ABSTRACTS OF PAPERS TO BE PRESENTED AT THE INTERNATIONAL PERMIAN-TRIASSIC CONFERENCE AUGUST 23-26, 1971, CALGARY, ALBERTA, CANADA

All Abstracts Received April 13, 1971

A NEW ZONAL SCHEME FOR TRIASSIC DEPOSITS FROM NORTHEAST U.S.S.R.

Y. V. ARKHIPO, Y. M. BYTSHKOV and I. V. POLUBOTKO
National Committee of Geologists of the U.S.S.R.

Triassic deposits from the Kolyma, Omolon, Viliga and Yana-Ochotskaya river basins in the northeast part of the Soviet Union were studied by the authors from 1960-1969. The result of this work is a new zonal scheme for Triassic deposits from this region. Figure 1 shows these zones, as compared to the zonal scheme for the Triassic of Canada devised by Tozer (1967).

Notes on Figure 1:

1. *Lower Triassic.* It is possible that the substages of the Olenekian can be considered equivalent to Tozer's Smithian and Spathian Stages.

2. *Middle Triassic.* The authors discuss the possible advantages of establishing three stages in the Middle Triassic. The lowest, named Kularian, would correspond to the Lower Anisian Substage of northeast U.S.S.R. (in Figure 1) and also to synchronous deposits in Canada and other regions in the Boreal-Pacific zoogeographical province. The middle stage, or Anisian, would then be equivalent to the present Upper Anisian Substage, since the latter corresponds to the Anisian in the stratotypical sections of Western Europe. The upper stage, or Ladinian, would remain as presently defined in the Boreal-Pacific zoogeographical province.

3. *Upper Triassic.* The Rhaetian can not be distinguished from the Upper Norian in the area studied and therefore should be regarded as the upper zone of the Norian. Also, as the most complete sections of the Triassic are located in northeast U.S.S.R. and in some regions of North America, the authors suggest it may be time to reconsider the location of the type sections for the divisions of the Trias.

PALYNOLOGY OF LATE PERMIAN AND EARLY TRIASSIC STRATA, SALT RANGE, WEST PAKISTAN

B. E. BALME
Department of Geology, University of Western Australia, Nedlands,
Western Australia 6009, Australia

A striking palynological break occurs at the contact between the Upper Permian Chhidru Formation and the Triassic Kathwai Member of the Mianwali Formation in the Salt and Trans-Indus Ranges of West Pakistan. Assemblages from the upper white sandstone unit of the Chhidru Formation are diverse and well preserved. Their gross characters suggest that the unit is regressive. Fifty-four common species have been described

SERIES	STAGE	SUB-STAGE	ZONES	
			NORTHEAST USSR	CANADA
UPPER TRIASSIC	NORIAN	Upper	Tosapecten efimovae	Choristoceras marshi
				Upper Rhabdoceras suessi
			Monotis ochitica	Lower Rhabdoceras suessi
			Monotis jakutica	
		Middle	Monotis scutiformis	Himavatites columbianus
		Lower	Otapiria ussuriensis	Drepanites rutherfordi
				Juvavites magnus
				Malayites dawsoni
	KARNIAN	Upper	Pinacoceras verchojanicum	Mojsisovicsites kerri
				Klamathites macrolobatus
				Tropites welleri
				Tropites dilleri
		Lower	Striatosirenites	Sirenites nanseni
			Sirenites hayesi	
			Protrachyceras seimkanense	Trachyceras obesum
			Protrachyceras omkutchanicum	
MIDDLE TRIASSIC	LADINIAN	Upper	Nathorstites gibbosus	Paratrachyceras sutherlandi
			Nathorstites lenticularis	Maclearnoceras maclearni
				Meginoceras meginae
		Lower	Arctoptychites krusini	Progonoceratites poseidon
			Longobardites oleshkoi	Protrachyceras subasperum
	ANISIAN	Upper	Frechites humboltensis	Gymnotoceras chischa
			Gymnotoceras blakei	Gymnotoceras deleeni
		Lower	Malletoptychites verchojanicus	Anagymnotoceras varium
			Arctohungarites laevigatus	Lenotropites caurus
			Grambergia taimyrensis	
LOWER TRIASSIC	OLENEKIAN	Upper	Prohungarites crasseplicatus	Keyserlingites subrobustus
			Parasibirites grambergi	Olenikites pilaticus
		Lower	Dieneroceras dieneri	Wasatchites tardus
			Hedenstroemia mojsisovicsi	Euflemingites romunderi
	INDUAN	Upper	Pachyproptychites turgidus	Paranorites sverdrupi
				Proptychites candidus
			Pachyproptychites strigatus	Pachyproptychites strigatus
		Middle	Glyptophiceras extremum	Ophiceras commune
		Lower	Otoceras boreale	Otoceras boreale
				Otoceras concavum

Fig. 1. Triassic stages, substages and ammonoid zones of northeast U.S.S.R. and Canada.

from the unit, including forms known previously from the Upper Permian of Western Europe, the U.S.S.R., North America and the "Gondwana" countries. Especially close similarities exist between pollen grains from the Chhidru Formation and those from the Middle Sakamena Group of Madagascar.

Assemblages from the Kathwai Member are poorly diversified and contain enormous numbers of small spinose acritarchs: a feature also of marine Lower Scythian deposits in other parts of the world. Only fourteen Permian species range into the Triassic and twelve of these are very rare in pre-Scythian strata. Major modifications of the Triassic assemblages occur at a horizon in the Upper Scythian, marked by the appearance in large numbers of the lycopsid genus *Aratrisporites* and the probable corystosperm *Falcisporites*.

A possible interpretation of the unusual composition and impoverishment of Early Scythian assemblages is that the spores and pollen they contain represent specialized marshland associations, that rapidly colonized broad coastal lowlands at the time of widespread Early Scythian transgression. Such coastal belts would be expected to be unusually extensive, following a prolonged period of emergence and erosion during the Late Permian. Spores and pollen grains of Early Triassic "upland" floras are therefore unrepresented, or extremely rare, in contemporaneous marine strata.

FLORAL MODIFICATIONS AT THE PERMIAN-TRIASSIC BOUNDARY IN AUSTRALIA

B. E. BALME[1] and R. J. HELBY[2]

[1]Department of Geology, University of Western Australia, Nedlands, Western Australia 6009, Australia
[2]Mining Museum, 28 George Street, Sydney, New South Wales, Australia

The discovery of Griesbachian ammonoid faunas in Western Australia, and the expansion of palynological and paleontological studies have, in recent years, provided a firmer biostratigraphic basis for establishing the Permian-Triassic boundary in Australia. Present evidence suggests that Permian and basal Triassic strata are separated, in all Australian basins, by a sedimentary or erosional hiatus. The magnitude of this is difficult to estimate, because of correlation difficulties within the predominantly continental successions that characterize the Australian Upper Permian.

Late Permian plant macrofossil associations are of the familiar Gondwana type, in which *Glossopteris* is a ubiquitous and predominant element. *Glossopteris* has never been found in Australian strata for which a Triassic age is unequivocally indicated by other fossil evidence. Spore and pollen assemblages from Australian Upper Permian sediments are among the most diverse encountered anywhere in the geological column. They are interpreted as representing part of a mature floral ecosystem, stabilized at least throughout the area of the present continent.

In Western Australia virtually none of the distinctive plant microfossil taxa persists into the Triassic. Here Early Scythian microfloras are characterized by lack of diversity and enormous numbers of small, spinose acritarchs. The microfloral break is less sharp at the base of the Triassic

in the Sydney Basin, although the trend towards lower diversity above the boundary is still apparent. Although Australian Early Triassic plant microfossil assemblages differ notably from those of the Late Permian they contain few new forms, apart from the lycopsid genus *Aratrisporites*. Almost all the well-characterized Scythian elements are known, usually as minor components, from Late Permian microfloras in Australia or other parts of the world. It may be concluded, therefore, that the close of Permian time was marked by widespread extinction of many plant taxa and relatively rapid migration of others. There is no palynological evidence implying accelerated evolutionary diversification of the land floras. By Late Scythian times the *Dicroidium*-flora had become established throughout the continent and persisted until the Early Jurassic.

Floral modifications at the Permian-Triassic boundary are spectacular, if not as complete and abrupt as those among certain invertebrate groups. Like other regional and local upheavals in the vegetation of the past they are concomitant with a period of shallow marine transgression, following extensive continental emergence and erosion. Increase in the total oceanic area is suggested as the primary mechanism effecting major transformations of the land floras.

PERMIAN-TRIASSIC RADIOMETRIC CHRONOLOGY

P. O. BANKS

Department of Geology, Case Western Reserve University,
Cleveland, Ohio 44106, U.S.A.

Radiometric ages pertaining to the Permian-Triassic time scale are reviewed. Information published within the last few years has not materially altered the conclusions of Smith (1964) and Tozer (1964) for the ages of the Permian and Triassic, respectively. The Middle and Lower Triassic are especially poorly represented and the age of the Permian-Triassic boundary cannot be considered confidently established better than somewhere in the interval 225-235 m.y., with attendant uncertainty in the duration of adjacent stages or epochs.

The principal problem has been a lack of datable units with sufficiently strict stratigraphic control. Even if this were to improve, a dependence on analyses from widely-scattered laboratories and localities would not likely result in better precision, unless interlaboratory calibrations are more fully documented, and consistent use is made of radiometric approaches providing evidence that the measured ages have not been modified by secondary processes. The greatest intrinsic interest of the time scale lies in determining the rates of geological and evolutionary processes, whereby age differences are more important than the ages themselves. Investigations dealing with limited geographical areas and limited spans of geologic time can probably achieve greater precision in this respect than is currently possible for the time scale as a whole, provided datable samples are available. The optimum conditions occur where volcanic flows or tuffs are interbedded with diagnostically fossiliferous sediments. Stratigraphers and paleontologists working closely with stratigraphic sections in the field are best situated to recognize such occurrences and bring them to the attention of geochronologists for mutual benefit.

GASTROPOD FAUNAL PATTERNS IN PERMIAN-TRIASSIC ROCKS

R. L. BATTEN

Department of Invertebrate Paleontology, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024, U.S.A.

The dominant gastropods in the highest Permian and lowest Triassic represent long-ranging, fairly conservative families. The last of the normal marine gastropod faunas which can be considered well balanced and rich occurs in the Kazanian and approximate equivalents. These are widely distributed: West Texas, Russia, Cambodia, China, Mongalia, Pakistan, Sicily and Timor. Significantly, these faunas include several Mesozoic elements which must have existed but are not found in the Lower Triassic. The uppermost Permian faunas are widespread but depauperate. They are known from the Bellerophonkalk and equivalents at various places along the western and central Tethyan belt; from Japan (Gujo Formation), from Burma (Plateau Limestone), and New Zealand (Walraki). These contain three to four genera of bellerophontids and pleurotomarians and several genera each of the murchisonaceans, loxonemataceans, neritopsaceans and subulitaceans. In the allegedly highest Permian beds of New Zealand, a single pleurotomarian genus *(Peruvispira)* is found.

Lower Triassic marine faunas containing gastropods are extremely rare. In the half dozen or so known localities, the assemblages are quite restricted and the superfamilies mentioned above from uppermost Permian are represented by only one, or, at most, a few species. It is not until the Middle Triassic in the central and eastern Alps, that a more diversified (but still restricted) marine gastropod fauna appears. This fauna retains a Paleozoic aspect, but also contains several Mesozoic families. By Late Triassic time, a more varied marine fauna developed and became widespread. Many new Mesozoic groups were present but there still was a strong Paleozoic aspect to the gastropods.

As in many other invertebrate groups, there is a large information gap in the Lower and Middle Triassic. To illustrate, there are nine Permian pleurotomarian families known, represented by about thirty-five genera. Thirty-one of these genera become extinct by latest Permian time; yet seven of the Permian families are well represented in the Upper Triassic faunas, and only a single Permian genus *(Worthenia)* is known from Lower and Middle Triassic rocks. Thus, changes within the gastropods at the Permian-Triassic boundary are not significant at the family level, but are highly conspicuous at the generic level. Further, many Paleozoic families (which are found in what are considered normal marine environments in the Paleozoic and Triassic) existed in the Early and Middle Triassic. Either their record has been destroyed or they were restricted to very limited areas.

EVALUATION OF THE PERMIAN-TRIASSIC UNCONFORMITY IN THE EASTERN GREAT BASIN OF THE UNITED STATES

H. J. BISSELL

Department of Geology, Brigham Young University, Provo, Utah 84601, U.S.A.

The concept of a "Cordilleran sea" was advanced by Walcott in 1893, depicted on a paleogeographic map by Schuchert in 1910, elaborated up-

on by Eardley in 1951 (when he termed it a geosyncline and noted that it consisted of a western (Pacific) and an eastern (Rocky Mountain) trough), and its history through the Paleozoic and Early Triassic was summarized by Armstrong in 1968. Permian and Lower Triassic rocks of parts of western Utah, eastern Nevada and south-central Idaho accumulated in the eastern trough — the Cordilleran miogeosyncline; this was a major depocenter in this downwarped portion of the earth's crust. Evidence favors the interpretation that thicknesses of measured sections of Permian and Triassic strata within most of this miogeosyncline represent true sediment accumulations, not stacked-up sheets resulting from thrust faulting or gravity sliding. In a few places adjacent to the eastern edge of the miogeosyncline, and also in places along its western boundary, some overthrust or gravity-driven segments are present; some of the latter may have been displaced during the Sonoma orogeny, whereas those along the eastern margin formed during the Laramide orogeny. However, for the most part, the Upper Permian and Lower Triassic marine sediments studied for this project are interpreted as being autochthonous carbonate and minor clastic sediments that accumulated in and adjacent to the axial part of the miogeosyncline, without orogenic interruption.

During Leonardian and Early Guadalupian time the Kaibab sea transgressed northward in the Cordilleran miogeosyncline, and possibly did not extend beyond what is now Wendover, Utah-Nevada. Characteristic sponges, bryozoans, brachiopods, algae and some other fossils permit safe correlation with southerly outcrops of the Kaibab. Throughout large areas of outcrop in western and northwestern Utah and adjacent eastern and northeastern Nevada, the Kaibab is overlain in succession by the Plympton, Indian Canyon and Gerster Formations; these four formations are collectively assigned to the Park City Group. The Loray Formation beneath the Kaibab in this part of the ancient miogeosyncline contains distinctive ammonoid faunas of Early Guadalupian age low in the section. These fossils also occur in the Phosphoria Formation farther north. A few thousands of feet of predominantly carbonate rock comprises that portion of the Park City Group above the Kaibab, and its contained conodonts may yet prove that rocks of Upper Permian age are present.

Wherever preserved, the sediments of Early Triassic age in this vast area rest with apparent blended and parallel disconformable relations upon the Gerster. Both the uppermost Paleozoic and lowermost Mesozoic sediments contain conodonts; perhaps a solution to the enigma of why the boundary between two erathems, the Permian and Triassic, is evidently represented by a hiatus of substantial time span, will be resolved when the microfossils are more completely studied. To date, no evidence of the presence of so-called "Ochoan-age" rocks has been found in this part of the Cordilleran region. The term Ochoan, therefore, is rejected for uppermost Paleozoic rocks in the Cordilleran miogeosyncline, and it is suggested that the portion of the Guadalupian in this area which is represented by the Gerster Formation is possibly as young as any Permian now known for the United States, and may be younger. The Permian-Triassic boundary may represent, therefore, a minor hiatus, not necessarily an erosional vacuity occupied by a long time interval.

PERMIAN-TRIASSIC BOUNDARY IN THE MIDDLE ROCKY MOUNTAINS

D. W. BOYD

Department of Geology, University of Wyoming, Laramie, Wyoming 82070, U.S.A.

Permian and Triassic strata of the Middle Rocky Mountain region (Wyoming, southwestern Montana, eastern Idaho, and northern Utah) reflect geosynclinal conditions to the west and shelf environments to the east. Sequences of thousands of feet of strata in southeastern Idaho and northern Utah give way eastward to intervals a few hundred feet thick. Geosynclinal areas were sites of deposition of Permian phosphorite, chert, and dark mudstone, and of Triassic olive shale, tan siltstone, and grey limestone. A broadly comparable west to east marine-nonmarine transition characterizes both systems, with red beds dominating in eastern Wyoming.

The specific boundary between the two systems at any one locality is placed primarily on lithologic evidence. Throughout much of the region, the beds below the contact are notably resistant to erosion whereas those above the contact are not. Attitudes are typically conformable on each side of the contact, and evidences of pre-Triassic erosion are aspects of microrelief on a generally flat surface of great extent. The contact commonly lacks a basal conglomerate, whereas minor intraformational conglomerates and discontinuity surfaces can be found within both Permian and Triassic sequences.

A change from carbonate to fine-grained, land-derived sediment typifies the contact through much of Wyoming. To the east, red beds overlie red beds, and to the west, each of the several Permian geosynclinal rock types can be found directly below Triassic shales and calareous siltstones. Sandstone forms the upper Permian beds in southwestern Montana. The Upper Permian strata commonly exhibit silicification, whereas the Lower Triassic beds do not. Bedded evaporites commonly occur in drab Lower Triassic strata of the shelf, whereas they are limited to the red bed sequence in the Permian.

Through most of the region, zone fossils are lacking in strata near the contact. For the most part, the youngest Permian faunas are either nondiagnostic, or are of Guadalupian aspect. In the Teton Pass area of northwestern Wyoming, a small collection of brachiopods suggests the possibility of post-Guadalupian Permian beds. Southeast Idaho has one of the thickest Lower Triassic marine sections in the world. It contains a notable sequence of Lower Triassic ammonoid zones, starting with an upper Otoceratan assembage, but ammonoids are absent in the shelf sequence. The Upper Permian and Lower Triassic strata contrast strikingly in diversity and abundance of fossils. Groups common in Perian strata but absent in Lower Triassic beds include bryozoans, productoids, seven bivalve superfamilies, echinoderms and scaphopods. Three bivalve general and linguloid brachiopods account for most of the Lower Triassic fossils.

Over the shelf, the youngest fossiliferous Permian strata were deposited in sublittoral to supralittoral carbonate environments, and a hiatus possibly representing several million years separates the two parallel sequences This area was probably subaerially exposed, but remained nearly at sea level. Erosion, solution, and soil formation were minimal, probably reflect-

ing lack of relief and arid climate. To the west, mudstone deposition may have persisted in some localities during much or all of this time. Renewed deposition on the shelf took place in shallow water in which high salinities prevailed farther west than in Permian seas.

THE PERMIAN-TRIASSIC BOUNDARY ON THE SAHARAN PLATFORM

P. F. BUROLLET AND G. BUSSON

Co. Française des Pétroles, 19 Av. de Messine, Paris, France

The nature of the Permian-Triassic boundary on the Saharan Platform area is geographically variable. In the northeastern region of the Saharan Platform (southern extremity of Tunisia and northern Tripolitania) the Permian, which is locally conformable upon the Carboniferous, and is itself overlain conformably by the Trias, is partially marine (the only marine Permian to be found on the African continent). Overlying the thick Lower Permian sequence with marine fossils, and a less fossiliferous Middle Permian that is mainly dated by its stratigraphic position, lies the richly-fossiliferous Upper Permian. This Upper Permian is extremely thick locally (about 6,000m or 19,680' at Tebaga de Medenine), thinning with increasing proportions of clastic material to the west, south and south-east. Before wedging out completely it discordantly trangresses various Paleozoic horizons. It is the precursor of the on-lapping transgressions that begin with a major transgression in the Trias and continue intermittently during most of the Mesozoic.

Although the Trias is sometimes conformable upon the Permian, it is found that to the west, south and south-east (Algeria, Tunisia and Libya) the Trias extends far beyond the Permian limits and transgresses older Paleozoic beds. The Lower Triassic, dated mainly by its stratigraphic position, and the richly fossiliferous Middle Trias together make up a clastic formation called the "Trias gréseuz". Toward the center and north-east of the basin part of this formation changes laterally to evaporites which continue to occur in the Upper Trias.

On the rest of the Saharan Platform, some of the continental beds are questionably identified as Permian. These are found in restricted, isolated, residual basins forming part of the Paleozoic cycle. (Tigentourine Series in the Polignac Basin; Abadla; Tindouf?). The absence of an overlying conformable Lower Triassic cover for these beds suggests that the Lower Trias was never deposited here.

TETRAPODS AND THE PERMIAN-TRIASSIC TRANSITION

E. H. COLBERT

Museum of Northern Arizona, Flagstaff, Arizona 86001, U.S.A.

The transition between the Permian and the Triassic Periods would seem to include one of the great faunal breaks in geological history. There is abundant evidence for this, particularly among fossils collected from marine rocks in the Northern Hemisphere. A question arises, however, as to whether all faunal breaks between these two geologic periods are as profound as some of them appear to be. This question is brought to the

fore by the record of sediments and included terrestrial vertebrates, especially as they occur in certain parts of the Southern Hemisphere. In South Africa there is little sedimentary evidence to distinguish between the top of the Permian *Cistecephalus* Zone and the base of the Triassic *Lystrosaurus Zone*. Although there are many extinctions among terrestrial vertebrates at the end of the Permian Period, there are also important holdovers from that period into the Triassic. The Carboniferous, Permian and Triassic terrestrial sediments are characterized by the presence within them of labyrinthodont amphibians, primitive reptiles, and diverse mammal-like reptiles, which is in decided contrast to the Jurassic and Cretaceous terrestrial sediments, containing modern types of amphibians and reptiles, as well as the ubiquitous and dominant archosaurian reptiles. Thus there was a significant break in vertebrate life at the end of the Triassic Period, as well as at the close of the Permian Period.

NEW AGE ASSIGNMENTS IN GLASS MOUNTAINS STRATIGRAPHY

G. A. COOPER[1] AND R. E. GRANT[2]

[1]Department of Paleobiology, U.S. National Museum,
Washington, D.C. 20560, U.S.A.
[2]U.S. Geological Survey, Room E 501, U.S. National Museum,
Washington, D.C. 20560, U.S.A.

Based on the preponderance of brachiopod evidence, the following new assignments are made: the upper part of the Gaptank Formation is placed in the Wolfcamp Series, as is the Skinner Ranch Formation. These assignments are based on early spasmodic arrival of such Permian elements as *Limbella* (an aulostegid brachiopod), *Scacchinella* (a well-known Permian type) and *Waagenoconcha* in rocks formerly considered of Late Pennsylvanian age. These three and other Permian types arrive in force in the famous *Uddenites*-bearing Shale Member of the Gaptank Formation, here placed at the bottom of the Permian. Many Pennsylvanian and Wolfcamp genera and the great biohermal assemblages of the Wolfcamp rocks had their heyday in the Skinner Ranch Formation, which represents the end of the Wolfcamp Series.

Faunas of the Road Canyon Formation have already been assigned to the Leonard Series by Cooper and Grant (1966) who regarded the preponderance of the fauna to be Leonard in generic content and general expression. Higher Word Formation assemblages are correlated with the Guadalupe type area as follows: China Tank Member fossils (formerly Second Limestone Member) appear in the Cherry Canyon Formation, Lower Getaway Limestone Member of the Cherry Canyon has the fauna of the Willis Ranch Member (Third Limestone of the Word of P. B. King) and Upper Getaway contains fossils of the Appel Ranch Member (Fourth Limestone of the Word). The South Wells Member of the Cherry Canyon, a black shale and carbonate facies, seems not to be represented in the Glass Mountains. Bell Canyon Formation (Hegler Member) fossils have been found in undolomitized limestone at the base of the Capitan Limestone in the Glass Mountains.

Although these changes are based largely on brachiopods they are in accordance with age indications of other groups in some cases, but not in all.

LIFT HIGH THE LAMP-SHELL, THAT ITS LIGHT MAY ILLUMINATE THE PRINCIPLES AND PRACTICES OF CORRELATION IN THE PERMIAN

G. A. COOPER[1] AND R. E. GRANT[2]

[1]Department of Paleobiology, U.S. National Museum,
Washington, D.C. 20560, U.S.A.
[2]U.S. Geological Survey, Room E 501, U.S. National Museum,
Washington, D.C. 20560, U.S.A.

Interpretation of events that produced the acknowledged differences between Permian and Triassic invertebrate faunas depends partly upon evaluation of the relative ages and correlations among rock units in the boundary regions and also of units within undoubted Permian or Triassic. Our study of Permian brachiopods has shown that their stratigraphic distribution leads to correlations that are different in certain parts of the section from those based upon the fusulinid Foraminifera or the ammonoid Cephalopoda.

Fusulinids are rare or absent in the Upper Permian strata most directly relevant to the Permian-Traissic boundary, so we have concentrated on comparison of correlations based on brachiopods with those based on ammonoids. Our salient conclusions are: 1) the index-fossil concept must be abandoned in favor of full and balanced evaluation of the total fauna at each level; 2) uncritical reliance upon first or last appearance of faunal elements must be abandoned in favor of the same considerations; 3) age determinations based upon inferred positions of faunas from regions with no stratigraphic sequences should be abandoned in favor of biostratigraphic zonations based upon actual and observed superposition; 4) hypothetical phylogenies should be abandoned in favor of observed evolutionary sequences within strata in physical contiguity; 5) crucial faunas should be analyzed in terms of the ecological requirements of their constituent organisms.

Application of these empirical priniciples to various Permian sequences leads us to the proposition that the following four-fold subdivision, in ascending order is suitable for worldwide correlations: Wolfcamp, Artinsk, Guadalupe and Dzhulfa. We follow Tozer (1969) in placing the top of the Permian above the beds that contain numerous Permian brachiopods, along with *Paratirolites,* in the Dzhulfa section. In Guryul Ravine, Kashmir, the only place where the boundary occurs in normal marine facies, within a lithic unit, and without evidence for unconformity, we place the top of the Permian within bed 52a of Nakazawa *et al.* (1970). The Permian-Triassic boundary in the Salt Range is placed in or at the top of the dolomite unit of the Kathwai Member of the Mianwali Formation, based upon the major constituents of the fauna and the weak evidence for a Triassic age.

Detailed analysis of the world's most complete Upper Permian sequences highlights the tenuous nature of present correlations. In west Texas the typically Permian productid brachiopods tend to decrease drastically in number in the Capitan Limestone and its equivalents, compared to earlier units. The only known fauna from the Ochoa Series is so generalized as to be hardly distinguishable from the Pennsylvanian farther east.

In the Salt Range, long considered to have a complete Upper Permian sequence, fusulinids terminate below the Wargal Limestone, but the sup-

posedly Late Permian guide foraminifer *Codonofusiella* occurs with an Artinskian *Monodiexodina* in the Amb Formation. The Salt Range is the only region where the supposedly latest Permian ammonoid *Cyclolobus* occurs in a continuous stratigraphic section. Its range begins in the Kalabagh Member of the Wargal Limestone and dies out below the top of the Chhidru Formation; this range based upon thirteen specimens. This rare ammonoid is absent from the Dzhulfa sections of Soviet and Iranian Armenia, but *Pseudogastrioceras,* whose range begins in the Wolf-camp in Texas and in the Kalabagh Member in the Salt Range, extends into beds that have been interpreted as the third zone into the Triassic in the Dzhulfa sequence (but below the highest Permian brachiopods, hence Permian in our estimation).

The New Zealand Permian, while thick and perhaps complete, is sparsely fossiliferous and lacks both fusulinids and ammonoids. Its stages are correlated with those in Australia by brachiopod species and then to the rest of the world by Australian brachiopods and ammonoids. Unfortunately, ammonoids terminate in the Lower Guadalupian (Word) of Australia. The southern Chinese Permian is truncated by a physical unconformity. The Wuchiaping Formation contains a large brachiopod fauna with many genera in common with the Chhidru Formation. The overlying Changsing and Talung formations (Upper Loping Series) also contain brachiopods characteristic of the Chhidru that range into the Dzhulfian, along with fusulinids that occur elsewhere in beds of Late Guadalupe age and with cyclolobid ammonoids with sutures that are simpler than those of *Cyclolobus.*

Some biostratigraphers place the base of the Triassic at the first appearance of ammonoids whose generic names normally appear on lists of Triassic fossils; others place it at the base of whatever lithic unit contains the bivalve *Claraia.* Both procedures are arbitrary; one fails to consider evoluntionary principles, the other neglects paleoecological conditions.

THE PERMIAN-TRIASSIC VERTEBRATE FAUNAS OF SOUTHERN AFRICA

A. W. CROMPTON

Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138, U.S.A.

The vertebrate faunas of the Late Permian and Early Triassic of southern Africa will be compared. Contemporary faunas from South America, India and China will also be considered. The dominant terrestrial vertebrates of the Permian were mammal-like reptiles but, except for a few specialized herbivores and small insectivores, all the mammal-like reptiles became extinct at the end of the Permian. During the Permian the Eosuchia (small insectivorous reptiles ancestral to the Archosauria and Lepidosauria) apparently formed a minor part of the terrestrial vertebrate fauna but with the extinction of the mammal-like reptiles these two subclasses underwent an explosive radiation and by the end of the Triassic formed the dominant elements of the terrestrial vertebrate faunas.

An attempt will be made to explain the shift from a fauna dominated by mammal-like reptiles to a fauna dominated by archosaurs and lepidosaurs in terms of the temperature control mechanism of these groups. It is concluded that the temperature control mechanism of the mammal-

like reptiles was similar to that of the monotremes and that the environmental temperatures had to be lower than the optimal body temperature during periods of activity. On the other hand, the temperature control mechanism during periods of activity of the lepidosaurs and primative archosaurs required environmental temperatures close to or higher than the optimal body temperature. This explanation may throw some light on the climatic conditions in southern continents during the Permian-Traissic transition.

PATTERNS OF MARINE FAUNAL DISTRIBUTION AND EVOLUTION IN THE UPPERMOST PERMIAN AND LOWERMOST TRIASSIC

A. S. DAGIS AND V. I. USTRITSKY

National Committee of Geologists of the U.S.S.R.

The Permian was a period of extremely sharp climatic zonation and consequent faunal differentiation. Definite trends in marine faunal composition and evolution are recognized in both the Permian polar regions (Boreal and Notal) and also in the tropical region.

In the Permian polar regions there was a significant faunal impoverishment and many groups of higher taxonomic rank were absent. The fauna of the Boreal and Notal areas consisted mainly of endemic genera or, rarely, families. Thus groups with a bipolar distribution, but absent from the tropical area, represented a major part of this fauna. A characteristic feature of the polar regions in the Late Permian is the reduction in the rate of the appearance of new forms and the gradual extinction of already existing Paleozoic groups. Thus only a few taxa survived the close of the Permian and passed into the Triassic in these regions.

In the tropical area, many endemic orders and superfamilies were present. Here the extinction of most of the Paleozoic groups began later and proceeded more rapidly than in the polar regions. Strata containing surviving Paleozoic groups will often yield typical Mesozoic faunal elements causing difficulties for those attempting to accurately define the Permian-Triassic boundary. A significant number of taxa of high rank thus pass from the Permian into the Triassic. Late in the Permian, the tropical area appears to have been a refuge for marine faunas. In Early Triassic times a general climatic amelioration took place, the seas transgressed and an abundant fauna migrated north and south from Tethys to occupy the polar regions. The beginning of this widespread transgression coincides with the base of the *Otoceras* Zone and it therefore seems appropriate to draw the Permian-Triassic boundary at this level.

PERMIAN-TRIASSIC OF THE WESTERN CORDILLERAN EUGEOSYNCLINE

W. R. DANNER[1] AND M. K. NESTELL[2]

[1]Department of Geology, University of British Columbia, Vancouver 8, B.C., Canada

[2]Department of Mathematics, University of Texas at Arlington, Arlington, Texas 76010, U.S.A.

Permian sequences in the western Cordilleran eugeosyncline range in age from Wolfcampian to Guadalupian. Limestone lenses in these sequences contain fusulinids, other foraminifera, algae, bryozoa, corals and brachiopods. Fusulinids are the most important fossils for stratigraphic

dating. A large proportion of Leonardian time is not represented by recognizable fossils. The latest Permian marine faunas are Tethyan types dominated by the fusulinid genus *Yabeina*. Its association with *Codono-fusiella* correlates it with the late Guadalupian of the American Southwest. In addition, the fusulinid genus *Reichelina* also occurs with *Codono-fusiella*. A higher fusulinid zone, the zone of *Palaeofusulina*, found in the Asiatic Tethys has not been found in North America.

The youngest Permian stratigraphic sequence is composed of bedded radiolarian cherts, large limestone lenses, argillite, greywacke and volcanic rocks. The radiolarian cherts may be as much as 5000 feet thick and form the thickest and most widespread radiolarian chert sequences known in the world. The chert-limestone-volcanic rock assemblage is typical of the Tethyan faunal areas and raises the question of whether the Tethyan faunas are a distinctive geographic realm or a facies fauna. The presence of the Tethyan faunal realm in western North America also raises the question of continental breakup and attachment due to sea-floor spreading.

It is possible that near the end of Permian time a segment of the Tethyan area moving eastwards collided with western North America, raising its depositional basins above sea level along the west side of North America. The resulting uplift did not produce intense deformation but resulted in the widespread western Cordilleran Late Permian-Early Triassic hiatus. By Middle Triassic time either part of the Tethyan block began to move away from North America, producing an ever-widening sea, or the major portion of it began to submerge and "oceanize."

The specialized adaptation to specific environments of many Late Paleozoic faunas and floras brought them to extinction as the world's major land masses were elevated and joined and areas of shallow seas markedly reduced. A change in polarity may have also taken place about this time and exerted an as yet unknown influence on the world's life.

Triassic rocks are conformable, unconformable, and in fault contact with the Permian. The actual contact is rarely visible and most often very difficult to establish with certainty. In several parts of British Columbia the contact appears to be represented by Upper Triassic marine volcanic rocks overlying Permian limestones.

In general the Triassic rocks in contact with the Permian are older to the east and younger to the west. The Triassic sequence appears to represent volcanic island marine deposition. Coral and spongiomorph reefs formed around the islands and dense to shelly limestones were deposited offshore, interbedded with volcanic rocks and clastics.

The puzzling hiatus between the Permian and Triassic in the western Cordilleran eugeosyncline should be viewed in the light of sea-floor spreading and its effect on stratigraphy, as well as from the standpoint of classical "layer cake" stratigraphy.

THE GEOLOGICAL SEQUENCE AND THE PERMIAN-TRIASSIC BOUNDARY IN AUSTRALIA AND EASTERN NEW GUINEA

J. M. DICKINS

Bureau of Mineral Resources, Geology and Geophysics,
Box 378, P.O. Canberra City, 2601, Australia

Upper Permian marine sequences are limited in area in comparison with Lower Permian. Uppermost Permian marine rocks have not so far

been recognized in Australia and lowermost marine Triassic (Otoceratan) is known from the Perth Basin. Brackish water beds of the same age are found in the Canning and possibly the Bonaparte Gulf Basin.

In the western part of Australia, Permian and Triassic rocks are known in the Bonaparte Gulf, Canning, Carnarvon and Perth Basins. The rocks in all basins are apparently separated by hiatus but without marked structural discordance. In the Bonaparte Gulf and Canning Basins, lagoonal or brackish-water Lower Triassic overlies marine Permian but uppermost Permian is apparently lacking. In the Carnarvon Basin, non-marine sandstone is regarded as Upper Permian and Lower Triassic is not known, although Middle to Upper Triassic has been identified in offshore drilling. In the Perth Basin, Otoceratan and younger Triassic in places overlies Upper Permian non-marine rocks with an hiatus. The position of the boundary is based on marine invertebrates and spores.

In eastern Australia, marine Lower and Upper Permian passes up into non-marine Upper Permian and Triassic, in the Bowen, Sydney and Tasmania Basins. The boundary has been placed at the highest occurrence of the *Glossopteris* flora and its associated microflora but currently this interpretation is under critical review. Breaks are recorded but their exact relationship to the boundary is not clear. The Tasman Geosyncline in eastern Australia was subject to instability and considerable igneous activity during the Permian and possibly into the Triassic. Radiometric dating shows widespread granitic intrusion close to the Permian-Triassic boundary.

In the central part of Australia, non-marine Permian and Triassic are generally separated by hiatus.

In eastern New Guinea, Permian marine rocks are recorded lying on an erosional surface of a granite which on radiometric evidence is close to the Permian-Triassic boundary. Lower Triassic has not been recognized.

The Lower Permian, thus, is a time of widespread marine transgression and an overall cool climate, followed in the Late Permian by withdrawal of the seas until in the latest Permian the sea may have retreated entirely from the present land mass. The climate became milder and by Triassic time warm to even tropical conditions existed. Tectonic and igneous activity were milder and less widespread in the Triassic. From the evidence the radical transformation of the fauna during Permian and Triassic time may well have been connected with the changes in paleogeographic conditions, particularly the withdrawal of shallow seas from the present continental area.

THE PERMIAN-TRIASSIC BOUNDARY IN THE MEDITERRANEAN AREA

R. C. DOUGLASS

U.S. Geological Survey, Room E 114, U.S. National Museum, Washington, D.C. 20560, U.S.A.

The area of the western Mediterranean and bordering continental Europe appears to have stabilized during Late Paleozoic time, with only minor basins on a continental mass and near-marine margins accumulating red bed deposits, interspersed with variable amounts of evaporites. Local outpourings of volcanic rocks suggest possible advance warnings of tectonic activities to follow, or perhaps only relaxation of compressional forces

after the last phases of Hercynian activity. Locally, more marine waters deposited the Bellerophon Limestone of the Italy-Yugoslavia area, but the age relationships of this limestone to the other Upper Permian deposits is not clear. The lowermost Triassic rocks may succeed the uppermost Permian in the continental basins and evaporite sequences. No evidence of marine lowermost Triassic has been documented for the western part of the Mediterranean area, but by Late Scythian to Early Anisian time marine deposits extended as far west as the southern Alpine areas and later Triassic marine rocks are not uncommon in that area.

Southeast of the continental mass, marine deposits of Early Permian age accumulated in a shallow seaway. Marine limestones with faunas including brachiopods and fusulinids of Early Permian age are known from Yugoslavia, Greece and Turkey. These are bedded deposits that have been preserved to the present in a disturbed (folded and faulted) condition, but in recognizable sequences. Whatever events took place after their deposition were not enough to metamorphose or destroy those deposits. Most of the marine rocks of later Permian age in the Mediterranean occur only as isolated cobbles, blocks and larger masses in deposits of Triassic or younger age. The rocks are of approximately the same age as the deposits in Tunisia. They are found in Sicily, Yugoslavia, Greece, Cyprus and Turkey. It is not known whether these rocks were originally deposited near their present positions or whether they have been transported tectonically over short or longer distance. The rocks have faunas in common that are of approximately Guadalupian age and they bear typically Tethyan fusulinid faunas rich in verbeekinids and neoschwagerinids.

The almost complete lack of Upper Permian marine beds in depositional sequence between the Afghanistan-Iran area on the east and Tunisia on the west suggests that diastrophic forces, possibly directly related to the closing of the Tethys seaway, have redistributed the rocks of Late Permian and possibly Early Triassic age throughout most of the Mediterranean area. Whether there was continuous deposition of marine Permian across this area is problematical, but it seems reasonable to assume an original break in the depositional pattern, with normal deposition at both ends.

The fusulinid faunas in the Mediterranean area reached their peak of abundance and diversity during the early part of the Guadalupian and then died out gradually in the later part of the Guadalupian. Only a trace of fusulinids lived on into the later Permian, with three or possibly four genera surviving into the Dzhulfian and those represented only in limited areas by few specimens.

The restriction of the continental seaways with the increase in saline deposits did not provide suitable environments for the continued success of the fusulinids. The marine areas marginal to the continental seas might have continued to provide suitable environments but the records of many such areas have since been destroyed by subsequent tectonic events. The few fusulinids that survived to Late Permian times were apparently more adaptable to the restricted environment available.

The Mediterranean area yields little information on the Permian-Triassic boundary because of the paucity of rocks assignable to Late Permian or Early Triassic age in the area. Where the rocks appear to be continuous, the evaporite facies makes age assignment difficult, and where the rocks are marine, the tectonic activity has destroyed the stratigraphic relationships.

PROBLEMS OF UPPER PERMIAN AND TRIASSIC STRATIGRAPHY ON THE RUSSIAN PLATFORM, IN THE LIGHT OF PALEOMAGNETIC, PALEONTOLOGICAL AND LITHOSTRATIGRAPHIC EVIDENCE

N. N. Forsh, A. N. Khramov and E. A. Molotovsky
National Committee of Geologists of the U.S.S.R.

Stratigraphic studies of reference sections of Upper Permian and Triassic red beds on the Russian Platform have led to the compilation of a detailed stratigraphic succession. At the same time paleontological work has revealed a vertical distribution of terrestrial vertebrate assemblages which closely corresponds with the stages and substages and therefore has some biostratigraphic value.

Detailed paleomagnetic studies of the Permian and Triassic red beds of the platform have indicated the presence of alternating normal and reversed magnetic episodes from which a standard paleomagnetic section has been compiled. This section may conveniently be correlated with the major subdivisions of the stratigraphic succession.

Continental deposits of the Kazanian Stage are characterized by the Fore-Ural *Deinocephalus* assemblage, while the Lower Tatarian Substage is typified by the Isheev *Deinocephalus* assemblage. Paleomagnetic work reveals that the deposits of the Ufimian and Kazanian stages, and the Lower Tatarian Substage, collectively represent a single, continuous paleomagnetic unit of reversed polarity (R_1P).

The Upper Tatarian Substage is characterized by the Severodvinsk *Pareiasaurus* and the Gorki *Batrachosaurus* assemblages. Paleomagnetically, this substage is divided into four units: N_1P, R_1P N_2P and R_2P. The unit R_2P is not present in the Kazan region and in the sections exposed in the southern Urals.

In the overlying Triassic deposits, the Lower Triassic section can be divided into four subdivisions based on alternations in paleomagnetic direction: N_1T, R_1T, N_2T, and R_2T. The Middle and Upper Triassic strata have normal magnetic fields and can provisionally be regarded as a single zone N_3T (the Fore-Ural zone).

Permian and Triassic deposits of the Russian Platform have long been considered a standard for correlation with synchronous rocks of other regions of the world. The relative distribution of normal and reversed magnetism in Permian and Triassic rocks on the platform is essentially the same as in North America, South Africa and Australia, thus demonstrating the objective value of paleomagnetic correlations. Boundaries of major zones, such as the R-Kiama-NR-Illavara zone and the NR-Illavara-N-Fore-Ural zone can therefore be regarded as reliable isochronous units of worldwide significance.

PERMIAN AMMONOID ZONATION

W. M. Furnish and B. F. Glenister
Department of Geology, University of Iowa, Iowa City, Iowa 52240, U.S.A.

Twelve Permian stages, each characterized by distinctive levels in ammonoid phylogeny, can now be defined; all have a geographic derivation in reference areas of the Urals, West Texas, Timor, Armenia, Pakistan, or

south China. Four series (Sakmarian, Artinskian, Guadalupian, and Dzhulfian) correspond to a traditional zonation of the past half-century, except that the non-marine sequence of the Russian Platform is regarded as an impractical reference. No pronounced break exists within this series of faunas. There is a perceptible difference between Upper and Lower Permian, but the extinction of six familial groups and introduction of two at the end of the Wordian Stage (basal Upper Permian) marks the greatest numerical change. Despite these differences, the Wordian-Capitanian boundary lies within the known range of seven familial groups constituting all the common ammonoids of the Guadalupian Series. The ammonitic Perrinitidae and Cyclolobidae serve collectively as primary zonal indices throughout the Permian. Where perrinitids are lacking, as in the Ural sections, and cyclolobids are too rare to be effective references, an additional five or six evolving groups can be employed to supplement the regular index forms and substantiate a sequential arrangement.

Twenty-eight ammonoid stocks of familial or subfamilial rank are recognizable in the Permian. Eleven of these phylogenetic units are represented in the Upper Pennsylvanian, but only one transgresses the Triassic boundary (as now defined). Directly ancestral forms are known for an additional four familial groups introduced at the base of the Permian. Two such stocks continue into the Triassic under different familial designations.

Extensive sequences of Permian ammonoid faunas have been found at only a few areas. Those of the Sakmarian and Artinskian Series are best known in the type area of the Ural Mountain region and to a lesser extent in Texas. A knowledge of the Guadalupian Series is based largely upon a combination of sections in Coahuila and West Texas, although the most diverse single fauna is from Sicily. Timor Permian ammonoids span all of the system except the Upper (Dzhulfian) Series. Late Permian has its best development in the eastern Tethys region.

Most Permian ammonoid families were cosmopolitan and many species had a worldwide distribution. A few genera within the Artinskian Series were endemic. Also, some goniatitic genera appear to have persisted in high latitudes, but such a relationship is obscured by range extensions of other forms within the Tethyan Upper Permian.

LATE PERMIAN AND EARLY TRIASSIC FAUNAL HISTORY: CATASTROPHE OR CONFORMITY?

D. J. GOBBETT

Sedgwick Museum, Cambridge University, Cambridge, England

The fossil record of the Late Permian and Early Triassic is reviewed. Difficulties of time-correlation in the Late Permian and insufficient knowledge of the time-distribution of Late Permian fossils has caused many of its interpreters to telescope events and to postulate a marked dislocation in the faunas over a very short time period (geologically instantaneous). This dislocation is used to define the Permian-Triassic boundary. It is argued that the factors influencing the evolution of organisms during the Late Permian and Early Triassic do not differ qualitatively from those at other times within the Phanerozoic. The Permian-Triassic boundary should be defined arbitrarily within a selected rock sequence and regardless of whether "Paleozoic" fossils are then to be found in Triassic rocks.

THE KUNGURIAN AND UFIMIAN STAGES OF THE PERMIAN

V. P. GORSKY AND E. A. GUSSEVA

National Committee of Geologists of the U.S.S.R.

Strata representing the time interval between the Artinskian and Kazanian Stages were examined by the authors from Permian type localities in the Fore-Urals region. Ostracoda are extremely widespread in distribution in these deposits and proved to be most useful for biostratigraphic purposes.

This study has shown that the Kungurian assemblage of lagoonal-marine Ostracoda is distinctive and easily separable from Artinskian and Kazanian assemblages. A clear division into Early and Late Kungurian subdivisions is possible, thus allowing recognition of two distinct substages. Two ostracode zones *(Bairdia reussiana* and *Paraparchites humerosus)* are distinguished in the Lower Kungarian, and one *(Acratia similaris)* in the Upper Kungurian. The *Bairdia plebeia* Zone of Early Ufimian age shows some resemblance to the latter, but, in general, all the ostracode zones may be delimited without difficulty in the Fore-Urals region.

The Artinskian and Kungurian Stages in the Fore-Urals region are separated by a well-defined lithological and paleontological boundary. The boundary between the Kungurian and Ufimian stages, on the other hand, is diachronous and is marked by a facies change from lagoonal to continental deposits. Significant differences between Ufimian and Kungurian freshwater Ostracoda have not yet been recognized, but such differences can be established between Ufimian Ostracoda (freshwater and marine) and those of the Kazanian.

Cyclofacies analysis indicates that strata from the lower part of the Ufimian are genetically related to those of the Kungurian. They form a single regressive series of sediments and are collectively equivalent to the other stages of the Permian, which apparently correspond, at least in the Fore-Urals region, to transgressive or regressive half-cycles of sedimentation.

Thus studies of Permian deposits from their type localities suggest that the interval between the Artinskian and Kazanian stages may conveniently be regarded as a single stage, comparable with the Svalbardian of the Boreal paleogeographic province.

PERMIAN-TRIASSIC RELATIONSHIPS AND FAUNAL CHANGES IN JAPAN AND EASTERN TETHYS

K. KANMERA[1]; K. NAKAZAWA[2] AND M. MINATO[3]

[1]Department of Geology, Faculty of Science, Kyushu University, Fukuoka, Japan
[2]Geological and Mineralogical Institute, Faculty of Science, University of Kyoto, Kyoto, Japan
[3]Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, Sapporo, Japan

The Late Paleozoic geosyncline of Japan was subjected to orogenic movements in Permian and Triassic times resulting in the disappearance of the marine carbonate facies, a reduction of sedimentary areas in the inner belt and a southward shifting of the main axis of the depositional

basin to the outer belt. Here two major facies can be differentiated: a western facies, characterized by deposition in shallow, highly-magnesian waters (latest Permian-earliest Triassic), and an eastern facies, characterized by rapid deepening and violent submarine volcanism.

The Upper Permian is divisible, in ascending order, into the zones of *Lepidolina kumaensis*, *Reichelina changsingensis-Palaeofusulina simplicata*, and *Staffella* spp., the last two allowing correlation with the uppermost Permian of China. The Upper Permian of the inner belt, which is referable to the last two zones, and yields many bivalves and gastropods, is unconformably overlain by strata containing the Lower Triassic ceratite *Glyptophiceras* cf. *gracile*. Embayment or inland-sea conditions, which prevailed in the inner belt during the latest Permian, are indicated by various lines of evidence, such as biofacies and lithfacies, percentage CaO, and intensity of radioactivity of the argillaceous rocks.

In the Kuma Mountains of the outer belt, 15m thick (49.2') unfossiliferous dolomitic beds lie between the *Staffella* spp. Zone and the Lower Triassic beds containing *Aspenites kamurensis*.

Upper Permian marine beds of carbonate facies, rich in fusulinids, corals and brachiopods, and terrigenous facies containing ammonoids and bivalves, cover a large part of south China and Indochina, but a widespread disconformity is recognized between the *Yabeina* Zone and the *Codonofusiella* Zone (Wuchiaping Stage, Lower Lopingian), and between the *Palaeofusulina* Zone (Changsing Stage, Upper Lopingian) and Lower Triassic with *Claraia* and *Ophiceras*.

Terrestrial facies with coal in the Wuchiaping, and with evaporites in the upper part of the Changsing, spread as the Permian sea gradually retreated southwestward into southern Kueichow, Szechuan and Yunnan. In southern Kueichow the *Pseudotirolites*-bearing Talung Formation, of terrigenous facies, is succeeded conformably by Lower Triassic strata containing *Claraia* and *Ophiceras*. In other parts of eastern Tethys, Middle or Upper Triassic beds rest conformably on Middle Permian or older rocks. Thus, in most areas of eastern Tethys the Permian-Triassic boundary is marked by a break in sedimentation. These changes were not contemporaneous everywhere, however, but occurred locally at different times.

Remarkable faunal changes took place between the *Yabeina-Lepidolina* Zone and the *Codonofusiella-Palaeofusulina* Zone, and at the Permian-Triassic boundary. All Permian species appear to become extinct at the systemic boundary in Japan and eastern Tethys. However, recent investigations reveal that some species of Permian brachiopods and bivalves survived into earliest Triassic in central Tethys, where they comprise a mixed fauna with lowest Triassic bivalves and ammonoids. Such a situation has been described from the continuous Permian-Triassic marine sequence of the Guryul Ravine section near Srinagar, Kashmir.

THE ECHINODERMS AND PERMIAN-TRIASSIC TIME

P. M. KIER

Department of Paleobiology, U.S. National Museum,
Washington, D.C. 20560, U.S.A.

The Permian-Triassic boundary is not of special significance in the development of most of the echinoderms. Although the Paleozoic echi-

noids are very unlike those of the Mesozoic, the transition between the two groups is gradual, covering a long period of time and not confined to the Permian-Triassic. The period of the greatest change in the echinoids is during the Late Triassic and Early Jurassic period. Over half of all the known orders of echinoids were introduced during this time, including the introduction of the "irregular" echinoids, development of compound ambulacral plates, introduction of gills, and the keeled tooth.

Although five orders and suborders of crinoids became extinct after the Guadalupian, this change as related to the Permian-Triassic boundary is not as catastrophic as it might seem at first glance. The decline in these taxa must have started earlier because all the Guadalupian species except one are restricted to Timor. Many genera become extinct at the end of the Permian but a large number also become extinct at the end of earlier and later periods. The Triassic and the Permian crinoid faunas are very distinct but much of this distinction may be due to the small number of crinoids known from the Triassic, and the lack of any Lower Triassic species. Although there is more evidence of significant change over the Permian-Triassic boundary in the crinoids than among other echinoderms, this change is probably more apparent than real. However, the absence of Triassic crinoids must indicate significant differences between the marine shallow-water environments of the Permian and Triassic.

Although the blastoids became extinct at the end of the Permian, their extinction probably bears little relationship to any events during the Late Permian, for their decline had begun far earlier. Only four genera are known from the Pennsylvanian of the world, and no Permian blastoids are known from the United States or Western Europe. The asteroids underwent no significant change during this period, with no new families originating during the Permian or Triassic. No new orders were introduced among the Ophiuroidea and no families became extinct during the Pennsylvanian, Permian, or Triassic. All the other classes of echinoderms became extinct before the Permian, and therefore are not dealt with herein.

In general, an evolutionary spurt did not occur in the echinoderms during the latest Permian or Early Triassic, but the absence of many echinoderms in the Early Triassic is evidence that the marine shallow-water environment was much different during this time from earlier or later. A great spurt in echinoid evolution occurred at the end of the Triassic and during the Early Jurassic. This great radiation may have been caused by the breakup of the continents which would have produced many new niches.

THE TRIASSIC SYSTEM IN THE SOVIET UNION

L. D. KIPARISOVA, T. M. OKUNEVA AND A. N. OLEYNIKOV
National Committee of Geologists of the U.S.S.R.

Widespread emergence of continental areas, begun in the Permian, continued into the Triassic in the U.S.S.R., reaching a maximum in the Early and Middle Triassic. Marine basins, especially epicontinental seas, decreased sharply and the importance of continental formations increased as a result of tectonism during the Late Permian and Early Triassic. Continental deposits were formed over vast platform areas, on peneplain-

ed Paleozoic folded structures of west Siberia, Kanzakhstan - Tien Shan and European Russia.

Marine Triassic sedimentation continued mainly in geosynclinal areas of the northeast, east and south of the U.S.S.R., where deposits consisting mainly of grey arenaceous and argillaceous strata were laid down under warm-temperate climatic conditions. Reef growth was absent in the Early and Middle Triassic but was renewed locally in Late Triassic times. Volcanism was much in evidence, especially in the Early Triassic of the Siberian Platform and west Transbaikal.

Active tectonism during the Paleozoic-Mesozoic interval may be demonstrated in most regions in the U.S.S.R. by disconformities and paraconformities. These result in the omission of parts of the Upper Permian and Lower Triassic in many sections. In the most complete marine sections, such as Verkhoyan, the Permian-Triassic systemic boundary is drawn at the base of the zone containing *Otoceras*, but in those regions where this rather rare form has not been found, the exact establishment of the boundary is difficult. Where continental or volcanic facies prevail, the problem is even greater. However, if terrestrial fossils are present, then the boundary is drawn at the base of the *Lystrosaurus* Zone, which appears to correspond to that of the zone containing *Otoceras*.

Climatic conditions at the beginning of the Triassic were apparently little changed from those of the Late Permian, but extreme marine regression caused great faunal changes, especially in benthonic forms. Thus the gradual extinction of Paleozoic faunal elements began in the Permian and increased toward the end of the period. By that time, fusulinids, trilobites, tabulate corals and tetracorals had disappeared, as well as some cystoids, blastoids and crinoids, while the representation of goniatites, brachiopods, bivalves and foraminifers was much reduced. In the Early Triassic, some Permian brachiopods *(Crurithyris, Fletcherithyris)*, bivalves *(Palaeoneilo, Atomodesma, Pteria, Posidonia, Bakevellia)*, nautiloids (Orthoceratidae, Grypoceratidae, etc.), agonialtites (Episageceratidae), ceratites (Xenodiscidae) and others continued to exist. At the same time new cephalopod families appeared, such as the Otoceratidae, Ophiceratidae, Sageceratidae and Syringonautilidae, while new bivalve genera included *Claraia, Eumorphotis, Leptochondria, Entolium* and *Anodontophora*.

The Triassic System in the U.S.S.R. is subdivided into three divisions. In the lower division of the marine Triassic, the Induan and Olenekian stages are recognized over large areas. The Middle Triassic is subdivided into the Anisian and Ladinian, and the Upper Triassic into Karnian, Norian and Rhaetian. Where continental deposits prevail, formations and series are correlated with the German standard succession by means of fossil plants.

Among immediate tasks suggested for detailed study in the Soviet Union are the following: the study of the systemic boundaries between the Permian, Triassic and Jurassic, the subdivision of the continental Triassic, the breakdown of stages into substages in the marine Triassic, and increased zonal refinement within the Permian and Triassic strata.

THE BIOSTRATIGRAPHY OF THE TRIASSIC OF SPITSBERGEN

M. V. KORCHINSKAYA

National Committee of Geologists of the U.S.S.R.

As a result of stratigraphic and paleontological research carried out by the author in Spitsbergen, a biostratigraphic scheme for the Triassic deposits has been worked out. The scheme, and its correlation with the Triassic standard suggested by Silberling and Tozer (1968) for North America, is given in Figure 2. It should be noted that the stratigraphic units in the last column are adopted from Buchan *et al.*, 1965.

BIOSTRATIGRAPHY OF THE LOWER TRIASSIC (SCYTHIAN)

B. KUMMEL

Museum of Comparative Zoology, Harvard University,
Cambridge, Massachusetts 02138, U.S.A.

Ammonoids of the Lower Triassic (Scythian) offer a unique opportunity to study a broad radiation of a group of invertebrate animals. This is, of course, due to the near extinction of ammonoids in the Late Permian. The survivorship of ammonoids across this threshold is extremely limited. Two of the surviving families led to no future radiations, the third, however, was the stem of the main radiation of Triassic ammonoids which include more than 400 genera. This particular threshold stock gave rise to approximately 140 genera during the Early Triassic (Scythian) alone.

Biochronology of the Lower Triassic (Scythian) began with the first proposal of a definition of this time unit by Mojsisovics, Waagen, and Diener (1895). Their proposal was based primarily on studies of ammonoid sequences in the Salt Range of West Pakistan by Waagen (1895) and in the Himalayas by Diener (1897). In the ensuing years much new data accumulated, clearly demonstrating that the original scheme encompassed no more than the lower half of the Lower Triassic (Scythian). In this period there gradually developed an elaborate sequence of zones. Each author of a particular regional faunal sequence laid claim toward "completeness" and "finality" for his arrangement. It is now very apparent that a scheme of 10 to 14 separate zones for purposes of worldwide correlation is impractical and unreal. It now seems probable that only four such zones serve for an international biostratigraphic scheme.

An evaluation of all Lower Triassic ammonoid genera now recognized is essential in reconstituting a biostratigraphic framework. Of the 136 genera recognized for this stage, 116 are present in the Tethys, only 52 in the circum-arctic region, and 73 in an intermediate region. In the evolutionary radiation of Scythian ammonoids there is a continuing expansion of numbers of taxa from the lowest to highest zone. At each of these recognized zonal steps the predominance of Tethys in numbers and diversity of taxa over that of the circum-arctic region is maintained at a ratio of approximately 2 to 1. Endemic elements are to a large extent confined to Tethys.

It has long been accepted that the lowest Scythian zone is that of *Otoceras-Ophiceras* as defined by Diener (1897; 1912). Discussion of this zone has always focused primarily on the genus *Otoceras* and this fact has led to a lack of perspective. In the Himalayas *Otoceras* and *Ophiceras* are associated, *Ophiceras* being by far the predominant element in the

Div.	Stage	Spitsbergen Zones	North American Zones	Spitsbergen Fauna and Flora	Ftn.
UPPER TRIASSIC	RHAET		Marshi		KAP TOSCANA FORMATION
	NORIAN		Suessi	*Oxytoma czekanowskii*	
			Columbianus	*Halobia cf. plicosa*	
			Rutherfordi	*H. cf. norica*	
			Magnus	*H. fallax*	*Danaeopsis marantacea, Asterotheca merianii, Paratersiella spetsbergensis Pterophyllum jaegeri Glossophyllum spetsbergense, Dictyophyllum* spp.
			Dawsoni		
			Kerri	*Estheriae*	
	KARNIAN		Macrolobatus	*Lima spitsbergensis*	
			Welleri	*Pleurophorus cf. perlongus*	
			Dilleri		
			Nanseni	*Discophyllites cf. ebneki, Nathorstites lenticularis H. gibbosus, H. tenuis, Paracladiscites cf. duiturnus, Trachyceratidae, Halobia zitteli.*	
			Obesum		
MIDDLE TRIASSIC	LADINIAN		Sutherlandi	*Nathorstites strongulatus, N. cf. sublenticularis, N. (?) aff. globosus, Protrachyceras sp. ind., Daonella subaretica, D. cf. dubia*	BOTNEHEIA FORMATION
			Maclearni		
			Meginae		
			Poseidon		
		Ptychites nanuk	Subasperum	*Daonella degeeri, Ptychites nanuk*	
	ANISIAN		Chischa	*Ptychites cf. trochlaeformis, Ussurites spetsbergensis, Frechites cf. humboldtensis, Gymnotoceras laqueatum, Parapopanoceras verneuili, Daonella lindströmi*	
			Deleeni		
			Varium		
		Grambergia	Caurus	*Grambergia, Lanubites, Stenopopanoceras, Japonites, Leiophyllites, Lenotropites, Pearylandites*	
LOWER TRIASSIC	OLENEKIAN	*Svalbardiceras spitsbergensis*	Subrobustus	*Svalbardiceras spitsbergensis, Popovites cf. occidentalis, Keyserlingites subrobustus, Prohungarites involutus, Posidonia aranea.*	STICKY KEEP FTN.
			Pilaticus		
		Anasibirites	Tardus	*Xenoceltites spetsbergensis, Hemiprionites typus, Wasatchites cf. tridentinus, Anasibirites sp. ind. Posidonia mimer*	
		Arctoceras blomstrandi	Romunderi	*Arctoceras blomstrandi, Euflemingites cf. cirratus, Prosphingites spathi, Posidonia mimer*	
	INDUAN		Sverdrupi	*Eumorphotis multiformis*	VARDEBUKTA FTN.
			Candidus		
		Proptychites	Strigatus	*Eumorphotis multiformis, Proptychites cf. rosenkrantzi, Ophiceras(?) sp. ind., Koninckites timorensis, Claraia cf. stachei*	
			Commune		
		Otoceras	Boreale	*Otoceras boreale*	
			Concavum		

Fig. 2. Stages, zones and associated flora and fauna of the Triassic of Spitsbergen.

fauna. The phylogenetic positions of *Otoceras* and *Ophiceras* are very different. The genus *Otoceras* is a derivative of *Pseudotoceras,* a genus which is part of an impressive radiation, mainly within Tethys, encompassing the family Araxoceratidae Ruzhentsev. *Otoceras* is the last surviving element of a Late Permian radiation. On the other hand, *Ophiceras* is a derivative of a xenodiscid stock and, in the earliest Scythian, underwent a very great evolutionary radiation. It is from this stock that most other Scythian taxa are directly or indirectly derived. There are thus two contrasting taxa that have commanded attention in recognition of this lowest zone, one a last surviving element, and the other the initiation of a significant widespread radiation. The duration of *Otoceras* into the Lower Triassic is most probably not the same within its known areas of distribution.

What has been ignored in the record of the Himalayan *Otoceras-Ophiceras* beds is the presence of a number of other taxa; these include *Anotoceras, Proptychites, Prionolobus, Xenodiscoides, Glyptophiceras, Episageceras,* and *Vishnuites.* There has been controversy as to the validity of at least some of these records. Careful review by the author of the literature, and some new collections, appear to substantiate Diener's original claims that these specimens were collected from the lowest zone of the Triassic.

PERMIAN-TRIASSIC BOUNDARY BEDS IN MIDDLE TETHYS

B. KUMMEL[1] AND C. TEICHERT[2]

[1]Museum of Comparative Zoology, Harvard University,
Cambridge, Massachusetts 02138, U.S.A.
[2]Department of Geology, University of Kansas, Lawrence, Kansas 66044, U.S.A.

Through much of Phanerozoic time Tethys was an extremely important province for the innovation and radiation of marine faunas and as a primary artery for the dispersal of such faunas. There is now ample documentation to show that for many segments of Phanerozoic time Tethyan marine faunas are more diverse and represented by larger numbers of taxa than provinces to the north and south. Three of the classical regions identified with the Permian-Triassic boundary problem are within Tethys. These are the Salt Range of West Pakistan, the central Himalayas, and the Dzhulfa region of Soviet Armenia. In recent years important sections have been identified near Abadeh, central Iran (Taraz, 1970), at Guryul Ravine, near Srinagar, Kashmir (Teichert, Kummel and Kapoor, 1970), in Nepal (Fuchs, 1967) and Kwangsi Province of south China (Chao, 1965). Historically the most controversial of these areas in regard to the Permian-Triassic boundary are Dzhulfa and the Salt Range.

For the Salt Range and adjoining Trans-Indus ranges the problem has recently been thoroughly documented by Kummel and Teichert (1970). The Permian-Triassic boundary there is interpreted to be a paraconformity representing a time gap of at least one Permian stage. The lowest Triassic zone is identified by the presence of *Ophiceras connectens* Schindewolf. There is as yet controversy as to the age of the Chhidru Formation (Furnish and Glenister, 1970; and Grant, 1970, *in* Kummel and Teichert, 1970). One of the most interesting aspects of this new study was the discovery of a rather diverse brachiopod fauna of "Permian" aspect in the lowest Triassic beds with *Ophiceras connectens.*

The stratigraphy and paleontology of the Permian-Triassic strata of the Dzhulfa region of Soviet Armenia have recently been monographed by Ruzhentsev and Sarycheva (1965) and collaborators. The strata with the ceratites *Paratirolites, Bernhardites,* and *Tompophiceras,* that also include the goniatite *Pseudogastrioceras,* a variety of productid brachiopods, tetracorals, and tabulates were interpreted by Ruzhentsev and Sarycheva (1965) as being of Early Triassic age. These same strata crop out on the Iranian side of the Araxes River at Kuhe-Ali Bashi, approximately five miles south of the main section known from Soviet Armenia. The section at Kuhe-Ali Bashi has been studied by Stepanov, Golshani, and Stöcklin (1969) and their conclusions regarding the Permian-Triassic boundary beds agreed with those of Ruzhentsev and Sarycheva (1965) for the equivalent strata in Soviet Dzhulfa. Our own studies at Kuh-e-Ali Bashi lead us to the conclusion that the controversial "transition beds" are Late Permian in age, not Early Triassic. These strata contain a much more diverse ammonoid fauna than previously known (15 species in 13 genera). Among genera recognized for the first time are: *Strigogoniatites, Neoaganides,* "*Pleuronodoceras,*" "*Pseudotirolites,*" "*Pseudostephanites,*" and *Urartoceras.* The specimens assigned by Shevyrev *(in* Ruzhentsev and Sarycheva, 1965) to *Tompophiceras* are not congeneric with the type species of that genus from the Lower Triassic of northeastern Siberia. Also the specimens assigned by Shevyrev *(in* Ruzhentsev and Sarycheva, 1965) to *Bernhardites* are not congeneric with the type species of that genus from the Lower Triassic of the Salt Range of West Pakistan.

At Guryul Ravine near Srinagar, Kashmir, a varied fauna of productid brachiopods, including *Spinomarginifera,* is associated in approximately 15 ft of strata with the typical Scythian (Lower Triassic) bivalve *Claraia.* These faunas are interpreted as true associations of surviving "Permian" and Lower Triassic faunal elements. This mixed association is similar to what we encountered in the lowest Triassic strata of the Salt Range and Surghar Range of West Pakistan.

The significance of these three sections in developing a theory to explain the great turnover in faunas at the Permian-Triassic boundary is obscure. The identification of the lowest Triassic on the basis of ammonoids, now greatly assisted by conodonts, appears secure. There is, as yet however, no consensus towards a definition and correlation of latest Permian strata. It is clear that there is a break in sequence in the Salt Range representing at least one stage of the Permian. The extent of this break at Dzhulfa and Guryul Ravine is not known. The parallelism of the boundary beds, the lack of striking physical features marking this boundary, and the essentially "normal" marine sedimentary facies of the boundary beds need to be accounted for in any generalized theory to explain the great faunal turnover.

THE PERMIAN-TRIASSIC BOUNDARY ON THE RUSSIAN PLATFORM

I. Y. LAPKIN, G. I. BLOM, N. V. GRIGORYEV, F. I. ENTSOVA, A. K. ZAMARENOV, I. Z. KALANTAR, Y. L. KISPERIUS, D. A. KUKHTINOV, E. M. LUTKEVICH, E. V. MOVSHOVICH, E. I. SOKOLOVA, B. P. STERLIN, P. I. SUVEIZDIS AND V. P. TVERDOCHLEBOV

National Committee of Geologists of the U.S.S.R.

The Lower Triassic is widespread over the Russian Platform and is represented by thick, mostly continental deposits containing few fossils. In

some areas the Lower Triassic deposits have been thoroughly studied but the exact positions of the upper and lower boundaries still remain questionable. Paleontological data strongly suggest the presence of a disconformity separating the Upper Permian from the Lower Triassic.

In the Petschora Basin and in the northern part of the Fore-Urals, red Triassic deposits of continental origin disconformably overlie red and grey strata of Tatarian age. The stratigraphic break is marked by an abrupt change in the conchostracan and plant assemblages, with the appearance of *Lioestheria* ex. gr. *gutta, Pseudoestheria aequale, Glossophyllum* sp., and *Pseudoaraucarites gorskii*. In anticlinal fold regions, such as the Petschora Range and the Seduyakhin Wall, Triassic deposits overlie Lower Permian, Carboniferous and Devonian rocks.

In the Kama and Volga Basins, it can be demonstrated that vertebrates, crustaceans and molluscs from the uppermost Vyatsky Beds of the Tatarian are quite different from those of the Ryabinsky Beds (lower part of Vetlugian Series) at the base of the Triassic. The Ryabinsky Beds contain numerous new species of Conchostraca, as well as several relict species from the Upper Permian.

Triassic deposits continue southwards from the Urals to the Kuibyshev area of the Volga Basin. Here the Vetlugian Series is divided into three sedimentary cycles, each with characteristic assemblages of terrestrial vertebrates, according to Shishkin and Otshev. In central and western areas of the southern Fore-Urals the lowermost sedimentary cycle lies at the base of the Triassic. However, in the eastern area, and also northeast of the Buzuluk Basin, the Triassic is represented only by the second or third cycle.

In the Pre-Caspian Basin typical Lower Triassic assemblages of Ostracoda and Charophyta occur, including several new forms belonging to the family Darwinulidae. The thickest and most complete Triassic sections are present in the central part of the basin and along its northern, western and southwestern sides. In the eastern and southeastern parts of the basin and in the Inder Lake district, conglomeratic sandstones of the Vetlugian Series overlap lower horizons of Tatarian age. The oldest zone of the Vetlugian Series *(Marginella* Zone) occurs in the central part of the basin (Aralsor District), where it directly overlies the Tatarian. South of the Volga and Ural rivers, rocks of Kazanian age are overlain by younger deposits represented by the *Sphaerachara karpinskyi* and *S. globosa* zones. Similarly, in the middle Emba Valley, different parts of the Sorkul Formation (Vetlugian Series) overlie the Upper Permian.

In the southern part of the Russian Platform, Lower Triassic deposits overlie Paleozoic deposits of the Pre-Volga monocline, the Pre-Donetz Basin, the northwest margin of the Donetz folded belt, and the Dneiper-Donetz and Pripyat Basins. The Early Triassic age of these strata is established by the presence of Ostracoda, Conchostraca and Charophyta.

In the Pre-Donetz Basin the Vetlugian once again transgressively overlies different horizons in the Permian (from Kazanian in the east to Asselian in the west) and Carboniferous. The Vetlugian Series, represented by the Dronovskaya, Korenevskaya and possibly by the lower part of the Serebrjanskaya Formations, can be traced from the northwestern margin of the Donetz folded belt through the Dneiper-Donetz Basin to the Pripyat Basin. The exact age of the Dronovskaya Formation has not yet

been established, for it contains a mixture of Lower Triassic and Upper Permian (Tatarian) Ostracoda and Charophyta. While the formation overlies the various horizons of the Lower Permian, Carboniferous and Pre-Cambrian with considerable angular unconformity in the marginal areas of the basin, some authorities, such as Lapchik, assign both the Dronovskaya and Korenevskaya formations to the Upper Permian.

Triassic deposits in the Polish-Lithuanian syncline are represented by the Neman Formation (argillo-arenaceous and marly rocks of the Buntsandstein), which transgressively overlies the Zechstein carbonate sequence (lowermost Verra to lower part of Leine cycles).

THE PERMIAN-TRIASSIC BOUNDARY AND ITS RELATION TO THE PALEOPHYTE-MESOPHYTE FLORAL BOUNDARY

S. V. MEYEN
National Committee of Geologists of the U.S.S.R.

Because of the widespread prevalence of continental deposits during the Permian-Triassic transition, the boundary can often be established only on the basis of assemblages of land animals and plants. It has been the practice of many authorities to correlate the Paleophyte-Mesophyte plant boundary with that of the Permian-Triassic, as in Siberia, India, Korea and other regions. In Western Europe, on the other hand, the Paleophyte-Mesophyte floral change has been placed at the begining of the Late Permian. The author believes that neither of these correlations is valid, for the Zechstein flora of Western Europe is, in reality, not typically mesophytic in aspect. The main elements of this flora appeared in the Early Permian and many had disappeared before the beginning of the Triassic. In places other than Western Europe, where plant-bearing beds have been directly correlated with type sections, the change from paleophytic to mesophytic does not coincide with the Permian-Triassic boundary, occurring at different stratigraphic levels in different parts of the world. For example, several mesophytic elements, sometimes dominating whole communities, characterize the Kungurian of the Fore-Urals region and the whole Permian section in Lower Asia. Again, the Upper Tatarian flora (especially that of the Vjatsky Beds) in the type sections of the Russian Platform is typically mesophytic in appearance, as has been recently shown by the author. It consists of peltaspermaceous pteridosperms, conifers and ginkgophytes, the only paleophytic elements being protosphagnaceous mosses. According to Sadovnokov, the Early Korvuntchana flora of the Tunguss Basin is typically mesophytic, and appears to be of Late Tatarian age, consisting of ferns (dominant group), peltaspermaceous pteridosperms, ginkgophytes and cycadophytes. In India the relationship is reversed, with a typical paleophytic flora, rich in glossopterids, characterizing the *Lystrosaurus* zone of the Lower Triassic. Until quite recently this flora was regarded as Permian, based essentially upon its paleophytic appearance.

These observations, then, strongly indicate that the replacement of paleophytic floras by mesophytic floras was not synchronous in various regions of the world and therefore can not be used to accurately delimit the systemic boundary. This gradual change from paleophytic to mesophytic flora in fairly complete sections, such as the south Fore-Urals, is similar to changes in marine faunas described previously by Ruzhentsev

and co-workers and ascribed by them to a vast regression at the end of the Permian. The regressive phase was probably concomitant with great volcanic activity in Northern Asia, as well as the removal of barriers which influenced plant migration and floral development during this time. However, the gradual and nonsynchronous nature of the floral changes across the boundary suggests that the rearrangement of barriers did not have a catastrophic effect on plant life.

GALACTIC MOTIONS, WORLD CLIMATE, AND MASS BIOTAL EXTINCTIONS: POSSIBLE INTERRELATIONS

A. A. MEYERHOFF

The American Association of Petroleum Geologists,
1444 South Boulder, Box 979, Tulsa, Oklahoma 74101, U.S.A.

Periods of evaporite maxima (warm worldwide climate, high S^{34}/S^{32} isotope ratios in salts, restriction of coal and petroleum formation to high altitudes, and crossings of the galactic plane by the solar system appear to coincide well with periods of mass biotal extinctions. The most notable extinctions took place at times when the solar system was crossing the galactic plane while in a perigalactic position in its orbit. The large amounts of cosmic radiation and high worldwide temperature during the solar system crossings of the galactic plane could, and should, have created high cosmic radiation—a condition potentially inimical to the survival of many biota. Thus the complex interactions among ocean-water salinity, changes increasing $S^{34/32}$ ratio, salt precipitation, increasing aridity at low and middle latitudes, increase in land area and decrease in epicontinental seas (following Late Paleozoic orogenies), and crossing of the galactic plane by the solar system could have led to the worldwide biotal extinctions of Permian-Triassic times.

Assuming that a relationship between these various factors existed, the author plotted curves for several of these phenomena, from Middle Proterozoic to Quaternary time: a curve for evaporite-maximum and evaporite-minimum periods of earth history, a curve for changes in S^{34}/S^{32} ratio, curves for times of maximum biotal extinctions and a curve for galactic orbital and oscillatory motions. The shapes of all curves so nearly coincide that a close interrelationship seems to be established between each of the phenomena that were plotted. Therefore, a good case can be made for postulating that times of mass biotal extinctions are closely related to the position of the solar system with respect to the galactic plane during galactic orbit.

PHANEROZOIC BIOTIC CRISES AND THEIR IMPLICATIONS FOR THE PERMIAN-TRIASSIC EXTINCTIONS

A. L. McALESTER

Department of Geology and Geophysics, Yale University,
New Haven, Connecticut 06520, U.S.A.

The well-known extinctions of many families of marine animals near the Permian-Triassic boundary were accompanied by comparable, but less remarked upon, reductions of the terrestrial biota, including both land plants and reptiles. Similar episodes of extinction within all major groups of fossilized organisms, including phytoplankton, marine animals, land plants (after the Silurian), and land animals (after the Carboniferous)

characterized Late Cambrian, Late Ordovician, Late Devonian and Late Triassic time. These reductions, affecting the entire preserved biosphere, suggest a single world-wide environmental change as the cause of the extinctions. In contrast to these major pre-Jurassic biotic crises, extinction episodes since the beginning of Jurassic time appear to have been more selective in their effect, suggesting a more complex cause or set of causes.

PERMIAN CONDENSED SEQUENCES, WESTERN CANADIAN ROCKY MOUNTAINS

A. McGugan and June E. Rapson-McGugan
Department of Geology, University of Calgary, Calgary, Alberta, Canada

The Permian sequence of Western Canada is examined stratigraphically, paleontologically and petrologically as an example of a condensed shelf sequence of clastic, phosphatic, carbonate and chert rocks which contains widespread, thin, persistent lithologic units and displays three principal associated paraconformities: one separating Middle Pennsylvanian and Lower Permian, one within the Upper Permian and one separating the Permian and Triassic. The latter contact corresponds to a marked lithological and faunal change in the succession.

Permian sandstones consist of quartz, chert, phosphatic and carbonaceous fragments, plus silicified sulphate grains; varieties of silica cement are dominant. All uppermost Paleozoic rocks contain negligible amounts of true clay material, either in the sandstones or in interbedded shaly-weathering intervals. If clastic clay had been present, its silica component might have contributed to the abundant silicification, but virtual absence of alumina in any form remains a problem. Triassic clastic components are similar, although feldspar and clay occur in variable (but noticeable) quantity; carbonate cement is dominant.

This study indicates the existence of three main derivative provenances: 1) many-cycled, clastic sedimentary rock from the hinterland; 2) local gypsum from an arid shoreline, and 3) phosphate produced on the shelf and characteristic of a starved, condensed sequence. The clastic products from these provenances have been modified by weathering, transport and diagenesis in differing continental, coastal and shelf environments of sorting, deposition and burial.

Condensation occurs ideally at a laterally mobile hinge-line separating the subaerial and shoreline sequences from the basinal sequence. The position of the hinge-line may change to produce demonstrable disconformities, paraconformities and possible diachronisms. The condensed sequence, with or without time-indicative fossils, may be complete or partially complete due to nondeposition, erosion and reworking or corrosion. All these factors make precise time relationships difficult to demonstrate.

Deposition of laterally persistent lithologic units is controlled by major factors such as eustatic and tidal cycles or regional epeirogenesis. There can be no such thing as an absolutely continuous sequence of sediments, and frequently, allocation of sedimentary sequences to transgressive or regressive cycles is open to more than one interpretation.

Orogenic activity of the earliest stages of the Tahetanian orogeny (approximating to the Permian-Triassic boundary) is indicated in several areas in the eugeosynclinal rocks of British Columbia. Specifically, this

includes regional metamorphism, ultramafics, angular unconformity and immature basal Triassic conglomerates in the Greenwood area (southern Omineca geanticline), Princeton-Ashcroft area, Skeena River and Yukon Plateau, and plutonism in the Coast Ranges and Omineca geanticline.

The above involves appreciation of the evolving paleogeography of the hinge line region due to the effects of distant, shifting diastrophism from Permian-Triassic time onwards.

THE PALEOMAGNETIC CONTRIBUTION TO THE PERMIAN-TRIASSIC BOUNDARY

A. E. M. NAIRN[1] AND D. N. PETERSON[2]

[1]Department of Geology, Case Western Reserve University,
Cleveland, Ohio 44106, U.S.A.
[2]Department of Geology, State University of New York College at Fredonia,
Fredonia, New York 14063, U.S.A.

There are two principal features characterizing the behavior of the geomagnetic field as observed in the study of samples from any given region. Commonly rocks are found with a polarity opposite to that anticipated and the directions themselves indicate an increasing deviation from the present rotational poles with time. The first is interpreted, in most cases, as evidence for the reversal of the geomagnetic field, the second in terms of progressive movement of blocks of continental extent with time (i.e. continental drift).

Although both of these features provide information relevant to the problems of the Permian-Triassic boundary, there is a distinct disadvantage in the small number of reliable results. It is only in recent years that magnetic cleaning has become a standard procedure for all rocks and in consequence many older results, even if they appear reliable, must be looked at with suspicion.

In contrast to the Triassic, the Permian geomagnetic field appears to have been remarkably stable during Permian times, fully justifying Irving's introduction of the "Kaiman Magnetic Interval". Detailed investigation does reveal a number of periods of reversed polarity, although as yet little may be said of their duration. These reversals are more common in the Late Permian than in the Early Permian. It may be coincidental that the Permian-Triassic boundary appears almost to coincide with a change in behavior of the geomagnetic field. If we make use of this, then it may be suggested that from the paleomagnetic standpoint the top half of the Ochoan should be included in the Triassic.

The declination-inclination data provide a means of establishing ancient geography, for the data from nearly all continents imply that considerable displacements must have occurred. This information can be used either as a means of creating paleogeographic maps or as a means of testing configurations arrived at by other means. Whenever there are Permian results from many horizons in a given region they can be interpreted satisfactorily by a single pole position although this is not necessarily so for all regions. For Triassic rocks we have concentrated upon results from the Lower Triassic whenever possible, but more general "Triassic" results must be used for some regions with the consequent introduction

of errors which may be appreciable. Models due to Dietz, Du Toit, and others have been examined in the light of the paleomagnetic data and the most consistent of these paleogeographic models is presented for Permian and Early Triassic times.

EXTINCTION OF BIVALVES AT THE PERMIAN-TRIASSIC BOUNDARY

K. NAKAZAWA

Geological and Mineralogical Institute, Faculty of Science, University of Kyoto, Kyoto, Japan

The stratigraphic distribution of bivalves, as measured by the change in numbers of superfamilies throughout geologic time, indicates evolutionary stability within the group from Carboniferous to Triassic. On the other hand, a more detailed survey of families and genera reveals a marked decline at the Permian-Triassic boundary and a spectacular re-expansion in the Late Triassic. This is demonstrated by the very small number of new genera in the Late Permian and the large number of new genera in the Late Triassic. Therefore, considerable extinction and expansion of bivalves during Permian and Triassic times did take place at the family level and particularly at the genus level.

A more detailed investigation shows that these faunal changes did not occur abruptly at the precise position of the Permian-Triassic boundary, or during the Late Triassic only, but were gradually introduced between Late Permian and Middle to Late Triassic times. A close relationship between Permian and Early Triassic constituent genera is also apparent. The bivalves were evidently less affected by the Permian-Triassic crisis than most other benthonic organisms, such as corals, bryozoans, brachiopods and crinoids. The difference may be partly attributed to the more stenohaline, stenothermal, and sessile life habits of these groups compared with the more adaptable bivalves.

The decline and subsequent resurgence of the Pterioida, the most predominant group throughout the Permian and Triassic, follows the evolutionary pattern seen in other bivalve groups. The only exception is the Nuculoida, which was not visibly affected by the Permian-Triassic crisis. Diversity of infaunal bivalves slightly exceeded that of epifaunal bivalves throughout the Permian, but decreased to about two-thirds of the latter during the Triassic. This was, no doubt, largely a result of the remarkable decline in the Triassic of the Pholadomyoida, a group which flourished in the Permian.

Members of the least-affected group, the Nuculoida, are detritus-feeders, while representatives of most of the other groups are suspension-feeders. These observations appear to support Tappan's opinion that the high rate of Permian extinction was caused by low production of phytoplankton resulting from low input of nutrients into the seas from the continents.

Worldwide distribution of many Early Triassic genera and species suggests that very broad ecological niches were left vacant after the mass extinction of certain other benthos, especially some groups of brachiopods and gastropods. These global changes in the Triassic also suggest broad alteration of climate and/or ocean currents from those of the Permian,

when the warm-water Tethyan province was clearly demarcated from the cooler Boreal and Gondwana provinces.

In conclusion, the worldwide regression disappearance of epicontinental seas, changes of climate and oceanic circulation, plus a probable scarcity of phytoplankton, all combined to bring about the mass extinction of many kinds of organisms at or near the Permian-Triassic systemic boundary. Among the benthonic organisms the bivalves were least affected because of their adaptability to changing benthonic habitats.

THE PERMIAN-TRIASSIC BOUNDARY IN THE CANADIAN ARCTIC ARCHIPELAGO

W. W. NASSICHUK, R. THORSTEINSSON,[1] E. T. TOZER[2] AND J. B. WATERHOUSE[3]

[1]Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, Calgary, Alberta, Canada
[2]Geological Survey of Canada, Ottawa, Ontario, Canada
[3]Department of Geology, University of Toronto, Toronto, Ontario, Canada

This paper summarizes lithostratigraphic work on Permian rocks in the Sverdrup Basin by Nassichuk and Thorsteinsson; investigation of Permian fusulinaceans by Thorsteinsson; Permian ammonoids by Nassichuk; Permian bachiopods by Waterhouse and Triassic lithostratigraphy and ammonoids by Tozer.

The relationship between Permian and Triassic beds is evident near the north, east and south margins of the Sverdrup Basin, particularly on northern and eastern Axel Heiberg Island; western Ellesmere Island; Cameron Island and Melville Island. The lithostratigraphy of the Permian rocks is rendered particularly complex in that several facies belts are generally in close proximity. A summary account has recently been published by Thorsteinsson *(in* Douglas *et al.,* 1970). Figure 1 in the text represents a generalized cross-section through the pre-Triassic sequence in the basin and illustrates the salient features of the succession. The overlying Triassic rocks are mainly sandstone with some conglomerate (Bjorne Formation) on the southern and eastern edges of the basin; in the axial part of the basin they are mainly siltstone and sandstone (Blind Fiord Formation). At individual outcrops the Permian and Triassic rocks appear to be concordant, without obvious evidence to indicate either erosion or nondeposition. Viewed regionally there is, however, clearly a substantial unconformity separating the Permian and Triassic rocks. The Bjorne Formation is transgressive on Melville and Ellesmere Islands where, in some sections, it rests directly upon pre-Permian formations.

Fossils are abundant in the Permian formations. Fusulinaceans, ammonoids and brachiopods have been studied in some detail. The study of the fusulinaceans does not contribute to dating the youngest Permian because these fossils do not persist to the top of the section; none younger than Early Artinskian (Aktastinian) occur. The highest Permian beds on the edge of the basin are those of the Trold Fiord Formation. The Trold Fiord beds contain the ammonoid *Neogeoceras and a brachiopod* fauna *(Wyndhamia,* etc.), both of which are interpreted as indicating an Early Guadalupian (Wordian) age. It is possible that beds exposed at the top of the Permian sequence in the vicinity of Blind Fiord, western Ellesmere Island are younger than the Trold Fiord Formation at any other

place; they contain a sparse brachiopod fauna possibly younger than Kazanian (Wordian) but this dating is extremely tentative.

In the Lower Triassic beds fossils are relatively abundant in the Blind Fiord Formation but rare in the Bjorne Formation. Four ammonoid zones have been discriminated within the earliest Triassic (Griesbachian) beds of the Blind Fiord Formation. *Otoceras* is restricted to the lower two zones *(Concavum* and *Boreale)*. The earliest zone *(Concavum)* has been recognized only in the Blind Fiord Formation of northern Axel Heiberg Island. The *Boreale* Zone is known in the Blind Fiord Formation from many localities on Ellesmere and Axel Heiberg islands. The only fossils known from the lower part of the Bjorne Formation are *Otoceras* sp. indet., indicating *Concavum* Zone or *Boreale* Zone.

The *Concavum* and *Boreale* zones are correlated with the beds containing *Otoceras woodwardi* in the Himalayas. The Lower Triassic sequence in Arctic Canada thus includes equivalents of the beds that define the base of the Triassic System.

Both the physical and paleontological evidence indicate a break in sedimentation between the Permian and Triassic in Arctic Canada. The physical evidence is the regional unconformity beneath the Blind Fiord and Bjorne formations. The paleontological evidence is the absence of faunas unquestionably indicative of latest Permian time (Upper Guadalupian, Dzhulfian and the *Paratirolites* fauna). Because the basal Triassic beds are correlated with those that define the base of the Triassic System it follows that the period of time unrepresented by sediments lies entirely within the Permian.

THE PERMIAN-TRIASSIC BOUNDARY IN THE EASTERN PART OF THE U.S.S.R.

T. M. Okuneva, B. S. Abramov, V. N. Andrianov, Y. V. Arkhipov, Y. M. Bytshkov, I. V. Bury, V. F. Vosin, V. M. Zavodovsky, A. V. Korobitsyn and V. I. Korostelyov
National Commitee of Geologists of the U.S.S.R.

The Upper Permian (presumably Tatarian) deposits of the basins of the middle and lower reaches of the Lena and Aldan rivers, and also of the upper reaches of the Jana and Indigurka rivers are overlain without visible break by Induan strata assigned to the *Otoceras* Zone (according to Abramov, Vosin and Korobitsyn). Characteristic of the uppermost Permian beds (Imtatshan Formation) are abundant *Strophalosia, Neospirifer invisus* and rare *Cancrinelloides obrutschevi*. The complete extinction of the brachiopod subfamily Licharewiinae also occurs at this stratigraphic level.

While the Imtatshan Formation and the Doulgalakh Formation are generally recognized as the highest stratigraphic units of the Permian in eastern and western Verkhoyan, respectively, authors Andrianov, Arkhipov and Korostelyov stress that the correlation of these formations with the Tatarian Stage of the Fore-Urals and the Dzhulfian Stage of Transcaucasus is still tentative.

Complete sections of the Lower Triassic are known from the basins of the Tompo and Delinja rivers of eastern Verkhoyan, where Triassic deposits overlie Permian strata without visible disconformity. In other

regions of Verkhoyan, stratigraphic breaks from the base of the Triassic up to the top of the Induan Stage have been established. The systemic boundary is drawn at the base of the *Otoceras boreale* Zone, above which Andrianov, Arkhipov and Korostelyov have recognized, in ascending order, the zones of *Episageras dalailamae, Glyptophiceras pascoei, Pachyproptychites strigatus,* and *Pachyproptychites turgidus.*

East of Verkhoyan, in the Ochotsk Massif and the Kolyma area of the Yana-Kolyma folded belt, marine Lower Triassic deposits with ceratitids and bivalves overlie the Permian Khivatsch Beds, which is probably a marine development of the Tatarian Stage. Zavodovsky believes this contact to be a conformable one, but according to Bytshkov, the fauna of the *Otoceras* Zone has not been discovered in this area and the exact stratigraphic position of *Epiageceras* and *Pachyproptychites,* recorded from the headwaters of the Upper Garmanda River, is uncertain. A contenous sequence from the Permian to the Triassic may exist in the upper reaches of the Kulu and Tenke rivers (Upper Kolyma region), where the Upper Permian deposits of the Khivatsch Beds, consisting of sandstones, conglomerates and shales with *Nuculana magna, Kolymia, Bellerophon* and *Rectoglandulina gigantea,* are overlain by a shale-sandstone sequence containing Conchostraca of Induan age. This sequence is followed by clay deposits with *Ophiceras* and *Glyptophiceras* ex gr. *extremum.* A continuous section of Permian-Triassic strata may also be demonstrated in the interior region of the Omolon Massif, where a 15-50m (approximately 48'-164') limestone sequence contains the Khivatsch fauna in the lower levels and numerous *Posidonia mimer* and rare *Hedenstroemia* and *Paranorites* in the upper levels.

In other regions of the northeast U.S.S.R. there is a stratigraphic break at the Permian-Triassic boundary and the Upper Permian is overlain by various horizons of the Lower, Middle and Upper Triassic.

In the Transbaikal region and in the extreme eastern part of the Soviet Union, Permian-Triassic boundary beds are poorly developed. In Transbaikal, laminated siltstones with *Ophiceras* and *Gyronites* are in tectonic contact with Lower Paleozoic rocks. In the area of the middle Amur River, Upper Permian sandstones with *Schizodus* and gastropods are succeeded by laminated siltstones with *Glyptophiceras, Metotoceras* (?) and *Posidonia.* In the Uda River Basin, the relationship between Olenekian siltstones and the underlying beds is uncertain, while in the southern maritime region a marked stratigraphic break separates the upper part of the Upper Permian and the lower part of the Lower Triassic, with beds containing *Gyronites* overlying different horizons of the Upper Permian.

NORTH ATLANTIC RIFTING IN RELATION TO PERMIAN-TRIASSIC SALT DEPOSITION

W. S. OLSON AND R. J. LEYDEN

Lamont-Doherty Geological Observatory, Palisades, New York 10964, U.S.A.

Opening of the North Atlantic Ocean, as dated by sea-floor spreading anomalies, supported by recent deep-sea drilling, coincides with the time of Mediterranean and Gulf Coast evaporite deposition. In a two-stage

process, oceanic waters were concentrated in the Mediterranean to the point of halite deposition and the concentrated saline solutions conducted by gravity along the Atlantic rift to the newly-opened Gulf Coast basin. Here the final concentration took place with deposition of the Louann salt. The volume of salt removed from the world ocean system caused a permanent reduction in salinity sufficient to explain extinctions of marine species.

A REVIEW OF UPPER PERMIAN BIOSTRATIGRAPHY IN THE BRITISH ISLES

J. PATTISON AND D. B. SMITH

Institute of Geological Sciences, Leeds, Yorkshire, England

The Late Permian in the British Isles was ushered in by rapid and widespread marine transgressions which brought into being the partly enclosed and moderately deep Zechstein Sea in the east, and the more restricted Bakevellia Sea in the west. In the Zechstein Sea, normal marine conditions existed during the first two of four major sedimentation cycles, and a full and varied marine fauna is present in thick marginal carbonates. Conditions were generally less favorable in the Bakevellia Sea, and sparse faunas in marginal carbonates and clastics are dominated there by bivalves. In both basins deposition in the early cycles was concluded by barren evaporites, which are particularly thick in the second cycle in the Zechstein basin.

The original basins are thought to have become almost completely filled by the end of the second cycle and space for subsequent sedimentation in the Zechstein Sea was provided mainly by continued differential subsidence. In this paleogeographic setting, the sediments of the third Zechstein cycle are almost everywhere of shallow-water, intertidal or supratidal origin, and this is reflected in the specialized and restricted gastropod-bivalve fauna of the third cycle carbonates. The trend to increasing impoverishment is continued in the sediments of the fourth and a minor fifth cycle, none of which have yielded recognizable marine fossils and which may not be of truly marine origin. Sediments of the third and subsequent cycles of the Bakevellia Sea basin have so far yielded no fossils, with the exception of a few bivalves in a marginal sub-basin which might have been flooded from the east rather than the west.

Subsequent sediments in both basins, and in areas not inundated by the Zechstein and Bakevellia seas, are mainly continental-margin red beds, predominantly red sandstones (some eolian) in areas marginal to the former basins, but passing basinwards into siltstones and mudstones. These sediments are mainly of very shallow water origin, and bear abundant evidence of repeated subaerial exposure. Apart from a few reptilian remains in sandstones near Elgin, in Scotland, these Upper Permian sediments have yielded no stratigraphically significant fossils, and appear to pass upwards, without a break, into similar continental sediments customarily assigned to the Triassic.

NON-MARINE FLORAL AND FAUNAL CHANGES AT THE PERMIAN-TRIASSIC BOUNDARY, U.S.S.R.

G. P. Radczenko, E. M. Mishina, I. S. Neustruyeva,
E. K. Obonitskaya, V. G. Otshev, G. M. Romanovskaya
and L. Y. Saidakovsky

National Committee of Geologists of the U.S.S.R.

The Permian and Triassic continental and lagoonal deposits occupy large areas in the U.S.S.R. and in some regions predominate over marine deposits. In such non-marine facies, plants, spores, pollen, ostracodes and vertebrates are important stratigraphic indicators.

Vertebrate studies in the eastern and southeastern parts of the Russian Platform have established the Permian-Triassic boundary at the base of the *Lystrosaurus* Zone, where a strong decrease in certain tetrapod groups and a marked increase in others, such as *Tupilacosaurus*, occurs. The *Lystrosaurus* Zone on the Platform and in the Fore-Urals region is usually correlated with the *Otoceras* Zone of the marine facies.

Study of freshwater ostracodes from the Russian Platform, Pre-Caspian, Kuznetsk and Tunguss Basins has shown that, at the end of the Late Permian, a number of families and subfamilies such as the Placideidae, Volganellidae, Tomiellinae, Iniellinae, Sinusuellinae and Permianinae, become extinct. At the beginning of the Triassic new genera and families do not appear, but changes at the taxonomic level of species do occur. Thus *Darwinula pseudoinornata, D. ovalis, Gerdalia wetlugensis, G. longa* and others are characteristic of the lowermost Triassic (including the *Lystrosaurus* Zone) of the Russian Platform.

The Permian-Triassic boundary may be accurately fixed on the basis of paleobotanical data, but varying plant assemblages are used, corresponding to the differing phytogeographical regions. Early Triassic subtropical floras of Tethys region (Russian Platform, Kazakhstan, Central Asia and Black Sea area) are characterized by *Pleuromeia* (or *Pleuromeiopsis*), *Voltzia, Lepidopteris, Tersiella, Equisetites* s.s. and new species of pre-existing Paleozoic genera. In the Tunguss phytogeographical province the Early Triassic flora includes *Schizoneura, Tungussopteris, Khonomakidium, Tersiella, Glossozamites, Voltzia* and *Pseudoaraucarites*, genera which are entirely absent from the Permian.

It should be emphasized that the exact position of the Permian-Triassic boundary in Siberia is presently under discussion.

Palynological researches suggest that great changes in floral content did not occur at the Permian-Triassic boundary. At the beginning of Triassic times the fern-ginkgo-cordaitian association continued to exist, with the gradual introduction of Mesozoic floral elements. The latter are represented in the Europe-American region by spores of Cyatheaceae, Lycopodiaceae, Selaginellaceae, *Chomotriletes* and *Camptotriletes, Periplecotriletes, Pleuromeia* and *Gnetaceaepollenites,* and in the Tunguss Basin by spores of *Cyathidites, Nevesisporites, Kraeuselisporites* and the pollen *Gnetaceaepollenites.* In both regions conifers are important.

At the Permian-Triassic boundary Mesozoic representatives of the Charophyta appeared. The Upper Paleozoic stomocharas and chorniells died out completely and were replaced by representatives of typically Mesozoic genera such as *Sphaerochara, Altochara, Porochara, Cuneatochara, Stenochara, Maslovichara* and *Stellatochara.*

UPPER PALEOZOIC AND LOWER MESOZOIC PALEOGEOGRAPHY AND PALEOCLIMATOLOGICAL EVENTS IN SOUTH AMERICA

A. C. ROCHA-CAMPOS

Institute of Geosciences and Astronomy, University of São Paulo,
São Paulo, Brazil

A preliminary correlation scheme for the Upper Paleozoic sequences and their relationship with the Lower Mesozoic strata is proposed as a basis for interpreting the paleogeography and paleoclimates of the continent.

Stratigraphic, biochronologic and radiometric data indicate that the Upper Paleozoic and Lower Mesozoic sequences are separated by an angular and/cr parallel unconformity in the Andean region. Chronologic uncertainties and/or conformable stratigraphic relationship make separation of Upper Paleozoic and Triassic sediments more difficult to trace in the southern sub-andean part of Bolivia, the Pre-cordillera of Argentina, the Parnaíba Basin and parts of the Brazilian portion of the Paraná Basin.

Upper Permian and Lower Triassic rocks are virtually absent from South American sedimentary basins. Consequently, data for the continent reveal only a partial record of the geological events related to the passage between the Paleozoic and Mesozoic eras.

Data obtained on the paleogeography and paleoclimatological development of South America fit in reasonably well with the postulated history of reassembled Gondwana continents during Late Paleozoic and Early Mesozoic times, based on paleomagnetic and other evidence.

The Late Paleozoic glaciation that affected South America, beginning in the Early Carboniferous, apparently ended rather abruptly in the Andean region after Late Carboniferous times, but a glacial climate still prevailed locally during the Early Permian in parts of the Paraná Basin. Conditions ameliorated towards a warm, arid climate in Early Permian times in the Andean region and possibly a little later in the Paraná Basin. This trend towards aridity reached its maximum in Late Permian and Triassic times.

THE PERMIAN-TRIASSIC BOUNDARY IN TRANSCAUCASIA

K. O. ROSTOVTSEV AND N. R. AZARIAN
National Committee of Geologists of the U.S.S.R.

Transcaucasia is one of the few places in the world where continuous marine sections of Upper Permian and Lower Triassic strata, containing a rich and diverse fauna, may be studied. The sections have been investigated by many authorities, but as yet there is no agreement on the exact position of the Permian-Triassic boundary.

Relatively complete sections co-exist with condensed sequences in Transcaucasia. Complete sections occur in the Dzhulfa Gorge of the Araxes River, near railway sidings Dorasham I and II, while condensed sequences occur elsewhere, as in parts of Nakhichevan A.S.S.R. and south-western Soviet Armenia.

Ruzhentsev and co-workers (1965) were able to recognize certain ammonoid and brachiopod assemblages in strata from both types of sections. In the more complete sections, the *Phisonites-"Berhardites"* beds are represented by a 20m (65.6 ft) thick clay lithofacies, while in the condensed sections these beds are represented by a thin limestones lithofacies not exceeding 2m (6.6 ft) in thickness. The *Paratirolites* and *Claraia* beds are usually represented in both types of sections by separate limestone lithofacies.

New discoveries of ammonoids in the *Claraia beds* are extremely important in determining the precise position of the systemic boundary. Several species of *Ophiceras* occur quite commonly in the lower part of these strata, while *Gyronites* and *Koninckites* occur sparingly in the upper part. Thus the *Claraia* beds are undoubtedly of Early Triassic age and correspond with the *Otoceras* and *Gyronites* Zones.

The *Claraia* beds are underlain by the *Phisonites-Paratirolites* beds and the upper part of the *Vedioceras* beds, containing a distinctive ceratite assemblage of *Otoceras, Glyptophiceras* and *Metophiceras,* together with rare tabulate and tetracorals, goniatites and productid brachiopods. Taking into consideration, then, the absence of Permian faunal elements in the *Claraia* beds and the similarity of underlying ammonoid assemblages in the *Phisonites-Paratirolites* beds to those of the Upper Permian Talung Formation of southern China, plus the other Permian faunal elements mentioned above, the authors favor a Permian-Triassic boundary between the *Paratirolites* beds and the *Claraia* beds.

The interval of the section from the *"Tompophiceras"* beds up to the *Paratirolites* beds may be regarded as the highest horizon of the Permian System not yet included in the standard scale. The authors here suggest that this stratigraphic interval, together with the *Phisonites* beds, be designated the Dorashamian Stage. This new stage is believed to have equivalents in Iranian Azerbaijan (Stepanov *et al.,* 1969), central Iran (Taraz, 1969) south China (Chao, 1959) and Madagascar (Tozer, 1969).

The Permian-Triassic boundary problem in Transcaucasia should not be considered completely solved, however. Some investigators believe that the ammonoids from the upper part of the *Vedioceras* beds and the *Phisonites* beds are truly Triassic in aspect. These workers explain the presence of relict Permian corals, goniatites and productids in these strata by uninterrupted transitional conditions from the Permian to the Triassic.

EVIDENCE FROM FOSSILS: BIVALVE MOLLUSCS

B. RUNNEGAR

Department of Geology, University of New England,
Armidale, New South Wales, Australia

A conventional plot of the number of bivalve genera at different times throughout the Permian and Triassic results in a spindle diagram with a narrow waist in the earliest Triassic. Only eighteen marine bivalve genera (seven new) are known from this period of time, in contrast to the more than 70 genera known from the Middle Permian and approximately 140 known from the Late Triassic. However a simple computation of the

number of genera and families of bivalves which survive from the Permian into the Triassic shows that between two and three times as many genera as are observed must have existed in earliest Triassic time. Some of these genera can be identified as the sole representative of a long-ranging family of bivalves *(Solemya, Parallelodon, Oriocrassatella)*; others are presumed to exist because the genus or family is found in Permian and later Triassic deposits *(Lopha, Costatoria,* Mytilidae, Pinnidae, Pteriidae, Isognomonidae, Carditidae, Astartidae, Pholadomyidae and others). A few must represent transitional forms between Paleozoic and Mesozoic families (Pseudomonotidae-Ostreidae, Megadesmidae-Ceratomyidae), and at least two genera are needed to rejuvenate the Lucinacea and Megalodontacea in the Middle and Late Triassic.

If the same strategy is applied to counts of mid-Permian bivalve genera, the observed numbers are not substantially increased. It can therefore be concluded that the known earliest Triassic bivalve faunas form an unusually poor record of the history of the Class — an effect which may artifically accentuate the observed change in this group at the Permian-Triassic boundary.

Curiously, marine bivalves are among the commonest of Early Triassic invertebrate fossils. Moreover, although fossiliferous earliest Triassic marine deposits are relatively rare, their fauna is surprisingly homogeneous, being dominated in all parts of the world by ammonoids and the bivalve genera *Claraia, Leptochondria, Bakevellia, Promyalina, Neoschizodus, Unionites,* and *Palaeoneilo.* How then can the demonstrably poor record of Early Triassic bivalve genera be explained?

Bivalves are not common Late Paleozoic fossils but they are widely distributed in space and time and are found in a variety of habitats (stable shelf, geosyncline, reef, epeiric sea and so forth). Many genera and species are confined to well-defined zoogeographic provinces (boreal, Tethyan, Gondwana). By contrast, earliest Triassic faunas are more homogeneous and nonprovincial, despite considerable local variation in lithofacies. Bivalves are common fossils, but their apparent abundance may only reflect the paucity of other earliest Triassic organisms.

Conventional graphs show a gradual decline in the number of bivalve genera from Middle through Late Permian, and a massive radiation in the Middle and Late Triassic. An analysis of the Permian decline, based on sequences of bivalve faunas from the United States, Japan, and Australia indicates that the number of genera which continue into the Triassic increases slowly throughout Permian time. There is a correspondingly slow decrease in genera belonging to Paleozoic families (Pterineidae, Pterinopectinidae, Modiomorphidae, Edmondiidae). Unclassifiable genera with no obvious antecedents or descendants *(Alula, Manzanella, Eurydesma, Actinodontophora* and others) form a small but relatively constant proportion of all Permian faunas. The remaining genera, largely responsible for the Late Permian decline in total number of genera, are all Paleozoic representatives of families continuing into the Mesozoic. Sixty per cent of these genera are epifaunal bivalves of the Subclass Pteriomorpha; many are scallops. The remainder (except for two nuculoids) are semi-infaunal to infaunal siphonate and nonsiphonate suspension feeders (Myophoriidae, Permophoridae, Astartidae, Megadesmidae, Pholadomyidae). Most of these forms do not reappear until the Middle or Late Triassic.

Epifaunal pteriomorphs and detritus-feeding nuculoids overwhelmingly dominate earliest Triassic assemblages. Bivalves which had eulamellibranch gills are rarely found, but must have existed somewhere in sufficient numbers to form a base for the massive Mesozoic radiation of siphonate eulamellibranch heterodonts and desmodonts. Their absence from apparently normal shelf deposits of the Early Triassic is difficult to explain in terms of most current theories of the cause of Late Permian extinctions (extraterrestrial hard radiation, phytoplankton famine, seawater salinity drop, worldwide regression, change in atmosphere composition), but may prove significant if the relationship between organism and environment can be better understood.

ACRITARCHS AND THE PERMIAN-TRIASSIC BOUNDARY

W. A. S. SARGEANT

Department of Geology, University of Nottingham, Nottingham, England

Studies of assemblages from the Lower Triassic of the Salt Range of West Pakistan are presented, following earlier work by the author on assemblages from the uppermost Permian of that region. The assemblages are of very small average size, and characteristically simple morphology; the most abundant genera by far are *Micrhystridium* and *Veryhachium*. In consequence, care and patience are needed in their study. The Permian assemblages already described by the author show stronger affinity with the Triassic than with the Paleozoic; nevertheless, the entry of many new types in the lowest Triassic assemblages makes it readily possible to differentiate between Permian and Triassic. The acritarchs therefore seem to offer potential value as stratigraphic indices for determining the position of the Permian-Triassic boundary; however, it will clearly be necessary to make comparative studies in other regions before this can be confirmed, since paleoecological controls cannot, at present, be entirely ruled out.

If the acritarchs prove as useful as this study suggests, they will be especially valuable, in view of their great abundance in small samples, in establishing this boundary in borehole studies. The absence of dinoflagellate cysts in all Triassic asemblages described to date is puzzling; it may reflect extreme climatic stability, rendering encystment during adverse conditions unnecessary. The aritarchs are certainly a polyphyletic assemblage of morphologically similar but unrelated forms. Although it seems virtually certain that these also are cysts, it cannot be conclusively affirmed that they are produced in response to adverse environmental conditions; encystment may be a necessary prerequisite to cell division, and unrelated to environmental seasonality.

LATE PERMIAN AND EARLY TRIASSIC FISH ASSEMBLAGES

B. SCHAEFFER

Department of Vertebrate Paleontology, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024, U.S.A.

The fishes of the Late Permian are represented by two families of sharks, one of ratfishes (holocephalans), one each of coelacanths and lungfishes and eight families of palaeonisciforms. There is also an occurrence in the

Ochoan of one semionotid holostean genus, which is closely related to certain Triassic genera. All of the families continued into the Triassic with the exception of two palaeonisciform ones.

During the Early Triassic (Griesbachian) two new palaeonisciform families appeared, neither of which shows evident relationship to Permian families. In addition, five distinctive families of more advanced actinopterygians, popularly called subholosteans (because they are in various ways intermediate between the palaeonisciforms and holosteans), entered the scene along with one new family of lungfishes (Ceratodontidae). The hybodontid sharks and the coelacanths became more diversified in terms of new genera than they were in the Late Permian.

In assessing the meaning of these data in terms of the Permian-Triassic boundary, it is important to note that the Late Permian fish record is far poorer in terms of known localities and assemblages than the Early Triassic one. It is also significant that no satisfactory lineages have been worked out for any of the Permian and Triassic genera. In spite of these limitations, the available facts suggest that the Permian-Triassic boundary has little significance for the fishes in relation to major extinctions or origination bursts. Unless there is an unrecorded time interval related to the boundary (rates of evolution for the pertinent families cannot be realistically estimated), it is reasonable to conclude that all of the families first known in the Early Triassic extended back into the Permian. This is true for the Semionotidae and it is the most reasonable explanation for the Triassic palaeonisciform and subholostean families.

THE CONTRASTING PLANT ASSEMBLAGES FROM PERMIAN AND TRIASSIC DEPOSITS IN SOUTHERN CONTINENTS

J. M. Schopf

U.S. Geological Survey, Orton Hall, Ohio State University,
155 South Oval Drive, Columbus, Ohio 43210, U.S.A.

The *Glossopteris-Gangamopteris* flora of Permian age seems to provide the most striking example of supercontinental endemism in the geologic record. The relatively small degree of floristic diversification within the large Gondwana region may be no less significant. Occasional overlap of elements from the *Glossopteris* assemblage into the Triassic tends to emphasize the great differences that generally exist between plant assemblages on either side of this systemic boundary. In much of Gondwanaland an actual discontinuity of record at this boundary is implied. In a few instances essential stratigraphic continuity seems established, but in each instance the most common floristic elements of the Permian are almost completely replaced by others in Triassic deposits of the southern continents. Ancestral and evolutionary relationships of the dominant elements of each assemblage, as well as effective means of dispersal, have important geologic implications.

Elsewhere I have developed the theme that the glossopterids may represent an early phyletic diversification from ancestors of the cordaiteans during the Early Carboniferous. The glacial hiatus near the base of the Permian has removed so much of the fossil record that details of phyletic connection may always remain obscure, but the suggestion of a cordaitean alliance seems the most probable of any that may be entertained as a tentative working hypothesis. Established elements of Eur-

american Carboniferous tropical, possibly upland, vegetation probably included plant groups that were able to disperse efficiently and adjust rapidly to the seasonal and periodic climatic regime that followed recession of ice sheets in southern areas during the Late Carboniferous (?) and Early Permian. Effective floristic isolation of Gondwanaland, which may have been as much owing to climatic causes as to the barrier function of the Tethys, was nearly complete during most of the Permian. *Glossopteris* seems to have persisted as a minor floral element in the Triassic, continuing to Rhaetic, but as a dominant element it seems limited to the Permian.

The dominant element of Early Mesozoic floras of southern continents is represented by the pteridosperm genus *Dicroidium*. A most important clue to the ancestry of *Dicroidium* is provided by the genus *Supaia* which is abundantly represented in the Hermit Shale of Early Leonard age (Artinskian) in Arizona. *Supaia* combines foliage features of Early Permian callipterids with the racheal habit of *Dicroidium* and thus serves, in general, to bridge the gap in ancestry. Records, however, seem lacking in the Upper Permian, so that the mode of translation from the Early Permian of Arizona to the Early Triassic of Gondwanaland is uncertain. The later history of *Dicroidium* was long confused with the northern and mostly Jurassic genus *Thinnfeldia,* but it now seems that *Thinnfeldia* is different from *Dicroidium,* and the two genera may not be closely related.

It is tempting to think of the change from glossopterid floras of the Permian to *Dicroidium* floras of the Triassic as climatically controlled. In Europe the most striking floral transition occurs between Early and Late Permian rather than at the systemic boundary. In the Gondwana area the change from a dominantly *Glossopteris* flora to a dominantly *Dicroidium* flora has generally been interpreted as a convenient and reliable means of differentiating the two systems. At many places, evidence of an hiatus may be inferred. However, in one well exposed section at Allan Nunatak, Antarctica, the change from a dominantly *Glossopteris* flora to a *Dicroidium* flora occurs without any distinct physical change or break in regime that might physically distinguish a Permian-Triassic boundary. The paleontological evidence clearly indicates a striking floristic change, but the reasons for the floral contrast are still speculative.

Any explanation must provide for (1) the abrupt decline of *Glossopteris* from a dominating element in the Permian to a minor and sporadic floristic element in the Triassic, and (2) repopulation of essentially the same area by a dominant diacroidioid vegetation whose ancestry was also founded on a northern source. The remarkable isolation of Gondwanaland has been emphasized, but it is also important to note that at two well-separated geologic intervals, groups of northern plants have successfully negotiated the intervening barrier. Each time, the elements from northern floras have been amazingly successful in regional repopulation of areas in the south. The ancestral connections of these plants, however, though geologically significant, seem to have escaped special consideration. The regional character of the southern plant assemblages can scarcely be explained by edaphic factors, though locally they may have been influential. Evidences of a variable, continental-type terrestrial environment occur within the Triassic as well as in the Permian. It seems most reasonable to infer that the proncipal control was largely adaptive on the part of the plants, moderated and facilitated by a rigorous seasonal climate.

GEOLOGICAL EVENTS DURING PERMIAN-TRIASSIC TIME ALONG THE PACIFIC MARGIN OF THE UNITED STATES

N. J. SILBERLING

Department of Geology, Stanford University, Stanford, California 94305, U.S.A.

Evidence for a complex history of diastrophism and igneous activity during latest Permian and much of Triassic time along the Pacific margin of the United States has long been recognized and was summarized by R. H. Dott, Jr., in 1961. In most of the western Cordillera, strata of Late Triassic or younger age rest unconformably on mid-Permian or older rocks, and a material record of geologic events at the earth's surface near the time of the systemic boundary is lacking. Western Nevada is exceptional, however, in having extensive exposures of stratified rocks such as those in the northern part of this region that belong to the Koipato Group and are close to the Permian-Triassic boundary in age. Except for its stratigraphic position unconformably above Permian strata as young as Leonardian, unequivocal evidence for the older age limit of the Koipato is not at hand. Ammonites probably belonging to the Spathian genus *Subcolumbites* have recently been collected from the upper part of the Koipato Group in the Humboldt Range, and the Koipato may be entirely of Early Triassic age. The Koipato Group comprises predominantly volcanic and volcanic-derived rocks ranging from intermediate to siliceous in composition, and it was deposited immediately following the episode of deformation named the Sonoma orogeny. Current studies indicate that during this orogeny a thick complex of oceanic Upper Paleozoic mafic volcanic rocks, bedded chert, and fine-grained siliceous and calcareous clastic rocks was carried eastward on the Golconda thrust over partly correlative shallow-water marine carbonate and clastic rocks of the continental shelf.

Farther south in western Nevada marine sedimentary rocks of late Griesbachian and Dienerian age are included in the Candelaria Formation which rests disconformably on Permian strata that contain a *Punctospirifer pulcher* fauna and rest in turn unconformably on lower Paleozoic rocks. As first suggested by R. C. Speed, the Candelaria Formation may represent the youngest rocks that were overridden by a thrust plate which resembles that of the Golconda thrust farther north but which includes serpentine along with sea-floor volcanic and sedimentary rocks. The Golconda thrust thus seems to be younger than early Early Triassic in the southern part of western Nevada and older than late Early Triassic farther north in western Nevada.

Both before the Sonoma orogeny, during the Late Paleozoic, and after it, during the Early Mesozoic, continental-shelf carbonate and clastic deposition took place in west-central Nevada without orogenic interruption. Events of the Sonoma orogeny near the beginning of Triassic time invite speculative explanation invoking plate tectonic theory. The abrupt thrusting of ocean-floor rocks onto the continent, followed by the arc-like volcanism of the Koipato Group, might best be attributed to collision of an isolated, east-facing, oceanic arc-trench system against the west side of the continent situated on the North American plate. Such an event could reflect some more general change in the interaction of the world's lithosphere plates at about the same time and thus be of more than only local significance.

TRIASSIC DEPOSITS FROM THE AFGHAN PART OF TETHYS AND THEIR CORRELATION WITH THE TRIASSIC OF THE SOVIET UNION

V. I. SLAVIN

National Committee of Geologists of the U.S.S.R.

Triassic deposits are not widespread in Afghanistan but are known from isolated outcrops in northern Afghanistan from the Pamir frontier in the east to the Iranian frontier in the west. In southern Afghanistan they can be traced from Jalalabad to Kandahar, along the southern slopes of the Hindu Kush and the Paro-Pamisus Range.

Three structural-statigraphic provinces involving Triassic rocks may conveniently be recognized: a north Afghan province with a great thickness of terrigenous sediments; a central province with a volcanic-terrigenous regime and a south Afghan province with an essentially carbonate sequence.

East of the north Afghan province are the Badakhshan and Nouristan zones. In the Badakhshan zone the lower and middle parts of the Triassic are composed of conglomerates and sandstones, while the upper part consists of a thick sequence of limestones, flysch-type sandy argillites and marl-argillite alternations. The Triassic sequence from the Nouristan zone is similar in lithology but has less total thickness. In view of the scarcity of diagnostic fossils the correlation of these rocks with those of the Central Pamirs is essentially a lithostratigraphic one.

Ladinian deposits are exposed in central and western parts of the north Afghan province in the Bandi-Turkestan area. Thick flysch-like sandstones and argillites, with interbedded coal layers and lenses, occur along the northern and western perimeter of the region and contain typical Ladinian fossils in their lower part. Above lie beds containing Karnian *Halobia* and ammonites, while the upper part of the sequence yields bivalves and ammonites of Norian aspect. Northwestwards, the deposits of the north Afghan province can be traced to the Mangishlak Peninsula and westwards to the vicinity of Meshkhed in Iran.

In the central Afghan zone, typical deposits from this region have been described from the area of Doab. In the lower part of the sequence volcanic strata are intercalated with limestone, conglomerate and sandstone beds. The thickness of the volcanic beds increases to over 2,000 m (approximately 6,560 ft) north of Doab, and these beds are overlain by Middle Triassic conglomerates, sandstones and shales with concretions. Fossils include representatives of the genera *Progonoceras, Monophyllites, Ceratites, Daonella* and *Entolium*. The overlying flysch-like deposits totalling over 1,000 m (approximately 3,280 ft) in thickness are correlated with the Upper Triassic sequence of the Bandi-Turkestan areas. Their Karnian-Norian age is confirmed by the presence of the bivalves *Halobia* and *Monotis salinaria*. Volcanic rocks with interbedded sediments containing Rhaetian *Baiera* and Rhaetian-Liassic spores and pollen complete the succession.

The thickest Triassic sequence totalling over 6,000 m (approximately 19,680 ft), has been described by Mikhailov and others from the western part of the central zone, north-east of Herat. Lower Triassic limestones, siltstones and sandstones, with species of *Eumorphotis, Myophoria, Naticella, Kashmirites* and *Tirolites,* overlie volcanic rocks, while Middle Tri-

assic limestones, sandstones and argillites with *Sturia sunsovini* and Karnian-Norian conglomerates complete the sequence.

The south Afghan province includes two regions: an eastern one (Kabul-Jalalabad) and a western one (Helmand). In the eastern region the Triassic is represented by an almost continuous carbonate sequence. The Lower Triassic strata consist of red and grey limestones with interbedded siltstones. Kemel has described a rich ammonite fauna from the Lower Triassic, enabling the Owenitan and Subcolumbitan zones of the Olenekian Stage to be recognized. Middle Triassic limestones contain *Beyrichites, Discoptychites* and other fossils in the Kabul area and *Japonites* near Jalalabad. Upper Triassic limestones and dolomites have yielded the coral *Procyclolites,* as well as megalodont remains.

In the western part of the south Afghan province ammonites are absent from the Lower Triassic limestones, but the bivalves *Claraia aurita, C. orbicularis* and *Eumorphotis* are abundantly represented. The Middle Triassic in this region comprises dolomitic limestones, the Upper Triassic thick megalodontid-rich limestones.

The presence of an essentially continental facies in the north Afghan province during Late Permian and Early Triassic times testifies to the absence of marine basins in the area. A marine transgression began no earlier than the Olenekian in this northern region. In southern Afghanistan, however, Triassic carbonates overlie Upper Permian carbonates without tectonic unconformity, although detailed studies indicate a slight hiatus in the stratigraphic succession. The absence of the earliest Triassic faunal zones here also indicates a time break.

Triassic sequences in the north Afghan province may be correlated eastwards with analogous deposits in the Central Pamirs. There is also a similar sequence in southern Mangishlak, the eastern coast of the Sea of Azov and the mountainous parts of the Crimea. The south Afghan Triassic sequence also has much in common with that of Armenia and Nakhichevan.

UPPER PERMIAN AND TRIASSIC DEPOSITS
FROM THE PRE-CASPIAN BASIN

E. I. SOKOLOVA, V. V. LIPATOVA, N. N. STAROZHILOVA AND A. G. SCHLEIFER
National Committee of Geologists of the U.S.S.R.

Isolated outcrops of Upper Permian and Triassic strata occur in the Pre-Caspian Basin in the areas of Lake Baskunchak (Mount Bolshoe Bogdo) and Lake Inder. Elsewhere in the region, these rocks occur at considerable depth where they have been encountered in deep borings.

The Pre-Caspian Basin is a salt dome region. Because of saline tectonics, the Upper Permian deposits are absent over the domal structures, and Triassic deposits are discordant with evaporites of Kungurian age. However, both Upper Permian and Triassic strata are found in adjacent districts and in interdomal regions.

The most complete sequences of Upper Permian rocks, totalling over 2,500 m (approximately 8,200 ft) occur at the surface in the eastern part of the basin and at depth in the central part, in the Aralsor bore. The

following units may be distinguished: the Ufimian Stage (tentative), comprising lagoonal and continental deposits; the Kazanian Stage, consisting of shallow-water marine and lagoonal deposits, grading upwards into continental deposits; and the Tatarian Stage, consisting of continental red beds. Various horizons of the Triassic are discordant on the eroded surface of the Tatarian and Kazanian beds.

The Triassic, of maximum thickness 2,500-2,700 m (approximately 8,200-8,856 ft) is represented by Lower Triassic (Vetlugian Series of Induan age and Baskunchakian Series of Olenekian age), Middle and Upper Triassic deposits. Recently, ostracode faunas have been used to subdivide the Triassic, and two main correlation schemes have been devised. According to Schliefer (and conditionally accepted my Sokolova), the Vetlugian Series, of continental red beds facies, consists of the following succession in ascending order: 1) *Marginella* Zone; 2) nonfossiliferous layer; 3) and 4) Charophyta zones; 5) *Gerdalia dactyla* Zone; 6) "horizon with various fossils". The Baskunchakian Series, of shallow-water marine and lagoonal deposits, contains three ostracode zones: 1) *Darwinula recondita,* 2) *Glorianella inderica* (both equivalent to the Bogdinskaya Formation, comprising the *Doricranites* and *Tirolites* Beds of Mount Bolshoe Bogdo) and 3) *Pulviella aralsorica* (equivalent to the Inderskaya Formation).

There is some faunal affinity between the Baskunchakian Series and the Middle Buntsandstein of the North German Basin, both units possessing species of darwinulids in common.

A second interpretation by Lipatova and Starozhilova recognizes only a single zone of oval darwinulids to correspond with Schliefer's first four divisions in the Vetlugian Series. This zone is correlated with the Lower Buntsandstein and the lower part of the Middle Buntsandstein of the North German Basin. These authors then recognize the *Gerdalia longa* Zone of the Baskunchakian Series as equivalent to *G. dactyla* Zone and "horizon with various fossils" of Schliefer and correlate it with the Bogdinskaya Formation of Mount Bolshoe Bogdo. This latter formation is considered to be equivalent to the upper layers of the Middle Buntsandstein and the Röt in Germany.

Lipatova and Starozhilova distinguish the following Middle Triassic ostracode zones in the basin: 1) *Darwinula pstinornata;* 2) *Lutkevichinella bruttanae;* 3) *Glorianella culta - G. inderica;* 4) *Laevicythere vulgaris* (= *Pulviella aralsorica*). The Middle Triassic or Muschelkalk age of these zones is confirmed by the similarity of the Charophyta assemblages to those from the Middle Triassic of East Germany, Sweden and Bulgaria. Schliefer, however, suggests that there are significant differences between the ostracode complexes in the Caspian and North German Basins and that caution should be used in ascribing a Middle Triassic age to the above zones.

The uppermost ostracode zone is that of *Gemmanella,* considered by the first three authors to be Middle Triassic and by Schliefer to possibly span late Middle and early Late Triassic times. True Upper Triassic deposits, of continental facies and containing diagnostic plant remains but no ostracodes, serve to complete the succession in the Pre-Caspian Basin.

PALEOCLIMATOLOGY OF THE PERMIAN

F. G. STEHLI

Department of Geology, Case Western Reserve University,
Cleveland, Ohio 44106, U.S.A.

Neither the role of climate in the apparent biotic crisis of the Permian nor the significance of Permian paleoclimatic data can be assessed without assumptions regarding the placement of continents. An almost infinite number of models is possible but three seem sufficiently well constrained to allow testing: 1) a present earth model, 2) a Permian paleomagnetic model, and 3) a sea-floor spreading model. Permian paleoclimatic data are here applied to a test of these three models.

The distribution of Recent organisms suggests a faunal ratio which is quantitative, temperature-sensitive, and self-normalizing for variations in sampling efficiency. When this parameter is plotted against latitude, the resulting curve changes sign at the equator and slopes toward the pole in each hemisphere if the latitude framework is correct. When the faunal ratio for Permian brachiopods is applied to a present earth model (1) and to the Permian paleomagnetic earth model (2), the present earth model can be shown to yield the best fit. An attempt to locate the Permian equator (change in sign of the faunal ratio curve) has not yet yielded definitive results because localities both adequately collected and close to the equator are few. The Northern Hemisphere data are adequate to permit location of the Permian rotational pole, and it is found to lie at 45° to the Permian paleomagnetic pole, thus denying the assumption fundamental to paleomagnetic interpretations of an axial magnetic field.

If one assumes a non-axial dipolar field, a combination of paleoclimatic and paleomagnetic data permits unique location of continents for which there is adequate information and thus allows a test of the sea-floor spreading model (3). From the paleoclimatic data for a well-studied continent with good sample control, it is possible to establish the azimuthal direction towards the rotational pole but not the distance. From the paleomagnetic data for the same continent, one can determine the azimuthal direction toward the magnetic pole and from inclination data the distance as well. These three spacial facts constrain the position of the continent to two locations on an arbitrary latitude-longitude framework. One of these locations is impossible because it can be occupied only if the continent is upside down and a unique relative location of this continent to other continents is thus found. There appears to be enough data for North America and Eurasia to allow such a test. When the test is made, the resulting configuration places North America against Europe in a manner generally consistent with the sea-floor spreading earth model in suggesting that no Atlantic Ocean existed in Permian time. With sufficient data, it may become possible in this same manner to find unique relative positions for other continents.

We see in summary that paleoclimatic data allow for the Permian but do not require the present earth model insofar as latitude is concerned, but do not permit any tests for longitudinal placement. The Permian paleomagnetic model is shown to be incorrect if the axial assumption is maintained. If a nonaxial but still dipolar field is assumed, then relative longitudinal placement is possible and suggests that for the North Atlantic region at least the sea-floor spreading earth model is correct.

Both the present earth model and the sea-floor spreading model leave the latitude of the Northern Hemisphere continents little changed, thus allowing a first approximation interpretation of Permian climate. It appears that the warm-water region of the Permian extended from 50° to 60° N. In the Southern Hemisphere, where control admittedly is poor and no model is easily tested, the warm-water region terminated around 25° to 35° S on a present earth model, suggesting a somewhat higher order of thermal asymmetry than now exists.

THE PERMIAN SYSTEM IN THE SOVIET UNION

D. L. STEPANOV, B. S. ABRAMOV, V. P. BARKHATOVA AND V. M. ZAVODOVSKY
National Committee of Geologists of the U.S.S.R.

While the type area for the Permian System is considered to be the eastern part of the Russian Platform and the Fore-Urals region, Permian deposits are also widely developed in the Asiatic part of the U.S.S.R. The Permian strata show great diversity in thickness, lithology and paleontological characteristics, reflecting very complex and varied sedimentary environments.

Intensive Variscan tectogenesis resulted in a predominantly geocratic regime during the Permian Period, and especially during the Late Permian. This caused a rapid and increasing reduction of epicontinental and geosynclinal seas which gradually were transformed into disconnected, semi-isolated basins of abnormal salinity. By the close of the Permian, continental conditions were representative of the major part of the platform, with marine conditions persisting mainly in the geosynclines (Tethys, Verkhoyan region) and on certain unstable areas of the platform, such as the Omolon and Kolyma massifs. These conditions also characterized Early Triassic time. During the Permian, major climatic changes were taking place, with the development of pronounced climatic belts. These events led to differentiation of biogeographic realms and provinces and, consequently, to contrasts among synchronous faunas and floras.

A peculiar feature of Permian faunas is the frequent occurrence of persistent and even relict assemblages. In many cases, the composition of Permian faunal and floral assemblages reflects environmental conditions more than geological age, while endemic types are common.

The problems mentioned above make elucidation of Permian stratigraphy difficult, particularly the interregional correlation of Permian strata. For example, the Permian-Triassic boundary is universally accepted as the level corresponding to the base of the *Otoceras* Zone. The recognition of this boundary in actual sections, however, often presents problems for which only provisional solutions are available. The major subdivision of the Permian System into two series is generally agreed upon in the U.S.S.R., although some specialists consider a threefold subdivision more rational.

The widespread distribution of highly fossiliferous marine deposits of Early Permian age allows subdivision of this series into stages that can be considered as global stratigraphic units (Asselian, Sakmarian, Artin-

skian stages). The predominance of terrestrial and lagoonal facies in the higher parts of the Permian sequence in the type area, however, prevents recognition of the classical stages (Kungurian, Ufimian, Kazanian, Tatarian) in other regions. Thus it is now difficult to regard these stages as standard units in a general stratigraphic scale, and we are still without a general subdivision of the Upper Permian into stages which can be adopted universally.

During the Permian, extinction of several marine faunal groups took place but not necessarily at the same time in different regions. Where marine conditions through Late Permian and Early Triassic times were continuous, some elements of the Permian fauna survived the close of the Paleozoic and persisted into the Early Triassic. Groups that flourished in the Triassic, such as ceratites, had already made their appearance in the Early Permian. Thus the change in composition of the marine fauna near the Permian-Triassic boundary was gradual, rather than catastrophic.

The development of a terrestrial tetrapod fauna near the end of the Permian was not marked by important changes in systematic composition, such as the extinction of pre-existing major groups or the appearance of new taxa of high rank. However, near the Permian-Triassic boundary there was a substantial alteration in biocoenotic relationships within the tetrapod fauna.

A significant change occurred in the insect fauna. Six Paleozoic orders became extinct and twelve new orders appeared by the end of Permian time.

Changes in the terrestrial flora near the end of the Permian were gradual, and the replacement of paleophytic by mesophytic plants was not synchronous everywhere. Indeed, in some sections, mesophytic floral elements are found to occur below the Permian-Triassic boundary, as presently established.

In spite of a general gradation of faunal and floral changes near the Permian-Triassic boundary, the boundary itself is sometimes distinct and even sharp. This usually reflects a widespread paraconformity at the base of the Triassic, representing a more or less considerable gap in the succession of strata.

LATE PERMIAN AND EARLY TRIASSIC CONODONT FAUNAS

W. C. SWEET

Department of Geology, Ohio State University,
125 South Oval Drive, Columbus, Ohio 43210, U.S.A.

Conodonts were common and widely distributed members of pelagic faunas in Late Permian and Early Triassic seas. Their minute skeletal elements have been recovered from rocks representing a considerable variety of sedimentary facies and they are more abundant and seemingly less provincial in distribution than most of the other types of fossils on which standard Upper Permian and Lower Triassic biostratigraphies are based.

Extensive collections from sections including the Permian-Triassic boundary in several important areas suggest that Late Permian and Early Triassic conodont faunas lacked great diversity but that they were characterized the world over by sequences of distinctive species of multi-element *Ellisonia,* and single element *Anchignathodus, Neogondolella,* and *Neospathodus. Anchignathodus,* which has a long range in Upper Paleozoic strata, makes its last appearance in *Ophiceras*-bearing Lower Triassic rocks and *A. isarcicus* (Huckriede), a distinctive short-lived species, marks a very useful level in lowermost Triassic strata in West Pakistan, Iran, and northern Italy. A succession of *Neogondolella* species, as yet incompletely worked out, may be the basis for dividing Upper Permian rocks into at least three zones. In western United States, Wordian *N. serrata* (Clark and Ethington) is succeeded in probable Capitanian strata by *N. rosenkrantzi* (Bender and Stoppel), which is also abundantly represented in the *Posidonia* shales and Productus Limestone of East Greenland. In East Greenland, *Martinia* shales and limestones above rocks with specimens of *N. rosenkrantzi* yield numerous representatives of *N. carinata* (Clark), which, with *Anchignathodus typicalis* Sweet and *Ellisonia teicherti* Sweet, also dominates the Iranian Dzhulfian and ranges upward into strata with Lower Triassic ammonoids or bivalves in Iran, Pakistan, India, and western United States. Like *Neogondolella, Neospathodus* evolved from ancestors with ozarkodiniform skeletal elements and the two genera are thus very closely related. However, the fact that they are only rarely represented in the same Upper Permian or Lower Triassic samples suggests that they may have been adapted to life in different environments.

Distribution of *Anchignathodus isarcicus* suggests a lowermost Triassic age for the *Ophiceras*- and *Glyptophiceras*-bearing Kathwai Member of the Salt Range Mianwali Formation; for strata at the base of the *Claraia* beds in the Kuh-e-Ali-Bashi section of the Dzhulfa region of Iran; and for rocks in the lower 10m (32.8 ft) of the Werfenian Seis beds of northern Italy. Dzhulfian strata below the level of *A. isarcicus;* uppermost Chhidruan carbonates in West Pakistan; and *Martinia* shales and limestones in the interval from which *Cyclolobus* has been reported in East Greenland, are all characterized by *Neogondolella carinata, Anchignathodus typicalis,* and *Ellisonia teicherti* and, in East Greenland, this fauna succeeds one with *N. rosenkrantzi,* which is also known from strata of probable Capitanian age in western United States.

In contrast with earlier faunas, Upper Permian conodonts are assignable to a limited number of taxa, nearly all of which seem to represent a single major stock or possibly two. These, however, passed the notorious Permian-Triassic filter with seeming indifference, to give rise to a much more varied, but still very closely interrelated fauna in the Lower Triassic. It is presently impossible to detect any hiatus in conodont faunal development at or near the Permian-Triassic boundary in East Greenland, Iran, West Pakistan, or India. Thus, if such an interruption occurred, either it must have been of very short duration or surviving conodonts had skeletons that were too generalized to record anything but major architectural changes.

SMALLER PROTISTAN EVIDENCE AND EXPLANATION OF THE PERMIAN-TRIASSIC CRISIS

HELEN TAPPAN[1] AND A. R. LOEBLICH[2]

[1]Department of Geology, University of California, Los Angeles, California 90024, U.S.A.

[2]Chevron Oil Field Research Company, P.O. Box 446, La Habra, California 90631, U.S.A.

The origin, diversification, adaptation, and extinction of organisms can only be understood by considering the biotic interrelationships within successive ecosystems. In spite of their inconspicuous appearance, smaller protistans are of prime importance to the global ecosystems, for marine food chains and atmospheric oxygen are both direct functions of photosynthesis by the plant protists. Other plant and animal protistans also are important components of many food chains. Unicellular and undifferentiated in nature, the protistans vary widely in other respects, and some demonstrated opposing reactions in the Permian-Triassic.

During the Early Paleozoic, phytoplankton included acritarchs and Prasinophyceaen green algae; their numbers were sharply reduced at the end of the Devonian, perhaps as a response to the rise of land plants. At present the submerged benthic plants along the coasts locally inhibit phytoplankton growth by their more successful competition for nutrients and light; such an effect was intensified in the Devonian by the first retention of nutrients in an important and extensive terrestrial biomass. External metabolites produced by modern phytoplankton inhibit bacterial development, hence the Late Paleozoic reduction in phytoplankton and resultant absence of these bactericidal compounds allowed bacterial increase. The increase in bacteria and decrease in phytoplankton food supply probably combined in decimating zooplankton levels. Planktonic radiolaria had been important, and tintinnids were present in the Early Paleozoic but became scarce by the Permian when radiolarian diversity was only one-fifth that of the Devonian. Zooplankton remained scarce through the Triassic. With the expansion of phytoplankton in the Jurassic (especially the coccolithophorids and dinoflagellates), zooplankton also diversified. Radiolarians, calpionellid tintinnids, and planktonic foraminifera all became of rock-forming abundance locally.

During the Late Paleozoic the scarcity of phytoplankton allowed an increase and diversification of benthic algae. The coralline red algae and the blue-greens (represented by stromatolites) were important during the Carboniferous, whereas dasyclad green algae expanded greatly during the Permian and Triassic. These photosynthetic plants did not replace phytoplankton in the food chain, for filter-feeding invertebrates could not utilize calcareous benthic algae. Planktonic larval stages of other invertebrates were vulnerable to the changes in productivity. Although some specialized benthonic foraminifera such as the Fusulinacea disappeared, other groups rose and disappeared in the Triassic. Some smaller foraminifera and various other invertebrates that persisted probably utilized detritus, benthic algae, or bacteria as food. Many of the agglutinated or porcelaneous foraminifera and even the hyaline Nodosariacea showed little reduction from the Carboniferous into the Mesozoic. The rate of taxonomic turnover of other protists and invertebrates continued to be high in the Triassic, until by the Rhaetic the foraminiferal assemblage had attained an aspect mch like that of the Early Jurassic.

Judging from modern representatives, neither relative land and sea positions nor water depth nor temperature could have been the single controlling factor in the protistan Permian-Triassic changes, as these highly adaptive organisms now are found at all latitudes in waters from intertidal to hadal depths and at wide variations in salinity. Seemingly, their abundance and diversity were most strongly influenced, then as now, by the availability of nutrients or food supply and thus controlled by the various biotic interrelationships.

UPPERMOST PERMIAN AND PERMIAN-TRIASSIC PASSAGE BEDS IN CENTRAL IRAN

H. TARAZ

Geological Survey of Iran, Geological Survey Institute, Box 1964, Tehran, Iran

A continuous marine carbonate sequence, commencing with the Artinskian transgression and ending with a regression of probably early Middle Triassic age, was discovered by the author in 1967 in central Iran, near the town of Abadeh (lat. 30° 55′ N; long. 53° 13′E). This sequence has a total thickness of over 2,650 m, or approximately 8,692 ft.

The units of the Abadeh sequence appear to be transitional and continuous. Artinskian and Guadalupian fossils, mostly fusulinids, are present in the lower part of this section. In the middle part, grey and red limestones (41.3 m or 135.7 ft thick) compare closely with the Dzhulfian and the Permian-Triassic passage beds of the Dzhulfa (Julfa) region of Soviet Armenia, which is the type section for the Dzhulfian Stage. The upper part of the Abadeh sequence represents the Lower Triassic *Claraia* Beds, locally known as the "calcaires vermicules facies". The section concludes with over 780 m (2,558 ft) of dolomite, tentatively assigned a Lower to Middle Triassic age by the author.

Because of the close proximity of the well-known Dzhulfa section, a detailed correlation between it and the Abadeh section has been attempted. This correlation has established that the fossil zones in the Dzhulfa region, attributed to the Dzhulfian, passage beds and lowermost Triassic, are also present in the Abadeh section. The main difference between the two sections is a lithological one, the Dzhulfa section comprising mainly shales, while the Abadeh section consists of marine limestones. In addition, the thickness of the latter section is less than that of Dzhulfa.

A preliminary study of conodonts indicates that the Permian-Triassic boundary lies within the middle portion of the Abadeh section. Conodonts typical of the lowermost Triassic beds of the Salt Range have been found in the Abadeh section, allowing a direct comparison between the two regions.

An abrupt change of facies occurs at the contact of the *Claraia* Beds with the *Paratirolites* Beds in the Abadeh section. Detrital deposits, or other evidence of erosion, have not been observed at this contact, and the same situation pertains in the Dzhulfa region. This similarity between the two regions of 1,100 km (683 mi) apart suggests that the sharp contact and abrupt change of facies is due to a sudden climatic change, rather than to a regression and sedimentary gap.

This postulated climatic change led to deposition of dolomitic sediments during Early to Middle Triassic times in central Iran, and it may

have been the main cause for extinction of stenohaline forms and the appearance of new faunas.

In the Upper Permian subdivision by Glenister and Furnish (1961), the boundary between the Guadalupian and Dzhulfian stages is consider-ed to be transitional. Study of the Abadeh section, however, suggests that there is a gap between these stages at this locality and a section of about 334 m (1,096 ft) of limestones, shales and marls, named the Abadeh Form-ation, separates Guadalupian from Dzhulfian strata. The author proposes that this formation be recognized as the Abadehian Stage, of pre-Dzhul-fian, post-Guadalupian age.

In general, the faunal transition across the Permian-Triassic boundary in the Abadeh section appears to have been gradual, rather than sharp. While the exact delineation of the Permian-Triassic boundary is not dis-cussed in this paper, a chart has been compiled to show the fossil zones and occurrences.

PERMIAN-TRIASSIC BOUNDARY BEDS IN EAST GREENLAND

C. TEICHERT[1] AND B. KUMMEL[2]

[1]Department of Geology, University of Kansas, Lawrence, Kansas 66044, U.S.A.
[2]Museum of Comparative Zoology, Harvard University,
Cambridge, Massachusetts 02138, U.S.A.

The Upper Permian and Lower Triassic formations of East Greenland are world-famous through the paleontological studies of Permian faunas by Dunbar (1955), Newell (1955), and Miller and Furnish (1940) and of Lower Triassic faunas by Spath (1930; 1935). In the early stages of these studies the strata underlying the Lower Triassic formations were believed to be of Carboniferous age. Thus no particular significance was attached to the presence of fragments of productids, bryozoans, crinoid stems, etc., in beds containing Lower Triassic ammonoids. This attitude changed with the recognition of *Cyclolobus*, a guide ammonoid of the Late Permian, in the strata previously considered to be of Carboniferous age (Miller and Furnish, 1940). Trümpy (1960; 1961), on the basis of field studies in the summer of 1958, came to the conclusion that the "Per-mian" faunal elements in the lowest Triassic formations were not derived but actual survivors. Trümpy concluded that in the Kap Stosch area dur-ing lowest Triassic time the benthonic niche was occupied by surviving Permian faunal elements but that the pelagic niche was dominated by Triassic ammonites.

Careful study of a number of Permian-Triassic sections in the Kap Stosch region in the summer of 1967 has provided a number of new ob-servations. First, the Permian-Triassic sections west of Kap Stosch (e.g., Ekstra Elv and River 1) are of homogeneous shale, silty shale, and silt-stone facies. None of the rock units are highly indurated but markedly "soft." Solifluction has so badly affected all outcrops that meaningful stratigraphic sections are next to impossible to obtain. The lowest Trias-sic strata in these regions do contain thin (1-5 cm) hard bands consisting of coquinas of ammonoids *(Glyptophiceras* and *Otoceras)* and containing fragments of productids, bryozoans, and other fossils of "Permian" aspect.

East of Kap Stosch (e.g. between Rivers 7 and 14), the lowest Triassic strata encompassing the *Glyptophiceras* Zone are up to 100 m (approximately 328 ft) thick. They are predominantly arkosic sandstone and conglomerate. A number of horizons yield fragmentary and whole specimens of productid brachiopods, fragments of crinoid stems, bryozoans, and other fossils in coarse sandstone and conglomerate matrix.

These strata, containing mixed associations, by their thickness, sedimentary structures, and composition, clearly indicate very rapid rates of deposition. These environmental considerations lead to the conclusion that the "Permian" faunal elements probably did not actually live and form part of the benthos during earliest Triassic time. The underlying Permian formations are of diverse facies among which biothermal, richly fossiliferous banks are important. Some of these banks weather easily yielding nearly perfectly preserved fossils free of matrix. We consider it more probable that the "Permian" faunal elements in the lowest Triassic formations have been brought into that environment as argillaceous boulders that, once coming to rest, dissolved leaving well-preserved fossils that were rapidly buried in the coarse sediment and in a free state were transported very little.

UPPER PERMIAN FUSULININAN ZONES AND PHYLOGENY OF STAFFELLOIDEA

R. TORIYAMA

Department of Geology, Faculty of Science, Kyushu University, Fukuoka, Japan

The *Paleofusulina-Codonofusiella-Reichelina* fauna appears to occupy the highest position in the Permian sequence of the Tethys province, as in Yugoslavia, Greece, Crimea, Pamir region, south China, Ussurisk and Japan. However, this fauna also ranges downwards, where it is associated with the Upper Guadalupian *Lepidolina-Yabeina* fauna in many of the regions mentioned above.

In the Kuman Stage of Japan, the *Reichelina changsingensis-Paleofusulina simplicata* Zone, which has recently been found in the Kamura and Tsukumi formations of south Kyushu, occupies the highest position in the fusulininan zones of Japan. Besides the two zone species, it includes *Nankinella* spp., but none of the verbeekinids or schwagerinids is associated with them. Although the stratigraphic relationship between the *Reichelina changsingensis-Paleofusulina simplicata* Zone and the *Lepidolina kumaensis* Zone has not been precisely determined, it is possible that the latter is stratigraphically lower than the former.

It is the prevailing opinion amongst Japanese stratigraphers and paleontologists that the *Yabeina globosa* Zone, whose exact stratigraphical position has long been under dispute, is regarded as ranging lower than the *Lepidolina kumaensis* Zone. However, it should be noted that the *Lepidoline kumaensis* fauna (Kuman biofacies) and the *Yabeina globosa* fauna (Kinshozan biofacies) seem to have overlapping stratigraphic ranges. These two faunas occur in different lithofacies, suggesting different ecological conditions. They have never been found together and it is thus difficult to settle their mutual stratigraphic relationships.

It is concluded that the Upper Permian of Japan is divisible into the *Reichelina changsingensis-Paleofusulina simplicata* Zone. *Lepidolina ku-*

maensis Zone and *Lepidolina shiraiwensis* Zone in descending order. The *Lepidolina kumaensis* fauna probably ranges up into the Dzhulfian and may have partly co-existed with the *Paleofusulina-Codonofusiella-Reichelina fauna*. The former may have persisted locally in a few ecologically favorable areas.

The phylogeny of the Staffellidae and Thailandinidae is important in the development of the fusulininan foraminifers. The spirotheca in these two families tends to be altered by secondary mineralization, although closely-associated specimens of fusulinids and verbeekinids do not display the same type of replacement and this difference in preservation is independent of stratigraphic position. Provisionally, these two families are grouped into the single superfamily Staffelloidea, but it is probable that the spirotheca of the Staffelloidea had inherently different original structures from that of the Fusulinoidea and Verbeekinoidea, consisting probably of aragonite. In other general characteristics of the shell the Thailandinidae are similar to the Neoschwagerinidae, and the Staffellidae resemble the Ozawainellidae.

Although material at our disposal is not sufficient to support a final conclusion, it is presumed that the Staffellidae and Thailandinidae comprise an independent stock in the Fusulinina which paralleled the successive evolutionary changes of the Ozawainellidae, Verbeekinidae and Neoschwagerinidae.

THE EARLIEST MARINE TRIASSIC ROCKS: THEIR DEFINITION, AMMONOID FAUNA, DISTRIBUTION AND RELATIONSHIP TO UNDERLYING FORMATIONS

E. T. TOZER
Geological Survey of Canada, Ottawa, Ontario, Canada

The base of the *Otoceras woodwardi* Zone (type locality in Himalayas) is accepted as the base of the Triassic System. Adoption of this convention is necessary because the Bunter of Germany, the base of which provides the definition of the Permian-Triassic boundary, is not adequately faunally characterized for recognition throughout the world. All rocks older than the *Woodwardi* Zone are regarded as pre-Triassic. In terms of the four Lower Triassic stages (Griesbachian, Dienerian, Smithian, Spathian) the *Woodwardi* Zone is Griesbachian.

The Griesbachian ammonoids are assigned to the following genera: *Episageceras, Metophiceras, Tompophiceras, Ophiceras, Discophiceras,* a new genus of Ophiceratidae, *Vishnuites, Proptychites, Otoceras* and *Anotoceras*. The record of *Pseudosageceras,* based solely on the Pastannah (Kashmir) occurrence, is rejected. The Pastannah bed was regarded as more or less correlative with the *Woodwardi* Zone by Diener and Spath but it lacks *Otoceras* and contains *"Pseudomonotis" himaica* Bittner and is thus probably Smithian. *Pseudosageceras* has long been regarded as a member of the Medlicottiaceae and therefore as a Paleozoic holdover but is here interpreted as a ceratitid related to *Hedenstroemia*.

In Canada Lower and Upper substages are discriminated within the Griesbachian. *Otoceras* and *Metophiceras* characterize the Lower Griesbachian. *Ophiceras* and *Proptychites* dominate the fauna of the Upper Griesbachian, in which *Otoceras* is unknown. These two substages are

clearly recognizable in East Greenland and Siberia, and possibly also at Spiti (Himalayas) and are thus of more than local significance. In Canada, Siberia, Greenland and Spitsbergen the earliest Triassic beds have *Otoceras* but no *Ophiceras*. Only in the Himalayas, where the sections are extraordinarily thin, and where individual beds may contain fossils of more than one age, is there any evidence to suggest that *Ophiceras* occurs in the earliest Triassic beds. The Lower Griesbachian is characterized by a meagre ammonoid fauna in which the only diagnostic genus is *Otoceras*, a distinctive genus obviously descended from Late Permian otocerataceans. In terms of ammonoid faunas it is impossible to identify the earliest Triassic beds unless *Otoceras* is present. *Ophiceras*-bearing beds are certainly not necessarily earliest Triassic, as held by Kummel and Teichert, but are more probably Upper Griesbachian.

Lower Griesbachian has been definitely identified only in the Himalayas, Arctic Canada, Alaska, East Greenland, Spitsbergen and northeast Siberia. These Lower Griesbachian beds commonly, if not invariably, rest concordantly upon Permian rocks but nowhere are the underlying Permian rocks demonstrably the youngest known beds of that System. As yet there is no known place where the youngest known Permian (e.g. the *Paratirolites* beds of Armenia) is followed by the earliest Triassic. The boundary everywhere seems to be marked by a hiatus with one or more of the standard units of the biochronologic scale missing. Where the record is preserved a worldwide event evidently interrupted marine sedimentation immediately before the deposition of the Lower Griesbachian sediments. A record may have been made in the ocean basins but was presumably long ago swept into a subduction zone where its identity has been lost forever.

PERMIAN FORMATIONS OF NORTHEAST U.S.S.R.

V. I. Ustritsky, V. N. Andrianov, Y. V. Arkhipov, V. G. Ganelin, V. I. Korostelyov and G. E. Chernyak
National Committee of Geologists of the U.S.S.R.

The Permian formations of northeast U.S.S.R. form part of the Boreal biogeographic realm. Marine faunas are characterized by a scarcity or absence of colonial corals, fusulinids, etc., and by the presence of endemic forms, making correlation with type sections in European Russia extremely difficult.

Permian sections described from the area comprise three main facies types: terrigenous sediments up to 8,000 m (approximately 26,240 ft) thick in the Verkhoyan area and the Kula Basin; clastics, mainly of Upper Permian age and reaching 1,000 m (approximately 3,280 ft) in the Kolyma region and the Gizhiga Basin; and carbonates, represented by Upper Permian limestones reaching 400m (approximately 1,312 ft) in thickness, occurring in the Omolon Massif region. In this latter section, Lower Permian strata are absent.

The Kygyltass Formation and most of the Echiy Formation of the Verkhoyan region, and the Munugudzhak unit of the area to the east, are clearly of Lower Permian age. These strata have yielded Artinskian ammonoids, such as *Paragastrioceras* and *Uraloceras* and the brachiopod *Jakutoproductus verchoyanicus*. Extremely shallow-water benthos includes the Lower Permian brachiopods *Spiriferella saranae, Horridonia*

cf. *timanica, Anidanthus bojkovi* and *Neospirifer paranitiensis*. This part of the section corresponds to the Asselian-Artinskian stages.

The middle part of the Permian section is assigned to the Lower Permian by some investigators and to the Upper Permian by others. Included here are the Tumara and Khabakh formations of the Verkhoyan region, and the Dzhigdali unit of the Omolon Massif region. Characteristic of this part of the section is the Upper Balakhonsky floral complex (usually considered to be Lower Permian) and the Baigendzhinsky ammonoid association. Among brachiopods represented are typical Upper Permian forms, such as *Spiriferella keilhavii* and *Rhynchopora lobjaensis*. However, forms typical of the Lower Permian are also present. The bivalve genus *Kolymia* is common. This part of the section should probably be correlated with the Kungurian and most of the Ufimian stages.

Upper Permian deposits are represented by the Delenzha and Dulgalakh Formations in the Verkhoyan area, and the associated Omolon, Gizhiga and Khivatsch units. The brachiopods *Licharewia, Stepanoviella* and *Megousia* are abundant, while the ammonoid *Spirolegoceras* and the Kolchuginsky floral complex are also present. These deposits are equivalent to the Kazanian and Tatarian stages (and probably also to the uppermost Ufimian Stage).

Sedimentary units of obviously glacial-marine origin occur in the Permian section of northeast U.S.S.R. and are of great importance in correlation. The thickest and most persistent of these units occurs in the middle Upper Permian, in the lower part of the Dulgalakh Formation. A second unit is present in the lower part of the Permian section, but its exact stratigraphic position has not yet been determined.

DIVERSITY-DEPENDENT FACTORS AND THE MARINE BIOSPHERE OF THE PERMIAN-TRIASSIC

J. W. VALENTINE AND E. M. MOORES
Department of Geology, University of California, Davis, California 95616, U.S.A.

When extinctions are caused by diversity-independent factors, rediversification may be accomplished by the radiation of new lineages for which these factors are not limiting. Lineages eliminated by diversity-dependent factors cannot be replaced, however, as long as the factors are operating. Thus a wave of extinction caused by diversity-independent environmental fluctuations may be immediately followed or even partially accompanied by a wave of diversification, while a wave of extinction caused by diversity-dependent factors will produce biotic impoverishment that will persist until the factors themselves are ameliorated.

The extinctions associated with the Permian-Triassic boundary were accompanied by a reduction in species diversity which persisted well into the Mesozoic, strongly suggesting that diversity-dependent factors were responsible. These factors are chiefly space and energy — that is, habitats and trophic resources. A reconstruction of Permian and Triassic continental geography suggests the appearance and persistence of low-diversity states for these factors. The regressive, supercontinental geographic pattern probably favored low provinciality and high trophic resource fluctuations. The geographic and eustatic pattern can be related to plate-tectonic processes.

THE UPPER PERMIAN AND LOWER TRIASSIC
OF WESTERN EUROPE — A PALYNOLOGICAL APPROACH

H. VISSCHER

Paleobotany, Fort Hoofddijk, Budapestlaan 42, Utrecht, The Netherlands

A considerable amount of information on palynological assemblages in the Permian and Triassic of Western Europe has become available over the past 15 years. It is already evident that palynology, alone or in combination with other methods, can be applied successfully in regional correlation of Permian and Triassic successions. On the other hand, it has never been emphasized that palynology might provide the primary biostratigraphic criteria for subdividing the Permian and Triassic systems in Europe. Palynological literature shows that there has been a strong tendency to attempt to correlate palynological data strictly with the conventional stratigraphic time-scale used in the area of investigation.

Although Western European classifications are now far more detailed, their nineteenth-century framework, essentially lithostratigraphic, is still frequently claimed to represent a reliable chronostratigraphic subdivision of a virtually complete sequence of Permian and Triassic rocks. However, the palynological data so far available cannot be reconciled with the existing schemes of chronostratigraphic classification and correlation. An alternative concept of the Western European Upper Permian and Lower Triassic, although tentative until supporting information is available, has been summarized in Figure 3.

Two general conclusions can be drawn: 1) The traditional reliance upon facies as an infallible means of subdividing the Permian and Triassic systems must be opposed. For example ,the classic Permian-Triassic boundary in Western Europe cannot be accepted because of the diachronous position of the Zechstein-Buntsandstein facies transition. 2) There are no reasons for maintaining complete Permian and Triassic sequences in the generalized stratigraphic column of Western Europe. With regard to the Permian, only the existence of the lowermost part (Autunian) and the uppermost part (Thuringian) can be demonstrated, a regional hiatus embracing the greater part of the Permian System. Also the Triassic seems to be incomplete. At least within the Lower Triassic there exists another hiatus of regional importance.

LATE PERMIAN AND EARLY TRIASSIC MICROFLORAS
OF NORTHWESTERN EUROPE

G. WARRINGTON

Institute of Geological Sciences, Leeds, Yorkshire, England

In north Germany and Britain the cyclic deposits of the Upper Permian Zechstein sequence yield relatively uniform microfloras dominated by bisaccate striate miospores of the genera *Lueckisporites, Protohaploxypinus, Striatopodocarpites, Striatoabietites, Taeniaesporites,* etc. Also abundant are disacciatrilete genera *(Klausipollenites, Falcisporites, Paravescicaspora).* Bisaccate genera with trilete or monolete marks *(Illinites, Jugasporites)* are rarer, as also are monosaccate forms (represented by *Nuskoisporites* and *Perisaccus).* Minor numbers of trilete asaccate forms and monosulcate miospores complete the assemblages. Zechstein assem-
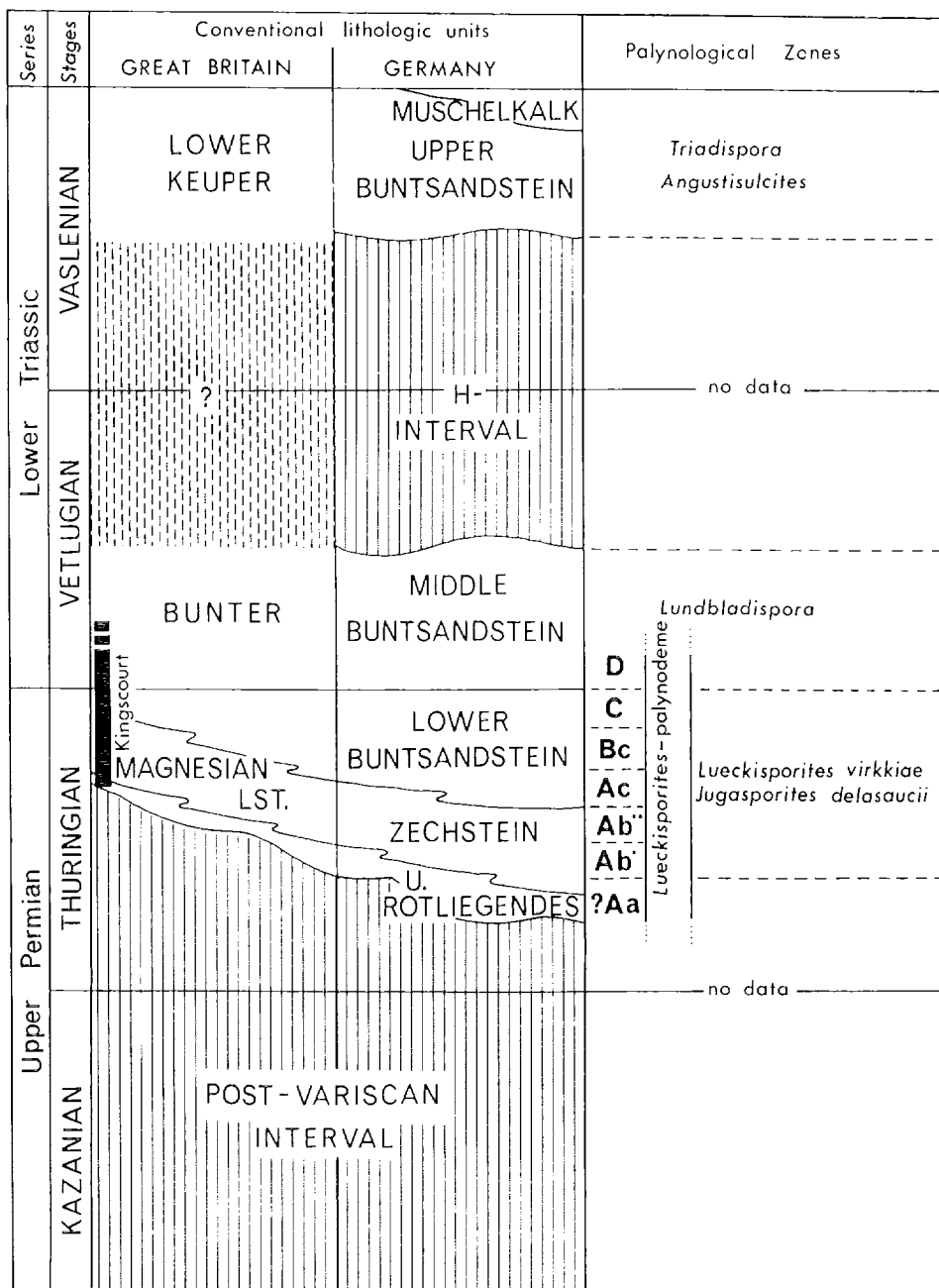
Fig. 3. Lithologic units, palynological zones and facies relationships within the Permian-Triassic of western Europe.

blages are generally most profuse in the lower cycles of the sequence and become more restricted upwards towards the base of the Trias which is usually taken at the base of the Buntsandstein sequence.

The lower and middle parts of the Bunter sequence have generally proved devoid of miospores although isolated assemblages are known. In the Upper Bunter (Röt) of Holland and Germany and the time-equivalent facies (the Keuper Sandstone, Waterstones and Lower Keuper Marl) in different parts of Britain, profuse and varied microfloras distinct from those of the Zechstein occur. These assemblages are dominated by disacciatrilete *(Alisporites, Voltziaceaesporites)* and disaccitrilete miospores *(Triadispora, Illinites),* whilst bisaccate striate forms represented by *Striatoabietites, Taeniaesporites, Tubantiapollenites, Lunatisporites* and *Angustisulcites* are rarer. Trilete asaccate forms are abundant and are represented by *Punctatisporites, Verrucosisporites, Cyclotriletes, Spinotriletes, Cyclogranisporites,* etc. A number of camerate forms (e.g. *Lundbladispora)* occur, as do certain monosaccate genera *(Nuskoisporites* and *Accinctisporites)* and monosulcate forms.

The general absence of miospores from the Lower and Middle Bunter hampers the creation of a clear picture of the relationship between the Zechstein and Upper Bunter (Late Scythian) microfloras. This hiatus may be the result of regional paleogeographical and climatological factors which produced an environment inimical to plant life and also sediments in which miospores are unlikely to be preserved in abundance.

THE PERMIAN-TRIASSIC BOUNDARY IN NEW ZEALAND AND NEW CALEDONIA AND ITS RELATIONSHIP TO WORLD CLIMATIC CHANGES AND EXTINCTION OF PERMIAN LIFE

J. B. WATERHOUSE

Department of Geology, University of Toronto, Toronto, Ontario, Canada

In New Zealand the stratigraphic contact between Triassic and Permian seems to be gradational locally, but there is no faunal intergradation, and it appears possible that basal Triassic faunas are not present. The Permian segment is unusually thick, almost entirely marine, and moderately fossiliferous. The penultimate faunas, characteristic of the Waiitian Stage, are normal Permian faunas, approximately equivalent to the Dzhulfian of Armenia, found also in Iran, Salt Range, Wuchiaping (China), Japan (Gujo), and perhaps the Kalouzin Suite of east Siberia (Licharew, 1966), though the latter may be as old as Ufimian. The uppermost Permian fauna, characteristic of the Makarewan Stage, has been correlated with the *Paratirolites* faunas of Armenia and south China (Changsing), but unlike these faunas, lacks any of the major brachiopod groups, such as Orthotetida or Productida, which virtually disappeared at the end of the Paleozoic Era. The brachiopod genera are members of superfamilies which survived into the Triassic, such as Rhynchonellacea, Spiriferacea and Dielasmatacea, but the genera are characteristic of the Permian Period. It is thus possible that the Makarewan Stage represents the very latest Permian, and the most convincing transition yet known into Triassic.

The earliest Triassic in New Zealand contains poorly dated bivalves. The earliest ammonoids are of Middle Scythian, or Smithian age.

The contact between Prmian and Triassic in New Caledonia is less well exposed, and falls somewhere between brachiopods and bivalves of Capitanian (=basal Tatarian) age, equivalent to the Puruhauan Stage of New Zealand, and Ladinian brachiopods. Ammonoids, including xenodiscids, have been described by Avias and Guerin as either Late Permian or Early Triassic. Some belong to *Cyclobus* and *Xenaspis* of Middle Permian (Capitanian) age.

The sequence of Permian faunas in New Zealand provides a key to the nature of the Permian-Triassic contact. The faunas alternate in composition and affinities. Three faunas in the sequence of eight are relatively impoverished generically, with strong affinities to faunas of eastern Australia, and coincide in age with the main glacial phases of the east Australian Permian. Overlying faunas are more diversified, and therefore indicative of relatively warmer water. Following faunas are very diverse, and include fusulinacea and reef-building corals, absent from the other suites. Each warm-water fauna is followed by an abrupt faunal change to a cool-water fauna.

This pattern of three cold episodes followed by warmer intervals is also reflected widely by faunas in the Northern Hemisphere through Canada and Siberia, and the cold episodes even affected paleotropical regions such as Texas, when cold-water genera such as *Yakovlevia* and *Spiriferella* were introduced for brief times. The pattern of glaciation and amelioration is also reflected in an intricate way by the nature of sedimentation, particularly in the formation of coral reefs, coal measures, tillites, salt deposits and red beds over the entire globe.

Furthermore, climatic changes provide a simple explanation for the great destruction of life at the end of the Permian Period. This is considered to have been real, affecting over 50 per cent of all life. Faunal analyses show that the genera and families which perished were essentially tropical in hibitat, and that a prime cause lay in unusually high temperatures for a brief interval.

THE DISTRIBUTION AND FORMATION OF PERMIAN-TRIASSIC RED BEDS

B. WAUGH

Department of Geology, University of Hull, Hull, Yorkshire, England

One of the most remarkable features of the Permian-Triassic is the widespread development of red bed sediments, occurring throughout Western Europe, western, interior and eastern United States, and parts of Russia, China, South America, southern Africa, India and eastern Australia. Furthermore, the general uniformity of facies types in all such regions must reflect similar tectonic settings of source and depositional area, mode of sedimentation and climate.

Two basic structural settings can be recognized: a) The arkosic red beds of orogenic basins and grabens, often passing laterally into alluvial plain deposits. The Newark Group of the eastern United States, the Permian arkoses of Peru and the Rotliegende arkosic fanglomerates and dune sands of Germany typify this category. b) Red beds of cratonic coastal plain and intertidal regions. This large group is represented by the thick, often evaporite-bearing, red bed sequences of the North American

(Supai, Dewey Lake, Chinle, Moenkopi formations, etc.) and European Permian-Triassic, and the Tatarian Series of Russia. The close association of dune sands, fanglomerates, playa and intertidal sands and shales, as well as evaporites and reefal dolomites, illustrates widespread arid conditions.

Although red beds are a common occurrence in the Permian-Triassic of the Northern Hemisphere, in the Southern Hemisphere they are mainly restricted to the Triassic. The Permian here is largely represented by coal measure sediments, and presumably Gondwanaland lay within the tropical climatic belt during this time. Indeed, stratigraphical and sedimentological evidence indicates that the Permian in general was a period of climatic contrasts, whereas, during the Triassic, perhaps as much as 75 per cent of the world's land was arid.

Thus, in the Triassic of Gondwanaland, the Roraima arkoses of Venezuela and adjacent regions characterize northern South American red beds. Vast desert regions are recognized in the Late Triassic of Uruguay and Brazil, with the alluvial Piramboia, playa deposits of the Santana, and dune sands of the Botucatu constituting the red Botucatu desert. Similarly, in southern Africa, the Stormberg Red Beds and the succeeding eolian Cave Sandstone, and in India, the Pachmari red sandstones and shales of the Mahadevi Series depict an extensive Gondwanide desert phase.

Using analogies from modern desert red beds it may be reasoned, on petrological and sedimentological grounds, that the red coloration of the Permian-Triassic sediments can be accounted for by *in situ* diagenetic alteration of non-red, iron-bearing detrital grains and clay minerals within the depositional basin. The desert environment is ideal for the formation and preservation of red ferric oxides.

Continuing aridity during the Permian Period undoubtedly led to a major increase in salinity of sea water, with a concomitant, progressive, large-scale decimation of those marine organims with limited salinity tolerances. It was probably only in isolated regions of persistent near-normal salinity that ony fauna could survive. However, during the Triassic, the extraction of enormous quantities of salt (for example around western Gulf of Mexico and North Africa) probably caused a return to normal salinities, and, consequently, a cosmopolitan fauna was re-established in this Period.

EVOLUTION OR REVOLUTION OF AMMONOIDS AT MESOZOIC SYSTEMIC BOUNDARIES

J. Wiedmann

Institüt und Museum für Geologie und Paläontologie der Universität Tübingen, 74 Tübingen, Sigwartstrasse 10, West Germany

Biologic revolutions at major stratigraphic boundaries, such as the Permian-Triassic, have been given numerous explanations, a few of which are: endogenous biological explanations (Schindewolf's typo-genesis); ecological factors (Simpson's Quantum Evolution, adaptive radiation, funal response to transgressions and regression, competition); physical factors (temperature, oxygen deficiency, geomagnetic reversals, impact of cosmic rays); sedimentary factors (nondeposition) or chemical explanations (diagenetic extinction).

In order to attempt to comprehend the true nature of these faunal revolutions and the possible influence of biological and physical factors, ammonite evolution at the Triassic-Jurassic and at the Jurassic-Cretaceous boundaries was re-studied and quantified. It is believed that the more detailed data now available gives a clearer impression of evolutionary events, not only at these boundaries, but also at the Permian-Triassic boundary.

It can be demonstrated that there is neither an abrupt and worldwide extinction, nor a spontaneous appearance of new elements at these caesuras as was, for example, generally supposed in the case of the Triassic-Jurassic boundary. Instead, one can recognize three distinct phases in the sequence of events: 1) A continuous, and quantitatively recognizable, disappearance of "old" faunal elements. 2) A similarly continuous, gradual, and largely synchronous appearance of, or substitution by, qualitatively "new" elements in very small populations, yet in various parallel lineages (as in mosaic evolution). 3) A quite revolutionary, and quantitatively very sudden, diversification of those new elements previously installed at the boundary.

Thus one can demonstrate both continuous evolution of the new elements (or true "typo-genesis"), as well as discontinuous spontaneous revolution, which does not produce qualitatively new characters and must be explained by diversification or adaptive radiation. This latter phenomenon needs no further explanation by internal biological factors or by higher mutation rates resulting from the impact of cosmic rays. It is believed that world-wide ecological factors, which promote greater niche diversity, suffice to explain these adaptive radiations.

FUSULINACEAN HISTORY AND ITS BEARING UPON PERMIAN BOUNDARY PROBLEMS

G. L. WILDE

Humble Oil and Refining Company, Denver, Colorado 80201, U.S.A.

Total extinction of fusulinacean foraminifera near the close of Permian time corresponds with extinctions among many families of Paleozoic animals. The tendency, however, is to think that these extinctions were rather abrupt, which carries a connotation of catastrophic biological revolution. Amongst the fusulinaceans, however, it can be demonstrated that the tendency toward extinction of the group had a rather early beginning accompanied by: (1) massive migrations away from former centers of proliferation, and (2) experimentation in shape, size, coiling, tunnel number and position, and shell composition. The absence of large genera, such as *Polydiexodina,* in latest Guadalupian rocks and the development of minute, complicated forms with possibly different shell compositions, point toward gradual, but extreme environmental changes. It is believed that these changes developed in response to geotectonic activity of a global nature. If it is true that continental masses were breaking up as early as Late Permian time, some knowledge of the loci of such pull-apart activity should help in reconstructing paleogeography for the time prior to the separation. Rather than making the picture more complicated, this reconstruction should help in deciding upon major stage boundaries within the Permian. Fusulinacean history offers important criteria for these boundary problems.

Most fusulinid specialists have commonly regarded the *Polydiexodina* faunas of North America so coeval with those of Asia (Turkey, Afghanistan, etc.). The so-called *Polydiexodina* of southern Asia, however, corresponds more closely to *Skinnerina,* an Early Guadalupian (Wordian) genus. This is extremely important because the true *Polydiexodina* faunas of North America probably correlate with the *Yabeina* Zone of Japan. The minute *Yabeina texana* Skinner and Wilde, of the Lamar Limestone (Upper Capitan) of Texas and New Mexico, seemingly represents a late, dwarfed representative of the genus.

The *Lepidolina* Zone equivalent in North America is probably post-Guadalupian (Early Ochoan), and is represented only by the *Paradoxiella-Paraboultonia-Codonofusiella-Reichelina* faunas. *Palaeofusulina* has not been found in North America, and its occurrence with *Codonofusiella* and *Reichelina* elsewhere probably corresponds to the Late Ochoan (Late Dzhulfian) Stage.