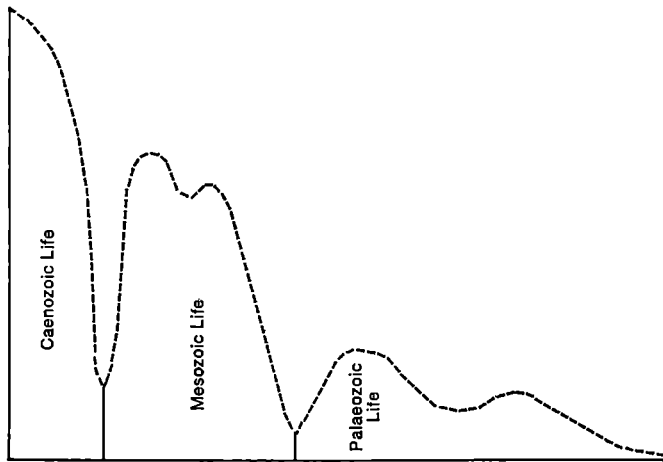

Fig. 1. Fluctuating diversity of the fossil record provided JOHN PHILLIPS with the evidence on which the erathem boundaries were based (After JOHN PHILLIPS, 1860).

The rapid development of the plate tectonics paradigm requires us to give the most careful attention to causality and probable synchroneity of world events in the selection of stratotypes because these events are of major importance in earth history but their chronologic resolutions may vary enormously. The nature and scope of geologic and biologic events should, in my opinion, influence the evaluation and selection of correlation datums. The selection of such datums should be regarded as preliminary and provisional, taking into account the character and content of units as well as their boundaries. There must be provision for adjustments necessitated by accumulation of new information.

One fact emerges from an examination of present stratigraphic practice. The systems, erathems, and to some extent the series, are such large units that they have limited use in correlation. Nevertheless, they are real chapters in earth history, generally composed of related groupings of historical episodes. Mostly, they have been modified many times during the development of geological science.

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Actually, the international correlation units of Phanerozoic stratigraphy are the biozones and stages, and it is groupings of these essentially regional, non-universal, units that compose the series and systems. It is not necessary, or even feasible, to establish separate and independent boundary stratotypes for the more comprehensive divisions. The top of the Paleozoic will coincide with the upper limit of the highest zone and stage, which at the present time is widely regarded as the Dzhulfian Stage (FURNISH, in LOGAN and HILLS, 1973). The base of the Triassic and of the Mesozoic is defined by the Griesbachian, Induan, or Scythian of various classifications (LOGAN and HILLS, 1973). Since the boundary in most places is represented by a persistent hiatus, we are compelled to accept for field operations the top of whichever zone or stage of the Paleozoic may lie immediately below overlapping rocks.

Instants of Geologic Time

The catastrophic philosophy of many nineteenth century geologists, and the subsequent recognition of real geologic rhythms, have strongly influenced the development of our standard stratigraphic system. As with other branches of science, related observational data have been grouped together and integrated into a system of theoretical knowledge that to some extent reflects origins and causes.

Since the 1940's, however, there has been a gradual shift of emphasis away from unit content (history) in stratigraphic classification to the idea of "isochronous", that is, chronostratigraphic, boundaries, in which correlation, resolution and convenience in dating are given priority ahead of historical significance.

This shift in attitude from history to chronometry came about because of differences in national usage, vagueness of definitions, and consequent difficulty in obtaining broad international agreement in definitions and correlation standards. A consensus has developed that every conceivable historical event must have uncertain and variable time limits in different regions so that definitions based solely on historical events generally may be impracticable. Nevertheless, we are completely dependent on historical events for recognition and correlation of stratigraphic units which are the tangible results of geological history, i. e., rocks and fossils must influence classification of chronostratigraphic units.

Logical arguments have been advanced that even the very best paleontological datums are time-transgressive and therefore have time limits that vary with distance of dispersal and accidents of preservation. In fact, attention to whole faunas, instead of selected elements, commonly shows that there are significant regional and provincial variations in both biotic content and vertical ranges and these are best evaluated by comparing many overlapping ranges of diverse kinds of fossils. Where a single guide fossil, or a single group (e. g., ammonites or conodonts) is stressed the significance of whole faunas and other historical records tends to be ignored.

We must become reconciled, therefore, to the fact that emphasis on single groups can lead to circularity of argument not appropriate to an advanced chronostratigraphy (e. g., certain rocks are of lowermost Triassic age because they contain a particular guide fossil).

SHAW (1964), and KAUFFMAN (1970) have convincingly demonstrated the superiority of a chronostratigraphy that combines all of the available evidence into a simple quantitative, or semi-statistical, internally consistent, scheme for long-range correlations. This takes into account available ranges of all fossils and other chronometric data. Continuous cross-reference among the many historical attributes, *e. g.*, lithic character, continuity of key strata (such as volcanic ash beds), sequence, degree of diagenetic alteration, radiometry, magnetic reversals, and so on, when brought together in context, provide a much higher order of accuracy of correlation than is possible by sole dependence on selected guide fossils. The significance of the latter can thus be tested and demonstrated by independent criteria.

Extinctions Versus First Appearances

It should be stressed that extinctions, particularly extinctions of an entire biotic complex may be instantaneous at the scale of geologic time. This generalization is not invalidated by exceptions, occasional relicts, such as the Permian blastoids of Timor. These can be evaluated and dated by reference to the whole faunal context. Although it is seldom viewed as significant, the extinction of a hardy, long-ranging clam or brachiopod is just as valid for biostratigraphic dating as the gradual origin or sudden extinction of the most rapidly evolving ammonite. Extinction is a final, non-recurring event. On the other hand, the origination of an assemblage with all of its components certainly requires appreciable time. The abrupt appearance of any taxon in one region implies an antecedent history elsewhere.

From these considerations, it seems to me that highest occurrences (extinctions), on the average, should be given equal weight or even greater preference than first appearances in defining chronostratigraphic boundaries. This general practice has been rejected by many biostratigraphers. OPPEL originated the convention of fixing boundaries of zones at first rather than last occurrences, but I see no valid theoretical or practical advantage in this. Both options should be considered in light of individual circumstances. Clearly, undeviating rigidity is undesirable. Extinction points are increasingly coming into favor in deep sea and oil field stratigraphy.

The Boundary Event

Even in the most complete sequences, broad taxonomic differences exist at the Permian-Triassic boundary. More striking, however, are contrasts in biotic communities below and above this horizon. For example, Permian faunas of many facies really do not gradually blend with those of the Triassic as we approach the erathem boundary. Notable exceptions are the ceratites and conodonts, all pelagic organisms represented by a very few conservative taxa. Extinctions greatly exceeded new appearances above the Guadalupian Series. This was not a simple serial replacement

of unsuccessful by more evolved species. The characteristic communities below the Triassic provided major roles for fusulinaceans, articulate brachiopods, bryozoans, stalked crinoids and corals, hardly any of which are found anywhere in the Lower Triassic. Nearly all of the Late Permian genera of ammonoids also become extinct and revolutionary changes also took place in the terrestrial floras (BALME, J. SCHOPF and MEYEN; all *in* LOGAN and HILLS, 1973).

The benthonic associations at the family level had prospered through tens of millions of years of the Late Paleozoic so that many Permian faunas have a superficial resemblance to those of the Carboniferous. Nothing closely comparable is known from the Lower Triassic even though some Paleozoic families do reappear again with little change in the Middle Triassic (NEWELL, 1967a; BATTEN; KIER; NAKAZAWA and RUNNEGAR; *in* LOGAN and HILLS, 1973). The highest Permian benthic communities are Paleozoic in aspect, not Mesozoic.

The few long-ranging families temporarily lacking in the Lower Triassic probably found refuge on the continental slopes during a low stand of the ocean level. These striking contrasts can, and should, be preserved in classification of the boundary formations. Lower Triassic marine faunas are impoverished and cosmopolitan while the Upper Permian is characterized by rich provincial faunas. Sweeping environmental changes on a world scale are indicated.

In coming to grips with a non-repetitive paleontological event like that which marks the Permian-Triassic boundary, I like to consider three possible basic parameters. These are: 1. stratigraphic hiatus and loss of a significant segment of the fossil record; 2. extinction of local biota and immigration of exotic organisms into a region, with or without mixing. Probably the replacement was largely a consequence of a third factor, 3. environmental changes. All three factors must have been involved in the marked biological turnover at the Permian-Triassic boundary.

A remarkable feature of the unconformity that separates Permian from Triassic rocks is that evidence of subaerial erosion and deep leaching commonly is absent or obscure. This suggests prevailing very low relief of lands and extensive submarine erosion, bypassing and stratigraphic condensation of sediments. Strata adjacent to the hiatus usually are essentially parallel (NEWELL, 1967b). From this curious structural relationship it seems probable that the widespread Artinskian orogenic cycle in Eurasia and the Americas was followed by diastrophic quiet and isostatic sinking along the deep-sea rift zones between crustal plates. In the non-marine sequences, dating and correlation of strata with the standard marine sequences is difficult and separate regional stratotypes unquestionably are necessary.

Evidently, Late Permian emergence of the continents greatly reduced, or eliminated, the major habitats of the most characteristic benthos of the epicontinental seas where environments must have been quite unlike the more restricted neritic waters of the continental slopes (NEWELL, 1962; 1967b; RUZHENTSEV, *in* RUZHENTSEV and SARYCHEVA, 1965; T. SCHOPF, 1974; SIMBERLOFF, 1974; JOHNSON, 1974). I have suggested elsewhere that a promising causal factor in the mass extinctions of whole biotas, both marine and non-marine, is the increased differential of seasonal temperatures that may be expected from increased continentality (NEWELL, 1971).

Search for a Boundary Stratotype

Ideally, a chronostratigraphic boundary should be established in the most nearly complete, reasonably accessible, fossiliferous sequence, that contains inter-stratified marine and non-marine elements. It is highly probable that most sections lack some of these attributes. Consequently, I believe that chrono-stratotypes should always be considered provisional and subject to replacement or revision within a rigorous framework of legal safeguards. The examples of the Silurian and Devonian Systems come to mind. The outcrops that provided the names of these systems certainly are not suitable for world standards and they are not so used. It is inevitable that the limits and even the location of some stratotypes will be changed in accordance with new discoveries and increasing knowledge.

An ideal sequence at the Permian-Triassic boundary has not yet been discovered. Complete sequences of plants and animals are not known at the Permian-Triassic boundary. Obviously, some compromise is required.

The most complete sequences commonly referred to the basal Triassic include an assemblage of primitive ceratites of the *Otoceras* fauna known only in Arctic, the eastern Soviet, and Tethyan regions (KUMMEL, 1972).

The genus *Otoceras* commonly is associated with *Ophiceras* and *(Xenodiscus?)* but tends to be limited to the lower part of the stratigraphic range of *Ophiceras*. TOZER (*in* LOGAN and HILLS, 1973) has suggested that the *Otoceras* assemblage should be regarded as a separate zone below the *Ophiceras* zone at the base of the Griesbachian Stage.

Hardly anything is known of the total biota of *Otoceras* time and correlations of this zone in non-marine sequences are very uncertain. Consequently, I think that it is premature to consider the matter settled at this time.

The most complete, readily accessible, sections lie in middle Tethys and it is somewhere in this area that stratotypes might be chosen. Gradational faunas have been reported in the Dzhulfian area along the Araxes River which forms the boundary between Soviet Transcaucasus and northwestern Iran (RUZHENTSEV and SARYCHEVA, 1965; STEPANOV, GOLSHANI and STÖCKLIN, 1969). However, ROSTOVTSEV and AZARYAN (*in* LOGAN and HILLS, 1973); and TEICHERT, KUMMEL and SWEET (1973) have shown that the supposed gradational beds are unquestionably Permian and no intermingling of Permian and Triassic benthos was recognized by them. Similar boundary conditions are reported in the Abadeh region of central Iran by TARAZ (1974).

KUMMEL and TEICHERT (1970) and their collaborators surveyed the classical sections in the Salt Range and Trans-Indus areas of Pakistan in admirable detail and found indications of mixing or survival of Permian brachiopods with *Ophiceras* near the erathem boundary. *Otoceras* is unknown in this area and there is some debate whether the Dzhulfian Stage is represented (several papers *in* LOGAN and HILLS, 1973). KUMMEL and TEICHERT *(op. cit.)* have concluded that there may be a brief hiatus within the boundary beds.

These authors also report some mixing of Permian and Triassic elements at Guryul Ravine, Kashmir (*in* LOGAN and HILLS, 1973). I have indicated reservations

elsewhere (NEWELL, in LOGAN and HILLS, 1973) about these "relict" faunas which could be, in part, or wholly, a product of mechanical reworking by turbidity currents and waves. Modern deep sea investigations are now revealing many cases of inter-mingling of transported fossils with *in situ* fossils without wear or breakage. NAKA-ZAWA and associates have revised their first impression about Guryul Ravine after a very elaborate, second field study; they now would relocate the Permian-Triassic boundary above most of the Permian elements of the allegedly mixed fauna, at the level of the lowest *Otoceras* specimens (NAKAZAWA et al., 1975). The Guryul Ravine section contains an excellent assemblage of the ceratites of the *Otoceras* zone, just above an occurrence of *Cyclolobus*.

Among the sequences of the central Himalayas the Dzhulfian Stage is not yet well known. For this it is necessary to refer to the Iranian and Transcaucasian sections, and less accessible sections in south China (FURNISH, in LOGAN and HILLS, 1973; SHENG and LEE, 1974).

Significance of the *Otoceras* Zone

The introduction of *Otoceras* certainly qualifies as a biologic event, a migration from elsewhere, since no genus can evolve *in situ*, but it was an insignificant event in terms of geological or biological history. Taken alone, it would not define a major boundary such as that between the Paleozoic and Mesozoic erathems. Its true value lies in its role as a biostratigraphic datum in Asia and the Arctic regions.

Logical arguments that have been posed in favor of choosing the base of the *Otoceras* zone as the Dzhulfian-Griesbachian chronostratigraphic boundary are:

1. This boundary has been almost universally adopted by ammonitologists since DIENER's 1912 work.

2. The *Otoceras* fauna is Triassic in aspect.

3. The zone is said to overlie an almost universal unconformity, a world-wide regression.

4. Permian extinctions were not instantaneous; they were taking place through-out the period. Therefore, the mass extinction event is of limited value as a chrono-stratigraphic boundary.

5. The *Otoceras* zone is about as close as any to the final low ebb of the Permian extinctions.

Arguments against:

1. Tradition and priority should now be subordinate in any revision of strati-graphic classification. The fauna (and flora) associated with *Otoceras* are hardly known. Decisions should be deferred until the *Otoceras* zone can be analyzed as an overlapping range zone in which all available criteria are evaluated. There is no logical reason to exclude other chronometric data and to give the primitive ceratites primacy.

2. In DIENER's day, ceratites *per se* were thought to be confined to the Triassic. This is not true. There are many ceratites in the Upper Permian and some of these (*Prototoceras; Xenodiscus*) are almost indistinguishable from *Otoceras* and *Ophiceras*.

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3. The paraconformity that separates the Permian and Triassic strata in many parts of the world is identified by paleontological evidence, but a hiatus may or may not always mark the paleontological interruption. In any case, unconformities are notoriously diachronous and it has not been demonstrated that the regression of the Late Permian reached its climax just prior to *Otoceras* time. JOHNSON (1974) has cautioned that the climax probably was much later. It is quite likely that the absolute nadir of marine extinctions occurred during, or possibly right after, *Otoceras* time.

4. It is true that extinctions have taken place sporadically during the Permian. Nevertheless, many invertebrate groups range into the *Paratirolites* zone and the *Otoceras* zone where they drop out permanently, as far as we know.

5. The earliest radiation of ceratites was in the Dzhulfian, not in the Lower Griesbachian. But a more outstanding event was the *Gyronites* radiation (fig. 2). The *Gyronites* deployment gave rise to many major lines of Mesozoic ammonites.

Recommendations

In the Himalayas, the boundary between the Permian and Triassic was arbitrarily drawn by MOJSISOVICS, WAAGEN and DIENER (1895) between the *Otoceras* zone and productid-bearing rocks below and modern ammonitologists have followed suit (e. g., DIENER, 1912; KUMMEL, *in* KUMMEL and TEICHERT, 1970). Other early investigators placed the *Otoceras* beds in the Permian (see RUZHENTSEV and SARYCHEVA, 1965, pp. 105, 106 for historical account).

Unknown to nineteenth century paleontologists, the genus *Otoceras* is the last survivor of a group of ceratites (fig. 2) that had their major radiation in the Upper Permian (KUMMEL, 1972). *Ophiceras* offers a different problem. Externally, Triassic *Ophiceras* is almost indistinguishable from some Permian *Xenodiscus*, from the external lobes.

SPINOZA, FURNISH and GLENISTER (1975) would distinguish Permian Xenodiscids from Triassic Ophiceratids by different suture development observable mainly in the early growth stages. But they point out that the early suture pattern of *Xenodiscus* is not known. Until this missing information is available there remains a possibility that some Permian *Xenodiscus* and Early Griesbachian *Ophiceras* are indistinguishable. As now understood both genera are highly variable and overlap with each other and *Glyptophiceras*.

A pelecypod, *Claraia*, distinctive pseudomonotid generally regarded as a guide of Griesbachian age, lies above the Dzhulfian rocks of Iran and Transcaucasia. In Kashmir, however, another and new species of this genus occurs in abundance below *Otoceras* ranging upward into the *Otoceras* beds. According to NAKAZAWA et. al. (1975), the Kashmir *Claraia* is a primitive species intermediate between Permian *Pseudomonotis* and characteristic Triassic examples of *Claraia*. Some specimens of the new *Claraia* were collected in association with *Otoceras* but mainly it occurs lower, in beds now considered to be Permian (NAKAZAWA, et. al., 1975).

SWEET (*in* LOGAN and HILLS, 1973) has worked out the conodonts of the boundary beds in south Asia and elsewhere. Each conodont zone is characterized

by one or more distinctive species. He has concluded that the boundary beds fall within the zone of *Anchignathodus typicalis*, a long-ranging species extending from the Lower Guadalupian of Texas into the *Ophiceras* beds of the Himalayas. It is replaced by a new and distinctive conodont assemblage in the *Gyronites* zone (fig. 2).
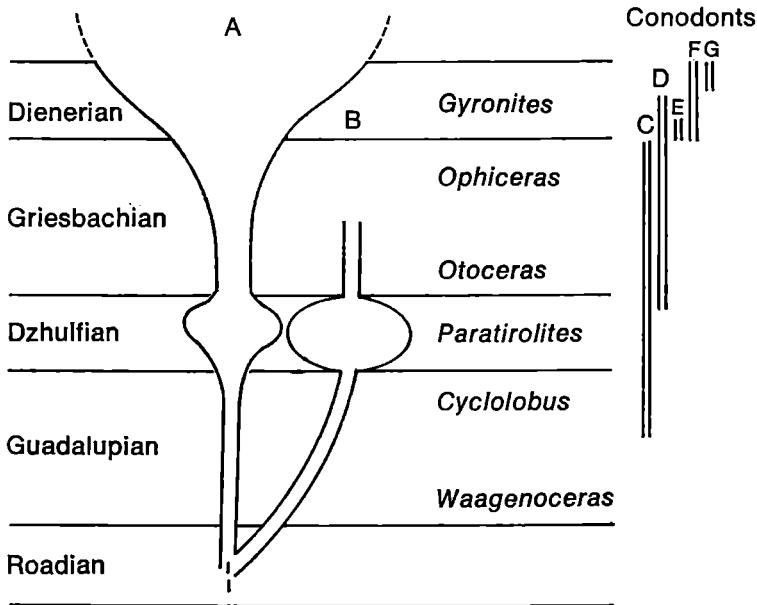

Fig. 2. Permian-Triassic boundary biostratigraphy. Left, tentative stages; right, tentative zones. A. *Xenodiscus-Ophiceras* lineage. Generic diversity diagrammatically represented; B. Otoceratidae, showing Dzhulfian radiation; C, D, E, F, G, conodont zones; respectively: *Anchignathodus typicalis, Ellisonia teicherti, Anchignathodus isarcicus, Neospathodus dieneri, N. cristagalli.*

The boundary rocks at Guryul Ravine in Kashmir are monotonous dark shales. An obscure paraconformity in the midst of such a sequence might be unrecognizable from physical evidence alone. NAKAZAWA et. al. (1975) think that the succession is probably uninterrupted, but the faunal evidence to be presented does not, in my opinion, require this conclusion.

The boundary at the base of the *Gyronites* zone makes a useful correlation event free from Permian species after the disappearance of the *Otoceras-Ophiceras* ceratites which seemingly mark the nadir of faunal diversity (fig. 2). In a re-evaluation of the scope of the Triassic, the *Gyronites* zone should be given careful consideration.

At present, there is no ideal stratotype that displays the Dzhulfian-Griesbachian common boundary. The lowermost Triassic is not well represented, or is lacking, in the type section of the Dzhulfian, and the uppermost Permian is not known in northern Canada where Griesbachian was named, or in Kashmir.

In the present state of knowledge, I am inclined to favor a provisional composite of the Araxes River exposures, the Salt Range and Guryul Ravine as co-stratotypes for the Permian-Triassic boundary.

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