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Papers presented at the 31st annual meeting, Rocky Mountain Section, Geological Society of America, April 28-29, 1978, at Brigham Young University, Provo, Utah, reviewing stratigraphic and paleontologic research in the Great Basin and honoring Dr. Harold J. Bissell.

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## EDITOR'S PREFACE

For the 1978 Rocky Mountain Section of the Geological Society of America meeting in Provo, Utah, a symposium was organized to mark the retirement of Professor Harold J. Bissell (program below). During the course of the symposium, held on April 29, several hundred present and past students, colleagues, and friends participated. Papers given at the symposium were invited from colleagues and former students. The theme of the symposium was a review of stratigraphic and paleontologic research in the Great Basin.

Of the nine papers presented in Provo, six are printed in this commemorative volume, dedicated to Harold J. Bissell, an enthusiastic teacher and student of Great Basin geology.

DLC

## SYMPOSIUM GREAT BASIN STRATIGRAPHY AND PALEONTOLOGY 29 April, 1978

David L. Clark and Lehi F. Hintze: Introduction to Symposium

Michael J. Brady and Richard B. Koepnick: A Middle Cambrian Platform-to-Basin Transition, House Range, West Central Utah

Richard A. Robison: Evolution of Some Trilobite Guide Fossils from the Middle Cambrian

J. Keith Rigby: Paleozoic Sponge Faunas of the Great Basin and Adjacent Areas

C. Kent Chamberlain: Trace-Fossil Ichnofacies in the Lower and Middle Paleozoic of Central Nevada

M. A. Murphy, J. B. Dunham, W. B. N. Berry, and J. C. Matti: Late Llandovery Unconformity in Central Nevada

Raymond C. Gutschick and Joaquin Rodriguez: Biostratigraphy of the Pilot Shale (Devonian-Mississippian) and Contemporaneous Strata in Utah, Nevada, and Montana

John A. Larson: Redeposited Carbonates of the Upper Oquirrh Formation, Utah

David L. Clark: Permian-Triassic Boundary: Great Basin Conodont Perspective

(Abstracts of papers published in vol. 10, no. 5, Geological Society of America Abstracts with Programs, March 1978)

# Permian-Triassic Boundary: Great Basin Conodont Perspective

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**ABSTRACT.**—The Great Basin could serve as a prototype for Permo-Triassic boundary problems in areas where marine sediment accumulation was discontinuous. The physical nature of the boundary indicates a range from angular discordance to paraconformity, and there has been no agreement concerning the magnitude of the missing record. Because most rock records are grossly incomplete, there may be little or no time difference between a paraconformity and an angular unconformity. Unfortunately, physical evidence alone is rarely sufficient to evaluate the magnitude of missing time. The most sensitive chronometers available to measure marine Permo-Triassic boundary time gaps may be conodonts. This group of organisms showed understandable, perhaps gradualistic, evolution during the Late Permian–Early Triassic and was unaffected by lowering of sea level and other environmental factors that severely affected benthic organisms worldwide. Conodont elements that occur in rocks adjacent to the Permo-Triassic boundary indicate that 7–8 stages are missing in the southern Great Basin, and 2–3 stages are missing in the northern Great Basin. This “quantification” of missing time also demonstrates that the upper beds of the Gerster Formation in northwestern Utah are post-Guadalupian and probably the youngest marine Permian known in North America. This conclusion is based on correlation of overlapping sequences of conodonts in west Texas and Utah as well as stage of neogondolellid evolution. Thus, conodont evidence quantifies the amount of missing Permo-Triassic time in the Great Basin and supports stratigraphic arguments for both major and minor time gaps.

## GREAT BASIN PERMO-TRIASSIC

Southern Area

### Stratigraphy

In the southern Great Basin, the Permian Kaibab is overlain by the Triassic Moenkopi Formation. Bissell (1973) has summarized the stratigraphic relationships of these units and concluded that the lack of prominent erosion, solution, or other subaerial features at the top of the Kaibab support the interpretation of the presence of a paraconformity between the Permian and the Triassic. Bissell suggested that perhaps there was never a complete withdrawal of marine water, at least from the deeper parts of the Kaibab–Moenkopi basin, during the Permo-Triassic transition. Support for this kind of an argument is given by Newell (1973) who pointed out that even “complete rock sequences have bedding planes that represent intervals of subaqueous bypassing or removal of sediments between times of accumulation” (p. 4). This idea has been carried to its maximum development by Garrels and Mackenzie (1971, p. 260), who have suggested that the Phanerozoic rock record may represent only 15–20% of Phanerozoic time. According to these students, most of geologic “time” is expressed in bedding planes. Bissell then argued with some support that “it has not been established that the Cordilleran miogeosyncline was entirely emptied of marine waters during Late Permian time” (1973, p. 341).

If philosophically it can be argued that even the rock record is a record of missing time, it follows that the difference between the amount of time indicated by a bedding plane and an angular unconformity may be minor. Obviously, the amount of time indicated could also be considerable. This philosophic approach is interesting, but it is not easily quantified or even tested except in rock sequences with some adequate control. Because all rock sequences have bedding planes, a “continuous” section is equally suspect as a sequence with prominent, well-defined, sedimentary breaks.

The fossil record provides a kind of control, however. A reliable biostratigraphy developed in a number of different areas can possibly be adapted for measuring the amount of missing time. But even complete fossil sequences (with established biostratigraphic utility) have problems. Absence of one or more members of an established sequence may be attributed to adverse ecologic or preservational factors and not necessarily missing time. Inadequate collection or problems associated with sound taxonomy are other sources of error. Nonetheless, in spite of the many problems, fossils are the most accessible tool with which to check the continuity of rock sequences. Fossils provide at least a minimum yardstick for strata interpretation; they may be, in fact, the best tools available for stratigraphic interpretations.

### Conodonts

In the southern Great Basin, the youngest Permian conodonts found are those in the Harrisburg Member of the Kai-

## INTRODUCTION

The Permo-Triassic interval includes one of the most widespread and profound physical and biological discontinuities of the geologic record. It was recognized 140 years ago and was the basis of the original Paleozoic-Mesozoic division of the time scale. More than a century after recognition of this division, details of the discontinuity still are being described. All of this work confirms that, with the exception of the central Tethys (Salt Range, Trans-Indus Range of Pakistan, Guryul Ravine of Kashmir, Julfa area of northwestern Iran and contiguous Russia) and the Kap Stosch area of East Greenland, the boundary indeed is unconformable. Even in the areas of more complete record, some students suggest that the boundary may be paraconformable, at best.

During the past 10 years a considerable number of significant studies of the fauna of the boundary beds have been published (e.g., Kummel and Teichert 1970, 1973; Sweet, 1970a,b; Teichert and Kummel 1976; Logan and Hills 1973). These studies have provided a detailed examination of the classic (=Tethyas) boundary beds as well as details of the boundary conditions in other parts of the world.

Studies of the Permo-Triassic boundary interval of the Great Basin have been published during this same time and have defined the same kinds of problems for Nevada and Utah that have been recognized in other places where the boundary has been studied. Also, a detailed investigation of a few key sections has led to definitive statements concerning the magnitude of the Permo-Triassic break in at least a part of the Great Basin (Clark and others 1977). In addition, the evolution and paleoecology of conodonts, a very important faunal element of the Permo-Triassic seas, can be better understood because of details furnished by the Great Basin Permo-Triassic record. These details and their relationship to worldwide Permo-Triassic changes are the subject of this paper.



most or Araksian Stage of the Dzhusfian Series in its type area is characterized by a group of Araxoceratidae (ammonoids) that have not been reported in North America. To further complicate classification, neither the Lamar nor the Gerster conodonts are known in the Dzhusfian area of Iran or Russia. As will be shown later, the Tethyan area was characterized by a different neogondolellid lineage during the Late Permian. Thus, type Araksian organisms apparently were not present in North America, and the post-Guadalupian fauna of North America is not known in the Tethyan area. Therefore, it is not possible to prove that the uppermost Gerster beds are Araksian by fossil comparison. If future work in either area fails to produce faunal elements that were present in both areas, it might be useful to recognize a North American post-Guadalupian Stage to include the upper Gerster rocks (perhaps a Gersterian Stage of the Dzhusfian Series).

The Dinwoody in the Terrace Mountains is conformable with the Gerster, and the lowest bed contains a fauna characterized by *Anchignathodus typicalis*, *A. isarcicus*, *Neogondolella carinata*, and *Ellisonia* spp., including *E. teichertii*. This assemblage is known elsewhere only in the lower Griesbachian stage of the Lower Triassic although certain members of the fauna occur in the latest Permian Chhidruan and Changhsingian, as well. The absence of physical evidence for a major time break between the Gerster and Dinwoody is reinforced by a conodont sequence that indicates only post-Araksian to pre-Griesbachian members missing. The absence of only two stages confirms that there is a relatively minor amount of missing time in the northern Great Basin Permo-Triassic interval (fig. 3).

#### PERMO-TRIASSIC CONODONT EVOLUTION

##### Introduction

Provincialism has been best documented for conodonts of the Ordovician and to a lesser extent for Late Triassic. Consideration of Permo-Triassic faunas leads to the conclusion that a degree of provincialism developed during the Late Permian, as well. Two distinct lineages of *Neogondolella* evolved during the Late Permian. The North American stock is understood from more or less complete sequences of neogondolellids in west Texas and the Great Basin. The second or Eurasian stock is less completely known but was important as the ancestral group of all Triassic neogondolellids, in both North America and Eurasia. Evidently this stock replaced the North American stock during the latest Permian.

##### North American Stock

The ancestor of the North American stock of neogondolellids was *N. bisselli* (Clark and Behnken 1979) (fig. 4). This conodont is known only from its P element, and it is assumed to have been a unimembrate species. *N. bisselli* occurs in uppermost Sakmarian (Sterlitamakian) rocks in several parts of the Great Basin and in west Texas. It gave rise to a variety of younger Artinskian species including *N. idahoensis* and *N. gracilis* as well as several species known in west Texas but not yet described. The upper Artinskian (Roadian) member of this stock is *N. serrata*, a form that ranges into the younger Guadalupian, as well. This key species evidently was the immediate ancestor of a complex of Guadalupian species, each characterized by a distinctive P element. The complex was especially well developed in the west Texas carbonate tongues associated with the Capitan reef complex (fig. 5). The Cherry Canyon and Bell Canyon carbonates contain *N. n. sp. A* in the South Wells, Manzanita, and most of the Hegler; *N. posterrata*, *N. rosen-*

*krantzii*, and *N. n. sp. B*, in the upper Hegler, Rader, and lower McCombs, and *N. n. sp. C*, in the upper McCombs and Lamar. *N. n. sp. D*, the youngest stage in this evolutionary sequence, occurs in the uppermost Gerster Formation of the Great Basin. *N. rosenkrantzii* and *N. bitteri* also occur in Guadalupian units of the Great Basin.

The evolution of the species from *N. serrata* through the Gerster can be understood from key morphologic features of the P element including (1) symmetry of the posterior end, (2)

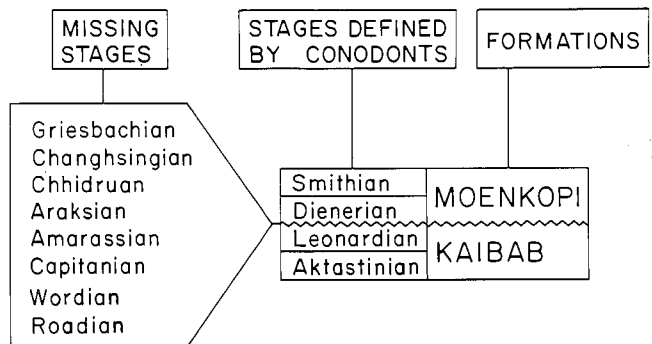


FIGURE 3.—The Gerster-Dinwoody contact in the northern Great Basin. Stages present or absent, as defined by conodonts, indicated.

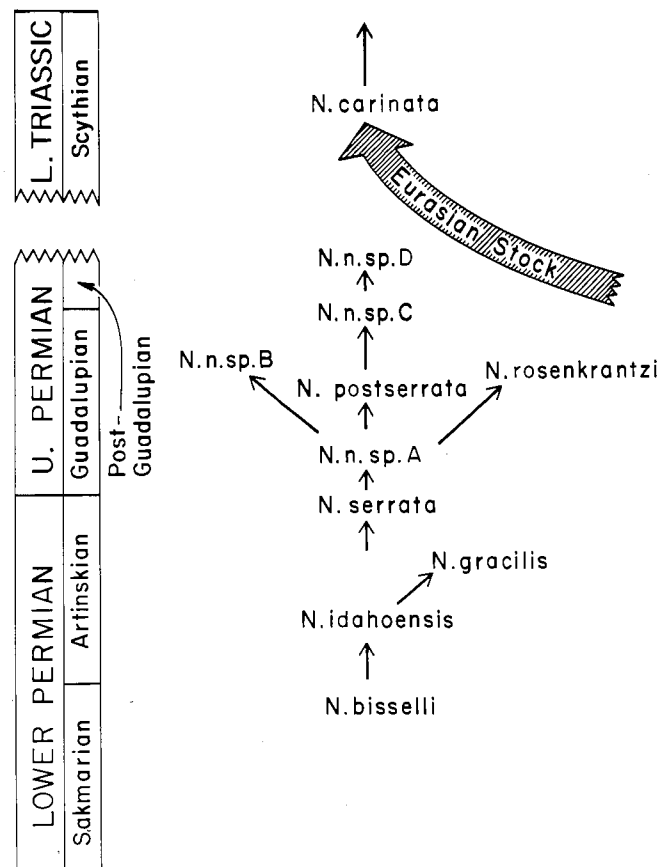


FIGURE 4.—Evolution of the North American stock of neogondolellids from *Neogondolella bisselli*. This stock was extinct following the Guadalupian and was replaced in the Triassic by a Eurasian stock of neogondolellids.



presence or absence of serrations on the anterior edge, (3) outline of whole element, (4) structure of the carina, (5) arching of the element, and (6) structure of the lower surface (fig. 6). Some of these features showed progressive modification throughout the Guadalupian (e.g., characteristics 1-4), and others changed very little (e.g., characteristics 5, 6). The posterior end symmetry (1) is especially important. It can be described in terms of three symmetry classes: (1) more or less symmetrical with carina intersecting center of posterior margin producing a bilaterally symmetrical posterior end, (2) sinistral, where the carina intersects posterior margin left of center or entire posterior end of element bends to left, and (3) dextral, where the carina intersects the posterior margin right of center, or the end of the element bends to the right. These symmetry classes are gradational but clearly definable in large collections. Some ~7000 west Texas and Great Basin Guadalupian P elements were classified according to posterior symmetry class (table 1). Several things can be interpreted from the data: (a) South Wells to Rader elements average 22% symmetrical posterior ends with a ratio of symmetrical to asymmetrical units of

1/3 (there is one symmetrical P element for every 3 asymmetrical elements). This ratio may also express the actual number of elements in a complete conodont apparatus. (b) McCombs elements have 25% symmetrical ends and approximately the same symmetrical/asymmetrical ratio as that of the older rocks. (c) Lamar elements have 37% symmetrical ends, and the symmetrical/asymmetrical ratio drops to 1/1.7. (d) Lower Gerster elements have 37% symmetrical ends and the same ratio as that of the Lamar. (e) Upper Gerster elements average 80% symmetrical ends or a symmetrical/asymmetrical ratio of 1/1.2 (fig. 7).

I propose that this represents an evolutionary sequence in which the percentage of symmetrical to asymmetrical P elements was increasing during the Permian. Other morphological characteristics of the fauna changed little. Even the Gerster section in the Terrace Mountains shows a progression of increasing symmetrical ends. Only 38 specimens were recovered from the 23-m section, and the chi square values were calculated to test the validity of the conclusions. The tests indicate that the difference between the lower samples (with 37% symmetrical ends) and the upper samples (with 80% symmetrical ends) is significant at the 98% level. Also, the upper beds of the Gerster at section 2 (Clark and others 1977) contain 100% symmetrical ends. Thus, the progressive posterior-end modification throughout the western North American Guadalupian appears to be a trend that was sustained in the uppermost Gerster beds of the Terrace Mountains. Surely, morphologically similar elements were responding in a similar manner to some ecologic stimulus throughout the Guadalupian.

If this interpretation is valid, the attainment of 80% symmetrical ends in the uppermost Gerster beds of northwestern Utah may be taken as evidence that the uppermost Gerster rocks are younger than the uppermost Guadalupian rocks (Lamar) of west Texas. No younger marine Permian than that of

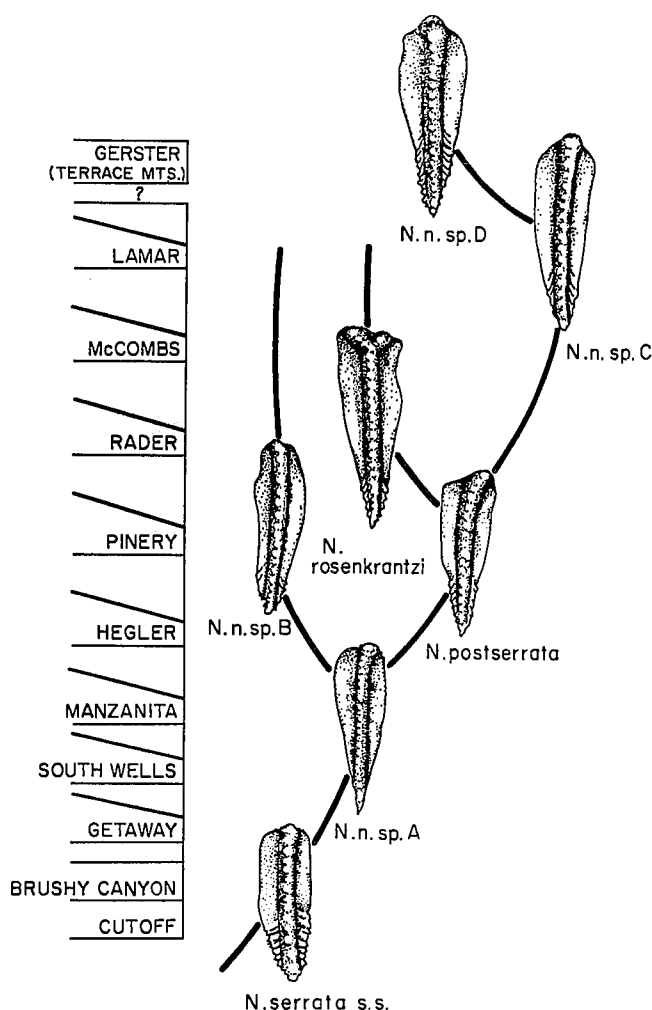


FIGURE 5.—Evolution of the younger Permian neogondolellids in the type Guadalupian of West Texas and in the Gerster Formation of the northern Great Basin (n. sp. D). Modification of the posterior end of the P elements is important in this evolutionary sequence.

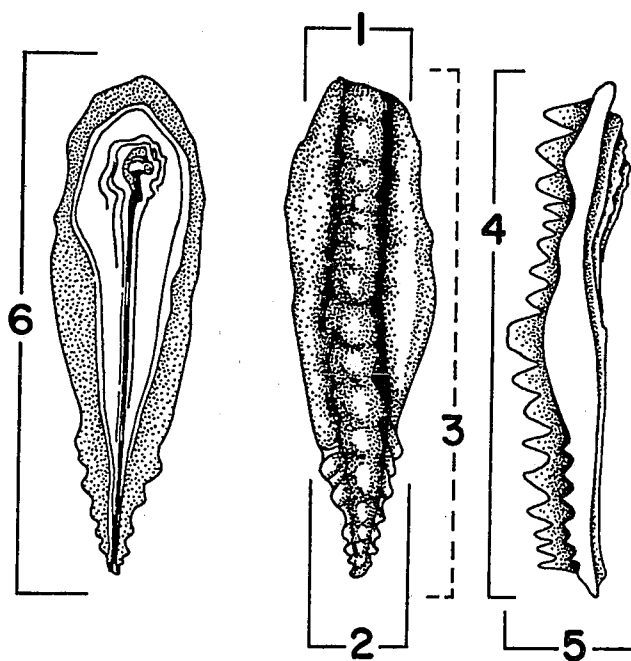


FIGURE 6.—Basic morphologic features important in the understanding of *Neogondolella* evolution. 1=posterior end symmetry, 2=anterior end ornamentation, 3=overall outline, 4=structure of carina, 5=arching of element, 6=structure of lower surface.

TABLE 1  
POSTERIOR-END SYMMETRY CLASSIFICATION OF *NEOGONDOLELLA* P ELEMENTS IN THE UPPER PERMIAN ROCKS

STRATIGRAPHIC UNIT	NUMBER OF ELEMENTS	SYMMETRICAL	SINISTRAL	DEXTRAL	% SYMMETRICAL
South-Wells through Rader	5556	1244	2114	2198	22
McCombs	121	31	46	44	25
Lamar	1732	641	550	541	37
Lower Gerster	8	3	2	3	37*
Upper Gerster	30	24	4	2	80*

\*data shows significant difference at 98% level

Texas has been reported. Although evolutionary stage attainment cannot be used to prove a classification with Araksian rocks (= Early Dzhulfian), the evidence is strong that the uppermost Gerster rocks of the Terrace Mountains are the youngest Permian marine rocks in North America.

#### Eurasian Stock

The Eurasian, principally Tethyan, stock may have had a similar ancestor to that of the North American stock, but the details are not clear. Late Artinskian or Guadalupian *Neogondolella siciliensis* (Kozur) and a few other species are followed by a Dzhulfian sequence including *N. leveni*, *N. orientalis*, *N. subcarinata*, and *N. carinata* (fig. 8). These latter species are especially well developed in the Dzhulfian rocks of the central and western Tethyas.

*N. carinata*, the youngest Permian member of the Dzhulfian sequence, is of special importance because it is characteristic of the Lower Triassic Griesbachian and part of the Dienerian, as well. As Sweet (1970a, b) has pointed out, this principal element of the Early Triassic fauna was unaffected by the Permo-Triassic crisis that affected most Paleozoic benthic organisms. Of particular importance is the fact that by the Early Triassic, this Eurasian stock in the form of *N. carinata* was the only neogondolellid in Eurasia, North America, or Australia. The extinction of the North American stock (represented by the youngest known member, *N. n. sp. D*) removed probable competitors, and as the Early Triassic seas covered parts of western North America, they contained only the Eurasian *N. carinata*.

North American and Eurasian neogondolellid stocks show some mixing prior to the replacement by the Eurasian group. Several students have reported Early Guadalupian *N. bitteri* in the Great Basin (Collinson and Wardlaw 1977, Behnken 1975), and this species has been reported from the Tethyan realm (Kozur 1975) as well. It appears close to specimens reported from Sicily as *N. siciliensis*. *N. rosenkrantzi*, originally reported from East Greenland and clearly a member of the North American *serrata* complex, shows some relationship to both of the former species. *N. rosenkrantzi* (fig. 5) occurs in Texas and the Great Basin.

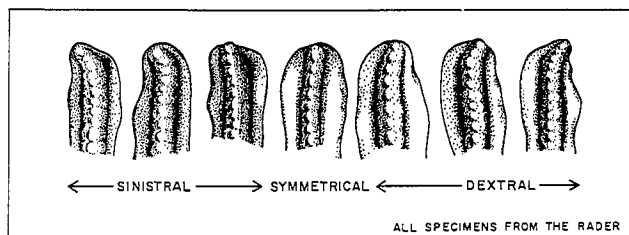


FIGURE 7.—Posterior end of P element of *Neogondolella* in the Upper Permian and symmetry classes. In the specimens shown here, a complete apparatus may have had one symmetrical, three dextral, and three sinistral elements.

#### PERMO-TRIASSIC CONODONT PALEOECOLOGY

The traditional and well-supported idea that conodonts were part of the pelagic realm has been questioned recently (Barnes and Fähræus 1975, Fähræus 1976). Basing their interpretations principally on Ordovician data, these students propose that conodonts were part of the nektobenthic realm. Certainly, it is possible that the range of ecologic adaptations among conodonts may have been large, perhaps from benthic to pelagic. It seems unlikely, however, that Permo-Triassic conodonts were benthic. No major benthic (or probably nektobenthic) group survived the Permo-Triassic transition unaffected (Newell 1973). Yet, the same conodont fauna that characterizes the youngest Permian Dzhulfian rocks is present and continuous through one or two stages of the oldest Triassic Griesbachian and Dienerian.

All of the evidence confirms that the Permo-Triassic transition involved a lowering of sea level (e.g., Schopf 1974) and

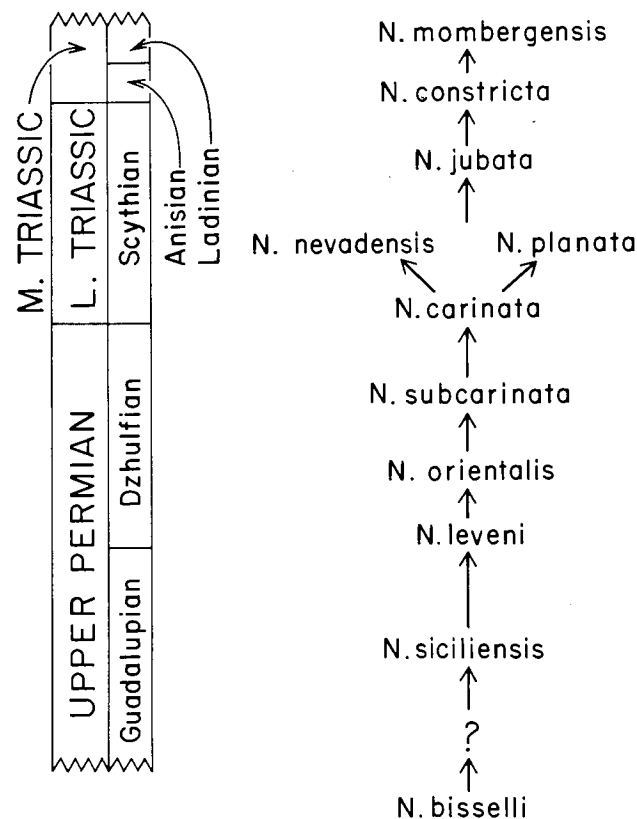


FIGURE 8.—Evolution of the Eurasian stock of neogondolellids in the Permian and Triassic. All Triassic neogondolellids, worldwide, evolved from the Eurasian stock.

elimination of the prime habitat for most of the benthic and related marine organisms. The new Triassic benthos (hexa corals, bivalves, brachiopods, etc.) are groups that replaced the benthic types that were affected by the Permo-Triassic crisis caused by sea-level lowering or perhaps reduction of salinity, as has recently been proposed (Lantzy and others 1977). Fish, ammonoids, and organisms of the pelagic realm were less affected, and the fact that conodonts reacted in a similar manner is strong support of a pelagic habitat.

#### SUMMARY

The rock record includes a variety of bedding planes and other unconformities that signify missing time. The differences among various unconformities may be physically profound, but philosophically the differences are of magnitude only. If the Phanerozoic rock record represents only 15–20% of Phanerozoic time (Garrels and Mackenzie 1971), it might be argued that there is no complete rock record (for time)—only pieces of incompleteness. Interpreting bedding planes and unconformities in terms of amount of time they represent is a difficult art. It is possible that the paleontologic record can be used to interpret the magnitude of missing time. The Great Basin Permo-Triassic boundary is a splendid example of the problems associated with interpreting incomplete time. Thus, Bissell (1973) argues that in the deep off-shore part of the Cordilleran Basin, the seas may have been continuously present during the Permo-Triassic interval even though he concedes that the paleontologic record has a demonstrable break. In a different vein, Collinson and others (1976) have pointed out that the disconformity present between Great Basin Permian and Triassic "marks a significant break in the stratigraphic record" (p. 824) and effectively used the physical conditions as well as the paleontologic gap of the Permo-Triassic boundary to support their ideas.

In a real sense, both views are valid. The paraconformity argument is supported by the philosophical approach that the entire record is a continuum of missing time with only minor intervals during which sediment accumulated and was preserved. But equally true is the practical argument that the Great Basin Permo-Triassic boundary, in places, has striking physical disconformity as well as a paleontologic gap of some proportions. The best method of quantification of missing time at present for the Great Basin rocks probably is using conodont biostratigraphy. Conodonts were a pelagic group that survived relatively unaffected the crisis that severely curtailed development of all important benthic groups. Absence and presence of members of known lineages can define the magnitude of missing time. In the southern Great Basin, the conodont record shows a gap of 7–8 stages between Leonardian species and those of the earliest Triassic. In the northern Great Basin only 2 or possibly 3 stages separate the Permian neogondolellids from their Triassic replacements, newly arrived from the Tethyas. Whether or not marine water remained in the deeper parts of the Cordilleran, but with no accumulation of sediment, is difficult to prove. Nonetheless, the amount of time for which there is no record can be quantified by conodonts. This is the unique perspective furnished by the conodonts of the Great Basin Permo-Triassic boundary.

#### ACKNOWLEDGMENTS

Harold J. Bissell first introduced me to geology and to the Permo-Triassic of the Great Basin a quarter of a century ago.

His enthusiasm and help have been of considerable benefit through the years.

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#### REFERENCES CITED

- Babcock, L. C., 1976, Conodont paleoecology of the Lamar Limestone (Permian), Delaware Basin, West Texas: In Barnes, C. R. (ed.), Conodont paleoecology, Geological Association of Canada Special Paper 15, p. 279–94.
- Barnes, C. R., and Fähræus, L. E., 1975, Provinces, communities, and the proposed nekrobenthic habit, of Ordovician conodontophorids: *Lethaia*, 8:133–49.
- Behnken, F. H., 1975, Leonardian and Guadalupian (Permian) conodont biostratigraphy in western and southwestern United States: *Journal of Paleontology*, v. 49, p. 284–315.
- Bissell, H. J., 1973, Permian-Triassic boundary in the eastern Great Basin area: In Logan, A., and Hills, L. V. (eds.), The Permian and Triassic systems and their mutual boundary, Canadian Society of Petroleum Geologists Memoir 2, p. 318–44.
- Clark, D. L., 1979, Adaptive and nonadaptive (genetic drift) evolution in *Neogondolella* and its significance for Upper Permian biostratigraphy: *Geologica et Palaeontologica*, v. 13, in press.
- Clark, D. L., and Behnken, F. H., 1979, Evolution and taxonomy of the North American Upper Permian *Neogondolella serrata* complex: *Journal of Paleontology*, v. 53, p. 263–275.
- Clark, D. L., Peterson, D. O., Stokes, W. L., Wardlaw, B., and Wilcox, J. D., 1977, Permian-Triassic sequence in northwestern Utah: *Geology*, v. 5, p. 655–58.
- Collinson, J. W., Kendall, C. B. St. C., and Marcantel, J. B., 1976, Permian-Triassic boundary in eastern and west-central Utah: *Geological Society of America Bulletin*, v. 87, p. 821–24.
- Collinson, J. W., and Wardlaw, B. R., 1977, Conodont-brachiopod biostratigraphy of the Park City Group (Permian) in eastern Nevada and western Utah: *Geological Society of America Abstracts*, v. 9, no. 5, p. 585.
- Fähræus, L. E., 1976, Conodontophorid ecology and evolution related to global tectonics: In Barnes, C. R. (ed.), Geological Association of Canada Special Paper 15, p. 11–26.
- Furnish, W. M., 1973, Permian stage names: In Logan, A., and Hills, L. V. (eds.), Canadian Society of Petroleum Geologists Memoir 2, p. 522–48.
- Garrels, R. M., and Mackenzie, F. T., 1971, Evolution of sedimentary rocks, New York, Norton, 397p.
- Kozur, H., 1975, Beiträge zur Conodontenfauna des Perm: *Geol. Paläont. Mitt. Innsbruck*, v. 5, p. 1–44.
- Kummel, B., and Teichert, C. (eds.), 1970, Stratigraphic boundary problems: Permian and Triassic of West Pakistan: Univ. of Kansas Department of Geology, Special Publications no. 4, 474p.
- , 1973, The Permian-Triassic boundary beds in central Tethyas: In Logan, A., and Hills, L. V. (eds.), The Permian and Triassic Systems and their mutual boundary, Canadian Society of Petroleum Geologists, p. 17–34.
- Lantzy, R. J., Dacey, M. F., and Mackenzie, F. T., 1977, Catastrophe theory: Application to the Permian mass extinction, *Geology*, v. 5, p. 724–28.
- Logan, A., and Hills, L. V. (eds.), 1973, The Permian and Triassic systems and their mutual boundaries: Canadian Society of Petroleum Geologists Memoir 2, 766p.
- Newell, N. D., 1973, The very last moment of the Paleozoic era: In Logan, A., and Hills, L. V. (eds.), The Permian and Triassic systems and their mutual boundaries: Canadian Society of Petroleum Geologists Memoir 2, p. 1–10.
- Schopf, T. J. M., 1974, Permo-Triassic extinctions: Relation to sea-floor spreading: *Journal of Geology*, v. 82, p. 129–43.
- Sweet, W. C., 1970a, Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan: Univ. Kansas, Department of Geology Special Publications, no. 4, p. 207–75.
- , 1970b, Permian and Triassic conodonts from a section at Guryul Ravine, Vihri District, Kashmir: Univ. Kansas Paleontological Contributions, v. 49, p. 1–10.
- Teichert, C., and Kummel, B., 1976, Permian-Triassic boundary in the Kap Stosch area, east Greenland: *Med. Grönland*, v. 197, 54p.