# PERMIAN[1]

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## INTRODUCTION

The Permian System was named by Murchison in 1841 for strata exposed in a large structural basin on the western flank of the Ural Mountains and takes its name from the Province of Perm about 1,200 km east of Moscow. Along the western flanks of the Urals, Carboniferous strata are overlain by sandstone, conglomerate, evaporite, shale, and marly limestone strata from which Murchison identified brachiopods that, in general, are similar to those of Carboniferous faunas elsewhere. They also contain fishes and amphibians similar to those in the Zechstein of the German Dyas, and correlate with the Magnesian Limestone, which in Great Britain overlies the Carboniferous coal measures. Murchison realized that the stratigraphic interval above the Carboniferous and below the Triassic must be more significant than suggested by the poorly fossiliferous reddish sandstone, shale, and dolostone of western Europe and that the Russian faunas and stratigraphic succession of the Perm region fitted into

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[1] Manuscript received August, 1976.

this part of the geologic column; therefore, the Permian became the only system (except for the North American usage of Mississippian and Pennsylvanian for Carboniferous) to be defined outside of northwestern Europe.

Neither the lower nor upper boundaries of the Permian System were well defined by Murchison and this has resulted in some confusion that has been compounded by later, more detailed biostratigraphic studies that have attempted to place the lower boundary at so-called "natural faunal breaks" in the succession. One consequence of this type of faunal approach to studies of Permian strata in the type area is an overemphasis on biostratigraphic units and a neglect of detailed lithologic studies. In the type area the upper boundary of the Permian with the Triassic System is in a clastic redbed continental succession and is defined on vertebrate fossils where these are available. Considering the work of Russian geologists available at the time and the fact that Murchison spent only the summers of 1840 and 1841 examining the whole of the geology of Russia in order to prepare his monograph on *The Geology of Russia in Europe and the Ural Mountains*, it is remarkable that there are not more problems with the definition of the Permian System.

As described in more detail by Murchison, de Verneuil, and von Keyserling (1845), the strata originally included in the Permian System clearly encompass beds of the Kungurian facies and the Ufimian, Kazanian, and Tatarian stages (Dunbar *et al.*, 1960). The thick section of Artinskian shale, sandstone, and conglomerate exposed in the southern flanks of the Ural Mountains contains ammonoids (Karpinsky, 1889) that are considerably more advanced phylogenetically than those known from Upper Carboniferous beds and can be correlated with faunas in other parts of the world that generally have been accepted as of Permian age. Karpinsky's Artinskian Stage, which he included in the Permian System, has the Sakmarian Limestone at its base. Ruzhentsev (1936), after a preliminary study of the ammonoids, proposed recognition of the Sakmarian Stage for this limestone and restricted the Artinskian Stage to the beds above the Sterlitamak beds.

Murchison considered the lower limestone units exposed on the Ufa plateau and Timan arch to be Upper Carboniferous, on limited fossil evidence. Chernyshev (1902), Frederiks (1928, 1932), and Tolstikhina (1935), while studying fossils from these beds, described them as Upper Carboniferous and considered them to constitute the "Uralian Stage" of de Lapparent (1902). Several distinctive fossil zones were eventually recognized and the next to lowest zone was designated as the Zone of *"Schwagerina" (=Sphaeroschwagerina),* which was also known from the lower part of the Sterlitamakian Stage in the southern flanks of the Urals. The "Uralian Stage" thus overlapped with the Sterlitamak and Artinskian beds but was not an exact equivalent. The lowest zone of the "Uralian" containing fossils of the Zone of *Triticites* is considered to be Upper Carboniferous, and the name Gzhelian Stage has been adopted for the major part of this Upper Carboniferous sequence.

The question of the placement of the lower boundary of the Permian was discussed by leading Soviet specialists in 1936 prior to the seventeenth International Geological Congress in 1937 and no consensus was reached on whether the base should be at the base of the *"Schwagerina"*-bearing beds, which form the lower part (Asselian) of the Sakmarian Stage, as indicated by Ruzhentsev's studies, or near the top of the "Uralian" equivalent at a stratigraphic position within the Sterlitamak beds as suggested by Rauzer-Chernousova (1940, 1949) based on fusulinacean studies. Earlier, in North America, Beede and Kniker (1924) had recognized the stratigraphic significance of the Zone of *Pseudoschwagerina* and had used that unit to recognize the base of the Permian in North America and elsewhere. It may be argued (Dunbar, 1940) that at least some Soviet paleontologists had correlated fossils, such as ammonoids, from the Asselian, Sakmarian, and Artinskian with Wolfcampian and Leonardian faunas described from North America. Because these North American faunas had been assigned to the Permian on the strength of their stratigraphic position with respect to the Zone of *Pseudoschwagerina,* many Soviet biostratigraphers decided to assign the Asselian, Sakmarian, and Artinskian stages to the Permian. In so doing a major marine faunal succession was included in the type sections of the Permian System. Chinese biostratigraphers (CHAO, 1965) have apparently maintained that the base of the Permian should not be placed this low and they choose a boundary that lies approximately at the base of the Ufimian Stage or near the base of the "Kungurian" facies.

In 1950, and again in 1960, the Soviet All-Union Institute of Petroleum Geology (VNIGRI) held conferences concerning the boundary between the Carboniferous and Permian and the subdivisions of the Permian System. The major conclusions of these conferences are summarized in Figure 1 (see also MIKLUKHO-MAKLAY, 1963; LIKHAREV, 1966; NALIVKIN, 1973). The base of the Permian System is placed at the base of the fusulinid Zone of *"Schwagerina."* One change in nomenclature that the second of these conferences adopted was the recognition of the Zone of *"Schwagerina"* as the Asselian Stage and the restriction of the Sakmarian Stage to the stratigraphic equivalents of the Tastuba and Sterlitamak beds.

# REGIONAL BIOSTRATIGRAPHY

## PERMIAN SYSTEM IN TYPE AREA

On the Russian platform and along the western margin of the Ural Mountains (Fig. 1) the Asselian, Sakmarian, and Artinskian stages show numerous facies changes, which also led to early stratigraphic confusion. Large, massive reef mounds are common along the southeastern edge of the Russian platform and these pass eastward into shale and sandstone along the downwarp at the western edge of the Uralian geosyncline. To the west on the Russian platform these stages include limestone, commonly dolomitized or silicified, dolostone, and anhydrite. In the northern part of the Russian platform Asselian and Sakmarian gypsum, anhydrite, and dolostone are widespread and overlain by Artinskian terrestrial red beds. Several structural arches on the Russian platform were exposed during these ages to form low islands. The Uralian geosyncline was in the initial process of being structurally compressed and uplifted, and formed an eastern source of clastic sediments.

Most of the Kungurian facies contains poorly fossiliferous gypsum and red shale (GLUSKO & FEDOROV, 1974). These rock types, although locally missing, are widely distributed on the Russian platform above Artinskian strata. Kungurian marly limestone and dolomitized limestone beds bearing restricted marine faunas are not widely distributed, and contain species having Artinskian affinities as well as other species having Kazanian affinities. NALIVKIN (1973) suggested that many of the evaporite beds presently considered to be Kungurian in age may eventually prove to be in part Artinskian, Ufimian, or Kazanian.

The Ufimian Stage is less continuously distributed and between the Volga River and the Ural Mountains these strata locally appear as red clastic, variegated clay, sandstone, and marly shale beds reaching as much as 150 m in thickness. The fauna is meager and includes fresh-water bivalves and ostracodes in the lacustrine and marly clays. These nonmarine strata of the Ufimian increase to 1,500 m in thickness near the Urals and indicate the presence of the Ural Mountain Range as a source of clastic sediment by Ufimian time. The lateral facies relationships between the Ufimian nonmarine strata, the evaporites of the Kungurian, and the brackish-water deposits of the Kazanian Stage are not well known.

The Kazanian Stage overlies the Kungurian and Ufimian stages, consists of 100 m or less of well-cemented, greenish-gray, impure limestone, clay and marly clay, and has a brackish-water or restricted marine fauna. Lithologically the Kazanian strata resemble the Zechstein beds of western Europe and are traditionally correlated with them. Kazanian strata and faunas are distributed in an elongate basin that extends north-south along the central part of the Russian platform. NALIVKIN (1973) compared these distributions to those of the modern Caspian

| PAMIRS | CHINA | | JAPAN | AUSTRALIA SYDNEY BASIN | | | N. AMERICA WEST TEXAS REF. SECS. | |
|---|---|---|---|---|---|---|---|---|
| Lower Triassic | Lower Triassic | | Lower Triassic | Lower Triassic | | | ?Middle Triassic | |
| | | | | | | | ? | |
| Pamirian | Lopingian | Changhsing Fm. | Mitaian | Newcastle Coal Measures | | | hiatus | |
| | | | ? | ? | | | ? | |
| | | Wuchiaping Ls. | Kuman | Tomago Coal Measures | | | Ochoan | |
| | ? | | | | | | ? | |
| Murgabian | Maokou Ls. (Maokouan) | | Akasakan | Maitland Group | Mulbring Fm. | | Guadalupian | Capitan Ls. (Capitanian) |
| | | | | | ? | | | |
| | | | | | Muree Fm. | | | Word Fm. (Wordian) |
| Kubergandinian | | | | | | | | |
| | | | Nabeyaman | | Branxton Fm. | | Leonardian | Road Canyon Fm. (Roadian) |
| | | | | | | "Fenestella Zone" | | Cathedral Mt. Fm. |
| ? | ? | | | | | | | |
| "Artinskian" | Chihsia Fm. (Chihsian) | | | | | | | |
| | | | | Greta Coal Measures | | | | Skinner Ranch Fm. |
| | | | Sakamotozawan | | | | | |
| | | | | Farley Fm. | | | | |
| ? | | | | | | | | |
| "Sakmarian" | | | | Rutherford Fm. | | | | |
| | Maping Ls. (Mapingian) | | | | | | Wolfcampian | Lenox Hills Fm. |
| | | | | ? | | | | |
| | | | | Allandale Fm. | | | | |
| | | | | | | | | Neal Ranch Fm. |
| | | | | ? | | | | |
| | | | | Lochinvar Fm. | | | | |
| | | | | ? | | | | |
| | ▨ | | Hikawan | | | | | |

FIG. 1. Type Permian section, other sections commonly used for regional standard sections, and their approximate correlation. In Turkmen SSR, the Asselian and Sakmarian equivalents commonly are referred

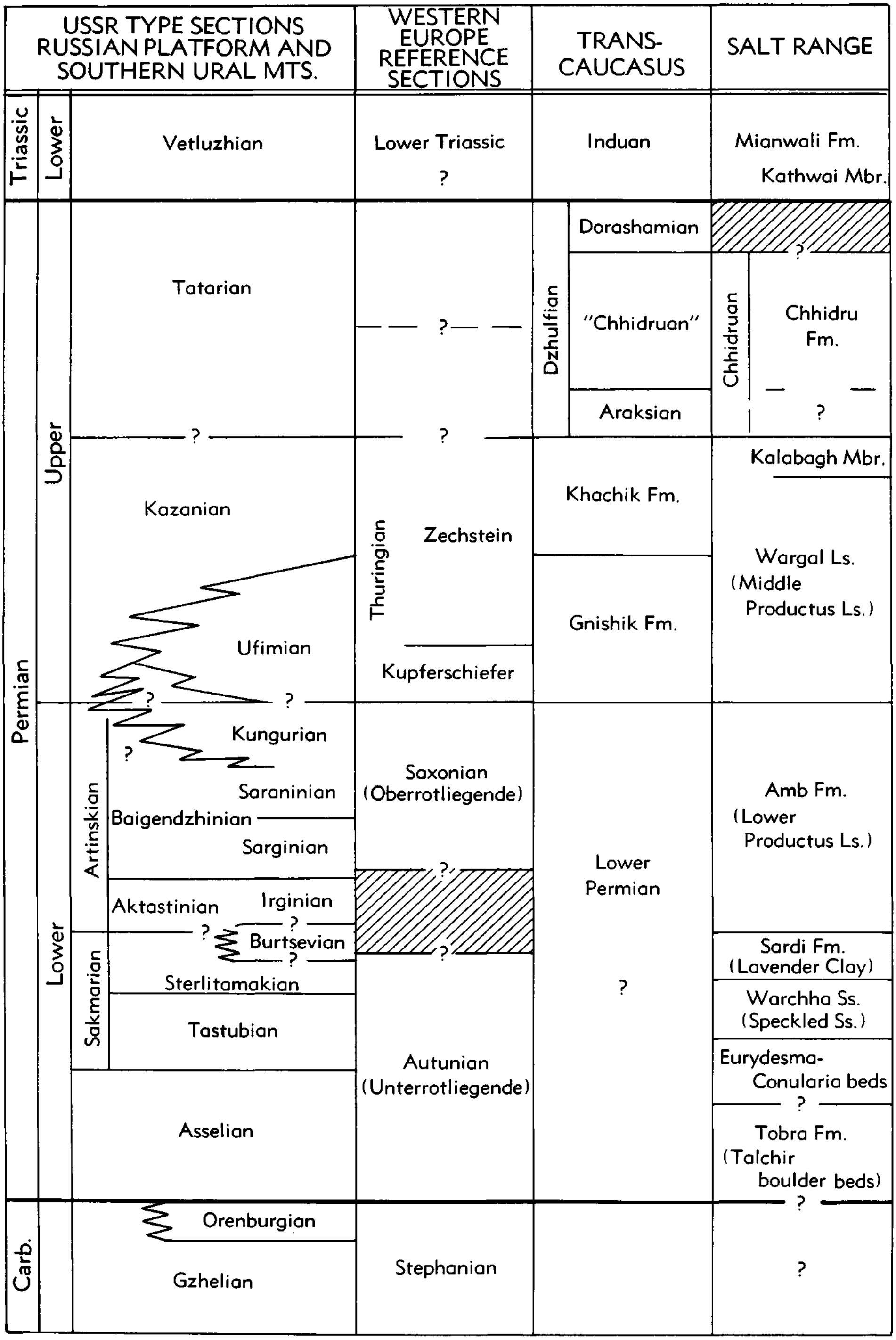

FIG. 1. *(Continued from facing page.)*

to the Karachatyrian Stage and the Artinskian equivalents to the Darvazian Stage (Ross & Ross, n).

Sea. The Kazanian fauna is lacking in colonial corals, cephalopods, trilobites, and echinoderms, but has two faunal facies; one in which bivalves predominate, the other in which brachiopods and bryozoans predominate. The main elements of the restricted Kazanian fauna are relicts of the earlier restricted Kungurian fauna and their local geographic and stratigraphic positions in Kazanian strata relate to facies variation in water of low salinity.

In the southeastern part of the Kazanian depositional basin near Orenburg, the strata include more sandstone and, locally, thick evaporite deposits. The eastern edge of the typical Kazanian impure limestone facies intertongues with red clastic beds that represent a coastal plain extending eastward toward the Urals. In the northern part of the Russian platform in Arkhangel Province, faunas from the lower part of the Kazanian include rare goniatites of the genus *Pseudogastrioceras,* or a closely related genus having a ventral sinus, indicative of an age equivalent to the Wordian Stage in North America (KULIKOV, PAVLOV & ROSTEVTSEV, 1973).

The Tatarian Stage is the highest and youngest of the Permian deposits on the Russian platform and is formed of brightly colored, variegated sandstone, conglomerate, and clastic strata that represent fluviatile, eolian, and lacustrine deposits with local evaporite beds. Although generally not richly fossiliferous, the fauna includes fish, bivalves, and ostracodes in the lacustrine deposits, and reptiles and amphibians in other deposits. Locally, plant fossils are common and thin seams of coal are present. Tatarian deposits are irregular in thickness and reach a maximum thickness of only a few hundred meters. These deposits are confined to the depositional basin of the earlier Kazanian sea and were attributed by NALIVKIN (1973) to deposition in arid conditions. These conditions of deposition continued without change into Triassic times over the same part of the Russian platform, and the Lower Triassic succession is called the Vetluzhian Stage. The Triassic fauna is not abundant but includes distinctive ostracodes, fresh-water phyllopods, reptiles, and a new flora. The Tatarian and Vetluzhian are similar in lithology and distribution so that their identification is based on the recognition of nonmarine faunas of different ages.

In summary, the Permian System in its type region on the southern and western margins of the Ural Mountains and on the eastern part of the Russian platform is a complicated set of intertonguing facies. These facies and their faunas reflect the progressive changes of depositional environments from a marine carbonate shelf, shelf edge, and elongate basin setting during the Late Carboniferous and earliest Permian (Asselian to early Artinskian) to a gradual restriction of marine circulation late in Artinskian and Kungurian times with the deposition of evaporites and presence of specialized faunas. This was accompanied by the continued closing and uplift of the Uralian geosyncline, which began at about this time to shed terrestrial debris westward in the form of the Ufimian deposits. By Kazanian time deposition was mainly confined to a shallow interior basin having water of low salinity and a specialized relict fauna derived from Kungurian time. By Tatarian time this interior sea dried up and gave way to fluviatile, eolian, and lacustrine deposits having terrestrial and fresh-water biotas. This set of conditions persisted into Early Triassic time.

## NORTHWESTERN EUROPE

Beds above the Carboniferous and below the Triassic are widespread in western Europe (Fig. 1) and are mainly red sandstone (Rotliegende beds) overlain unconformably by beds of conglomerate, chalcopyritic shale, dolomitic limestone, evaporites, and shale (Zechstein beds). Because of this consistent twofold division these beds were once known as the Dyas. The Rotliegende beds are subdivided into a lower part, the Autunian Series (Unterrotliegende), and an upper part, the Saxonian Series (or Oberrotliegende). The Zechstein, which forms the Thuringian Series, is subdivided into a basal conglomerate, a copper-bearing shale (Kupferschiefer), a dolomitic limestone (Zechstein), and an evaporite unit consisting of red clay, thin-bedded dolomitic limestone, anhydrite, halite, sylvite, and magnesium salts.

Autunian rocks are less widely distributed in western Europe than later Permian strata and are closely associated with the Upper Carboniferous Stephanian coal basins. Generally Stephanian deposits are followed with little interruption by Autunian deposits, which are commonly dark-gray to red shale, locally containing volcanics and some thin coal beds. Plant fossils, including *Walchia* and *Callipteris,* and the vertebrates, *Palacohatteria* and *Archegosaurus,* are common. Most of these basins were tectonically active during the Autunian and in the Saar-Nahe basin as much as 3,000 m of sediment was deposited during this epoch.

Saxonian deposits are more widely distributed and usually unconformably overlie Autunian and older rocks. They are younger than the Saale tectonic phase, last major movement of the Hercynian orogeny, and show a major change in geographic distribution and climates. The Saxonian includes conglomerate and sandstone deposits that reach a maximum thickness of about 500 m.

Thuringian deposits also are widely distributed in northwestern Europe where they unconformably overlie Saxonian beds. The base is marked by a thin conglomerate that contains rare *Cancrinella cancrini,* which is also found in the Kazanian of the Russian platform. Above this conglomerate lies the Kupferschiefer, a thin 0.6-m bed that contains well-preserved fish fossils, such as *Palaeoniscus,* and plants, such as *Voltzia.* The Kupferschiefer is a possible facies equivalent of the Kungurian on the Russian platform. The Zechstein dolomitic limestone, which is 5 to 10 m thick and contains an impoverished fauna having low species diversity but considerable numbers of individuals, is the prominent marker bed in the region. Coelenterates, cephalopods, and echinoderms are rare or lacking and bryozoans, brachiopods, bivalves, and gastropods are abundant. The brachiopods *Horridonia horrida, Strophalosia goldfussi, Dielasma elongata, Pterospirifer alatus, Spiriferina multiplicata, Punctospirifer cristata,* and *Cleiothyridina pectinifera* are characteristic of the Zechstein or its stratigraphic equivalent, the Magnesian Limestone of Great Britain. Small reefs form a distinctive facies and include some brachiopods and numerous fenestrate bryozoans. Conodonts and smaller foraminifers also occur in the Zechstein but their study is still in progress. The upper part of the Thuringian is a complex evaporite facies that includes shale, limestone, and various evaporitic salts, including bitter salts. Although the thickness of these evaporites varies from place to place for several reasons, locally in northern Germany they reach several hundred meters in thickness. In the uppermost part of this evaporitic sequence, sandy shales contain a few marine fossils such as the bivalves *Schizodus* and *Gervilleia* and the brachiopod *Dielasma.*

The extent of the Thuringian sea is well known for northwestern Europe where it covered most of Germany, parts of Poland and Great Britain, and the North Sea. It is difficult to establish whether or not this sea also connected to the east with the Kazanian sea on the Russian platform. Low species diversity and general similarity of faunas in the two regions suggest similar ecological conditions if not some interchange of faunas.

## CENTRAL EAST GREENLAND

The Permian of the central East Greenland succession, the Foldvik Creek Formation, has a basal conglomerate lying on a regional unconformity with topographic relief. Above this basal conglomerate, a 30- to 40-m interval has a number of intertonguing lithologies including light-gray dolomitic limestone, gypsum, shale, and near the top, a fish-bearing black *"Posidonia* Shale." Overlying this is the brachiopod-rich *"Martinia* Shale" that grades laterally from gray limestone to calcareous shale and siltstone. In the upper part of this unit is a prominent *"Productus"* bed. The *"Martinia* Shale" is unconformably overlain by the clastic Lower Triassic Kap Stosch Formation, which contains blocks of Foldvik Creek Limestone (TEICHERT & KUMMEL, 1972). On the basis of brachiopods, DUNBAR (1955, 1961) correlated the Foldvik Creek Formation with the Zechstein and Magnesian Limestone, and considered the brachiopods to be at least as young as the Capitanian of the west Texas standard sections. The ammonoids from *Martinia*-bearing limestone include *Medlicottia malm-*

*quisti* and *Cyclolobus kullingi* (Miller & Furnish, 1940b), which were believed to represent a latest Permian fauna; however, subsequent studies have shown that *Cyclolobus* ranges through much of the upper Permian, and primitive species occur as low as the *Timorites* Zone (Furnish, 1966). *C. kullingi* is a primitive species and therefore may be early Capitanian in age. Corals from the Upper Permian of the Kap Stosch area (Flügel, 1973) include 11 genera and subgenera that are older than Dzhulfian corals and possibly equivalent in age to the *Yabeina* Zone.

Reconstructions of Pangaea for late Paleozoic time place Greenland and parts of North America against northern Europe and the Barents shelf (Dietz & Holden, 1970). In such a geography the Upper Permian deposits of central East Greenland are in juxtaposition with the northwestern end of the Late Permian Thuringian basin. The faunas from the Permian of central East Greenland are of particular interest because they provide clues for the correlation of units in the Thuringian of northwestern Europe (and possibly the Kazanian of the Russian platform) with other Late Permian successions in Spitsbergen and the Canadian Arctic islands.

## OTHER NORTHERN AREAS

The Permian of Pechora and Pay-Khoy of northeastern Europe, north East Greenland, Spitsbergen, the Canadian Arctic islands, Yukon, and east-central Alaska share many features with each other. The Lower Permian parts of these successions commonly have well-developed fusulinid zones, particularly for the Asselian to lower Artinskian equivalents, with one or more evaporite units and clastic marginal facies. These Lower Permian beds also show abrupt changes in thickness and lithologies and include shelf and platform clastics, a few shelf evaporites, shelf-edge carbonate bank and basinal evaporites, limestone and shale. The marked changes in thickness apparently relate to late phases of Hercynian structural adjustments equivalent to those of northwestern Europe during the Autunian, but in a marine shelf environment.

Unconformably above these Lower Permian beds is a succession of limestone, cherty limestone, chert, and sandstone that forms the Brachiopod Cherts of Spitsbergen (see recent summary by Gobbett, 1963), the Upper Marine Group of north East Greenland (Dunbar *et al.*, 1962), and the Assistance Formation of the Grinnell Peninsula (Harker & Thorsteinsson, 1960). *Streptorhynchus, Derbyia, Dictyoclostus, Muirwoodia, Kochiproductus, Waagenoconcha, Stenoscisma, Rhynchopora, Pterospirifer,* and *Spirifella* are common in these faunas (Harker & Thorsteinsson, 1960), and their abundance and widespread distribution led Stepanov (1957) to propose the name Svalbardian Stage as a replacement for the Kungurian and Ufimian stages. In present usage, the Svalbardian is important as a northern facies (or regional stage) and, although it is difficult to correlate with the Russian platform sections, Stepanov (1936, 1937) suggested that the faunas had most similarity to those in the upper part of the Kungurian and lower part of the Kazanian. Later, Stepanov (1957) included the brachiopod fauna from central East Greenland in his Svalbardian although Dunbar (1955), Frebold (1950), and Harker and Thorsteinsson (1960) had pointed out some differences in generic and specific composition. Also, Frebold, Harker, and Thorsteinsson considered that many similarities are present and the faunas are either of somewhat different facies of the same age or the central East Greenland faunas are only slightly younger. In the Canadian Arctic islands, Thorsteinsson (1974) showed that the Trold Fiord Formation and its apparent lateral equivalent, the Degerböls Formation, unconformably overlies the Assistance Formation and its lateral facies, the Van Haven Formation. The Trold Fiord and Degerböls formations contain a sparse fauna of corals, brachiopods, and ammonoids of probable Guadalupian age. Future studies may demonstrate that part of the central East Greenland faunas are of the same age as those of the Trold Fiord and Degerböls formations.

## TETHYAN AREA

The Hercynian orogenic belt extends generally east-west from central western Europe with few interruptions into central Asia and eastern Asia. Although the Hercynian orogeny started in the later part of the Early Carboniferous, a number of strong orogenic pulses occurred during the Middle and Late Carboniferous, and the final major interval of deformation in Europe, the Saale phase, took place in the middle or later part of Artinskian time. This last phase of Hercynian deformation terminated formation of the Autunian coal-basin structures of northwestern Europe and many similar structures in other parts of Europe and southwestern Siberia (LAPKIN & SOLOVYEV, 1969). One result of this final phase was to separate the shallow seas on the northern side of the Hercynian Mountain belt (in which accumulated Kazanian and Zechstein deposits and strata to the north in Greenland, Spitsbergen, the Barents shelf, and northern Canada) from a large significant shelf and Tethyan geosyncline to the south. Although the exact details of the geographic features involved in the separation of the southern geosynclinal seas and the northern epicontinental seas need further study, the faunas on either side attest to a nearly complete isolation after the early part of the Artinskian.

In seas south of the Hercynian orogenic belt a distinctive fusulinacean, coral, and brachiopod fauna rapidly evolved. Later orogenic movements, particularly during Cenozoic times, have greatly complicated the relationships of Tethyan strata, and their interpretation is a major problem in Permian biostratigraphic and biogeographic studies. Several linear belts of Permian rock seem to have been present, each of which may have included shallow reef deposits, shallow clastic deposits, and deeper water clastic and carbonate deposits. These depositional belts fringed a number of small cratonic areas that have since been displaced and moved much closer together (YANSHIN, 1965).

The extent of the Tethyan belt during the Permian (Fig. 1) can be judged by the distribution of its distinctive fauna that extends from as far west as Tunisia, through Sicily, the Carnic Alps, Yugoslavia, Greece, Crimea, Turkey, Iran, Iraq, Soviet Middle Asia, northern Pakistan, Mongolia, China, Indochina, Indonesia, New Zealand, Japan, Soviet Maritime Province, Kamchatka, southern Alaska, British Columbia, Washington, Oregon, and into California. This Tethyan fauna is now fragmented and has been displaced in pieces to many latitudes and different climatic belts, but overall similarity of the fauna suggests free communication and great diversity within warm to tropical waters.

In the southern part of the Soviet Union where a large portion of the Tethyan belt is exposed, considerable effort has been directed toward establishing correlations with the type Permian on the Russian platform and the Ural region with inconclusive results (ARAKELIAN *et al.*, 1964; STEPANOV, 1970). Relatively few species are common to the two areas and regional stages are used widely for the Tethyan realm. The Lower Permian is divided into the Karachatyrian and Darvazian stages (VLASOV, LIKHAREV, & MIKLUKHO-MAKLAY, 1962) and the Upper Permian into the Murgabian and Pamirian stages. The following is a summary of the diagnostic faunas (LIKHAREV & MIKLUKHO-MAKLAY, 1972).

The Karachatyrian Stage contains a much greater diversity of fusulinaceans than the Asselian or Sakmarian, including species of *Ozawainella, Boultonia, Schubertella, Quasifusulina, Occidentoschwagerina, Zellia, Pseudoschwagerina, Schwagerina, Sphaeroschwagerina, Robustoschwagerina, Pseudofusulina, Paraschwagerina, Rugososchwagerina,* and primitive *Parafusulina.* Brachiopods are common and include species of *Isogramma, Enteletes, Dictyoclostus, Terebratuloidea, Stenoscisma, Spirifer, Martinia, Dielasma,* and *Notothyris,* and corals include species of *Tachylasma, Caninia, Timorphyllum, Caninophyllum, Cyathaxonia, Amplexocarinia, Allotropiophyllum,* and *Lophophyllidium.* In addition, gastropods, bivalves, and algae (*Tubiphites, Eugenophyllum,* and *Epimastopora*) are abundant and ammonoids are lacking or not reported.

The Darvazian Stage also includes a diverse fusulinacean fauna including numerous species of *Nankinella, Sphaerulina, Yangchienia, Minojapanella, Kahlerina, Darvasites, Robustoschwagerina, Nagatoella, Pseudofusulina, Chusenella, Parafusulina, Brevaxina, Misellina, Armenina,* and primitive *Cancellina.* Brachiopods include species of *Enteletes, Echinoconchus, Productus (Striatifera?), Wellerella, Martinia, Heterolasmina,* and *Notothyris*; corals include, in the lower part of the stage, species of *Verbeekiella, Cyathocarinia, Sinophyllum, Amplexocarinia,* and in the upper part *Yatsengia* and *Granophyllum.* Ammonoids include *Propinacoceras, Prosicanites, Perrinites, Marathonites,* and *Agathiceras.* Among the algae are *Mizzia, Tubiphites, Epimastopora,* and *Girvanella.*

The Murgabian Stage contains a diverse fusulinacean fauna that is particularly widely dispersed, including numerous species of *Leella, Neofusulinella, Pseudofusulina, Paraverbeekina, Verbeekina, Armenina, Neoschwagerina, Praesumatrina, Sumatrina,* and *Polydiexodina.* Brachiopods include species of *Derbyia, Chonetella, Linoproductus, Dictyoclostus, Productus, Martinifera,* and *Lyttonia.* Corals include species of *Yatsengia, Granophyllum, Waagenophyllum,* and *Polythecalis;* the ammonoids include species of *Neostacheoceras, Tauroceras, Paraceltites,* and *Adrianites;* and algae include species of *Gymnocodium, Permocalculus, Indopolia, Cyrocopora,* and *Vermiporella.*

Although the Pamirian Stage generally is not as complete in the Soviet Union as equivalent beds in China, it does contain a typical high Upper Permian fauna and locally the section is nearly complete. Fusulinaceans and other foraminiferids include species of *Reichelina, Palaeofusulina, Codonofusiella, Lasiodiscus, Colaniella,* and *Pachyphloia.* Brachiopods are represented by species of *Enteletella, Striatifera, Marginifera, Urushtenia, Tschernyschewia, Wellerella, Pugnax, Ambocoelia, Athyris,* and *Hemiptychina.* Ammonoids include species of *Prototoceras, Rotaraxoceras, Araxoceras,* and *Urartoceras;* algae include species of *Gymnocodium, Permocalculus,* and *Vermiporella.*

In the Pamirs, the Pamirian Stage commonly rests unconformably on the Murgabian Stage (Leven, 1967) and is unconformably overlain by strata assigned to the Triassic System. In the southeastern Pamirs, a number of lithologic facies are present, which include the zones of *Yabeina, Codonofusiella-Reichelina,* and *Palaeofusulina* of very late Permian age. Elsewhere in the Pamirs the Permian section is not as complete and it is not clear whether this is because of nondeposition or pre-Triassic erosion. Ammonoids are apparently not recorded from these Pamirian beds.

Another classic Upper Permian section, which was believed for a long time to have a transitional boundary with the Triassic, is located in the Trans-Caucasus (Fig. 1) along the Aras (=Araks, Araxes) River near Dzhulfa, Soviet Azerbaijan, and Julfa, Iran. Ammonoids and brachiopods are common in several of these beds (Abich, 1878) and the section has been restudied in detail by several groups (Ruzhentsev & Sarycheva, 1965; Stepanov, Golshani, & Stöcklin, 1969; Kummel & Teichert, 1973). The combined list of genera of ammonoids from the Dzhulfian Stage is impressive and appears to represent a nearly complete succession of post-Guadalupian, pre-Triassic ammonoids. Fusulinaceans are common in the lower 2 to 5.5 m of the Dzhulfian Stage and include *Codonofusiella* and *Reichelina* in a fine-grained, bituminous limestone that lithologically contrasts with the underlying Khachik Limestone, which carries a late Guadalupian fauna. Higher in the Dzhulfian *Araxoceras* and *Oldhamina* are common and a few beds containing *Codonofusiella* and *Reichelina* form the succeeding 8 to 20 m. Above these are up to 19 m of coral-, brachiopod-, and ammonoid-bearing beds with the *Vedioceras* and *Haydenella* fauna. Above these are 4.5 m of beds with the ammonoids *Phisonites, Xenaspis,* and *Xenodiscus,* and the brachiopod *Comelicania* and others. Soviet scientists choose to place the top of the Permian at the top of this *Phisonites* unit, but most other scientists also include the succeeding Ali Bashi Formation, about 18 m thick, in the Permian, which includes *Paratirolites* and several other ammonoids (Kummel & Teichert, 1973). Above this are 10 to 20 m of fine-grained limestone containing the Triassic bivalve *Claraia.*

Two other sections or areas of considerable historical interest to the problems of the uppermost Permian biostratigraphy are in and near the Salt Range of Pakistan (Fig. 1) and in Kashmir (Kummel & Teichert, 1966, 1970, 1973). The Chhidru Formation ("Upper *Productus* Limestone") of the Salt Range contains a fauna that is similar to that from the lower part of the Dzhulfian Stage in having mainly corals, brachiopods, and ammonoids but no fusulinaceans. The overlying Kathwai Member of the Mianwali Formation (uppermost part of "Upper *Productus* Limestone") contains the ammonoids *Ophiceras* and *Glyptophiceras* which KUMMEL and TEICHERT (1973) considered to be indicative of Early Triassic age, and the brachiopods *Enteletes, Orthothetina, Spinomarginifera,* and *Martinia,* which GRANT (1970) considered to be typical Permian genera and equivalent in age to the Dzhulfian brachiopods listed and described by RUZHENTSEV and SARYCHEVA (1965).

The section at Guryul Ravine, Kashmir (HAYDEN, 1907; MIDDLEMISS, 1910), also has been of considerable interest as a sequence that passes conformably from uppermost Permian into Lower Triassic strata (KUMMEL & TEICHERT, 1973; NAKAZAWA *et al.,* 1975). Here, as in the Salt Range, Triassic ammonoids and bivalves are associated with brachiopods that belong to genera usually considered to be Late Permian. Also, conodonts of the *Anchignathodus typicalis* Assemblage-Zone cross the Permian-Triassic boundary. The Late Permian Zeewan Formation (120 m thick), which rests on the Panjal volcanics, is sandy in its upper part and detailed faunal studies are needed. Fusulinaceans have not been reported.

The Pamirian, Dzhulfian, and Chhidruan stages appear to represent approximately the same time interval. The Pamirian may include somewhat older beds in its lower part than the other two and the Chhidruan may not include beds as young as latest Dzhulfian. Faunal zones that can be laterally traced and that include fossils common in Upper Permian strata in other geographical areas are much needed. Some of the faunas studied are closely associated with particular depositional environments and the lateral equivalency of different facies is commonly difficult to determine. The Lopingian Series in South China offers possibilities for establishing a reliable biostratigraphic framework for this latest Late Permian interval (Fig. 1) (SHENG, 1963; CHAO, 1965).

The Lopingian Series unconformably overlies the Maokou Limestone, which has the Zone of *Yabeina* in its upper part. The series was subdivided by CHAO (1965), and a lower part is made up of the Wuchiaping Limestone and its lateral equivalents, such as the Hoshan Limestone, the Lungtan Coal Series in the lower Yangtze valley, and the Loping Coal Series in north-central Kiangsi. These coal series, reaching 600 to 700 m in thickness, have continental sandstone and shale interbedded with marine shale and thin limestone beds that yield brachiopods and ammonoids. The continental beds include floras of *Taeniopteris, Pecopteris, Sphenopteris, Cladophlebis,* and *Gigantopteris.* Common brachiopods are *Chonetes, Dictyoclostus,* and *Squamularia.* In the lower third of this succession the ammonoids *Anderssonoceras, Prototoceras, Araxoceras, Kiangsiceras, Vescotoceras,* and *Pseudogastrioceras* are common and are similar to those in the lower part of the Dzhulfian Stage. Near the top of this succession, continental beds have *Neuropteris, Lepidodendron,* and *Lobatannularia.*

The upper part of the Lopingian Series, the Changhsing Limestone, is 120 to 150 m thick and has a *Palaeofusulina-Reichelina* fusulinacean fauna in north-central Kiangsi. This limestone is typically developed in the Changhsing coal field of northern Chekiang where it is formed of 25 to 34 m of dark-gray to black limestone and siliceous interbeds. The lower part contains *Pseudotirolites* and *Pseudogastrioceras.* The upper part contains *Stacheoceras, Pachydiscoceras, Rotodiscoceras, Trigonogastrites,* and *Changhsingoceras* in association with *Palaeofusulina, Reichelina,* and the brachiopods *Oldhamina, Dictyoclostus,* and *Hustedia.* In many parts of South China the predominantly limestone facies of the Changhsing changes laterally into the Talung Formation, which consists of siliceous shale and limestone and contains *Palaeofusulina, Pseudogastrioceras, Pseudotirolites,* and other genera of ammonoids. CHAO (1965) estimated that the Changhsing and Talung strata contain more than 100 species and 30 genera of ammonoids, most of which are not described. In South China the Lopingian Series has at least two ammonoid zones, the *Prototoceras-Araxoceras* Zone in the lower part and the *Pseudotirolites-Pleuronodoceras* Zone in the upper part.

Fusulinaceans are common in much of the Lopingian Series of the Permian of South China (Sheng, 1963) and, although not present in some of the Iranian, Soviet, Pakistan, and Kashmir sections, they are more widely distributed (Toriyama, 1973) than most of the ammonoid genera listed by Chao (1965). Toriyama (1973) reviewed these high Upper Permian occurrences of fusulinaceans and concluded that three zones could be recognized. A late Guadalupian fusulinacean assemblage-zone includes *Yabeina, Lepidolina, Codonofusiella, Reichelina,* and a large variety of Verbeekininae; a lower Dzhulfian (lower Lopingian) assemblage-zone has *Codonofusiella* and *Reichelina* but without other fusulinaceans (except possibly in Japan where the *Lepidolina kumaensis* Zone may extend into this zone); and an upper Dzhulfian (upper Lopingian) assemblage-zone includes *Palaeofusulina* and *Reichelina*. These fusulinacean zones, as well as those based on ammonoids and brachiopods, are in need of further investigations.

Other well-studied Permian Tethyan sections (Fig. 1) include Japan and the Carnic Alps, which are discussed in more detail under fusulinacean zonation. The Japanese sections were deposited in eight different tectonic settings (Toriyama, 1973), each with its own lithofacies and structural history, occurring in an outer tectonic zone, an inner tectonic zone, and a number of massifs and basins. The base of the Permian, drawn at the base of the *Pseudoschwagerina* Zone, is usually unconformable on Carboniferous and older rocks. Four Permian series are commonly recognized:

| SERIES | ZONE |
|---|---|
| Kuman | *Yabeina yasubaensis-Lepidolina toriyamai* (lacks *Neoschwagerina*) |
| Akasakan | *Neoschwagerina craticulifera-Verbeekina verbeeki* |
| Nabeyaman | *Parafusulina kaerimizensis-Neoschwagerina simplex* |
| Sakamotozawan | *Pseudoschwagerina morikawai-Pseudofusulina vulgaris* |

In only two or three sections are Triassic strata preserved above these Permian beds. The Kuman Series is usually not present or, if present, may lie either unconformably or in fault contact with the underlying Akasakan Series, suggesting a period of mountain-building activity that may correspond to the Tungwa movements of China. An earlier orogenic pulse also seems to have been widespread during the latter part of the Nabeyaman Epoch. Both orogenic intervals resulted in considerable changes in paleogeography.

Tethyan deposits of southern Europe are shared by Austria, Italy, Yugoslavia, Greece, and Sicily and include a complex sequence of Permian rocks. One of the better known successions is the Lower Permian of the Carnic Alps, which consists of 200 to 270 m of limestone and interbedded shale and 200 to 400 m of massive limestone (Flügel & Schönlaub, 1972). These form the Rattendorfer Limestone and Shale and the Trogkofel Limestone. The Trogkofel is locally reefoid and also includes a clastic facies and breccia. The overlying beds rest disconformably on the Trogkofel Limestone and include 30 to 40 m of red clastic Grödener Shale. This clastic depositional phase probably is a result of the Saale tectonic pulse that terminated Autunian deposition in northwestern Europe. Thus, the Grödener is approximately equivalent to the lower clastic portion of the Zechstein. Above this are up to 200 m of *Bellerophon*-bearing shale and limestone that are equivalent to the middle and upper part of the Zechstein.

The Rattendorfer and Trogkofel beds contain a diverse, apparently normal marine Tethyan fauna including many fusulinaceans, corals, brachiopods, and cephalopods. This depositional pattern started in the Late Carboniferous with the deposition of the Auernig clastic beds and a few marine limestone beds bearing plants, fusulinaceans, corals, and brachiopods of either Stephanian or Gzhelian affinities. The Rattendorfer beds have abundant and diverse fusulinacean faunas that include typical Asselian and Sakmarian species. The Trogkofel Limestone is particularly rich in Artinskian cephalopods, including *Medlicottia* near the base and *Agathiceras, Popanoceras,* and *Thalassoceras* near the top. The Grödener beds are plant-bearing and are similar in lithology to the Saxonian facies of northwestern Europe. The *Bellerophon*-bearing beds represent a complex of lagoonal facies having a number of different lithologies in which brachiopods, gastropods, bivalves, and rare cephalopods show affinities to both the Zechstein and the Upper Permian of the Salt Range. Northwestward from the Carnic Alps, the Permian strata thin and become nonmarine, and to the southeast, in Yugoslavia, Greece, Crimea, and Turkey, the Upper Permian carries a varied Tethyan fauna that includes fusulinaceans, brachiopods, and other invertebrates.

## NORTH AMERICA

Permian strata of North America include shallow marine shelf deposits, evaporites and nonmarine beds in much of the midcontinent and southwestern regions, nonmarine plant-bearing beds in parts of West Virginia and adjacent areas (Dunkard Group), and a complex set of eugeosynclinal and miogeosynclinal sediments in the western Cordillera as far east as Utah, Idaho, and western Alberta (McKee *et al.,* 1967).

The Dunkard Group was deposited in a semi-isolated nonmarine basin along the western flank of the Appalachian orogenic belt, and on the basis of plant fossils appears to be no younger than latest Autunian and no older than earliest Permian.

The midcontinent and much of the southwestern region is characterized by a complicated set of lithofacies that were gradually modified by changes in sea level, movements related to tectonics of the craton, and gradual filling-in of basins and troughs. The Ouachita sector of the Appalachian orogenic belt lay as a large S-shaped feature to the south and actively moved against the southern margin of the North American craton, closing a deep marine sea that reached from west Texas into southern Oklahoma and Arkansas. Block faulting and resulting deposition progressively closed off the sea in northern Oklahoma and Kansas by the end of Wolfcampian time and the normal marine faunas, which were rich in fusulinaceans, bryozoans, bivalves, and crinoids gave way to specialized brackish and saline faunas in the later part of the Permian. By the early part of the Leonardian, the east Texas shelf between the Midland basin and the Ouachita belt also progressively developed into a broad, low, deltaic plain and the deposits are rich in nonmarine vertebrate fossils. Shelf-edge carbonate banks of algae, fusulinaceans, bryozoans, brachiopods, and crinoid debris fringed most of the Delaware and Midland basins during the Early Permian (Fig. 1) and these basins had considerable topographic relief; the Midland basin being in part below a sill restricting water circulation and bottom faunas.

During the Leonardian the reefs around the Delaware basin continued to deposit thick sedimentary units. By Guadalupian time the Midland basin was restricted as the Ouachita orogenic belt and debris from it closed the passage at the southern end of the Central Basin platform. A marine channel to the south and southwest supplied the Delaware basin with normal marine water and large marginal reefs continued to form around that basin (King, 1949; Newell *et al.,* 1953). To the south in northern Mexico volcanics finally closed this channel and marked the end of Guadalupian deposition. The faunal zonation of these west Texas reference sections is discussed in the Fusulinacean and Ammonoid sections of this review.

Westward in New Mexico and southeastern Arizona, other fault-bounded blocks show generally similar histories of basin infilling during the Early Permian (Ross, 1973), and the gradual restriction of faunas to very specialized biofacies by Leonardian time. Although carbonates of Guadalupian age are extensive over the southwestern end of the transcontinental arch in the Grand Canyon region, the biofacies were not normal marine, probably somewhat brackish, having a predominantly molluscan fauna. North of the western end of the transcontinental arch, block-faulted marine basins and clastic source areas extended well into Utah during Early Permian time and appear to be the continuation of the structural patterns seen in Arizona, New Mexico, and Texas. These basins and adjacent clastic source areas have many thousands of meters of displacement and the basins are filled mainly with conglomerate, sandstone, and shale, with locally well-developed limestone having a normal marine fauna including fusulinaceans. Farther north in Montana, Alberta, and Yukon, the western edge of the Permian cratonic shelf was more stable and extensive thin sheets of sandstone are common in the Lower Permian and a few are apparently as young as early Late Permian. Marine faunas are meager in these shelf and shelf-edge clastic belts but a few limestones and silicified limestones contain Early Permian brachiopods, corals, and fusulinaceans.

In central eastern Alaska, Canadian Arctic islands, and northeastern Greenland this shelf clastic facies is well developed and intertongues near the shelf edge with thicker carbonate beds that have well-developed Early Permian fusulinacean, coral, bryozoan, brachiopod, and ammonoid faunas. These faunas are similar to those in Spitsbergen, the northern Urals, and the Russian platforms, but have not been completely studied.

West of the Permian edge of the North American craton several different, highly deformed sedimentary belts have contrasting faunas of Early and early Late Permian age and are presently aligned more or less parallel to the former cratonic edge (Monger & Ross, 1971). Some of these, particularly the eastern belt, have Lower Permian shale and limestone deposited on structurally disturbed lower and middle Paleozoic strata. Some of the diverse Early Permian faunas of these strata are similar to those of the reefs and carbonate banks along the Ural geosyncline. A central belt includes thick, extensively developed carbonate banks and reefs that rest on ribbon chert, basaltic tuffs, and greenstone, and are overlain by basalts. These limestones have an abundant Tethyan fauna of fusulinaceans, bryozoans, brachiopods, ammonoids, crinoids, and a rich algal flora, and they were probably deposited in shallow, tropical or subtropical water. Further west, other parts of the Cordillera have a pre-Devonian granitic basement overlain by a thick Lower Permian carbonate sequence with algae, fusulinaceans, corals, bryozoans, brachiopods, and crinoids, which also may represent a part of the Tethyan flora and fauna. Other fusulinaceans having affinities with the west Texas faunas are found in places in British Columbia and Yukon in another one of these Cordilleran tectonic belts. Interpretations of these distributions generally imply a significant geographical rearrangement of late Paleozoic strata during the Mesozoic and early Cenozoic. The youngest well-dated Permian fusulinaceans include primitive *Yabeina* with Wordian ammonoids, suggesting that in much of this region deposition was minor after middle Guadalupian time.

The relationships between these structurally bounded belts that have different sedimentary origins and contrasting faunas are only partially worked out; however, parts or pieces of many of these belts extend from southwestern Alaska through western Canada and western United States into Baja California and Sonora. These belts are principally identified by their faunal affinities and by their stratigraphic and structural relationships to underlying and overlying rock units.

In northern Mexico, east of Sonora, the Permian was deposited in basins much like those in Arizona, New Mexico, and west Texas, and on the flanks of the Ouachita-Marathon orogenic belt that turns south into Mexico. In Chiapas, in southern Mexico, light-gray thick-bedded limestone has yielded an abundant and diverse Lower Permian fauna in an algal-rich limestone, and in Belize dark-gray limestone in dark shale also has Lower Permian fusulinaceans. The remainder of Central America and the Caribbean region is composed of rocks that are mostly Jurassic or younger in age, and Permian strata are not reported.

## GONDWANA CONTINENTS

### AUSTRALIA

Major sequences of Permian strata are located in four basins in the western part of Australia (Perth, Carnarvon, Canning, and Bonaparte Gulf basins) and in five basins along the Tasman geosyncline in the eastern part of Australia (Tasmanian, Sydney, Maryborough, Bowen, and Yarrol basins). Based on faunal and floral associations (Dickins, 1970; Thomas, 1971), six subdivisions are correlated between the western basins and the Bowen basin in the east, and from there to other eastern basins (Runnegar, 1969; Dear, 1971). The earliest Permian fauna (Stage A, Dickins, 1970) of

Asselian and early Sakmarian age is characterized by the bivalve *Eurydesma,* which was apparently adapted to cold water. In the west it is known only from the Carnarvon basin, but it is more widely distributed in the eastern basins. Glacial marine tillites, clastic strata, and volcanics are present in this interval in most basins. The second faunal assemblage (Stage B, DICKINS, 1970) of late Sakmarian or early Artinskian age is more widely distributed, suggesting more widespread marine conditions, and in the Carnarvon basin this assemblage contains a few genera of Tethyan affinities. The bivalve *Edmondia* is characteristic of this fauna and is associated with *Oriocrassatella, Astartella, Pseudomyalina,* and *Atomodesma.* In the Bowen and Sydney basins the bivalves *Astartila?, Megadesmus,* and *Eurydesma,* the brachiopods *Ingelarella, Strophalosia,* and *Notospirifer,* and the ammonoid *Uraloceras* also occur in this fauna (ARMSTRONG *et al.,* 1967). The third subdivision (Stage C, DICKINS, 1970) is largely nonmarine and dominated by clastic sediments. In many of the basins coal beds formed in this interval and contain the plant fossils *Gangamopteris, Glossopteris,* and *Dadoxylon* (DAVID & BROWNE, 1950). The fourth subdivision (Stage D, DICKINS, 1970) includes another widespread marine fauna, which in the western basins has additional genera of Tethyan affinities (TEICHERT, 1974) and locally reaches considerable thickness (up to 2,000 m) in the Carnarvon basin. An older (Stage $D_1$) and a younger (Stage $D_2$) part of this faunal assemblage have been recognized. A late Artinskian age was suggested by DICKINS (1970) for the older part and a Kazanian age was indicated for the younger.

The fifth subdivision (Stage E, DICKINS, 1970) is a succession of coal and plant-bearing clastic strata that generally lack marine fossils. The sixth subdivision (Stage F) includes the youngest Permian marine faunas of western Australia, which occur in the upper part of the Liveringa Formation (Hardman Member). This fauna includes many genera of bivalves (such as *Phestia, Megadesmus, Astartila?, "Allorisma," "Modiolus," Atomodesma, Aviculopecten, Girtypecten?, Acanthopecten, Streblopteria, Pseudomonotis, Schizodus, Oriocrassatella,* and *Astartella*) and several genera of gastropods. It is probably Tatarian (Dzhulfian) in age.

Permian ammonoids are rare in most Australian sequences and include 17 species from the western basins and two from the Sydney basin in the east (GLENISTER & FURNISH, 1961). From the western basins several species of *Uraloceras* and *Juresanites* occur in the Holmwood Shale (upper part of Stage A) and suggest a Sakmarian age. *Thalassoceras, Metalegoceras,* and *Propopanoceras* in the Nura Nura Member of the Poole Sandstone (Stage B) are of late Sakmarian age. Several ammonoid assemblages of Artinskian (Baigendzhinian) age have been reported and include species of *Neocrimites, Propinacoceras,* and *Pseudoschistoceras.* The lower beds of the Liveringa Formation (Lightjack Member) and beds of approximately the same age (Stage D) contain *Pseudoschistoceras, Agathiceras,* and possibly *Propinacoceras,* indicating an age near the Early-Late Permian boundary or slightly above. The ammonoid fauna from the Kockatea Shale of the Perth basin is now known to be early Triassic in age. In the Sydney basin in eastern Australia (Fig. 1), the Farley Formation contains *Uraloceras,* brachiopods, gastropods and bivalves, of probable late Sakmarian age; the Branxton Subgroup has *Neocrimites,* corals, and bryozoans of Artinskian (Baigendzhinian) age.

An extensive Late Permian insect fauna is known from the Newcastle Coal Measures near Newcastle and Lake Macquarie in the northern part of the Sydney basin in eastern Australia (TILLYARD, 1917-36). This insect fauna lacks many of the forms usually found in Permian tropical or subtropical moist-forest assemblages and is dominated by the orders Hemiptera and Mecoptera. These insects are distinctively more advanced than those of the Early Permian of Kansas and include many genera that are closely related or ancestral to orders that are typically Mesozoic and younger. This fauna is generally considered to be Tatarian in age based on a few closely similar species that are found in the Russian section. In Tasmania, the Permian-Triassic boundary is drawn at the top of the Cygnet Coal Group (BANKS & NAQVI, 1967).

## INDIA AND PAKISTAN

The Permian deposits of India and Pakistan are distributed in a number of fault-bounded basins located along three structural trends in peninsular India, and to the north in elongated fold belts on the flanks of the Himalayan orogenic belt. The successions in peninsular India lie on a Precambrian basement, are called the Gondwana Group, and generally have a tillite or a diamictite at their base. Clastic nonmarine strata dominate the overlying parts of the Gondwana Group (Permian to Early Cretaceous) and have interbedded coal and only a few thin marine beds. Two marine assemblages are recognized, suggesting two different intervals of flooding. The oldest (Asselian or early Sakmarian) has an *Eurydesma* fauna, was deposited within the Talchir Boulder beds, and was probably a cold-water assemblage. Three other localities have more diverse faunas, which are generally considered to be of late Sakmarian age. *Eurydesma* may be present in these three faunal assemblages, along with bryozoans, brachiopods, gastropods, bivalves, ostracodes, and echinoderms (Teichert, 1974). Some of these fossil groups include genera known also from Australia and South America and others are nearly cosmopolitan. The faunas suggest that these beds were the result of brief marine flooding of the Gondwana depositional basins by water from the northern edge of the Indian craton.

The Permian strata exposed in the flanks of the Himalayan Mountains appear to represent deposits along the edge of the Indian craton that bordered the southern Tethys. Diamictite in the Salt Range is overlain by marine clastic and carbonate units that carry a fossil succession having mostly Tethyan forms (Zaluch Group = Lower, Middle, and Upper "Productus" Limestone of early reports) (see discussion above on Tethyan Belt).

## AFRICA

Central, southern, and parts of northwestern Africa were consolidated by the end of Middle Carboniferous time into a relatively stable platform. Block faulting developed basins for clastic deposition during the Permian and the stratigraphic succession (Karroo Series) that is preserved is similar to that of peninsular India. At the base, the Dwyka Tillite (or Diamictite) Group is widespread and in southwestern Africa marine tongues are found with *Eurydesma, Conularia, Archaeocidaris,* and the fish *Palaeoniscus.* Nonmarine shaly tongues near the base have *Glossopteris* fragments, and shales near the top have *Glossopteris* and the Gondwana aquatic reptile *Mesosaurus,* which is also found in South America. These fossils suggest a Late Carboniferous to Asselian (or early Sakmarian of some authors) age and presumably are equivalent to the earliest Permian assemblages of India and Australia.

Above the Dwyka Group, the Ecca Group is widely distributed and is mainly fine- to coarse-grained sandstone with some shaly beds. In the Karroo trough these strata are mostly gray shale, siltstone, and subgraywacke sandstone having *Gangamopteris, Glossopteris,* and *Cyclondendron.* To the east in Natal, Transvaal, and Orange Free State, coals are well developed and to the west in southwestern Africa red sandstone and shale are typical of the Ecca. Much of the middle part of the Ecca Group represents cyclic deposition associated with several widespread coal beds. Most of these depositional cycles have only the nonmarine portion preserved, but locally some marine shale is preserved above the coal. In the Dundee district in northern Natal, one such occurrence yielded *Paraceltites?,* which suggests a latest Early Permian or Late Permian age for that part of the Ecca (Teichert & Rilett, 1974). Northward the Ecca Group thins and lies directly on the pre-Permian platform where the Dwyka Tillite is missing.

The youngest Permian beds are nonmarine and they form the lower part of the Beaufort Group, which passes upward into strata of Triassic age. Six reptilian zones are recognized in the Beaufort but only the lower three are Permian. These are the Zone of *Tapinocephalus,* overlain by the Zone of *Endothiodon,* and finally by the Zone of *Cisticephalus* at the top of the Permian. This lower part of the Beaufort Group seems to be restricted to the Karroo trough.

## MADAGASCAR

The western half of Madagascar is underlain by a succession of Gondwana strata that have many features of the southern African, peninsular Indian, and Salt Range successions. The Permian part of this succession is the Sakoa Group and the lower part of the overlying Sakamena Group. A tillite, the lowest formation, is overlain by mainly nonmarine sandstone and shale beds with several marine limestone and shale units. The *Glossopteris-Gangamopteris* flora, associated reptiles, and the occurrence of several coal beds are similar to the Karroo Series of southern Africa. Productid and spiriferid brachiopods are common in the marine shale and limestone units. The lower part of the Sakamena Group in northern Madagascar also has several marine limestone and shale units and these include productid, spiriferid, and atrypid brachiopods, bivalves, and cephalopods, such as *Cyclolobus, Episageceras, Xenodiscus, Propinacoceras,* and *Popanoceras,* that are similar to those of the Chhidru Formation of the Salt Range, Pakistan (Teichert, 1974).

## SOUTH AMERICA

East of the Andean belt most of South America had a Permian history that is closely similar to that of Africa. By Middle or Late Carboniferous time the shield areas of South America formed a large platform, which, based on geological similarities, appears to have been continuous with that of western Africa. The Gondwana deposits in the Parana basin that lie unconformably on this platform are of glacial origin and are similar to those in southwestern Africa (Caster, 1952). The Itararé Group at the base has shaly interbeds with paleoniscid fish, ammonoids, and *Glossopteris* and *Rhacopteris* floras that are probably of Middle and Late Carboniferous age. The overlying Guatá Group has local glacial sediment, coal, and marginal marine deposits. *Eurydesma* and *Glossopteris* occur in the upper part of the Guatá and suggest an Early Permian age. Higher, the Iratí Formation has *Mesosaurus,* and the Estrada Nova Group and Rio Do Rasto Group are mainly clastics that contain an extensive plant succession and a few marine tongues having sparse invertebrates. Rynchosaurid reptiles *Cephalonia* and *Scaphonyx* are found in the overlying Santa Maria Redbeds and are of Middle Triassic age.

# FAUNAL ZONATION AND DISTRIBUTION

In reviewing the zonation and geographical distribution of Permian faunas, groups have been selected that have been widely used for correlation or that have shown a strong potential use, as in the case of conodonts. Such groups are likely to have received more thorough study and more detailed phylogenetic analysis than other groups. Because of limitation of space and time, the following groups are examined in hierarchical order: fusulinaceans (foraminiferid protozoans), other foraminifers, corals, bryozoans, brachiopods, ammonoids, and conodonts. Other groups that are widely distributed, but which have been less thoroughly studied or less widely used for correlation, such as sponges, bivalves, gastropods, arthropods, and echinoderms, are not discussed. It is recognized, based on a number of local studies, that many of these groups also may have a potential importance in evaluating worldwide biostratigraphic and paleogeographic problems.

## FUSULINACEANS

Fusulinaceans are a group of large extinct protozoans that evolved rapidly during the late Paleozoic. Of the more than 80 genera recognized in Permian strata only about a dozen are Carboniferous holdovers (Fig. 2). Two major intervals of unusually rapid evolution are known; the first in Early Permian during the Asselian in all parts of the world, and the second during the later part of the Darvasian and early part of the Murgabian in the Tethyan faunal realm.

The phylogeny and geologic history of fusulinaceans has been summarized by Ross (1967; 1978) and Rozovskaya (1975) and Figure 2 is based on these reports. All of the six Permian families are assigned to

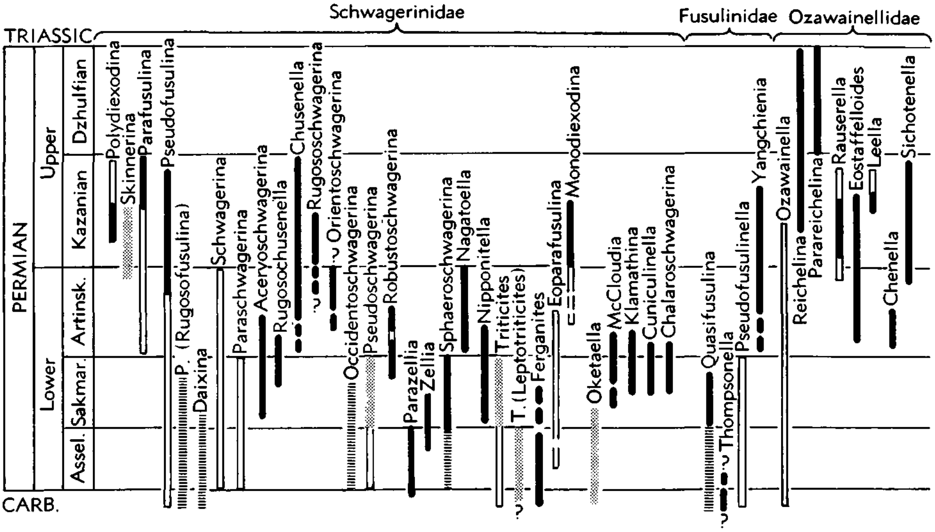

FIG. 2. Ranges of fusulinacean genera arranged by families and their geographic distribution. [Explanation: unshaded, cosmopolitan distribution; black, Tethyan distribution; ruled pattern, Uralian, Franklinian, and northeastern Cordilleran distribution; stippled pattern, midcontinent, southwestern

the one superfamily, Fusulinacea, and are recognized on the basis of differences in wall structure and other internal features. Although the Ozawainellidae evolved into at least nine genera during the Middle Carboniferous and again into three or four genera in the Late Permian, the family is more important because it gave rise to the families Fusulinidae, Schubertellidae and Staffellidae. In their evolutionary development genera of the Fusulinidae become markedly elongate along their axis of coiling. Only one of the three subfamilies, the most primitive group, the Fusulinellinae, ranged into the Permian. It survived until the Late Permian, and retained the basically simple unfolded septa and simple layered-wall structure. By Late Carboniferous time, the Fusulinidae gave rise to the Schwagerinidae, which evolved only slowly during the Late Carboniferous. In Asselian, Sakmarian, and lower Artinskian rocks, genera in the family Schwagerinidae are important zonal fossils, particularly genera with inflated chambers such as *Sphaeroschwagerina, Pseudoschwagerina, Paraschwagerina, Robustoschwagerina, Zellia, Parazellia, Occidentoschwagerina, Acervoschwagerina,* and *Rugososchwagerina,* which have distinctive ranges. Also important are the elongate subcylindrical genera derived from *Pseudofusulina,* such as *Eoparafusulina,* primitive *Parafusulina,* and primitive *Monodiexodina.* Several inflated genera extended into the later part of the Early Permian and *Rugososchwagerina* extended into the early part of the Late Permian. Several of these inflated genera may have been pelagic; however, most other fusulinaceans were benthonic. In southwestern North America, schwagerinids extend through the Guadalupian Series before becoming extinct and include many of the descendants of the Early Permian schwagerinids together with a few Tethyan migrant genera. Advanced species of *Parafusulina* and the first appearance of *Chusenella, Skinnerina, Nipponitella,* and *Polydiexodina* occur in the Guadalupian.

The Schubertellidae, a second family that evolved from the Ozawainellidae, had a conservative Carboniferous history; however, during the Permian it started to expand and one of its lineages, *Boultonia,* eventually gave rise to a burst of Late Permian genera that extended to the end of the Permian. The schubertellids are small, and many became uncoiled and are closely associated with reefs and shallow lagoonal deposits in the later part of the Permian.

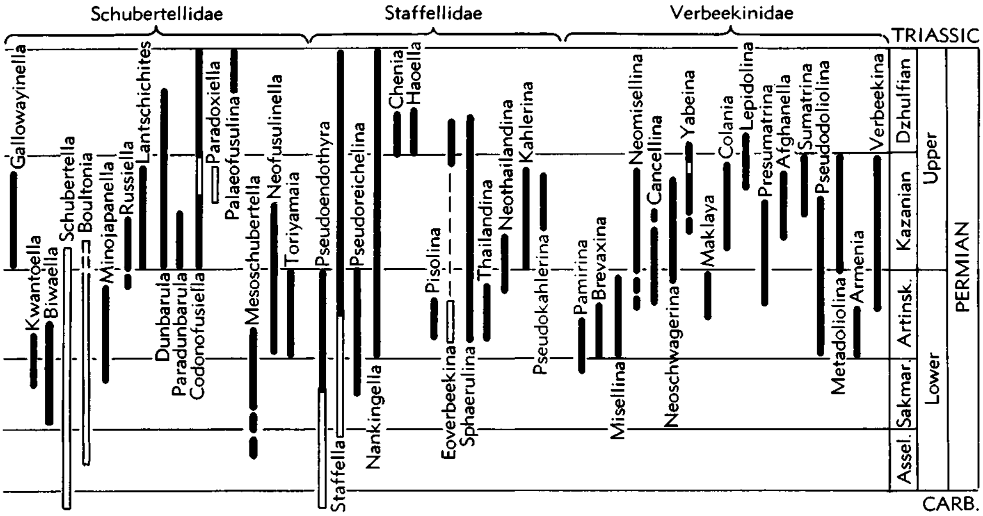

FIG. 2. *(Continued from facing page.)*
North American, and northern Andean distribution.] (Data principally from Ross, 1967, and Rozovskaya, 1975; Ross & Ross, n.)

The Staffellidae, which also arose from the Ozawainellidae, had a few, small conservative Carboniferous genera; however, in the later part of the Early Permian this family rapidly evolved. It reached greatest diversity in the early part of the Late Permian, but only one of two genera occur in youngest Permian strata and are associated with back-reef lagoonal sediments.

The Verbeekinidae arose from the Staffellidae and rapidly evolved in the later part of the Early Permian into five or six lineages before becoming extinct about the middle of the Late Permian. Some of its genera are large, subspherical forms with complex internal features.

In addition to their common ancestry, the Staffellidae and Verbeekinidae are similar in that they evolved rapidly in the later part of the Early Permian and early part of the Late Permian, increased in size, and had strongly modified wall structures. The schubertellid subfamily Boultoninae increased in diversity in the early part of the Late Permian but showed an even greater diversity of genera in the latest part of the Permian before becoming extinct. Most of the generic diversity in the Schwagerinidae occurred in the early part of the Early Permian and only a few new genera appeared in the Late Permian. The family Fusulinidae includes one long-ranging lineage that extended into the Late Permian. The family Ozawainellidae had a diversity peak in the early part of the Late Permian. These phylogenetic patterns suggest that the early part of the Early Permian and the early part of the Late Permian were times of major fusulinacean diversification, and later parts of the Early Permian and the latest Permian were times of restriction of previously successful lineages. These evolutionary patterns appear to be associated with changes in geographical distributions and the development of regional and endemic lineages.

## FUSULINACEAN ZONES OF THE RUSSIAN PLATFORM, URAL REGION, AND ADJACENT REGIONS

The Late Carboniferous and Early Permian fusulinacean zonation of the Russian platform and Ural region is well known from extensive studies by Rauzer-Chernousova (1937, 1940, 1949, 1965), Rauzer-Chernousova and others (1958), Syemina (1961), Shcherbovich (1969), Mikhaylova (1974), and many others. Although there is a lack of agreement among some Soviet paleontologists as to which of the zones should be used for defining the base of the Permian and subdivisions within the Permian, the actual sequence of zones and the fusulinacean assemblages that form these zones have been extensively studied.

The zones characterized by *Montiparus, Triticites,* and *Pseudofusulina* (*i.e.,* the Kasimovian, Gshelian, and Orenburgian stages) are generally included in the Upper Carboniferous. The overlying zones are included by many in the Lower Permian and that procedure is followed in this review.

Eight fusulinacean assemblage-zones are recognized from the type area of the Lower Permian; however, no fusulinaceans have been reported from Upper Permian strata in this area or in areas that were laterally connected with it to the north (VISSARIONOVA *et al.,* 1949).

### ASSELIAN

The Asselian Stage contains three fusulinacean zones. These are separated on the basis of different species of *Sphaeroschwagerina* and combine to make up the "Zone of *Schwagerina*" as commonly used in Soviet literature. The lowest is the Zone of *Sphaeroschwagerina fusiformis* and *Sphaeroschwagerina vulgaris,* which includes about 33 characteristic species of *Pseudofusulina, Pseudofusulinella, Schubertella, Triticites, Jigulites, Daixina, Schwagerina,* and *Pseudoendothyra.* In the middle is the Zone of *Sphaeroschwagerina moelleri* and *Pseudofusulina fecunda,* which includes 57 characteristic species of *Pseudoendothyra, Pseudofusulinella, Schubertella, Fusiella, Triticites, Jigulites, Daixina, Pseudofusulina, Schwagerina, Pseudoschwagerina,* and *Sphaeroschwagerina.* At the top is the Zone of *Sphaeroschwagerina sphaerica* and *Pseudofusulina firma,* which includes 38 characteristic species of *Pseudoendothyra, Pseudofusulinella, Schubertella, Triticites, Pseudofusulina, Schwagerina,* and *Sphaeroschwagerina.*

Within the Asselian, species of *Sphaeroschwagerina* show an evolutionary trend toward becoming more globose in outline. *Pseudofusulina* has many lineages of species including some that have strongly rugose outer walls and others that develop heavy secondary deposits.

Unfortunately, many Soviet micropaleontologists prefer to continue to use the generic concept of VON MOELLER (1877) for the genus *Schwagerina* rather than the type specimens illustrated by EHRENBERG (1854, plate xxxvi, x, c, figs. 1-4) as *"Borelis princeps,"* to which VON MOELLER (1877) referred as follows: *"Als eine typische Form derselben sehe ich die Schwagerina princeps Ehrenb. an.*[6]*"* Although VON MOELLER illustrated thin sections of highly inflated forms that he believed were the same as EHRENBERG's species, polished and thin-section study of EHRENBERG's material showed it to be quite different in internal features and probably closely related, if not identical, to *"Fusulina" krotowi* (DUNBAR & SKINNER, 1936; DUNBAR, 1958). Earlier, DUNBAR and SKINNER (1931) had erected *Pseudofusulina* for elongate forms that, as it turned out, had many of the features of EHRENBERG's *Borelis princeps* and, for several years after 1936, *Pseudofusulina* was considered by most non-Soviet micropaleontologists to be a synonym of *Schwagerina.* The North American forms, which previously had been assigned to *Schwagerina* were placed in *Pseudoschwagerina* and it was assumed that the Soviet species also belonged there. Between 1936 and 1976, 10 new genera have been proposed for various inflated schwagerinids, including *Sphaeroschwagerina,* using VON MOELLER's specimens of *"princeps"* as its type. In contrast to *Pseudoschwagerina,* which occurs in many of the same stratigraphic beds with it, *Sphaeroschwagerina* has low, thin-walled juvenile whorls that lack folded septa and massive chomata and the two genera are easily distinguishable.

The result of this nomenclatural confusion over use of the name *Schwagerina* is even more awkward because it is associated with the naming of several distinctive, widely distributed, and easily recognized biostratigraphic zones within the Asselian Stage. Thus the *"Schwagerina"* zones of the Russian platform and Urals are based on species that are neither *Schwagerina* nor *Pseudoschwagerina,* but species of *Sphaeroschwagerina.*

### SAKMARIAN

This stage has been divided into two major subdivisions (RAUZER-CHERNOUSOVA

1965), the Tastubian "superzone" and the Sterlitamakian "superzone," which are identified on the basis of different species of *Pseudofusulina.* The lower part of the Tastubian is identified as the Zone of *Pseudofusulina moelleri* and includes about 10 additional species of *Pseudofusulina, Fusiella, Triticites,* and *Pseudoendothyra.* The upper part of the Tastubian is the zone of *Pseudofusulina verneuili* and includes five other species of *Pseudofusulina, Pseudofusulinella, Fusiella, Pseudostaffella,* and *Schubertella.*

The Sterlitamakian is essentially the Zone of *Pseudofusulina plicatissima, P. urdalensis, P. schellwieni, P. intermedia,* and *P. callosa.* It also includes several species of *Rugosofusulina, Daixina,* and *Pseudofusulinella.* The Burtsevian "superzone" is included by many Soviet biostratigraphers as a facies of the upper part of the Sterlitamakian. It includes nearly a dozen closely related species of *Pseudofusulinella,* including *P. concavutas, P. vissarionovae, P. paraconcavutas, P. pseudoconcavutas, P. delicata, P. schellwieni, P. kutkanensis,* and *P. juresanensis.* Although the trend appeared in the Tastubian, the fusulinacean faunas at this time began to show a marked decrease in generic and species diversity; and limestone facies are less widely developed, particularly in many parts of the Russian platform.

#### ARTINSKIAN

The Irginian Substage includes *Pseudofusulinella concessa, P. paraconcessa, P. solida, P. schellwieni, P. verneuili,* and *Parafusulina lutugini. Parafusulina lutugini* is a long-ranging species that has many primitive features of the genus. Its age relationship to other primitive lineages of *Parafusulina,* such as those in the Leonardian Series of North America, is poorly known.

## FUSULINACEAN ZONES OF THE TETHYAN REGIONS

The most complete stratigraphic record of Permian fusulinaceans occurs in the Tethyan regions (Fig. 2). These regions were sites of major structural deformation during Permian and post-Permian time so that the structure is usually complex and strata have complicated facies relations because of large and changing topographic relief. Fusulinaceans are well studied from several of these Tethyan regions and, in spite of the structural and stratigraphic difficulties, a fusulinacean zonation has been established that greatly aids the correlation of these rocks with the type Permian (ARAKELIAN *et al.*, 1964). Although not all of the biostratigraphic problems are resolved, particularly near the top of the Permian (NAKAZAWA, ISHII, *et al.*, 1975; NAKAZAWA, KAPOOR, *et al.*, 1975), the Tethyan fusulinacean succession for Japan is the most thoroughly documented (TORIYAMA, 1958, 1963, 1967) and is used in the following discussion of zonation as the reference standard for the regions.

#### SAKAMOTOZAWAN SERIES

The Sakamotozawan includes the zones of *Pseudoschwagerina morikawai* and *Pseudofusulina vulgaris,* and in its type section is defined as the stratigraphic range of *Pseudoschwagerina.* Three subzones based on species ranges are recognized. The lowest, the Subzone of *Pseudoschwagerina morikawai,* has associated species of *Triticites* and is correlated with the Asselian Stage. It commonly is not present above a widespread Carboniferous-Permian unconformity. The middle, the Subzone of *Pseudofusulina vulgaris,* is distributed more widely in Japan and other Tethyan regions and is associated with more advanced inflated genera such as *Robustoschwagerina,* advanced species of *Paraschwagerina,* species of *Nagatoella,* and holdover species of *Triticites.* This subzone appears to correlate with some part of the Sakmarian Stage. The highest unit is the Subzone of *Pseudofusulina ambigua,* which also has a wide distribution in Tethyan successions. This subzone is marked by a profusion of related species of *Pseudofusulina,* such as *P. krafti, P. globosa, P. fusiformis, P. japonica,* and others. *Nagatoella* and *Schwagerina* are locally common, and *Triticites* is rare. Primitive *Misellina,* one of the early verbeekinids, first appears in the subzone of *Pseudofusulina vulgaris* and is well developed in the Subzone of *Pseudofusulina ambigua.* The fauna with *Misellina* is sufficiently different in its species assemblage to suggest a different depositional facies.

### NABEYAMAN SERIES

The Nabeyaman is identified as the Zone of *Parafusulina* and is characterized by species of the *Parafusulina kaerimizensis, Parafusulina matsubaishi,* or *Pseudofusulina japonica* stage of development; however, these species and species with these stages of development are known to range also into overlying zones. Much of this zone is equivalent to the Zone of *Cancellina,* which is abundant in some facies. The Zone of *Parafusulina* also includes primitive species of *Neoschwagerina,* marking the Subzone of *Neoschwagerina simplex,* a species that forms an important facies in which *Cancellina, Verbeekina,* and *Yangchienia* also are commonly well represented. Because of facies differences, this zone is difficult to interpret at present. In correlation, the Nabeyaman Series usually is placed as equivalent to the middle, or middle and upper parts of the Artinskian Stage and to the middle, or middle and upper parts of the Leonardian.

### AKASAKAN SERIES

This series is the Zone of *Neoschwagerina* as characterized by the Subzone of *Neoschwagerina craticulifera* below and the Subzone of *N. margaritae* above. The *Neoschwagerina craticulifera* fauna is widely distributed in Tethyan regions and includes additional species of *Neoschwagerina, Afghanella, Pseudodoliolina, Verbeekina, Parafusulina,* and *Pseudofusulina.* The higher *Neoschwagerina margaritae* assemblage also is widely distributed and includes additional species of most of the genera of the lower subzone although species of *Parafusulina* and *Pseudofusulina* become increasingly rare. Elsewhere in the Tethyan regions, *Skinnerina* (primitive *Polydiexodina* of authors) occurs low in this Zone of *Neoschwagerina* and suggests correlation with the lower part of the Guadalupian Series.

### KUMAN SERIES

This is the youngest series that is usually recognized in Japan and in most part corresponds to the Assemblage-Zone of *Yabeina* and *Lepidolina* in which *Neoschwagerina* is not recorded. Although the stratigraphic evidence is not entirely clear, it appears that the lower part of this zone is dominated by *Yabeina globosa* and *Lepidolina elongata* and the middle part is dominated by *Lepidolina kumaensis* and *L. shiraiwensis.*

### YOUNGEST TETHYAN FUSULINACEAN ZONES

The upper part of the Kuma Formation on which the Kuman Series is defined includes species of *Codonofusiella, Rauserella, Parareichelina, Dunbarula, Sichotenella, Staffella,* and *Nankinella* along with smaller foraminiferids. Elsewhere in Japan a fauna dominated by *Codonofusiella, Reichelina,* and *Palaeofusulina* are known from a few high Permian strata and these are probably equivalent in age to a part of the Loping Series of south China (Toriyama, 1973). The most complete development of the youngest Permian fusulinacean zonation is in southern and central China (Nanking, Inst. Geol. and Paleont., 1974; Sheng, 1963, 1965), in southeast Asia (Toriyama, 1975; Toriyama *et al.,* 1974; Lyem, 1971, 1974), and in southeast Pamir (Leven, 1967, 1975). Two assemblage-zones apparently are present, a lower Zone of *Codonofusiella* and *Reichelina* and an upper Zone of *Palaeofusulina* and *Reichelina* (Sheng, 1963; Toriyama, 1973). Both *Codonofusiella* and *Reichelina* appear in the underlying Zone of *Yabeina* and *Lepidolina* and extend into younger strata that contain *Palaeofusulina.* As far as can be determined, the extinction of *Palaeofusulina, Codonofusiella, Reichelina,* and associated genera in the highest Permian fusulinacean zone took place prior to the first appearance of the Triassic fauna.

Permian fusulinaceans are widely distributed in southern and southwestern China (Chen, 1934, 1956; Sheng, 1963, 1965) and have a zonation that closely parallels that of Japan. The lower part of the Maping Limestone includes one or more Late Carboniferous (as used in this review) species zones of *Triticites.* As these rocks include mainly latest Carboniferous zones (characterized by *Quasifusulina, Rugosofusulina,* and *Pseudofusulina*), the unconformity with the underlying Huanglung Series (characterized by *Fusulina* and *Fusulinella*) may represent a long hiatus. The higher parts of the Maping Limestone contain *Pseudoschwagerina, Zellia, Quasifusulina, Rugosofusulina, Paraschwagerina, Pseudofusulina,* and *Triticites,* which correlate with the Asselian and, possibly, parts of the Sakmarian Stage of the Russian platform. Post-Maping diastrophism resulted in considerable erosion prior to the deposition of the Chihsia Formation. This widespread unconformity is one of the reasons that Chinese geologists consider the Chihsia Formation to be the lowest Permian unit (SHENG & LEE, 1964). The Chihsia Formation contains part of the Zone of *Parafusulina* and includes the Subzone of *Misellina.* The overlying Maokou Formation includes the upper part of the Zone of *Parafusulina,* with the Subzone of *Cancellina,* and the Zones of *Neoschwagerina* and *Yabeina* (CHEN, 1956). The Chihsia and Maokou Formations comprise the Yangsinian Series. Disconformably overlying the Maokou Formation is a thick sequence of limestone of the Lopingian Series that has *Codonofusiella* in the lower 400 m (Wuchiaping Limestone) and *Palaeofusulina* in the upper 100 m. The Lopingian Series lacks *Yabeina* and *Lepidolina* and, therefore, is probably younger than all but the upper part of the Kuman Series of Japan. Shale and limestone with the Triassic *Claraia* bivalve fauna lie above the Lopingian Series.

### PAMIRS

The Permian of Soviet Middle Asia, particularly in the Pamir region, has a nearly complete succession that LEVEN (1967, 1975) divided into three series. The lowest is the Yaikian Series having Asselian, Sakmarian, and probably early Artinskian equivalents, that is, the zones of *Sphaeroschwagerina* through to the earliest of the primitive *Parafusulina,* and is equivalent to the upper part of the Maping Limestone of southwestern China. The middle series, the Kushanian, is subdivided into three regional stages, the Chisyanaian Stage (encompassing the Zone of *Misellina*), the Kubergandinian Stage (encompassing the Zone of *Cancellina*), and the Murgabian Stage (including the Zone of *Neoschwagerina*). The highest series, the Pamirian (LEVEN, 1967), was renamed the Arianian (LEVEN, 1975) and three stages were recognized, the Keptenian (Capitanian) (zones of *Yabeina* and *Lepidolina*), the Dzhulfian (Zone of *Paradunbarula*), and the Chansinian (Changhsingian) (Zone of *Palaeofusulina*) at the top. As in the southwestern China section, regional unconformities lie below the Zone of *Misellina* and above the zones of *Yabeina* and *Lepidolina.*

## FUSULINACEAN ZONES OF NORTH AMERICA

The succession of fusulinaceans is known for a number of stratigraphic sequences in western and southwestern North America. The standard reference sections in west Texas include the Wolfcampian and Leonardian series of early Permian age in the Glass Mountains and the Guadalupian and Ochoan series of late Permian age in the Guadalupe Mountains.

The usually accepted placement of the lower boundary of the Permian in North America has been at the base of the Zone of *Pseudoschwagerina* (BEEDE & KNIKER, 1924; THOMPSON, 1954) and this corresponds closely to the base of the Asselian Stage on the Russian platform, which also contains primitive *Pseudoschwagerina,* as well as primitive *Sphaeroschwagerina.* In the type section of the Wolfcampian Series, the first *Pseudoschwagerina* appears in the Neal Ranch Formation (ROSS, 1959, 1963a) and, using this criterion, the upper beds of the underlying Gaptank Formation (Bed 2 of the Gray Limestone Member and the *Uddenites*-bearing shale of R. E. KING, 1931, 1938) are considered to be Carboniferous. The fusulinacean fauna in Bed 2 is meager and includes advanced species of *Triticites,* including some that are similar to *Daixina* and, possibly *Schwagerina.*

The lower part of the Wolfcampian, the Neal Ranch Formation, contains the Zone of *Pseudoschwagerina uddeni* and associated species of *Paraschwagerina, Pseudofusulina, Schwagerina, Stewartina, Schubertella, Eoparafusulina,* and advanced species of *Triticites* (DUNBAR & SKINNER, 1937; ROSS, 1963a). The upper part of the Wolfcampian Series, the Lenox Hills Formation, contains the Zone of *Pseudoschwagerina robusta* and advanced species of *Paraschwagerina, Eoparafusulina, Schwagerina,* and small *Staffella?* (ROSS, 1963a).

The type Leonardian Series has been subdivided into three formations, the Skinner Ranch Formation at the base, the Cathedral Mountain Formation, and the Road Canyon

Formation at the top (Cooper & Grant, 1964, 1966, 1973), which have a thin-bedded lateral facies, the Hess Limestone (Ross, 1960, 1962a). The Skinner Ranch Formation and the lower part of the Hess Limestone are characterized by *Schwagerina hawkinsi, S. crassitectoria, S. guembeli, S. dugoutensis, Parafusulina spissisepta, P. allisonensis,* and *Eoparafusulina linearis.* The Cathedral Mountain Formation contains *Parafusulina durhami* and laterally equivalent strata contain *Schwagerina setum* and *Skinnerella* sp. All the species of *Parafusulina* from the Skinner Ranch and Cathedral Mountain formations have low cuniculi and are considered primitive because these structures appear irregularly in the early volutions. Road Canyon fusulinaceans include *Parafusulina* having well-developed cuniculi, such as *P.* cf. *P. lineata* and *P. sullivanensis.*

The lower part of the Guadalupian Series in the Glass Mountains, the Word Formation, contains *Rauserella, Skinnerina,* and large species of *Parafusulina* with well-developed cuniculi and large proloculi. In the Guadalupe Mountains, the lower part of the Guadalupian also is characterized by large advanced species of *Parafusulina,* such as *P. rothi, P. maleyi,* and rare specimens of *Leella.* The upper part of the Guadalupian, the Capitan Limestone, is characterized by several species of *Polydiexodina* that have a central as well as accessory tunnels. The upper member of this limestone contains a few genera and species with Tethyan affinities, such as *Yabeina texana* and *Codonofusiella paradoxica.* The Ochoan Series is an evaporite succession that lacks fusulinaceans and other normal marine fossils, and our understanding of the correlation of this series is based on its stratigraphic position in one depositional basin where it lies above strata of Capitanian age and below Middle Triassic nonmarine strata.

Elsewhere in North America depositional facies became gradually unsuited for fusulinaceans during the Early Permian as parts of the epicontinental seas became filled in by sediments or were uplifted. This is well shown in the midcontinent region, where fusulinaceans did not survive beyond the Wolfcampian, and in the Midland basin and the east Texas shelf, where they did not survive beyond the Leonardian. The block-faulted basins to the west in New Mexico and southeastern Arizona generally lack fusulinaceans in strata younger than Wolfcampian or early Leonardian, except for one thin limestone unit of local extent that has early Guadalupian species of *Parafusulina* (Ross, 1973).

To the north and west of the transcontinental arch the general stratigraphic range of fusulinaceans is similar to that of Early Permian fusulinaceans, being widespread and becoming progressively restricted before the middle of the period. Only in the strongly deformed structural belts of the western Cordillera do fusulinaceans range well up into the Late Permian. Along this western cratonic shelf Early Permian fusulinaceans from east-central Alaska, northern Canada (Thorsteinsson, 1974), Greenland (Dunbar *et al.,* 1962), and the northern part of the Russian platform spread southward and reached into southern Alberta, and a few reached the Basin and Range region in Nevada and Utah (Slade, 1961).

South of the transcontinental arch, as far as Venezuela, Colombia, Bolivia, and Peru, the Early Permian fusulinid faunas are similar in general composition as far as the limited data permit comparison.

The early Permian of northern California (Skinner & Wilde, 1965) has a particularly diverse fauna of fusulinaceans and parts of this fauna and later Permian fusulinaceans of both Tethyan and non-Tethyan affinities occur to the north in Oregon, Washington, British Columbia, Yukon, and Alaska in structurally complex rocks (Monger & Ross, 1971). Primitive species of *Yabeina* and *Waagenoceras* (Ross & Nassichuk, 1970) suggest that the upper part of the Zone of *Neoschwagerina* is equivalent in age to the early part of the Guadalupian (Word Formation). It is not clear how high in the Permian the succession in these western belts of strata extend, but locally they seem to be at least as young as the Zone of *Yabeina* and *Lepidolina.*

## GEOGRAPHIC DISTRIBUTION

Fusulinaceans are recorded from North America, South America, Europe, Asia, and northern Africa, but are unknown from

Australia, Antarctica, and central and southern Africa (Ross, 1967). They are associated with normal marine limestones and are common in bioherms and banks having coral, algal, and echinodermal fragments in three types of depositional settings. The first type is thin-bedded, algal-rich limestone on cratonic shelves usually associated with widespread, rapid transgressions and regressions of the shoreline across areas of low relief during the Early Permian (Ross, 1972). Ecological niches on these shelves were numerous and, as each shelf was more or less isolated from the others, endemic species abound and a few endemic genera also are present. The second type includes reefs and lagoons as well as some deeper water carbonate environments between the reefs on cratonic shelf edges. Different species and even different genera inhabited each of the various shelf and shelf-edge environments. Cratonic shelf and shelf-edge environments are particularly important because their stratigraphic successions are generally uncomplicated by major contemporaneous or later structural deformation so that facies relations can be traced. The third depositional setting is less thoroughly understood but includes thick carbonate deposits with abrupt lateral changes in depositional facies into dark shale, graywacke, and ribbon chert (MONGER & Ross, 1971). The carbonate facies are associated with basaltic, noncratonic igneous rocks and are probably closely related to reef environments on former island arcs or oceanic ridges. The abundantly fossiliferous limestone normally includes a wide variety of corals, bryozoans, brachiopods, crinoids, and algae in addition to many species and genera of fusulinaceans, and indicates tropical or subtropical shallow-water deposition. Deposits of this type were usually strongly deformed by contemporaneous or later structural events and their internal stratigraphy is complicated and generally difficult to work out in detail.

Near the end of Carboniferous and the beginning of Permian time, a few generic and species complexes became widely dispersed, perhaps several times within relatively brief intervals (Ross, 1962b). These species groups established lineages in different regions that can be traced through several geologic stages. Early Permian fusulinacean faunas are dominated by genera and species of Schwagerinidae that evolved into many well-defined lineages (Ross, 1967; 1977). Several genera, such as *Sphaeroschwagerina, Pseudoschwagerina, Paraschwagerina, Zellia,* and *Parazellia,* are short ranging and are found in the earlier part of the epoch. *Sphaeroschwagerina, Zellia, Parazellia, Robustoschwagerina, Acervoschwagerina,* and *Biwaella* are commonly found only in the Tethyan-Uralian-Franklinian region and most occurrences outside of that region represent sporadic, brief migrations that did not survive for any appreciable length of time. In contrast, one major lineage, *Pseudoschwagerina,* was present for only the early part of its history in that region and then became confined to the midcontinent-southwestern North American region and to the Andean belt of South America. Although not as completely known as those from North America and Eurasia, these Andean fusulinaceans are most closely related to those from southwestern North America and should be included with that region (Ross, 1963b, 1967).

The later part of the Early Permian Epoch was marked by increasing endemism in species complexes in most genera of Schwagerinidae and also in several other families. Dispersals between different regions became less frequent and before the end of Early Permian time three regions developed strongly differentiated faunas. A Tethyan region, a separate Uralian-Franklinian region, and a southwestern North American-Andean region are recognizable. Separation of the Tethyan region from the Uralian-Franklinian region after the early part of Artinskian time appears sharp because fusulinaceans in these regions became markedly different and faunal correlations between all three regions becomes increasingly difficult as species and generic endemism increases. The Schubertellidae, Ozawainellidae, Staffellidae, and Verbeekinidae evolved rapidly into nearly 40 genera that became dominant in the Tethyan region (GOBBETT, 1967). By the beginning of Late Permian time the Tethyan fusulinacean faunas became distinctively endemic and are difficult to correlate with those of other areas. Each of the three regions should be considered a separate faunal realm beginning at this time.

In the Tethyan region *Pseudoendothyra,* a long-ranging conservative genus from the Middle Carboniferous or earlier, began a remarkable evolutionary diversification in the later part of the Early Permian Epoch, giving rise to a dozen genera of advanced Staffellidae. One of these gave rise to *Misellina,* the earliest verbeekinid. The Schubertellidae show a significant but smaller evolutionary burst and a few generic and several species complexes of the Schwagerinidae show increasingly endemic distribution at this time. Although the Verbeekinidae and Schwagerinidae died out and the latest Permian Lopingian faunas were composed of only six Tethyan genera and one new genus, *Palaeofusulina,* all seven of these genera became extinct before the beginning of the Triassic.

Outside the Tethyan realm, fusulinaceans have a much different history in middle and late Artinskian and Late Permian times. In the Uralian-Franklinian realm the number and diversity of fusulinaceans decreased rapidly. The few surviving lineages of Fusulinidae and Staffellidae died out in the region before the Artinskian and *Pseudofusulina, Schwagerina,* and primitive *Parafusulina* continued until about the end of Early Permian time when they also died out. The Late Permian in the Uralian-Franklinian realm lacks a fusulinacean fauna.

In the midcontinent-southwestern North American-Andean region progressive reduction in the extent of epicontinental seas resulted in the fusulinacean distribution being reduced to the southwestern part of North America where, in the later part of Early Permian time, *Schwagerina,* primitive *Parafusulina,* and *Staffella* were dominant. Fusulinidae and early lineages of Verbeekinidae are absent. Representatives of *Schubertella* and *Boultonia* appeared at different times in the region and indicate separate temporary dispersals during the Early Permian. Several other genera, such as *Robustoschwagerina,* temporarily dispersed into the region during the later part of the Early Permian. By the beginning of Late Permian time the fusulinacean genera were greatly reduced to abundant advanced *Parafusulina* and rare *Skinnerina* and *Rauserella.* By the beginning of Capitanian time, these genera were replaced by *Polydiexodina,* a probable emigrant from the Tethyan fauna.

A few other genera, such as *Paradoxiella, Codonofusiella, Yabeina,* and *Leella,* appeared for short intervals in the southwestern North American realm during Late Permian time, but they established no long lineages of species. In general, the southwestern North American realm is identified by species complexes of *Parafusulina* and *Polydiexodina,* which dominated the fusulinacean fauna from the Leonardian to the end of the Guadalupian, and by the general lack of persistent lineages of Verbeekinidae. By latest Permian time, fusulinaceans became extinct in this realm.

## OTHER FORAMINIFERIDA

Few studies on nonfusulinacean foraminiferids are available for Permian strata, although arenaceous and smaller calcareous foraminiferids commonly are present in nonfusulinacean-bearing shale and limestone. Lituolidae, Textulariidae, Ammodiscidae, Lagenidae, and Nodosinellidae of Asselian, Sakmarian, and Artinskian age are recorded from the Bashkirian region (LIPINA, 1949; MOROZOVA, 1949). From the Kazanian of the Russian platform 27 genera of arenaceous foraminifers were reported from acid residues (UCHARSKAJA, 1970). In the Maritime Territory of the Soviet Union, NIKITINA (1969) located widely distributed *Hemigordiopsis* in the zones of *Neoschwagerina* and *Yabeina.* The genus is also recorded from northern Caucasus and Cyprus. PANTIC (1970) described *Hemigordiopsis,* other foraminiferids, and algae from the middle and upper parts of the Permian of western Serbia, which includes the Zone of *Reichelina-Codonofusiella* at the top. Although additional studies of smaller foraminiferids are available for various parts of the Permian succession (see SOSNINA, 1965; ISHII *et al.,* 1975; OKIMURA *et al.,* 1975), our understanding of their phylogeny and distributional patterns remains poorly known.

## CORALS

Many late Paleozoic coral genera have

long geological ranges and wide geographic distributions, whereas other groups of genera have restricted geological ranges and also restricted geographic distributions (Fig. 3). This pattern of distributions presents difficulties in analyzing the biostratigraphy, interregional correlations, and paleobiogeography of Permian Anthozoa. The comprehensive summations by HILL (1948, 1957, 1958), the most recent compilation reviewing the worldwide distribution of Permian Rugosa, noted the distinct distribution of some waagenophyllid genera and reaffirmed her earlier interpretations that the distribution of rugose corals was strongly influenced by environmental conditions. In relatively shallow, nearshore, clastic marine environments the coral assemblages consisted principally of small, solitary, morphologically simple, nondissepimented corals. In contrast, in relatively deeper water offshore marine environments the coral assemblages were dominated commonly by large solitary or compound dissepimented corals.

MINATO and KATO (1965a, 1965b, 1970) extensively studied the phylogeny and distribution of two distinctive families of Rugosa, the Durhaminidae and Waagenophyllidae (Fig. 3), and they demonstrated the distinct biogeographic distribution of genera in these two families. The durhaminid distribution plotted on a map of the world with present-day geographic locations was in the more northerly subarctic and arctic regions of the northern hemisphere with a southerly extension along the western part of North America, whereas the waagenophyllids were distributed in lower latitudes of Europe, Eurasia, and southern Asia. Earlier detailed investigations on the Permian Anthozoa of the Soviet Union by SOSHKINA *et al.* (1941), SOKOLOV (1955), and others provided considerable information on faunal assemblages in the Ural Mountain region and the Russian platform. VASILYUK *et al.* (1970) and SHCHUKINA (1973) have more recently provided additional information on the distribution of faunas, and ROWETT (1972, 1975a) and STEVENS (1975a) have presented further as-

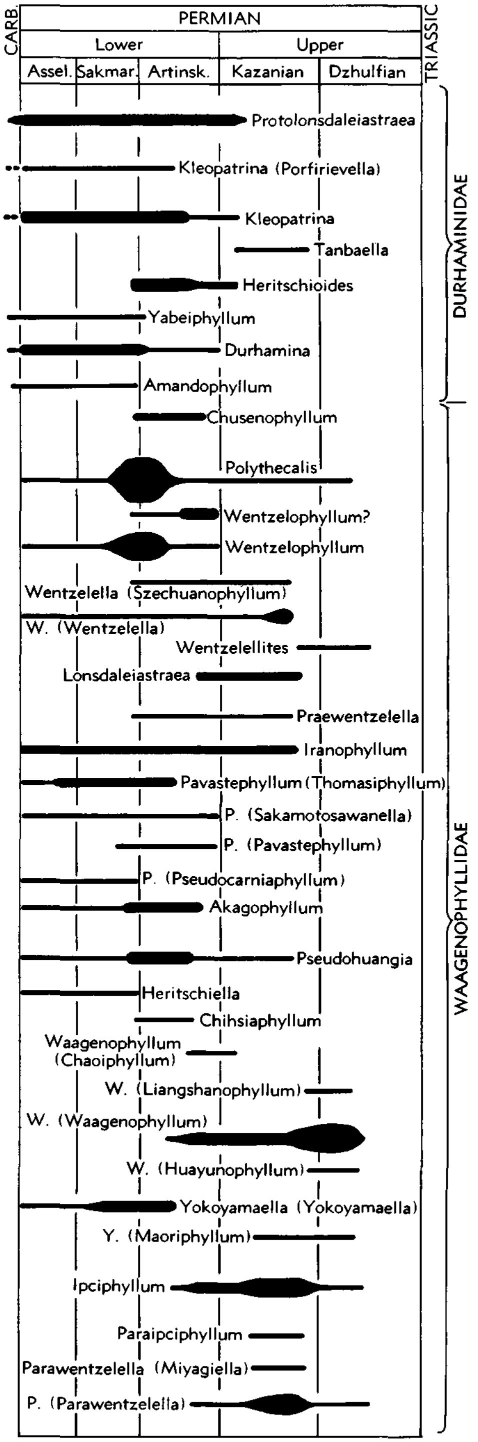

FIG. 3. Ranges of genera of the rugose coral families Durhaminidae and Waagenophyllidae. (Data from Minato & Kato, 1965a and 1965b; Ross & Ross, n.)

pects of the paleobiogeography of Early Permian Rugosa.

Presently, Permian corals are considered to form three faunal provinces, two of which, the Ural-Artinsk and Tethys, are partly identified on the basis of other faunal distributions, particularly fusulinid provinces (see Ross, 1967). The third province includes the more poorly delimited fauna of the midcontinent and southwestern parts of the United States and possibly also Central America and the northern Andes of South America. The Ural-Artinsk province (so named by Vasilyuk, 1970) is dominated by durhaminid rugose corals and extends from the southern Ural Mountain region and Russian platform north and westward to the region of Vest Spitsbergen and the Canadian Arctic Islands into western North America and possibly Central America. The coral assemblages of this province were originally identified in the Ural Mountain region and the geographic boundaries have been more clearly defined as more studies have been undertaken. The other distinct province, the Tethys, is dominated by waagenophyllid corals and extends from Tunisia across the Carnic Alps, Donbas, Crimea, Caucasus, Transcaucasus, Iran, Pamirs, Pakistan, Nepal, parts of China, Japan, Maritime Territory of the Soviet Union, Timor, New Zealand, and Australia. The Early Permian faunal assemblages of the midcontinent of the south-central and southwestern parts of the United States appear to form another province that has some endemic forms and a mixing of genera at different times from both the Ural-Artinsk and Tethyan provinces. Mixing of generic assemblages from the Ural-Artinsk and Tethys provinces also occurred in the Early Permian (Sakmarian) in the western (Carnic Alps) and eastern (parts of China and Japan) regions of the Tethys province.

## URAL-ARTINSK PROVINCE

In the Ural Mountain region and Russian platform the exceedingly rich, Early Permian (Asselian and Sakmarian) coral faunas have many genera, most of which range upward from the Carboniferous. They include massive colonial forms such as the lonsdaleiid *Thysanophyllum,* the lithstrotionids *Orionastraea* and *Stylastraea,* the durhaminid *Protolonsdaleistraea,* as well as solitary fasciculate caniniids. The durhaminid *Kleopatrina* and the aulophyllid *Protowentzelella,* which appear for the first time in the Urals in the Early Permian, may occur in older Carboniferous strata in other parts (Novaya Zemlya and Alaska) of the Ural-Artinsk province (Stevens, 1975a). Except for *Protowentzelella* and *Thysanophyllum,* all these genera continue into the Artinskian. In the upper part of Artinskian and in Kungurian strata colonial Rugosa are absent and only small long-ranging solitary forms are present along with tabulates such as *Cladochonus.*

In the late Asselian or early Sakmarian of Vest Spitsbergen, the massive colonial corals include *Thysanophyllum, Stylastraea, Kleopatrina,* and *Protolonsdaleiastraea.* The Canadian Arctic islands have a fauna that is principally Artinskian in age and have the massive corals *Stylastraea, Protolonsdaleiastraea,* and *Kleopatrina,* as well as *Clisiophyllum?* and *Caninia.*

Faunal assemblages of Artinskian age from northern Alaska (Lisburne Peninsula and northeast Brooks Range) are strongly dominated by small, simple nondissepimented corals (Rowett, 1975b). The fauna includes the polycoeliids *Tachylasma, Ufimia,* and *Sochkineophyllum*; the hapsiphyllids *Amplexizaphrentis, Allotropiophyllum,* and *Euryphyllum*; the metriophyllid *Stereocorypha*; the laccophyllid *Amplexocarinia,* and cyathopsid *Hornsundia.* These assemblages occur in nearshore clastic marine facies. In east-central Alaska the Artinskian coral fauna is also in the same facies and has small nondissepimented corals such as the lophophyllidiid *Lophophyllidium* and the hapsiphyllids *Euryphyllum, Hapsiphyllum, Neozaphrentis,* and *Amplexizaphrentis.* In southern and southeastern Alaska, in the Sakmarian and Artinskian, the coral faunas are markedly different from those of northern Alaska. Here they are dominated by large dissepimented solitary and colonial corals that inhabited a deeper water eugeosynclinal environment. The solitary forms include the lophophyllidiids *Lophophyllidium* and *Stereostylus*; the aulophyllids *Clisiophyllum* and *Auloclisia*; and the cyathopsids *Bothro-*

*phyllum, Timania, Caninophyllum,* and *Caninia.* The compound fasciculate dissepimented corals are the durhaminids *Durhamina* and *Heritschioides.* Massive cerioid corals are rare and are represented by the durhaminid *Protolonsdaleiastraea* and the waagenophyllid *Wentzelella.* The occurrence of a waagenophyllid in this Ural-Artinsk assemblage may represent mixing of the faunas of the Ural-Artinsk and Tethyan assemblages or, as suggested by MONGER and ROSS (1971), the Tethyan faunas are part of a tectonic belt that has been structurally moved against the Ural-Artinsk province. Tabulates are also common in this southern region and include the auloporids *Syringopora* and *Cladochonus,* and the favositid *Michelinia,* and the sinoporid *Sinopora.*

In Nevada in the western United States, a coral fauna of probably early Sakmarian age contains the massive colonial lonsdaleiid forms *Thysanophyllum, Sciophyllum, Eastonoides,* and *Lithostrotionella*; the massive colonial durhaminid *Kleopatrina*; the fasiculate durhaminid *Durhamina*; a fasciculate lithostrotionid, and solitary forms such as the cyathopsid *Caninia* and the lophophyllidiid *Stereostylus.*

In the Upper Permian Kazanian deposits of the Russian platform coral faunas are widely distributed and consist of long-ranging solitary forms such as the polycoeliids *Plerophyllum* and *Calophyllum.* In Alaska, in the northeast Brooks Range, strata of probable Kazanian age contain the metriophyllid *Duplophyllum* and the polycoeliid *Pseudobradyphyllum.* In the Kap Stosch area of central East Greenland in beds of late Guadalupian age, 11 rugose genera from six families are all solitary forms and include *Calophyllum, Pentamplexus, Amplexocarinia, Cryptophyllum, Lytvolasma?, Amplexizaphrentis, Bradyphyllum, Sinophyllum, Hapsiphyllum?,* and *Leonardophyllum?* (FLÜGEL, 1973).

Corals have not been reported from the Tatarian of the Russian section or from other latest Permian strata of the Ural-Artinsk province.

## TETHYAN PROVINCE

In the Tethyan province colonial and solitary waagenophyllids and solitary zaphrentid and caniniid forms commonly characterize the coral assemblages. Extensive documentation of the waagenophyllids by MINATO and KATO (1965b) provided much of the data in the following summary. Some of waagenophyllid genera such as *Waagenophyllum (Waagenophyllum), Ipciphyllum, Akagophyllum,* and *Polythecalis* have a wide geographic distribution, and, in addition, many waagenophyllid genera have long geological ranges. Some with short geologic ranges and limited geographic distribution may be useful in regional and, possibly interregional correlation. MINATO and KATO (1965b) considered the following coral genera or subgenera to have such short ranges: *Pavastehphyllum (Pseudocarniaphyllum)* and *Heritschiella,* which characterize the Zone of *Pseudoschwagerina* in strata of Asselian or, possibly, Sakmarian age; *Chihsiaphyllum* and *Polythecalis (Chusenophyllum),* which characterize the Zone of *Pseudofusulina* and occur in rocks of usually late Sakmarian, but possibly also early Sakmarian age; *Waagenophyllum (Chaoiphyllum),* which occurs in the Zone of *Parafusulina* of early to middle Artinskian age; *Parawentzelella (Miyagiella), Paraipciphyllum,* and *Wentzellites,* which characterize the Zone of *Neoschwagerina* of early Wordian (early Guadalupian) age; and *Waagenophyllum (Liangschanophyllum), Waagenophyllum (Huayunophyllum),* and *Wentzelloides,* which identify the Zone of *Yabeina* of Capitanian age.

In the Early Permian (Zone of *Pseudoschwagerina*), waagenophyllid corals are widely distributed and a number of genera, such as the solitary forms *Iranophyllum, Iranophyllum (Laophyllum), Pavastehphyllum (Sakamotosawanella), Pavastehphyllum (Pseudocarniaphyllum), Akagophyllum, Pseudohuangia, Yokoyamaella, Polythecalis, Wentzelophyllum, Wentzelella,* and *P. (Pavastehphyllum)* range upward from the Carboniferous. *Pavastehphyllum (sensu lato)* appears to characterize the earliest Permian coral assemblages. In the Donbas and Pamirs, the coral fauna of the Zone of *Pseudoschwagerina* includes the tabulate *Michelinia* and the lophophyllidiid *Lophocarinophyllum,* as well as abundant caniniids and zaphrentids, *Pavastehphyllum,* and the colonial forms *Pseudohuangia* and *Heritschiella* (Vasilyuk *et al.*, 1970). In China, the Zone of *Pseudoschwagerina* has *Caninia* and *Pseudocarniaphyllum* (Sheng & Lee, 1964). In the Early Permian of Australia and Timor only solitary nondissepimented corals, such as *Euryphyllum, Tachylasma, Verbeekiella* and *Plerophyllum* and tabulates such as *Cladochonus* and *Thamnopora* occur.

From the Zone of *Pseudofusulina,* usually correlated as late Sakmarian but possibly in part also early Sakmarian, the waagenophyllids *Pseudohuangia* and *Lonsdaleiastraea* identify this interval. During the Artinskian some of the earlier waagenophyllid genera such as *Akagophyllum, Wentzelophyllum, P. (Polythecalis), Yokoyamaella,* and *Pseudohuangia* became rarer and genera such as *Waagenophyllum (Waagenophyllum), Ipciphyllum, Parawentzelella* and *Lonsdaleiastraea* became increasingly significant in the coral assemblages. In the Transcaucasus, Pamirs, and Caucasus, a rugose coral fauna of marked diversity contains *Wentzelophyllum, Yatsengia, Ipciphyllum,* and *Parawentzelella.* In the Pamirs the coral assemblage includes *Carnithiaphyllum, Iranophyllum, Pavastehphyllum (Pavastehphyllum), Yatsengia,* and *Heritschiella:* In China this zone has the tabulate *Hayasakia* and the rugose forms *Stylidophyllum* and *Polythecalis.* In Timor and Australia only small, solitary rugose corals, such as *Euryphyllum, Plerophyllum, Allotropiophyllum,* and *Verbeekiella,* and tabulates are present.

The Zone of *Neoschwagerina,* correlated with the early Wordian (early Guadalupian), has an abundant waagenophyllid, *Ipciphyllum. Waagenophyllum (Waagenophyllum)* continued to diversify with wide distribution of its species. At this time the genus extended into the Caucasus, Crimea, and Pamirs, and in the Pamirs the coral assemblage also included *Yatsengia* and *Iranophyllum.* In the Maritime Territory of the Soviet Union and in China *Wentzelella* is distinctive, but in the Transcaucasus waagenophyllids are poorly developed and the coral assemblage consists mostly of plerophyllids. In the southern part of the Tethys, waagenophyllids reached Timor and New Zealand but did not reach Australia where only small, solitary rugose corals are found.

The Zone of *Yabeina,* correlated with the Capitanian (late Guadalupian), is the time of greatest diversity and abundance of *Waagenophyllum.* At this time *P. (Pavastehphyllum)* reached Tunisia (Stevens, 1975b). In the latest Permian (Dzhulfian), the coral fauna in most parts of the Tethys consisted of solitary corals and is known as the *Plerophyllum* fauna. Environmental conditions in the Tethys were apparently suitable for only a few corals and as conditions continued to change these corals gradually became extinct. In China, in the region between Shensi and Szechuan provinces, a rich coral assemblage with *Waagenophyllum, Lophophyllidium,* and *Liangshanophyllum* occurs in a limestone with the fusulinids *Codonofusiella* and *Reichelina,* and represents the highest occurrence of an extensive Permian coral assemblage (Chao, 1965). A primitive species of *Waagenophyllum* has been reported also from the Pamirian of the Pamirs. In many other areas, such as Transcaucasus, Iran (Flügel, 1968), Nepal, Timor, and China, micheliniid tabulates and small plerophyllid corals, such as *Plerophyllum, Pleramplexus,* and *Wannerophyllum,* and polycoeliids *Polycoelia* and *Ufimia* are present. Flügel (1970), in discussing the gradual decline and extinction of the rugose corals in the Upper Permian in the Tethys, considered the genera with more complex morphology to become extinct first. These would be the cerioid forms with dissepiments or with dissepiments and presepiments, for example, *Wentzelella* and *Yokoyamaella (Maoriphyllum)* with dissepiments and *Polythecalis* with dissepiments and presepiments. These genera occur only as high as the top of the Zone of *Yabeina.* This was followed by extinctions in fasciculate forms with dissepiments (for example, *Waagenophyllum,* which extends as high as the Zone of *Codonofusiella*), and finally, extinctions of forms with septal columella (for example, *Lophophyllidium,* which extends to the top of the Zone of *Codonofusiella*).

## MIDCONTINENT NORTH AMERICAN PROVINCE

Lower Permian rocks of the midcontinent region of the United States extend from Nebraska into Kansas and Oklahoma. To the southwest in Texas, Lower Permian rocks occur in the north-central and western regions of the state. The coral faunas of the Wolfcampian in shallow, nearshore, cyclothem deposits of Kansas (Moore & Jeffords, 1941) and biohermal limestones in west Texas (Ross & Ross, 1962, 1963) are sparse and are dominated by solitary corals, especially *Lophophyllidium.* In the Lower Permian, however, this genus is not as abundant as it was in the Upper Carboniferous. Other solitary corals are *Neokoninckophyllum, Lophamplexus,* and *Stereostylus.* In Kansas, the waagenophyllid *Heritschiella* indicates a dispersal of a genus in a family that has a distinctively Tethyan distribution. In the Leonardian in the Glass Mountains, Texas, the fauna has *Lophophyllidium, Stereostylus, Amplexocarinia,* and *Durhamina.* The occurrence of *Durhamina* represents mixing of a genus that is widespread in the Ural-Artinsk province. Other Early Permian genera in the midcontinent are the aulophyllids *Palaeosmilia* and *Dibunophyllum,* the timorphyllid *Leonardophyllum,* and the auloporid tabulate *Aulopora.* Rowett (1975a) noted that these faunas have similarities with those in northwestern South America. Such genera as *Lophophyllidium* and *Stereostylus* are widely distributed in western North America including Alaska, suggesting periodic mixing with faunas from the small *cul-de-sac* Midcontinent North American province bounded by the transcontinental arch on the north and west and by the Marathon-Ouachita orogenic belt to the east and south. The sparse Upper Permian coral faunas of the Guadalupian of west Texas include the aulophyllid *Palaeosmilia* and the tabulate *Cladopora.*

## BRYOZOANS

Bryozoans (ectoprocts) are a significant part of Permian faunas in certain environmental settings. The Cystoporata and Cryptostomata are dominant and the Trepostomata are far less abundant than at other times in the Paleozoic (Fig. 4). The Cystoporata with 24 genera in six families show a gradual increase in abundance and diversity through the Permian, becoming restricted in distribution in the later part of the Permian. The Cryptostomata with 57

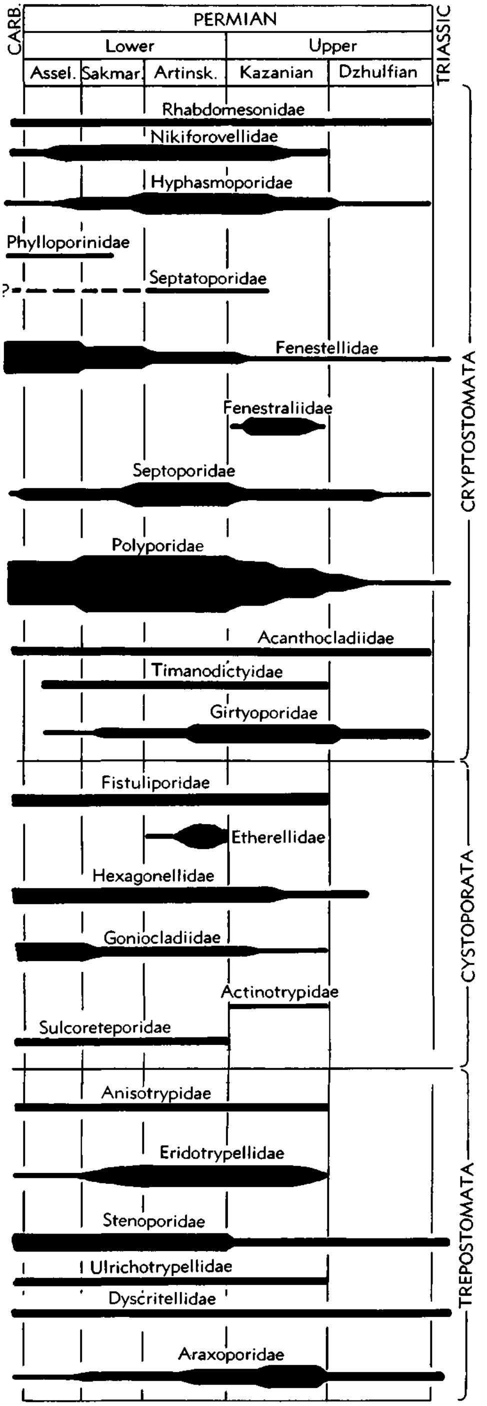

Fig. 4. Range and relative abundance of families of Bryozoa (after J. R. P. Ross, 1978).

genera in 12 families have a pattern of development in the Permian similar to the Cystoporata. The Trepostomata are represented by 19 genera in six families and show a pattern of increased, albeit limited, diversification through the Permian until late Kazanian time. Data for this review came from many reports, but principal references were J. R. P. Ross (1978), Gorjunova (1975), and Morozova (1970). The biogeographic distribution of the bryozoans is summarized for nine different regions in the Permian.

## RUSSIAN PLATFORM AND URALIAN SEA

During the Permian, on the Russian platform and adjacent shelf areas a rich fauna of bryozoans continued from the Carboniferous into the later part of the Kazanian. These faunas have been extensively documented by Russian scientists including Nikiforova (1939), Trizna (1950), Shulga-Nesterenko (1952), Trizna and Klautsan (1961), and Morozova (1970). In the Early Permian (Asselian and Sakmarian), fenestrate cryptostomes of the families Fenestellidae and Polyporidae were dominant members of the hydractinoid reefs and adjacent shelf biota. Other groups, represented by cryptostomes such as *Ascopora, Nicklesopora, Streblotrypa, Acanthocladia,* and *Timanodictya,* the stenoporid *Rhombotrypella,* and the cystoporates *Hexagonella, Fistulipora,* and *Ramipora,* were also part of this rich fauna. In the Artinskian, generic diversity was still high with an abundance of fenestellids and polyporids, the trepostome *Rhombotrypella,* the cystoporates *Hexagonella* and *Goniocladia,* and the cryptostomes *Ptylopora* and *Ptyloporella.* During Artinskian time the trepostomes *Pseudobatostomella* and *Stenopora* and the fistuliporid cystoporate *Eridopora* became proportionally more significant in the faunas.

Toward the end of Artinskian time the bryozoans show a marked reduction in generic diversity and this appears to relate to changes resulting from tectonic movements and subsidence in the Uralian Sea and on the Russian platform. *Fenestella, Polypora, Rhombotrypella, Pseudobatostomella,* and *Streblotrypa* are still present but *Clausotrypa* and *Hexagonella* have disappeared. In Kazanian time the distribution of bryozoans shows an increasing generic diversity gradient from the southern part of the Uralian Sea north and westward to the edge of this sea (Morozova, 1970). Eleven genera are present in the southern part of the Uralian Sea in the region of Tatarian SSR, whereas in the north in the Arkhangel region, 26 genera are present. Genera that are well represented in all parts of this Uralian Sea include the trepostomes *Pseudobatostomella, Dyscritella, Rhombotrypella,* and *Tabulipora,* the fenestellids *Wjatkella* and *Fenestella,* and the cryptostomes *Streblascopora, Pinegopora, Parafenestralia,* and *Triznella.* Bryozoans have not been reported in higher units of the Upper Permian on the Russian platform and adjacent regions.

## FRANKLINIAN SEA AND ADJACENT SHELF AREAS

Bryozoans from this region that lay north and west of the Uralian Sea stretching from Novaya Zemlya to Spitsbergen, Greenland, and Canadian Arctic islands are poorly known, but they appear to have affinities with the faunas of the Russian platform. In the Sakmarian of northeastern Greenland (Ross & Ross, 1962) the trepostomes *Rhombotrypella, Stenopora,* and *Tabulipora,* and the cryptostomes *Polypora, Fenestella,* and *Timanodictya* occur. A sparse Lower Permian fauna from Novaya Zemlya contains *Pseudobatostomella?, Fenestella, Ramipora,* and *Hyphasmopora.* From Spitsbergen an upper Permian fauna of probable Kazanian age contains *Fenestella, Polypora, Ptylopora, Septopora,* and *Ramipora.*

## ZECHSTEIN SEA

In western Europe (England, Germany, Poland, and southern Baltic region), bryozoans, mainly fenestrate cryptostomes, are present in the Upper Permian. The faunas in the Zechstein or equivalents, such as those in the Magnesian Limestone of England, have low generic diversity. The polyporid *Kingopora* and *Fenestella* have a wide distribution. In small reefs in the Zechstein Limestone of Germany the fauna also includes the cryptostomes *Thamniscus, Acan-*

*thocladia, Penniretepora,* and *Synocladia,* the trepostome *Stenopora,* and the hexagonellid cystoporate *Coscinotrypa.*

## SOUTHERN REGION OF NORTH AMERICA

Faunas from this region, which are presently poorly known, have been described from the midcontinent region of the United States (Moore & Dudley, 1944) and Texas (Girty, 1908). In the Lower Permian of the midcontinent region (Nebraska, Kansas and Oklahoma), cryptostomes are abundant in strata of Wolfcampian age and are represented by *Fenestella, Polypora, Septopora, Thamniscus, Streblotrypa, Rhombopora,* and *Syringoclemis.* The fistuliporid cystoporate *Cyclotrypa* occurs in the Wolfcampian of Nebraska and the hexagonellid cystoporate *Meekopora* in the Wolfcampian of Kansas. These cystoporates are present in the Leonardian together with *Meekoporella* and *Fistulipora,* and all four genera extend up into the Wordian (lower Guadalupian). In the Guadalupian two other cystoporates, *Goniocladia* and *Epiactinotrypa,* also appear. The Guadalupian cryptostomes have marked diversity with *Fenestella, Polypora, Thamniscus, Acanthocladia, Girtyopora,* and *Girtyoporina.* The trepostomes are *Pseudobatostomella?, Paraleioclema?* and *Stenopora.* Higher in the succession in the upper Guadalupian (Capitanian) the fauna has the cystoporates *Fistulipora* and *Goniocladia,* the cryptostomes *Fenestella, Acanthocladia,* and *Girtyoporina,* and the trepostome *Paraleioclema.*

## ANDEAN SEA

Two faunas in the Lower Permian of southern Peru occur in strata of Wolfcampian age. They have the cystoporates *Meekopora* and *Goniocladia* and the cystoporates *Fenestella, Polypora, Septopora, Rhombopora,* and *Acanthocladia.*

## NORTHERN TETHYAN SEA

The abundant bryozoan faunas of Japan occur in rocks in various structural blocks and basins, and they range in age from Asselian (Zone of *Pseudoschwagerina*) to Pamirian (Zone of *Yabeina-Lepidolina*) (Sakagami, 1970). Bryozoans from the Zone of *Pseudoschwagerina* range in age from Asselian into the Sakmarian and include the cystoporates *Fistulipora, Coscinotrypa,* and *Sulcoretepora,* the trepostomes *Pseudobatostomella, Stenopora,* and *Tabulipora,* and a great many different cryptostomes (e.g., *Fenestella, Penniretepora, Polypora, Anastomopora, Thamniscus, Hayasakapora,* and *Streblascopora*).

In Japan, bryozoans of the Zone of *Parafusulina,* correlated with the Artinskian, include a number of genera that range up from the Zone of *Pseudoschwagerina,* such as *Fistulipora, Pseudobatostomella, Stenopora, Fenestella, Penniretepora, Hayasakapora,* and *Streblascopora.* Hexagonellid cystoporates show considerable diversity with *Meekopora, Meekoporella,* and *Prismopora.* In the Zone of *Neoschwagerina,* correlated with the Wordian of the Guadalupian (Ross & Nassichuk, 1970), many genera range up from the Zone of *Parafusulina,* and additional genera include the hexagonellid *Fistulamina,* the cryptostomes *Septopora* and *Saffordotaxis,* and the trepostome *Ulrichotrypella.* The youngest bryozoans in the succession occur in the Zone of *Yabeina-Lepidolina* and range in age from upper Guadalupian to possibly Dzhulfian. The cystoporates have high diversity and include *Fistulipora, Meekopora, Prismopora, Sulcoretepora, Coscinotrypa, Goniocladia,* and *Ramipora.* The trepostomes are still sparse and the cryptostomes include *Septopora, Synocladia, Rhabdomeson,* and *Clausotrypa.*

In the Maritime Territory and Kabarovsk region of the Soviet Union the structurally complex suite of rocks has a rich bryozoan fauna (Nikitina *et al.,* 1970). Little is known of the Lower Permian faunas. In Upper Permian strata of Kazanian age the bryozoan fauna contains *Fenestella, Polypora, Coscinotrypa, Dyscritella, Paraleioclema,* and *Permoleioclema.* From the upper part of the Zone of *Yabeina,* Morozova (1970) listed 30 genera, 18 of which occur in both the Maritime Territory and Kabarovsk region. The fauna common to both areas contains the cystoporates *Fistulamina* and *Fistulipora,* the trepostomes *Dyscritella, Ulrichotrypella, Hinganella, Stenodiscus?, Tabulipora, Paraleioclema,* and *Permoleioclema,* and abundant cryptostomes, such as *Rhabdomeson, Streblascopora, Maychella, Clausotrypa, Fenestella, Polypora, Septopora, Girtyoporina,* and *Girtyopora.*

From the Kolyma and Omolon massifs and adjacent regions, an Upper Permian fauna has a great abundance of cryptostomes, such as *Fenestella, Wjatkella, Maychella, Polypora, Synocladia,* and *Timanodictya,* the cystoporate *Fistulipora,* and the trepostomes *Dyscritella* and *Primorella.*

## CENTRAL TETHYAN SEA

The well-developed bryozoan faunas of the Darvas and Pamir regions range in age from Asselian into the Pamirian (Gorjunova, 1975). The faunas are abundant in the Lower Permian and sparse in the Upper Permian. In southwestern Darvas, the bryozoans from strata of Asselian and Sakmarian age include the cystoporates *Fistulipora, Actinotrypella, Goniocladia, Ramiporidra,* and *Sulcoretepora,* the trepostomes *Rhombotrypella* and *Primorella,* and the cryptostomes *Rhabdomeson* and *Streblascopora.* Strata of Artinskian age contain a small cystoporate fauna of *Fistulipora, Eridopora, Cyclotrypa,* and *Hexagonella.* Only the two cystoporates *Fistulipora* and *Hexagonella* occur in the Artinskian in central Pamir. In southeastern Pamir, the lower Permian (Sakmarian) has beds filled with the cryptostome *Nikiforovella,* and in the Artinskian, a more diverse fauna includes the cystoporates *Fistulamina* and *Ramiporidra,* the trepostomes *Rhombotrypella* and *Dyscritella,* and abundant representatives of the cryptostomes *Pamirella* and *Streblascopora.*

High in the Permian (Pamirian) of southwestern Darvas the cystoporate *Fistulipora* is the only bryozoan reported. No bryozoans have been recorded from the intervening stages. In central Pamir, where stages are not presently differentiated, the fauna has the cystoporates *Fistulipora* and *Eridopora* and the cryptostome *Ogbinopora.* In southeast Pamir the Murgabian has the cystoporate *Hexagonella* and the trepostome *Araxopora.*

In the Transcaucasus region of the south-central Soviet Union, the Upper Permian fauna is dominated by cryptostomes (Morozova, 1970). The bryozoan assemblages in the lower part of the Guadalupian (Gnishikian) consist of the cryptostomes *Fenestella, Septopora, Polypora, Rhabdomeson, Ogbinopora,* and *Streblascopora,* the cystoporates *Fistulipora, Cyclotrypa, Hexagonella,* and *Sulcoretepora,* and the trepostomes *Paraleioclema* and *Araxopora.* In the upper part of the Guadalupian (Kachikian) the trepostome *Araxopora* is the only genus reported. The Dzhulfian includes the cryptostomes *Synocladia, Polypora, Septopora, Streblotrypa,* and *Girtyoporina,* and the cystoporate *Fistulipora.*

In central-eastern China, the Lower Permian Chihsia Limestone has the cosmopolitan genera *Fistulipora, Fenestella, Polypora,* and *Septopora* (Loo, 1958). The first three of these genera as well as *Stenopora* and *Dyscritella* occur in the Upper Permian in the Maokou Formation of China and the Jisu Honguer Limestone of Inner Mongolia. In addition, in the Upper Permian of China, the cryptostome *Acanthocladia* has been reported, and in Inner Mongolia other genera are the cryptostomes *Rhabdomeson, Streblascopora, Maychella, Girtyopora,* and *Girtyoporina,* the cystoporates *Fistulamina* and *Hexagonella,* and the trepostomes *Tabulipora* and *Paraleioclema* (Grabau, 1931; Morozova, 1970). In China, in higher units of the Permian, the Loping Series contains *Fistulipora, Polypora, Septopora, Penniretepora, Synocladia, Pseudobatostomella,* and *Paraleioclema.*

## SOUTHERN TETHYAN SEA

In central-eastern Afghanistan abundant bryozoans occur in strata ranging in age from Sakmarian into Kazanian. The Lower Permian faunas of Sakmarian and Artinskian age have numerous polyporids and fenestellids such as *Polypora (Pustulopora)* and *Fenestella,* which range through the entire sequence, and *Polypora (Paucipora)* and *Minilya.* Other cryptostomes are *Rhombopora, Saffordotaxis, Septopora,* and *Rhabdomeson.* The cystoporates include *Cyclotrypa, Meekopora, Goniocladia,* and *Sulcoretepora.* The trepostomes have low representation with *Tabulipora, Dyscritella,* and *Rhombotrypella.* The Upper Permian (Kubergandinian) faunas have a number of genera that extend up from the Artinskian, including *Rhombotrypella* and the four cystoporates noted above. The cryptostomes *Ascopora, Streblascopora, Septopora,* and *Acanthocladia* first appear in the Permian. Higher in the Upper Permian (Murgabian), *Tabulipora* reappears and the cystoporates are represented by *Goniocladia, Hexagonella,* and *Coscinotrypa,* and the cryptostomes by *Streblascopora, Rhabdomeson, Thamniscus,* and *Reteporidra.*

In the Salt Range of Pakistan, the recorded Lower Permian (Artinskian) faunal assemblages are not as diverse. Lower Permian (Artinskian) strata contain the cystoporates *Fistulipora* and *Hexagonella,* the trepostomes *Stenopora* and *Stenodiscus,* and the cryptostomes *Fenestella, Polypora, Rhombopora, Thamniscus, Acanthocladia,* and *Girtyopora.* In the Upper Permian, the two cystoporates noted above are associated with *Goniocladia,* and the cryptostomes are limited to *Polypora, Rhombopora,* and *Synocladia.*

In Thailand the Lower Permian bryozoan faunas of late Sakmarian to late Artinskian age have abundant cystoporates and cryptostomes. The cystoporates include *Fistulipora, Coscinotrypa, Hexagonella, Goniocladia, Ramipora, Liguloclema,* and *Sulcoretepora,* and cryptostome assemblages consist of *Fenestella, Polypora, Thamniscus, Penniretepora, Acanthocladia, Rhabdomeson, Ascopora, Streblascopora, Streblotrypa?, Rhombopora, Timanodictya?,* and *Ogbinopora.* Other members of the faunas are the trepostomes *Dyscritella* and *Leioclema?.* In Malaya a distinctive Upper Permian fauna of Guadalupian age includes *Fenestella, Pseudobatostomella, Araxopora, Paraleioclema,* and *Clausotrypa.*

In western Australia, in the Fitzroy trough of the Canning basin and in the Carnarvon basin (Crockford, 1951; Ross, 1963), Lower Permian (Sakmarian) bryozoan assemblages contain the cystoporates *Evactinostella, Hexagonella,* and *Fistulipora,* the cryptostomes *Streblascopora, Fenestella, Polypora,* and *Lyropora,* and the trepostomes *Dyscritella, Stenopora,* and *Paraleioclema.* In rocks of Artinskian age the fauna shows a marked increase in diversity with the addition of the cystoporates *Prismopora, Fistulamina, Evactinopora, Eridopora, Liguloclema, Etherella, Goniocladia,* and *Ramipora,* and the cryptostomes *Synocladia, Minilya, Streblotrypa, Acanthocladia, Septopora, Saffordotaxis, Rhabdomeson, Megacanthopora?, Callocladia?, Rhombocladia, Streblotrypa,* and *Streblocladia.* In the Bonaparte Gulf basin in strata considered to be in the lower part of the Upper Permian, the sparse fauna consists of *Fistulipora, Rhombopora, Streblotrypa,* and *Ramipora.* In Upper Permian strata of Tatarian age in the Fitzroy trough, the assemblage has *Stenodiscus* and *Dyscritella.*

In Timor, bryozoan faunas that are assignable to stratigraphically identified units range in age from Early Permian into the Late Permian. The sparse fauna from the Bitauni Beds of Artinskian age comprise the cystoporate *Fistulipora,* the cryptostomes *Rhombopora, Streblascopora,* and *Fenestella,* and the trepostomes *Ulrichotrypa* and *Hinganella.* Upper Permian bryozoan faunas occur in the Basleo and Amarassi beds of Kazanian age. In the Basleo Beds, cystoporates are more abundant and include *Fistulipora, Eridopora, Fistulotrypa, Goniocladia,* and *Hexagonella,* and, in addition, the trepostome *Hinganella* and the cryptostomes *Streblascopora* and *Fenestella.* In the overlying Amarassi Beds, the sparse fauna consists of *Fistulipora, Fenestella, Clausotrypa,* and *Stenopora.* Higher in the sequence in strata of probable Kazanian age the fauna has the two cryptostomes *Rhabdomeson* and *Streblotrypella.*

## TASMAN GEOSYNCLINE (EASTERN AUSTRALIA)

In northeastern Australia the Permian bryozoan faunas show a pattern of generic diversity comparable to that of Western Australia. In the Lower Permian (Sakmarian) of the Bowen basin and Springsure shelf, Queensland, the fauna is sparse and contains *Fenestella* and *Polypora* (Wass, 1969). In strata of Artinskian age cystoporates and cryptostomes are abundant and include *Fistulipora, Ramipora, Goniocladia, Liguloclema, Saffordotaxis, Rhombopora, Streblascopora, Diploporaria, Penniretepora, Polypora,* and *Minilya.* The trepostomes are *Stenopora, Dyscritella,* and *Stenodiscus.* In the Upper Permian the fauna of Kazanian age comprises the cryptostomes *Saffordotaxis, Penniretepora, Ptylopora, Levifenestella, Septatopora, Fenestella,* and *Poly-*

*pora,* and the trepostomes *Paraleioclema?, Stenopora,* and *Stenodiscus.*

In the Sydney basin of southeastern Australia, formations of Sakmarian age have a restricted fauna, including *Stenopora* and *Dyscritella.* In deposits of Artinskian age, species diversity increases, particularly in the genus *Stenopora*; other genera are *Pseudobatostomella?, Rhombopora, Fenestella, Minilya,* and *Polypora.* In Tasmania, rocks of the same age also show great species diversity in *Stenopora* and also contain *Hemitrypa?* and *Stenodiscus.*

## BIOGEOGRAPHIC DISTRIBUTION

During a large part of the Early Permian (Asselian to Artinskian) a number of cystoporate genera had cosmopolitan distribution, including the fistuliporids *Fistulipora* and *Cyclotrypa,* the hexagonellids *Hexagonella, Coscinotrypa,* and *Meekopora,* and the goniocladiids *Ramipora* and *Goniocladia. Cyclotrypa, Meekopora, Ramipora,* and *Goniocladia* continued to have cosmopolitan distribution in the Kazanian. Other cystoporates form a distinctive part of many Tethyan faunas and in the Early Permian are represented by the hexagonellids *Evactinopora, Evactinostella, Fistulamina, Prismopora,* and the sulcoreteporid *Sulcoretepora.* During the Late Permian, Tethyan cystoporate assemblages included the fistuliporid *Fistulotrypa,* the hexagonellids *Fistulamina, Prismopora,* and the sulcoreteporid *Sulcoretepora.*

Trepostomes generally paralleled the cystoporates in being mainly either cosmopolitan or Tethyan. Cosmopolitan genera ranging through the Early and into the Late Permian were *Stenopora, Tabulipora, Rhombotrypella,* and, possibly, *Pseudobatostomella.* Genera restricted to the Tethyan included *Paraleioclema* in the Early and Late Permian and *Permoleioclema, Araxopora, Primorella, Dyscritellina, Arcticopora,* and *Permopora* in the Late Permian. Some genera, such as *Dyscritella,* were widely distributed in the Uralian and Tethyan seas early in the Permian, dispersed into southern Europe in the Artinskian and became restricted to the Tethys in the Late Permian.

The cryptostome genera provide more detailed distributional data for delineating faunas of the Uralian, Franklinian, Tasman, Zechstein, and Tethyan seas, and they exhibit dispersal patterns different from those of the cystoporates and trepostomes. From the Asselian through the Kazanian the fenestellids *Fenestella* and *Penniretepora* and the polyporid *Polypora* were cosmopolitan. The septaporid *Septapora* was cosmopolitan during the Sakmarian, then apparently was restricted to the Tethyan Sea during the Artinskian and had a worldwide distribution again in the Kazanian. The septaporid *Synocladia* first appeared in the Franklinian Sea and gradually dispersed so that it was cosmopolitan by the early part of the Kazanian. In the Uralian Sea, the fenestellids *Ptylopora* and *Ptiloporella* were distinctive genera during the Early Permian and the fenestraliids *Parafenestralia* and *Triznella* were distinctive in the Late Permian. Certain genera apparently were restricted to the Tethyan Sea in the Permian and include the fenestellid *Minilya,* the polyporid *Lyropora,* the nikiforovellid *Nikiforovella,* and the rhabdomesid *Pamirella.* In the Tethyan Sea, the girtyoporid *Hayasakapora* ranged through the Permian, the hyphasmoporid *Ogbinopora* occurred in the Artinskian and the Kazanian, and the girtyoporid *Tavayzopora* was present during the Kazanian. Some cryptostomes displayed a bipolar distribution during the Early Permian, such as the septaporid *Synocladia* and the fenestellid *Diploporaria,* occurring in the Uralian Sea and the Tasman geosyncline, and in the Late Permian the fenestellid *Ptylopora* was present in the Franklinian Sea and Tasman geosyncline. Dispersal of some genera, such as the timanodictyid *Timanodictya* and the rhabdomesid *Ascopora,* from the Uralian Sea into the Tethyan Sea occurred during the Early Permian. Other genera, such as the nikiforovellid *Clausotrypa,* were present in the Uralian Sea in the Early Permian and the Tethyan Sea in the Late Permian.

# BRACHIOPODS

The evolution and dispersal of Permian brachiopods were extremely complex and their taxonomy, phylogeny, and stratigraphic and geographic distributions are known in only broad outline on a worldwide basis. Thus, considerable uncertainty exists concerning the placement of many genera and some families into a generally accepted scheme of classification (Williams *et al.,* 1965; Rudwick, 1970; Waterhouse & Bonham-Carter, 1975). These problems in classification introduce many additional uncertainties for establishing stratigraphic and geographic distributions of families and superfamilies (Fig. 5) in addition to those uncertainties associated directly with the stratigraphic record.

The most diverse order during the Permian was the Strophomenida followed by the Spiriferida and Rhynchonellida. These three orders account for more than four-fifths of the Permian brachiopods, and most of the Permian extinctions occurred in these groups. The strophomenids, which generally had either a reduced pedicle opening or none in the adult shell, had two types of adaptation to fixing or positioning their shell on or in the substrate. The Productacea used tubular spines as anchoring devices in soft or shifting substrates and the Strophalosiacea and Davidsoniacea generally cemented their shell to other shells. During the Permian the strophalosiaceans, richthofeniaceans, and lyttoniaceans flourished in reeflike bioherms that gradually became more abundant and complex in their ecological organization.

Most Early Permian brachiopods are continuations of well-established Late Carboniferous lineages or are relict lineages having Middle or Early Carboniferous origins. Many Late Carboniferous genera range into Sakmarian and Artinskian deposits. Only a few new families evolved during the Permian, such as the Chonetellidae, Tschernyschewiidae and, possibly, the Athyrisinidae, and only one superfamily, the Richthofeniacea.

Extinction of families and genera was gradual within the later part of the Permian and the majority of the families became extinct by the beginning of Dzhulfian time (Fig. 5). Although one or two genera in each of the orders survived the close of the Permian, most of the Dzhulfian genera apparently became extinct before the end of the period; however, it should be noted that our knowledge of the Dzhulfian faunas is still very incomplete.

## DISPERSAL PATTERNS

The dispersal patterns in the six superfamilies of Strophomenida contrast in several ways. During the Early Permian the Davidsoniacea had widely distributed genera, most of which are nearly cosmopolitan, and during the Late Permian they showed a gradual reduction in number of genera and a development of endemic genera. The chonetaceans are few in number, being the end of a long, diverse phyletic lineage of which the Permian representatives are essentially cosmopolitan. The genera of the seven Permian families of strophalosiaceans, although of different numerical importance, are mainly endemic genera with only a few appearing in more than one faunal province. The richthofeniaceans were widely distributed during the Early Permian but were restricted to the Tethyan before the end of the Artinskian. The productacean families had several dispersal patterns during the Permian. The linoproductids, and to a lesser extent the overtoniids, were represented in the Permian by a few genera that probably were part of relict lineages whose distributions record much earlier dispersals. The Echinoconchidae, Buxtoniidae, and approximately half of the Dictyoclostidae and Linoproductidae were mostly cosmopolitan. The remaining Dictyoclostidae and Linoproductidae and most of the Marginiferidae were strongly provincial in their distributions and were probably endemic. The Lyttoniacea have one nearly cosmopolitan genus, three that are of more limited distribution, nine that are Tethyan, and one that is present in southwestern North America.

In the rhynchonellids, the rhynchonellaceans are of interest because of their relict pattern of distribution; a few genera had provincial distributions following the superfamily's great Devonian evolutionary diversification. In the Camarotoechiidae *Paranorella* and *Leiorhynchoidea* survived into the Permian of southwestern North America. The rhynchotetradid *Goniophoria* survived as a successful relict in the Tethyan region. Of the Atriboniidae, three genera are found only in the Upper Permian of the Tethys and the other few are widely different in geologic age and scattered in geographic dis-

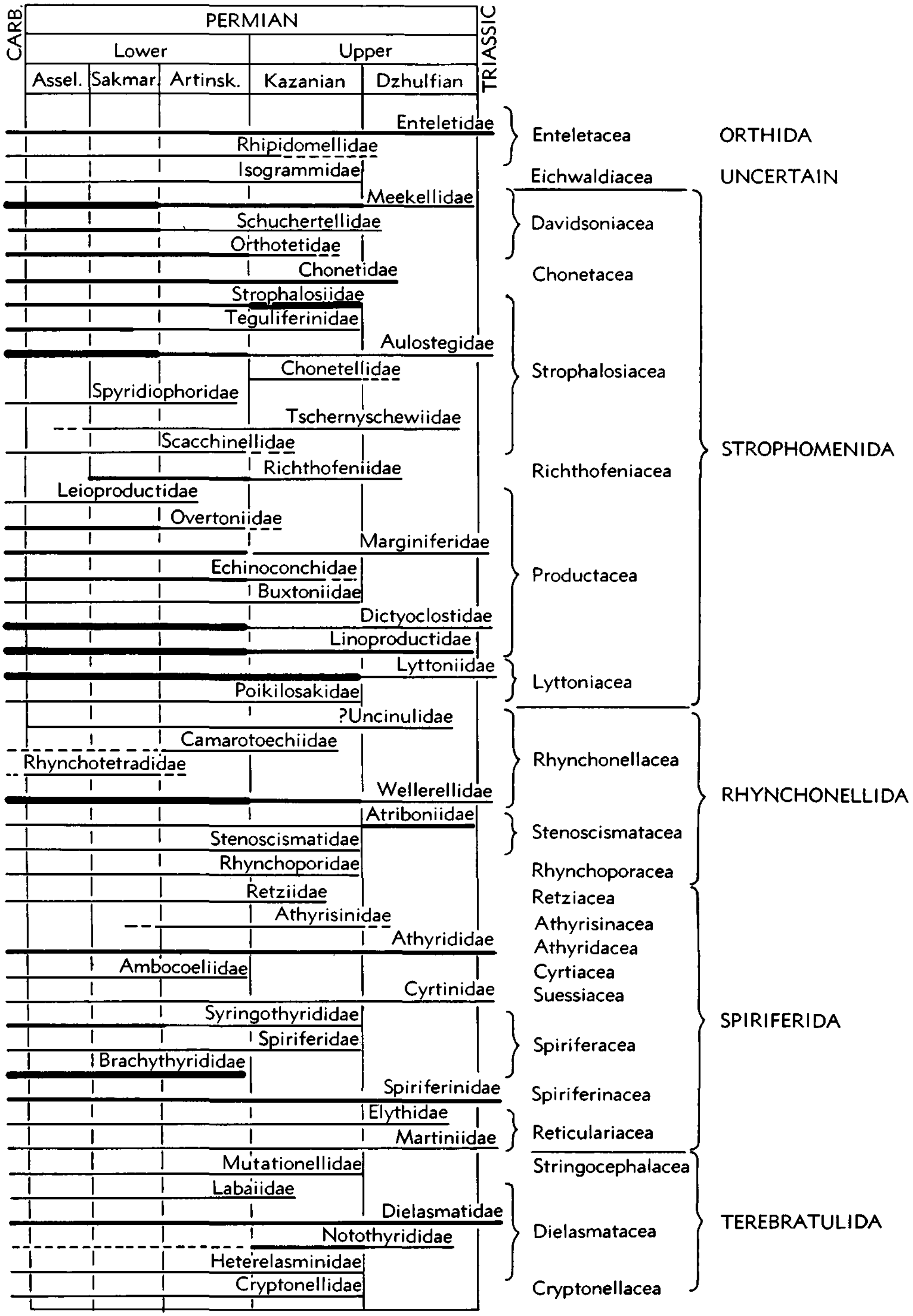

FIG. 5. Ranges and relative importance of families of articulate brachiopod superfamilies. [Dashed lines indicate uncertain extent of range. Increasing line widths indicate 1 to 2 genera, 3 to 5 genera and 6 or more genera.] (Data from Williams *et al.*, 1965, and Grant, 1970; Ross & Ross, n.)

tribution, such as *Camerisma* from the Mississippian of Alaska and the Artinskian of the Tethys and Soviet Union. Similar stratigraphic and geographic gaps are also characteristic of the ranges of the four Permian generic survivors of the Stenoscismatidae that have Lower Carboniferous and Permian records but lack Middle and Upper Carboniferous records.

The third major Permian order, the Spiriferida, has three families that are represented by more than one or two relict lineages. The Syringothyrididae are almost entirely Tethyan, Ural region-Russian platform or northern in distribution. The Brachythyrididae are mostly cosmopolitan or bipolar in distribution. The Spiriferinacea has a few cosmopolitan genera, but most others are known from particular geographical provinces. The few Permian genera of the Martiniidae and the Spiriferidae were also mainly provincial and only the three Permian genera of Elythidae had nearly cosmopolitan distribution.

The Terebratulida had about 19 genera during the Permian and seven were widely distributed or nearly cosmopolitan, and the remainder are reported from one or two provinces. The order Orthida had seven Permian genera and were widely distributed.

These patterns of distribution suggest that the Permian distributions of most Orthida, Davidsoniacea, Productacea, Rhynchonellacea, Stenoscismatacea, Spiriferida, and Terebratulida were the result of earlier dispersals, possibly as early as the Early Carboniferous in some groups and as late as Late Carboniferous in others. The small number of new Permian genera in these taxa and the generally low numbers of individuals and geographic restriction of many of these genera suggest that they are relict faunal lineages that had fairly wide ecological tolerances. In the Strophomenida, the Productacea show a similar trend but with less reduction in the number of genera, perhaps because their major evolutionary diversification had occurred only in the later part of the Carboniferous Period. The Strophalosiacea and very specialized Richthofeniacea and Lyttoniacea showed the greatest evolutionary increase of genera during the Permian, most of which were endemic and restricted to either the Tethys province or to the southwestern North American province.

## ASSOCIATIONS AND DIVERSITY PATTERNS

Permian brachiopods may appear in localities and lithofacies that lack ammonoids, corals, and fusulinaceans and as a group brachiopods probably occupied a great range of habitats. Differences in brachiopod community assemblages may indicate different paleolatitudes, depths (including a variety of communities below the photic zone), or paleobiogeographic provinces (RUNNEGAR & ARMSTRONG, 1969). Many of these distributional differences have been attributed to temperature effects (WATERHOUSE & BONHAM-CARTER, 1975). Three types of brachiopod associations are: 1) low diversity brachiopod associations, mainly from Australia, New Zealand, and Siberia, which lack associated fusulinids and corals and are near glacial deposits; 2) high diversity brachiopod associations that are almost always associated with corals and fusulinids, and frequently algae, but never with glacial deposits; and 3) intermediate diversity brachiopod associations that commonly, but not always, occur with corals and fusulinaceans. The low diversity associations are believed to have been adapted to cool or cold waters, the high diversity associations to warm tropical water, and the intermediate associations to temperate waters.

Low diversity brachiopod associations in the Gondwanan marine faunas are characterized by the Martiniidae as well as Linoproductidae, Strophalosiidae, Aulostegidae, Wellerellidae, and Spiriferidae. Members of some of these families, as well as Reticulariidae and Heterelasminidae, are common in Siberian faunas. These low diversity associations are accompanied by characteristic bivalve assemblages that include the Eurydesmatidae, Deltopectinidae, Edmondiidae, and Pholadomyidae.

Brachiopod associations of intermediate diversity include chiefly Marginiferidae and Echinoconchidae with numerous Rhynchoporiidae, Buxtoniidae, Dictyoclostidae, and Ambocoeliidae. Important in these associations are Lingulidae, Discinidae, Chonetidae, Rhynchotetradidae, Retziidae, and Spiriferinidae. Many of these families also are found in the high diversity brachiopod associations, although only as a minor part.

High diversity brachiopod associations are characterized by Meekellidae, Aulostegidae, Richthofeniidae, Lyttoniidae, Stenoscismatidae, Uncinulidae, Athyrisinidae, Elythidae, Heterelasminidae, Cryptonellidae, Isogrammidae, Enteletidae, Rhipidomellidae, and others. These associations usually occur with colonial corals and fusulinaceans.

Several interesting trends become apparent in these various associations during the Permian. On the Russian platform, Sakmarian brachiopod faunas and their ecological and faunal associations differ from Asselian ones at the species level and extend with little change into lower Artinskian strata (Aktastinian). In general, the Asselian, Sakmarian, and lower Artinskian brachiopods are widespread, and within a region, each brachiopod faunal association shows a general taxonomic consistency suggesting no major change in physical environments but occasional minor fluctuations. In upper Artinskian strata (Baigendzhinian) the rhipidomellids and overtoniids, which contribute prominently to earlier Permian brachiopod faunas, decrease in importance and marginiferids and dictyolostids become increasingly abundant. Kazanian (and Zechstein) associations become much less diverse than lower Permian faunas in central and eastern Europe, apparently in response to salinity changes or fluctuations.

After Kazanian time brachiopod faunas became rare, particularly low and intermediate diversity associations, and soon after high diversity associations also became rare. In those areas where younger brachiopod faunas survived, associations became considerably less diverse, presumably because of continued ecological changes in shallow-shelf environments.

Permian brachiopods have received considerable attention and their early use in establishing local and regional zonation of the Permian in the Urals and Russian platform (Chernyshev, 1902; Frederiks, 1932) was paralleled by their use in North America (Girty, 1909; R. E. King, 1931). Detailed stratigraphic zonation based on local or regional ranges of species and genera of brachiopods is available for a number of stratigraphic sequences. Cooper (in Dunbar *et al.*, 1960) outlined preliminary range information on genera and species from the Glass Mountains of west Texas and later studies in the Glass Mountains have greatly expanded our knowledge of brachiopod distribution in that succession (Cooper & Grant, 1972, 1973, 1974, 1975, 1976). Brachiopod studies are particularly important in the Gondwana and eastern Siberian successions, which commonly lack many of the other marine fossil groups. In the Urals and Russian platform, brachiopods dominate one of the facies of the upper part of the Artinskian and the Kazanian apparently as a result of their tolerance to salinity changes. Brachiopod faunas of the Tethyan region are the most diverse and it is in this region that most of the evolutionary changes were introduced, such as the specialization in the richthofeniids, scacchinellids and lyttoniids.

Brachiopods from the Dzhulfian Stage have been described from only a few segments of the Tethyan region and considerable additional information is needed to fully understand the complicated stratigraphic facies interrelations in the uppermost part of the Permian. A number of lineages of Permian brachiopods continue into the overlying ammonoid zone of *Otoceras* and *Ophiceras,* which has long been taken as the lowest zone of the Triassic and, therefore, a few representatives of typically Permian families survived into earliest Triassic time before they became extinct.

## AMMONOIDS

Study of the distribution and evolution of Permian ammonoids (Fig. 6) has had many important influences on the present concepts of subdividing the Permian System into series and stages (Furnish, 1973). As most specialists studying Permian ammonoids believe that this nektonic group shows little evidence of paleogeographical provincialism, they have concentrated their attentions on the rapid, commonly spectacular, evolutionary history of the ammonoids. Most families, genera, and even many species are apparently cosmopolitan and most geographical differences have been considered to be the result of incomplete collections. A few differences in paleogeographic distributions were noted by FURNISH (1973); for example, *Perrinites* was common in Permian tropical latitudes and the Paragastrioceratinae and Metalegoceratinae were common in Permian temperate latitudes during Artinskian time. During Late Permian times ammonoid diversity gradually decreased as more and more families became extinct and new families did not evolve to replace them. In Permian strata younger than Capitanian age only three new families appear and these are geographically restricted.

In spite of detailed knowledge of their phylogeny and rapid evolutionary history, Permian ammonoids generally are only locally abundant in fine-grained clastic beds. Relatively few of the localities having these abundant faunas are in the same or closely related stratigraphic sections. Because of this distribution, ammonoid specialists tend to use the stage of evolution and position within phylogenetic successions as criteria for assigning ages to these scattered ammonoid occurrences (FURNISH, 1973). Because of these considerations, the subdivisions of the Permian based on ammonoid occurrences are a mixture of the concepts of chronostratigraphic and genus- and species-range zones, and ammonoid "stage" names are derived from those parts of the world where ammonoid assemblages of those ages are abundant (Fig. 6). The lowest 12 of the 16 ammonoid assemblages are based on taxonomic ranges in relatively thick stratigraphic sections in which the biostratigraphic relationships with units above and below are known for ammonoids and also for other faunal groups. Ammonoid assemblages are named from the lower parts of the Lower Permian from the southern Ural region, the upper part of the Lower Permian and the lower parts of the Upper Permian from the west Texas region, and higher assemblages of the Upper Permian are named from Timor, Indonesia, the Dzhulfa (Julfa) region of Soviet Nakhichevan Azerbaidzhan and Iran, Salt Range of Pakistan, and southwestern China. Thus, the general scheme of ammonoid subdivision is pragmatic and usable even if it does not fully agree with the American Code of Stratigraphic Nomenclature (A.C.S.N., 1961). The actual application of some of the names differs in rank and range from that used by specialists in other groups (Fig. 1), and contributes to the existing general confusion about unit boundaries. The following general summary is based largely on the works of RUZHENTSEV (1951, 1952, 1966, 1974) and a summary by FURNISH (1973).

## LOWER PERMIAN ZONATION

### ASSELIAN STAGE

In the southern Urals ammonoids in this stage include a number of gastrioceratid genera that range upward from the Carboniferous as well as some pronoritid, daraelitid, uddenitin, gonioloboceratid, thalassoceratid, adrianitid, and vidrioceratin genera that have close Late Carboniferous ancestors. Three families, the metalegoceratids, paragastrioceratids, and popanoceratids first appear in Asselian strata and, along with the first common members of one subfamily, the sicanitins, are widely distributed. RUZHENTSEV (1951, 1952, 1966) considered *Artinskia* of the *A. kazakstanica* group and primitive species of *Paragastrioceras, Propopanoceras,* and *Juresanites* as typical of the Asselian ammonoid assemblage. RUZHENTSEV (1966) listed the following Permian genera, which first appear and are common in the Asselian Stage: *Sakmarites, Akmilleria, Kargalites (Kargalites), Marathonites (Almites), Prostacheoceras,* and *Protopopanoceras.*

Strata of equivalent age in west Texas and the midcontinent region of North America have numerous early perrinitids (a family not found in the Ural region), represented by *Properrinites.* Other taxa in these earliest Permian ammonoid assemblages are closely similar to those in the Ural region.

### SAKMARIAN STAGE

In the southern Ural and Ufa plateau regions the Tastubian Substage of the Sakmarian contains the first true members of *Metalegoceras* and *Uraloceras* along with many holdover genera from the underlying Asselian Stage. In western North America a number of species of *Properrinites,* such as *P. boesei* and *P. denhami,* are found in ammonoid assemblages of this age as well

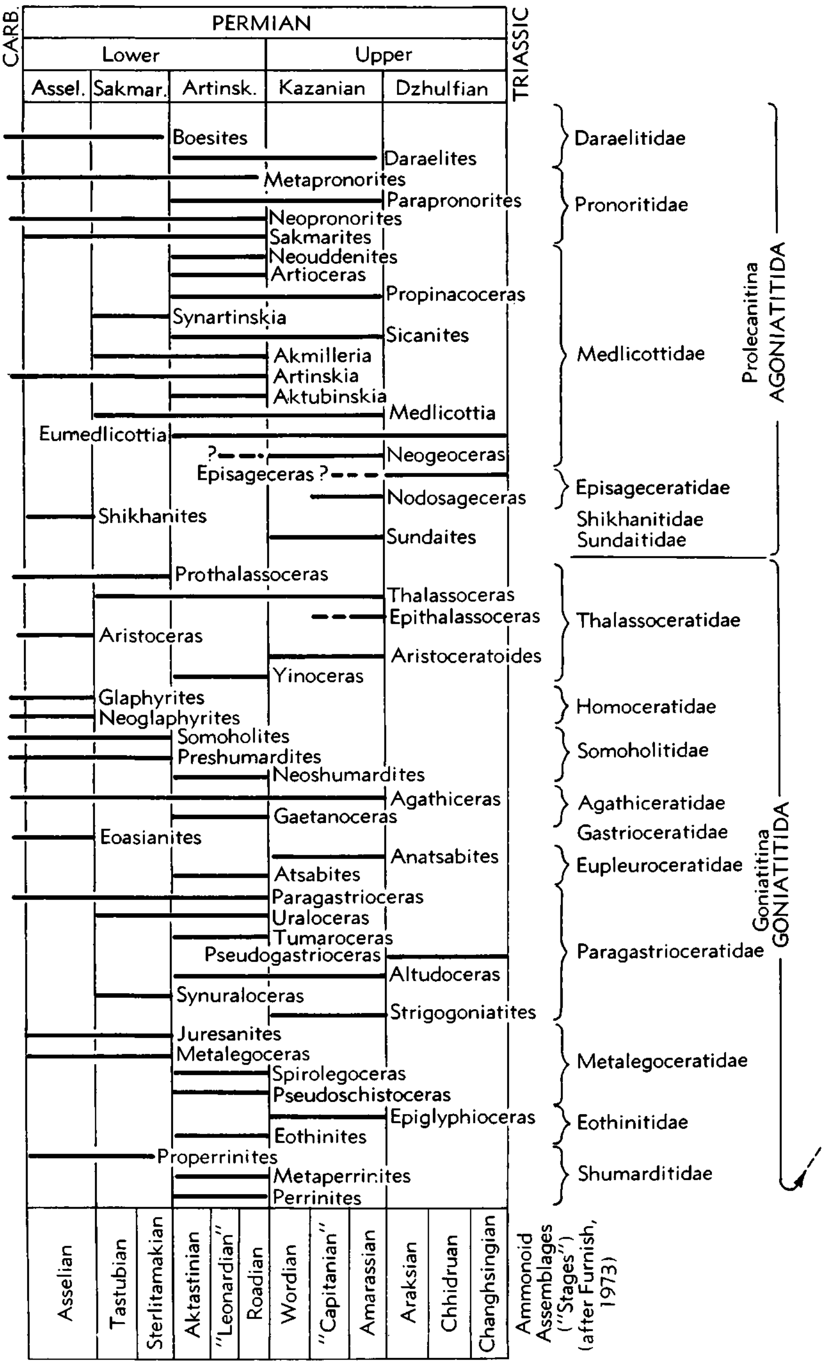

FIG. 6. Ranges of ammonoid genera arranged by families. (Data principally from Ruzhentsev, 1962, and Spinosa *et al.*, 1975; Ross & Ross, n.)

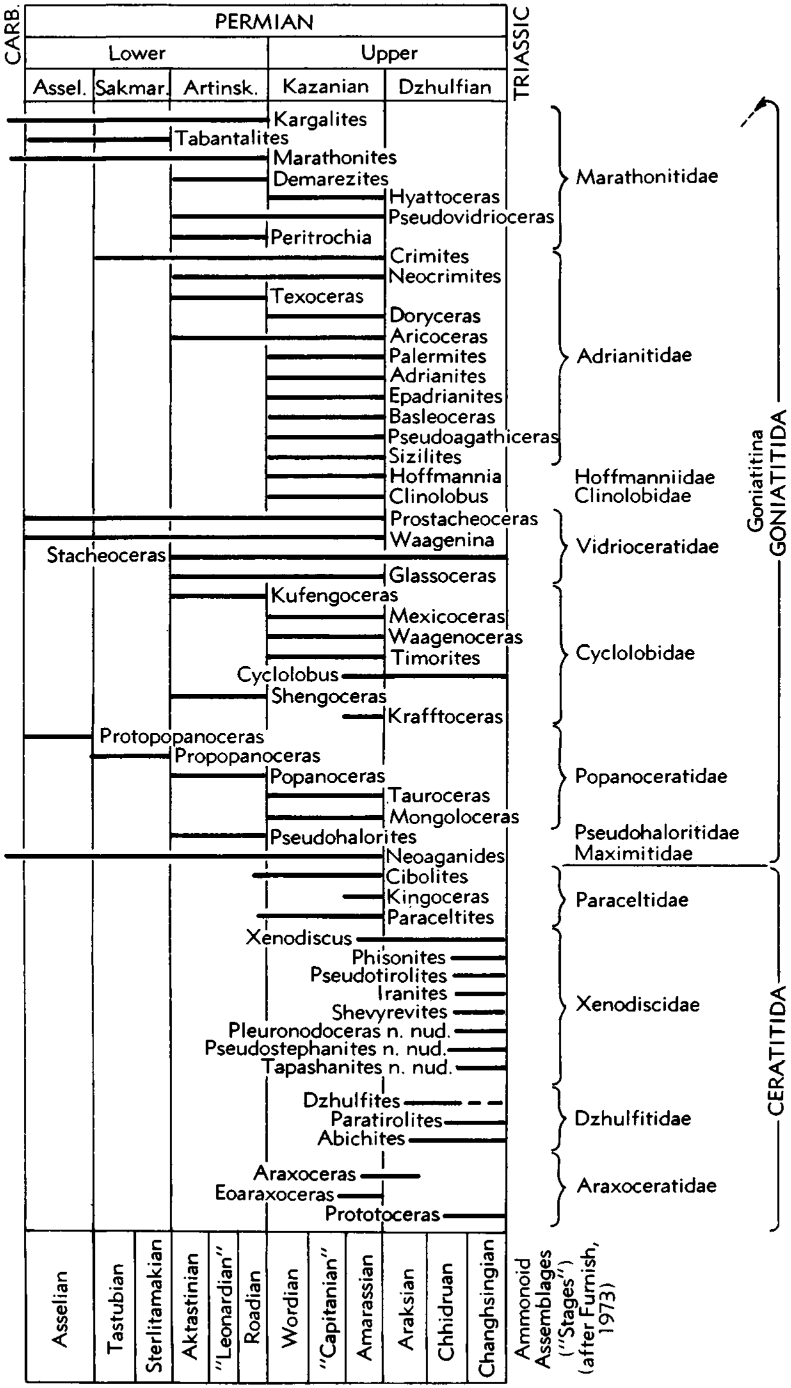

FIG. 6. *(Continued from facing page.)*

tinctive of a post-"Capitanian," latest Guadalupian, age. FURNISH (1973), FURNISH and GLENISTER (1970), and SPINOSA *et al.* (1975) identified the following "Amarassian Stage" or assemblage of ammonoid species: *Strigogoniatites angulatus, Epadrianites timorense, Stacheoceras tridens, Timorites curvicostatus, Cyclolobus persulcatus, Hyattoceras subgeinitzi, Sundaites levis, Syrdenites* sp., *Episageceras noetlingi, E. nodosum, Xenodiscus wanneri, "Hyattoceras"* sp., and *"Parapronorites"* sp. In the La Colorada beds of Coahuila, Mexico, *Xenodiscus wanneri, Kingoceras kingi,* and *Eoaraxoceras ruzhencevi* are associated in a southwestern North American assemblage of this age. Based on a number of logical models of phylogenetic lineages, the Amarassian ammonoid assemblage is most likely to be equivalent in age to the upper beds of the Guadalupian Series (i.e., the upper part of the Bell Canyon Formation and the Lamar and Tansill carbonates).

### DZHULFIAN STAGE

According to FURNISH (1966, 1973) and FURNISH and GLENISTER (1970), the highest Permian stage is represented by three subdivisions, the Araksian, Chhidruan, and Changhsingian (Fig. 6), which are based on ammonoid assemblages from three geographically separate segments of the present Himalayan Mountain chain. The Araksian Substage is based on the *Araxilevis-, Araxoceras-,* and *Oldhamina*-bearing beds, whose faunas were described in detail from the Araks Gorge at Dorasham Station near Dzhulfa by RUZHENTSEV and SARYCHEVA (1965). The ammonoids occur in the upper part of these beds and include a wide variety of specialized otocerataceans (Araxoceratidae) and other ammonoids of Paleozoic ancestry. Abundant *Araxoceras, Rotaraxoceras, Prototoceras, Pseudotoceras,* and *Vesocotoceras* are in association with *Pseudogastrioceras* and characterize the fauna. Three rarely found genera, the medlicottid *Syrdenites* and the cyclolobaceans *Stacheoceras* and *Cyclolobus,* are also associated with this faunal assemblage in nearby localities. The *Cyclolobus* species is considered to be primitive and was assigned to *C. kullingi,* originally described from central East Greenland. At Abadeh, in central Iran, TARAZ (1969, 1971, 1973) reported a thicker, possibly more complete, sequence than at Dzhulfa. TARAZ (1973) believed that the Abadeh section fills in a hiatus that lies beneath the *Araxilevis* beds at Dzhulfa and that the Abadeh section is younger than the Guadalupian Series of North America. FURNISH (1973) pointed out that the late Guadalupian Amarassian ammonoid fauna of the La Colorada beds near the top of the Permian section at Las Delicias, Coahuila, Mexico, has a similar ammonoid composition to those in the upper part of TARAZ's (1969, 1971) Abadeh section and that this fauna is overlain by an Araksian assemblage above which appears a Chhidruan assemblage.

WAAGEN (1889-91) recognized the Chhidru beds in the upper strata of the Upper *Productus* Limestone, Salt Range of Pakistan, with an abundant and diverse invertebrate fauna. TEICHERT (1966) and KUMMEL and TEICHERT (1970) summarized the stratigraphy of these beds and the distribution of fossils in them. *Cyclolobus* ranges through a small interval in the upper third of the Chhidru Formation of KUMMEL and TEICHERT (1970) and is represented by three species of which *C. oldhami* and *C. teicherti* are the best known. These are intermediate in stage of evolution between *C. kullingi* from the Araksian assemblage and the cyclolobids of the Changhsingian assemblage. Other Chhidruan ammonoids include *Stacheoceras antiquum, Eumedlicottia primas, Episageceras wynnei,* and *Xenodiscus carbonarius.*

Basing his conclusions mainly on indirect evidence, FURNISH (1973) believed that the *Vedioceras-Oldhamina* assemblage, which lies above the Araksian ammonoid assemblage in the Dzhulfa sections, is equivalent to the Chhidruan ammonoid assemblage of the Salt Range. In the Dzhulfa region the *Vedioceras-Oldhamina* assemblage includes *Vedioceras* and *Dzhulfoceras,* which in the region are restricted to that assemblage, and *Urartoceras, Rotaraxoceras, Prototoceras,* and *Pseudotoceras* ranging upward from the *Araxoceras* beds below.

The highest Permian beds of Dzhulfa and the Salt Range are thin and have restricted ammonoid faunas (FURNISH, 1973; KUM-

MEL, 1972). At Dzhulfa, these strata have yielded coarsely ribbed xenodiscids, dzhulfitids, a maximitid, *Neoaganides,* and rare *Pseudogastrioceras* and *Stacheoceras.* A comparable assemblage having a more abundant fauna has been reported from the Changhsing Limestone of northern Chekiang, China. In its lower part this limestone includes *Pseudotirolites* and *Pseudogastrioceras* and in the upper part it has *Stacheoceras, Pachydiscoceras, Rotodiscoceras, Trigonogastrites,* and *Changhsingoceras.* Associated with these ammonoids are *Palaeofusulina, Reichelina, Oldhamina, Dictyoclostus,* and *Hustedia.* CHAO (1965) stated that "The Changhsing Limestone changes into siliceous limestone, siliceous shale, and sandstone at many places in South China, where they are called the Talung Formation (equivalent to Hoshan Formation of Sun, 1939)." Although it is not clear from CHAO's statement if this is a lateral or a vertical lithofacies change, or both, he combined ammonoids from both lithologic units in his analysis of the "Changhsing or Talung ammonoids." The Talung Formation is disconformably overlain by Lower Triassic shales bearing *Claraia.*

Correlations with other regions are commonly indirect (CHAO, 1965; FURNISH, 1973). The Loping Coal Series that lies beneath the Changhsing Limestone is correlated with most of the Dzhulfa beds of Iran and with the Chhidru Formation of the Salt Range. CHAO (1965) suggested that the reddish limestone and shale with *Paratirolites* just beneath the Lower Triassic beds bearing *Claraia* at Dzhulfa are possibly equivalents of the Ali Bashi Formation (see also KUMMEL & TEICHERT, 1973; TOZER, 1969, 1971; FURNISH, 1973; TEICHERT, KUMMEL, & SWEET, 1973; and KUMMEL, this volume).

## CONODONTS

In contrast to studies of Devonian, early Carboniferous, and Triassic conodonts, study of Permian conodonts has not yet advanced to the point of establishing a worldwide scheme of biostratigraphy. Several studies have recently shown the potential use of conodonts in establishing zonation, particularly in strata having few ammonoids or fusulinaceans (CLARK & ETHINGTON, 1962; BENDER & STOPPEL, 1965; SWEET, 1970; CLARK & BEHNKEN, 1971; KOZUR, 1973, 1975; BEHNKEN, 1975). Nevertheless, relatively few stratigraphic successions are known in the detail that is available for the Upper Devonian and Lower Carboniferous.

Most detailed studies of Permian conodonts have dealt with biostratigraphic problems of either the Carboniferous-Permian or Permian-Triassic boundary (CLARK & BEHNKEN, 1971) or have described relatively isolated faunas (Fig. 7). For reasons that are not entirely clear, the North American standard Permian reference sections in west Texas have yielded neither abundant nor diverse conodont faunas, and correlation of stratigraphic sections having more plentiful conodonts with these standard sections is not as precise as might be desired (BEHNKEN, 1975). Also, few conodont studies deal with the type Permian sections in the Russian platform and Urals, and conodont correlation with those sequences is not possible at present.

### WESTERN NORTH AMERICA

The present conodont zonation for the Permian is based largely on studies by CLARK and BEHNKEN (1971) and BEHNKEN (1975) in the western North American Cordillera in central Nevada and southeastern Idaho and some studies in portions of the succession in the Guadalupe Mountains of west Texas (Fig. 7). Apparently some confusion exists concerning the boundaries and thicknesses of many of the named units in the Great Basin and the resultant uncertainty leads to difficulty in correlation with the west Texas standard sections.

BEHNKEN (1975) recognized two conodont zones, the *Idiognathodus ellisoni* Assemblage-Zone and the *Neogondolella bisselli-Sweetognathus whitei* Assemblage-Zone, which he considered to be Wolfcampian in age. KOZUR (1975) considered that the base of the Permian should be placed at the base of the second of these zones. In the Riepe Springs and Ferguson Mountain formations of Nevada, *Idiognathodus ellisoni* occurs without other platform conodonts and marks a zone of early

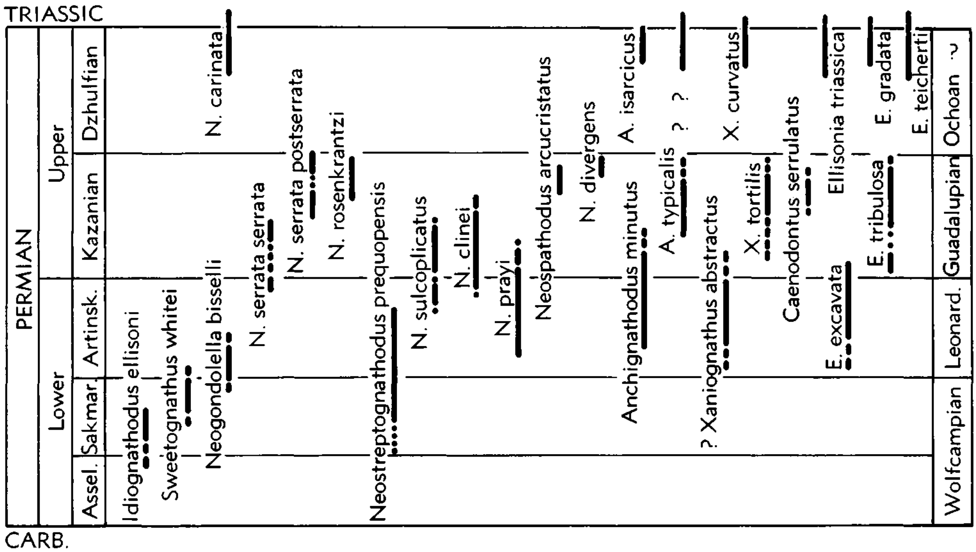

FIG. 7. Ranges of zonally important species of conodonts, principally based on Lower Permian taxa in the western United States (Behnken, 1975) and Upper Permian taxa in Pakistan (Sweet, 1970; Ross & Ross, n).

and middle Wolfcampian age. *Neostreptognathodus pequopensis* is rare in this assemblage-zone. The lower 30 m of the Pequop Formation contains mainly *Sweetognathus whitei* and the succeeding 82 m contain abundant *Neogondolella bisselli, N. pequopensis,* and several species of *Xaniognathus.* The top of this zone approximates the Wolfcampian-Leonardian boundary in the Glass Mountains as based on correlations using fusulinids (SLADE, 1961).

Conodont zones assigned to the Leonardian in the Great Basin region include, at the base, the *Neostreptognathodus pequopensis* Assemblage-Zone and the *Neostreptognathodus sulcoplicatus-N. prayi* Assemblage-Zone. The *N. pequopensis* Zone is identified on the abundance of *N. pequopensis.* Also in this zone are a few specimens of *Xaniognathus abstractus, Anchignathodus minutus,* species of *Hindeodella,* and *Ellisonia excavata.* The *N. sulcoplicatus-N. prayi* Zone is late Leonardian to early Guadalupian in age and includes elements of *Xaniognathus abstractus, Neogondolella idahoensis, Neostreptognathodus clinei, Anchignathodus minutus, Ellisonia excavata,* and *Hindeodella* spp. Considerable geographical and local stratigraphic variations appear in the occurrence of the two guide species of *Neostreptognathodus* and associated species. BEHNKEN (1975) placed the upper limit of this zone at the base of the first appearance of faunas containing either *Neogondolella rosenkrantzi* or *N. serrata.*

The overlying *Neogondolella serrata serrata* Assemblage-Zone begins with the first appearance of this species and in places overlaps with the upper ranges of many species found in the preceding lower zone. *Xaniognathus tortilis* and *Ellisonia tribulosa* first appear in this zone. This assemblage-zone appears in strata of possible late Leonardian age and ranges into strata of probably early Wordian age in the Guadalupe Mountains, west Texas, and the Meade Peak Member (Phosphoria Formation) in Idaho.

Three conodont assemblage-zones characterize the remaining parts of the Guadalupian Series. The *Neogondolella rosenkrantzi-Neospathodus arcucristatus* Assemblage-Zone is based on the assemblages from the upper 30 m of the Plympton Formation and the lower part of the Gerster Formation of eastern Nevada (BEHNKEN, 1975). The first appearance of either *Neo-*

*gondolella rosenkrantzi* or *Neospathodus arcucristatus* marks the base and the last appearance of *N. arcucristatus* marks the top of the zone. The upper part of the Gerster Formation contains the *Neogondolella rosenkrantzi-Neospathodus divergens* Assemblage-Zone, which includes *Ellisonia tribulosa. N. divergens* appears at the base of the zone and the top of the zone is an erosional unconformity. This assemblage also has been reported from the Zechstein of Germany (Bender & Stoppel, 1965). Based on available strata preserved beneath the basal Triassic unconformity, these assemblage-zones form the upper portion of the conodont zonation in the Permian miogeosyncline of Nevada, Utah, and southeastern Idaho.

In the Guadalupe Mountains of west Texas, the youngest recognized zone, the *Neogondolella serrata postserrata* Assemblage-Zone, lies above the *N. serrata serrata* Zone and includes strata of late Wordian and Capitanian age. In addition to *N. serrata postserrata,* this assemblage includes *Anchignathodus typicalis, Xaniognathus tortilis, Ellisonia tribulosa, Prioniodella decrescens, P. anguinea, P. cteniforma,* and *Caenodontus serrulatus. N. serrata postserrata* currently is known only from the west Texas region.

From the scattered occurrences of Permian conodonts that are available for comparison, Wolfcampian and early to middle Leonardian species appear to be widely dispersed and within the western United States are regionally distributed with few indications of provincialism. On the other hand, the late Leonardian and Guadalupian species begin to show increasing provincial distributions, which may relate to biofacies rather than geographic isolation. The highest part of the Gerster Formation (correlated on the basis of brachiopods and the ammonoid *Timorites*) is considered to be Capitanian in age, and has a conodont fauna similar to that of the lower part of the Zechstein of Germany.

### SALT RANGE, PAKISTAN

Conodonts from the uppermost Chhidru Formation in Pakistan are the youngest Permian representatives yet described (Sweet, 1970). In general, conodonts are rare in most of the Upper Permian in the Salt Range and nearby areas of Pakistan and only the white sandy beds in the upper 1 to 5 m of the Chhidru Formation contain a definable conodont fauna. The *Anchignathodus typicalis* Assemblage-Zone includes *A. typicalis, A. isarcicus, Ellisonia triassica, E. gradata, E. teicherti, Neogondolella carinata,* and *Xaniognathus curvatus* and occurs in the uppermost 4 m of the Chhidru Formation (Permian) and lowermost 1 to 3 m of the overlying Mianwali Formation (Triassic). Based on other faunal evidence (Kummel & Teichert, 1970), this zone straddles the Permian-Triassic boundary and supports the view that if a paraconformity is present, the resulting hiatus is of relatively short duration. Brachiopods (possibly reworked from earlier deposits) were collected from the same beds as those containing this conodont assemblage and have a Guadalupian, rather than a later Permian aspect (Cooper, in Kummel & Teichert, 1966; Grant, 1970).

## PALEOGEOGRAPHIC RECONSTRUCTION

Possible geographic arrangements for the various epicontinental seas, miogeosynclines, and eugeosynclines during the Permian Period suggest that a modified Dietz-Holden model (Dietz & Holden, 1970; Smith, Briden, & Drewry, 1973) may help to explain some of the apparent problems in phylogenetic histories and biogeographic distributions. Two time intervals, Early Permian (Asselian) and Late Permian (Kazanian), are examined on world reconstructions (Fig. 8 and 9).

Early Permian epicontinental seas reached their maximum distribution during the Asselian (Fig. 8). Mountain building and deformation of the Ouachita-Appalachian-Hercynian belt continued and, although mountains were high, marine epicontinental embayments were still extensive. The Uralian geosyncline was very narrow and probably relatively deep but connected the Russian platform with the Hercynian belt of the Tethyan region. Shallow-water marine connections with southwestern North Amer-

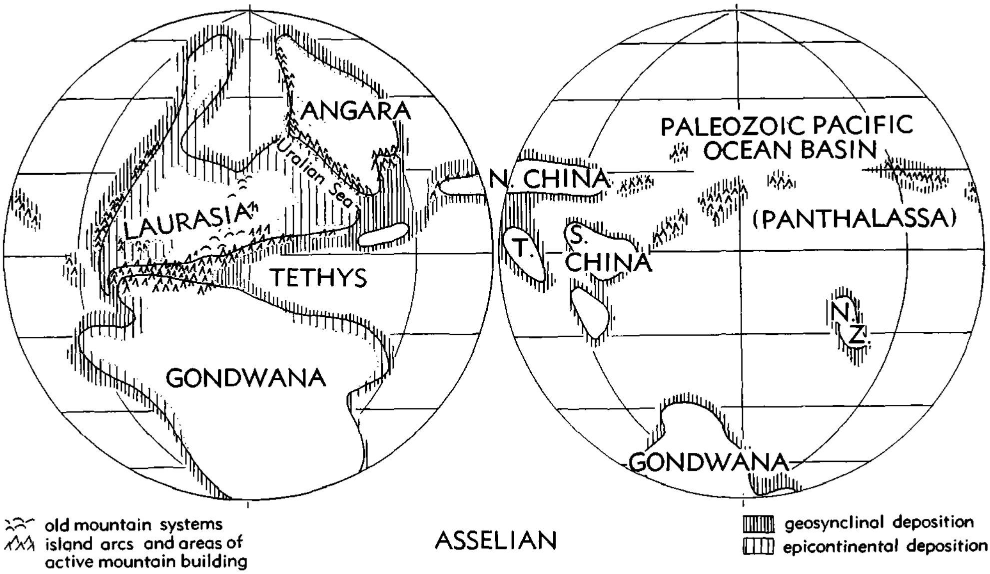

Fig. 8. Paleobiogeography during Asselian Age with connection between Uralian and Tethyan seas well established. Volcanic islands include parts of Tethyan region that have been added to continents at a later time, probably during Mesozoic and Cenozoic (Ross & Ross, n). [Explanation: *N. Z.*, New Zealand; *T*, Tarim stable block.]

ica and western South America were by way of the Franklinian geosyncline and northern and western Canadian shelves so that distance and latitude produced temperature gradients that reduced the dispersal of many marine invertebrate faunas.

During Sakmarian time, exchange of marine invertebrates became increasingly less frequent between the Tethyan region, the Uralian-Franklinian region, and the southwestern North American region (Ross, 1970). By late Artinskian time direct marine connections between the Tethyan region, the Uralian geosyncline, and Russian platform ceased and from this time until the end of the Permian the Tethyan faunas became increasingly endemic and formed a distinctive faunal realm. By the beginning of Late Permian (Fig. 9) the northern Pangaea epicontinental seas (Kazan and Zechstein seas) lacked fusulinaceans, and only a few genera of smaller Foraminiferida were present. Other marine invertebrates show similar specialized faunas. The late Late Permian (Dzhulfian) was a time of minor inundation of the epicontinental shelves and many of those seas had unusual environments of deposition. Of the Early Permian geosynclines, only parts of the Tethyan geosyncline remained a marine seaway in the later part of the Late Permian.

Although much is known about shallow-water marine faunas of the Permian Period, many questions about their distribution, dispersal, and phylogeny remain unanswered (Ustritskiy, 1974). Large parts of Asia and South America are poorly known. New Zealand has an interesting Permian fauna but a poorly understood geographic position in the late Paleozoic. Parts of the southern Eurasian Tethyan belt may have been widely separate sialic blocks that have been united at a much later time. In the Cordilleran and Andean structural belts of North and South America, strata containing Tethyan realm marine faunas, which were probably tropical or subtropical with relatively high diversity, lie next to strata having non-Tethyan faunas that were probably temperate and have low diversity. As these strata in these structural belts are older than 150 my, and, therefore, older than present sea floors, these belts may include carbonate banks and platforms associated with old tropical island arcs and other uplifted ocean crustal fragments that have been added to the western side of the Americas during the Mesozoic.

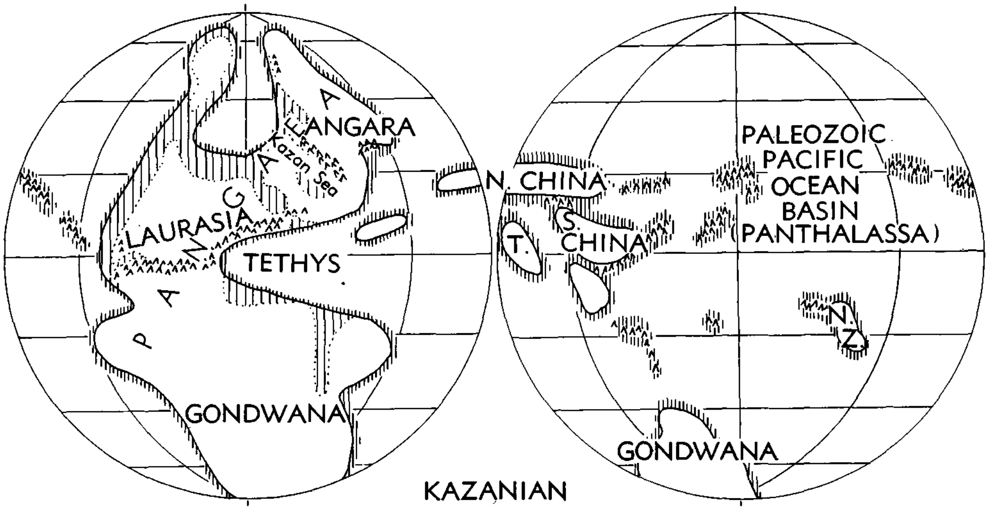

FIG. 9. Paleobiogeography during Kazanian Age with connection broken between Uralian and Tethyan seas (Ross & Ross, n). [See Fig. 8 for explanation of abbreviations and symbols.]

## SUMMARY AND CONCLUSIONS

Several patterns in Permian faunas and biostratigraphy appear consistently in the different fossil groups examined. During Asselian time, and to a lesser extent during Sakmarian time, many of the shallow-water marine faunas are widely distributed in the Tethyan and Uralian-Franklinian region, or, at least, there were several short intervals of faunal exchange followed by longer intervals of restricted dispersals between these regions. In this respect, Asselian patterns represent a continuation of Late Carboniferous distributional patterns and may relate to the continuation of cyclic deposition associated with marine transgressions and regressions that gradually decreased in extent and magnitude during Asselian and Sakmarian time. Nearly all Asselian and Sakmarian marine faunas either lack or have very low species diversity in the Gondwana sequences where glacial beds are common. This suggests that repeated fluctuations of glacial conditions (which gradually decreased in importance), marine transgressions and regressions, and faunal dispersal and restriction may be closely interrelated because of repeated changes in climatic conditions and in sea levels. Within the Asselian and Sakmarian intervals, climatic zonation is suggested by several of the faunal groups based on the amount of generic and specific diversity, in the association or nonassociation with abundant calcareous algae, based on shell growth patterns, and by the distribution of carbonate reefs and banks in contrast to sections having predominantly shallow-water sandstone. Some groups, such as many of the bryozoans and brachiopods, lived in a broader range of marine shelf and slope environments and their distributions were less strongly related to the distributions of shallow epicontinental flooding than were other groups, such as fusulinaceans and corals. Cephalopod distributions, and probably also conodont distributions, were a function of neritic habitats and relate to the direction and extent of different surface currents.

By Artinskian time many shallow benthic marine faunas showed marked provinciality, particularly between the Tethyan region and the Ural-Franklinian region. This is possibly best shown by the distribution and phylogenetic patterns in fusulinaceans and corals. Direct faunal connections for many groups seem to have been broken in Sakmarian or early in Artinskian time between the Uralian Sea and the Tethys, particularly for fusulinaceans, corals, bryozoans, and brachiopods. Cephalopods and some bryozoans retained some widely dispersed, nearly cosmopolitan, genera and families, but genera in many other groups were restricted in distribution to particular regions at this time. The main cause for the disruption of avenues for faunal dispersal appears to have been the last of the major orogenic episodes associated with the Hercynian orogeny. This appears to coincide with the uplift of the southern end of the Uralian geosyncline and southern part of the Russian platform. Uplifts within the Early Permian also modified many dispersal paths in parts of southern Asia and in North America.

New patterns of biogeography and phylogeny, and changes in sedimentary patterns began with these late phases of the Hercynian orogeny and were of major significance in forming a starting point for the clear identification of a Tethys ocean and a Tethyan faunal realm that reached from northern Africa, through the Alps, Yugoslavia, Greece, Turkey, Crimea, Iran, Iraq, Afghanistan, Pakistan, Kashmir, China, Japan, Indochina, New Zealand, Maritime Provinces of the Soviet Union, and parts of Alaska, Yukon, British Columbia, Washington, Oregon, and California—a much larger and more elongate realm than the Mesozoic Tethys. The fauna was diverse, abundant, and associated with algal and crinoid banks and reefs. The contrasting northern European and northern North American faunas were mainly composed of relict genera and decreased rapidly in diversity as depositional environments became poorly suited to a normal marine biota.

In Kazanian time the Tethyan fauna reached its greatest Permian diversity as shown by fusulinaceans, corals, bryozoans, and cephalopods, whereas the Zechstein and Uralian-Franklinian faunas had very low species diversity in the few groups that survived in those seas. Some elements of the Tethyan fauna spread into parts of the Tasman geosyncline in eastern Australia suggesting warmer seas. By the end of Kazanian time, an orogeny of major magnitude affected the Japanese, Chinese, and adjacent regions in the eastern Asian segments of the Tethys. Present evidence suggests that deposition ceased in many parts of the eastern Tethys after this orogeny.

Marine Dzhulfian fossils are known only in the Eurasian part of the Tethys, which more closely approximates the distribution of the Mesozoic Tethys. Dzhulfian faunas are of particular interest because they contain the remnants of a once prolific Tethyan fauna of Kazanian age and the phylogenetic ancestors for many of those Triassic faunas that evolved rapidly after the beginning of the Mesozoic. Paleozoic faunal groups, such as the fusulinaceans, became extinct at different times during the Late Permian and only a few Paleozoic lineages in groups such as the brachiopods and bryozoans survived into the earliest part of the Triassic. For these reasons the Late Permian and Early Triassic are generally regarded as times of acute ecological stress for shallow marine organisms.

The biogeographic and biostratigraphic relations within the Permian System have many unanswered questions. The lower boundary of the system is still in the process of being examined critically and in the Tethyan region a three-fold, rather than a two-fold, subdivision may be more applicable. Age relationships between Tethyan and non-Tethyan faunas are difficult to establish with precision after the middle part of the Early Permian because different lineages evolved independently in each faunal province. Reasons for these separate faunal provinces continue to be investigated and include studies on orogenic changes and climatic differences that probably contributed to provinciality. Climates during the Permian appear to have become gradually warmer as indicated by a decrease in glacial beds and in cyclical sedimentary deposition and by an increase in evaporite deposition from Asselian through Kazanian time. The magnitude of the latitudinal temperature gradients for the Permian and possible major temperature fluctuations at different times during the period are poorly known; however, the extinction of many genera and families of late Paleozoic marine organisms near the end of Kazanian or early in Dzhulfian time may have resulted from oceanographic changes that related to these climatic changes. Terrestrial plants and animals of the Permian also show geographical distributions that have been interpreted as reflecting latitudinal or temperature differences. The inferences are that latitudinal differences in temperature and floral and faunal distributions were broadly similar to those of the recent (Ross, 1974). Particular interest has centered on Gondwanan distributional questions (Romer, 1968; International Union of Geological Sciences, 1969; Keast & Glass, 1972; Ustritskiy, 1974) and on floral provinces (Tschudy & Scott, 1969; Plumstead, 1973; Hart, 1974).

The highest Permian (Dzhulfian) is the least well known part of the system and its upper boundary is the subject of much biostratigraphic study (Grunt & Dmitriev, 1973; Ishii, Fischer, & Bando, 1971; Ishii, Okimura, & Nakazawa, 1975; Kahler, 1974a, 1974b; Menner *et al.*, 1970; Meyen, 1970; Abich, 1878; Grant, 1970; Kummel & Teichert, 1970, 1973; Tozer, 1969, 1971; Nakazawa, 1974; Ruzhentsev & Sarycheva, 1965; Stepanov, Golshani, & Stöcklin, 1969). At present, distinctive faunas characterize the Dzhulfian Stage only in the Eurasian part of the Tethys. To suggest that deposition ceased everywhere else during this time interval seems implausible. Therefore, considerably more data are needed in order to document the faunal changes and extinctions that characterize the latest part of the Permian Period and the end of the Paleozoic Era.

## REFERENCES

**Abich, Hermann,** 1878, *Eine Bergkalkfauna aus der Araxesenge bei Djoulfa in Armenien:* Geol. Forschungen in den Kaukasischen Landern, v. 1, 128 p.

**American Commission on Stratigraphic Nomenclature,** 1961, *Code of stratigraphic nomenclature:* Am. Assoc. Petrol. Geologists, Bull., v. 45, p. 645-665.

**Arakelian, R. A., Rauzer-Chernousova, D. M., Reytlinger, E. A., Shcherbovich, S. F., & Efimova, N. A.,** 1964, *Znachenie Permskikh foraminifer Zakavkazya dlya korrelyatsii Permi v predelakh Tetisa:* Mezhdunarodnyy Geol. Kongress 22 Sessiya 1964, Doklady Sovetskikh Geologov, p. 63-75. [*The importance of Permian Foraminifera in the Transcaucasus for the correlation of the Permian within the Tethys.*]

**Armstrong, J. D., Dear, J. F., & Runnegar, Bruce,** 1967, *Permian ammonoids from Eastern Australia:* Geol. Soc. Australia, Jour. v. 14, p. 87-97.

**Banks, M. R., & Naqvi, I. H.,** 1967, *Formations close to the Permo-Triassic boundary in Tasmania:* Royal Soc. Tasmania, Papers & Proc., v. 101, p. 17-30.

**Beede, J. W., & Kniker, H. T.,** 1925, *Species of the genus Schwagerina and their stratigraphic significance:* Univ. Texas, Bull. 2433 (1924), 96 p.

**Behnken, F. H.,** 1975, *Leonardian and Guadalupian (Permian) conodont biostratigraphy in western and southwestern United States:* Jour. Paleontology, v. 49, p. 284-315.

**Bender, Hans, & Stoppel, Dieter,** 1965, *Perm-Conodonten:* Geol. Jahrb., v. 82, p. 331-364.

**Caster, K. E.,** 1952, *Stratigraphic and paleontologic data relevant to the problem of Afro-American ligation during the Paleozoic and Mesozoic:* in The problem of land connections across the South Atlantic, with special reference to the Mesozoic, E. Mayr (ed.), Am. Museum Nat. History, Bull., v. 99, art. 3, p. 105-152.

**Chao King-koo,** 1965, *The Permian ammonoid-bearing formations of South China:* Scientia Sinica, v. 14, p. 1813-1826.

**Chen Shu,** 1934, *Fusulinidae of South China, Part I:* China Geol. Survey, Palaeont. Sinica, ser. B, v. 4, no. 2, 185 p. (in English, Chinese summary).

——1956, *Fusulinidae of South China, Part II:* Acad. Sinica, Palaeont. Sinica, n.ser. B, no. 6, p. 17-72.

**Chernyshev [Tschernyschew], T. N.,** 1902, *Verkhnekamennougoliya brakhiopodi Urali i Timan:* Geol. Komiteta, Trudy, v. 16, part 1, 749 p. [*Upper Carboniferous brachiopods of the Urals and Timan.*]

**Clark, D. L., & Behnken, F. H.,** 1971, *Conodonts and biostratigraphy of the Permian:* in Symposium on conodont biostratigraphy, W. C. Sweet & S. M. Bergström (eds.), Geol. Soc. America, Mem. 127, p. 415-439.

———, & **Ethington, R. L.,** 1962, *Survey of Permian conodonts in western North America:* Brigham Young Univ. Geol. Studies, v. 9, p. 102-114.

**Cooper, G. A., & Grant, R. E.,** 1964, *New Permian stratigraphic units in the Glass Mountains, West Texas:* Am. Assoc. Petrol. Geologists, Bull., v. 48, p. 1581-1588.——1966, *Permian rock units, in the Glass Mountains, West Texas:* U.S. Geol. Survey, Bull., v. 1244-E, p. E1-E9.——1972, *Permian brachiopods of West Texas, I:* Smithson. Contrib. Paleobiology, no. 14, 231 p.——1973, *Dating and correlating the Permian of the Glass Mountains in Texas:* in The Permian and Triassic Systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 363-377.——1974, *Permian brachiopods of West Texas, II:* Smithson. Contrib. Paleobiology, no. 15, p. 233-793.——

1975, *Permian brachiopods of West Texas, III:* Smithson. Contrib. Paleobiology, no. 19, p. 795-1921.——1976, *Permian brachiopods of West Texas, IV:* Smithson. Contrib. Paleobiology, no. 21, p. 1923-2285.

**Crockford, Joan,** 1951, *The development of bryozoan faunas in the Upper Palaeozoic of Australia:* Linnean Soc. New South Wales, Proc., v. 76, p. 105-122.

**David, T. W. E., & Browne, W. R.,** 1950, *The geology of the Commonwealth of Australia:* v. I, xx + 747 p., Arnold (London).

**Dear, J. F.,** 1971, *Strophomenoid brachiopods from the higher Permian faunas of the Back Creek Group in the Bowen Basin:* Queensland Geol. Survey, Publ. 347, Paleont. Papers, no. 21, 39 p.

**Dickins, J. M.,** 1970, *Correlation and subdivision of the Permian of Western and Eastern Australia:* Australia Bur. Min. Res., Geology and Geophysics, Bull. 116, p. 17-27.

**Dietz, R. S., & Holden, J. C.,** 1970, *Reconstruction of Pangaea: Breakup and dispersion of continents, Permian to present:* Jour. Geophys. Res., v. 75, p. 4939-4956.

**Dunbar, C. O.,** 1940, *The type Permian: its classification and correlation:* Am. Assoc. Petrol. Geologists, Bull., v. 24, p. 237-281.——1955, *Permian brachiopod faunas of central East Greenland:* Meddel. Grønland, v. 110, no. 3, 169 p. ——1958, *On the validity of Schwagerina and Pseudoschwagerina:* Jour. Paleontology, v. 32, p. 1019-1021.——1961, *Permian invertebrate faunas of central east Greenland:* in Geology of the Arctic, G. O. Raasch (ed.), v. 1, p. 224-230, Univ. Toronto Press (Toronto, Can.).

———, **& Skinner, J. W.,** 1931, *New fusulinid genera from the Permian of West Texas:* Am. Jour. Sci., ser. 5, v. 22, p. 252-268.——1936, *Schwagerina versus Pseudoschwagerina and Paraschwagerina:* Jour. Paleontology, v. 10, p. 83-91. ——1937, *Permian Fusulinidae of Texas:* Univ. Texas, Bull., v. 3701, p. 517-825.

———, **chairman, & others** (Permian Subcommittee of Nat. Res. Council's Committee on Stratigraphy), 1960, *Correlation of the Permian formations of North America:* Geol. Soc. America, Bull., v. 71, p. 1763-1806.

———, **Troelsen, John, Ross, C. A., Ross, J. R. P., & Norford, B. S.,** 1962, *Faunas and correlation of the late Paleozoic rocks of northeast Greenland: pt. I, General discussion and summary:* Meddel. Grønland, v. 164, no. 4, 16 p.

**Ehrenberg, C. G.,** 1854, *Mikrogeologie. Das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbständigen Lebens auf der Erde:* 374 p., Voss (Leipzig).

**Flügel, Helmut,** 1968, *Korallen aus der oberen Nesen-Formation (Dzhulfa-Stufe, Perm) des zentralen Elburz (Iran):* Neues Jahrb. Geologie, Paläontologie, Abh., v. 130, p. 275-304.——1970, *Die Entwicklung der rugosen Korallen im hohen Perm:* Geol. Bundesanst. Aus., Verhandl., no. 1, p. 146-161.——1973, *Rugose Korallen aus dem oberen Perm Ost-Grönlands:* Geol. Bundesanst. Aus., Verhandl., no. 1, p. 1-57.

———, **& Schönlaub, H. P.,** 1972, *Geleitworte zur stratigraphischen Tabelle des Paläozoikums von Österreich:* Geol. Bundesanst. Verhandl., 1972, no. 2, p. 187-198.

**Frebold, Hans,** 1950, *Stratigraphie und Brachiopodenfauna des marinen Jungpalaeozoikums von Holms und Amdrups Land (Nordostgrönland):* Meddel. Grønland, v. 126, no. 3, p. 1-37.

**Frederiks, G. N.,** 1928, *Le Paléozoique supérieur de l'Oural:* Soc. Géol. Nord, Ann., v. 53, p. 138-171.——1932, *Verkhnii paleozoy zapadnogo i yuzhnogo sklona Urala:* Geol.-Razved. Upravl., Izvestiya, vyp. 106, p. 1-89. [*The Upper Paleozoic of the western and southern slopes of the Urals.*]

**Furnish, W. M.,** 1966, *Ammonoids of the Upper Permian Cyclolobus-Zone:* Neues Jahrb. Geologie, Paläontologie, Abh., v. 125, p. 265-296.——1973, *Permian stage names:* in The Permian and Triassic Systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 522-548.

———, **& Glenister, B. F.,** 1970, *Permian ammonoid Cyclolobus from the Salt Range, West Pakistan:* in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Univ. Kansas Dept. Geology, Special Publ. 4, p. 153-175.

———, ———, **Nakazawa, Keiji, & Kapoor, H. M.,** 1973, *Permian ammonoid Cyclolobus from the Zewan Formation, Guryul Ravine, Kashmir:* Science, v. 180, p. 188-190.

**Gemmellaro, G. G.,** 1887, *La fauna dei calcari con Fusulina della Valle del Fiume Sosio nella Provincia di Palermo:* Giornale Sci. Nat. & Econ. Palermo, v. 19, p. 1-106.——1888, *Appendice: La fauna dei calcari con Fusulina della Valle del Fiume Sosio nella Provincia di Palermo:* Giornale Sci. Nat. & Econ. Palermo, v. 20, p. 9-36.

**Girty, G. H.,** 1909, *The Guadalupian fauna:* U.S. Geol. Survey, Prof. Paper 58 (1908), 651 p.

**Glenister, B. F., & Furnish, W. M.,** 1961, *The Permian ammonoids of Australia:* Jour. Paleontology, v. 35, p. 673-736.

**Glushko, V. V., & Fedorov, D. L.,** 1974, *Do pitannya pro korelyatsiyu Permskikh tovshch na okrainakh Russkoi platformi:* Geol. Zhurnal, v. 34, p. 3-13. [*Some thoughts about correlation of Permian beds occurring at the margins of the Russian platform.*]

**Gobbett, D. J.,** 1963, *Carboniferous and Permian brachiopods of Svalbard:* Norsk Polarinst., Skrifter 127, 201 p.——1967, *Palaeozoogeography of the Verbeekinidae (Permian Foraminifera):* in Aspects of Tethyan biogeography, G. E.

Adams & D. V. Ager (eds.), Systematics Assoc. Publ., no. 7, p. 77-91.

**Goryunova, R. V.,** 1975, *Permskie mshanki Pamira:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 148, 127 p. [*Permian Bryozoa of Pamir.*]

**Grabau, A. W.,** 1931, *The Permian of Mongolia:* Natural History of Central Asia, v. 4, 665 p., 35 pl., Am. Museum Nat. History (New York).

**Grant, R. E.,** 1970, *Brachiopods from Permian-Triassic boundary beds and age of Chhidru Formation, West Pakistan:* in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Univ. Kansas Dept. Geology, Special Publ. 4, p. 117-151.

**Grunt, T. A., & Dmitriev, B. Ju.,** 1973, *Permskie Brakhiopodi Pamira:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 136, 211 p. [*Permian Brachiopoda of Pamir.*]

**Harker, Peter, & Thorsteinsson, Raymond,** 1960, *Permian rocks and fauna of Grinnell Peninsula, Arctic Archipelago:* Canada Geol. Survey, Mem., no. 309, 98 p.

**Hart, G. F.,** 1974, *Permian palynofloras and their bearing on continental drift:* in Paleogeographic provinces and provinciality, C. A. Ross (ed.), Soc. Econ. Paleontologists & Mineralogists, Spec. Publ., no. 21, p. 148-164.

**Hayden, H. H.,** 1907, *The stratigraphical position of the Gangamopteris beds of Kashmir:* India Geol. Survey, Records, v. 36, no. 1, p. 23-39.

**Hill, Dorothy,** 1948, *The distribution and sequence of Carboniferous coral faunas:* Geol. Mag., v. 85, p. 121-148.——1957, *The sequence and distribution of Upper Paleozoic coral faunas:* Australian Jour. Sci., v. 19, p. 42-60.——1958, *Sakmarian geography:* Geol. Rundschau, v. 47, p. 590-629.

**International Union of Geological Sciences,** 1969, *Gondwana stratigraphy:* Internatl. Union Geol. Sciences Symposium, 1st, Mar del Plata, 1967, UNESCO, Earth Sciences ser., v. 2, 1,173 p. (Paris).

**Ishii, Ken-ichi, Fischer, Jochen, & Bando, Yuji,** 1971, *Notes on the Permian-Triassic boundary in Eastern Afghanistan:* Jour. Geosciences, Osaka City Univ., v. 14, art. 1, p. 1-18.

**———, Okimura, Yuji, & Nakazawa, Keiji,** 1975, *On the genus Colaniella and its biostratigraphic significance:* Jour. Geosciences, Osaka City Univ., v. 19, art. 6, p. 107-138.

**Kahler, Franz,** 1974a, *Iranische Fusuliniden:* Geol. Bundesanst. Wien, Jahrb., v. 117, p. 75-107.——1974b, *Fusuliniden aus T'ienschan und Tibet:* Repts. Scientific Expedition to North-western Provinces of China under leadership of Dr. Sven Hedin, Sino-Swedish Expedition, Publ. 52, V, Invertebrate palaeontology 4, p. 1-147 (Stockholm).

**Karpinskiy, A. P.,** 1889, *Ueber die Ammoneen der Artinsk-Stufe und einige mit denselben verwandte carbonische Formen:* Acad. Impér. Sci. St. Pétersbourg, Mém., 7$^{e}$ sér., v. 37, no. 2, p. 1-104.——1890, *Ob ammoneyakh artinskogo yarusa i o nekotorykh skhodnynkh s nimi kamennougolnykh formakh:* Zapiski Mineral. Obshch., ser. 2, ch. 27. [*On ammonites of the Artinskian Series and on certain similarities with Carboniferous forms.*] [Not seen by author.]

**Keast, Allen, Erk, F. C., & Glass, Bentley (eds.),** 1972, *Evolution, mammals and southern continents:* 543 p., State Univ. New York Press (Albany).

**King, P. B.,** 1931, *The geology of the Glass Mountains, Texas; Part I:* Univ. Texas, Bull., no. 3038(1930), 167 p.——1938, *Geology of the Marathon region, Texas:* U.S. Geol. Survey, Prof. Paper 187(1937), ix + 148 p.——1949, *Geology of the southern Guadalupe Mountains, Texas:* U.S. Geol. Survey, Prof. Paper 215(1948), 183 p.

**King, R. E.,** 1931, *The geology of the Glass Mountains, Texas; Part II:* Univ. Texas, Bull., no. 3042(1930), 245 p.

**Kozur, Heinz,** 1973, *Beiträge zur Stratigraphie von Perm und Trias:* Geologie, Palaeontologie Mitt. Innsbruck, v. 3, p. 1-31.——1975, *Beiträge zur Condontenfauna des Perm:* Geologie, Palaeontologie Mitt. Innsbruck, v. 5, p. 1-44.

**Kulikov, M. V., Pavlov, A. M., & Rostevtsev, V. N.,** 1973, *O nakhodke goniatitov v nizhne-Kazanskikh otlozheniy severnoy chasti Russkoy platformy:* Akad. Nauk SSSR, Doklady, v. 211, p. 1412-1414. [*On a find of goniatites in the lower Kazanian in the northern part of the Russian platform.*] (Eng. transl., Doklady, Earth Sciences Sec., v. 211, p. 112-114.)

**Kummel, Bernhard,** 1972, *The Lower Triassic (Scythian) ammonoid Otoceras:* Harvard Univ., Museum Comp. Zoology, Bull., v. 143, p. 365-417.

**———, & Teichert, Curt,** 1966, *Relations between the Permian and Triassic formations in the Salt Range and Trans-Indus Ranges, West Pakistan:* Neues Jahrb. Geologie, Paläontologie, Abh., v. 125, p. 297-333.——1970, *Stratigraphy and paleontology of the Permian-Triassic boundary beds, Salt Range and Trans-Indus Ranges, West Pakistan:* in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Univ. Kansas Dept. Geology, Special Publ., v. 4, p. 1-110.——1973, *The Permian-Triassic boundary beds in central Tethys:* in The Permian and Triassic Systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 17-34.

**Lapkin, I. Yu., & Solovev, V. O.,** 1969, *Permskie tektonisheskie dvizheniya v Evrazii:* Akad. Nauk SSSR, Doklady, v. 184, p. 410-413. [*Permian diastrophism in Eurasia.*]

**Lapparent, A. A. de,** 1902, *Traité de géologie:* 3rd edit., v. 2, F. Savy (Paris). (v. 1 and 2, 1645 p.)

**Leven, E. Ya.**, 1967, *Stratigrafiya i fuzulinidy Permskikh otlozheniy Pamira:* Akad. Nauk SSSR, Geol. Inst., Trudy, v. 167, p. 1-224. [*Stratigraphy and fusulinids of the Permian deposits of Pamir.*]——1975, *Yarusnaya schkala Permskikh otlozhenii Tetisa:* Moskov. Obshch. Ispyt. Prirody, Byull., Otdel. Geol., v. 50, p. 5-21. [*Permian stages of the Tethys.*]

**Likharev, B. K.**, 1966, *Stratigrafiya SSSR. Permskaya Sistema:* Akad. Nauk SSSR, Ministerstvo Geol. SSSR, 536 p. (Moscow). [*Stratigraphy of the USSR. Permian System.*]

———, & **Miklukho-Maklay, A. D.**, 1972, *Stratigraphy of the Permian System:* Internatl. Geol. Congress India 1964, Rept. 22nd Sess., pt. 8., Palaeontology & Stratigraphy, p. 205-222.

**Lipina, O. A.**, 1949, *Melkie foraminifery pogrebennykh massivov Baschkirii:* Akad. Nauk SSSR, Geol. Inst., Trudy, v. 105 (geol. ser. 35), p. 198-243. [*Small foraminifers from subsurface of the Bashkirian massif.*]

**Loo Lin-huang**, 1958, *Chiek chiang hang chow chi shia shyr tann yan chung de jii geh tair shean chorng:* Ku Sheng Wu Hsüeh Pao (Acta Palaeont. Sinica), v. 6, p. 293-304. [*Some bryozoans from the Chihsia Limestone of Hangchow, western Chekiang.*] (In Chinese and English.)

**Lyem [Liêm], N. V.**, 1971, *Novyye pozdnepermskiye vidy Neoendothyra (Endothyrida) iz Svernogo Vyetnama:* Paleont. Zhurnal, 1971, no. 3, p. 110-111. [*New Late Permian species of Neoendothyra (Endothyrida) from North Vietnam.*] (Engl. Transl., Paleont. Jour., 1971, no. 3, p. 382, 383.)——1974, *Rod Palaeofusulina i yego novyye vidy iz Vyetnama:* Paleont. Zhurnal, 1974, no. 4, p. 11-17. [*The genus Paleofusulina and its new species from Vietnam.*] (Engl. transl., Paleont. Jour., 1974, no. 4, p. 447-454.)

**McKee, E. D., et al.**, 1967, *Paleotectonic investigation of the Permian System in the United States:* U.S. Geol. Survey, Prof. Paper 515, 271 p.

**Menner, V. V., Sarycheva, T. G., & Chernyak, G. E. (eds.)**, 1970, *Stratigrafiya Kamennougolnykh i Permskikh otlozeniy severnogo Verkhoyanya:* Nauchno-Issledov. Inst. Geol. Arktiki, Trudy, v. 154, p. 1-190. [*Stratigraphy of Carboniferous and Permian deposits of northern Verkhoyansk.*]

**Meyen, S. V.**, 1970, *Permskie flory:* in Paleozoyskie i Mezozoyskie flory Yevrazii i fitogeografiya etogo vremeni, V. A. Vakhrameyev and others, Akad. Nauk SSSR, Geol. Inst., Trudy, v. 208, p. 111-157. [*Permian floras: in Paleozoic and Mesozoic floras of Eurasia and the phytogeography of those eras.*]

**Middlemiss, C. S.**, 1910, *A revision of the Silurian-Trias sequence in Kashmir:* Geol. Survey India, Records, v. 40, p. 206-260.

**Mikhaylova, Z. P.**, 1974, *Fuzulinidy verkhnego Karbona Pechorskogo Priuralya:* Akad. Nauk SSSR, Komi filial Inst. Geol., 116 p., Izd. Nauka, (Leningrad). [*Fusulinids of the Upper Carboniferous of the Pechoran Urals.*]

**Miklukho-Maklay, A. D.**, 1963, *Verkhniy Paleozoy sredney Azii:* 329 p., Leningrad. Gosudar. Univ. (Leningrad). [*Upper Paleozoic of Central Asia.*]

**Miller, A. K., & Furnish, W. M.**, 1940a, *Permian ammonoids of the Guadalupe Mountain region and adjacent areas:* Geol. Soc. America, Spec. Paper, v. 26, 242 p.——1940b, *Cyclolobus from the Permian of eastern Greenland:* Meddel. Grønland, v. 112, no. 5, 7 p.

**Minato, Masao, & Kato, Makoto**, 1965a, *Waagenophyllidae:* Hokkaido Univ., Jour. Fac. Sci., ser. 4, v. 12, 241 p.——1965b, *Durhaminidae (tetracorals):* Hokkaido Univ., Jour. Fac. Sci., ser. 4, v. 13, p. 11-86.——1970, *The distribution of Waagenophyllidae and Durhaminidae in the Upper Paleozoic:* Japan. Jour. Geology & Geography, v. 41, p. 1-14.

**Moeller, V. von**, 1877, *Ueber Fusulinen und ähnliche Foraminiferen-Formen des russischen Kohlenkalks:* Neues Jahrb. Mineralogie, Geologie, Paläontologie, Jahrg. 1877, p. 139-146.

**Monger, J. W. H., & Ross, C. A.**, 1971, *Distribution of fusulinaceans in the Western Canadian Cordillera:* Canad. Jour. Earth Sciences, v. 8, p. 259-278.

**Moore, R. C., & Dudley, P. M.**, 1944, *Cheilotrypid bryozoans from Pennsylvanian and Permian rocks of the midcontinent region:* Kansas State Geol. Survey, Bull., v. 52, p. 229-408.

———, & **Jeffords, Russell**, 1941, *New Permian corals from Kansas, Oklahoma and Texas:* Kansas State Geol. Survey, Bull., v. 38, pt. 3, p. 65-120.

**Morozova, I. P.**, 1970, *Mshanki pozdney Permi:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 122, 347 p. [*Bryozoa of the Late Permian.*]

**Morozova, V. G.**, 1949, *Predstaviteli semeistv Lituolidae e Textulariidae iz Verkhnekamennougolnykh i Artinskikh otlozhenii Baschkirskogo Priuralya:* Akad. Nauk SSSR, Geol. Inst., Trudy, v. 105 (geol. ser. 35), p. 244-275. [*Representatives of the families Lituolidae and Textulariidae from the Upper Carboniferous and Artinskian deposits of the Bashkirian Ural region.*]

**Murchison, R. I.**, 1841, *First sketch of some of the principal results of a second geological survey of Russia, in a letter to M. Fischer:* Philos. Mag., v. 19, p. 419-422.

———, **Verneuil, Édouard de, & Keyserling, Alexander Graf von**, 1845, *The geology of Russia in Europe and the Ural Mountains:* v. 1, Geology, Chapter 8, Permian System, p. 137-170, J. Murray (London).

**Nakazawa, Keiji**, 1974, *On the Permian-Triassic boundary problem:* Chigaku Zasshi Jour. Geography (Tokyo), v. 38, p. 1-24.

———, **Ishii, Ken-ichi, Kato, Makoto, Okimura, Yuji, Nakamura, Koji, & Haralambous, Diomedes**, 1975, *Upper Permian fossils from the Island of*

*Salamis, Greece:* Kyoto Univ., Mem. Fac. Sci., ser. geol. & mineral., v. 41, p. 21-44.

———, **Kapoor, H. M., Ishii, Ken-ichi, Bando, Yuji, Okimura, Yuji, & Tokuoka, Takao,** 1975, *The Upper Permian and the Lower Triassic in Kashmir, India:* Kyoto Univ., Mem. Fac. Sci., ser. geol. & mineral., v. 42, p. 1-106.

**Nalivkin, D. V.,** 1973, *Geology of the U.S.S.R.:* transl. from the Russian by N. Rast, 827 p., Univ. Toronto Press (Toronto).

**Nanking Institute of Geology & Paleontology (ed.),** 1974, *Hsi nan ti chü ti tseng ku sheng wu shoŭ ts'e:* 454 p., Ke Hsüeh ch'u Pān she (Nanking). [*A handbook of the stratigraphy and paleontology in southwest China.*] (In Chinese.)

**Newell, N. D., Rigby, J. K., Fischer, A. G., Whiteman, A. J., Hickox, J. E., & Bradley, J. S.,** 1953, *The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico:* 236 p., W. H. Freeman and Co. (San Francisco).

**Nikiforova, A. I.,** 1939, *Novyye vidy verkhnepaleozoyskikh mshanki predgornor polosy Bashkirii (krome sem. Fenestellidae i Acanthocladiidae):* Neft. Geol.-Razv. Inst., Trudy, ser. A, v. 115, p. 70-101. [*New species of Upper Paleozoic bryozoans from the foothills belt of Bashkiria (except the families Fenestellidae and Acanthocladiidae).*]

**Nikitina, A. P.,** 1969, *Rod Hemigordiopsis (Foraminifera) v verkhney Permi Primorya:* Paleont. Zhurnal, 1969, no. 3, p. 63-69. [*Genus Hemigordiopsis (Foraminifera) in the Upper Permian of the Maritime Province.*] (Engl. transl., Paleont. Jour., 1969, no. 3, p. 341-346.)

———, **Kiseleva, A. V., & Burago, V. I.,** 1970, *Skhema biostratigraficheskogo raschleneyiya barabashskoy svity verkhney Permi Yugo-Zapadnogo Primorya:* Akad. Nauk SSSR, Doklady, v. 191, p. 187-189. [*Scheme for biostratigraphic subdivision of the Upper Permian Barabash Suite in the southwest Maritime Province.*]

**Okimura, Yuji, Ishii, Ken-ichi, & Nakazawa, Keiji,** 1975, *Abadehella, a new genus of tetraxid Foraminifera from the Late Permian:* Kyoto Univ., Mem. Fac. Sci., ser. geol. & mineral. v. 41, p. 35-48.

**Pantic, Smiljka,** 1970, *Lithostratigraphy and micropaleontology of the Middle and Upper Permian of Western Serbia:* Zavod Geol. Geof. Istraz., (Geol.), ser. A, Bull., no. 27 (1969), p. 239-272.

**Plumstead, E. P.,** 1973, *The late Paleozoic Glossopteris flora:* in Atlas of palaeobiogeography, Anthony Hallam (ed.), p. 187-205, Elsevier (Amsterdam).

**Rauzer-Chernousova, D. M.,** 1937, *O fuzulinidakh i stratigrafii verkhnego Karbona i Artinskogo yarusa zapadnogo sklona Urala (reyume doklada):* Moskov, Obshch. Ispyt. Prirody, Byull., n. ser., otdel. geol., v. 45, p. 478-480. [*On the fusulinids and stratigraphy of the Upper Carboniferous and Artinskian stage on the western slopes of the Urals.*]——1940, *Stratigrafiya verkhnego Karbona i Artinskogo yarusa zapadnogo sklona Urala i materialy k faune fuzulinid:* Akad. Nauk SSSR, Geol. Inst., Trudy, geol. ser., no. 2, v. 7, p. 37-99. [*Stratigraphy of the Upper Carboniferous and Artinskian Stage on the western slopes of the Urals and materials on the fusulinid fauna.*]——1949, *Stratigrafiya verkhnekamennougolnykh i Artinskikh otlozheniy Bashkirskogo Priuralya:* Akad. Nauk SSSR, Inst. Geol. Nauk, Trudy, v. 105, geol. ser. 35, p. 3-21. [*Stratigraphy of Upper Carboniferous and Artinskian deposits of Bashkirian Ural region.*]——1965, *Foraminifery stratotipicheskogo razreza Sakmarskogo yarusa (r. Sakmara, Yuzhnyy Ural):* Akad. Nauk SSSR, Inst. Geol. Nauk, Trudy, v. 135, p. 1-80. [*Foraminifera in the stratotype section of the Sakmarian Stage (Sakmara district, southern Urals).*]

———, **Shcherbovich, S. F., Rozoskaya, S. E., & Schamov, D. F.,** 1958, *Shvagerinobyy gorizont Russkoy Platformy i podstilayushchie ego otlozheniya:* Akad. Nauk SSSR, Inst. Geol. Nauk, Trudy, v. 13, p. 1-154. [*Schwagerinid horizons of the Russian platform and their underlying deposits.*]

**Romer, A. S.,** 1968, *Fossils and Gondwanaland:* Am. Philos. Soc., Proc., v. 112, p. 335-343.

**Ross, C. A.,** 1959, *The Wolfcamp series (Permian) and new species of fusulinids, Glass Mountains, Texas:* Washington Acad. Sci., Jour., v. 49, p. 299-316.——1960, *Fusulinids from the Hess member of the Leonard formation, Leonard series (Permian), Glass Mountains, Texas:* Cushman Found. Foram. Res., Contrib., v. 11, p. 117-133. ——1962a, *Fusulinids from the Leonard Formation (Permian), western Glass Mountains, Texas:* Cushman Found. Foram. Res., Contrib., v. 13, p. 1-21.——1962b, *Evolution and dispersal of the Permian fusulinid genera Pseudoschwagerina and Paraschwagerina:* Evolution, v. 10, p. 306-315.——1963a, *Standard Wolfcampian Series (Permian), Glass Mountains, Texas:* Geol. Soc. America, Mem., v. 88, p. 1-205.——1963b, *Early Permian fusulinids from Macusani, southern Peru:* Palaeontology, v. 5, p. 817-823.——1967, *Development of fusulinid (Foraminiferida) faunal realms:* Jour. Paleontology, v. 41, p. 1341-1354.——1970, *Concepts in Late Paleozoic correlations:* in Radiometric dating and paleontologic zonation, O. L. Bandy (ed.), Geol. Soc. America, Spec. Publ., v. 124, p. 7-36.——1972, *Paleoecology of fusulinaceans:* 23rd Internatl. Geol. Congress, 1968 Proc., I.P.U., p. 301-318.——1973, *Pennsylvanian and Early Permian depositional history, southeastern Arizona:* Am. Assoc. Petrol. Geologists, v. 57, p. 887-912.——1974, *Paleogeography and provinciality:* in Paleogeographic provinces and provinciality, C. A. Ross (ed.), Soc. Econ. Paleontologists & Mineralogists, Spec. Publ., no. 21, p.

1-17.——1976 (ed.), *Paleobiogeography:* 427 p., Dowden, Hutchinson, & Ross (Stroudsburg, Pa.). ——1978, *Evolution of fusulinaceans in Late Paleozoic space and time:* in Historical biogeography, plate tectonics and the changing environment, A. J. Boucot, & J. Gray (eds.), 37th Biology Colloquium, Oregon State University (in press).

———, & **Nassichuk, W. W.,** 1970, *Yabeina and Waagenoceras from Atlin Horst area, northern British Columbia:* Jour. Paleontology, v. 44, p. 779-781.

———, & **Ross, J. P.,** 1962, *Pennsylvanian, Permian rugose corals, Glass Mountains, Texas:* Jour. Paleontology, v. 36, p. 1163-1188.

**Ross, J. R. P.,** 1963, *Lower Permian Bryozoa from Western Australia:* Palaeontology, v. 6, p. 70-82. ——1978, *Permian ectoprocts in space and time:* in Historical biogeography, plate tectonics and the changing environment, A. J. Boucot, & J. Gray (eds.), 37th Biology Colloquium, Oregon State University (in press).

———, & **Ross, C. A.,** 1962, *Faunas and correlation of the late Paleozoic rocks of northeast Greenland, Part IV, Bryozoa:* Meddel. Grønland, v. 167, no. 7, 65 p.——1963, *Late Paleozoic rugose corals, Glass Mountains, Texas:* Jour. Paleontology, v. 37, p. 409-420.

**Rowett, C. L.,** 1972, *Paleogeography of Early Permian waagenophyllid and durhaminid corals:* Pacific Geology, v. 4, p. 31-37.——1975a, *Provinciality of late Paleozoic invertebrates of North and South America and a modified intercontinental reconstruction:* Pacific Geology, v. 10, p. 79-94.——1975b, *Stratigraphic distribution of Permian corals in Alaska:* U.S. Geol. Survey, Prof. Paper 823-D, p. 59-75.

**Rozovskaya, S. E.,** 1975, *Sostav, sistema i filogeniya otryada Fusulinida:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 149, p. 1-267. [*Composition, systematics and phylogeny of the order Fusulinida.*]

**Rudwick, M. J. S.,** 1970, *Living and fossil brachiopods:* 199 p., Hutchinson University Library (London).

**Runnegar, B. N.,** 1969, *The Permian faunal succession in Eastern Australia:* Jour. Geol. Soc. Australia, Spec. Publ., no. 2, p. 73-98.

———, & **Armstrong, J.,** 1969, *Comments on series and stages in the Permian of New Zealand:* Royal Soc. New Zealand, Trans., geol., v. 6, p. 209-212.

**Ruzhentsev [Ruzhencev], V. E.,** 1936, *Novye dannye po stratigrafii Kamennougolnykh i nizhnepermskikh otlozheniy Orenburgskoy i Aktyubinskoy oblastey:* Problemy Sovetskoy Geologii, v. 6, no. 6, p. 470-506. [*New data on the stratigraphy of the Carboniferous and Lower Permian of the Orenburg and Aktyubinsk Districts.*]——1951, *Nizhnepermskie ammonity yuzhnogo Urala—I: Ammonity sakmarskogo yarusa:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 33, 188 p. [*Lower Permian ammonoids of the southern Urals—I: Ammonoids of the Sakmarian Stage.*] ——1952, *Biostratigraphiya Sakmarskogo yarusa v Aktyubinskoi Oblasti Kazakhskoi SSR:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 42, 87 p. [*Biostratigraphy of the Sakmarian Stage in the Aktyubinsk region of Kazakhstan SSR.*]——1955, *Osnovnye stratigraficheskie kompleksy Ammonoidei Permskoi sistemy:* Akad. Nauk SSSR, Izvestiya, biol. ser., no. 4, p. 12-132. [*Fundamental stratigraphic assemblages of Ammonoidea of the Permian System.*]——1956, *Nizhnepermskie ammonity yuzhnogo Urala—II: Ammonity Artinskogo Yarusa:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 60, 275 p. [*Lower Permian ammonites of the southern Urals—II: Ammonites of the Artinskian Stage.*]——1962, *Nadotryad Ammonoidea:* in Yu. A. Orlov (ed.), Osnovy Paleontologii, v. 5: Mollyuski—Golovonogie, 1, p. 243-438, Nedra Press (Moskva). [*Superorder Ammonoidea, Mollusca—Cephalopoda.*] ——1966, *Osnovnyye kompleksy ammonoidey Kamennougolnogo perioda:* Paleont. Zhurnal, 1965, no. 2, p. 3-17. [*Principal ammonoid assemblages of Carboniferous Period.*]——1974, *O semeystvakh Paragastrioceratidae i Spirolegoceratidae:* Paleont. Zhurnal, 1974, no. 1, p. 19-29. [*On the families Paragastrioceratidae and Spirolegoceratidae.*] (Engl. transl. Paleont. Jour., v. 8, no. 1, p. 14-24.)

———, & **Sarycheva, T. G. (eds.),** 1965, *Razvitie i smena morskikh organismov na rubezhe Paleozoya i Mezozoya:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 108, 431 p. [*The development and change of marine organisms at the Paleozoic-Mesozoic boundary.*]

**Sakagami, Sumio,** 1970, *On the Paleozoic Bryozoa of Japan and Thai-Malayan districts:* Jour. Paleontology, v. 44, p. 680-692.

**Shcherbovich, S. F.,** 1969, *Fusulinidy pozdnegshelskogo i Asselskogo Vremeni Prikaspiyaskoy sineklizy:* Akad. Nauk SSSR, Geol. Inst., Trudy, v. 176, p. 1-82. [*Fusulinids of the late Gzhelian and Asselian Stages of the Caspian syneclise.*]

**Shchukina, V. Y.,** 1973, *Kompleksy Kamennougolnykh i Permskikh korallov Sredney Azii:* Sovetskaia Geologiia, no. 3, 1973, p. 53-68. [*Carboniferous and Permian coral complexes of Central Asia.*]

**Sheng Jin-chiang,** 1963, *Permian fusulinids of Kwangsi, Kueichow and Szechuan:* Palaeont. Sinica, n. ser. B, no. 10, p. 129-247.——1965, *Hai nan tao si pu de ting ley:* Ku Sheng Wu Hsüeh Pao (Acta Palaeont. Sinica), v. 13, no. 4, p. 563-590. [*Fusulinids from the western part of Hainan Island, Kwangtung Province.*] (In Chinese with English summary.)

———, & **Lee, H. H.,** 1964, *Carboniferous-Permian boundary in China:* Congrès Internatl. Strat. Géol. Carbonifère, 5$^{e}$, Paris, 1963, Compte

Rendu 2, p. 775-779.

**Shulga Nesterenko, M. I.,** 1952, *Novyye nizhnepermskie Mshanki Priuralya:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 37, 84 p. [*New Lower Permian Bryozoa of the Ural region.*]

**Skinner, J. W., & Wilde, G. L.,** 1965, *Permian biostratigraphy and fusulinid faunas of the Shasta Lake area, northern California:* Univ. Kansas Paleont. Contrib., Protozoa, Art. 6, p. 1-98.

**Slade, M. L.,** 1961, *Pennsylvanian and Permian fusulinids of the Ferguson Mountain area, Elko County, Nevada:* Brigham Young Univ. Geol. Studies, v. 8, p. 55-92.

**Smith, A. G., Briden, J. C., & Drewry, G. E.,** 1973, *Phanerozoic world maps:* in Organisms and continents through space and time, N. F. Hughes (ed.), Palaeont. Assoc., Spec. Paper no. 12, p. 1-42 (London).

**Sokolov, B. S.,** 1955, *Tabulyaty paleozoya Evropeiskoe chasti SSSR. Obshchie voprosy sistematiki i istorii razvitiya Tabulyat:* Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst., (VNIGRI), Trudy, n. ser., v. 85, 525 p., 90 pl. [*The Paleozoic Tabulata of European USSR. General problems in the systematics and developmental history of Tabulata.*]

**Soshkina, E. D., Dobrolyubova, T. A., Porfirev, G. S.,** 1941, *Permskie Rugosa Evropeiskoi chastii SSSR:* Paleontologiya SSSR, v. 5, Ch. 3, no. 1, 304 p., Akad. Nauk SSSR (Moskva). [*Permian Rugosa of the European part of the USSR.*]

**Sosnina, M. I.,** 1965, *Nekotorye Permskie fuzulinidy i lagenidy Sikhotz-Alinya:* Vses. Nauchno-Issled. Geol. Inst., n. ser., v. 115, p. 142-168. [*Some Permian fusulinids and lagenids from Sikhote-Alin.*]

**Spinosa, Claude, Furnish, W. M., & Glenister, B. F.,** 1970, *Araxoceratidae, Upper Permian ammonoids from the Western Hemisphere:* Jour. Paleontology, v. 44, p. 730-736.——1975, *The Xenodiscidae, Permian ceratitoid ammonoids:* Jour. Paleontology, v. 49, p. 239-283.

**Stepanov, D. L.,** 1937, *Permskie brakhiopody Shpitsbergena:* Arkt. i Antarkt. Nauchno-Issledov. Inst., Trudy, v. 76, p. 105-192. [*Permian Brachiopoda of Spitsbergen.*]——1957, *O novom yarus Permskoy sistemy Artinski:* Leningrad Gosud. Univ., Vestnik, v. 24, ser. geol. geogr., v. 4, p. 20-24. [*On a new stage of the Permian System Artinskian.*]——1970, *The problems of the stratigraphy of the Permian system and the correlation of the main sections of the marine Permian:* Internatl. Geol. Congr. India, 1964, pt. 8, Palaeontology & Stratigraphy, p. 189-204.

———, **Golshani, F., & Stöcklin, Jovan,** 1969, *Upper Permian and Permian-Triassic boundary in North Iran:* Geol. Survey Iran, Rept. 12, 72 p.

**Stevens, C. H.,** 1975a, *Occurrence and dispersal of boreal massive Rugosa in the Early Permian:* Pacific Geology, v. 10, p. 33-42.——1975b, *New Permian Waagenophyllidae (rugose corals) from North Africa:* Jour. Paleontology, v. 49, p. 706-709.

**Sweet, W. C.,** 1970, *Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan:* in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Univ. Kansas, Dept. Geology, Spec. Publ. no. 4, p. 207-271.

**Syemina, S. A.,** 1961, *Stratigrafiya i Foraminifery (fuzulinidy) shvagerinogo gorizonta Oksko-Tsninskogo podnyatiya:* Akad. Nauk SSSR, Geol. Inst., Trudy, v. 57, p. 1-70. [*Stratigraphy and Foraminifera (fusulinids) of the schwagerinid horizon of the Oksko-Tsninskian Arch.*]

**Taraz, Hushang,** 1969, *Permo-Triassic section in central Iran:* Am. Assoc. Petrol. Geologists, Bull., v. 53, p. 688-693.——1971, *Uppermost Permian and Permo-Triassic transition beds in central Iran:* Am. Assoc. Petrol. Geologists, Bull., v. 55, p. 1280-1295.——1973, *Correlation of uppermost Permian in Iran, Central Asia, and South China:* Am. Assoc. Petrol. Geologists, Bull., v. 57, p. 1117-1133.

**Teichert, Curt,** 1966, *Stratigraphic nomenclature and correlation of the Permian "Productus limestone," Salt Range, West Pakistan:* Geol. Survey Pakistan, Records, v. 15, pt. 1, p. 1-20.——1974, *Marine sedimentary environments and their faunas in Gondwana area:* Am. Assoc. Petrol. Geologists, Mem., v. 23, p. 361-394.

———, **& Kummel, Bernhard,** 1972, *Permian-Triassic boundary in the Kap Stosch area, East Greenland:* Canad. Petrol. Geologists, Bull., v. 20, p. 659-675.——1973, *Nautiloid cephalopods from the Julfa beds, Upper Permian, Northwest Iran:* Harvard Univ., Museum Comp. Zoology, Bull., v. 144, p. 409-433.

———, ———, **& Sweet, W. C.,** 1973, *Permian-Triassic strata, Kuh-e-Ali Bashi, northwestern Iran:* Harvard Univ., Museum Comp. Zoology, Bull., v. 145, no. 8, p. 359-472.

———, **& Rilett, Michael,** 1974, *Revision of Permian Ecca Series cephalopods, Natal, South Africa:* Univ. Kansas, Paleont. Contrib., Paper 68, 8 p.

**Thomas, G. A.,** 1971, *Carboniferous and Early Permian brachiopods from western and northern Australia:* Australia Bur. Min. Res., Geology and Geophysics, Bull. 56, p. 1-215.

**Thompson, M. L.,** 1954, *American Wolfcampian fusulinids:* Univ. Kansas Paleont. Contrib., Protozoa, Art. 5, p. 1-226.

**Thorsteinsson, Raymond,** 1974, *Carboniferous and Permian stratigraphy of Axel Heiberg Island and Western Ellesmere Island, Canadian Arctic Archipelago:* Canada Geol. Survey, Bull., v. 224, 115 p.

**Tillyard, R. J.,** 1917-36, *Upper Permian insects from N.S.W.:* Linnean Soc. New South Wales, Proc., v. 42, p. 720-756; v. 44, p. 231-256; v.

46, p. 413-422; v. 47, p. 279-282; v. 49, p. 429-435; v. 51, p. 1-30, 265-282; v. 60, p. 265-279, 374-391.

**Tolstikhina, M. M.,** 1935, *Kamennougolnye otlozheniya tsentralnoy chasti Ufimskogo plato i ikh fatsii:* Tsentralnyi Nauchno-Issledov. Geol.-Razved. Inst. (TsNIGRI), Trudy, no. 65, p. 1-36. [*Carboniferous deposits of the central part of the Ufa Plateau and their facies.*]

**Toriyama, Ryuzo,** 1958, *Geology of Akiyoshi. Part III, Fusulinids of Akiyoshi:* Kyushu Univ., Mem. Fac. Sci., ser. D, geol., v. 7, p. 1-264.——1963, *The Permian:* in F. Takai, T. Matsumoto, & R. Toriyama (eds.), Geology of Japan, p. 43-58, Univ. Tokyo Press (Hongo, Tokyo).——1967, *The fusulinacean zones of Japan:* Kyushu Univ., Mem. Fac. Sci., ser. D, geol., v. 18, p. 35-260. ——1973, *Upper Permian fusulinacean zones:* in The Permian and Triassic systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 498-512.——1975, *Fusuline fossils from Thailand, Part IX, Permian fusulines from the Rat Buri Limestone in the Khao Phlong Phrab area, Sara Buri, Central Thailand:* Kyushu Univ., Mem. Fac. Sci., ser. D, geol., v. 23, p. 1-116.

———, **Kanmera, K., Kaewbaidhoam, S., & Hongnusonthi, A.,** 1974, *Biostratigraphic zonation of the Rat Buri Limestone in the Khao Phlong area, Sara Buri, Central Thailand:* in Palaeontology of Southeast Asia, T. Kobayashi, & R. Toriyama (eds.), v. 14, p. 25-48, Univ. Tokyo Press (Tokyo).

**Tozer, E. T.,** 1969, *Xenodiscacean ammonoids and their bearing on the discrimination of the Permo-Triassic boundary:* Geol. Mag., v. 106, p. 348-361.——1971, *Triassic time and ammonoids: problems and proposals:* Canad. Jour. Earth Sci., v. 8, p. 989-1031.

**Trizna, V. B.,** 1950, *K Kharakteristike rifovykh i sloistykh fatsiy tsentralnoy chasti Ufimskogo Plato:* Vses. Nauchno-Issled. Geol.-Razved. Inst. (VNIGRI), v. 135, Microfauna SSSR, no. 3, p. 47-144. [*About characteristics of the reef and stratified facies of the central part of the Ufimian Plateau.*]

———, **& Klautsan, R. A.,** 1961, *Mshanki Artinskogo yarusa Ufimskogo Plato i ikh rol v stratigrafii etogo yarusa v Priuralye:* Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst.(VNIGRI), v. 179, Microfauna SSSR, no. 13, p. 331-453. [*Bryozoa of the Artinskian Stage of the Ufimian Plateau and their role in stratigraphy of that stage in the Ural region.*]

**Tschudy, R. H., & Scott, R. A. (eds.),** 1969, *Aspects of palynology:* 510 p., Wiley-Interscience Publishers (New York).

**Ucharskaya [Ukharskaya], L. B.,** 1970, *Novyye Kazanskie peschanye foraminifery Russkoy platformy:* Paleont. Zhurnal, 1970, no. 4, p. 21-28. [*New Kazanian arenaceous Foraminifera of the Russian platform.*] (Engl. transl., Paleont. Jour., 1970, no. 4, p. 468-476.)

**Ustritskiy, V. I.,** 1974, *O bipolyarnosti faun pozdnego Paleozoya:* Paleont. Zhurnal, 1974, no. 2, p. 33-37. [*On the bipolarity of late Paleozoic faunas.*] (Engl. transl., Paleont. Jour., 1974, v. 8, no. 2, p. 148-151.)

**Vasilyuk, N. P., Kachanov, Ye. I., & Pyzhyanov, I. V.,** 1970, *Paleobiogeograficheskiy ocherk Kamennougolnykh i Permskikh tselenterat:* in Zakonomernosti rasprostraneniya paleozoyskikh korallov SSSR, D. L. Kaljo (ed.), Vses. Simpos. Izuch. Iskop. Korallov SSSR, 2nd, Trudy, no. 3, p. 45-60. [*Paleobiogeographic sketch of Carboniferous and Permian coelenterates.*]

**Vissarionova, A. Ya., Kireeva, G. D., Lipina, O. A., Morozova, V. G., Rauzer-Chernousova, D. M., Suleymanov., I. S., Shamov, D. F., & Shcherbovich, S. F.,** 1949, *Foraminifery verkhnekamennougolnykh i Artinskikh otlozheniy Bashkirskogo Priuralya:* Akad. Nauk SSSR, Inst. Geol. Nauk, Trudy, v. 105 (geol. ser. no. 35), p. 1-275. [*Foraminifera from Upper Carboniferous and Artinskian deposits of Bashkirian Ural region.*]

**Vlasov, N. G., Likharev, B. K., & Miklukho-Maklay, A. D.,** 1962, *K faunisticheskoy kharakteristike razreza nizhnepermskikh otlozheniy yugo-zapadnogo Darvaza:* Akad. Nauk SSSR, Doklady, v. 144, p. 1105-1108. [*About faunal characters of the Lower Permian deposits of southwest Darvas.*]

**Waagen, William,** 1889-91, *Salt Range fossils. IV. Geological results:* Geol. Survey India, Mem., Palaeont. Indica, ser. 13, v. 4, pt. 1, p. 1-88 (1889); v. 4, pt. 2, p. 89-242 (1891).

**Wass, R. E.,** 1969, *Australian Permian Polyzoan faunas: distribution and implications:* in Stratigraphy and palaeontology: Essays in honour of Dorothy Hill, K. W. S. Campbell (ed.), p. 236-245, National University Press (Canberra, Australia).

**Waterhouse, B. J.,** 1969, *World correlations of New Zealand Permian Stages:* New Zealand Jour. Geol. Geophys., v. 12, p. 713-737.——1972a, Review of "Stratigraphic boundary problems: Permian and Triassic of West Pakistan": Jour. Paleontology, v. 46, p. 158-160.——1972b, *The evolution, correlation, and paleogeographic significance of the Permian ammonoid family Cyclolobidae:* Lethaia, v. 5, p. 251-270.

———, **& Bonham-Carter, G. F.,** 1975, *Global distribution and character of Permian biomes based on brachiopod assemblages:* Canad. Jour. Earth Sci., v. 12, p. 1085-1146.

**Williams, Alwyn, & others,** 1965, in R. C. Moore (ed.), Treatise on invertebrate paleontology, Part H, Brachiopoda, 2 v., 927 p., Univ. Kansas Press & Geol. Soc. America (Lawrence, Kansas; New York).

**Yanshin, A. L.,** 1965, *Tectonic structure of Eurasia:* Geotektonika, no. 5, p. 7-35 (transl. by D. A. Brown, Australian National Univ.).

# TRIASSIC[1]

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## CONTENTS

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[1] Manuscript received July, 1976.

# INTRODUCTION

The term Trias, later modified in English to Triassic, was proposed in 1834 by F. von Alberti for a sequence of strata in central Germany lying above Permian (Zechstein) and below Jurassic (Lias) rocks of marine origin. The name refers to a threefold division of the strata into a lower unit of nonmarine red beds (Buntsandstein or Bunter), a middle unit of marine limestone, sandstone, and shale (Muschelkalk), and an upper unit of nonmarine rocks (Keuper) that are similar to the lower division. The original definition of the Trias by von Alberti reads as follows (translation from Wilmarth, 1925, p. 64): "Whoever examines more closely the foregoing analysis and tabulates all the fossils of the three hitherto separate formations; whoever examines, further, the transition of the different forms one into the other, and, indeed, considers the entire structure of the mountains and the decidedly different character of the fossils of the Zechstein (Permian) from those of the Lias (Lower Jurassic), will realize that the Bunter sandstone, Muschelkalk and Keuper are the result of one period, their fossils, to use E. de Beaumont's words, being the thermometer of a geological period; that their separation into three formations is not appropriate, and that it is more in accord with the concept of a 'formation' to unite them into a single formation, which I shall provisionally name *Trias*."

This type of strata described by von Alberti is typical of Triassic strata of northern Europe, France, Spain, and north Africa; it is commonly known as the Germanic facies. In contrast to the predominantly continental Germanic facies, there is in the Alps a complete fossiliferous sequence covering all of Triassic time that is commonly called the Alpine facies and that, with the addition of units in the lower beds from southern Asia, forms the primary standard sequence of stages and zones.

This contribution is concerned solely with marine facies and invertebrates of the Triassic. A recent review of Triassic tetrapods was given by Cox (1973).

# STAGES AND ZONES OF THE TRIASSIC

The first comprehensive proposal for subdivision of the Triassic into series, stages, and zones was by von Mojsisovics, Waagen, and Diener (1895). The sequence for what is now the Middle and Upper Triassic was based on Alpine faunas and formations, that for the Lower Triassic on Salt Range and Himalayan data. This proposal was not free of serious errors due largely to what is now recognized as misinterpretation of structural relations and nonrecognition of some condensed faunas; however, since 1895 there have been continuing efforts to clarify the stage and zonal scheme. In recent years thick deposits of fossiliferous Triassic strata which are uncomplicated by difficult structural relations have been recognized in British Columbia and Nevada. These areas have yielded equivalents of most of the faunas first discovered in India and Siberia. These sequences have been summarized by Tozer (1967) and Silberling and Tozer (1968) and it is now well established that for Triassic studies, the western American sequences are equal in importance to the Alpine-Mediterranean sequence. The Alpine and western American zonal sequences and stages are shown in Figure 1.

Most stages of the Triassic have been fairly well stabilized for the past several decades. There are, of course, constant refinements as gaps in sequences are recognized and correlations more firmly established. The best review of the general status of Triassic stages and zones has been presented by Tozer (1974).

The Middle and Upper Triassic stage names have been universally accepted; this is not so for the Lower Triassic. Until a couple of decades ago, Scythian was used by many as the Lower Triassic stage name. The term was originally used by von Mojsisovics, Waagen, and Diener (1895) as a series. The first attempt to divide the Lower Triassic into more than one stage was by Kiparisova and Popov (1956) who suggested two stages (Induan and Olenekian) for this "series." This idea was elaborated on in contributions published by the same authors (Kiparisova & Popov, 1961, 1964a,b). Tozer (1965), on the basis of fine fossiliferous sequences in arctic Canada, proposed a four-stage nomenclature for the Lower Triassic (Griesbachian, Dienerian, Smithian and Spathian). Vavilov and Lozovskiy (1970) maintained the two-fold division of Kiparisova and Popov but in addition divided the Olenekian into two substages. Recently Zakharov (1973, 1974) has proposed a three-fold division (Induan, Ussurian, Russian).

It is not possible in the scope of this paper to discuss in detail the respective merits of these various schemes of classification; however, I believe the four-fold division proposed by Tozer to have the most merit, and for this paper and in the revisions of the Triassic ammonites for the *Treatise* I have chosen to consider Griesbachian, Dienerian, Smithian, and Spathian as substages of the Scythian stage.

## STRATIGRAPHY AND PALEOGEOGRAPHY

"The distribution of the continents and seas in Eotriassic times, as Diener has shown, was probably not unlike that of the present day, except for the extended Thetis" (Spath, 1930, p. 87). The Diener paper referred to by Spath was his well-known work *"Die marinen Reiche der Triasperiode"* (Diener, 1915). The statement is essentially correct though written long before the advent of plate tectonics. One needs to keep in mind that in the circum-Atlantic area marine Triassic is known only from Svalbard, east coast of Greenland (in a northward opening embayment), and near the tip of the Antarctic Peninsula. In all the intervening region none has been recorded. At the same time it is intriguing to keep in mind the presence of presumed Middle Triassic conodonts in Upper Cretaceous rock from the Cameroons of western Africa. The distribution of land, sea, and volcanic area for the Upper Triassic is shown in Figure 2, plotted on a modern-day map. A number of paleogeographic maps for the Triassic based on plate tectonics and paleomagnetism have been published. The most recent and probably the best of these is by Briden, Drewry, and Smith (1974).

The paleogeography of the Triassic, disregarding the state of the Atlantic region, is basically a boreal sea impinging on North America, with an embayment along the east coast of Greenland, on Svalbard and on the northeastern Soviet Union from the Taymyr Peninsula to the sea of Okhotsk. Geosynclinal conditions prevailed along much of the western part of North and South America. Similar conditions were to be found along the eastern Pacific margin in Japan, New Guinea, New Caledonia, and New Zealand. Australia had very restricted marginal marine encroachments during the Early Triassic. Marine Triassic has now been reported from the Antarctic Peninsula and has been known for some time in northern Madagascar. Finally there is the great Tethys. From eastern Spain to Indonesia there are now known many dozens of well-documented areas of marine Triassic strata, many containing rich and diverse faunas. The northern boundary of Tethys lay north of the Alps, through the southern part of the USSR eastward to southern China. The southern boundary lay across northern Africa and the northern portion of the Indian shield. Much of northwestern Europe was occupied by marine seas in Middle Triassic time. A comprehensive review of the biostratigraphy of the Permian and Triassic including 35 charts, one of which is a world map of deposits of this age, has been prepared by Anderson and Anderson (1970) and Anderson (1973).

In the following section each of the main paleogeographic regions will be discussed in terms of the thickness and facies represented, with some general comments on the completeness of the faunal record. Due to limitations of space I have chosen to discuss in slightly more detail areas where stratigraphic and paleontologic data have only

| Faunal Zones in the Alpine Region (after Zapfe, 1974, with supplements) | | | | Ammonoid Zones in North America (after Tozer, 1971) | |
|---|---|---|---|---|---|
| RHAETIAN | Choristoceras marshi | Austrirynchia cornigera<br>Rhaetavicula contorta | | Choristoceras marshi | RHAETIAN |
| NORIAN | Rhabdoceras suessi | Cladiscites tornatus<br>Cochloceras<br>Cycloceltites | | Rhabdoceras suessi | UPPER NORIAN |
| | | "Halorites horizon" | | Himavatites columbianus | MIDDLE NORIAN |
| | | Cyrtopleurites bicrenatus | Didymites<br>Drepanites | Drepanites rutherfordi | |
| | | Juvavites magnus | | Juvavites magnus | |
| | | Malayites paulckei | | Malayites dawsoni | LOWER NORIAN |
| | | Mojsisovicsites kerri | | Mojsisovicsites kerri | |
| CARNIAN | | Anatropites spinosus | | Klamathites macrolobatus | UPPER CARNIAN |
| | | Tropites subbullatus | | Tropites welleri | |
| | | Tropites dilleri | | Tropites dilleri | |
| | Trachyceras austriacum | Trachyceras<br>Sirenites<br>Joannites<br>Coroceras<br>Carnites | | Sirenites nanseni | LOWER CARNIAN |
| | Trachyceras aon | Trachyceras<br>Protrachyceras<br>Lobites<br>Joannites | | Trachyceras obesum | |

Fig. 1. Sequence of zones and stages for Alpine area and western America (adapted from Zapfe, 1974).

recently been acquired. This has necessitated treating some areas that have been studied for long periods of time and where facies relations are extremely complex, for example, the Alpine area and western United States, in short general summary statements. The Alpine area is, of course, the birthplace of marine Triassic stratigraphy, but I feel justice could not be done in the space allowed.

## NORTHWESTERN EUROPE

Lower and Upper Triassic strata of northwestern Europe are essentially nonmarine, mostly red, and with evaporites. The Middle Triassic (Muschelkalk) is marine. The facies are limestone and dolomite, some sandy, and sandstone units and some evaporite. These deposits were laid down in an inland sea with some connections to the Tethys in the south. Recent drilling programs in the North Sea show the Triassic there to be essentially nonmarine detrital facies with evaporites (Brennand, 1975; P. A. Ziegler, 1975; W. H. Ziegler, 1975).

The Muschelkalk fauna, as is usual with

| Faunal Zones in the Alpine Region (after Zapfe, 1974, with supplements) | | | | Ammonoid Zones in North America (after Tozer, 1971) | |
|---|---|---|---|---|---|
| LADINIAN | Protrachyceras archelaus | | Protrachyceras<br>Arpadites<br>Joannites | Frankites sutherlandi<br>Maclearnoceras maclearni<br>Meginoceras meginae | UPPER LADINIAN |
| | "Protrachyceras" reitzi | | "Protrachyceras"<br>Anolcites<br>Hungarites | Progonoceratites poseidon<br>Protrachyceras subasperum | LOWER LADINIAN |
| ANISIAN | Aplococeras avisianum | | Aplococeras<br>Hungarites<br>Kellnerites<br>"Ceratites" ex gr. subnodosi | Gymnotoceras occidentalis<br>Gymnotoceras meeki | UPPER ANISIAN |
| | Paraceratites trinodosus | | Paraceratites<br>Bulogites<br>Seminorites<br>Ptychites<br>Flexoptychites<br>Beyrichites | Gymnotoceras rotelliforme | |
| | Paraceratites binodosus | | Acrochordiceras<br>Balatonites<br>Ptychites<br>Norites<br>Beyrichites | Balatonites shoshonensis<br>Acrochordiceras hyatti | MIDDLE ANISIAN |
| | | | Dadocrinus gracilis<br>beginning of Physoporella pauciforata | Lenotropites carus | LOWER ANISIAN |
| SCYTHIAN | Eumorphotis inaequicostatus | E. telleri | no ammonites<br>Tirolites cassianus<br>Tirolites carniolicus | Neopopanoceras haugi<br>Subcolumbites beds<br>Columbites & Tirolites beds | SPATHIAN |
| | | | | Wasatchites tardus<br>Euflemingites romunderi | SMITHIAN |
| | Claraia aurita | | Eumorphotis venetiana<br>Claraia clarai | Vavilovites sverdrupi<br>Proptychites candidus | DIENERIAN |
| | | | | Proptychites strigatus<br>Ophiceras commune | UPPER GRIESBACHIAN |
| | | | | Otoceras boreale<br>Otoceras concavum | LOWER GRIESBACHIAN |

FIG. 1. *(Continued from facing page.)*

inland seas, is characterized by numerous individuals but few species. The faunas consist mainly of ammonites *(Ceratites)*, crinoids, bivalves, and brachiopods.

## NORTH MEDITERRANEAN REGION

Triassic studies of the marine facies be-

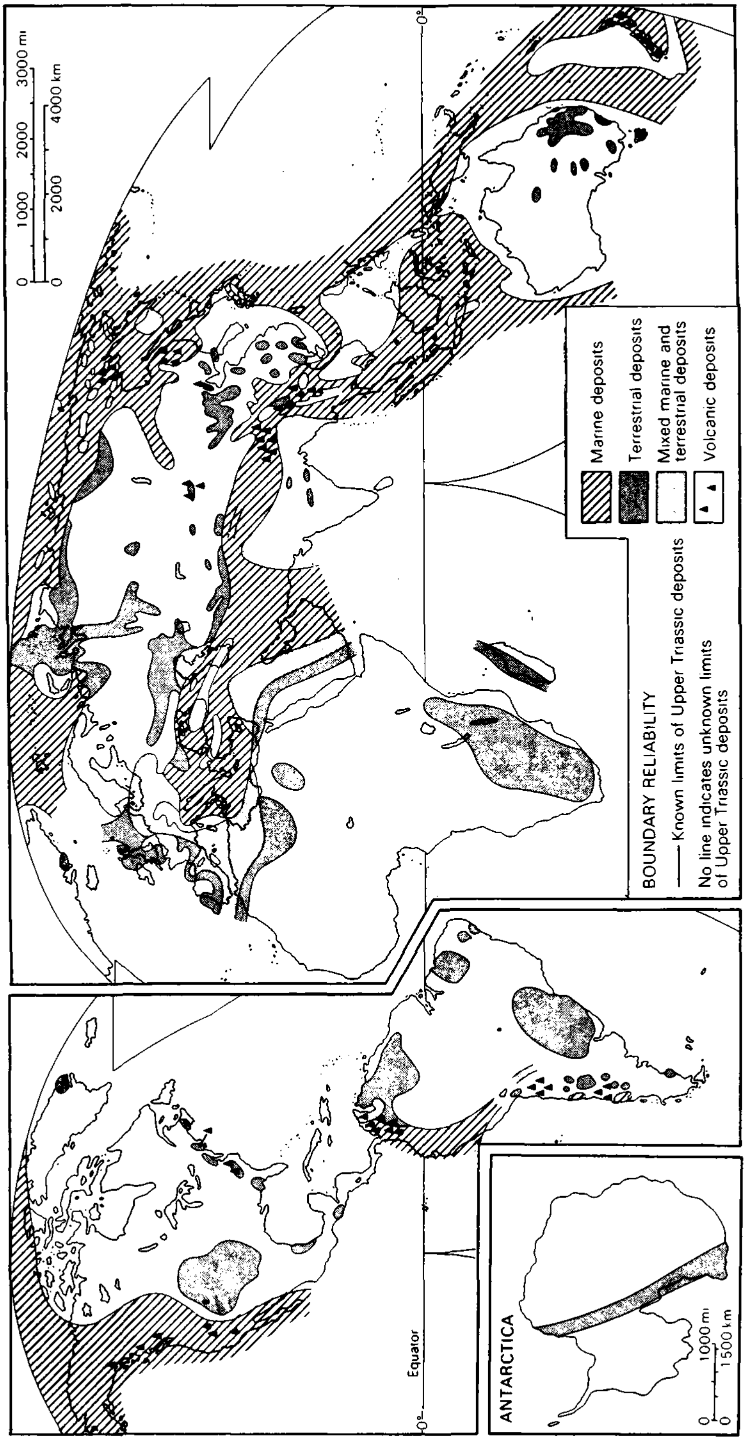

FIG. 2. Distribution of land, sea, and volcanic deposits for the Late Triassic. ("Triassic Period," Encyclopaedia Britannica, published with permission. Modified figure.)

gan in the Alpine region and the area has continued to be a focal point for such studies. The extremely interesting early phase of research on the Triassic of this region was ably summarized by von Zittel (1901). The most recent updating on Triassic studies in the Alpine-North Mediterranean region was presented in a symposium held in Vienna, May, 1973, edited by H. Zapfe (1974).

The vast variety of facies and the extremely complex tectonic history of the region have made interpretations of sequence and correlation often very difficult. Even so, the biostratigraphic framework worked up from studies of faunal sequences in the region continues to be of premier importance, although now the sequences of western and arctic North America are becoming equally important.

Paleogeographic interpretations for the Triassic of the Alpine-North Mediterranean region are extremely difficult because of present structural relations and complexity of facies. It is not possible in limited space to do justice to this important region, thus the following remarks are in the nature of a brief summary.

The Lower Triassic of the Alpine-North Mediterranean region is represented by the Werfen Formation. This unit is highly variable in lithology, including marly limestone, oolitic limestone, evaporite, siltstone, shale, and sandstone. The lower part of the Werfen contains the common lower Scythian bivalve *Claraia*. The upper part contains the well-known *Tirolites* fauna monographed by Kittl (1903) and revised by Kummel (1969). The Werfen ammonoid fauna consists of only 11 genera, six of these being endemic to the Alpine-Mediterranean region. This fauna is considered to be of late Scythian age. A very instructive review of the Werfen Formation of the southern Alps has recently been published by Assereto *et al.* (1973).

The Anisian, Ladinian, and Carnian were times of great paleogeographic differentiation as reflected in the great diversity of facies. The dominant facies are carbonates, both limestone and dolomite, with extensive reef development. In addition, there are detrital formations, clay shale to conglomerate, evaporite, and volcanics. Many of these units are very fossiliferous.

The remainder of the Triassic is represented primarily by thick dolomite and limestone formations, forming reef complexes in many places. Most of these units are generally sparsely fossiliferous; however, in the Hallstatt facies, consisting of red mottled marble, cephalopods are quite abundant.

## ISRAEL

Excellent summaries of the Triassic of Israel have been contributed by Druckman (1974) and Picard and Flexer (1974). The Triassic in southern Israel consists of nearly 1,000 m of sedimentary rocks, which are partly exposed in Makhtesh Ramon, Har 'Arif, 'Araif e-Naga, Zarqa Ma'in, Wadi Hisban, and Nahr e-Zerqa and partly or entirely penetrated by a number of deep wells.

The sequence consists of five formations (from bottom to top) as follows: The Zafir Formation of Scythian age, consisting of alternating shale, fossiliferous limestone and sandstone; the Ra'af Formation of late Scythian-early Anisian age, consisting mainly of fossiliferous limestone; the Gevanim Formation of Anisian age, consisting of sandstone, siltstone and shale with minor amounts of limestone; the Saharonim Formation of late Anisian-Carnian age, consisting of fossiliferous limestone, dolomite and sparse gypsum and anhydrite layers; the Mohilla Formation of Carnian-Norian age, consisting of anhydrite and dolomite.

This Triassic sequence was deposited in various environments of deposition including near-shore and shallow-marine environments, very shallow lagoons, and shoaling tidal flats.

The source area for the detrital influx during the deposition of the Zafir and Gevanim formations was situated in the southeast and was, probably, part of the Arabo-Nubian massif. The sea was situated to the northwest, the direction from which it transgressed during the deposition of the Ra'af and Saharonim formations.

The Triassic ended with a period of regional uplift, subaereal exposure, slight erosion, and development of lateritic soils.

## IRAN

Considerable progress has been made in the past decade or so in the study of the Triassic of Iran. The data have been very well summarized by SEYED-EMAMI (1971). Triassic strata outcrop in north Iran, in the Julfa region and the Alborz Mountains, in central Iran, in the Zagros Mountains, the Nakhlak region of north-central Iran, and at Agh-Darband in extreme northeast Iran.

The famous Permian-Triassic strata of the Julfa region and adjoining Azerbaijan region of the Soviet Union have received considerable attention in recent years because of the conformable sequence of uppermost Permian and lowest Triassic rocks. The stratigraphy and paleontology of these strata cropping out north of the Aras River (in Azerbaijan) have been dealt with by RUZHENTSEV and SARYCHEVA (1965) and more recently by ROSTOVTSEV and AZARYAN (1973). South of the Aras River at Kuh-e-Ali Bashi equally comprehensive studies have been published by STEPANOV, GOLSHANI, and STÖCKLIN (1969), TEICHERT, KUMMEL, and SWEET (1973), and KUMMEL and TEICHERT (1973). RUZHENTSEV and SARYCHEVA (1965) and STEPANOV, GOLSHANI, and STÖCKLIN (1969) came to the conclusion that the so-called "transitional beds" with *Paratirolites, Shevyrevites, Dzhulfites,* and *Iranites* were Early Triassic in age. In contrast, TEICHERT, KUMMEL, and SWEET (1973), KUMMEL (1973), and ROSTOVTSEV and AZARYAN (1973) presented convincing arguments for the late Permian age of these beds.

Above the "transitional beds" at Kuh-e-Ali Bashi are limestone and dolomite units, the Elikah Formation, which are also well developed in the Alborz Mountains, and contain *Claraia* in the lower part. Recently ROSTOVTSEV and AZARYAN (1973) reported finding *Ophiceras* and *Gyronites* ammonites from correlative strata in Soviet Dzhulfa that clearly establish an Early Triassic (Scythian) age. The middle and upper parts of the Elikah Formation in Iran are much less fossiliferous and the record to date is ambiguous; however, evidence indicates that the formation extends into the Norian. The upper surface of the Elikah Formation is a widespread disconformity, and SEYED-EMAMI (1971) concluded that the absence of Upper Triassic rocks in most parts of north Iran is due to widespread pre-Liassic erosion rather than to nondeposition.

A sequence of Permian-Triassic formations very similar to that at Julfa occurs in the Abadeh region of central Iran northeast of the main Zagros thrust zone, between Esfahan and Shiraz. The geology and stratigraphy of the Abadeh region have been thoroughly treated by TARAZ (1969, 1971a, 1971b, 1972, 1973, 1974).

In the eastern part of central Iran the Lower Triassic consists of reddish calcareous and argillaceous shales containing thin intercalations of limestone and dolomite. This unit is known as the Sorkh Shale Formation and is overlain by well-bedded, light-colored dolomite of the Shotori Formation. These two formations may reach a thickness of 1,000 m and are overlain disconformably by the Upper Triassic Nayband Formation; they are considered, from their stratigraphic position, to be Lower to Middle Triassic and to correspond probably to the Elikah Formation in north Iran. The Nayband Formation consists of dark shale, sandstone, and fossiliferous limestone intercalations, with a total thickness of 2,800 m. The contact of the upper Nayband Formation with the overlying Shemshak Formation (Rhaetic?-Liassic) is gradational. Paleontological analysis of the Nayband Formation is as yet incomplete, but it appears to include much of the upper Ladinian to Rhaetian (SEYED-EMAMI, 1975).

In the Zagros Mountains of south and southwest Iran, the Triassic consists of evenly bedded, grayish dolomite having a thickness of up to 400 m, known as the Khaneh Kat Formation. Paleontological data are incomplete, but parts of the Lower, Middle, and perhaps Upper Triassic are represented.

One of the newer Triassic discoveries in Iran is in the Nakhlak region of north-central Iran, which has yielded abundant ammonoids in contrast to most of the other regions previously discussed. This Triassic sequence, named the Nakhlak Group, attains a thickness of 2,500 m and is divided into three formations (DAVOUDZADEH & SEYED-EMAMI, 1972). The lower unit (Alem Formation) consists of, from bottom to top, thin- to well-bedded sandy limestone, red and violet shales containing ammonoids, gray-green tuffaceous limestone, gray nodular limestone, and olive shale with big ceratites. Ammonoid studies by TOZER (1972) indicated that this unit is late Scythian-Anisian in age. The overlying Baqorog Formation consists of sandstone and coarse-grained conglomerate. Presence of the conglomerate is interpreted as evidence of diastrophic movements in the Ladinian. This unit has not yielded fossils, but on the basis of stratigraphic position is thought to be early and middle Ladinian in age. The uppermost unit of the Nakhlak Group (Ashin Formation) consists of dark sandstone and shale with a few intercalations of sandy limestones. Only a few fossils have been found to date but these indicate a late Ladinian age (TOZER, 1972).

From the northeastern corner of Iran, in the area of Agh-Darband (east of Mashad), another Triassic sequence is known, which has not been studied in detail, but lithologically resembles the Nakhlak Group. It has yielded Anisian and Carnian ammonoids.

## CASPIAN REGION

In the Caspian depression are found as much as 2,500 m of Triassic strata. The Lower Triassic consists of red and varicolored clays, siltstone, sandstone, and conglomerate with interbedded, thin, fossiliferous marine limestone. The Middle Triassic is essentially the same. The Upper Triassic (600-800 m) consists of red and gray clay with interbeds of sandstone, pebble beds, and coal. All of the Upper Triassic is of continental origin.

Much of the Permian and Triassic of the Caspian depression is known only from the subsurface; however, there are a few areas of outcrop, and one of these is at Mt. Bogdo where the first Lower Triassic ammonite, *Ammonites bogdoanus* VON BUCH (1831), was described.

In the Mangyshlak Peninsula, along the east side of the Caspian, are very thick sequences of fossiliferous Lower Triassic strata. Several horizons contain ammonites, all of late Scythian age (SHEVYREV, 1968). The lower part of the sequence has unfossiliferous red beds, but the beds above are fossiliferous non-red shale, sandstone, and limestone. The faunas of the thin marine intercalations of the Caspian depression are the same as those of Mangyshlak.

## AFGHANISTAN

In recent years a number of stratigraphical and paleontological studies of Triassic strata, all within approximately 100 km of Kabul, have been published. A useful summary of the Triassic of Afghanistan has been published by KAEVER (1969).

At Kotal-e-Tera, near the village of Altimur, 90 km southeast of Kabul, KUMMEL and ERBEN (1968) and KUMMEL (1968) described a relatively thin sequence of ammonitiferous limestone. The lowermost of these faunas represents the middle Scythian (Smithian), above this is another horizon of ammonoids representing the late Scythian (Spathian). The uppermost part of the sequence at Kotal-e-Tera has yielded only a few specimens of ammonoids, but these are clearly of Anisian age. From the Azras Valley, Paktia Province, just east of Kotal-e-Tera, COLLIGNON (1973) described a fine suite of Triassic ammonoids containing middle Scythian faunas as at Kotal-e-Tera, as well as one fauna of Anisian age and one of Ladinian age.

FISCHER (1971) published a detailed description of the Kohe Safi region, just east of Kabul, from where HAYDEN (1911) described the Kingil Series. This unit, essentially all carbonates, is 1,420 m thick and ranges in age from Artinskian through Oxfordian. The Triassic portion is 487 m thick. The lower 44 m of the Triassic rocks contain ammonites of two distinct zones. The lowest of these faunas is of early Scythian (Dienerian) age, described by ISHII, FISCHER, and BANDO (1971). Above this occurs the middle Scythian (Smithian) fauna as at Kotal-e-Tera. The upper part of this Triassic sequence is essentially unfossiliferous except for the upper 28 m, which contains *Megalodon* of latest Triassic age.

Approximately 100 km northwest of Kabul in the Khenjan region of the western Hindu Kush are 150 m of detrital strata containing a rich bivalve fauna of Ladinian age, recently described by Farsan (1972, 1975).

Along the northern flank of the western Hindu Kush is a detrital and volcanic sequence named the Doab Series by Hayden (1911). This unit rests unconformably on fusulinid limestone of Permian age and is overlain unconformably by the Jurassic Saighan Series. The upper part of the Doab Series consists of assorted volcanic deposits with a few interbeds of marl and sandstone. Fossil plants of Rhaetic age are known from the uppermost part of the series. The lower Doab Series, however, consists only of sedimentary units containing Middle Triassic ammonoids (Furon & Rosset, 1951).

## PAKISTAN

One of the most famous regions of outcropping Triassic formations is in the Salt Range of Pakistan. These formations have played a particularly important role in the development of our Triassic zonal scheme, especially for the Scythian stage. In addition, interest in these formations is heightened because they conformably overlie upper Permian formations, and because of this they have attracted the attention of nearly every student of the causes of abrupt faunal breaks at the Permian-Triassic boundary.

The early studies of the Triassic of the Salt Range by Wynne (1878) and Waagen (1895) concluded that the sequence encompassed all of the Lower Triassic and even part of the Middle Triassic. It was not until much later that it was realized that the sequence and faunas as known by Waagen (1895) included only the lower half of the Scythian.

More recently new stratigraphic studies incorporating new paleontological data have been reported by Kummel (1966b, 1970) and Kummel and Teichert (1970b). It is now clear that Waagen's work was largely confined to the central part of the Salt Range where he recognized, from bottom to top, the following units: the Lower Ceratite Limestone, the Ceratite Marl, the Ceratite Sandstone, and the Upper Ceratite Limestone. West of the central part of the Salt Range, that is, west of Nammal Gorge, the "Lower Ceratite Limestone" is present but the remainder of the Triassic section is shale with some sandstone facies. The section as a whole thickens westward.

A modern nomenclature for some of the Permian and Triassic formations has been introduced by Kummel and Teichert (1966). As mentioned above, the Salt Range Triassic sequence as known to Waagen encompasses only the lower half of the Scythian. Interestingly enough the lowest unit of the sequence, a dolomite unit (the Kathwai Member) was not recognized by Waagen. Schindewolf (1934) described *Ophiceras connectens* from the lowest part of the Kathwai. Kummel and Teichert (1970a) have published a detailed account of the stratigraphy and paleontology of the uppermost Permian and the lowest Triassic beds (the Kathwai Member).

Kummel (1966b) recognized a shale and sandstone unit (Narmia Member) above the Upper Ceratite Limestone from which he described a small fauna of ammonoids of late Scythian age; thus, it now appears that the Salt Range sequence includes essentially all of the Scythian. Above the Narmia Member are shale and sandstone units (Tredian Formation) that unfortunately are unfossiliferous.

Thick sequences of mainly fine-detrital rocks are in the Quetta and Hindubagh region of west central Pakistan. Unfortunately, these strata are not very fossiliferous. According to published reports only six specimens of ammonoids have been recorded, few of which were found in place (Diener, 1906; Kummel, 1966a). In addition to the ammonoids these strata contain a species of *Monotis,* all indicating a Late Triassic age.

In recent years, Dr. A. N. Fatmi of the Pakistan Geological Survey has collected a middle Scythian ammonoid fauna from the Quetta region (personal communication). This fauna has as yet not been described and documented.

## HIMALAYAS

Triassic formations crop out in a broad belt extending from Kashmir through Spiti, Garhwal, and Kumaon, into Nepal and adjoining regions of Tibet. The best summaries of data on these formations are by

DIENER (1912), PASCOE (1959), and GANSSER (1964). The facies are marine, dark shale and limestone with no igneous rocks, except in Kashmir. The limestone is of dark or gray color, well bedded, and in some horizons either concretionary or dolomitic. In the majority of sections there is a remarkable contrast between the light-gray dolomitic limestone units of the upper portion of the Triassic section and the dark-colored shale and limestone of the lower portion. This normal development of the Triassic in the Himalayas is also characterized by the regular distribution of each single horizon over a comparatively large area, and by the absence of facies of red limestone and marble. In the Kiogar area at the border between Kumaon and Tibet exotic blocks occur at Malla Johar where the Triassic is developed in a facies considerably different from that in the main region of the Himalayas. In this region the Triassic is much thinner, and most of the Triassic horizons are developed in a facies of red limestone and marble showing a remarkable resemblance to the Hallstatt limestone of the eastern Alps. This assemblage is known as the Tibetan facies and that discussed above, as the Himalayan facies (VON KRAFFT, 1902).

The two best known sections of the Triassic of Himalayan facies are at Spiti and Painkhanda. A third section at Byans, to the southeast of Painkhanda and near the Nepal border, is also important but less well known.

The Scythian beds of Spiti and Painkhanda are of approximately equal thickness (12.5 m) and lithology (gray limestone and shale). At Byans the Scythian is 47 m thick and consists of the Chocolate Limestone. The Anisian of Spiti and Painkhanda is also of similar facies and thickness (31 m). In Byans the Anisian is of a purer limestone facies.

Ladinian strata are thick (93 m) and richly fossiliferous at Spiti, but at Painkhanda they are very thin and poorly fossiliferous. They have not been traced further east. The same marked decrease in thickness to the southeast is seen in the Carnian strata. At Spiti the Carnian is 480 m, at Painkhanda 248 m thick, and in Byans very thin. In Spiti the Carnian is quite shaly and very fossiliferous. The shaly beds are replaced by limestone to the southeast.

The lower and middle Norian is approximately 310 m thick throughout this region and consists of shale, limestone, and sandstone, generally quite fossiliferous. In Byans on the other hand, the lower and middle Norian consists mainly of black shale. The upper Norian throughout the region consists of massive limestone that contains *Megalodon* in the lower parts, passing upward into limestone of middle Jurassic age. The paleontological data on these Triassic units of the central Himalayas have been compiled by DIENER (1895, 1897, 1906, 1907, 1908, 1909) and VON KRAFFT and DIENER (1909).

The Triassic strata of Tibetan facies as represented at Malla Johar and the other regions are quite different from the corresponding deposits in the Himalayan region. The strata are known entirely from exotic blocks of which there are two distinct types. One is represented by massive gray, dolomitic limestone resembling upper Norian rocks of the Himalayan facies; however, the latter is well bedded, not massive. This rock type is also unfossiliferous. The other type of exotic blocks is red limestone and marble resembling the Hallstatt facies of the Alpine region. The faunas of the Scythian and Anisian have strong affinities to corresponding strata of the Himalayan facies. The Carnian faunas, on the other hand, have strong affinities to the Triassic Mediterranean faunas.

To the northwest of this central Himalayan region, in Kashmir, the Triassic is also well developed and not too unlike that discussed above, except for the intercalations of the Panjal Traps, which range in age from Permian to Late Triassic. The Lower Triassic appears to be conformable with the underlying Permian and consists of dark-colored shale and limestone. A detailed study of the upper Permian and lower Triassic strata has recently been published by NAKAZAWA *et al.* (1975). The Anisian and Ladinian are characterized by gray shale, nodular, concretionary and platy limestone and some sandy limestone. The

Upper Triassic strata become progressively more calcareous and the Norian consists of massive dolomite and limestone, practically barren of fossils.

Recent extensive studies in Nepal by G. Fuchs (1964, 1967) have added greatly to our stratigraphic knowledge of this region. The Triassic in central Nepal attains a thickness of 500 to 1,400 m. The Lower Triassic consists of gray limestone, shale, and dark nodular limestone. The Middle Triassic and Carnian are represented by blue limestone, marl, and dark shale, grading upward into brown to black shale, siltstone and sandstone with some concretions. The limited fossil data available indicate a Norian age. The uppermost part of the sequence is sandstone that grades upward into massive limestone. These units are believed to be latest Triassic in age and appear to grade into rocks of Jurassic age.

## CHINA AND SOUTHEAST ASIA

Marine Triassic strata are largely confined to the southeastern quarter of China with, of course, a connection westward to Tethys. Paleogeographic maps for the three series of the Triassic have been compiled by Liu (1959). These maps clearly show a progressive decrease in the area of marine seas from the Early to the Late Triassic. The Lower Triassic has received a fair amount of attention by paleontologists and stratigraphers, but that is not so for the Middle and Upper Triassic. The Lower Triassic consists of carbonate, detrital, and mixed facies with fairly abundant ammonoid and bivalve faunas. The most comprehensive monograph on Scythian ammonoids is by Chao (1959).

The Triassic is as yet incompletely known in Burma. In the Arakan Yoma are thick sections of fine-grained detrital rocks, with some limestone that contains Upper Triassic fossils, mainly bivalves such as *Halobia* and *Monotis*. Sahni (1938) reported a lowest Scythian fauna including *Glyptophiceras, Lytophiceras, Vishnuites,* and others from an argillaceous limestone and shale sequence within dolomites at Na Kham in the northern Shan States. Unfortunately no additional data aside from Sahni's abstract are available. Also known from the northern Shan States are the Napeng beds consisting of argillaceous, yellow shale and marl with some limestone. The fossils from these strata consist of bivalves, including *Avicula contorta, Myophoria, Gervillia praecursor, Pecten, Modiolopsis,* and others suggesting a Rhaetic age (Healey, 1908).

The Triassic System of Malaysia and Thailand has been carefully reviewed by Tamura *et al.* (1975). Prior to World War II, data were very sparse, but since the war there has been a tremendous intensification of field stratigraphic and paleontologic studies. The region, however, is structurally very complex, and the results to date are mainly the identification and delineation of stratigraphic units and to some extent description of their faunas. Geosynclinal conditions prevailed in these regions during the Triassic. The rock facies are extremely varied including fine to coarse detrital sediments, chert, limestone, and volcanics. Tamura *et al.* (1975) included a correlation chart of the Triassic for the region and a detailed bibliography. On the basis of ammonoid, bivalve, and conodont studies, portions of all stages of the Triassic have been identified. The descriptive work on these fossils is most advanced on the bivalves, followed by the conodonts, but many of the ammonoids still remain to be described. The Malayan ammonoids include upper Scythian, upper Anisian, upper Ladinian, and lower and upper Norian faunas. In Thailand, on the contrary, only upper Anisian and lower Carnian faunas have been identified to date. Bivalves are much more profuse and more widely distributed than ammonoids. The Scythian *Claraia,* Anisian-Norian myophoriids, Ladinian-Carnian *Daonella,* and Carnian-Norian *Halobia* are important forms. Scythian, lower Anisian, and lower Carnian conodont faunas have been identified in the Malay Peninsula. The literature on these faunas from Malaysia and Thailand is extremely extensive but is all listed in the bibliography of Tamura *et al.* (1975).

The Triassic of North Viet Nam is very poorly known. A report by Khúc *et al.* (1965) on a fairly large assemblage of fossil faunas, mainly bivalves, is a valuable contribution. These authors were able to identify the presence of portions of all stages of the Triassic.

## INDONESIA

Timor is one of the most remarkable fossiliferous Triassic localities in the world from which approximately 1,000 species of marine invertebrates have been described. The ammonoids have been monographed by WELTER (1914, 1915, 1922), DIENER (1923), ARTHABER (1927), and PAKUCKAS (1928). Essentially all of the faunas described in these and other papers have come from eastern Timor where they occur in exotic blocks, mostly in carbonate facies. In Sumatera (Sumatra), Borneo, Sulawesi (Celebes), and elsewhere, the Triassic consists mainly of detrital facies and is not as fully represented. Since these early studies, very little geological or paleontological work has been done.

Western Timor has received considerable attention in recent years, noted especially by the monograph by AUDLEY-CHARLES (1968) on the geology of western Timor (formerly Portuguese Timor). Paleontological studies have been produced by NAKAZAWA and BANDO (1968) on Scythian-Anisian ammonoids and by NOGAMI (1968) on conodonts. Other studies by these authors are in progress (BANDO, personal communication).

## AUSTRALIA

The basic tectonic pattern for the Paleozoic of Australia is the active Tasman geosyncline along the eastern portion of the island continent and a series of basins along and opening on the Indian Ocean on the western side. By the close of the Permian the Tasman geosyncline was in a terminal orogenic state, although no orogenic activity affected the western areas. The interior of the continent had long been emergent. The Late Permian was a time of extensive regression and by the close of the period, the continent was essentially completely emergent.

Marine incursions during the Triassic were limited to restricted areas in the east and west coastal regions of Australia; in the interior of the continent and especially in the east, extensive terrestrial strata are found. In the east, marine Triassic strata are present in the Maryborough basin, Queensland. From the Traveston Formation RUNNEGAR (1969) has recorded a middle Scythian (Smithian) ammonoid fauna containing such genera as *Anaflemingites, Dieneroceras,* and *Flemingites.* Also from within this basin DENMEAD (1964) and P. J. G. FLEMING (1966) recorded a Lower Triassic bivalve fauna from the Brooweena Formation.

In western Australia Lower Triassic fossiliferous, marine detrital strata are present in the Perth and Carnarvon basins and in brackish water sediments in the Canning basin. In the Perth basin outcrops of the Kockatea Shale near Mount Minchin have yielded an extremely interesting assemblage of ammonoids generally poorly preserved as molds. The presence of these fossils was first recorded by EDGELL (1964), who correctly concluded that they belonged to the middle Scythian (Smithian), and this has been further documented by SKWARKO and KUMMEL (1974). The remaining data on the marine Triassic of the Perth basin come from bore holes. The first marine macrofossils of Triassic age in the Australian region were recovered from cores of the Kockatea Shale from the Beagle Ridge (BMR 10) bore. DICKENS and MCTAVISH (1963) described a small group of ammonoids, which they interpreted as early Scythian in age. Later MCTAVISH and DICKENS (1974) extended the age of the Kockatea Shale to include most of the lower half of the Scythian. Beneath the horizon that yielded the ammonoids, specimens of *Claraia* were obtained. The Dongara No. 4 bore is approximately 65 km north of the Beagle Ridge (BMR 10) borehole in the Perth basin. Two cores from the Kockatea Shale yielded the following ammonoids: *Proptychites* sp. indet., *?Koninckites* sp. indet., *?Paranorites* sp. indet., and *Gyronites frequens* (SKWARKO & KUMMEL, 1974). These ammonoids are of early, but not earliest, Scythian age.

Recently MCTAVISH (1973) contributed valuable data from conodont studies of subsurface samples from the Perth and Carnarvon basins. He concluded that these conodont faunas of Triassic age can be correlated with the Lower Triassic conodont zonation proposed for the Salt Range by SWEET (1970a). They range in age from early to late Scythian (Dienerian to Spathian).

Early in 1970 the Burmah Oil Australia Ltd. drilled Sahul Shoal No. 1, and the core has yielded fragments of ammonites and bivalves. Though the material is poorly preserved and fragmentary, SKWARKO and KUMMEL (1974) suggested that one of the ammonoids belongs to the genus *Nicomedites* of Anisian age. A macrofauna of this age was previously unknown in the Australian region.

## NEW GUINEA

In recent years a great amount of new data has become available on the Triassic of New Guinea, hitherto almost a complete blank. The first records of marine faunas of this age are by SKWARKO (1967) and since then a series of papers have appeared (SKWARKO, 1973a, 1973b; SKWARKO & KUMMEL, 1974). So far Anisian and Upper Triassic horizons have been identified.

## NEW ZEALAND

During the later Paleozoic and early Mesozoic, New Zealand was the site of rapid marine sedimentation in a persistent geosynclinal zone lying between a rising geanticline of Precambrian-Devonian strata, metamorphics and igneous rocks to the west, and the Pacific Ocean to the east (FLEMING, 1962). The thick sequence of sediments laid down in the New Zealand geosyncline range from those now metamorphosed to form the Haast Schists (undated but perhaps mostly Carboniferous) through the Permian to the Hokonui System (Triassic and Jurassic). The western, marginal portion of the geosyncline, referred to as the Hokonui facies, is characterized by very thick moderately fossiliferous, detrital sequences, which are abundantly tuffaceous. Eastward of the Hokonui facies range extremely thick sequences of graywacke and argillite, with some spilitic pillow lava, lenticular limestone and radiolarian chert, known as the Torlesse facies. This portion of the geosyncline is sparsely fossiliferous. The best review of the Mesozoic of New Zealand is by FLEMING (1970).

Ammonoid faunas representing all stages of the Triassic have been reported; however, only a fraction of the standard zones has been recognized. The ammonoids are similar to those of Tethyan and circum-Pacific localities. The brachiopod and bivalve faunas, however, contain a fair percentage of endemic genera and species. Interesting discussions of New Zealand zoogeography have been published by MARWICK (1953) and FLEMING (1967).

## JAPAN

The best summary of the Triassic System of Japan is by BANDO (1964); good resumés can also be found in TAKAI *et al.* (1963) and MINATO, GORAI, and HUNAHASHI (1965). Marine Triassic formations of Japan crop out in relatively limited areas on Honshu, Shikoku, and Kyushu islands. The principal areas are in the southern part of the Kitakami area of northern Honshu, the Kwanto area of east-central Honshu, the Maizuru area of west-central Honshu, the Yamaguchi area of southern Honshu, and on Shikoku and Kyushu islands.

In the Kitakami region, fossiliferous Lower and Middle Triassic formations are widely distributed. No Carnian has been recognized and Norian units have very restricted distribution. On the other hand, in the Kwanto area fragmentary parts of the Lower Triassic and some Upper Triassic formations have been identified. No Middle Triassic has been recognized. In the outer zone of southwest Japan, on Shikoku and Kyushu islands, the Triassic sequence is fragmental because of very complicated geologic structure. The main units recognized are the upper part of the Middle Triassic and Upper Triassic formations. Lower Triassic limestone is found as lenticular bodies at only three outcrops. In the inner zone of southwest Japan, the Lower and Middle Triassic are present in the Maizuru area. In the southern part of Honshu Island in the Yamaguchi area, the Triassic is mainly represented by Upper Triassic detrital strata representing interbedded marine and coal-and plant-bearing terrestrial beds. The marine strata contain typical Upper Triassic bivalves. A very limited extent of Ladinian strata is also found in the region.

In a very general way the Lower and Middle Triassic formations consist of fine-detrital facies (black shale, sandy siltstone, and argillaceous limestone). The Upper Triassic, in contrast, is more characterized by coarse-detrital facies. The boundary between the two facies is drawn between the Ladinian and Carnian, which marks the Akiyoshi orogeny. Very valuable paleogeographic reconstructions for the Triassic of Japan can be seen in MINATO, GORAI, and HUNAHASHI (1965).

The Lower and Middle Triassic formations have yielded many characteristic ammonoids and bivalves. Ammonites from the Upper Triassic are rare in Japan.

## NORTHEASTERN SIBERIA

Marine Triassic formations are extensively developed northeast of a line connecting the Taymyr Peninsula and the Primorye Territory around Vladivostok. The facies are almost entirely detrital, consisting of dark-colored sandstone, siltstone, and shale.

Zonal schemes for northeastern Soviet Union and the southern Primorye Territory have been summarized by KIPARISOVA, OKUNEVA, and OLEYNIKOV (1973). Fourteen, mainly generic zones are recognized with approximately two dozen, mainly local zones in northeastern Soviet Union and a dozen in the southern Primorye Territory. The Lower and Middle Triassic zones are based almost entirely on ammonoids whereas in the Upper Triassic many of the local zones are based on species of the bivalves *Otapiria, Oxytoma,* and *Monotis.* On the basis of literature surveys it appears that in general the formations are moderately to sparsely fossiliferous. It also appears that many of the zones have been recognized in as yet only one or a few places. The lowest zones of the Scythian (Griesbachian) are known only from the south Verkhoyansk synclinorium. In some areas, as in the southern Primorye Territory, the next youngest zones of the Scythian (Dienerian) are the basal beds.

In the region around the lower part of the Olenek River the lower Scythian is represented by fine to coarse detrital deposits, with some tuff-containing plant remains. The upper Scythian consists of argillite with limestone bands containing ammonites. The Middle Triassic formations appear to be entirely marine, but in the Upper Triassic continental deposits, some coal bearing, become quite common. In general there is a distinct break or disconformity with the overlying Jurassic strata. A brief treatment of the stratigraphic sequences and faunal zones for northeastern Soviet Union can be found in KIPARISOVA, OKUNEVA, and OLEYNIKOV (1973).

Excellent lithopaleogeographic maps for the Soviet Union are available (VERESHCHAGIN & RONOV, 1968, sheets 1-12) and a comprehensive text on the Triassic System is in KIPARISOVA, RADCHENKO, and GORSKIY (1973).

## SVALBARD

Triassic deposits are widespread in Svalbard, cropping out in excellent exposures on the east and west coasts of central and southern Vestspitsbergen, at the south end of Nordavst Land, and underlying the Edge, Barents, and Wilhelm islands, and on the east coast of Bear Island (Bjørnøya). An excellent summary of the Triassic stratigraphy of Svalbard has been published by BUCHAN *et al.* (1965). Summaries of the biostratigraphy have been presented by TOZER and PARKER (1968) and KORCHINSKAYA (1973).

The Triassic rocks in Svalbard consist of a preponderance of marine shale and siltstone with continental sandstone in the upper part suggesting a platform of epeirogenic environment of deposition. The lower part of the sequence containing a sparse fauna of bivalves consists of fine-grained flaggy sandstone probably formed under shallow marine conditions, and interbedded shale and siltstone. This is followed by the main marine shale sequence which continues into the lower part of the uppermost unit (the Kapp Toscana Formation). The dominant rock type is thin-bedded gray to black bituminous shale, whereas harder, yellow-weathering siltstone is common. The upper part is characterized by the occurrence of red-weathering clay-ironstone nodules. Fossils are fairly abundant—ammonites, bivalves, and vertebrates being the most common. The uppermost part of the Triassic is a nonmarine sequence consisting of gray-green, flaggy, cross-bedded sandstone alternating with sandy shale. Thin coal seams and common plant remains are present and suggest deposition in lagoonal or continental conditions.

Ammonoids and bivalves are the predominant marine invertebrates in the Triassic formations of Svalbard. Ammonoid horizons indicate the presence of some zones from the Lower, Middle, and lower Upper (Carnian) Triassic. Some bivalve faunas indicate the presence of Norian marine horizons in the upper part of the Triassic sequence. The lower part of the Scythian has yielded *Otoceras boreale,* followed by *Claraia* cf. *C. stachei,* and *Proptychites* cf. *P. rosenkrantzi.* The middle and upper Scythian are well represented by ammonoid faunas. The Anisian and Ladinian have yielded varied suites of ammonoid faunas, but as yet relationships and precise correlations for many are ambiguous. The lower Carnian is represented only by a single ammonoid zone. The upper part of the highest Triassic formation (Kapp Toscana Formation) consists of marine and continental facies. From the marine facies KORCHINSKAYA (1973) reported *Halobia* cf. *H. plicosa, H.* cf. *H. norica,* and *H. fallax.* From another locality she reported *Pterotoceras(?) svalbardi.* The continental facies contains plant remains.

## GREENLAND

During the late Paleozoic and early Mesozoic northeast Greenland underwent major faulting leading to the formation of a compound system of horst and graben structures. The Triassic basin trended north-northeasterly and its extent was rather similar to that of the Carboniferous-Permian molasse trough. To the west the basin was bounded by a peneplaned high ground of Caledonian folded rocks, including Old Red Sandstone, which contributed abundant detritus into the basin. In the Triassic, sedimentary transport from an eastern highground is also clearly indicated.

The lowest Scythian (Griesbachian) formation consists of 500 to 800 m of marine shale, sandstone, and conglomerate. The formation is fairly fossiliferous, containing in sequence species of *Otoceras, Ophiceras,* and *Proptychites.* The unit is referred to as the Wordie Creek Formation by many authors, but TEICHERT and KUMMEL (1973) recommended abandonment of the name because of ambiguities.

The presence of fossil remains of distinctly late Paleozoic aspect in beds with such typical Lower Triassic forms as *Otoceras* and *"Glyptophiceras"* in the lower part of this Scythian sequence has stimulated considerable interest. This association was first noted by SPATH (1930, 1935) who considered the Paleozoic elements to have been derived and of Carboniferous age. TRÜMPY (1960, 1961), on the other hand, on the basis of his own field work came to the conclusion that the Paleozoic elements were not derived. TEICHERT and KUMMEL (1973, 1976), on the basis of field studies made in the summer of 1967, concluded that the Paleozoic elements are all derived. They considered some of the Paleozoic elements as having 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 sediments, and thus in a free state were transported very little. The majority of fossils, however, were washed out of soft rocks and were badly broken during transportation.

The remainder of the Triassic sequence consists of mudstone and sandstone, with some gypsum and dolomite beds. At a few horizons impoverished faunas are composed mainly of bivalves. The uppermost unit consists of sandstone containing Rhaetic plant remains.

Only one occurrence of Triassic deposits is known from northern Greenland, and that is in Peary Land. Here the succession consists of 630 m of a lower shaly division of late Scythian age and an upper sandy division of early Anisian age (KUMMEL, 1953b).

## ARCTIC CANADA

Triassic rocks are present in the Sverdrup Basin and crop out on Ellesmere, Axel Heiberg, Cornwall, Table, Exmouth, Cameron, Melville, Prince Patrick, Brock, and Borden islands. An excellent summary of the stratigraphy of the Canadian Arctic Archipelago has been published by THORSTEINSSON and TOZER (1970).

In the axial part of the Sverdrup basin and in parts of the marginal area Lower Triassic rocks rest disconformably upon Permian strata. In places the youngest Permian rocks are Guadalupian; elsewhere they are late Artinskian. Latest Permian strata are unknown. The oldest Triassic rocks are earliest Scythian (lower Griesbachian) in age. It appears that the Permian-Triassic boundary is paraconformable and that the gap in the sedimentary record is within the highest Permian and not in the Lower Triassic.

Marine conditions prevailed throughout the axial part of the Sverdrup basin from earliest Scythian to the Carnian. Some of the Lower Triassic beds on the margins were probably deposited in a nonmarine environment. For this interval the sections on the margins of the Sverdrup basin differ from those of the axis both in thickness and lithology. Most of the rocks on the south and east margins consist of sandstone and calcareous siltstone (Bjorne and Shei Point formations); the axial part is shale and siltstone (Blind Fiord and Blaa Mountain formations). In the northwest margin of the basin, the sections are of mixed character. The Bjorne Formation disconformably overlies Permian strata and consists mainly of quartzose, commonly cross-bedded sandstone with conglomeratic interbeds on the extreme margins of the basin. Fossils are rare but *Otoceras* (lower Scythian-Griesbachian) occurs near the base at one locality and poorly preserved lower Lower Triassic ammonoids are known from other localities. Marine fossils are unknown in the beds on the south margin of Sverdrup basin. The Bjorne is overlain by Anisian strata and is thus fairly well dated as Early Triassic. The contemporary rocks exposed on the western coast of Ellesmere Island and on eastern and northern Axel Heiberg Island are the Blind Fiord Formation, which consists of green and gray siltstone, fine-grained sandstone and shale. The Blind Fiord beds are well dated by ammonoid faunas.

The Shei Point and Blaa Mountain formations are essentially contemporaneous and of Anisian, Ladinian, and Carnian age. Typical Shei Point rock is gray, brown weathering, highly calcareous siltstone and fine-grained sandstone, with bioclastic layers composed of brachiopod and bivalve shells in the upper part. Shale is typical Blaa Mountain lithology.

Throughout central Ellesmere Island, the top of the Shei Point Formation is marked by the upper Carnian "*Gryphaea* Bed"; 31 m of calcareous sandstone with coquinoid layers of *Gryphaea* and *Plicatula*. A similar and apparently contemporary *Gryphaea* bed is found in the Blaa Mountain Formation of northwestern Axel Heiberg Island. The upper Carnian *Gryphaea* beds are thus widely distributed on the margins of the Sverdrup basin and their occurrence probably indicates an interval of shoal-water conditions along the border of the Sverdrup basin following uplift.

The Blind Fiord and Blaa Mountain formations of the axial part of Sverdrup basin were laid down some considerable distance from shore. In the Triassic there were two sources of sediments, one essentially continuous, feeding sediment to the south and east margins of the basin, and the other, an intermittent source (or sources), providing sediment to the north and northwest margins of the basin.

The highest Triassic formation in the Sverdrup basin is the Heiberg, which consists mainly of nonmarine, carbonaceous sandstone, with marine beds at several levels in the lower part. The lower marine beds with *Meleagrinella antiqua* are probably lower Norian, the higher marine strata include middle Norian beds and strata with the cosmopolitan upper Norian *Monotis ochotica*. The beds above those with *Monotis* are entirely nonmarine, with fossil plants and thin coal seams. They may be partly Jurassic, but if so, they are not younger than Sinemurian.

## WESTERN CANADA

Triassic strata of western Canada are represented by a complex array of sediments and volcanics laid down in distinct eugeosynclinal and miogeosynclinal segments of the Cordilleran geosyncline. The geology of western Canada has been well summarized by Douglas *et al.* (1970). Lower Triassic rocks are not known in the western (eugeosynclinal) parts of the Cordilleran geosyncline in Canada although they are present a few kilometers south in Washington. Middle Triassic ribbon chert, argillite, greenstone, possibly coeval ultramafic rock, and minor limestone occur locally in the northwestern and central parts, apparently lying conformably on the Permian. In the southernmost parts of the geosyncline, Middle Triassic rocks characterized by sharpstone conglomerate, unconformably overlie late Paleozoic rocks. The western sequences represent generally quiescent eugeosynclinal conditions possibly prevailing from the Permian. An intermittently emergent arch (Quineca geanticline) separated the eugeosyncline from the miogeosyncline. In the miogeosyncline are Lower Triassic siltstone and shale that disconformably overlie the lower Upper Permian. The entire western margin of the craton was probably emergent and stable, these conditions prevailing throughout the period.

In the late Middle Triassic, parts of the Cordilleran geosyncline underwent deformation and plutonic activity (Tahlternian orogeny). Uplift at the end of the orogeny established the main tectonic elements that prevailed until Middle Jurassic time. The lower Upper Triassic, Carnian, is represented on the western edge of the eugeosyncline mainly by a thick succession of submarine basaltic flows. Slightly to the east they are represented by andesitic and basaltic flows, pyroclastics, and clastics containing volcanics and Middle Triassic and earlier debris. The latter for the most part derived from islands and volcanoes within the eugeosyncline. In the miogeosyncline siltstone and sandstone accumulated, grading eastward, along the margin of the craton, into an evaporitic and red-bed facies with basal shoreline and offshore sandbars.

In the late Late Triassic, Norian, volcanism persisted in parts of the eugeosyncline, red beds are present in some areas around uplifted geosynclines, and clastic rocks. During latest Norian, carbonate deposition prevailed throughout much of the geosyncline. The sections are remarkably thin but complete in the northern and eastern elements, and indicate quiescent conditions of deposition to the end of the Triassic.

## WESTERN UNITED STATES

Marine Triassic formations are present only in the western Cordilleran geosynclinal area. Thick sequences of miogeosynclinal facies are present in eastern Nevada, western Utah, southeastern Idaho, western Wyoming, and southwest Montana. Eugeosynclinal facies including volcanics are found in western Nevada, California, Oregon, and Washington. In the eastern half of the miogeosyncline only the Lower Triassic is of marine facies and these in many places are overlain by Upper Triassic terrestrial red bed formations. Along the hinge line between the miogeosyncline and the craton the Lower Triassic marine beds interfinger with red beds. In southeastern Idaho the marine section contains an excellent sequence of ammonite faunas, especially for the upper half of the Scythian (Kummel, 1954). The base of these marine sequences is at various levels within the Scythian indicating a complex pattern of transgression over an irregular terrane. The eugeosynclinal suite of western Nevada has yielded a fairly complete succession of zonal ammonites, however, not as complete as that known in British Columbia (Silberling & Tozer, 1968). In California only the Upper Triassic is fossiliferous.

## SOUTH AMERICA

Marine Triassic formations in South America are entirely confined to the Andean region and then are fairly extensive only in the Norian. To the west of the Andes all Triassic formations are of terrestrial detrital deposits and volcanics, mainly of Late Triassic age.

No marine deposits of Early Triassic age have yet been identified. Shallow-water marine deposits containing Middle Triassic

(Anisian) fossils are present in a coastal strip of central Chile (Zeil & Ichikawa, 1958; Barthel, 1958). The Ladinian-Carnian is represented only by volcanic deposits in various parts of Chile. In the Norian, however, the sea transgressed an area from central Colombia to southern Bolivia and along the coastal region of Chile. Deposition in this seaway was mainly limestone, and to the north it grades into continental red-bed facies. The most conspicuous fossil in these formations is *Monotis subcircularis* (Westermann, 1973). The Utcubamba Formation of northern Peru has yielded a silicified fauna containing bryozoans, brachiopods, gastropods, nautiloids, ammonoids, scaphopods, bivalves, and crinoid ossicles; however, only the ammonoids are fairly abundant (Jaworski, 1922; Kummel & Fuchs, 1953).

The best general discussion of the distribution of South American Triassic deposits and paleogeography is by Harrington (1962).

## ANTARCTICA

Continental Triassic strata have long been known on Antarctica, yet the first record of marine Triassic has only recently been published (Thomson, 1975). The Legoupil Formation in the northwestern part of the Antarctic Peninsula has yielded a small poorly preserved fauna, from which Thomson has identified *Bakevelloides* aff. *B. hekiensis* and *Neoschizodus* sp. nov. In addition, other fossils include a possible fragment of an inarticulate brachiopod, a serpulid, a gastropod, and some possible arthropod tracks. Most species of *Bakevelloides* are Late Triassic in age. *Neoschizodus* sp. nov. is the commonest element in the fauna. It is closely related to *N. laevigatus* (von Zieten) of Early to Middle Triassic age, but differs in some features.

## SUMMARY

The Triassic was a time of great emergence of the continents and little tectonic activity. Marine deposition in shelf and geosynclinal environments are confined to Tethys, the circum-Pacific region, and the circum-Arctic. With the exception of the Middle Triassic conodonts in the Cameroons of western Africa, no marine strata are known from the Atlantic region between Svalbard and the northwestern part of the Antarctic Peninsula. The relationship between sea and land changed little during the Triassic.

Within Tethys, Triassic strata are represented by a wide range of facies. Carbonates are dominant but fine to coarse detrital facies are also present. In the circum-Arctic region the sedimentary facies are almost entirely fine to coarse detrital. Along the western part of North America there are well-developed miogeosynclinal and eugeosynclinal regions. The miogeosynclinal areas are characterized by carbonate and fine to coarse detrital facies that thin and intertongue with red-bed facies on the adjoining shelf. The eugeosynclinal areas contain mainly detrital facies. Marine Triassic deposits are not well represented along the western region of South America except for thick carbonates of Late Triassic age in Colombia, Ecuador, and Peru. Along the western margins of the Pacific, geosynclinal conditions prevailed with detrital and volcanic facies. Shelf deposits are very limited.

## TRIASSIC FAUNAS

Triassic faunas are strikingly different from those of the underlying Permian. Absent is the great diversity of brachiopods, bryozoans, echinoderms, and foraminifers. The primary elements of Triassic faunas are brachiopods, gastropods, nautiloids, ammonoids, bivalves, and conodonts. All other groups are sparsely represented. In this chapter the focus is on an overview of the primary fossil groups in Triassic faunas. The nature and definition of the Permian-Triassic boundary has received much attention in recent years. In this debate much has been written on so-called "mixed" Permian-Triassic faunas at the boundary. This subject will be covered in the discussion of the brachiopods, as it is this phylum that plays an important role in nearly all these discussions.

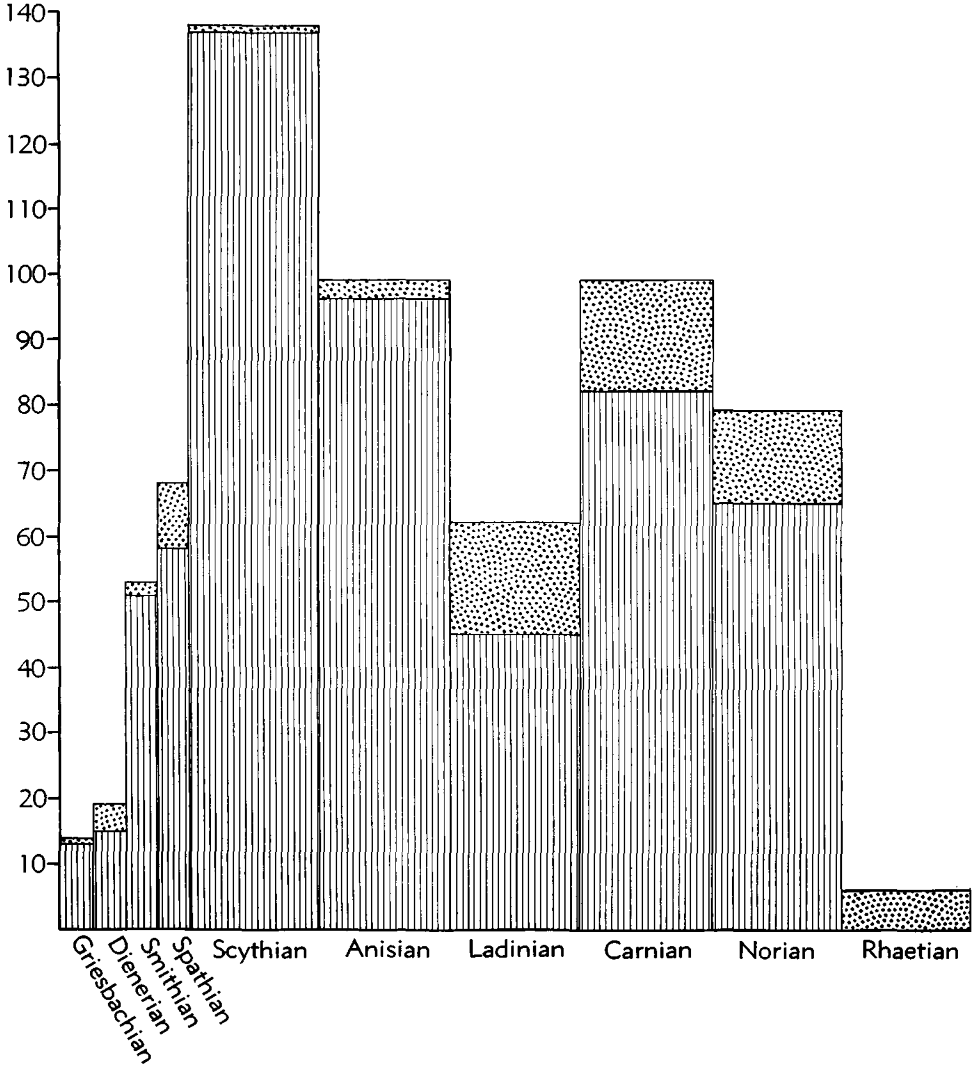

FIG. 3. Total genera and new genera (lined area) of ammonoids of the Triassic Period (Kummel, n).

## AMMONOIDS

Ammonoids are the predominant invertebrate fossils of the Triassic. They are the most abundant, widely distributed, and diverse of all the invertebrates for this period. For these reasons they have historically been the primary basis for establishing the biostratigraphic framework of the Triassic.

The forthcoming revision of the ammonoid volume of the *Treatise* (Part L) recognizes 13 superfamilies, 76 families (and 6 subfamilies), and 431 genera and subgenera of which 16 are nonnominate subgenera. The first comprehensive summary of Triassic ammonoid genera was in *Fossilium Catalogus* Part 1 by DIENER (1915), who recognized 247 genera and subgenera. In an updating of the *Fossilium Catalogus* on Triassic ammonoids KUTASSY (1933) recognized 277 genera and subgenera. The increase in numbers of genera in the last 45 years is due in no small part to noteworthy discoveries and monographs on sequences in the southern Soviet Union, southern China, Primorye, northeastern Siberia, Arctic Canada, British Columbia, and western United States.

Total genera and new genera per stage are shown in graphic form in Figure 3. The distribution of genera by stage and within the major paleogeographic regions is as follows:

| | Total Genera | Tethys | W. Pacific | E. Pacific | Arctic |
|---|---|---|---|---|---|
| Rhaetian | 6 | 6 | 4 | 5 | 3 |
| Norian | 79 | 78 | 8 | 51 | 10 |
| Carnian | 100 | 81 | 13 | 57 | 23 |
| Ladinian | 62 | 49 | 13 | 34 | 15 |
| Anisian | 100 | 81 | 24 | 45 | 26 |
| Scythian | 138 | 118 | 53 | 55 | 52 |

It is clear from this summary that the diversity of ammonoids throughout the Triassic is greatest in Tethys and least in the circum-Arctic.

Approximately 66 genera of ammonoids have been found in the Upper Permian (B. F. Glenister, letter May 17, 1976), and a dramatic change in the composition of ammonoid populations occurs at the Permian-Triassic boundary. Most Permian genera and families became extinct, and the lower Scythian (Griesbachian) is characterized by a completely new radiation centered around the Ophiceratidae. This family is a direct descendant of the Xenodiscidae (Spinosa, Furnish, & Glenister, 1975).

The number of genera per superfamily for each series of the Triassic is as follows:

| | Lower | Middle | Upper |
|---|---|---|---|
| Otocerataceae | 1 | 0 | 0 |
| Noritaceae | 90 | 7 | 1? |
| Hedenstroemaceae | 11 | 3 | 1 |
| Dinaritaceae | 26 | 2 | 0 |
| Ceratitaceae | 1 | 58 | 3 |
| Clydonitaceae | 0 | 17 | 51 |
| Choristocerataceae | 0 | 1 | 6 |
| Tropitaceae | 0 | 4 | 58 |
| Lobitaceae | 0 | 2 | 5 |
| Arcestaceae | 0 | 13 | 11 |
| Megaphyllitaceae | 2 | 9 | 1 |
| Nathorstitaceae | 0 | 6 | 1 |
| Pinacocerataceae | 1 | 22 | 19 |
| Phyllocerataceae | 4 | 5 | 5 |

The Noritaceae and secondarily the Dinaritaceae are the predominant groups in the Lower Triassic radiation. Of the 13 Triassic superfamilies only seven are represented in the Lower Triassic and four of these have four or less genera. All superfamilies are represented in Middle Triassic faunas; the predominant group are the Ceratitaceae. The Pinacocerataceae are also well represented. Twelve superfamilies are represented in the Upper Triassic but four of these by three or less genera; the main groups are the Clydonitaceae and Tropitaceae. At the close of the Norian there was again an extensive wave of extinction and only six genera are present in the Rhaetian and these became extinct by the close of the Triassic.

## NAUTILOIDS

The evolutionary history of nautiloids shows no dramatic change in tempo at the Permian-Triassic boundary (Kummel, 1953a). Families that account for peak development of the Nautilida in the late Paleozoic and Triassic are the Tainoceratidae, Grypoceratidae, and Liroceratidae. Except for a liroceratid doubtfully recorded from the Devonian, all these families began in the Mississippian. Whereas the number of genera gradually increased with time in each of these evolutionary lines, rates of evolution were not such as to produce many new families. Thus it seems that as early as the Mississippian the principal evolutionary lines of nautiloids had become firmly established and these maintained their identity and character until the close of the Triassic. Only a few minor radiations (families) appeared in this interval. This pattern is also reflected in the number of genera carried over from one period to the next. Eleven genera persisted from Mississippian to Pennsylvanian, and 20 from Pennsylvanian to Permian. Only four Triassic genera are also known from the Permian, but this number is deceptive, for in each of the three evolutionary lineages that extend from the Permian into the Triassic, the core Permian genus evolved directly into the core Triassic genus: *Metacoceras* (Penn.-Perm.) to *Mojsvaroceras* (Trias.), *Domatoceras* (Penn.-Perm.) to *Grypoceras* (Trias.), and *Liroceras* (Miss.-Perm.) to *Paranautilus* (M.Trias.-U.Trias.). Consequently, the large number of Triassic genera is the result of

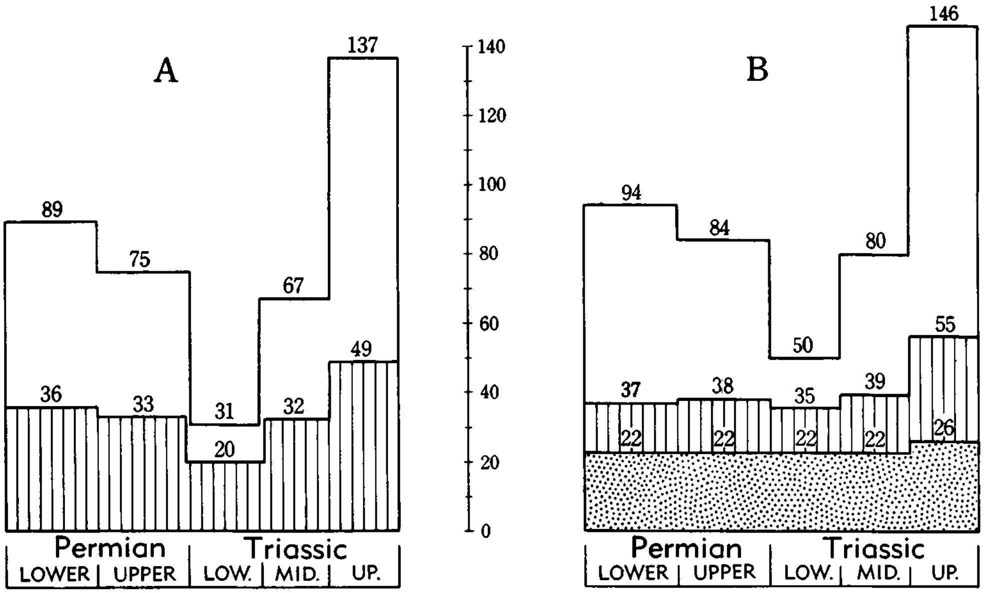

FIG. 4. Diversity of Permian and Triassic marine bivalves measured by the numbers of genera, families, and superfamilies (after Nakazawa & Runnegar, 1973).——*A.* Observed occurrences of genera (solid line) and families (ruled area).——*B.* Estimated numbers of genera (solid line), families (ruled), and superfamilies (stippled).

a broad evolutionary radiation in each of the principal evolutionary lineages during the Late Triassic. Triassic nautilid evolution, then, represents just the culmination of patterns and trends begun in the Mississippian.

Nautilids nearly became extinct after their peak development in the Late Triassic; only *Cenoceras* survived from the Triassic into the Early Jurassic. At this time, a new radiation began, resulting in a modest proliferation of new genera in the Late Jurassic.

## BIVALVES

Bivalves are the second most important invertebrate group in the Triassic rock record. They likewise have the same status in the dating of Triassic strata. Though relatively common in the rock record, they have not received the intensity of study as have the ammonoids. Thin-shelled bivalves, such as *Claraia, Posidonia, Daonella, Halobia,* and *Monotis* are particularly striking forms for their extremely widespread geographic distribution and their usefulness for correlation. A few remarks on some of these genera are given below.

The most recent summary of Permian-Triassic bivalves is by NAKAZAWA and RUNNEGAR (1973) and provides the basis for the following discussion. One of their primary conclusions is that ". . . there is reasonable evidence that marine bivalves belong with the group of invertebrates least affected by events at the close of the Paleozoic Era" (NAKAZAWA & RUNNEGAR, 1973, p. 609).

The number of bivalve genera and families decreased during the Late Permian reaching a low during the Early Triassic and then began to increase gradually during the Middle Triassic (Fig. 4). Only 19 marine bivalve genera (9 new) are known from the earliest Triassic, in contrast to about 70 genera known from the middle part of the Permian and approximately 140 known from the Late Triassic. These authors stress that the anomalous low diversity of Early Triassic forms must be the result of an unusually poor record of the history of the class—"an effect which accentuates the observed change in this group at the Permian-Triassic boundary." They point

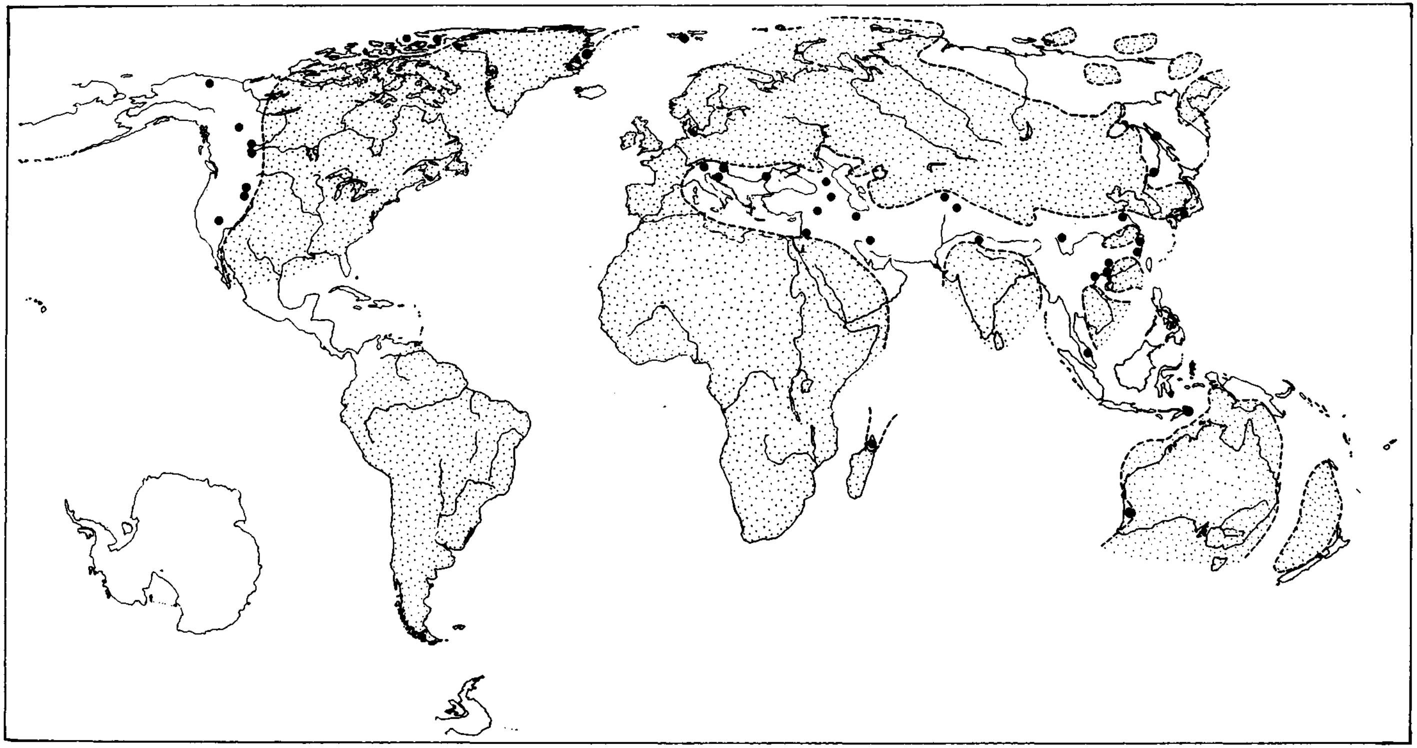

FIG. 5. Distribution of bivalve genus *Claraia* during early Scythian time (from Kummel in Hallam, 1973, published with permission of Elsevier Scientific Publishing Co.).

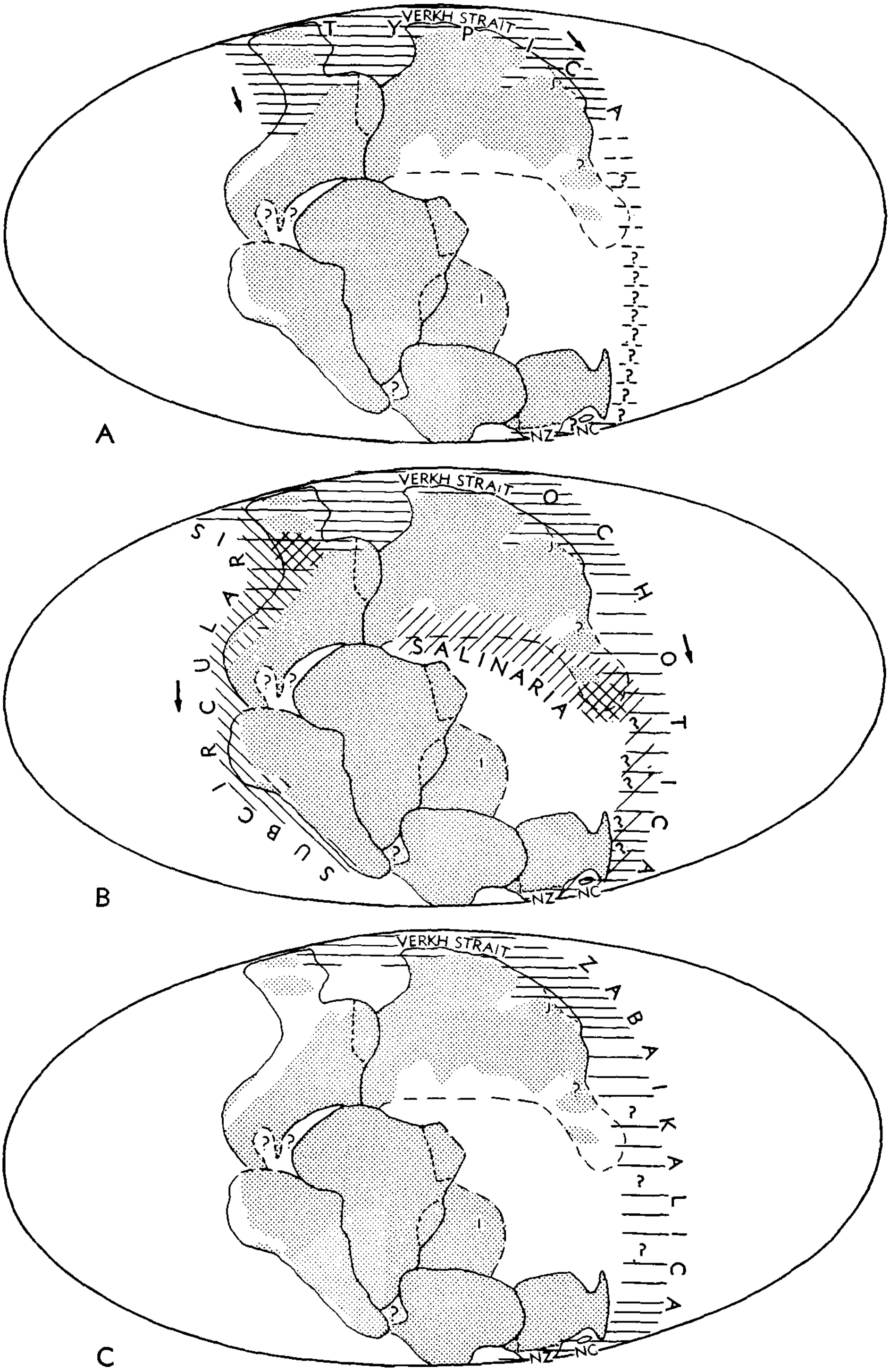

FIG. 6. Zoogeographic distribution of *Monotis* by species groups in relation to probable position of Late Triassic land areas (gray) and oceans (from Westermann in Hallam, 1973, published with permission of

out that 1) many genera and families are represented in Permian strata and reappear in the Middle and Late Triassic (e.g., *Lopha, Waagenoperna, Lyriomyophoria, Costatoria, Modiolus,* Pinnidae, Pteriidae, Terquensiidae, Carditidae, Astartidae, Pholadomyidae); 2) a few must represent transitional forms between Paleozoic and Mesozoic families: Pseudomonotidae-Gryphaeidae (NEWELL & BOYD, 1970), Megadesmidae-Ceratomyidae (RUNNEGAR, 1965), among others. NAKAZAWA and RUNNEGAR (1973) concluded on this basis that two to three times as many genera as are observed must have existed in earliest Triassic time.

The record of diversity of the various orders of bivalves is highly variable. The Nuculoida remained virtually stable throughout the two periods. Other groups, the Arcoida, Mytiloida, Unionida, Trigonioida, and Veneroida, show no essential change during the Permian-Triassic transition but did undergo diversification in the Middle and Late Triassic. The most significant drop in diversity is within the epifaunal Pteroida, which include nearly half of all Permian and Triassic bivalve genera.

In the introductory remarks to this section, mention was made of thin-shelled bivalves; the distribution of *Claraia* and *Monotis* will illustrate the importance of these groups. *Claraia* is confined to the lower part of the Scythian and is present in nearly every area where marine lower Scythian strata are present (Fig. 5). That is, it is present throughout Tethys at a large number of localities, southeast Asia, western Australia, China, Japan, northeast Siberia, northeast Greenland, the Arctic Islands of Canada, and in a number of localities in the western Cordillera of North America. The genus is generally found in fine-grained calcareous facies. Though many species of *Claraia* have been described, it is apparent that some species are cosmopolitan.

The Upper Triassic (Norian) *Monotis* is another of the important thin-shelled bivalves that is instructive for zoogeographic analysis and in biostratigraphy. WESTERMANN (1973) has recently published an excellent review of this genus and this forms the basis for the brief summary remarks given here. There are approximately 60 named species and subspecies; however, WESTERMANN's studies led him to conclude that only 19 to 20 "good" species and 12 to 14 subspecies (non-nominate) are justified. For purposes of analysis of zoogeographic distribution, he recognized five groups (those of *Monotis typica, M. salinaria, M. ochotica, M. subcircularis,* and *M. zabaikalica*). *Monotis* occurs in a wide variety of sedimentary facies, ranging from presumed deep-water to shallow-water facies. They do appear, however, to have avoided restricted inland seas. Most authors have interpreted *Monotis* as being pseudoplanktonic because of its mode of occurrence and extraordinary lateral extent of distribution. In his recent summary paper, WESTERMANN (1973) concluded on morphological grounds that it is more likely that they were prevalently benthic "with perhaps a few specimens of the population attached to floating objects, sufficient to permit pseudoplanktonic distribution of the species."

The earliest species of *Monotis* are members of the *M. typica* group. There is some dispute as to whether the earliest occurrences are latest Carnian or early Norian, but this need not concern us here. These early forms are circum-Arctic in distribution extending through the Verkhoyansk Strait to Japan and down into northeastern British Columbia. Later, in the middle Norian, various subspecies of *M. typica* became abundant in different areas of the distributional range (*M. scutiformis* mainly in eastern Siberia and Japan, *M. pinensis* in Alaska to British Columbia, *M. iwaiensis* in Japan). There was, in addition, a further spread southward along the eastern Pacific margin to Vancouver Island and possibly also along the western Pacific margin to Borneo, New Zealand, and New Caledonia (Fig. 6).

The area of distribution of *Monotis* expanded greatly in the late Norian with each

FIG. 6. *(Continued from facing page.)*

Elsevier Scientific Publishing Co.).——*A.* Late Carnian(?) to Middle Norian.——*B.* Early Late Norian. ——*C.* Latest Norian (?to Rhaetian). [Explanation: *I,* India; *J,* Japan; *N.C.,* New Caledonia; *N.Z.,* New Zealand.]

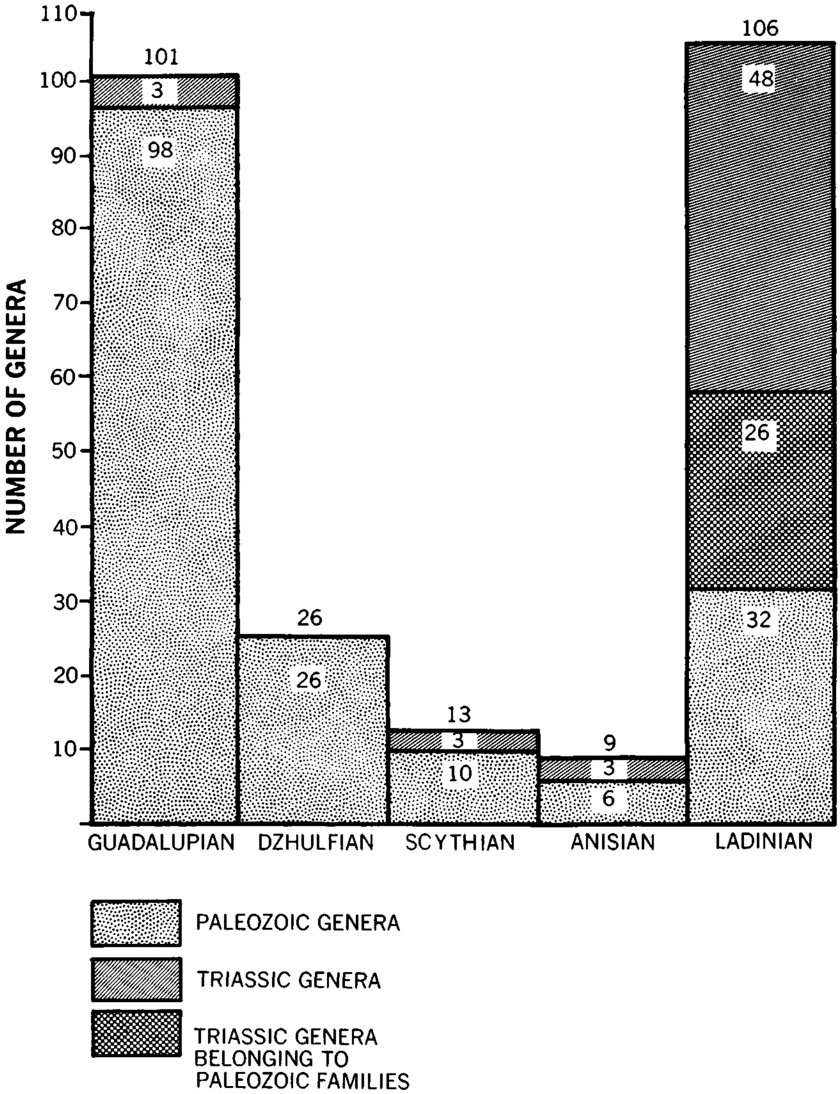

Fig. 7. Distribution of gastropod genera for stages of the Upper Permian-Middle Triassic (from Batten, 1973).

major tectonic region being occupied by a dominant *Monotis* group. The *ochotica* group generally abounds in the area of the former *M. typica* group, except for the northeastern Pacific margin where it is rare, and is found southward in the western Pacific to New Caledonia and New Zealand. The *M. subcircularis* group is found mainly along the eastern Pacific margin as far as central Chile, but occurs disjunctively and probably rarely also in Indonesia and possibly in the Mediterranean. The *M. salinaria* group occurs throughout Tethys and disjunctively also in Alaska, Yukon Territory, and probably in the southwestern Pacific and northeastern Siberia.

The close of the *Monotis* radiation in latest Norian (and ?Rhaetian) is dominated by almost smooth forms of the *M. zabaikalica* group. The group is entirely confined to the Arctic region and along the western Pacific with *M. zabaikalica* dominant in

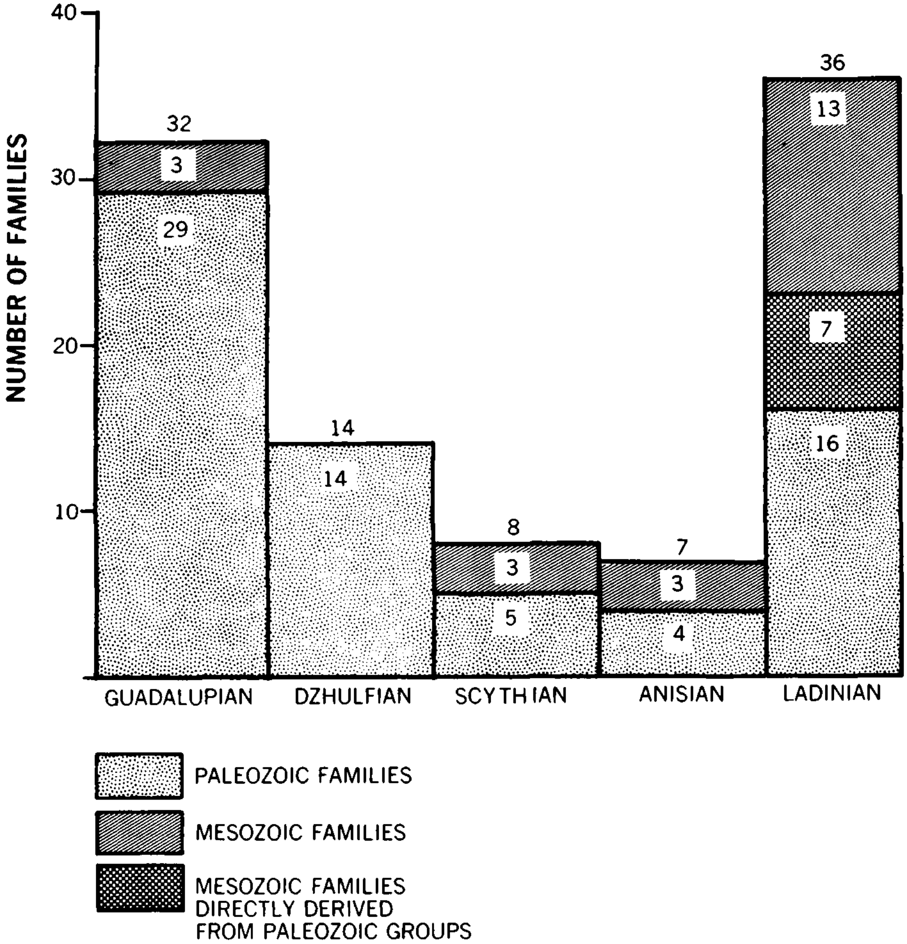

Fig. 8. Distribution of gastropod families for stages of the Upper Permian-Middle Triassic (from Batten, 1973).

eastern Siberia and *M. calvata* in New Zealand and New Caledonia.

## GASTROPODS

Though an extremely important molluscan group, gastropods are not very common in most Triassic strata. As a result, there have been relatively few monographic studies on Triassic gastropods. Until recently there had been no general survey of Triassic gastropods from which one could assess the overall degree and amount of change in Triassic gastropod diversity for a meaningful comparison with underlying Permian and overlying Jurassic faunas. These data have recently been summarized by Batten (1973) in a splendid review article on Permian and Triassic forms. The summary given here is based on Batten's article.

During the late Paleozoic, the gastropods underwent two episodes of adaptive radiation, the earliest occurring during the Tournaisian and Visean stages of the Lower Carboniferous. This was followed by a decrease in diversity in the Late Carboniferous. The second radiation and the one of prime concern here occurred in the Guadalupian. At this time the most diverse fauna of the Paleozoic developed, with about 100 genera and 30 families. These Permian faunas in overall balance were much like those of the preceding two periods but richer. The 10 dominant families in terms of species frequencies are: Bellerophontidae, Sinuitidae, Eotomariidae, Euomphalidae, Omphalotrochidae, Phymatopleuridae, Neritopsidae, Pseudozygopleuridae, Subulitidae, and Murchisoniidae.

It is of particular interest that these are the last diverse faunas of the Paleozoic. The next normal marine gastropod fauna occurs in the Ladinian. Between the latest Guadalupian and the first Dzhulfian occurrence, some 62 Permian genera and 12 families disappeared (Fig. 7, 8).

Only four Dzhulfian faunas contain more than three to five genera. Altogether, these include 26 genera and 14 families. By far the most common group is the bellerophontids; the other important constituents are the eotomariids, neritopsids, and murchisoniids. Batten made note of the fact of sparse numbers of genera per family and apparently large numbers of individuals of few species. This condition apparently also prevailed in the Early Triassic. Of interest also is that of the total Dzhulfian fauna, only three genera survived from the preceding radiation; the others are relatively long ranging and conservative. Most of these are found in facies that indicate brackish to lagoonal conditions.

What is particularly interesting is that the Dzhulfian and Scythian faunas as now known lack genera that occur in the Guadalupian and reappear in the Ladinian! There are 32 Guadalupian genera and 16 families in the Triassic, none of which are known in the Dzhulfian.

Scythian gastropod faunas are rare. When found they form thin accumulations in limestones and invariably one or, at most, several species are present in great numbers. Most Scythian assemblages resemble those of the Dzhulfian in their lack of diversity. The main difference is that the bellerophontids were displaced by other gastropods. No significant change in faunal diversity occurred in the Anisian.

Ladinian faunas are rich and widespread. They contain 106 genera and 36 families, a diversity quite comparable in size to that of the Guadalupian. On further analysis, 32 of the 106 genera are found to belong to Paleozoic families.

Batten emphasized that there is about as much difference between the Guadalupian and Ladinian gastropod faunas as there is between the Devonian and Lower Carboniferous faunas. The main Mesozoic faunal turnover of the gastropods occurred at the close of the Triassic.

## BRACHIOPODS

There is no satisfactory analysis of Triassic brachiopods and their stratigraphic distribution. The great decrease in diversity of Mesozoic and Cenozoic brachiopods has long been established; however, details are lacking. A number of reasons can be cited for this state of affairs. First, brachiopods are not really very abundant in Triassic rocks. Secondly, very few individuals have devoted any significant period of time to their study. The most prominent specialist on Triassic brachiopods was A. Bittner who published numerous papers at the turn of the century. Brachiopods do form part of many general faunal studies, but these serve mainly to emphasize the paucity of this group in comparison to ammonoids and bivalves. A few years ago I wrote to G. A. Cooper asking his opinion of the brachiopods stated to occur in the Lower Triassic in the recent volume of the *Treatise on Invertebrate Paleontology* (Part H), Brachiopoda (A. Williams *et al.*, 1965). He answered (letter of June 14, 1971): "So far as I know, the Lower Triassic is almost a blank for brachiopods. As a matter of fact, the whole Triassic is a critical time in brachiopod history and a kind of never-never land between Permian and the Jurassic."

Whereas the systematic study of Triassic brachiopods is, and generally has been, at a low level, there is one aspect that has aroused considerable interest in recent years —this is the occurrence of Permian-type brachiopods in lowermost Scythian strata. These occurrences have stimulated intensive debate as it relates to the Permian-Triassic boundary.

The first such report was by H. S. Bion (1914) concerning an occurrence in the Pahlgam area of Kashmir, near Srinagar. All the data available are from a brief statement in the Annual Report for 1913 of the

Geological Survey of India. BION (1914, p. 39) wrote as follows: "About 20 feet above the base of the black shales there is a layer of calcareous nodules from which many specimens of *Otoceras* have been obtained associated with almost all the other members of the fauna of the *Otoceras* beds of the Central Himalayas. Good collections have been obtained from Nagaheran in the Dachhigam State Rakh and from the Pahlgam-Aru basin. Some thirty feet above the *Otoceras* layer there is another fossiliferous horizon characterized by *Ophiceras* from which one specimen of *Otoceras* was also procured, but the rest of the black shale division seems to be barren. A surprising element in the fauna of the basal *Otoceras* layer is furnished by the presence of the genus *Productus,* of which three specimens have been obtained from near Pahlgam. In spite of this Permian element I consider that the fauna of the *Otoceras* bed of Kashmir has a decided Triassic aspect."

This brief but highly interesting account went unnoticed for many years. TEICHERT and KUMMEL made an attempt in June, 1968, to locate BION's locality but were unsuccessful. Since BION's report, seven additional localities or areas have yielded Permian-type brachiopods in horizons with lowest Triassic ammonoids. These are the Guryul Ravine of Kashmir, Salt Range of West Pakistan, the Dzhulfa region along the Aras River in the Soviet Union and Iran, Shikoku Island of Japan, East Greenland, Ellesmere Island of Arctic Canada, and the lower Dinwoody Formation of Montana.

The Permian-Triassic strata of the Guryul Ravine, near Srinagar, Kashmir, were first reported on by HAYDEN (1907) and in more detail by MIDDLEMISS (1910). Recently TEICHERT, KUMMEL, and KAPOOR (1970) visited the area and discovered that the "Black Shales" unit of MIDDLEMISS contained fossiliferous beds in which *Spinomarginifera* and other productid brachiopods, typically Permian in aspect, are in association with *Claraia,* a bivalve typical of the lower half of the Scythian. Later that year NAKAZAWA *et al.* (1970) published a more comprehensive report on the sequence and faunas of these boundary beds at Guryul Ravine. These authors discovered in the critical boundary beds, in addition to the productids and *Claraia,* species of *Otoceras, Ophiceras,* and *"Glyptophiceras."* NAKAZAWA *et al.* (1970) came to the same conclusion as to the placement of the Permian-Triassic boundary as TEICHERT, KUMMEL, and KAPOOR (1970). Also, at about this time, SWEET (1970b) reported on the conodonts from the Permian-Triassic boundary beds from samples submitted by TEICHERT. His main conclusion was that "conodonts from the upper 57 feet of the Zewan Series and the lower 124 feet of the overlying Lower Triassic beds in the section at Guryul Ravine, Kashmir, represent four distinct conodont faunas that may be correlated with those of the *Anchignathodus typicalis, Neogondolella carinata, Neospathodus dieneri,* and *Neospathodus crystagalli* zones of the Salt Range and Trans-Indus Ranges of Pakistan." SWEET (1973) further refined his discussion of the Kashmir sequence and integrated his conodont data with those of NAKAZAWA *et al.* (1970) on ammonoids and *Claraia.* Finally, in collaboration with a co-author (MIKAN & SWEET, 1974) further analysis of the Kashmir section renewed interest in the problem. The abstract is worth quoting in full: "Graphic correlation, using published data on the ranges of conodonts and key ammonoids, have been effected between important Permo-Triassic sections in Kashmir, the Salt Range of Pakistan, and the Julfa district of northwest Iran. Although there are unresolved taxonomic and distributional problems, a preliminary analysis of the results indicates that the Kashmir and Iranian sections record an essentially unbroken sequence of latest Permian and earliest Triassic rocks, and that in the Salt Range, Permian rocks range higher (Changhsinghian?) and Triassic strata lower (lower Griesbachian) as has been assumed by recent authors." GRANT and COOPER (1973) have discussed the Guryul Ravine section on the basis of data presented by TEICHERT, KUMMEL, and KAPOOR (1970), SWEET (1970b), and NAKAZAWA *et al.* (1970) from the viewpoint of their expertise on brachiopods. They took exception to the conclusions of the above mentioned workers and placed the boundary at the base of bed 52a of NAKAZAWA *et al.* (1970).

In a final report on the Upper Permian and Lower Triassic of Kashmir, NAKAZAWA *et al.* (1975) placed the Permian-Triassic boundary at the first appearance of *Otoceras woodwardi* (that is, the base of their bed 52). In their preliminary report (NAKAZAWA *et al.,* 1970) the boundary had been placed at the base of their bed 47, which coincides with the first appearance of *Claraia.* It is in beds 47-49 that the majority of Permian brachiopods are present, associated with *Claraia stachei* (BITTNER). In their final report they assigned the *Claraia* to a new species *C. bioni.* The "Permian" elements in bed 52 are now limited to *Marginifera himalayensis, Pustula* sp., *Estheripecten haydeni,* and *Claraia bioni.*

In the classic area of the Salt Range, brachiopods discovered in the Permian-Triassic boundary beds have been the focal point of a stimulating and continuing debate. KUMMEL and TEICHERT (1966, 1970b) reported Permian-like brachiopods in the lower part (mainly lowest one foot) of the dolomite unit of the Kathwai Member of the Mianwali Formation. The initial collections were studied by G. A. COOPER, but as more material was obtained, the study was taken over and published by R. E. GRANT (1970). He reported the following forms from this horizon: *Enteletes* sp., *Orthothetina* cf. *O. arakeljani* SOKOLSKAYA, *O.* sp., *Ombonia* sp., *Derbyia?* sp., *Spinomarginifera* sp., *Linoproductus* sp., *Lyttonia* sp., *Spirigerella* sp., *Crurithyris? extima* GRANT, *Martinia* sp., *Whitspakia* sp., dielasmatids gen. et sp. indet. GRANT (1970) correlated the fauna from the basal foot of the dolomite unit with the Dzhulfian of Armenia. In 1973, GRANT concluded that since *Crurithyris? extima* occurred above the fauna of the lowest foot of the dolomite unit that this upper portion was of Changhsingian age (uppermost Permian), a conclusion quite different from that of KUMMEL and TEICHERT (1970b, 1973).

An important addition to the problem was the discovery by GRANT of a fauna of brachiopods in the white sandstone unit of the Chhidru Formation, which immediately underlies the dolomite unit of the Kathwai Member. From this unit GRANT (1970) identified the following forms: *Aulosteges* sp., *Callispirina* sp., *Chonetella* sp., chonetid indet., *Cleiothyridina* sp. cf. *C. capillata* (WAAGEN), *Derbyia* sp. cf. *D. plicatella* WAAGEN, dielasmatids indet., *Enteletes* sp. 1, *Hemiptychina* sp., *Hustedia* sp., *Kiangsiella* sp., *Linoproductus* sp., *Lyttonia* sp., *Martinia?* sp., *Neospirifer* sp., *Orthotichia* sp. 2, *Richthofenia* sp., *Spiriferella?* sp., *Spirigerella* sp., *Waagenoconcha?* sp., *Whitspakia* sp. 1. GRANT (1970) concluded that this assemblage is typical for the Chhidru Formation as a whole, which he believed to be of Guadalupian age.

KUMMEL and TEICHERT (1970b, p. 73) found this conclusion difficult to accept and stated some of their points as follows: "It appears that the direction of comparisons has been downward stratigraphically with no attention paid to the possibility of longer ranges of the taxa concerned. None of the species have been definitely identified and named, and most of the 19 genera recognized in the white sandstone assemblage have long ranges. Eleven of them originated in the Carboniferous or Devonian; eight genera range through most or all of the Permian. Attempting to make refined correlations on such long-ranging genera is indeed a difficult task."

The "Permian" brachiopods of the Kathwai Member, GRANT (1970) considered to be quite different from those of the underlying white sandstone unit. It should be noted, however, that of the 11 genera recorded from the Kathwai Member seven are also present in the white sandstone unit and only one species, a new one, has been definitely named. As to the age of the brachiopod assemblage from the dolomite unit of the Kathwai Member, GRANT (1970, p. 125) concluded that it "contains some genera that point to a latest Guadalupian (Lamar equivalent) age, and others that point to a Dzhulfian, or even early Triassic age." The same technique and philosophies applied to the white sandstone assemblage were used to analyze the Kathwai brachiopods. Of the 11 genera in the Kathwai fauna, six, or possibly seven, originated in the Carboniferous, or earlier, and four appear to be confined to the Permian. The extended ranges of some of the genera had already been pointed out by STEPANOV (1967).

The Dzhulfa area of Soviet Armenia has long been a classic area for study of the Permian-Triassic boundary problem. One of the intriguing aspects was the reported association of Permian brachiopods and corals with "ceratitic" ammonoids. A comprehensive report on the Permian and Triassic faunas of this region, edited by Ruzhentsev and Sarycheva (1965), is an important contribution. They placed the Permian-Triassic boundary just beneath an approximately 20-meter thickness of strata that contain Permian brachiopods and corals along with ceratitic ammonoids (*"Tompophiceras," Dzhulfites, "Bernhardites,"* and *Paratirolites*). These strata were included in the Induan Stage (lowest Scythian). These critical strata are now known to crop out south of the Aras River, in northwestern Iran. A comprehensive report on these occurrences has been published by Stepanov *et al.* (1969). These authors, in discussing the 20 m of beds with the so-called mixed fauna, came to the same conclusion as Ruzhentsev and Sarycheva (1965), that they are earliest Triassic (Induan) in age. Kummel and Teichert had the opportunity of visiting the same Iranian locality, known as Kuh-e-Ali Bashi. Their report (Teichert, Kummel, & Sweet, 1973) presented a detailed summary of the stratigraphy and paleontology of the critical 20 m of strata with the so-called mixed fauna (which they named the Ali Bashi Formation). One of the most important finds were ammonoids previously known only from the Changhsingian fauna of southern China. Their primary conclusion was that the Ali Bashi Formation does not contain any distinctively Triassic components and is latest Permian in age.

The only report known to me on "Permian" brachiopods in Lower Triassic strata from Japan is a brief statement by Nakazawa (1971) concerning a relict productoid *(Plicatifer?)* and a Paleozoic-type bivalve *("Streblochondria")* from the middle Scythian Kurotaki Limestone in Shikoku.

The first mention of a mixed Permian-Triassic fauna from East Greenland in the boundary zone is by Spath (1930, p. 69) and he commented further on this matter in 1935. At the time of Spath's first writing on this subject, the beds underlying the Triassic were believed to be Early Carboniferous in age. It is easy to understand why redeposition seemed to be the natural answer. Shortly after, the age was changed to Late Carboniferous (Frebold, 1931). Frebold (1932) moved part of the "Upper Carboniferous" into the Lower Permian and Aldinger (1935), revising the fish fauna of the *"Posidonomya* shale," placed these beds in the Artinskian. Miller and Furnish (1940) described the ammonoid *Cyclolobus* from the *Martinia* beds of Clavering Ø; in line with the thinking of that time, this made these beds latest Permian in age. Trümpy (1960, 1961) visited the Kap Stosch area of East Greenland and made observations on the Permian-Triassic boundary problem. His main conclusion was that mixed faunas did indeed occur and that in East Greenland faunas of Permian and Triassic habitus co-existed for a time.

In the summer of 1967 Teichert and Kummel visited Kap Stosch specifically to study the Permian-Triassic boundary beds. The primary conclusions of their study (Teichert & Kummel, 1973, 1976) are as follows: 1) The Permian fossils occur in different localities from the very base of the Triassic System up to a distance of between 80 and 100 m above this base. They represent remains of bryozoans and brachiopods, with minor fragments of ostracodes, crinoids, and echinoids; 2) between Rivers 7 and 14 (southwest of Kap Stosch) all Permian fossils occur in arkosic sandstone or conglomerate along with ophiceratids or *Otoceras* or both; 3) almost all Permian fossils are damaged or badly broken into unidentifiable fragments; 4) the specimens that can be identified belong to species that occur in the typical *Productus* limestone and *Martinia* shale facies of the Upper Permian directly below the Triassic; 5) the Permian-Triassic sections southwest of Kap Stosch are of homogeneous shale, silty shale, and siltstone facies; nearly all are markedly soft. Solifluction has so badly affected all outcrops that meaningful stratigraphic sections are next to impossible to obtain; 6) the Permian fossils in the Early Triassic sediments do not represent survivors from the Permian into the Triassic but were redeposited from some land area to the west in which Permian outcrops occurred. A most

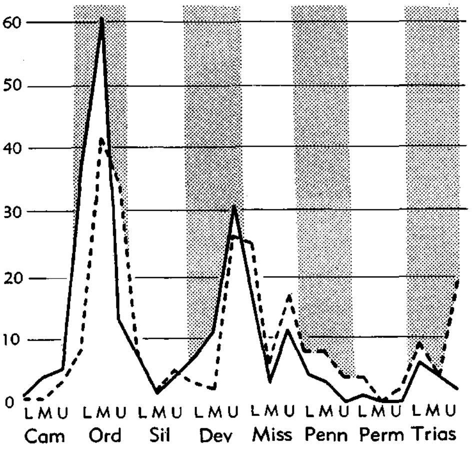

FIG. 9. Total new conodont form genera (solid line) that appeared during Cambrian through Triassic compared with total number that became extinct (dashed line) during the same period (from Clark, 1972).

probable mode of transport of some of the specimens was in argillaceous boulders.

WATERHOUSE (1972) has described a single specimen consisting of the ventral valve of an overtoniid brachiopod (*?Krotovia* sp.) from the Blind Fiord Formation (Early Triassic-Griesbachian age) on Axel Heiberg Island. No other fossils were found in the bed that yielded the brachiopod specimen. The stratigraphy of this area has been worked out by R. THORSTEINSSON and E. T. TOZER and the age assignment and correlation of the beds seem to be most reasonable. WATERHOUSE (1972, p. 486) concluded "It is not clear whether the specimen was derived from Permian rocks or was really of Griesbachian age. The latter appears likely from the fact that no similar specimens are known from underlying Permian."

Recently Permian brachiopods have been noted from the Dinwoody Formation of western Wyoming and Montana. All that is available in print on this is a short note by GRANT and COOPER (1973, p. 585) that is worth quoting as it warrants following up: "Recently D. W. Boyd (University of Wyoming) sent Grant a collection of brachiopods from the lower part of the Dinwoody Formation at Teton Pass, Wyoming. Preliminary identification suggested a Dzhulfian age, with a small productid like *Spinomarginifera,* or *Echinauris* and possibly also *Araxathyris,* although Cooper would call the latter *Composita.* Field work in Montana since the Symposium also turned up Permian type brachiopods as high as 8 feet above the base of the basal Dinwoody at two places in southern Montana and W. L. Stokes (University of Utah) brought to the Symposium a small collection of well-preserved brachiopods from the Dinwoody Formation that certainly look Permian. At least seven genera of brachiopods of Permian aspect now have been obtained from the supposedly Triassic Dinwoody Formation, a situation analogous to that of the Dolomite unit of the Salt Range."

It should be clear from the above brief review that there is at the moment no consensus as to precisely how the Permian-Triassic boundary should be defined nor as to the interpretation of "Permian" brachiopods along with Triassic ammonoids.

## CONODONTS

One of the dramatic new elements in the biostratigraphic analysis of the Triassic has been the study of its conodonts. Systematic study of these Triassic fossils began in 1956 (MÜLLER, 1956; TATGE, 1956). There had been earlier reports of Triassic conodonts but these generally were interpreted as reworked Paleozoic forms. Since 1956 there has been an increasing number of Triassic conodont faunal studies, especially of the Early Triassic faunas.

A brief but excellent overview of conodont diversity from the Cambrian through the Triassic has been presented by CLARK (1972). He produced a number of graphs to illustrate conodont diversity through time, one of which is here produced as Figure 9. CLARK's (1972, p. 150) analysis of this graph is as follows: "Here, the total new form genera that evolved during each epoch is plotted against the number of form genera that became extinct during that epoch. In this figure, the presence of the dashed line above the solid line is the signal of an approaching crisis, i.e., more form genera were becoming extinct than were evolving. Significantly, the Middle Ordovician peak is followed by a large drop in the Silurian when approximately as many

| Series | Stage | Substage | Ammonoid Zones (after Tozer, 1971) | Conodont Zones |
|---|---|---|---|---|
| UPPER TRIASSIC | RHAETIAN | | Choristoceras marshi | Conodonts present but not diagnostic |
| | NORIAN | UPPER NORIAN | Rhabdoceras suessi | 22 Epigondolella bidentata |
| | | MIDDLE NORIAN | Himavatites columbianus<br>Drepanites rutherfordi<br>Juvavites magnus | 21 |
| | | LOWER NORIAN | Malayites dawsoni<br>Mojsisovicsites kerri | 20 Epigondolella abneptis |
| | CARNIAN | UPPER CARNIAN | Klamathites macrolobatus<br>Tropites welleri<br>Tropites dilleri | 19 Paragondolella polygnathiformis |
| | | LOWER CARNIAN | Sirenites nanseni<br>Trachyceras obesum | 18 Neospathodus newpassensis |
| MIDDLE TRIASSIC | LADINIAN | UPPER LADINIAN | Frankites sutherlandi<br>Maclearnoceras maclearni<br>Meginoceras meginae | 17 Epigondolella mungoensis |
| | | LOWER LADINIAN | Progonoceratites poseidon<br>Protrachyceras subasperum | 16 Neogondolella mombergensis |
| | ANISIAN | UPPER ANISIAN | Gymnotoceras occidentalis<br>Gymnotoceras meeki<br>Gymnotoceras rotelliforme | 15 Neogondolella constricta |
| | | M. ANISIAN | Balatonites shoshonensis<br>Acrochordiceras hyatti | 14 |
| | | L. ANISIAN | Lenotropites caurus | |
| LOWER TRIASSIC (SCYTHIAN) | SPATHIAN | | Neopopanoceras haugi<br>Subcolumbites beds<br>Columbites & Tirolites beds | 13 Neospathodus timorensis |
| | | | | 12 Neogondolella jubata |
| | | | | 11 |
| | | | | 10 Platyvillosus |
| | SMITHIAN | | Wasatchites tardus<br>Euflemingites romunderi | 9 Neogondolella milleri |
| | | | | 8 Neospathodus conservativus |
| | | | | 7 Parachirognathus—Furnishius |
| | | | | 6 Neospathodus pakistanensis |
| | DIENERIAN | | Vavilovites sverdrupi<br>Proptychites candidus | 5 Neospathodus cristagalli |
| | | | | 4 Neospathodus dieneri |
| | | | | 3 Neospathodus kummeli |
| | GRIESBACHIAN | UPPER GRIESBACHIAN | Proptychites strigatus<br>Ophiceras commune | 2 Neogondolella carinata |
| | | LOWER GRIESBACHIAN | Otoceras boreale<br>Otoceras concavum | 1 Anchignathodus typicalis |

FIG. 10. Triassic ammonoid and conodont zones (after Sweet *et al.*, 1971).

form genera were becoming extinct as were evolving. The real crisis is first evident during the Late Ordovician when more form genera became extinct than appeared. The consequence is the first conodont crisis, that of the Silurian. Number of new form genera exceeds number of extinct taxa by the Early Devonian and the second evolutionary expansion was during the Late Devonian. Significantly, however, the large number of extinct form genera during the Late Devonian and succeeding Early Mississippian more than offset this expansion and by the Early Mississippian, more genera were becoming extinct than were evolving. This pattern was never reversed during the following years of conodont evolution. The dip during the Middle Mississippian may not be real. Very few students have used this "epoch" designation (middle) during the past 30 years and numbers put on the cards express this bias. Probably a straight line drop from Late Devonian to Late Mississippian is more accurate. The second crisis is a result of the gradual reduction in number of form genera which reached a low in the Permian when no new form genera appear but extinction continued. This is the most profound crisis that conodonts experienced until the Triassic extinction."

In regard to the ancestry of Triassic forms, only one or two Paleozoic genera survived the Permian crisis and relatively few Permian forms contributed to the later Triassic bloom. Considering the conodont assemblages at or near the Permian-Triassic boundary Sweet (1973, p. 630) summarized the data as follows: "All major Permian conodont stocks and most of the species known from latest Permian rocks passed the notorious Permian-Triassic filter with seeming indifference, hence there is no detectable change in conodont faunas at the level of the Permian-Triassic boundary in any of the presumably complete sections from which conodonts are currently known."

Conodont biostratigraphical zonation is developing at a rapid rate. The best general summary of this aspect of conodont studies is that by Sweet *et al.* (1971). In that study the authors recognized a sequence of 22 faunal zones (Fig. 10). Further refinement of this scheme is actively being pursued.

## REFERENCES

**Aldinger, Hermann**, 1935, *Das Alter der jungpaläozoischen Posidonomyaschiefer von Ostgrönland:* Medd. Grønland, v. 98, no. 4, 24 p.

**Anderson, H. M., & Anderson, J. M.**, 1970, *A preliminary review of the biostratigraphy of the uppermost Permian, Triassic and lowermost Jurassic of Gondwanaland:* Palaeont. Africana, v. 13, p. 1-22, charts 1-22.

**Anderson, J. M.**, 1973, *The biostratigraphy of the Permian and Triassic:* Palaeont. Africana, v. 16, p. 59-83.

**Arthaber, Gustav von**, 1927, *Ammonoidea Leiostraca aus der oberen Trias von Timor. 2^E^ Nederlandsche Timor-Expeditie, 1916:* Mijnw. Nederl.-Indië, Jaarb., Jaarg. 1926, p. 1-174, pl. 1-20.

**Assereto, R., Bosellini, A., Fantini Sestini, N., & Sweet, W. C.**, 1973, *The Permian-Triassic boundary in the southern Alps (Italy):* in The Permian and Triassic Systems and their mutual boundary, Alan Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 176-199, text-fig. 1-6.

**Audley-Charles, M. G.**, 1968, *The geology of Portuguese Timor:* Geol. Soc. London, Mem., no. 4, 76 p., 10 text-fig., 13 pl.

**Bando, Yuji**, 1964, *The Triassic stratigraphy and ammonite fauna of Japan:* Tohoku Univ., Sendai, Sci. Rept., ser. 2, geol., v. 36, no. 1, 137 p., 38 text-fig., 15 pl.

**Barthel, K. W.**, 1958, *Eine marine Faunula aus mittleren Trias von Chile:* Neues Jahrb. Mineralogie, Geologie, Paläontologie, v. 106, pt. 3, p. 352-382.

**Batten, R. L.**, 1973, *The vicissitudes of the gastropods during the interval of Guadalupian-Ladinian time:* in The Permian and Triassic Systems and their mutual boundary, A. Logan and L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 596-607, text-fig. 1-5.

**Bion, H. S.**, 1914, *Tract N. of Srinagar and Pahlgam:* in India Geol. Survey, General report for 1913, Rec., v. 44, no. 1, p. 39-40.

**Brennand, T. P.**, 1975, *The Triassic of the North Sea:* in Petroleum and the continental shelf of North-west Europe, A. W. Woodland (ed.), v. 1, Geology, p. 295-310, John Wiley & Sons (New York and Toronto).

**Briden, J. C., Drewry, G. E., & Smith, A. G.**, 1974, *Phanerozoic equal-area world maps:* Jour. Geology, v. 82, p. 555-574, text-fig. 1-18.

**Buch, Leopold von**, 1831, *Explication de trois planches d'ammonites:* 4 p. (Paris).

**Buchan, S. H., Challinor, A., Harland, W. B., & Parker, J. R. R.**, 1965, *The Triassic stratigraphy of Svalbard:* Norsk Polarinst., Skrifter, no. 135, 92 p.

**Chao Kingkoo**, 1959, *Lower Triassic ammonoids from western Kwangsi, China:* Palaeont. Sinica, v. 145, p. 1-355.

**Clark, D. L.**, 1972, *Early Permian crisis and its bearing on Permo-Triassic conodont taxonomy:* Geol. Palaeont., SBI, p. 147-158, text-fig. 1-11, tab. 1-3.

**Collignon, Maurice**, 1973, *Ammonites du Trias inférieur et moyen d'Afghanistan:* Ann. Paléontologie, v. 59, no. 2, p. 8-39, 10 pl.

**Cox, C. B.**, 1973, *Triassic tetrapods:* in Atlas of paleobiogeography, Anthony Hallam (ed.), p. 213-223, text-fig. 1-3, tab. 1-4, Elsevier Scientific Publ. Co. (Amsterdam, London, New York).

**Davoudzadeh, M., & Seyed-Emami, K.**, 1972, *Stratigraphy of the Triassic Nakhlak Group, Anarak*

*Region:* Iran Geol. Survey, Rept., no. 28, p. 5-28, text-fig. 1-8.

**Denmead, A. K.,** 1964, *Note on marine macrofossils with Triassic affinities from the Maryborough Basin, Queensland:* Australian Jour. Sci., v. 27, no. 4, p. 117.

**Dickens, J. M., & McTavish, R. A.,** 1963, *Lower Triassic marine fossils from the Beagle Ridge (BMR 10) bore, Perth Basin, western Australia:* Australia Geol. Soc., Jour., v. 10, pt. 1, p. 123-140.

**Diener, Carl,** 1895, *The cephalopods of the Muschelkalk:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 2, pt. 2, p. 1-120, pl. 1-31.——1897, *The Cephalopoda of the Lower Trias:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 2, pt. 1, p. 1-181, pl. 1-23.——1906, *Fauna of the Tropites-Limestone of Byans:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 5, no. 1, p. 1-201, pl. 1-27.——1907, *The fauna of the Himalayan Muschelkalk:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 5, no. 2, p. 1-139, pl. 1-17.——1908, *Ladinic, Carnic, and Noric faunae of Spiti:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 5, no. 3, p. 1-157, pl. 1-24.——1909, *Himalayan fossils. Fauna of the Traumatocrinus-Limestone of Painkhanda:* India Geol. Survey, Mem., Palaeont. Indica, ser. 15, v. 6, pt. 2, p. 1-39, pl. 1-5. ——1912, *The Trias of the Himalayas:* India Geol. Survey, Mem., v. 36, pt. 3, p. 1-176, text-fig. 1-12, 2 tab.——1915, *Fossilium Catalogus, pt. 8, Cephalopoda Triadica:* 369 p., W. Junk (Berlin).——1923, *Ammonoidea Trachyostraca aus der mittleren und oberen Trias von Timor:* Mijnw. Ned. Oost-Ind., Jaarb., v. 49, p. 73-276, atlas, pl. 1-32.

**Douglas, R. J. W., Gabrielse, H., Wheeler, J. O., Stott, D. F., & Belyea, H. R.,** 1970, *Geology of western Canada:* Canada Geol. Survey, Econ. Geol. Rept., no. 1, p. 365-488, text-fig. 1-53, 20 pl.

**Druckman, Yehezkeel,** 1974, *The stratigraphy of the Triassic sequence in southern Israel:* Israel Geol. Survey, Bull., no. 64, 94 p., 20 text-fig., 31 maps.

**Edgell, H. S.,** 1965, *Triassic ammonite impressions from the type section of the Minchin Siltstone, Perth Basin:* West. Australia Geol. Survey, Ann. Rept. for 1963-1964, p. 55-57, 1 pl.

**Farsan, N. M.,** 1972, *Stratigraphische und paläogeographische Stellung der Khenjan-Serie und deren Pelecypoden (Trias, Afghanistan):* Palaeontographica, v. 140, Abt. A, p. 131-191, text-fig. 1-8, pl. 38-46.——1975, *Pelecypoden aus der Khenjan-Serie von Zentral-Afghanistan (Mittel-Trias):* Palaeontographica, v. 149, Abt. A, p. 119-139, pl. 20,21.

**Fischer, Jochen,** 1971, *Zur Geologie des Kohe Safi bei Kabul (Afghanistan):* Neues Jahrb. Geologie Paläontologie, Abhandl., v. 139, no. 3, p. 267-315, text-fig. 1-17.

**Fleming, C. A.,** 1962, *New Zealand biogeography: a palaeontologist's approach:* Tuatara, v. 10, p. 53-108.——1967, *Biogeographic change related to Mesozoic orogenic history in the southwest Pacific:* Tectonophysics, v. 4, no. 4-6, p. 419-427, text-fig. 1,2.——1970, *The Mesozoic of New Zealand: chapters in the history of the circum-Pacific mobile belt:* Geol. Soc. London, Quart. Jour., v. 125, no. 498, pt. 2, p. 125-170, text-fig. 1-27, pl. 8,9.

**Fleming, P. J. G.,** 1966, *Eotriassic marine bivalves from the Maryborough Basin, south-east Queensland:* Queensland Geol. Survey, Publ. 333, Palaeont. Paper 8, p. 17-29, text-fig. 1-3, pl. 1-9.

**Frebold, Hans,** 1931, *Das marine Oberkarbon Ostgrönlands:* Medd. Grønland, v. 84, no. 2, p. 1-88, 8 pl.——1932, *Marines Unterperm in Ostgrönland und die Frage der Grenzziehung zwischen dem pelagischen Oberkarbon und Unterperm:* Medd. Grønland, v. 84, no. 4, p. 1-35, 1 pl.

**Fuchs, G. R.,** 1964, *Note on the geology of the palaeozoics and mesozoics of the Tibetan zone of the Dolpo Region (Nepal-Himalaya):* Geol. Bundesanstalt, Verhandl., v. 1, p. 6-15, 1 map. ——1967, *Zum Bau des Himalaya:* Öst. Akad. Wiss., Math.-naturwiss. Kl., Denkschr., v. 113, p. 1-211, 70 text-fig., 9 maps.

**Furon, R., & Rosset, L. F.,** 1951, *Contributions à l'étude du Trias en Afghanistan:* Museum Natl. Histoire Nat., Bull., sér. 2, v. 23, p. 558-565.

**Gansser, Augusto,** 1964, *The geology of the Himalayas:* p. iii-xv, 3-289, 149 text-fig., Interscience Publishers, John Wiley & Sons, Ltd. (London, New York, Sydney).

**Grant, R. E.,** 1970, *Brachiopods from Permian-Triassic boundary beds and age of Chhidru Formation, West Pakistan:* in Stratigraphic boundary problems, Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Dept. Geology, Univ. Kansas, Spec. Publ. 4, p. 117-151, text-fig. 1, pl. 1-3.

———, **& Cooper, G. A.,** 1973, *Brachiopods and Permian correlations:* in The Permian and Triassic systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 572-595, text-fig. 1-7.

**Hallam, Anthony (ed.),** 1973, *Atlas of palaeobiogeography:* 531 p., Elsevier Scientific Publ. Co. (Amsterdam, London, New York).

**Harrington, H. J.,** 1962, *Paleogeographic development of South America:* Am. Assoc. Petrol. Geologists, Bull., v. 46, no. 10, p. 1773-1814, text-fig. 1-34.

**Hayden, H. H.,** 1907, *The stratigraphical position of the Gangamopteris Beds of Kashmir:* India Geol. Survey, Records, v. 36, no. 1, p. 23-39. ——1911, *The geology of northern Afghanistan:* Geol. Survey India, Mem., v. 39, p. 1-96.

**Healey, Maud,** 1908, *The fauna of the Napeng beds* *or the Rhaetic beds of upper Burma:* India Geol. Survey, Mem., Palaeont. Indica, n. ser., v. 2, no. 4, p. 1-88, 10 pl.

**Ishii, Ken-ichi, Fischer, Jochen, & Bando, Yuji,** 1971, *Notes on the Permian-Triassic boundary in eastern Afghanistan:* Jour. Geosci., Osaka City Univ., v. 14, art. 1, p. 1-19, text-fig. 1,2, 3 pl.

**Jaworski, Erich,** 1922, *Beiträge zur Geologie und Paläontologie von Südamerica XXVI. Die marine Trias in Südamerika:* Neues Jahrb. Mineralogie, Geologie, Paläontologie, Beil.-Bd. 47, Heft 1, p. 93-200, pl. 4-6.

**Kaever, Matthias,** 1969, *Die Trias Afghanistans:* Zentralbl. Geologie Paläontologie, Teil I, v. 1, p. 170-186.

**Khuc, Vu, Dagys, A. S., Kiparisova, L. D., Nguyen, Nguyen Ba, Srebrodolskaia, I. N., & Bao, Troung Cam,** 1965, *Les fossiles charactéristiques du Trias au nord Viet-Nam:* Direction Générale Géol. RDV. Hanoi, p. 6-77, pl. 1-19.

**Kiparisova, L. D., Okuneva, T. M., & Oleynikov, A. N.,** 1973, *The Triassic system in the U.S.S.R.:* in The Permian and Triassic systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 137-149, text-fig. 1, tab. 1,2.

———, **& Popov, Yu.N.,** 1956, *Raschlenenie nizhnego otdela triasovoii sistemy na yarusy:* Akad. Nauk SSSR, Doklady, v. 109, no. 4, p. 842-845. [*Separation of the lower part of the Triassic System into stages.*]

———, **Radchenko, G. P., & Gorskiy, V. P. (eds.),** 1973, *Stratigrafiya SSSR. Triasovaya sistema:* Akad. Nauk SSSR, Minist. Geol., Minist. Vysshego Sred. Spetsial. Obrazovan. SSSR, 557 p., 96 text-fig., appendix 1-9. [*Stratigraphy of the USSR. Triassic System.*]

**Kittl, Ernst,** 1903, *Die Cephalopoden der oberen Werfener Schichten von Muć in Dalmatien sowie von anderen dalmitinischen, bosnischherzegowinischen und alpinen Lokalitäten:* Geol. Reichsanst. Wien, Abhandl., v. 20, p. 1-77, pl. 1-11.

**Korchinskaya, M. V.,** 1973, *Biostratigraphy of Triassic deposits of Svalbard:* in The Permian and Triassic systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 261-268, 1 tab.

**Krafft, Albrecht von,** 1902, *Lower Trias fossils:* Geol. Survey India, Gen. Rept., 1901-1902, p. 5.

———, **& Diener, Carl,** 1909, *Lower Triassic Cephalopoda from Spiti, Malla-Johar and Byans:* India Geol. Survey Mem., Palaeont. Indica, ser. 15, v. 6, no. 1, p. 1-186, pl. 1-31.

**Kummel, Bernhard,** 1953a, *American Triassic coiled nautiloids:* U.S. Geol. Survey, Prof. Paper 250, p. 1-104, 43 text-fig., pl. 1-19.——1953b, *Middle Triassic ammonites from Peary Land:* Medd. Grønland, v. 127, no. 1, p. 1-21, pl. 1.——1954, *Triassic stratigraphy of southeastern Idaho and adjacent areas:* U.S. Geol. Survey, Prof. Paper 254H, p. 165-194.——1966a, *A Triassic ammonite from the Hindubagh Region, Baluchistan, West Pakistan:* Harvard Univ., Museum Comp. Zoology, Breviora, no. 248, p. 1-5, pl. 1.——1966b, *The Lower Triassic formations of the Salt Range and Trans-Indus Ranges, West Pakistan:* Harvard Univ., Museum Comp. Zoology, Bull., v. 134, no. 10, p. 361-429, pl. 1-4.——1968, *Additional Scythian ammonoids from Afghanistan:* Harvard Univ., Museum Comp. Zoology, Bull., v. 136, no. 13, p. 483-569, text-fig. 1-5, pl. 1-3.——1969, *Ammonoids of the late Scythian (Lower Triassic):* Harvard Univ., Museum Comp. Zoology, Bull., v. 137, no. 3, p. 311-690, pl. 1-71.——1970, *Ammonoids from the Kathwai Member:* in Stratigraphic boundary problems, Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Dept. Geol., Univ. Kansas, Spec. Publ. 4, p. 177-192, text-fig. 1,2, 2 pl.

———, **& Erben, H. K.,** 1968, *Lower and Middle Triassic cephalopods from Afghanistan:* Palaeontographica, v. 129, Abt. A, p. 95-148, text-fig. 1-20, pl. 19-24.

———, **& Fuchs, R. L.,** 1953, *The Triassic of South America:* Soc. Geol. Perú, Bol., v. 26, p. 95-120.

———, **& Teichert, Curt,** 1966, *Relations between the Permian and Triassic formations in the Salt Range and Trans-Indus ranges, West Pakistan:* Neues Jahrb. Geologie, Paläontologie, Abhandl., v. 125, p. 297-333, text-fig. 1-4, pl. 27-28.——(eds.), 1970a, *Stratigraphic boundary problems: Permian and Triassic of West Pakistan:* Dept. Geology, Univ. Kansas, Spec. Publ. 4, 474 p. ——1970b, *Stratigraphy and paleontology of the Permian-Triassic boundary beds, Salt Range and Trans-Indus ranges, West Pakistan*: in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Dept. Geol., Univ. Kansas, Spec. Publ. 4, p. 1-110, text-fig. 1-19.——1973, *The Permian-Triassic boundary in central Tethys:* in The Permian and Triassic systems and their mutual boundary, Alan Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 17-34, 10 text-fig.

**Kutassy, A.,** 1933, *Fossilium Catalogus, I, Animalia, Pt. 56, Cephalopoda triadica II:* p. 371-832, W. Junk (Berlin).

**Liu Hung-yün,** 1959, *Paleogeographical maps of China* [in Chinese]: 69 p., Institute of Geology and Paleontology, Academia Sinica, K'o hsüeh ch'u pan shê (Peking).

**McTavish, R. A.,** 1973, *Triassic conodont faunas from western Australia:* Neues Jahrb. Geologie Paläontologie, Abhandl., v. 143, no. 3, p. 275-303, pl. 1,2.

———, **& Dickens, J. M.,** 1974, *The age of Kockatea shale (Lower Triassic), Perth Basin—A reassessment:* Geol. Soc. Australia, Jour., v. 21, pt. 2, p. 195-201, text-fig. 1,2.

**Marwick, John,** 1953, *Faunal migrations in New Zealand seas during the Triassic and Jurassic:* New Zealand Jour. Sci. Technology, v. B34, no. 5, p. 317-321.

**Middlemiss, C. S.,** 1910, *A revision of the Silurian-Trias sequence in Kashmir:* India Geol. Survey, Records, v. 40, no. 3, p. 206-260.

**Mikan, F. A., & Sweet, W. C.,** 1974, *Graphic correlation of key Permo-Triassic sections in Kashmir, Pakistan and Iran:* Geol. Soc. America, Abstracts with Programs, v. 6, no. 6, p. 531.

**Miller, A. K., & Furnish, W. M.,** 1940, *Permian ammonoids of the Guadalupe Mountain region and adjacent regions:* Geol. Soc. America, Spec. Paper 26, 242 p., 44 pl.

**Minato, Masao, Gorai, M., & Hunahashi, M. (eds.),** 1965, *The geologic developments of the Japanese Islands:* 442 p., 137 text-fig., 30 maps, 44 tab., Tsukiji Shokan Co., Ltd. (Tokyo).

**Mojsisovics, E. von, Waagen, Wm., & Diener, Carl,** 1895, *Entwurf einer Gliederung der pelagischen Sedimente des Trias-Systems:* Akad. Wiss. Wien, Sitzungsber., v. 104, no. 1, p. 1271-1302.

**Müller, K. J.,** 1956, *Triassic conodonts from Nevada:* Jour. Paleontology, v. 30, no. 4, p. 818-830, pl. 95,96.

**Nakazawa, Keiji,** 1971, *On the Lower Triassic Kurotaki fauna in Shikoku and its allied faunas in Japan:* Kyoto Univ., Mem. Fac. Sci., ser. geol. min., v. 37, no. 2, p. 163-172.

——, **& Bando, Yuji,** 1968, *Lower and Middle Triassic ammonites from Portuguese Timor (Palaeontological study of Portuguese Timor, 4):* Kyoto Univ., Mem. Fac. Sci., ser. geol. min., v. 34, no. 2, p. 83-114, text-fig. 1-14, pl. 4-7.

——, **Kapoor, H. M., Ishii, Ken-ichi, Bando, Yuji, Maegoya, T., Shimizu, D., Nogami, Yasuo, Tokuoka, T., & Nohda, Susumu,** 1970, *Preliminary report on the Permo-Trias of Kashmir:* Kyoto Univ., Mem. Fac. Sci., ser. geol. min., v. 37, no. 2, p. 163-172.

——, ——, ——, ——, **Okimura, Y., & Tokuoka, T.,** 1975, *The Upper Permian and the Lower Triassic in Kashmir, India:* Kyoto Univ., Mem. Fac. Sci., ser. geol. min., v. 42, no. 1, p. 1-106, text-fig. 1-15, 12 pl.

——, **& Runnegar, Bruce,** 1973, *The Permian-Triassic boundary: A crisis for bivalves?:* in The Permian and Triassic systems and their mutual boundary, A. Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 608-621, text-fig. 1-4, tab. 1-4.

**Newell, N. D., & Boyd, D. W.,** 1970, *Oyster-like Permian Bivalvia:* Am. Museum Nat. History, Bull., v. 143, no. 4, p. 217-282, text-fig. 1-34.

**Nogami, Yasuo,** 1968, *Trias-Conodonten von Timor, Malaysien und Japan (Palaeontological study of Portuguese Timor, 5):* Kyoto Univ., Mem. Fac. Sci., ser. geol. min., v. 34, no. 2, p. 115-136, pl. 8-11.

**Pakuckas, C.,** 1928, *Nachtrag zur mittel- und obertriadischen Fauna der Ammonea trachyostraca C. Diener's aus Timor, mit Einleitung und stratigraphischer Zusammenfassung von G. von Arthaber:* Mijnw. Ned. Ind., Jaarb., v. 56, p. 143-218, pl. 1,2.

**Pascoe, E. H.,** 1959, *A manual of the geology of India and Burma:* v. 2, 3rd edit., p. x-xxii, 485-1343, Government of India Press (Calcutta).

**Picard, L., & Flexer, A.,** 1974, *Studies on the stratigraphy of Israel. The Triassic:* p. 7-62, text-fig. 1-25, Israel Institute of Petroleum (Tel Aviv).

**Rostovtsev, K. O., & Azaryan, N. R.,** 1973, *The Permian-Triassic boundary in Transcaucasia:* in The Permian and Triassic systems and their mutual boundary, Alan Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 89-99, text-fig. 1, pl. 1-3.

**Runnegar, Bruce,** 1965, *The bivalves Megadesmus Sowerby and Astartila Dana from the Permian of eastern Australia:* Geol. Soc. Australia, Jour., v. 12, p. 227-252.——1969, *A Lower Triassic ammonoid fauna from southeast Queensland:* Jour. Paleontology, v. 43, no. 3, p. 818-828, text-fig. 1-3, pl. 103-104.

**Ruzhentsev, V. E., & Sarycheva, T. G. (eds.),** 1965, *Razvitie i smena morskikh organizmov na rubezhe Paleozoya i Mezozoya:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 108, p. 1-431. [*Development and change of marine organisms at the Paleozoic-Mesozoic boundary.*]

**Sahni, M. R.,** 1938, *Discovery of Lower Triassic at Nakkam, northern Shan States:* 25th Indian Sci. Congress, Proc., pt. 4, Abstracts, sec. 3, no. 19, p. 114.

**Schindewolf, O. H.,** 1934, *Zur Stammesgeschichte der Cephalopoden:* Preuss. Geol. Landesanst., Jahrb., v. 55, p. 258-283, pl. 19-22.

**Seyed-Emami, Kazem,** 1971, *A summary of the Triassic in Iran:* Geol. Survey Iran, Rept., no. 20, p. 41-53, text-fig. 1,2.——1975, *A new species of Distichites (Ammonoidea) from the Upper Triassic Nayband Formation of the Zefreh area (central Iran):* Neues Jahrb. Geologie Paläontologie, Monatsh., Jahrg. 1975, no. 12, p. 734-744.

**Shevyrev, A. A.,** 1968, *Triasovye ammonoidei yuga SSSR:* Akad. Nauk SSSR, Paleont. Inst., Trudy, v. 119, p. 1-272. [*Triassic ammonoids of the southern USSR.*]

**Silberling, N. J., & Tozer, E. T.,** 1968, *Biostratigraphic classification of marine Triassic in North America:* Geol. Soc. America, Spec. Paper 110, p. 1-63.

**Skwarko, S. K.,** 1967, *First Upper Triassic and ?Lower Jurassic marine Mollusca from New Guinea:* Bur. Min. Res., Geol. Geophys., Canberra, Bull. 75, p. 37-82, 6 pl.——1973a, *Middle and Upper Triassic Mollusca from Yuat River, eastern New Guinea:* Bur. Min. Res., Geol. Geophys., Canberra, Bull. 126, p. 28-50, text-fig. 1-5, pl. 13-27.——1973b, *On the discovery of*

*Halobiidae (Bivalvia, Triassic) in New Guinea:* Bur. Min. Res., Geol. Geophys., Canberra, Bull. 126, p. 51-54, pl. 28.

———, & **Kummel, Bernhard,** 1974, *Marine Triassic molluscs of Australia and New Guinea:* Bur. Min. Res., Geol. Geophys., Canberra, Bull. 150, p. 1-17, pl. 37-42.

**Spath, L. F.,** 1930, *The Eotriassic invertebrate fauna of East Greenland:* Medd. Grønland, v. 83, p. 1-90, pl. 1-12.——1935, *Additions to the Eotriassic invertebrate fauna of East Greenland:* Medd. Grønland, v. 98, p. 1-115, pl. 1-23.

**Spinosa, Claude, Furnish, W. M., & Glenister, B. F.,** 1975, *The Xenodiscidae, Permian ceratitoid ammonoids:* Jour. Paleontology, v. 49, no. 2, p. 239-283, 22 text-fig., 6 pl.

**Stepanov, D. L.,** 1967, *Carboniferous stratigraphy of Iran:* Iran Geol. Survey, internal rept. (unpubl.), geol. note 38.

———, **Golshani, F., & Stöcklin, J.,** 1969, *Upper Permian and Permian-Triassic boundary in north Iran:* Iran Geol. Survey, Rept. no. 12, p. 3-72, text-fig. 1-6, geol. pl. 1-3, pl. 1-15.

**Sweet, W. C.,** 1970a, *Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus ranges, West Pakistan:* in Stratigraphic boundary problems: Permian and Triassic of West Pakistan, Bernhard Kummel & Curt Teichert (eds.), Dept. Geology, Univ. Kansas, Spec. Publ. 4, p. 207-271, text-fig. 1-6, pl. 1-5. ——1970b, *Permian and Triassic conodonts from a section at Guryul Ravine, Vihi District, Kashmir:* Univ. Kansas Paleont. Contrib., Paper 49, p. 1-10, pl. 1.——1973, *Late Permian and Early Triassic conodont faunas:* in The Permian and Triassic systems and their mutual boundary, Alan Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 630-646, 5 text-fig.

———, **Mosher, L. C., Clark, D. L., & Collinson, J. W.,** 1971, *Conodont biostratigraphy of the Triassic:* in Symposium on conodont biostratigraphy, W. C. Sweet & S. M. Bergström (eds.), Geol. Soc. America, Mem., no. 127, p. 441-465.

**Takai, F., Matsumoto, T., & Toriyama, R. (eds.),** 1963, *Geology of Japan:* 279 p., 30 text-fig., Univ. California Press (Berkeley).

**Tamura, Minoru, Hashimoto, W., Igo, H., Ishibashi, T., Iwai, J., Kobayashi, Teichii, Koike, T., Pitakpaivan, K., Sato, T., & Yin, E. H.,** 1975, *Contributions to the geology and paleontology of Southeast Asia, CLI; The Triassic System of Malaysia, Thailand and some adjacent areas:* in Geology and paleontology of Southeast Asia, Teichii Kobayashi & R. Toriyama (eds.), v. 15, p. 103-149, text-fig. 1,2, tab. 1-8, Univ. Tokyo Press (Tokyo).

**Taraz, Hushang,** 1969, *Permo-Triassic section in central Iran:* Am. Assoc. Petrol. Geologists, Bull., v. 53, no. 3, p. 688-693.——1971a, *Uppermost Permian and Permian-Triassic passage beds in central Iran (Abst.):* Internatl. Permian-Triassic Conference, Calgary, 1971, Program with Abstracts, Canad. Petrol. Geologists, Bull., v. 19, no. 2, p. 364-365.——1971b, *Uppermost Permian and Permo-Triassic transition beds in central Iran:* Am. Assoc. Petrol. Geologists, Bull., v. 55, no. 8, p. 1280-1294.——1972, *Géologie de la région Surmaq-Deh Bid, Iran Central:* Univ. Paris-Sud, Orsay, Thèse Sér. A, no. 1007, p. 224. ——1973, *Correlation of uppermost Permian in Iran, Central Asia, and South China:* Am. Assoc. Petrol. Geologists, Bull., v. 57, no. 6, p. 1117-1133.——1974, *Geology of the Surmaq-Deh Bid area Abadeh Region, Central Iran:* Iran Geol. Survey, Rept. no. 37, p. 3-148, 50 text-fig., 17 photo.

**Tatge, Ursula,** 1956, *Conodonten aus dem germanischen Muschelkalk:* Paläont. Zeitschr., v. 30, p. 108-127, 129-147, pl. 5,6.

**Teichert, Curt, & Kummel, Bernhard,** 1973, *Permian-Triassic boundary in the Kap Stosch area, East Greenland:* in The Permian and Triassic systems and their boundary, Alan Logan & L. V. Hills (eds.), Canad. Soc. Petrol. Geologists, Mem. 2, p. 269-285, text-fig. 1-3.——1976, *Permian-Triassic boundary in the Kap Stosch area, East Greenland:* Medd. Grønland, v. 197, no. 5, p. 1-47, text-fig. 1-7, pl. 1-16, tab. 1.

———, ———, & **Kapoor, H. M.,** 1970, *Mixed Permian-Triassic fauna, Guryul Ravine, Kashmir:* Science, v. 167, p. 174-175, text-fig. 1.

———, ———, & **Sweet, Walter,** 1973, *Permian-Triassic strata, Kuh-e-Ali Bashi, northwestern Iran:* Harvard Univ. Museum Comp. Zoology, Bull., v. 145, no. 8, p. 359-472.

**Thomson, M. R. A.,** 1975, *First marine Triassic fauna from the Antarctic Peninsula:* Nature, v. 257, p. 577-578, text-fig. 1,2.

**Thorsteinsson, R., & Tozer, E. T.,** 1970, *Geology of the Arctic Archipelago:* Geol. Survey Canada, Econ. Geology Rept. 1, ed. 5, p. 548-590, text-fig. 1-12, pl. 1-8.

**Tozer, E. T.,** 1965, *Lower Triassic stages and ammonoid zones of Arctic Canada:* Canada Geol. Survey, Paper 65-12, p. 1-14, text-fig. 1,2.——1967, *A standard for Triassic time:* Canada Geol. Survey, Bull. 156, p. 1-103, pl. 1-10.——1972, *Triassic ammonoids and Daonella from the Nakhlak Group Anarak Region, Central Iran:* Iran Geol. Survey, Rept. no. 28, p. 29-69, text-fig. 1-4, pl. 1-10.——1974, *Definitions and limits of Triassic stages and substages: suggestions prompted by comparisons between North America and the alpine-mediterranean region:* in The stratigraphy of the alpine-mediterranean Trias, Symposium, Helmuth Zapfe (ed.), Öst. Akad. Wiss., Schrift. Erdwiss, Komm., v. 2, p. 195-206, tab. 1.

———, & **Parker, J. R.,** 1968, *Notes of the Triassic stratigraphy of Svalbard:* Geol. Mag., v. 105, no. 6, p. 526-542.

**Trümpy, Rudolf,** 1960, *Über die Perm-Trias-Grenze* *in Ostgrönland and über Problematik stratigraphischer Grenzen:* Geol. Rundschau, v. 49, no. 1, p. 97-103.——1961, *Triassic of East Greenland:* in Geology of the Arctic, G. O. Raasch (ed.), v. 1, p. 248-254, Univ. Toronto Press (Toronto).

**Vavilov, M. N., & Lozovskiy, V. R.,** 1970, *K voprosu o yarusnom raschlenenii nizhnego triasa:* Akad. Nauk SSSR, Izvestiya, ser. geol., no. 9, p. 93-99, 2 tab. [*On the problem of Lower Triassic stage differentiation.*]

**Vereshchagin, V. N., & Ronov, A. B. (eds.),** 1968, *Triassovyy, Yurskiy i Melovoy periody:* in Atlas litologo-paleogeografitcheskikh kart SSSR, A. P. Vinogradov (ed.), v. 3, 71 maps, Ministerstvo Geol. SSSR, Akad. Nauk SSSR (Moskva). [Triassic, Jurassic and Cretaceous Periods in *Atlas of the lithological-paleogeographical maps of the USSR.*]

**Waagen, Wilhelm,** 1895, *Fossils from the Ceratite Formation:* India Geol. Survey, Mem., Palaeont. Indica, ser. 13, Salt Range Fossils, v. 2, p. 1-323, pl. 1-40.

**Waterhouse, J. B.,** 1972, *A Permian overtoniid brachiopod in Early Triassic sediments of Axel Heiberg Island, Canadian Arctic and its implications on the Permian-Triassic boundary:* Canad. Jour. Earth Sci., v. 9, no. 5, p. 486-499, text-fig. 1-3, tab. 1-7.

**Welter, O. A.,** 1914, *Die Obertriadischen Ammoniten und Nautiliden von Timor:* Paläontologie von Timor, Lief. 1, 258 p., 36 pl., E. Schweizerbart (Stuttgart).——1915, *Die Ammoniten und Nautiliden der Ladinischen und Anisischen Trias von Timor:* Paläontologie von Timor, Lief. 5, p. 71-136, pl. 83-95, E. Schweizerbart (Stuttgart).——1922, *Die Ammoniten der unteren Trias von Timor:* Paläontologie von Timor, Lief. 11, p. 83-154, pl. 155-171, E. Schweizerbart (Stuttgart).

**Westermann, G. E. G.,** 1973, *The Late Triassic bivalve Monotis:* in Atlas of palaeobiogeography, Anthony Hallam (ed.), p. 251-258, text-fig. 1-3, tab. 1, Elsevier Scientific Publ. Co. (Amsterdam, London, New York).

**Williams, Alwyn, et al.,** 1965, *Treatise on invertebrate paleontology, Part H, Brachiopoda:* R. C. Moore (ed.), 2 vol., xxxii + 927 p., 746 text-fig., Geol. Soc. America and Univ. Kansas Press (Lawrence, Kansas).

**Wilmarth, M. G.,** 1925, *The geologic time classification of the United States Geological Survey compared with other classifications, accompanied by the original definitions of era, period and epoch terms:* U.S. Geol. Survey, Bull. 769, 138 p.

**Wynne, A. B.,** 1878, *On the geology of the Salt Range in the Punjab:* India Geol. Survey, Mem., v. 14, p. 1-313.

**Zakharov, Yu. D.,** 1973, *Novoe yarusnoe i zonalnoe raschlenenie nizhnego otdela triasa:* Akad. Nauk SSSR, Sibir. Otdel., Geol. Geofiz., no. 7, p. 51-59. [*New stage and zonal differentiation for the Lower Triassic.*]——1974, *The importance of palaeobiogeographical data for the solution of the problem on the Lower Triassic division:* in Die Stratigraphie der alpin-mediterranen Trias, Symposium, Helmuth Zapfe (ed.), Öst. Akad. Wiss., Schrift. Erdwiss. Komm., v. 2, p. 237-243.

**Zapfe, Helmuth (ed.),** 1974, *Die Stratigraphie der alpin-mediterranen Trias:* Öst. Akad. Wiss., Schrift. Erdwiss. Komm., v. 2, 251 p., 42 text-fig., 12 pl., 15 tab.

**Zeil, W., & Ichikawa, K.,** 1958, *Marine Mittel-Trias in der Hochkordillere der Provinz Atacama (Chile):* Neues Jahrb. Mineralogie, Geologie, Paläontologie, v. 106, pt. 3, p. 339-351.

**Ziegler, P. A.,** 1975, *North Sea basin history in the tectonic framework of northwestern Europe:* in Petroleum and the continental shelf of North-west Europe, A. W. Woodland (ed.), v. 1, Geology, p. 131-148, John Wiley & Sons (New York, Toronto).

**Ziegler, W. H.,** 1975, *Outline of the geological history of the North Sea:* in Petroleum and the continental shelf of North-west Europe, A. W. Woodland (ed.), v. 1, Geology, p. 165-187, John Wiley & Sons (New York, Toronto).

**Zittel, K. A. von,** 1901, *History of geology and palaeontology to the end of the nineteenth century:* 562 p., Charles Scribner's Sons (New York).