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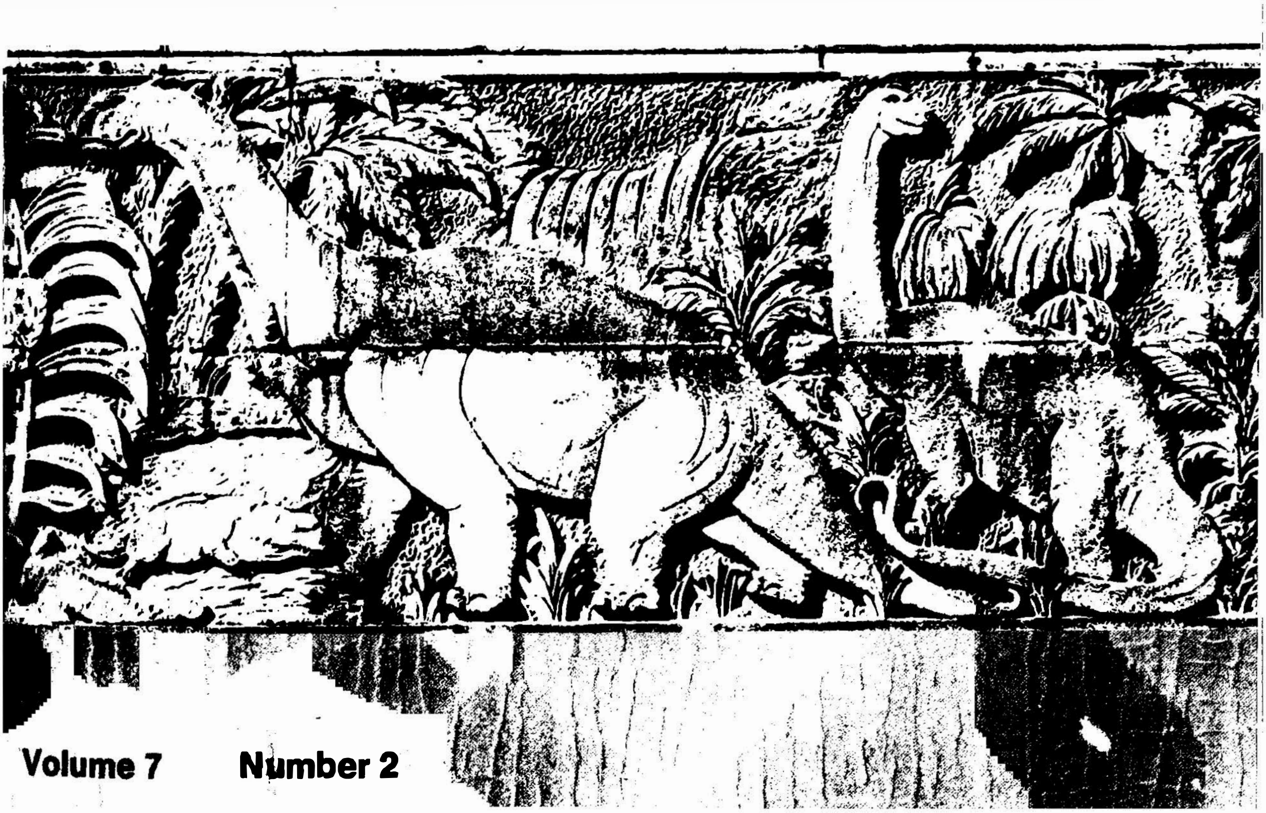
World Correlations for Permian Marine Faunas



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World Correlations for Permian Marine Faunas

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by

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Abstract

The marine Permian faunas of the world are subdivided into eight stages and nineteen substages, the Asselian Stage, with the Surenan, Uskalikian, and Kurmaian Substages; the Sakmarian Stage, with the Tastubian, Sterlitamakian, and Aktastinian Substages; the Baigendzinian Stage, with the Sarginian and Krasnoufimian Substages; the Kungurian Stage, with the Filippovian and Irenian Substages, the latter including the Nevolin, Elkin, and Ufimian horizons; the Kazanian Stage with the Kalinovian and Sosnovian Substages; the Punjabian Stage with the Kalabaghian and Chhidruan Substages; the Djulfian Stage with the Urushtenian and Baisalian Substages, and the Dorashamian Stage with the Vedian and Ogbinan Substages and perhaps Griesbachian Substage or modification thereof. This offers the most extensive and refined scheme of correlation available for the Permian System, in which brachiopod correlations agree well with those proposed for the less abundant Permian ammonoids, and palaeotropical Fusulinacea. Each stage is discussed in terms of its type region and fauna based chiefly on Soviet or Pakistan outcrops, and then traced over the world in various palaeogeographic settings. The base of the Permian Period as understood in some regions possibly overlaps with Late Carboniferous, and the top of the marine Permian probably needs to be elevated to incorporate part or all of the Griesbachian 'Stage', generally classed as basal Triassic. Such questions should be resolved by international discussion.

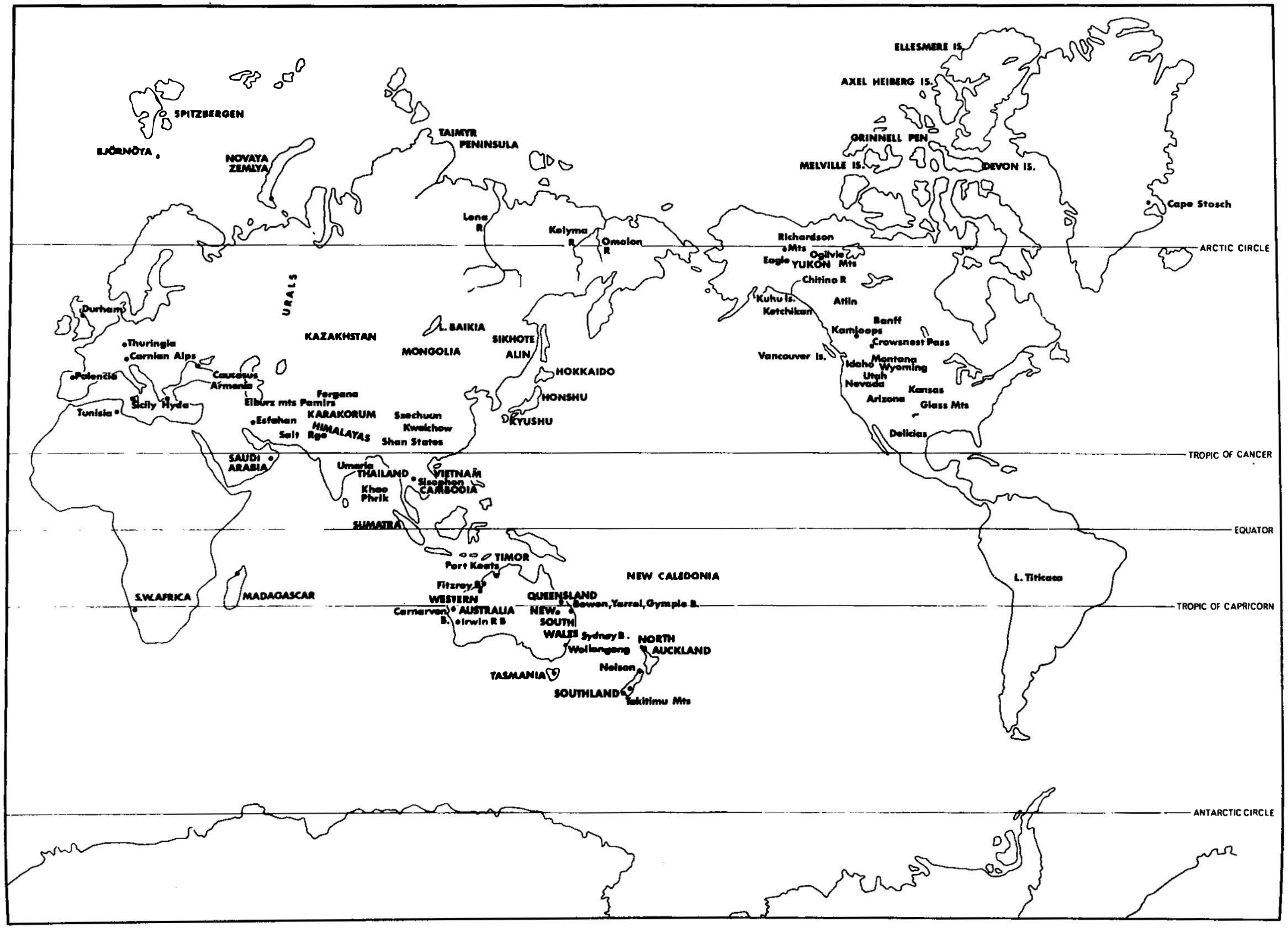

Fig. 1. Mercator projection, showing some of the place names significant for marine Permian corrleations.

Introduction

The Permian System, proposed on the basis of rocks and faunas of the Ural Mountains and Russian Platform in the Soviet Union by Murchison (1841), was one of the more significant periods of earth history. From a scientific viewpoint, the period ended with the greatest of life catastrophes (McAlester, 1973). At its base peculiarly distributed tillites helped suggest the theory of continental drift to Wegener (1929), and its rocks have provided some of the most convincing evidence for continental movement (Irving & Parry 1963). Economically the system has proved to be of high value. Indeed, the copper deposits in the middle Permian Kupferschiefer of Thuringia and Saxony gave the impetus to studies by one of the fathers of geology, Abraham Gottlieb Werner, who taught at the mining school in Freiberg, east Germany. The rich salt, copper, uranium, phosphate, and other mineral deposits of sedimentary and igneous origin, found widely over the world, are reinforced by many oil and gas fields, and enormous coal resources, notably in the fragments of Gondwana and the Tunguskian and other basins of the Soviet Union.

But any full understanding of Permian events and causes in the evolution of life, climatic change, and development of continents and mineral wealth depends on firm control of sequence, or relative age, and this has been markedly lacking for the period. In the first place, in Europe and European Russia, where stratigraphy and palaeontology were established during the nineteenth century, much of the upper half of the Permian System is terrestrial, without marine fossils. This meant that studies elsewhere were done in a vacuum, because no good European section was available for comparison. Secondly, many of the best studies on Permian fossils have been concentrated on Fusulinacea and Ammonoidea. But Fusulinacea are absent from extensive Permian outcrops, including large tracts of the Arctic, the entire continent of Australia, and many other important regions. Ammonoidea are also restricted in distribution, and are seldom numerous enough to establish even local zonation. Both are superbly useful where found, but neither group was common enough and widespread enough to permit detailed and world wide zonation for Permian faunas. We are forced to use ordinary benthos, such as Brachiopoda and to less extent Bivalvia and Gastropoda, and these are so numerous and diverse that it has taken more than a century of study to master the distribution and range of useful species and genera.

It is now timely to incorporate all these studies into a detailed correlation of marine faunas in the Permian System (Table 1, 2). The following outline summarizes the stratigraphic and faunal content of the Russian-based stages and zones, and then traces the faunas over the globe, through similar and different palaeogeographic realms. The study is based on four interrelated procedures by the writer:

1. Detailed studies of faunas and stratigraphy in western and Arctic Canada, Nepal, New Zealand, Thailand, New Caledonia, and Australia, with more limited studies or assessments of faunas from Iran, Burma, India, and England.
2. Study at institutions and museums of faunas described from Mexico, United States, Bolivia, Peru, Spitsbergen, Siberia, Urals, Russian Platform, Tunisia, England, Germany, Sicily, Armenia, Madagascar, Salt Range, Himalayas, Cambodia, and Laos. Faunas from Japan, China, Bellerophonkalk of Austria and Yugoslavia, Karakorum and Greenland have not been seen at first hand.
3. Field observations in United States, Mexico, Bolivia, Brazil, Alaska, East Germany, Carnian Alps (Austria and Italy), Salt Range, Himalayas, and Armenia.
4. Perusal of literature on Permian stratigraphy and faunas, in which faunas were

Series	Stage	Substage	Horizons	P Number & Symbol	
Permian or Triassic		Dienerian			
Upper Permian	Dorashamian	Griesbachian		19	PDg
		Ogbinan		18	PDo
		Vedian		17	PDv
Middle Permian	Djulfian	Baisalian		16	PJb
		Urushtenian		15	PJu
	Punjabian	Chhidruan		14	PPc
		Kalabaghian		13	PPk
	Kazanian	Sosnovian		12	PZs
		Kalinovian		11	PZk
	Kungurian	Irenian	Ufimian	10 c	PKl
			Elkin	10 b	
			Nevolin	10 a	
		Filippovian		9	PKf
Lower Permian	Baigendzinian	Krasnoufimian		8	PBk
		Sarginian		7	PBs
	Sakmarian	Aktastinian		6	PSa
		Sterlitamakian		6	PSs
		Tastubian		4	PSt
	Asselian	Kurmaian		3	PAk
		Uskalikian		2	PAu
		Surenan		1	PAs
Upper Carboniferous	Orenburgian			0	
	Gshelian			0	
	Kasimovian			0	

Table 1. Subdivisions of the marine Permian System

reassessed, reidentified, and aged, it must be stressed, independently from the view expressed in the work, against a total world framework of zones and ages. As far as possible, studies are complete up to the end of 1973.

A companion work to this study is the paper 'Global distributions and character of Permian biomes based on brachiopod assemblages' by Waterhouse & Bonham-Carter (1975) which provides a compact data bank for the distribution of marine brachiopod faunas, substage by substage, with occurrences of brachiopod families and cluster analyses of their associations. The paper by Waterhouse (1975) sets out new taxa for use in the present work. A forthcoming paper will summarize radiometric values for the period, in the light of new stratigraphic advances.

TRANSLITERATION OF RUSSIAN NAMES

In the transliteration of Russian names it has been decided to use proper nouns rather than adjectival derivatives for formational and other stratigraphic terms, thus eliding the 'sk' from many words. In view of the fact that English is not phonetic and not consistent, it is impossible to provide a phonetic rendition of foreign words although various pseudophonetic and somewhat comical renditions are available. Therefore the chief concern has been to treat the words with consistent spelling, and to slightly anglicize them, as must be done if they are to be acceptable, and in some instances, perhaps to enter common usage amongst English-speaking geologists.

Stage	Substage	Permian Platform Urals		Salt Range	Armenia
Dorashamian	Griesbachian	TATARIAN	Kutuluk		
	Ogbinan				*Paratirolites* Z *Comelicania* Z + *Araxilevis* Z
	Vedian		Malokinel		
Djulfian	Baisalian				*Codonofusiella* Z = Abadeh
	Urushtenian		Bolshkinel	Kathwai M	
Punjabian	Chhidruan			Chhidru Fm +	Hachik H
	Kalabaghian		Sok	Kalabagh M +	Gnishik H
Kazanian	Sosnovian	Sosnovian +		Middle	Armik H
	Kalinovian	Kalinovian +		Wargal Fm	
Kungurian	Irenian	Ufimian H + Elkin H + Nevolin H +		Lower	
	Filippovian	Filippovian +			Asni H
Baigendzinian	Krasnoufimian	Saranin (+)		Amb	
	Sarginian	Sarginian +		F	
Sakmarian	Aktastinian	Aktastinian +		Sardi Fm	Davalin H
	Sterlitamakian	Sterlitamakian +		Warchha Fm	
	Tastubian	Tastubian +		*Conularia* Beds	
Asselian	Kurmaian	Kurmaian +		*Eurydesma* beds Talchir	
	Uskalikian	Uskalikian +			
	Surenan	Surenan +			

Table 2 a. Intercorrelations of the most significant marine sequences in the world, for the Permian Period.

M - Member, Fm- Formation, H Horizon, Z - Zone, f - fauna,

+ type for substage.

Arctic Canada		USA Texas		New Zealand		Queensland Australia	China
Griesbachian +		Ochoan Gp		Productus Creek G - Maitai G	*Aperispirifer nelsonensis* Z	? Rewan Fm Baralaba CM	Changsing ? Fm
					Durvilleoceras Z		Wuchiaping Fm
		Capitan L	Hegler M Cherry Canyon M		*Spinomartinia* Z	Tamaree Fm?	
					Plekonella multicostata Z	Upper South Curra Lmst	Maokou Fm
					Martiniopsis woodi Z		
		Word Fm	Appel Ranch M		*Terrakea brachythaerum* Z	Pelican Ck f	
Tahkandit F	*Cancrinelloides* Z		Willis Ranch M		*Echinalosia ovalis Notospirifer* Z	Scottville f	
			?				
			China Tank M				
	Lissochonetes						
	Pseudosyrinx Z		Road Canyon Fm	Takitimu G	*Terrakea exmoorensis* Z	Gebbie G IIIc IIIb IIIa	
	Sowerbina Z	Cathedral Mountain Fm			*Echinalosia* Z *Martinia* Z		Chihsia Fm
	Antiquatonia Z						
Jungle Creek F	*Jakutoproductus* Z	Lenox Hills Fm			*Notostrophia* Z	Sirius Shale Tiverton Fm	
	Tornquistia Z				*Mourlonia* *Atomodesma*		
	Yakovlevia Z					Lizzie Ck Fm	
	Tomiopsis Z	Neal Ranch ? Fm				Burnett Fm Joe Joe Fm	Maping Fm
	Orthotichia Z						
	Kochiproductus Z	Gaptank					

Table 2b. Intercorrelations of the most significant marine sequences in the world for the Permian Period.

CM - Coal Measures; Fm - Formation; f - fauna; Gp - Group; H - Horizon; L - Limestone; M - Member; Z - Zone

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1. Correlation Methods for Marine Permian Invertebrate Faunas

Permian marine faunas and floras are abundant and diverse, and it will probably be found that a number of groups are useful for correlation, when sufficiently studied. Brachiopoda are widespread, moderately numerous, and have been studied for over a century so that these have to assume the main burden of correlation in many regions (Fig.1). Where present, Fusulinacea and Ammonoidea are of high value. All three groups were subject to facies and climatic interference. Fusulinacea were least tolerant, and showed strong provinciality (Ross, 1967b). Ammonoidea were a little more tolerant, but their species and genera were not as wide ranging geographically, nor as tolerant of so many facies as a number of brachiopod species, in spite of what has been written about free floating short lived ammonoid shells (cf. Ustritsky, 1974). Thus ammonoids are absent from most Permian outcrops. Brachiopods varied in their distribution and control by lithofacies, but a number were highly tolerant, widely dispersed, and very short lived. They are the most common macro-invertebrate marine fossil in many Permian deposits.

A number of other groups have high potential. Bivalvia and Gastropoda were rather rare in many parts of the world during the Permian, but ranged more widely than Fusulinacea or Ammonoidea, and locally are valuable. Bryozoa are particularly widespread and numerous, and will probably prove to be as useful as Brachiopoda, but have been somewhat neglected. Studies of microfossils are beginning to show high promise. Small Foraminifera and ostracods have been used successfully for subdividing the Kungurian and Kazanian stages in the Soviet Union and conodonts appear to have excellent potential. Admittedly Grant & Cooper (1973) devastatingly criticized the work by Sweet (1970) on the Permian-Triassic conodonts as being inconsistent, and 'too deferential': but such flaws may not lie in the conodonts themselves. However it still has not been established that they occur abundantly in high palaeolatitudes or in rock with glacial sediment. Plant spores and acritarchs have been studied widely in recent years (Balme, 1970; Hart, 1970; Visscher, 1973), but floral divisions are extremely broad at the moment.

Because of controversy over correlations for the Permian Period, some writers have stressed that each fossil group obeyed its own laws, with evolution proceeding at various rates, so that species of one group were unlikely to have lived and died in phase with species of other groups. This has been most absurdly, yet seriously epitomised in the remark 'Ammonoids don't speak to Fusulines and Fusulines don't speak to Brachiopods'. Although it would be possible to express this concept in some sort of evolutionary model, there is little evidence to support such a view. The present controversies over correlation have resulted from differing interpretations of the same fossils. Errors of correlation have been made, and these may not be excused by allegations of widely disparate behaviour of different fossil groups. The present work will show how, over the entire globe, Fusulinacea, Brachiopoda, and Ammonoidea, and from what is known, the less studied groups, all behaved in harmony. Already it is clear that the Ammonoidea and Fusulinacea are in close agreement for the Early Permian, and brachiopod evidence agrees perfectly with world ammonoid subdivisions for the Early and most of the Middle Permian, indeed for the entire Permian but for one sequence, in the Salt Range. A study by Waterhouse (1973a) on faunas in south-east Asia showed that Fusulinacean zones conformed well with brachiopod zones of the same region. It appears likely that for the duration of a zone various life forms belonged to a closely interlinked plexus of contemporaneous communities, governed by climate and lithofacies,

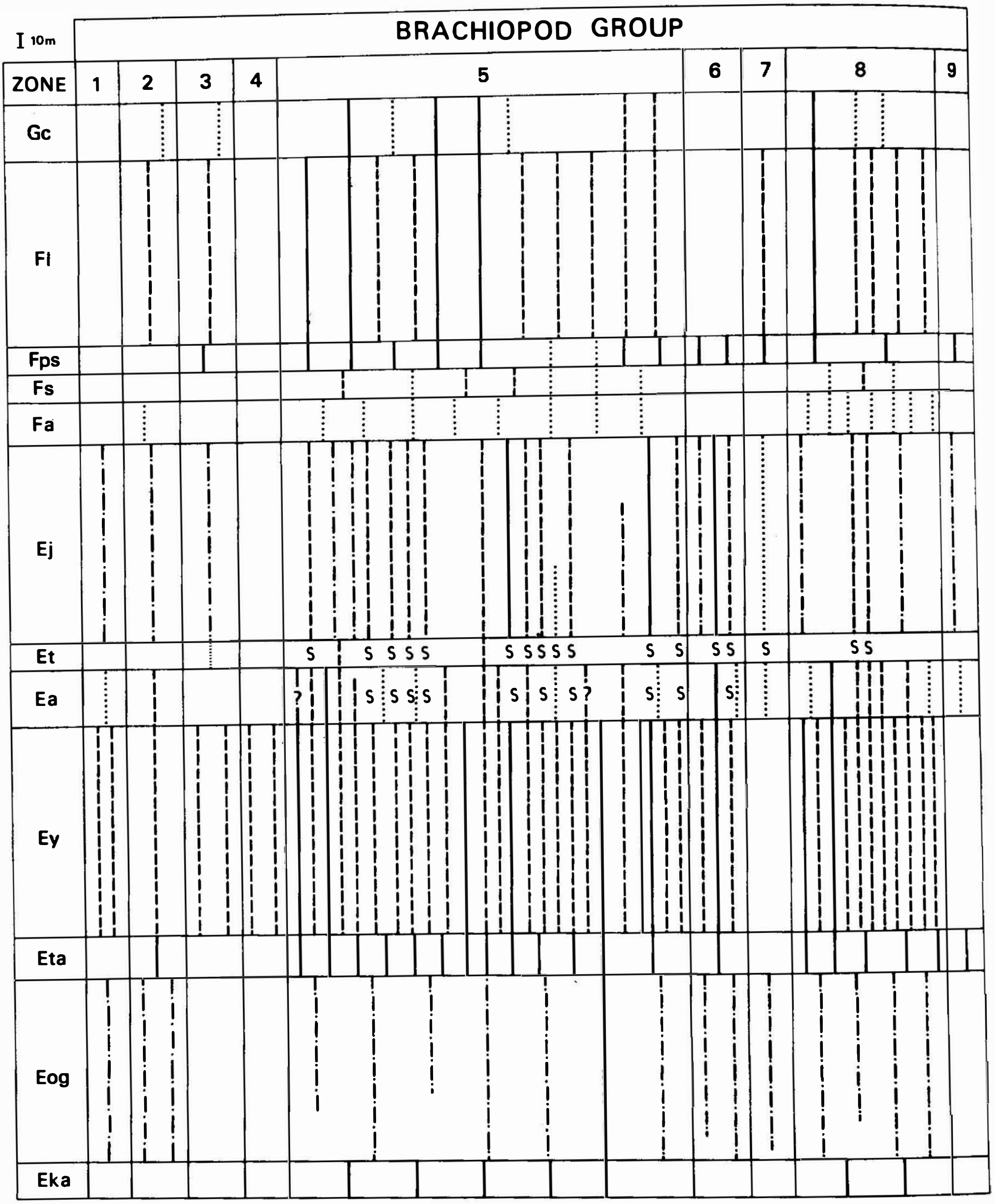


Fig. 2. Range chart of brachiopod species in Permian beds of the north Yukon Territory, Arctic Canada. Species that commence in a zone are assigned a distinct kind of line, and many are replaced from zone to zone, though a few persist. The species are grouped as follows: 1. Inarticulata (zone Ea); Orthida; 2. Davidsoniacea; 3. Chonetidina; 4. Strophalosicacea; 5. Productacea; 6. Rhynchonellida; 7. Atrypida; 8. Spiriferida; 9. Terebratulida. Zones match the type stages and sub-stages, based also on biozones, of the Urals as follows: GC – Lower Kazanian or Kalinovian; Fl – Nevolin; Fps – Filippovian; Fs – Krasnoufimian; Fa – Sarginian; Ej – Aktastinian; Et and Ea – Sterlitamakian; Ey – Tastubian; Eta – Kurmaian; Eok – Uskalikian; Eka – Surenan. The symbol S links species absent from an intervening zone. Thickness approximate, exaggerated for narrow zones.

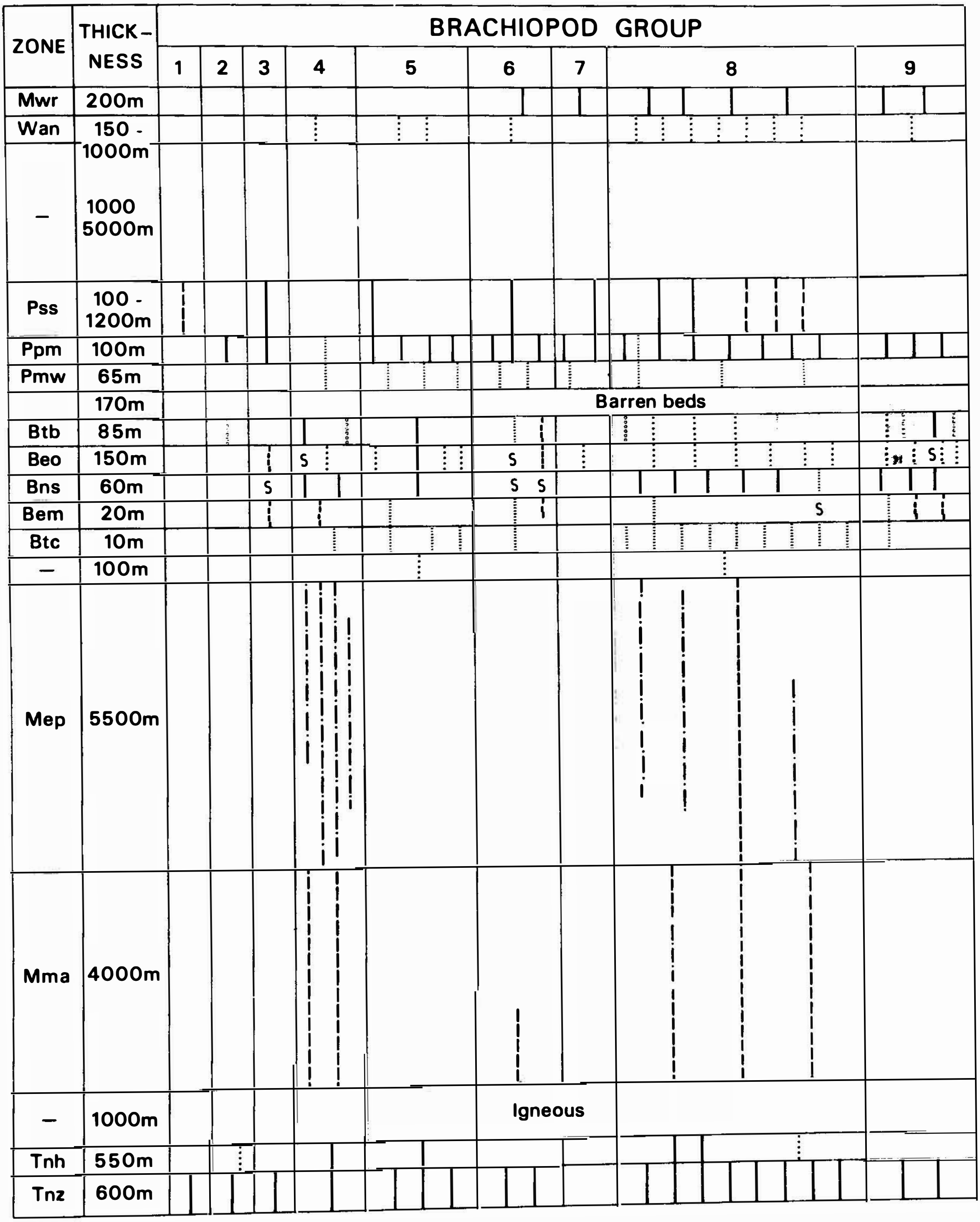


Fig. 3. Range chart for brachiopod species of Permian beds in New Zealand, style and species groups as in Fig. 2, including an Inarticulate in Zone Pss. Stratigraphic columns not fully to scale, and including as shown intervals without brachiopods. Zones match the type stages and substages of Urals, Russian Platform, and Greater and Lesser Caucasus in Armenia as follows: Mwr – Dienerian Substage (of early Triassic age, but with Permian brachiopod genera); Wan – Vedian; Pss – Urushtenian; Ppm – Chhidruan; Pmw – Kalabaghian; Btb – Sosnovian; Beo – Kalinovian; Bns – Ufimian; Bem – Elkin; Btc – Nevolin; – ?Filippovian; Mep – Krasnoufimian; Mma – Sarginian; Tnh, Tnz – Aktastinian.

under prevailing trophic and geochemical conditions. Any evolutionary change to one segment would have had drastic effects on co-habiting groups, at least at the same trophic level, which would then affect life at other trophic levels. Evidence is convincing that Fusulinacea and Brachiopoda (and one would suspect, Bryozoa and Anthozoa) were closely interlinked. Certainly some ammonoid species behaved with greater toleration by living for a longer time, but generally they still show, within their limits of distribution, new incomings at the same time as the rest of the faunas.

Communities and Biozones

Permian marine fauna and flora were organised in communities, for which studies are just commencing (Waterhouse, 1973c). Communities are characterised by their numerically preponderant and large-sized species—perhaps one, to three or four—and may be objectively established by counting individuals in collections after assessing the extent of interference by transport, postburial solution, and extraction. Within the marine environment, a number of different communities generally developed in any one region, each governed by different primary species that were favoured, in the case of brachiopods, by bottom sediment especially, and also influenced by depth, and other biota. As today, a large measure of background control was exerted by salinity, and by temperature, affecting geochemical conditions and trophic resources, so that diversity increased towards the palaeoequator. Over the world, a succession of fossil biomes or major associations of communities were organised, each occupying 15°—30° latitude, in reflection of climate and trophic resources.

The relationship between communities and biozones is particularly critical for biostratigraphy and chronostratigraphy. In practice, palaeontologists have included a number of correlative communities in a single biozone, because the communities shared a sufficient number of species to make up a 'faunal assemblage zone', or each had individuals of a given key species, sufficient to designate a 'range zone', or all shared an important species that made a significant 'first entry', often of high correlative value. Individual communities, though treated as zones in some texts, occupied too small a part of the sedimentary column to be readily mapped as single zones, for one low bluff may expose two to five communities or even more, recurrently. Thus, biozones embrace various fossil communities which were distinguished by their differing response to different environmental parameters, and are correlated because they share significant species. These major assemblages of contemporaneous communities strongly approach the modern 'biome' (Krassilov, 1974; Waterhouse 1974a; Waterhouse & Bonham-Carter, 1975), and are essentially identical with biotic provinces.

Few species within zones of Permian age show morphological clines, anobservation confirmed by Eldredge & Gould (1972) who stated that the geological record seldom reveals what they called 'phyletic gradualism'. Specific and general changes, and as a result, zonal and community boundaries, were abrupt, greatly aiding correlation. This is an important observation, against current fashions in evolutionary theory, but cannot be denied for at least a number of Permian successions that have been discussed in modern terms. Two examples are shown for the brachiopod faunules of Yukon Territory and New Zealand (Fig.2,3). A further example may be drawn from the description of faunas and floras from central Afghanistan (Fig.4) by Termier *et al.* (1974), where a moderately complete succession displays marked and episodic changes in the faunas, changes which appear to coincide with those of the Canadian and New Zealand successions. Termier *et al.* (1974) concluded that the faunal changes were to considerable extent climatically induced, as also hypothesised for the New Zealand and Canadian changes (Waterhouse, 1963; Bamber & Waterhouse, 1971). Once again, there is a suggestive similarity between biozones which appear to have been climatically controlled, and biomes, which are definitely climatically controlled, (Krassilov,1974), or more particularly, geographic subdivisions of a biome, that is, provinces.

CORRELATION OF BIOZONES

Succession

The abrupt changes in the fossil record which provide boundaries for biozones, reinforced by the recurrent nature of major faunal assemblages (Waterhouse, 1973c), establish the basis for world wide correlation. In correlating strata and faunas prime value lies in stratigraphic succession, as also emphasized by Cooper & Grant (1973) in their discussion of the Permian in west Texas. Degrees of freedom, and chance or error are greater in fitting a single faunule into a standard sequence, than in matching a complete sequence with the standard. Let the standard sequence S_1 contain the sequential units:

a_1, b_1, c_1, d_1, e_1, and f_1.

From faunal analysis, a_1 differs from b_1, and from stratigraphic (and rarely evolutionary) analysis, a_1 is older than b_1. Let the sequence S_2 be correlated contain the sequential units:

a_2, b_2, c_2, d_2, e_2.

An established correlation, i.e. faunal similarity between b_1 and b_2 severely restricts possibilities for remaining correlations, for a_2 must now be either older than a_1, as old as a_1, or perhaps as old as b_2. For correlating c_2, the choices are narrowed to six (b_1; c_1; d_1; e_1; f_1; or younger). If each faunule differs, and has upper and lower age limits, the choice is further restricted. And if $b_1 = b_2$, and $d_1 = d_2$, it becomes easy to correlate all five units.

It is likely in many sequential correlations that some faunas may be more positively correlated than others. Some horizons that do not share key species, but share a similar relationship to horizons that do share key species, are deemed correlative. In following this practice, it is advisable to assess where possible a number of communities, for one outstanding community may have been distinguished from contemporaneous communities only by its ecologic rather than temporal parameters.

From inspection it is clear that there are two prime requisites of the standard sequence:

1. that it be complete,
2. that it be in stratigraphic order.

The reason that Permian correlations have been so long delayed lies in the fact that, for more than a century, the world standard has not been complete, and that for the last decade, the sequence has been disordered because the *Cyclolobus* ammonoid zone has been placed too high in the column. As shown in Table 3 the Upper Permian has long been based on the Tatarian red beds, virtually useless for world correlation. The Tatarian equivalents in west Texas—New Mexico, mainly in the so-called Ochoan Stage, are of little more use. An attempt to replace the gap with marine based sequences by ammonoid workers (Miller & Furnish, 1940; Glenister & Furnish, 1961; Furnish, 1973) recognised three stages called Chhidruan, Amarassian, and Capitanian, for units that overlap to considerable degree, being each based on different and miscorrelated sections in the Salt Range, Timor, and New Mexico. Moreover the Chhidruan Stage was incorrectly placed above the so-called Araksian Stage instead of below it (Waterhouse, 1972a, b; Stepanov, 1973; Grant & Cooper, 1973; Taraz, 1973; Termier *et al.*, 1974; Kozur, 1974).

Units

A fundamental question lies in the nature of the units that we seek to correlate. It is widely understood that stages, as defined in Hedberg (1972), are the basic chronostratigraphic unit, but in fact, stages are more or less arbitrary, convenient or historically based bundles of zones—both vertically and laterally. If we are to search for

Table 3. Sources of difficulty arising from use of faulty standard sections

Treatise, Moore et al. 1965.		Furnish 1973	Present Standard	
"Europe" *	"North American" +	Ammonoidea	Stage	Substage
Tatarian (non-marine)	Ochoan (No few marine fossils)	Changhsingian Chhidruan (out of order)	Dorashamian	Griesbachian
				Ogbinan
				Vedian
			Djulfian	Baisalian
		Araksian		Urushtenian
	Guadalupian	Amarassian (=Chhidruan) Capitanian (=Chhidruan Kalabaghian)	Punjabian	Chhidruan
				Kalabaghian
Kazanian		Wordian	Kazanian	Sosnovian
				Kasinovian
Kungurian			Kungurian	Irenian
		Roadian		Filippovian
Artinskian	Leonardian	Leonardian	Baigendzinian	Krasnoufimian
				Sarginian
		Aktastinian	Sakmarian	Aktastinian
Sakmarian	Wolfcampian	Sterlitamakian		Sterlitamakian
		Tastubian		Tastubian
		Asselian	Asselian	Kurmaian
				Uskalikian
				Surenan

* Europe, meaning world standard

\+ North America, meaning Texas, and certainly not Canada or Alaska more objective means of effecting correlation, we look in the first place at biozones (Fig.2,3). Biozones summarise the faunal ranges, acmes, entries, and assemblages, all of which largely coincide at least for the Permian Period. It is biozones that carry the burden of correlation. Stages are further removed from actual outcrops and fossils, and may serve as a convenient simplification and summary of the evidence based on zones. They are much less 'realistic' or 'actualistic' than zones because they often contain widely disparate zones. For instance the Asselian Stage includes three biozonal horizons referred herein to the Surenan, Uskalikian and Kurmaian Substages. The upper and lower faunas are rather similar, the intervening faunas very different. In the Kungurian Stage, the Filippovian Substage is impoverished, the following Nevolin horizon of the Irenian Substage is very richly fossiliferous and different, the following Elkin and Ufimian horizons are somewhat like the Filippovian. The groupings are somewhat arbitrary and have to be, because each zone differs so widely from preceding and succeeding zones.

Perhaps the main usefulness of stages is that they: 1, group disparate zones into a few units, readily understood by non-specialists, and readily mapped for geological surveys; and 2, incorporate barren rock, that often may be at least roughly correlated by its lithologic content, or by radiometry. In a very approximate way, zones scale off the days, and stages scale off the weeks for a period, which matches the month. This analogy expresses well the comparative accuracy.

Subzones and superzones, substages

There are some problems in the use of biozones, even leaving aside the question of exact relationship between communities and zones, discussed previously, with attendant difficulties offered by barren or faunally impoverished beds, and areas with deeply weathered or no outcrop. The prime difficulty centres around scale, or duration of a biozone. Although many sequences display a succession of assemblage zones, that could equally well be treated as range zones on the basis of a number of species, the pattern is frequently overprinted by more or less short-lived acme zones or even range zones of usually one or a very few species that often invade a number of communities simultaneously. Evidently a species has suddenly enjoyed a highly successful burst, and thus marks, at least locally, a most useful datum place. Now how are these 'bursts' to be treated? They correspond in most respects with zones. But the fact that it is sometimes hard to match these zones with comparable zones elsewhere would suggest that they were in some cases very short lived, and possibly of local extent only. Therefore such phenomena were classed as subzones, or 'zone within a zone' by Bamber & Waterhouse (1971). This appears to be a realistic and pragmatic method of sustaining, instead of concealing the evidence. Because the subzone may be upgraded if correlative subzones are found to be extensive and significant, the terminology allows flexibility.

A second term that is mentioned widely in literature, yet which has found no formal definition or consistent application is 'superzone'. It is here suggested that superzone should be restricted chiefly to laterally contiguous and probably correlative biozones, characterised by different assemblages, acme zones and range zones, but linked by certain key species, which do not necessarily range for the full extent of the zone or superzone. This in other words is a step towards the abstract stage concept, still governed by faunal data, but going beyond actual species presence and absence to incorporate species and biozones believed to be contemporaneous. It is close especially to substage, which differs by incorporating barren rock, non-marine rock, and igneous rock. In the past superzones have sometimes been used as a term for very long ranging species but this has seldom been very useful for correlation, and is the same as the range zone. In the present study nineteen substages are recognised and widely correlated around the globe, corresponding approximately with the number of brachiopod super-

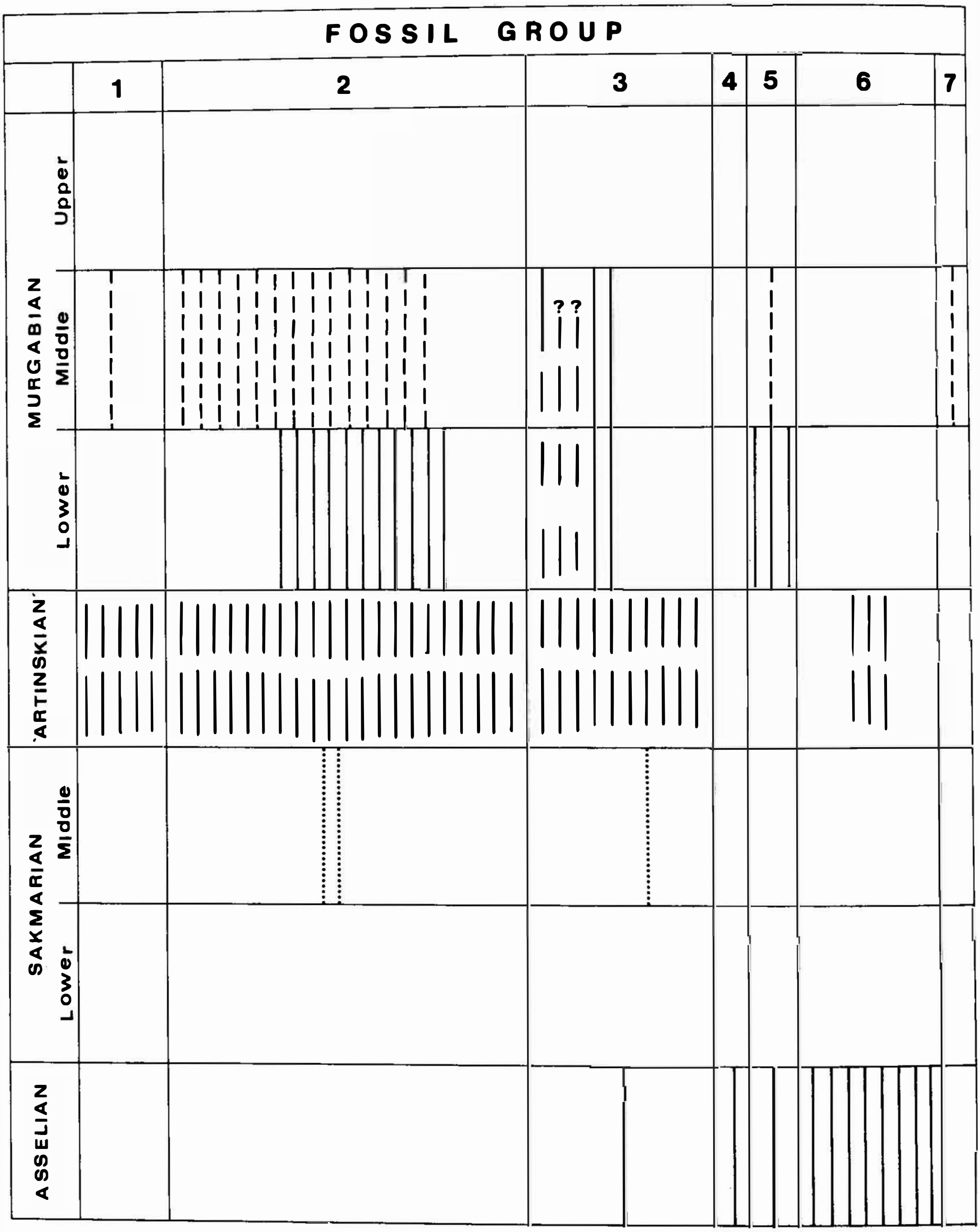
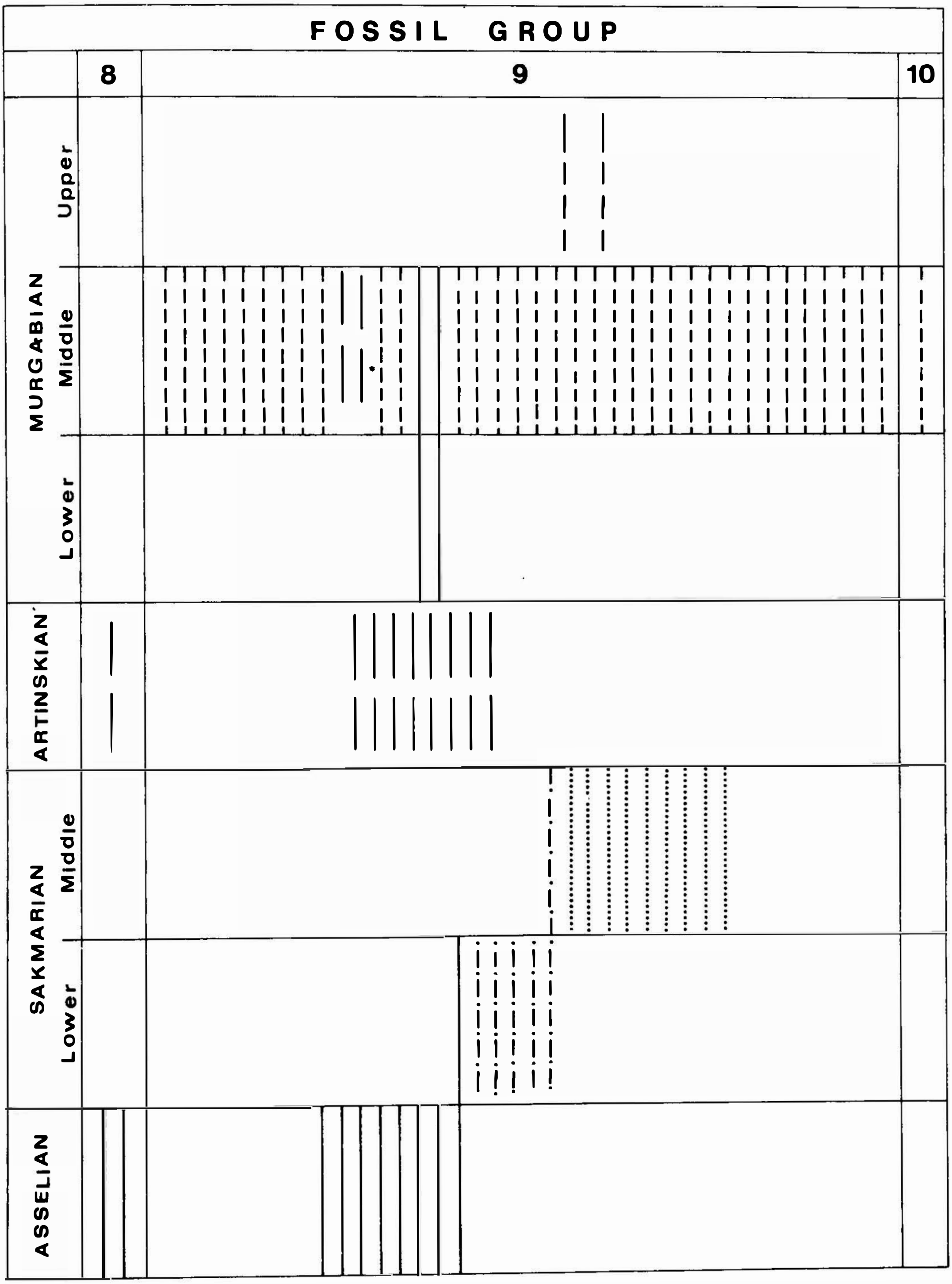


Fig. 4. Chart of species ranges for Permian at Wardak, central Afghanistan, compiled from Termier *et al.* (1974). Note repeated influx of short-lived new or different species, and predominance of brachiopoda, with limited occurrences of Cephalopoda and Fusulinacea, as is usual for most Permian successions. 1. Algae; 2. Foraminifera; 3. Bryozoa; 4. Scyphozoa; 5. Annelids; 6. Bivalvia; 7. Cephalopoda; 8. Gastropoda; 9. Brachiopoda; 10. Arthropoda. In addition some sixteen species of Anthozoa occur in the lower Murgabian (Kungurian approximately). Intercorrelations are somewhat more complicated than for Yukon and New Zealand, so that this chart is not completely correct. It is



based solely on Termier *et al.* (1974). The Murgabian is probably ?Fillippovian, ?Irenian and Kazanian. Fusulinacea and ammonoidea are more abundant nearby in the sections of Tezak (see Termier *et al.*, 1972).

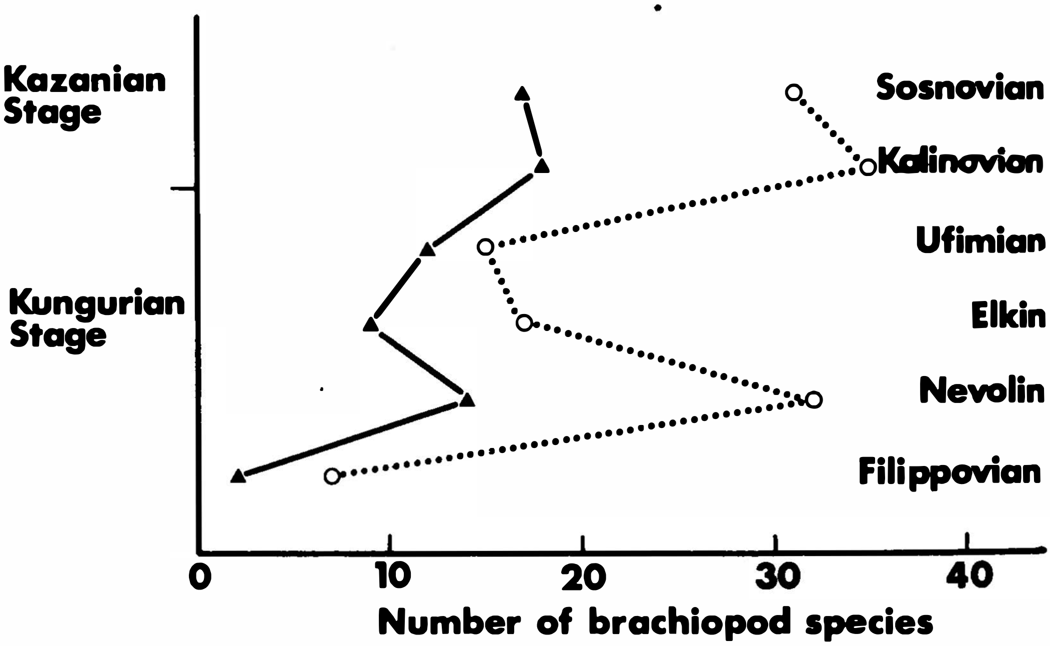


Fig. 5. Diversity graph or "Faunal Signature" of brachiopod species from early Middle Permian sequences of Russian Platform – Urals (world standard) – dotted line – and New Zealand – solid line – showing similar and correlative signatures. Russian data based on studies summarised in Branson (1948), Likharev (1966), Chalishev (1966) and Zolotova *et al.* (1966). New Zealand data summarised from Waterhouse (1973c). Correlations are supported by entry of key species, and succession.

zones. There are likely to be a few more still to be unravelled, perhaps between the Kazanian and Punjabian Stages and within the Chhidruan Substage. Definition of the Permian superzones lies beyond the scope of the present study, for it is easier to deal with substages, but the succession is generalized in Tables 49-52,and the concept underpins the correlations set out in this study.

Key species

The entry of key species that suddenly became prolific and enjoyed a short lived burst offers a most practical method for correlation. There are many such instances at generic and specific level amongst brachiopods. The entry (or re-entry) of the genera *Kochiproductus* and *Attenuatella* at the base of the Permian Period, the incoming of certain species of *Streptorhynchus*, *Cleiothyridina*, *Spiriferellina*, and *Dielasma* in the Kungurian Stage, and of *Cancrinelloides*, *Licharewia*, and *Permospirifer* at the base of the Kazanian Stage enable extensive correlation. All of course are open to revision. The species that are useful for zonal correlation, to the level of substage, are wide-ranging tolerant forms, found in many communities, as either dominants or subordinates, or both. Others were briefly so preponderant numerically that they were prime species over a wide range of lithofacies.

Recurrent and alternating species and genera

On a pragmatic basis, it has been found that some genera appear widely for brief recurrent intervals—such as *Attenuatella* (Table 4). Studies are not yet advanced enough to decide whether one or several species were involved at any one horizon, but the presence and absence of this genus provide several datum planes, especially for the Asselian and Sakmarian Stages. It may be doubted that this genus would everywhere mark exactly the same time, and it is assumed that the recurrent entry of the genus was probably limited to certain palaeogeographic realms, apparently of palaeotropical and especially palaeotemperate character, although this cannot be finally established until the occurrences in Australia come under good control.

In some instances, genera alternated for the part of a succession. For instance throughout the early Middle Permian, the finely costate genus *Neochonetes* alternated with more diversely ornamented allies *Lissochonetes*, *Dyoros*, and *Chonetina* (Table 5). The principal exception is offered by the Magnesian Limestone of England, which has *Neochonetes* and has been regarded as of Nevolin age. Perhaps high salinity affected the fauna, or perhaps the age is really Ufimian, as proposed by Likharev (1959).

Faunal Signature

Throughout a succession zones vary in the number of taxa present, and by plotting the numbers a zig-zag curve is derived, (cf. Miloradovich, 1940) which could be called a faunal signature (Fig.5). This is clearly in part controlled by facies and sampling, but the relative diversity in different collections may be assessed by the formula:

$$\frac{\text{no. of species present—no. of shared species}}{\text{no. of shared species}}$$

As a control for collections from a longer time interval, the number of shared species may be replaced by the number in each collection of the ten most common genera present in the entire succession. Clearly lithofacies and other environmental parameters may have a strong influence on faunal signature. But environment itself changed through time, and thus recorded time.

The concept of faunal signature is in its infancy, but if it works, then departures from the typical signature should reflect local interference to diversity, caused ultimately by unsuitable facies, or other environmental parameters than can be investigated after adequate sampling. It is to be expected that the curves of the faunal signature in

Standard Substages	Yukon	Glass and Hueco Mts.	Kolyma R.	Spitsbergen	Kazhakstan	Mongolia	Tibet	Carnian Alps	Austra- lia	Brazil
Sarginian										
Aktastinian										
Sterlitamakian	A	A							?A	?A
Tastubian		?-								
Kurmaian	A	?-	A				A	A		
Uskalikian		?-								
Surenan	A	?-		?A	A	A		A		

Table 4. Summary of occurrence of *Attenuatella* in a number of correlative horizons (A) and absence from intervening horizons. Occurrence poorly controlled as yet in East Australia, Brazil, and Hueco and Glass Mts.

	Russian Platform	Kolyma (O) Petchora	Greenland (G) Novaya Zemlya (NZ)	Canadian Arctic (A) Archipelago Yukon (Y)	West Americas	California (NC) Europe	Sikhote Alin Taimyr (T)	Salt Range (R) Sumatra	Queensland (Q) New Zealand
?Sosnovian		*Lissochonetes* O					*Lissochonetes* T	*Chonetina* R	
Kalinovian	*Neochonetes*	*Tornquistia* O	*Neochonetes* NZ	*Neochonetes* AY					*Neochonetes*
Ufimian	*?Neochonetes*								*Neochonetes*
Elkin	*Chonetinella*	*Lissochonetes*							
Nevolin	*Chonetinella* *Chonetina*	*Lissochonetes* *Tornquistia* ----------- *?Dyoros* *Arctochonetes* *Tornquistia* *Lissochonetes* *Chonetina* *Neochonetes*	*Chonetina* G *Lissochonetes* G NZ	*Lissochonetes* AY *Chonetinella* A	Meade Peak *Lissochonetes*	*Lissochonetes* *Chonetinella* NC *Neochonetes*	*Chonetina* *Lissochonetes*	*Chonetina*	*Lissochonetes* Q
Filippovian	*Neochonetes*			*?Neochonetes* AY	*Neochonetes* Chocal				

Table 5. Correlations of early Middle Permian strata with alternating occurrences of *Neochonetes* with other chonetids.

reflecting diversity may also convey data about biomass, and so help calibrate environment and time by reflecting changes in trophic resources. Little use of the concept has been made in the present study, other than to use a sudden change in diversity as a suggestion for more refined correlation, to be tested by other means.

Limits of correlation techniques for brachiopods

Some correlation techniques will not work for brachiopods. Few genera were so short-lived that their ranges can be reliably used in the way that ammonoid genera are used, so that correlation must be at a specific rather than generic level. There are some exceptions to this rule, though it will probably transpire that such short-lived genera were rather rare, and sometimes of limited distribution, including some palaeotropical brachiopods. Amongst examples of short-lived genera, *Timaniella* Barkhatova, member of the Spiriferellinae, is found in early Middle Permian beds of Timan, northern Canada, Kamchatka, and perhaps northern Manchuria and central British Columbia.

First entries may also be unreliable. For instance, Cooper (1957) correlated a sizable brachiopod faunule from central Oregon with the Wordian (Mid-Permian), largely, it would seem, on the basis of the presence of Productacean genus *Muirwoodia* Likharev, which entered the Texan sequences of the Glass Mountains in the Wordian. But *Muirwoodia* itself is found widely in the early Permian of the Soviet Union and Canada, and a number of specific brachiopod links strongly suggested that the Oregon faunas are Early Permian (Bamber & Waterhouse, 1971), as confirmed by Fusulinacea (Wilde, 1971). Campbell (1965) stated that *Maorielasma* Waterhouse, a Terebratulid, was restricted to early Middle Permian faunas (chiefly Kungurian-Kazanian), but it is found in late Sakmarian faunas in New Zealand. Armstrong (1968) asserted that the Ambocoeliid genus *Attenuatella* Stehli was not known below the Artinskian. Yet the type species is Sakmarian, and the genus is most widespread and numerous in rocks of Asselian age.

The nature of error in these three examples differed in each instance. Cooper (1957) was well aware that *Muirwoodia* ranged into older rocks in the Soviet Union, but preferred to make correlations with nearby sequences in North America. Subsequent studies have shown that the faunas belonged to different palaeogeographic realms. Armstrong (1968), on the other hand, appears to have overlooked or misinterpreted various references, something that is easily excused in these days of burgeoning literature and inadequate tabulation of data. Campbell (1965) thoroughly studied world literature, and his statement was correct on the basis of what was then known. Any statement on age carried the risk of being upset by later discoveries.

The supposed upper limit of a genus also has dangers. Grant (1970, p.121) placed correlative value on the disappearance of *Waagenoconcha* after the early Guadalupian (Wordian) in the Glass Mountains, but correlations by Grant & Cooper (1973) clearly revised the concept and extended the upper range. On the other hand, as Grant (1970) noted, the Rhynchotetradidae, represented by *Septacamera*, does not appear to be known from any faunas younger than Kungurian. Perhaps we need to be cautious here, for the genus, which is easily confused with Stenoscismatids, may yet be found in younger rocks. Bamber & Waterhouse (1971) and Waterhouse (1972b) noted that the Overtoniidae largely disappeared at the end of the Sakmarian Stage in widely disparate geographic realms of North America from the Canadian Arctic Islands, Yukon, Canadian Rockies, to Texas. Yet a few younger occurrences were noted in that region (Waterhouse, 1972b), and the family appears to have persisted in the Urals and North Russia into the Baigendzinian Stage, with a few younger occurrences. The change was geographic i.e. provincial, rather than climatic or biomal. The Rhipidomellidae also disappeared or more accurately, diminished, early (Dagis & Ustritsky 1973).

Faunal assemblages are easily misjudged without firm control of species. It is all

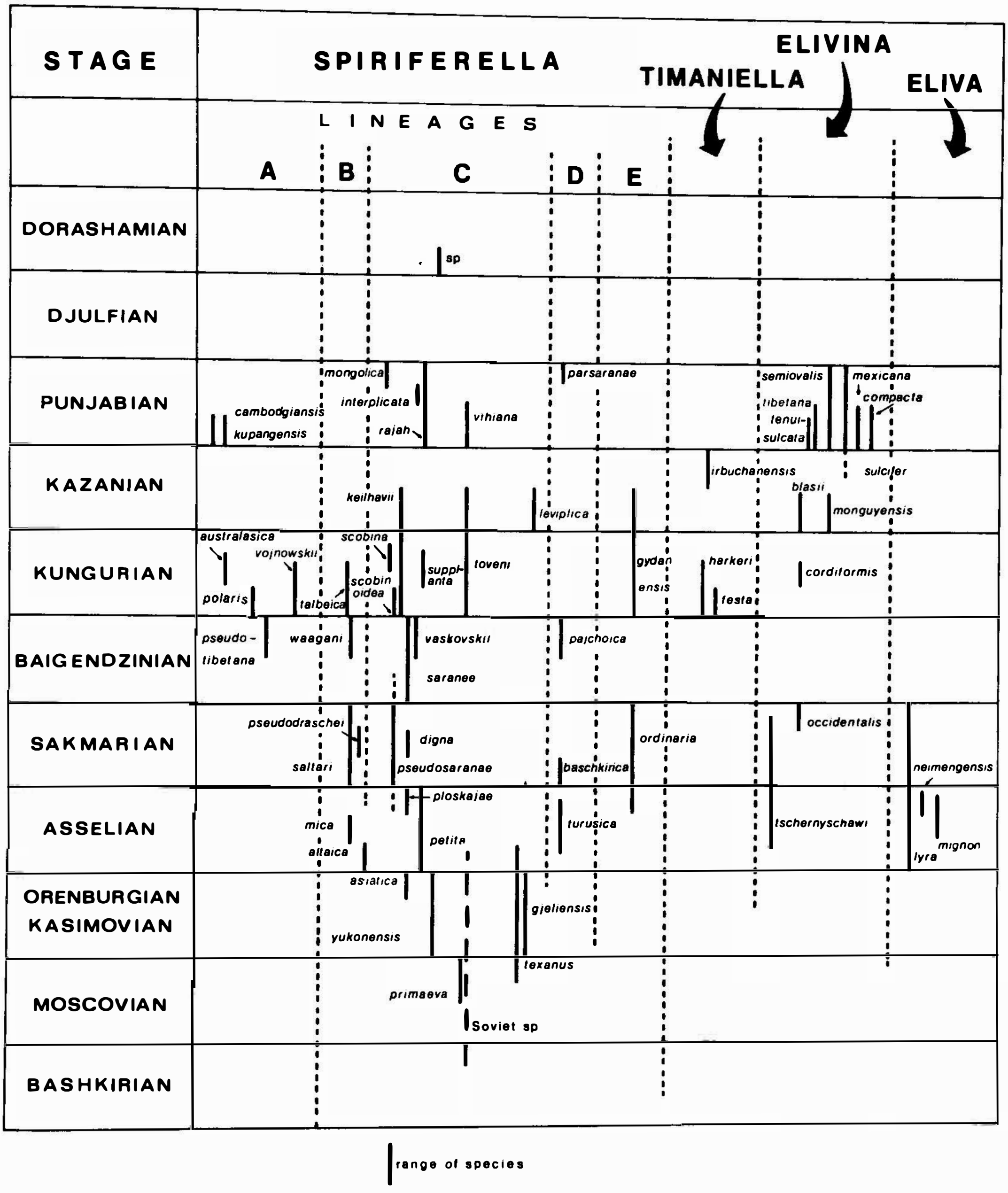


Fig. 6. Range chart and interrelationships for the genera *Spiriferella, Timaniella,* and *Elivina*, based on examination of material and wide survey of literature, by Mrs J. Waddington and the writer in a study on the genera for the Geological Survey of Canada.

too easy to go on incorporating fauna after fauna into one huge or portmanteau assemblage zone on the basis of a few shared, perhaps long ranging species, or even to use different shared species in progressing up the column. It is the uncontrolled use of this technique that explains the enormous units recognised by Runnegar (1969b) in the east Australia Permian, in which virtually the entire Permian has been subdivided into a mere five divisions. Runnegar (1969b) suggested that several New Zealand biozones in a Permian succession 4,000 to 5,000 m thick were of Kazanian age (Table 6) because some Kazanian-like species were present. To the writer the entries of many new genera and species, some specifically close to Chhidruan species, suggest a post-Kazanian age, confirmed by the stratigraphic position over *Lepidolina* and *Yabeina* of post-Kazanian (Kalabaghian) age. A still younger Permian fauna from New Zealand was included by Runnegar (1969b) in the same Kazanian Stage. It is indeed of Kazanian aspect generically, but the species differ, and, with stratigraphic position, demand a Late Permian or Vedian age. Allied faunas in Australia were included in the same all-embracing 'Kazanian'Stage (Runnegar & Ferguson, 1969), incorporating faunas and rocks much younger than the type Kazanian of the world standard.

The difficulties and possibilities inherent in brachiopods may be assessed from the species range and evolutionary chart of Fig. 6. The genus *Spiriferella* has many species in at least five distinct lineages which have to be disentangled before any evolutionary pattern can be assembled, not an easy task because there are so many species, and still many gaps in the record, although these are being reduced rapidly by numerous Russian studies. Species lived through one to often three or four zones, a relatively long time for brachiopods, and prime correlation is better based on Productida. Moreover the genus was not world-wide, being rare in palaeotropical regions, and completely absent from the south polar waters of east Australia, the highly saline Zechstein Sea of Europe, and rare or absent from the Phosphoria Sea of north-west United States. Even so, this genus was diverse, and tolerated a wider range of lithotopes and temperature than any known Fusulinacean or ammonoid genus of Late Palaeozoic age. It is clear that the real difficulty in using brachiopod species lies not in the short or lengthy ranges or restricted distribution, but in the very large number of taxa to be resolved before identification can be ascertained. The huge number of brachiopod species have held up advances in systematics and correlation, in contrast to Ammonoidea and Fusulinacea, where progress has been aided by the small number of taxa involved, enabling ready mastery of morphological and chronological differences, through brilliant research. A further barrier to the use of brachiopods lies in the need for revision of much of the literature, in which specimens have been misidentified, or not described in modern terms. This is one of the chief facets underlying the temporary and tentative nature of the scheme here proposed for subdividing the Permian, because too many of the zones and stages are based on faunal assemblages and presence or absence of genera rather than on species ranges. But there is little alternative, pending revision of species from Pakistan, Himalayas, south east Asia, and the Urals.

Use of statistical techniques

So far no statistical treatment has proved satisfactory for making correlations, probably because species have not been used from restricted zones. Grant & Cooper (1973) used cluster analyses of brachiopod genera from a few regions to support their correlations, but their scheme is unconvincing, because the clusters appear to indicate palaeogeographic affinities rather than chronologic control. Several of their clusters link faunas clearly in sequence from one region, rather than link correlative faunas from different regions. Williams (1973) more appropriately clustered genera to indicate faunal provinces, and Waterhouse & Bonham-Carter (1972) clustered families to indicate major assemblages, controlled principally by climatic rather than temporal factors, and probably corresponding with fossil biomes.

Runnegar (1969b)	New Zealand Sequence	Waterhouse 1963, 1973c, herein	
		Substage	Stage
Kazanian Stage	Lower Stephens Fm *Aperispirifer nelsonensis* Zone, 150-200m	Vedian	Dorashamian
	Waiua Fm 700m, barren		
	Greville Fm *Durvilleoceras woodmani* Zone, 500m	Baisalian	Djulfian
	Little Ben Ss etc. *Spinomartinia spinosa* Zone, 30-200m	Urushtenian	
	Spiriferella Zone Tramway Ss, Wooded Peak Lmst *Plekonella multicostata* Zone, 20-200m	Chhidruan	Punjabian
	Lower Ag4 Lmst *Martiniopsis woodi* Zone, 20-100m	Kalabaghian	
	barren Upper Mangarewa Fm 0-170m	? Sosnovian	? Kazanian
	Middle Mangarewa Fm *Terrakea brachythaerum* Zone, 85m		
	Lower Mangarewa Fm *Echinalosia ovalis* Zone, 150 m	Kalinovian	

Table 6. Alternative correlations for New Zealand Permian, by Runnegar (1969b) and Waterhouse (1963; 1973c).

Fm - Formation; Lmst - Limestone; Ss - Sandstone

2. Review of Chronologic and Biostratigraphic Sub-divisions of the Marine Permian

The Permian Period as proposed by Murchison (1841) embraced rocks and faunas in the Urals Mountains and Russian Platform, now chiefly referred to the Middle Permian, followed by terrestrial beds of the Tatarian Stage. Karpinsky (1874) showed that the underlying 'Artian' or 'Artinskian' beds were of post-Carboniferous age, and in 1889 included them as well in the Permian System. During the twentieth century, attention focussed on the pre-Artinskian *Schwagerina* and *Pseudofusulina* beds, more recently called the Sakmarian Stage, (see Dunbar, 1940) and these have come to be incorporated in the Permian System, although a number of Fusulinacean experts have maintained, in both Russia and China, that the *Schwagerina* horizon is Carboniferous.

In recent years palaeontologists of the Soviet Union have done much to clarify their own Permian sequence, by re-examining their successions and faunas in detail. The Sakmarian has been subdivided into a number of units, by Rauser-Chernossova and colleagues working on Fusulinacea, and by Ruzencev, studying Cephalopoda. The local Russian subdivisions, recognised by fauna and lithology, offer a standard for wide-ranging correlation, and it is a prime contention of this study that the subdivisions can be recognised anywhere in the world through detailed faunal analysis. The Middle Permian has received attention from brachiopod workers such as Gerassimov (1952a, b, 1956) and Grigorieva (1962) and stratigraphers such as Zolotova *et al.* (1966), with fine studies on Ostracoda and Foraminifera. Both Early and Middle Permian faunas have been extensively and well studied in Siberia by many palaeontologists. Because the Kungurian Stage has few Fusulinacea, or Ammonoidea, and the Kazanian Stage has none, a number of North American authorities have tried to transfer the world standard to west Texas and New Mexico, and made very grave miscorrelations as a consequence. Understandably, Australian palaeontologists such as Dickins (1956) and Campbell (1953, 1965) who have had to rely on Brachiopoda and Bivalvia have correlated their faunas more successfully. In truth, the Kungurian and Kazanian Stages have had their faunas fairly fully described, and there should be little difficulty in understanding and correlating the middle part of the Permian Period.

The Late Permian Period has been studied principally in Armenia, and across the border in Iran (Ruzencev & Sarytcheva, 1965; Stepanov *et al.* 1969). However the Late Permian has been a considerable source of difficulty and controversy during the last thirty years. Much of the reason lies in the terrestrial nature of the standard Tatarian Stage, making it very difficult to correlate with marine sequences. An alternative standard, used in the United States, has fossils slightly higher in the column than in the Russian Platform, but also is unsatisfactory. During the late 1930's and early 1940's, a quite erroneous view of the Late Permian prevailed, in which a single stage was recognised, on the basis of the Fusulinacean *Yabeina* (Thompson, 1946) and correlative ammonoid *Cyclolobus* (Miller & Furnish, 1940). Fusulinacean experts soon recognised that *Yabeina-Lepidolina* beds were not of Late Permian age, as especially well demonstrated by Chinese sequences (Sheng, 1964). But one school of thought has campaigned to retain *Cyclolobus* as a key to the top of the Permian (Ruzencev & Sarytcheva, 1965; Stepanov *et al.*, 1969; Glenister & Furnish, 1961; Furnish, 1966, 1973; Kummel & Teichert, 1964, 1970; Nakazawa *et al.*, 1970), even though Spath (1934, p.24) and Schenk *et al.* (1941, p.2197) had clearly indicated that beds and faunas of the same age as *Cyclolobus* were overlain by younger pre-Triassic beds at Djulfa in Armenia. The alleged young age for *Cyclolobus* was based primarily on the supposed evolutionary development of an ammonoid lineage from *Waagenoceras* to *Timorites* to *Cyclolobus*. This is largely theoretical, because the three have never been found in any one sequence, except at Timor. where *Timorites* co-exists with *Cyclolobus*. Grant (1968), Grant & Cooper (1973), and Waterhouse (1966, 1972a, b) have contended that *Cyclolobus* was essentially correlative with *Timorites*, and that neither were of Late Permian age. Glenister & Furnish (1970) and Furnish (1970, 1973) even appear to have inverted the sequence, to retain *Cyclolobus* as the key to the Late Permian. Grant & Cooper (1973) criticised the scheme in detail for the Salt Range and west Texas, and Waterhouse (1972a) demonstrated that *Cyclolobus* and *Timorites* could have evolved from different lineages at the same time, and occupied different palaeogeographic realms in the Late Middle Permian. Other authors have also not accepted the inversion of the sequence (e.g. Stepanov, 1973; Dickins in Grant & Cooper, 1973, p.579; Taraz, 1973; Termier *et al.* 1974; Kozur, 1974).

A second related problem concerned the top of the Permian System. Ruzencev & Sarytcheva (1965) referred Permian-type ammonoids and brachiopods from Armenia to the 'Eotriassic', and Stepanov *et al.* (1969) even included as Eotriassic an underlying zone with *Comelicania* and *Janiceps*, clearly correlative with the Late Permian Bellerophon Limestone of the Carnian Alps in Austria and Italy. This view was opposed by Waterhouse (1967a, 1972a, b, etc.) on the basis of brachiopods. Although Grant (1970) at first accepted the Eotriassic age, it was put aside by Grant & Cooper (1973). The conclusions based on brachiopods were anticipated by Yakovlev (1931) and by Spath (1934). Rostovtsev & Azaryan (1973) demonstrated that the controversial 'Eotriassic' beds were overlain by beds with the 'Early Triassic' ammonoids *Ophiceras* and *Gyronites*, and agreed that the underlying beds were Late Permian in age.

Further confusion concerns the top of the Permian System. Diener (1909) defined the basal Triassic faunas primarily by the absence of the Productida so characteristic of the Permian Period. The first Triassic faunas, he believed, were typified by the ammonoids *Otoceras* and *Ophiceras*, with the bivalve *Claraia*, and supposed *Norella*, a Triassic brachiopod. However *Norella* is very like the mid-Permian genus *Boloria* Grunt in appearance and the writer found *Norella*—like forms in ?Smithian, not Griesbachian, faunas of Nepal. Nevertheless Diener's definition if not his application was sound, for Chao (1966), Tozer (1969, 1973) and Waterhouse (1967a, 1972a, b) used the presence of Permian-type brachiopods in the so-called Eotriassic of Armenia to date those rocks as Permian, and Grant & Cooper (1973) followed a similar approach in fixing the Permian-Triassic boundary in Kashmir. It has now been established that Permian-type brachiopods, including Productida, occur higher than realised by Diener (1909), certainly with *Otoceras*, and possibly with *Ophiceras* (Waterhouse, 1973b). These brachiopods have not been reworked, but lived in place with *Otoceras* and accompanying 'Triassic' ammonoids. Moreover, as similar faunas are found all over the globe, there is no question of them being pockets of late survivors that somehow survived an earlier major catastrophe that wiped out most forms of Permian life, an unsubstantiated thesis reiterated by Kummel and Teichert since 1964. The 'final catastrophe', if there was one, post-dated the Griesbachian Stage or Substage. Does this mean we have to redraw the boundary, or change the definition? Kozur (1973a, b), Newell (1973) and Waterhouse (1973b) have argued for placing the Permian-Triassic boundary within or above the Griesbachian, and international discussion is required to decide whether the boundary should be moved, or retained.

RELATIVE VALUE OF CERTAIN MARINE FOSSIL GROUPS

The primacy of Brachiopoda

The responsibility of correlation for Permian marine faunas has fallen in the past principally on Fusulinacea and Ammonoidea. But the present study allots prime value to Brachiopoda, and this shift in emphasis needs to be explained. The overriding reason for using Brachiopoda is because they were the predominant marine macrofossil of the Permian Period, and therefore can be used to correlate more rocks, on a wider basis. Against an ill-informed but widely reiterated misapprehension, brachiopod species and genera, during the Permian Period, were *less* latitudinally or facies-controlled than Fusulinacea or Ammonoidea, and just as short-lived. Severe problems remain. They were so diverse a group that mastery on a world-wide basis is difficult, if not impossible provided we persist in our present techniques, because systematic, communal and zonal (i.e. ecologic and temporal) studies are all required before their potential can be realised. At present the most critical short-coming lies in the failure of palaeontologists to re-examine the Early Permian brachiopod faunules of the Urals. If the standard sections are to be in the Urals, as argued herein, it is the duty of the host country to provide adequate and up modern studies of Brachiopoda. Until that is done, some questions of correlation remain insoluble.

Fusulinacea and nomenclatural problems

In Permian carbonates of relatively low palaeolatitudes, Fusulinacea are more numerous, and more useful than even Brachiopoda, but they are severely restricted in distribution, with none known from vast tracts of Permian marine rocks, including those of the entire continent of Australia. It is therefore impossible to use them for world-wide correlation. Moreover, in many regions, such as Arctic Canada, Afghanistan, New Zealand, to mention a few, they are present at only a few intervals. Additional problems that beset the stratigrapher lie in the lack of knowledge of communal associations, and the response of species to various ecologic and biologic parameters has scarcely been assessed. Consequently we understand little of the apparent wide differences of species ranges in different parts of the world, and the marked provincialism set out by Ross (1967b).

A frustrating nomenclatural tangle bedevils our appreciation of key Fusuline genera of the Late Carboniferous and Early Permian, with baffling effects on correlation and boundary problems. This concerns the three genera *Schwagerina* Moeller 1877, *Pseudoschwagerina* Dunbar & Skinner 1936, and *Pseudofusulina* Dunbar & Skinner 1931. According to Kahler & Kahler (1966), *Schwagerina* was initially based on shells mistakenly identified as *Borelia princeps* Ehrenburg. Russian authorities have granted primacy to the intention of Moeller, and retained the definition, by renaming Moeller's specimens as the type species *Schwagerina moelleri* Rauser-Chernossova. American authorities have stressed the citation of the type species, and centred their understanding of *Schwagerina* on *Borelia princeps* Ehrenburg. *Pseudoschwagerina* Dunbar and Skinner 1936, type species *Schwagerina uddeni* Beede & Kniker was erected for shells long considered by the Russians to be true *Schwagerina*. Now the two schools persist side by side, with the ridiculous situation that a Russian *Schwagerina* is not an American *Schwagerina*. Throughout this text *Schwagerina* as used by the Russians is accompanied by an asterisk, following Kahler & Kahler (1966).

Pseudofusulina is just as confusing. Kahler & Kahler have discriminated a number of species groups, those of uncertain standing, those as understood by the Soviet school, indicated throughout the text as *Pseudofusulina**, a group as used by the Russians, *and* by Thompson (1948), shown herein as !*Pseudofusulina** and the group *Pseudofusulina*

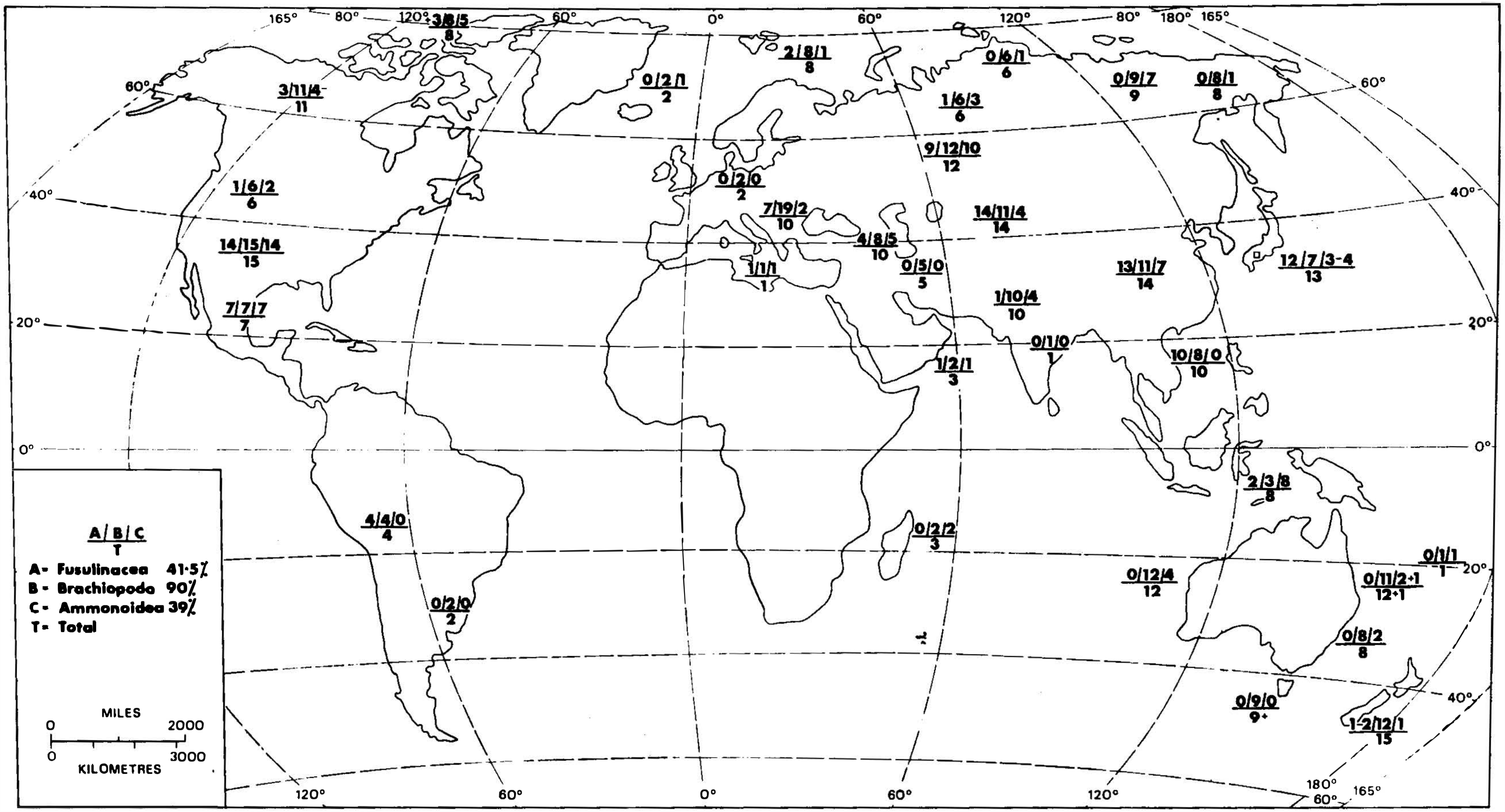


Fig. 7. Provisional estimates of number of substages represented faunally in various regions, with estimates of number of substages bearing Fusulinacea, Brachiopoda, and Ammonoidea. The chart omits several significant full sequences of Fusulinacea, such as that of the McLoud Limestone of California, and may underestimate the number of Fusulinacean zones for Arctic Canada, Pamirs, China and Japan. It also fails to show that Fusulinacea where present were generally abundant, and so provide a good indication of age. Brachiopoda clearly were of major significance in Permian sequences as shown by this chart, and the number is underestimated for several sequences where they have been present, or probably present, but not described, as in Arctic Canada, Armenia, Pamirs and Japan, and probably China. Ammonoidea are somewhat exaggerated in significance, because they were counted even where rare – and gain because the Griesbachian – basal Dienerian is included, when ammonoids for the first time became widespread enough to allow world-wide correlation.
Number of substages with Fusulinacea 41.5%; number of substages with Brachiopoda 90%; number of substages with Ammonoidea 39%.
Total number of substages with marine invertebrate faunas: 265.

as understood by Thompson (1948).

Throughout this text the nomenclature of Fusulinacea is matched where possible to Kahler & Kahler (1966).

The value and limitation of Ammonoidea

Students of ammonoids have long shared the lead in subdividing the Permian Period on a world-wide basis. Of recently proposed classifications one of the most outstanding in applicability and fineness of control is that proposed by Furnish (1973), building on the excellent studies by a number of American and Russian experts. But ammonoids *cannot* be allotted primacy of place as an aid for correlation, because they are too rare in too many sequences. This comparative rarity may be objectively established from basic data provided by Furnish (1973, fig.1, reproduced herein as Table 10), which shows how the twelve so-called ammonoid stages are based on only fifteen regional sequences around the entire world. Fifteen would hardly seem enough, but indeed, to reach even that modest score, the Glass Mountains and adjoining Delaware Basin were counted separately, and the nearby midcontinental states separately again. Timor was included even though it offers no stratigraphic sequence. Even sequences in the Basin and Range Province (with only two scattered stages), western Canada (two), Mediterranean (three widely scattered), and the huge region of eastern Australia (three, widely scattered) were counted as offering serious evidence. One ammonoid succession was tabulated in the 'Himalayan System', perhaps referring to the Salt Range, where ammonoids of pre-Kalabagh age are scarce, and not significant. The Himalayas themselves include one or perhaps two ammonoid zones, with a further Griesbachian horizon. Published literature on 'Arctic America' shows a modest sequence of ammonoid zones that depend heavily on other fossils for local intercorrelation: few stratigraphic sections show a succession of ammonoid zones, so far as is known. Thus the 'valuable regions' showing a mere three or more ammonoid faunules in some sort of stratigraphic sequence are about eight in number (Mexico, United States, Armenia, Pamirs, Western Australia, Urals, Verchoyan Mts., China), and perhaps the Canadian Arctic Archipelago should now be included. They do indeed provide a most valuable scheme, in spite of the scarcity of ammonoids, thanks to the excellent ammonoid studies. By contrast, as outlined in the present work, the following areas contain three or more brachiopod faunas in sequence (see Fig.7).

Americas, Arctic: Glass Mts., and Delaware Basin, Midcontinental U.S.A., Coahuila, El Antimonio, Canadian Arctic Archipelago, western Canada (eastern Rockies), Yukon, Alaska, Alaska Panhandle, Spitsbergen-Bear Island.

USSR: Urals, Russian Platform, Petchora, Pai Hoi, Timan, Taimyr Peninsula, Verchoyan Mountains, Kolyma River-Omolon Plateau, Fergana-Pamirs, Donetz Basin, Greater Caucasus, Crimea, Armenia-North Iran.

Asia: Central Iran, Elburz Mountains, Salt Range (Pakistan), Kashmir, Thailand, Cambodia-Vietnam-Laos, South China, Central China, North China, Japan.

Australasia: Western Australia (Carnarvon, Bonaparte Gulf, Perth, Canning Basins), Queensland (Bowen, Yarrol, Gympie Basins), New South Wales (Sydney Basin), Tasmania, south and north South Island, New Zealand.

Regions such as Novaya Zemlya, Nepal, Baikal, Ussuriland, Mongolia, and Karakorum are omitted because although sections are known, they have not been resolved, either because work is in preparation, or was done so long ago that it has dated badly. Timor, though with large brachiopod faunas, should not be counted.

Regions of equal size, say 15° latitude and 15° longitude (at the equator), provide the following comparative number of sequences with three or more abundantly fossiliferous substages in indisputable sequence.

Brachiopoda	Ammonoidea
Mexico — United States	Mexico — United States
Rocky Mts	
Alaska — Yukon	
Canadian Arctic Archipelago	Canadian Arctic Archipelago
Spitsbergen, North Greenland, Petchora Novaya Zemlya	
Peru — Bolivia	
Urals	Urals
Europe (Austria, Italy, Yugoslavia)	
Armenia — Iran	Armenia — Iran
Pamirs, Salt Range, Kashmir	Pamirs — Salt Range
Nepal, Burma	
Taimyr	
Lena and Kolyma Rivers	Lena River
Japan, Korea, Ussuriland	
Lake Baikal, Mongolia	
China	China
South-east Asia	
Timor, northwest Australia	Timor, Western Australia
Southwest Australia	
Queensland	
Tasmania, New South Wales	
New Zealand	
Total: 22 regions	8 regions

Of these major regions, only central North America has more than six ammonoid zones in sequence, in one compact area, compared with more than twenty of the regions with five or more brachiopod zones in sequence. Moreover in each region, sections that have ammonoids are extremely few. Even in the Urals, richest of all Permian areas in terms of numbers of ammonoids, the material is found in scattered outcrops that often had to be correlated by means of Fusulinacea (Barkhatova, 1964). As Furnish noted, 'At most localities, in America at least, Cephalopods are generally too rare to provide a satisfactory guide' (1973, p.528). The same holds true for most of the world.

Coahuila, north-west Mexico, is one of a few areas with ammonoids scattered through several zones in section. In the Salt Range, ammonoids are extremely rare (Grant & Cooper, 1973), and cannot be used for even local correlation. In the closely studied region of west Texas, unusually rich in ammonoids, Dr R.E. Grant, (pers. comm.) has estimated that some 5,000 ammonoids have been recovered from 97 localities, compared with some 3,000,000 brachiopods from about 800 localities. In Yukon Territory, Arctic Canada, some 1,500 localities have been collected from 50 sections, by staff of the Geological Survey of Canada and the writer with his associates. Ammonoids have been found in five of those localities—that is 0.3%—scattered in two or three zones out of the eleven zones present. In New Zealand, five areas have been mapped in examining some fourteen brachiopod zones. Ammonoids have been found in only two areas, in one zone, at about 10 localities. In east Australia, Permian rocks with more than ten brachiopod zones are exposed in numerous sections, in several huge basins. Widely scattered few ammonoids are found within only three zones in some ten localities. A serious problem lies in the sparse occurrence of ammonoids in any one section. There are so many intervals without ammonoids, let alone diagnostic ammonoids, that only fragments of the section can be accurately dated, or zoned by ammonoids. The bulk of sections lies between zones, and boundaries are impossible to draw with accuracy. Interestingly enough, Furnish (1973) commented that it would be possible to record some 300 occurrences of ammonoid families in various localities. In a massive compilation of Permian brachiopod families, we have just compressed the data from more than 50,000 occurrences (Waterhouse & Bonham-Carter, 1975).

The results of using for prime correlation a group of fossils that are so rare may be illustrated for the Late Palaeozoic Permian successions of Queensland, eastern Australia. We could erect a sequence of some 9-10 zones based on brachiopods, these clearly being the prime fossil for at least local correlation, as established for example by Maxwell (1954), Campbell (1961), and Dear (1972), in contrast to the long ranges ascribed to some of the bivalves by Runnegar (1969a). If world correlation is to be based on ammonoids, only two horizons can be ascribed an international stage or substage, and of course these lack any supporting evidence, so that there can be no possibility of falsifying or verifying the assumptions. (It may be added that the ages ascribed to the ammonoids by Armstrong *et al.*, 1967 are almost certainly false, when other evidence is considered). But by refusing to consider other evidence, some degree of superficial consistency is attained. The procedure of relying solely on Ammonoidea amounts basically to an unproved and unadmitted assertion that world-wide correlation by using benthonic fossils is intrinsically impossible, except perhaps at the scale of a period.

Correlation potential

The relative usefulness of ammonoids and brachiopods may be assessed by ratio of correlation potential (cp).

$$\mathrm{cp} = \frac{\mathrm{Zi}}{\mathrm{S}}$$

where Zi = number of zones in sequence i with given group of fossils;
and S = total number of fossiliferous zones in a succession.

As summarized in Fig. 7, the world correlation potential for Fusulinacea is only 0.41; and for Ammonoidea only 0.39; and for Brachiopoda, 0.9. For local sequences, the correlation potential for Ammonoidea is generally very much lower, insofar as ammonoids may be found in only a few localities, compared with hundreds of localities with Fusulinacea or Brachiopoda.

For instance, in the Permian zones of the Ogilvie Mountains, Yukon Territory, as set out previously, Ammonoidea and Fusulinacea are found in two of eleven zones, yielding a correlation potential of 0.18, compared with a potential of 1.0 for Brachiopoda. If we consider the number of macrofossil localities for the entire northern Yukon Territory, the correlation potential for ammonoids falls to 0.003, compared with a ratio of 0.99 for Brachiopoda.

Correlation value

The correlation value (cv), may be assessed as a percentage from the formula:

$$\mathrm{cv} = \left[\frac{(\frac{\mathrm{Zi}}{\mathrm{S}}) \times (\frac{\mathrm{Pz}}{\mathrm{Ri}})}{\mathrm{Pz}}\right] \times 100$$

where Pz = total number of Permian zones, and Ri = range of given fossil group. The correlation value of brachiopod genera is relatively low: say —

$$\left[\frac{0.9 \times (\frac{19}{19})}{19}\right] \times 100 = 4.7\%$$

Whereas the correlation for an ammonoid genus may in favourable instances be:

$$\left[\frac{.39 \times (\frac{19}{3})}{19}\right] \times 100 = 13\%$$

But the average brachiopod species ranges from one to four zones,

with an average correlation potential of	40—50%
and an optimum value up to	90%
Compare this with an average correlation potential for ammonoid species of some:	20%
and optimum value for short-lived ammonoid species of	39%

In most sequences, the correlation value for ammonoids is well below 10%, compared with well over 50% for Brachiopoda.

Risk of error

If correlation potential (cp) is low the chance of error increases, as expressed by the concept 'risk of error' (E)

$$E = (1 - cp) \times \frac{100}{1}$$

If, for example, we have as in Queensland, Australia, only two ammonoid biozones in a sequence of at least eleven biozones, the risk of error

$$E = (1 - \frac{2}{11}) \times \frac{100}{1} = 82\%$$

This appears to be too high to be acceptable under normal standards of correlation accuracy.

With such a low correlation potential and high risk of error, it must be asked why ammonoids have proved so useful in the past for correlation. The answer probably lies in the brilliance of research by ammonoid experts, and especially in their willingness to undertake world-wide correlation, as opposed to more regional correlations attempted by other palaeontologists.

Conodont studies

Conodont studies such as those by Sweet (1970a, b, 1973), Kozur (1973a), and Clark & Behnken (1971) have on the whole conformed to the correlation scheme outlined by Glenister & Furnish (e.g. 1961), and so have been somewhat superseded by the more refined scheme offered by Furnish (1973). As emphasised by Clark & Behnken (1971, p.417), 'the Permian System represents the last frontier for conodont research' and this modest appraisal would appear to be well justified in view of the critical reassessments of Late Permian and Early Triassic conodont correlations of Sweet (1970a, b, 1973) by Kozur (1973a, b, 1974), Newell (1973), and Grant & Cooper (1973). The chief problem appears to lie in the newness of the work. So few sequences have been available for cross-comparison that data have naturally been adjusted to what was understood to be the current world classification of the Permian Period.

The conodont zones as set out by Clark & Behnken (1971) are reproduced in Table 7, and may be discussed in turn.

The zone placed at the start of the Permian by Clark & Behnken (1971), with *Idiognathodus ellisoni*, is now considered to be Carboniferous (Dr H. Kozur, Freiberg, pers. comm.). The overlying *Sweetognathodus whitei* zone was too broadly defined, and includes three species, of which *whitei* is restricted to the Asselian. Younger forms not yet investigated occur in the Sakmarian Stage. (Dr H. Kozur, pers. comm.). According to Dr Kozur (in litt. 1 May, 1975), *Neostreptognathodus sulcoplicatus* is in fact restricted to the Roadian (which I assume includes Meade Peak, that is, Nevolin rather than Filippovian) but the genus *Neostreptognathodus* occurs in the Leonardian (Baigendzinian) and in the Roadian, as well as the 'Artinskian' of the Cis-Ural. *Gondolella* occurs in a different facies, and *G. idahoensis* is found in both 'Leonardian' and 'Roadian'.

The supposedly following zone of *Neogondolella serrata* is reported from the Bone Springs Formation, Leonardian according to Clark & Ethington (1962), 'basal Wordian or Guadalupian' according to Clark & Behnken (1971), and Sweet (1973), presumably implying a roughly Roadian (Filippovian) age as confirmed to me by Dr R.E. Grant. It thus almost certainly commenced at the same time as the *Gondolella idahoensis* Zone, and the sequence appears to have been reversed by Clark & Behnken (1971). Sweet (1973, p.641) found *Neogondolella serrata* (Clark & Ethington) throughout the Word, and into the Capitan as high as the mid-Capitan Rader Limestone in the type Guadalupian, but Dr Kozur (in litt. May 1975) considers this may be a distinctive subspecies. Contemporaneous faunas of western United States had different species that failed to enter the Glass Mountains and Delaware Basin (Sweet, 1973).

The name species of the supposedly overlying *Merrillina arcucristatus* Zone occurs in the Plympton and lower Gerster beds of Nevada and Utah. Although correlated with the high Word and lower Capitan by Clark & Behnken (1971, p.427), these beds are probably very little younger than the Meade Peak Shale. Kozur (1975) has synonymised *arcucristatus* with *galeatus* Bender & Stoppel from the Kazanian of Sicily. It is clearly coeval with *serrata s.l.*

Fortunately the following zones occur in a sequence of faunas, although even in these zones, ranges of critical species overlap considerably, including even the name species. The supposed Capitan succession of conodonts commences with the *Gondolella* n.sp. previously of the '*Gondolella rosenkrantzi*' Assemblage Zone, found not in the type Capitan of New Mexico but in the upper Gerster Formation of Nevada, with a so-called *Punctospirifer pulchra* (Meek) fauna. Leaving aside dubious or unsubstantiated reports, this fauna is found in the upper Phosphoria beds and Ervay and Franson Members of the Park City Formation of Idaho, Utah, and Wyoming, just above a Filippovian-Nevolin ammonoid-brachiopod assemblage, and is assessed as being Nevolin to Kazanian age, in other words, Wordian. Dr G.A. Cooper has correlated the Gerster brachiopods with those of the Appel Ranch Member of the type Word (i.e. Sosnovian) in the Glass Mountains, Texas (Cooper in Bissel, 1973, p.324). But the conodont workers have assumed a lower Capitanian age. Other world faunas with some of the same conodonts are also Kungurian-Kazanian, i.e. Wordian, coming from the lower Zechstein and Greenland, (both Kungurian as here defined, to include Ufimian) and Sosio beds of Sicily (Kazanian). Disturbingly, the supposed key species *G. rozenkrantzi* Bender & Stoppel is known from the underlying *Neospathodus arcucristatus* Clark & Behnken (*Merrillina galeatus*) Fauna as well, so that the zones are ill-defined, to say the least. However, according to Dr Kozur, various so-called *rozenkrantzi* need to be reassigned.

Merrillina divergens (Bender & Stoppel) characterises the succeeding zone, but again, is stated to overlap the underlying zone. It is ascribed, with no independent sup-

			Clark & Behnken, 1971	Suggested correlation
World standard	Texan standard		Conodont zones	
Chhidruan	Chhidruan		*Anchignathodus* Fauna	Griesbachian - Chhidruan
Capitanian	GUADALUPIAN	Capitanian	*Merrillina divergens* Fauna	? Kazanian
			(overlap)	
			Gondolella n.sp. = so-called "*rosenkrantzi*" Assemblage Zone	Kazanian
=Kazanian		Wordian	*Merrillina arcucristatus* = *galeatus* Fauna	Kazanian-Kungurian
Artinskian	Leonardian		*Neogondolella serrata* Fauna	Kazanian to Baigendzinian
			(overlap)	
			Gondolella idahoensis Fauna	Upper Baigendzinian ?Nevolin
			(overlap)	
			Neoreptognathodus sulcoplicatus Unit	Nevolin
				Sakmarian
Sakmarian	Wolfcampian		*Gondolella bisselli* -*Sweetognathodus whitei* Assemblage Zone	Asselian
			Idiognathodus ellisoni Assemblage Zone	Carboniferous

Table 7. Conodont zonation, based partly on Clark & Behnken (1971, fig. 4), emended to follow their text (p. 427), and Sweet *et al.* (1971, p. 444).

	Anchignathodus parvus	*Isarchicella isarcicus*	*Gondolella carinata subcarinata*	*Gondolella orientalis*	*Gondolella leveni*	*Ellisonia teicherti*	*Anchignathodus typicalis*	*Merrillina divergens*	*Gondolella rosenkrantzi*	*Merrillina arcucristatus =galeatus*	*Gondolella serrata*	*Gondolella idahoensis*	*Neostreptognathodus sulcoplicatus*
Dienerian													
Griesbachian	X	X				X	X						
Ogbinan			X										
Vedian			X										
Baisalian				X	X	X	X						
Urushtenian					X	?	?	?					
Chhidruan						X	X						
Kalabaghian								?			X Subsp		
Sosnovian								or ?	X		X		
Kalinovian									?	?	X		
Irenian									?	?	X	X	X
Filippovian											?		? aff
Krasnoufimian													? aff
Sarginian													

Table 8. Possible ranges of key species of conodont zones; ? indicates uncertainty of age. As shown in the text, Clark & Behnken (1971) have suggested other ranges, and the chart also differs from new proposals by Dr Kozur, outlined in the text.

porting evidence, to the late Capitanian by Clark & Behnken (1971) and Dr Kozur considers that it is Abadehian (Urushtenian).

Recent work by Kozur (1974) has greatly enhanced our understanding of later Permian conodont zones:

Conodont Assemblage Zone	Ammonoid Zone	Stage
Anchignathodus parvus	upper *Ophiceras commune*	"Griesbachian"
Isarcicella isarcicus	lower *Ophiceras commune*	"Griesbachian"
Gondolella carinata subcarinata	*Phisonites-Paratirolites*	Dorashamian
Gondolella orientalis	*Vedioceras ventroplanum*	Baisalian
Gondolella leveni	up to top of *Araxoceras latum*	Baisalian-Urushtenian
Merrillina divergens		

Most conodont studies (e.g. Sweet, 1973; Kozur, 1973a, b) have accepted and sought to establish a Late Permian age for the ammonoid *Cyclolobus*, and this erroneous assumption has probably undercut their preferred correlations. However new and refined work by Kozur (1974) has reversed earlier conclusions, and now adds strong support for the position of *Cyclolobus* as adduced from brachiopod studies by Grant (1970; Grant & Cooper, 1973) and Waterhouse (1966, 1972a). Some aspects of Kozur's present scheme still differ from the correlations discussed here, for he correlates the Chhidruan Substage and the lower Zechstein with the Urushtenian (Abadehian) Substage; the Kazanian Stage with the Capitanian; and the Sosio fauna with the Kungurian Stage. These are substantial differences, but discrepancies will probably be overcome now that the true position of *Cyclolobus* has been recognised. Moreover, Kozur and his colleagues are now revising and subdividing long-ranging guide species, and beginning to recognise the occurrence of contemporary but different guide species and communities. Nonetheless, it appears doubtful that conodonts will ever be able to provide world-wide correlations for the marine Permian. None have yet been found in the cold-water Permian faunas, despite intensive search in east Australia (Nicol, 1975).

DISCUSSION OF CORRELATION SCHEMES

*Correlations proposed by Grant & Cooper (*1973)

A number of tentative schemes for correlating Permian marine faunas have been offered in recent years, and some examples may be chosen to illustrate the difficulties involved. That of Grant & Cooper (1973) is reproduced in Table 9. These authors placed high value on a number of different groups, including conodonts, sponges, Fusulinacea, Brachiopoda, and Ammonoidea. They were highly critical of conodont work by Sweet (1970) and ammonoid studies by Furnish & Glenister (1970) but successfully reinterpreted the basic data, especially for the Salt Range, Pakistan. Grant & Cooper (1973, p.578) deprecated the use of first appearances for correlation, one of the chief criteria used by many authorities. The present writer would regard first appearances as a prime method of correlation, and fully concurs with Wilde (1968, p.12) when he 'prefers basing major time stratigraphic breaks on the first appearance of new faunas'. Grant & Cooper (1973, p.578) 'preferred as complete analysis as possible of the total fauna'. Why this contradicts Wilde's view may not be clear, but elsewhere they emphasized a preference for relying on faunal assemblage (Cooper & Grant, 1973). As a natural consequence value was placed on cluster analyses of genera for correlation (Grant & Cooper, 1973, p.588, figs. 5,6). Their graphs confirmed that the Basleo and Kalabagh-Chhidru faunas have a high coefficient of similarity at a generic level. But so

	European Series	North American Provincial Series	World Stage		Salt Range	South China		Himalaya and Kashmir	E. Greenland Axel Heiberg Is.
Lower Trias	Scythian (Griesbachian)								
Upper Permian	Tatarian	Ochoan	Dzhulfian	Changhsingian	Changhsingian	Loping	Changhsingian	Dzhulfian?	Svartevaeg = Foldvik Creek
				Araksian			Wuchiaping	Brachiopods	
					Chhidru			? ? ? Productus	
	Kazanian	Guadalupian	Capitanian		Kalabagh	-		Shale	
					Wargal			(absent at Guryul Ravine)	
			Wordian			Maokou		? ? ?	
Lower Permian	Ufimian		Roadian		Amb	Chihsia and Yangsin		Zewan Series *Gangamopteris* Lower Gondwana *Glossopteris*	
		Leonardian	Baigendzinian						
	Kungurian								
	Artinskian		Aktastinian		Lavender Clay?				
	Sakmarian	Wolfcampian			Speckled sandstone				
	Asselian				Talchir Series	Maping			

Table 9. Suggested correlations of Permian sections by Grant & Cooper (1973, fig. 4, p. 586).

do the Word and Capitan faunas, according to their graphs, and these faunas are not correlative, but in sequence. The only other close lateral pairing is shown between Greenland (one brachiopod zone) and Spitsbergen (at least three zones and two stages). The so-called Guadalupian and Djulfian Stages are also paired, and again, we know that they are in sequence, not correlative. Clearly, the clusters demonstrate ecologic rather than temporal links—especially pronounced at generic levels, as well shown by Williams (1973) in his cluster analyses of Ordovician genera. There is time significance as well of course, but this would be enhanced by analysis of species rather than genera.

The correlation table offered by Grant & Cooper (1973) does not depend entirely on cluster analyses, although it is difficult to be sure, because little documentation is provided. Miscorrelations between the Texas-New Mexico standard, and the world or so called European standard are particularly severe. The Kazanian Stage is supposed to match the entire Guadalupian Stage for instance, and the Roadian Stage is supposed to match the Ufimian. The Chhidruan is correlated with the lower Djulfian. The Svartevaeg fauna of Axel Heiberg Island, and the Foldvik Creek fauna of east Greenland are correlated with the Kazanian and entire Guadalupian. (They appear to be Kungurian.) So one may go on. The reason for such errors probably lies in the likelihood that Grant & Cooper (1973) did not follow their own advice, and carefully analyse faunal content, including brachiopods, for many of the faunas. Instead, they used assessments from the literature, often based on a few ammonoids. The world correlation table of Grant & Cooper (1973) contrasts in accuracy with the interpretation of the richly fossiliferous and facially complex Permian of west Texas and New Mexico by Cooper & Grant (1973). Here their correlations are indeed based on species ranges and faunal assemblages, and provide overwhelming proof of the value of their procedures, and degree of sophisticated correlation that can be achieved through mastery of brachiopod faunas.

Ammonoid scheme of Furnish (1973) (Table 10)

The scheme outlined by Furnish (1973) provides world correlations in good agreement with the Lower Permian and much of the Middle Permian subdivisions used in the present scheme. Furnish relied solely on ammonoid data, and therefore severely restricted possibilities of correlation. Concentrating on only one group must deprive any scheme of checks and balances from other groups, and ammonoids are not a good class on which to place sole reliance for they are too rare to resolve problems of correlation for many parts of many columns in most parts of the world. They have to be used so broadly in international correlation that verification or falsification is seldom possible. In many instances, the most ammonoids can achieve is correlation of one or two parts of the column, leaving gaps so huge that it is impossible to map boundaries. Yet ammonoids, because they are few, and have been well studied, are highly useful in making pioneer studies and initial correlations, to precede studies of the benthos. For a full two thirds of the Permian Period to the 'Amarassian Stage', agreement between the studies by Furnish (1973) and the larger number of sequences in the present work is excellent. The younger Permian differs, between the two models, because the Chhidruan Stage of the Salt Range appears to have been miscorrelated with younger faunas of China and Armenia (see Waterhouse, 1972a, b). This is not just a question of ammonoids versus brachiopods. It reflects two different understandings of the ammonoid *Cyclolobus*. According to Furnish (1973), one lineage was present (Fig. 8), that evolved orthogenetically from *Waagenoceras* into *Timorites*, into *Cyclolobus*. *Cyclolobus* characterised one Permian stage, with primitive *Cyclolobus* at the base (=*Godthaabites* Frebold) and *Changhsingoceras* Chao at the top. According to Waterhouse (1972a, b), *Waagenoceras* evolved into *Timorites*, at the same time as *Cyclolobus* evolved from *Godthaabites*, and *Changhsingoceras* was a much later derivation from *Cyclolobus*

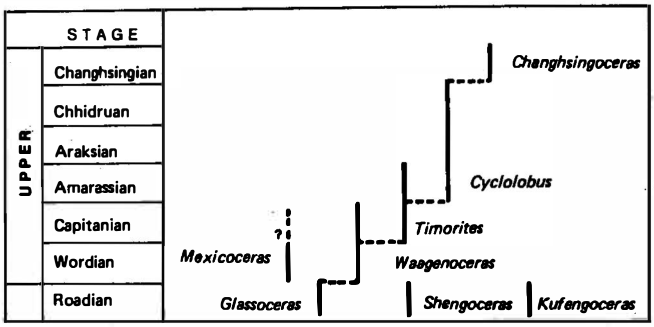


Fig. 8. The evolution of the Cyclolobidae, summarised from Furnish (1973). Note the linear development from *Glassoceras* through to *Cyclolobus*, and probably on to the poorly known *Changhsingoceras*. The family commenced in the "Lower Permian" i.e. Roadian Substage, according to Furnish (1973), and typified the Upper Permian in his sense of the period.

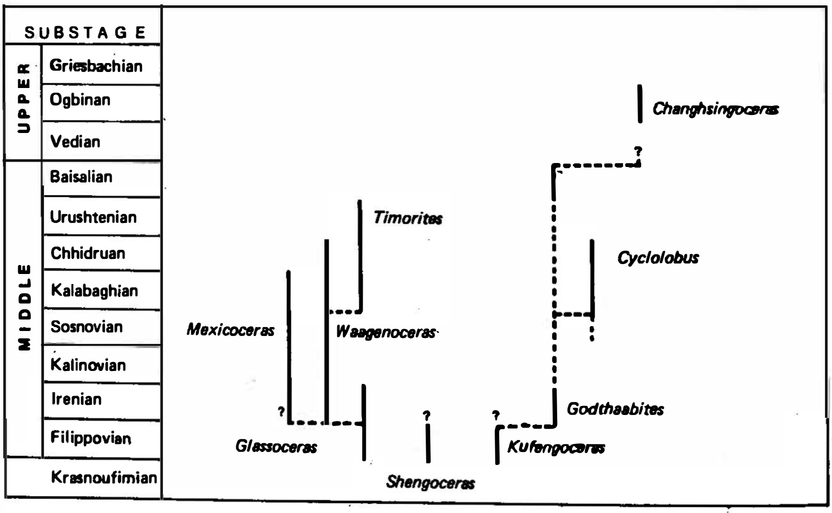


Fig. 9. Evolutionary development of the Cyclolobidae, following Waterhouse (1972a). There is some uncertainty over some ages, indicated by queries. Note the gaps in the record, not unreasonable in view of the delicacy of the shell. The family is regarded principally as a bilinear Middle Permian group.

System	Series	Stage \ Region	Midcontinent USA	Glass Mountains	Delaware Basin	Coahuila	Basin and Range	Western Canada	American Arctic	Mediterranean	Ural Mountains	Trans-Caucasus	Himalaya System	South China	Timor	Western Australia	Eastern Australia
Triassic							X		X	X		X	X	X	X	X	X
Upper Permian	Dzhulfian	Changhsingian										X		X			
		Chhidruan										X	X	X			
		Araksian							X			X		X			
	Guadalupian	Amarassian			X	X								X	X		
		Capitanian		X	X	X								X	X		
		Wordian		X	X	X		X	X	X				X	X		
Lower Permian	Artinskian	Roadian	X	X	X	X	X		X				X		X	X	
		Leonardian	X	X	X	X			X	X	X		X	X	X	X	X
		Aktastinian	X	X	X				X		X				X		X
	Sakmarian	Sterlitamakian	X	X	X		X	X			X					X	X
		Tastubian	X	X	X						X				X	X	
		Asselian	X	X	X						X						
Pennsylvanian			X	X					X		X						

Table 10. Chart illustrating some of the areas with important Permian ammonoid faunas in sequence, from Furnish (1973).

(Fig. 9). Waterhouse (1972b) adduced much support from correlations based independently on Fusulinacea and Brachiopoda and stratigraphic sequence. Furnish (1973) based his argument on internal evidence of sutural development.

Furnish (1973) does not discuss methodology for his correlations, but the reader may infer that first appearances are allotted some significance, for instance in the acceptance of *Otoceras* as marking the base of the Triassic. Ammonoid sutural evolution played a critical role in Furnish's understanding of the Late Permian, though this procedure has been attacked by Spath (1934), Cooper & Grant (1973) and Grant & Cooper (1973). Interestingly, it would appear that succession also played a vital role in Furnish's scheme, because many of the correlations are not in fact based on shared species, or in some instances, even shared genera. Correlations are stated *ex cathedra*. It is believed that they are correct, showing that high value is to be attached to the concepts of succession and ammonoid evolution held by Dr Furnish and his colleagues, provided that these are adequately checked against other evidence.

*Literature review by Anderson (*1973)

A number of large charts and map-summaries of the Permian Period have been presented by Anderson (1973) from compilations of the literature, without critical assessment of evidence. In striving to allot primacy to ammonoids Anderson was of course confronted by the scarcity of ammonoids in so many of the significant sections and his columns reveal many miscorrelations, and non-existent unconformities. Virtually no attention was paid to the type world Permian of Russia and extensive sequences of Siberia.

*Correlation scheme of Ustritsky (*1971) (Table 11)

The Permian correlations offered by Ustritsky (1971) are of considerable interest because they most closely approximate the arrangement used some decades ago, before recent advances by Fusuline, brachiopod and ammonoid studies especially in Armenia and south China. The scheme is thus rather close to that used in the Treatise volumes (Moore, 1965), or in Australia by Runnegar (1969b). Thus *Cyclolobus* is shown as latest Permian, as the linear descendant of *Timorites* and *Waagenoceras*. As a consequence, the significance of the Tatarian Stage or its marine correlatives is not conveyed, being reduced to a sliver in one column and omitted entirely in favour of the Kazanian in another column. The entire Middle and Late Permian is severely condensed. Moreover, the Kazanian Stage is shown as Late Permian, post-*Yabeina* and post-*Timorites* in age, a totally unwarranted correlation. The Ufimian is exaggerated in significance, and shown as equivalent to *Timorites* and *Waagenoceras*, as well as *Yabeina* and *Verbeekina*. The use of a mere four major subdivisions does not appear to have saved the scheme from serious error. The scheme of Furnish (1973) is not only more refined, but certainly an enormous improvement in accuracy. There is little guarantee that broad accuracy will be achieved by using 'safe' and coarse units of correlation.

TYPE REGIONS

There are several regions contending for consideration as world standard sections for stages of the Permian Period. Although the Permian System was first conceived from rocks and faunas of the Urals and Russian Platform, as confirmed by the very name Permian, based on the Russian city of Perm, several workers from the United States have attempted to have much or even all of the world standard transferred to west Texas and New Mexico. For example Furnish (1973) based 'World Ammonoid Stages' on the Permian of Texas-New Mexico for the so-called Leonardian, Roadian,

Urals Stages		Mikhluko-Macklay Stages	Ammonoid Zones	Fusulinacea Zones
Tatarian Kazanian	Kazanian	Pamiran	*Cyclolobus* Zone	Small Foraminifers
Ufimian Suite or Stage	Paikhoian	Murgabian	*Timorites*	*Yabeina*
Kungurian Artinskian Sakmarian	Artinskian	Darvasian	*Waagenoceras* *Perrinites*	*Verbeekina* *Parafusulina*
Asselian	Asselian	Karachatirian	*Properrinites*	*Pseudoschwagerina*

Table 11. Correlation scheme of Ustritsky (1971, Table 9).

Wordian, and Capitanian Stages. Younger Permian standards were erected from scattered regions in Timor, Salt Range, and China. Grant & Cooper (1973) asserted that the world standard for the Roadian, Wordian, and Capitanian units are to be found in Texas, and also used the Changhsingian Stage of China. The basal Permian (Asselian and Sakmarian) was left blank, implying at least some doubt about the use of Asselian-Sakmarian as a world standard. Of course the designation of world standards should properly be left to an international commission. In the meantime it is proposed that, wherever possible and convenient, the standard sections should be somewhere in the Soviet Union for the following reasons:

1. Historically, the Permian System was first conceived and proposed on the basis of Russian rocks and faunas (Murchison, 1841).
2. The Soviet Union has an abundance of rocks and faunas providing adequate standards in most instances.
3. The volume of work by Soviet palaeontologists on Permian problems exceeds that from any other country. They have attained fine control over many regions, and their work may be readily interpreted and extended elsewhere. There is good emphasis on stratigraphic and faunal succession for a number of fossil groups.

The Asselian and Sakmarian rocks and faunas are all diverse and well known, though revision is required for the brachiopods. The suggestion that the Leonard of west Texas replace the Baigendzinian is indefensible, as Baigendzinian faunas are virtually as diverse, historically long established, and much more extensive geographically. Moreover Baigendzinian zonation is more refined, whereas the Leonardian (=Cathedral Mountain) has not been subdivided. Faunally, the Kungurian and Kazanian Stages are so well entrenched in the literature that it would seem impossible, certainly most undesirable, to replace them. They are finely divided, in contrast to the crude double division of the Texas sequence (Roadian, Wordian). Indeed it may be noted that Cooper (1957) and Grant (1971) miscorrelated even other North American faunas, from Oregon and Arctic Canada, with faunas of west Texas, to demonstrate that the Glass Mountains standard does not guarantee successful correlation.

The next segment of time offers more difficulty. The Capitanian Stage of New Mexico, reinforced by the equivalent faunas of Las Delicias at Coahuila, Mexico, offers diverse though geographically restricted and somewhat unusual faunas, sufficient for an excellent standard. However, the Kalabaghian, Amarassian, and Chhidruan Stages from the Salt Range, Pakistan and Timor, Indonesia, have also been proposed. Waterhouse (1972b) and Grant & Cooper (1973) pointed out that the absence of any sequence must rule out the Amarassian Stage. Furnish (1973) disagreed and commented that 'the stratotype as a reference serves secondarily to the faunal content in time-stratigraphic definitions. This thought is not in accord with the Stratigraphic Code'... (Furnish, 1973, p.523). The Kalabaghian and Chhidruan Stages, used and defined by Waterhouse (1972a, b) and here treated as substages of the Punjabian Stage (Schenk *et al.* 1941), are based on rocks and faunas in the Salt Range, Pakistan, and are underlain and overlain by faunas in sequence. Although lacking Fusulinacea, they have highly diverse brachiopods, numerous bivalves and other invertebrates and a few ammonoids, sufficient to act as standards. Perhaps there will be some preference for replacing them with Soviet sequences. The Murgabian Stage of central Asia appears to have diverse Fusulinacea, and more brachiopods are being described (Grunt & Dimetriev, 1973). Alternatively, the Gnishik and Hachik faunas described by Ruzencev & Sarytcheva (1965) and Stepanov *et al.* (1969), as evaluated by Waterhouse (1972a), may suffice. Ammonoidea as usual are sparse or missing in these faunas, but selection of these units would help provide the standard for many substages in one region. Moreover, such a selection might obviate political difficulties, as similar sequences occur in Iran.

The Late Permian is well displayed by sequences in Armenia. Faunal units have been formally proposed by Waterhouse (1972a), based on geographic localities, with designated type sections, specific zones, and faunas described by Ruzencev & Sarytcheva (1965). Rostovtsev & Azaryan (1973) have further proposed a comprehensive name for the upper two faunas from the same region, so that the two works combine to give a logical, and one would hope, widely acceptable subdivision. Glenister & Furnish (1970) proposed an undefined Araksian Stage which Furnish (1973) equated with the zones equivalent to the lower and middle Baisalian fauna of Waterhouse (1972c). Faunally the Araksian Stage is inadequate, for the real boundaries lie with the Baisalian Substage, as also shown by Kozur (1974), not Araksian Stage. The Baisalian unit not only was defined earlier (of small consequence) but is more realistic. The base of the Baisalian Substage presents some problems. Meagre faunas in the area, as discussed by Waterhouse (1972b), point to a related but slightly older substage, called the Abadehian in central Iran by Taraz (1971, 1973). Furnish (1973) suggested that this interval matches the Amarassian Stage of Timor, and the uppermost Coahuila beds of Mexico and the writer agrees, at least with the Mexican correlation. Kozur (1974) matched the Abadehian with the bulk of the Chhidru Formation. The same Abadehian interval has had very rich faunas described from the Urushtenian Horizon of the Greater Caucasus. I provisionally use the name Urushtenian Substage, long established through Fusulinacean and brachiopod work, and with much richer faunas than the Abadehian of central Iran, but leave the Russians to designate a type area where they wish.

Grant & Cooper (1973) and Furnish (1973) referred Late Permian beds to the Changsingian (Changhsingian) Stage of south-west China, based on superb sections and rich faunas described in part by Huang (1933), Sheng (1964), and Chao (1966). But Rostovtsev & Azaryan (1973, p.94) pointed out that the stratigraphic position of the Changhsing Limestone is not well established, and that it is not latest Permian, and that its faunas are not well known. Kozur (1974) judged the Changhsing interval to be late Baisalian and early Dorashamian.

Finally there is the question of the Griesbachian or its equivalents. This stage, of debated Permian or Triassic age, has been carefully defined and its ammonoids described by Tozer (1967). Brachiopods are rare, and some may wish to transfer the standard section to Armenia. Waterhouse (1973b) argued for retention of the stage as it now stands, subject to international adjudication, but it is true that it has the disadvantage of commencing above an unconformity.

Type sections and stage names

An international subcommission is required to resolve the replication of available names for stages, and designation of various type sections, especially for the younger Permian rocks and faunas. In such decisions it is to be hoped that the decision be based primarily not on the priority of a proposal, but especially on the usefulness and relevance to the rest of the world, and to lesser degree on the proper observation of the rules of stratigraphic nomenclature (Hedberg, 1972).

Finally, it must be observed that some obligation lies with the country responsible for the standard sections. Access should be readily granted to overseas specialists, and faunal elements should be provided to at least some institutions in other countries. In this regard, Drs G.A. Cooper and R.E. Grant have provided a model of generosity and helpfulness. They have not only guided numerous specialists in the field through the Glass Mountains, west Texas, but have donated limestone blocks with magnificently silicified brachiopods to many institutions.

Substages

The earlier subdivisions treated as stages in Waterhouse (1972a, 1973a, b) are

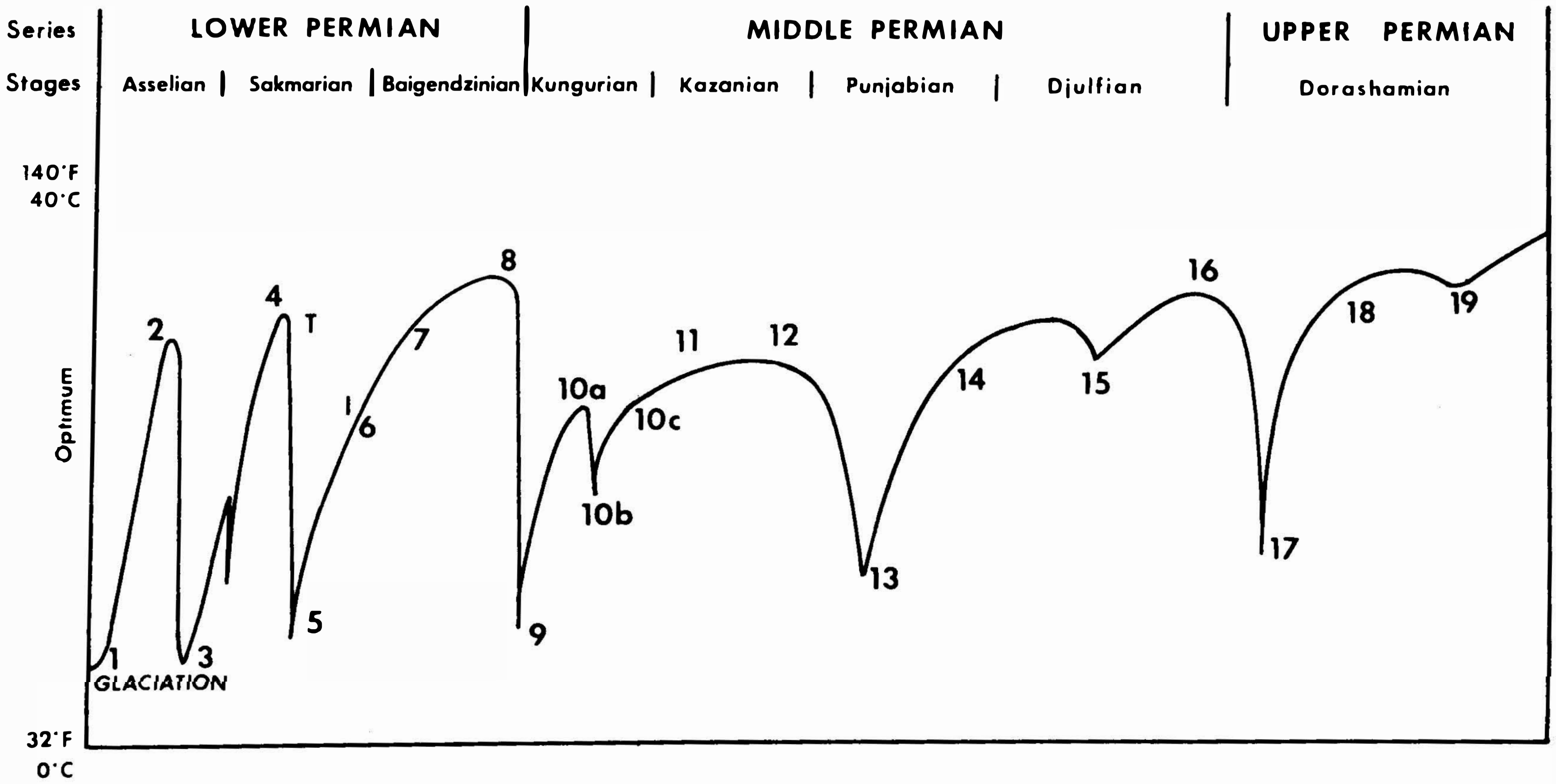


Fig. 10. Hypothecated world temperature changes and their relationship to Permian series and stages, with substages numbered as in Table 1, p. 3. Based on distribution of tillites, coral reefs, salt deposits, and coal deposits, and fluctuating faunal diversities. Redrawn from Waterhouse (1973d, p. 462, fig. 10).

perhaps too ambitious, and therefore a number have been reduced herein to substages. This makes the scheme simple and easy to remember, retains a fair degree of consistency with previous work, and enables broad correlation for inadequately understood faunas that cannot be matched precisely with a zone.

Major subdivisions of the period

To some extent stages can only be arbitrarily grouped, but for the Permian Period a natural grouping is suggested by major faunal changes that occurred in response to major climatic changes (Fig.10). It is clear from the stratigraphic record of east Australia, New Zealand and north-east Siberia that three major glacial episodes may be recognised, in the Surenan Substage, Filippovian Substage, and Vedian Substage. The first two were followed by several further glacial episodes and world-wide refrigeration, and then by world-wide climatic amelioration. Thus a three-fold division seems natural. The first, and longest, early Permian subdivision retained many Carboniferous genera. Diagnostic forms included *Pseudoschwagerina*, numerous brachiopods, and Perrinitid ammonoids. The Middle Permian saw the significant entry of *Neoschwagerina*, and Cyclolobid ammonoids. The Late Permian saw the entry of *Phisonites* , an ammonoid, and brachiopods *Comelicania* and *Janiceps*.

A two-fold division for the system is widespread in the literature, although early work in the United States, Japan, and China recognised a three-fold division. A two-fold division was warranted for rocks of the Urals and Russian Platform, because the upper third or half was terrestrial, and too poor to justify more than two divisions. Now that a fully marine sequence is established, it is clear that a three-fold division is justified, especially as the Russians for a time referred the upper third, not to just a discrete section of the Permian, but an entirely different system.

A second and minor question concerns the start of the Middle Permian, placed by some authorities at the base of the Kungurian Stage, and now by some American workers at the start of the correlative Road Canyon Formation in the Glass Mountains of west Texas. Others have favoured a higher boundary, at the top of the Kungurian Stage, or above the Road Canyon Formation, by stressing the survival in the Kungurian Stage of earlier forms. Dubious statistical support was claimed from a cluster analysis that slightly discriminates the Road Canyon faunas from Wordian and Capitanian faunas, with no data on the relationship to the Cathedral Mountain faunas. Other workers, such as Wilde (1968) and Waterhouse (1972a, 1973a), have stressed the significance of incoming rather than outgoing forms. There can be no question that a great faunal change occurred at the start of the Kungurian Stage, even though many species survived from older faunas.

3. The Base of the Permian

In recent years the base of the Permian System has been placed at the base of the Asselian deposits and faunas of the Urals and Russian Platform. It is widely agreed that to some extent the boundary is fixed arbitrarily, because successive faunas show incremental changes to the extent that various options have been supported at different times, ranging recently from the base of the Orenburgian, (see Table 12) to the base of the Sakmarian, the latter boundary still favoured by Chinese geologists.

A. SIGNIFICANT MARINE BIOTA

Fusulinacea

The Asselian Stage has been primarily distinguished by its Schwagerinids. *Pseudoschwagerina* and in particular *Schwagerina* are characteristic genera, although they do not always provide consistent time planes, and Barkhatova (1964) stated that neither the start nor end of *Schwagerina** (in the Russian sense) can be relied on for dating. In the Russian Platform and Urals, the Asselian Stage is underlain by the Orenburgian Stage with *Pseudofusulina** in the Russian sense (e.g. Nalivkin, 1972). Dr R.A. Douglass and Dr G. Wilde have informed me that *Pseudofusulina* (in the American sense) is a reliable key to the Permian Period. Certainly, in North America, and over much of Asia, *Pseudofusulina* appears to be restricted to the Permian, though beds with '*Pseudofusulina*' from the Pamirs and indeed Austria are generally assigned to the Late Carboniferous as discussed subsequently. Judged from brachiopods, the Austrian faunas could be Permian but the faunas of south Fergana are likely to be Carboniferous. It would appear that the communities of Fusulinacea should be studied as well as zones, and until this is done, and until *Pseudofusulina* is clearly delimited, it remains difficult to decide whether or not *Pseudofusulina* commenced in pre-Permian time. And until this is decided, it is obviously difficult to draw the boundary on Fusulinacean evidence.

Ammonoidea

Ruzencev (1952) has done a great deal to clarify and establish the Asselian Stage from ammonoid studies in the Urals. It is he who has most clearly enunciated reasons for fixing the boundary at the base of the Asselian Stage.

'The position of the upper boundary of the Carboniferous System has long been under discussion, a few stratigraphers drawing it at the base of the Orenburgian Stage, but the great majority placing it at the base of the Asselian Stage and a minority at the top of that stage. Such diversity of opinion is probably largely due to the fact that the upper boundary of the system is not clearly so sharply expressed as the lower boundary, even in terms of ammonoid changes... The Permian ammonoid assemblage as a whole is peculiar, but it formed very gradually. Of the eight highly characteristic Permian families, the Medlicottiidae and Shumarditidae appeared in the Moscovian Stage, the Marathonitidae in the Zhigulian (=Jigulevian), the Adrianitidae and Vidrioceratidae in the Orenburgian, the Paragastrioceratidae, Metalegoceratidae and Popanoceratidae in the Asselian. It is interesting that in the Sakmarian Stage no new families appeared. This constitutes definite evidence against the third version of the boundary, in which it is placed at the top of the Asselian Stage... A count shows that the Zhigulian (=Jigulevian)

System	Stage		Kotelnich	River Sakmara
PERMIAN	Upper Tatarian		Variegated sandstones and clays with beds of marl (162m)	Red sandstones, siltstones and marls (200-1500m)
	Lower Tatarian		Marls and clays with beds of dolomite (113m) Variegated sandstones and clays (153m)	
	Upper Kazanian		Gypsiferous, muddy limestones (28m)	Above, red beds; below, limestones & grey clays (200m)
	Lower Kazanian		Grey limestones. Marls and clays at the bottom; and a fauna (79m)	
	Ufian (=Ufimian)		Red sands and clay (29m)	Red beds (200m)
	Kungurian		Gypsum and anhydrite with beds of dolomite (175m)	Gypsum with sequences of clays and sandstones towards the bottom (1800m)
	Artinskian			Conglomerates & sandstones (450m) Clays with bands of sandstones (700m)
	Sakmarian		Interbedded dolomites and anhydrites (56m)	Ammonite-bearing argillites with beds of sandstone and marl (100-1200m)
	Asselian		Grey and dark grey gypsiferous dolomites (77m)	Argillites, marls and sandstones. Fusulinids are present (500m)
CARBONIFEROUS	Orenburgian		Grey dolomites and limestones with beds of gypsum (128m)	Marls, argillites with beds and sandstone & limestone (200-300m)
	Gshelian			Flysch-like alternating sequence of argillites and sandstones with boulder conglomerates (100m) (Moscovian)
	Kasimovian		Grey limestones, dolomites and gypsum (75m)	
	MOSCOVIAN	Mayachkovian suite	Interbedded pale limestones and dolomites (113m)	
		Podolian Ste.	Grey limestones & dolomites (52m)	
		Kashirian Ste.	Above, limestones; below, sandstones & clays (46m)	
		Verelian Ste.	Red clays & sandstones with beds of limestone (40m)	
			Dolomitized limestones (12m)	
			Namurian dolomites	

Table 12. Upper Palaeozoic successions in the Russian Platform and Urals slightly emended from Nalivkin (1973, tables 12, 30).

and Orenburgian assemblages have 21 genera in common, the Orenburgian and Asselian 16, and the Asselian and Sakmarian 21. Six new genera appeared in the Orenburgian age, 11 in the Asselian and 7 in the Sakmarian. These data are sufficient evidence in favour of the second version of the boundary, which places it at the base of the Asselian. But the arithmetical count is not the whole story.

'In the Orenburgian assemblage such Carboniferous genera as *Uddenoceras*, *Daixites*, *Neodimorphoceras*, *Aristoceras*, *Gonioloboceras*, *Glaphyrites*, *Paraschistoceras*, *Schistoceras*, and *Shumardites* are clearly predominant. Ammonoids of Permian appearance play a completely subordinate part here. There are accordingly no sufficient grounds for assigning the Orenburgian Stage to the Permian System... In the Asselian assemblage all the principal families of the Permian ammonoids are already represented together with such characteristic Permian genera as *Sakmarites*, *Akmilleria*, *Artinskia*, *Paragastrioceras*, *Juresanites*, *Properrinites*, *Kargalites* (subgenus *Kargalites*), *Marathonites* (subgenus *Almites*), *Prostacheoceras*, *Protopopanoceras* and others. The number of ammonoids of Carboniferous appearance in this complex is quite insignificant. It must be emphasized that this peculiar fauna developed at the beginning of the Asselian or 'Schwagerinan' age; therefore the ammonoid evolution offers no grounds whatsoever for assigning the Asselian Stage to the Carboniferous System. The boundary between the Carboniferous and the Permian must therefore be drawn at the base of the Asselian.' Quoted from Ruzencev, 1965, slightly emended from translation in International Geological Review, volume 8, No. 1, pp. 57,58.

However, few informed readers would be willing to accept Ruzencev's conclusions from the data he has presented. After all, the Orenburgian is clearly close to the Asselian in terms of ammonoids, underlining the fact that the decision is arbitrary. There is however, a more critical point to be evaluated. Ruzencev (1965) stated that the Asselian fauna developed at the beginning of the Asselian or 'Schwagerina' Stage, a point crucial for placing the boundary at the start of the Asselian. But the statement is not sustained by his more thorough discussion of Asselian ammonoids (Ruzencev, 1952). According to this treatise, three ammonoid zones are recognised in the Asselian, and the basal zone is characterised by the loss of a number of Orenburgian genera including *Uddenites* and *Prouddenites*, and by the proliferation of *Glaphyrites*, *without the appearance of a single new genus* (italics mine, directly translated from Russian). If this is correct, and it has never been countermanded in the literature, it suggests that the start of the Asselian was diagnosed simply by means of a depauperized ammonoid fraction in animal communities. Even the proliferation of *Glaphyrites* only repeated a phenomenon that occurred also in Moscovian times, and the genus ranged from Mississippian to Sakmarian (Dr W.W. Nassichuk, pers. comm.) The basal Asselian *may* mark a significant event, but then again, it may mark simply the final dwindling of an essentially Orenburgian faunule. It must be asked, was the early Asselian really Orenburgian? Barkhatova (1964) asserted that Ruzencev (1952) had in practice alloted primacy to Fusulinacea, even though he strongly criticised their value:

'In the type section of the subdivision described by Ruzencev in Bashkiria, along the Suren and Uskalik rivers ... ammonoids are absent. At a number of places their position within the section cannot be accurately located in relationship to the base and top of the given subdivision' ... (Barkhatova, 1964, p.274). It can thus be said that the basal Asselian was characterised by early Asselian Fusulinacea, and by impoverished, late Orenburgian ammonoids. It might then be argued that *Pseudofusulina* and *Pseudoschwagerina*, or shells so-called, dominated different but contemporaneous communities, to suggest that the Orenburgian and Asselian belong together in one major unit.

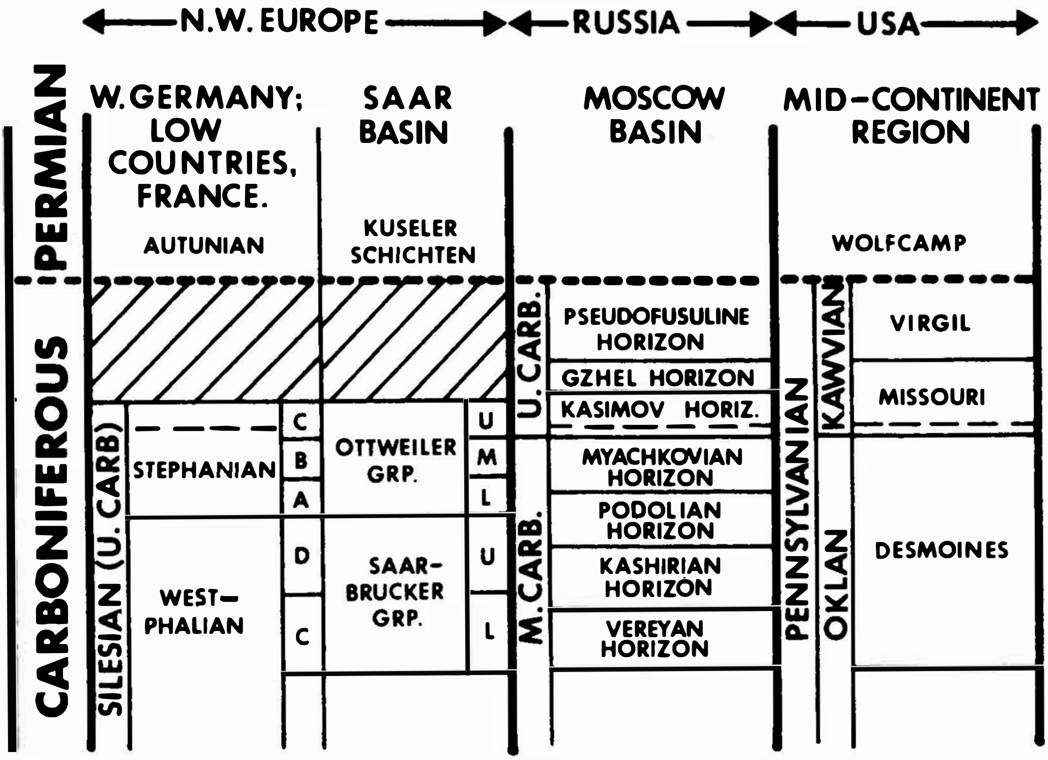


Fig. 11. Late Carboniferous correlations suggested by spores, according to Anderson (1973, p. 69, table 3), based on Helby (1969, pp. 69–71).

Brachiopoda

Clearly what is needed is a third source of evidence, from the brachiopods, which by virtue of being less facies controlled and far more widespread, could prove decisive. But there are few modern studies on the Uralian brachiopods, and Asselian and younger brachiopods from the Urals and Russian Platform require re-examination before they can be accurately fitted into a modern stratigraphic framework. More attention has been paid to Late Carboniferous brachiopods, summarised by Miloradovich (1949), Stepanov (1951), Likharev (1939), Ivanov (1935), Mironova (1967), Ivanova & Ivanova (1955), and Sarytcheva & Sokolskaia (1952), but the attempted division of faunas is not as fine as for Fusulinacea or Ammonoidea. Generally the Late Carboniferous Period is subdivided, if at all, into only two units, Kasimovian and Gshelian, which apparently incorporates the Orenburgian. In other works, Kasimovian and Gshelian are combined to make the Jigulevian, below the Orenburgian. From very imperfect stratigraphic control, it is judged that the Kasimovian, and Gshelian form one major faunal assemblage, of about stage rank, as distinct from the Asselian Stage. But where the Orenburgian brachiopod affinities lie is far from clear. There can be little confidence in the boundary until the brachiopods are studied or reassessed zone by zone.

REGIONS SIGNIFICANT FOR PLACEMENT OF THE BOUNDARY

Pamirs, Austria

Several other regions are significant in assessing where the boundary should be drawn. Rich faunas are known in the Pamirs, where extensive Fusulinacean zones, rich brachiopod faunas (Volgin, 1960), and a number of ammonoid specimens are found in the Sakmarian and Baigendzinian Stages. Russian fusulinacean experts have placed the Permian-Carboniferous boundary at the base of the Karachatirian Suite with *Pseudoschwagerina*, above the Dastar Horizon with *Pseudofusulina*, and the Uchbulak Horizon with *Triticites* and *Pseudofusulina*, regarded as Gshelian, including Orenburgian, and Kasimovian (Mikhluko-Maklay, 1958).

The tectonically complicated Austrian sequences in the Carnian Alps include Fusulinacea and Brachiopoda, with no significant Ammonoidea. *Pseudoschwagerina* enters the lower *Pseudoschwagerina* limestone at the base of the Rattendorfer beds, and is taken to indicate the base of the Permian by Kahler & Pray (1963). *Pseudofusulina* is found in underlying faunas in the upper Auernig beds. The Auernig beds also contain brachiopod faunas of general Late Carboniferous and Early Permian appearance, with *Attenuatella frechi* (Schellwien), member of a genus which is widespread in Early Permian deposits. Perhaps, like *Pseudofusulina*, *Attenuatella* entered pre-Permian faunas in some regions. But the general correlations in this region could accommodate a Permian age, provided that cryptic Carboniferous or Early Permian unconformities are present. It is interesting to note the presence of rolled blocks of sediment in the Auernig beds, suggesting the possibility of sharply lowered (glacio-eustatic?) sea-level. A final decision requires close analysis of the fusuline and brachiopod species. Floras from these beds are generally assigned to the Stephanian, which opens the further question of adjudicating a boundary between Carboniferous typified by non-marine beds in Europe, and Permian based on marine beds in Russia. The possibility of offlap, with a sizable gap, proposed by Helby (1969), or overlap is high. Helby (1969) suggested that Stephanian C matched the Kasimovian horizon of Russia (Fig. 11). But Wagner & Prinz (1970) recorded plants and brachiopods from Spain that may not support Helby's hypothesis. They assigned the plants from Spain to Stephanian A, and the brachiopods to the 'Kasimovian', chiefly on the basis of direct correlation with the Middle Kalkarme beds of Austria. If the Spanish and Austrian faunas are really basal Permian it seems that much of the younger Stephanian may prove to be Permian.

West Texas, United States

The Early Permian faunas of west Texas, ranging into north Texas, Kansas, etc., are virtually as diverse as those of the Urals. In the standard Wolfcamp sequence primitive Schwagerinids and *Pseudofusulina*, according to American definitions, and various brachiopods indicate a basal Permian age for the *Uddenites* Shale in the Gaptank beds, as summarized by Cooper & Grant (1973). Strong objection to this is voiced by Furnish (1973), who argued that the boundary should be retained for the sake of stability and because ammonoids from this shale include several with Carboniferous links, including *Uddenites*, *Prouddenites*, and *Uddenoceras*, listed also from the Jigulevian (Kasimovian, Gshelian) and Orenburgian of the Late Carboniferous in the Urals by Ruzencev (1962, p.352). Yochelson (1954) pointed out that the gastropod *Omphalotrochus* normally typified Permian faunas, including the Gaptank beds, but was found in the earlier (apparently Gshelian) *Omphalotrochus* Zone, well below the Asselian Stage.

It is noteworthy that Girty in King (1937) recorded '*Ambocoelia*', from the *Uddenites* fauna. This might prove to be *Crurithyris* or *Attenuatella* which widely characterized Early Permian faunas. Cooper & Grant (1973, p.366) in their discussion of the problem noted the presence of the following allegedly Permian brachiopods in the *Uddenites* shale: *Scacchinella*, *Waagenoconcha**, *Kochiproductus*, *Limbella*, *Teguliferina*, *Orthotetella*, *Echinauris*, *Fimbrinia**, *Martinia**, *Diplanus*, *Tropidelasma*, *Parenteletes*, *Spirifer* of *S. condor* type*. Of these, *Kochiproductus* is in my view the most significant, and several of the other genera have scarcely any other than local significance, those genera asterisked being particularly common in Carboniferous deposits, with *Teguliferina* typifying early Gshelian-Kasimovian faunas in the Moscow Basin. Similar brachiopods, including *Waagenoconcha*, *Martinia*, and *Spirifer* of the *condor* type are found in the Cisco beds of the mid-continent (i.e. North Texas), with an *Uddenites* ammonoid fauna, and *Teguliferina*, *Limbella*, and *Scacchinella* occur in the Marathon Basin with Virgilian Fusulinacea. Cooper & Grant (1973) included these faunas also in the basal Permian. The Pennsylvanian would close in their view with the Missourian Stage, which may be approximately Kasimovian according to the Russian standard. If so, this would appear to lower the Permian boundary to include the Gshelian faunas of Russia.

Australia

East Australia has impoverished Late Carboniferous and Early Permian faunas, that are significant for Gondwana correlations. As in Argentina, there has been considerable discussion over the start of the period, which is usually taken as indicated by the plant *Glossopteris*. The Late Carboniferous rocks of Australia appear to be extremely condensed, and no sizable marine post-Moscovian fauna of Carboniferous age is known from east Australia. Just above the ?Moscovian faunas are found glacial sediments, which have been dated as Carboniferous, but could be early Permian, with some support from rare *Eurydesma* found close to this horizon in New South Wales. However Gonzalez (1973) has recorded *Eurydesma* from the Argentina with *Levipustula*, a genus especially typical of the early Moscovian, although perhaps persisting into younger faunas.

Helby (1969) suggested that the Stephanian to Permian floral change was represented in east Australia as the replacement of the *Grandispora* flora by the *Potonieisporites* flora in the basal part of the glacial Seaham Formation (Fig. 11), correlated with the Kasimovian Stage. He showed the Dalwood Group to be as old as

Gshelian, with *Glossopteris* entering a little later, and replacing *Rhacopteris*. Thus even plants, and the significant bivalve *Eurydesma*, would appear to have been of Permian aspect by supposed Gshelian time, suggesting that the boundary could be lowered. However, none of Helby's Late Carboniferous ages for Australian beds are well established.

Yukon Territory, Canada

The Yukon Territory, especially in the north Ogilvie Mountains, offers superb, well exposed, and continuously fossiliferous sequences, especially rich in brachiopods. Fusulinacea have not been fully studied, and are missing from the Early Permian segment. Ammonoids are too few or localized to provide any sort of succession. But the brachiopods are closely allied to those of the Urals and Russian Platform, and reveal links with the Glass Mountains.

In the Ettrain Formation (Bamber & Waterhouse, 1971) the early zones are approximately early Moscovian—late Bashkirian, judged from small Foraminifera. They are followed by three consecutive brachiopod zones called the *Buxtonia* Zone, the *Gemmulicosta*, *Praehorridonia*, and *Reticulatia* zones, all correlative, and the *Purdonella-Gibbospirifer* zones which may approximately match the Kashirian, Podolian, and Mayachkovian suites respectively of the Moscovian Stage (Table 11). The overlying faunas in the Yukon Territory, chiefly in a new formation yet to be named, are characterized by an influx of brachiopod genera, including species of *Orthotichia*, schuchertellids, *Tubersulculus*, *Krotovia*, *Kozlowskia*, *Chaoiella*, *Crurithyris*, Atriboniidae, *Brachythyris ufensis*, broad ribbed *Choristites*, and the distinctive genus *Duartia*. These faunas include the Ck and Dos (*Kozlowskia* and *Orthotichia-Septospirifer*) zones in sequence of Bamber & Waterhouse (1971). In a general way these faunas are Kasimovian-Gshelian, and perhaps Orenburgian, in terms of the Russian succession.

They are followed by a suite of zones, characterized by many different brachiopod genera, including *Tomiopsis*, *Attenuatella*, *Kochiproductus*, and many productids that clearly mark a major faunal change, in the E faunas of Bamber & Waterhouse (1971). Fusulinacea and Ammonoidea are too rare to be highly significant. It is clear that the major faunal boundary falls at the base of the E faunas, or Jungle Creek Formation, but this does not necessarily mean that the boundary has been placed at that horizon in other countries.

Verchoyan, Orulgania, North-east Siberia

Thick, chiefly clastic sequences with abundant brachiopods and frequent intervals with Ammonoidea are found in the Verchoyan region near the Lena River of north-east Siberia. In north Verchoyan, and Orulgania, as outlined by Menner *et al.* (1970, p.44ff), the Tiksin Suite appears to be of mid-Carboniferous age, correlated with the Makarov Horizon of Taimyr Peninsula (Table 13). It is overlain by the Soybol Suite with early *Jakutoproductus* and various Cephalopoda, including *Yakutoceras* and *Parajakutoceras*. In Orulgania on the east flank of the Verchoyan anticline, many brachiopod species are found in the Yupenchin Suite, including genera *Semicostella*, *Antiquatonia*, *Plictotorynifer*, and others that suggest a Carboniferous age. Younger beds in this region, assigned to the Suyorgan Suite, include *Fimbrinia*, *Jakutoproductus*, *Cancrinella*, *Linoproductus*, *Brachythyris*, *Paeckelmanella*, *Settedabania*, *Martinia* and *Attenuatella*. Menner *et al.* (1970, p.47) correlated the faunas with those of the Ekachan Suite of Set-Davan, and upper Makarov beds of Taimyr Peninsula. Ammonoids include *Owenoceras orulganense* Popov, *Agathiceras uralicum* (Karp.) and *Eoshumardites artigensis* Popov, leaning towards a Carboniferous age. Plant horizons of the Suyorgan beds include *Noeggerathiopsis*, often regarded as exclusively of Per-

Taimyr Peninsula	Haraulakh	Orulgan	Kolyma Massif	Set-Davan	Zabaikal
Upper Turuzov Horizon	Verchoyan Suite	Kigiltass Suite		Djuptagin Suite	Hiposhin Suite
Jakutoproductus verchoyanicus (Fred.), *Anidanthus boikowi* (Step.)					
Lower Turuzov Horizon		Haldan Suite		Surkechan	Upper Shaz-agaitui Suite
Linoproductus (?) achunowensis (Step.), *Jakutoproductus cheraskovi* Kash., *L. aagardiformis* Sem., *Camarophoria* ex gr. *pentameroides* (Chern.) *Martinia semiglobosa* Gemm., *Spiriferella gjeliensis* Step.					
Upper Makarov Horizon	Soybol Suite	Suyorgan Suite Yupenchin Suite	Lower Argidjin Suite Burgali Suite	Natalin & bulk of Ekachan Suite	Most of Shazagai Suite
Fimbriania cristatotuberculata (Kozl.), *Jakutoproducts cheraskovi* Kash., *Balakhonia insinuata* (Girty), *Orulgania tukulaensis* (Kash.), *Plicotorynifer snjatkovi* Abr., *Settedabania stepanovi* Abr., *Yakutoceras trianguliumbilicatum* (Popov), *Stenopronorites* ex gr. *karpinskii* Libr., *Aldanites rotundus* (Popov)					
Lower Makarov Suite	Upper Tik-sin Suite		Magar Suite	Hatinach Suite	Upper Tuthaltu Harashibir Suites
Waagenoconcha sarytchevae (Ben.), *Stegacanthia (?) taimyrensis* (Einor), *Eomarginifera migai* (Chernyak), *Dictyoclostus byrangi* (Einor), *Choristites (?) anikeevi* Einor, *Tangshanella byrangi* Chernyak					

Table 13. Middle and Late Carboniferous correlations for north and east Siberia, proposed by Menner et al. (1970, Table 1, p.7).

mian age. The supposedly Late Carboniferous Haldan Suite includes brachiopods that suggest either an Early Permian or Late Carboniferous age, with *Fimbrinia, Tubersulculus, Jakutoproductus, Levicamera, Stenoscisma, Ambocoelia,* and *Orulgania.* By Canadian standards they appear rather like those of the Late Carboniferous D faunas, if *Ambocoelia* is correctly identified. Overlying faunas of the Verchoyan Suite include *Kochiproductus porrectus* (Kut.), possibly indicative of an Asselian age, with *Neoglaphyrites, Agathiceras uralicum* (Karp.), *Uraloceras simense* Ruzh., *Neopronorites skvorzovi* (Chern.) and *Paragastrioceras verneuili* Ruzh.

Clearly Verchoyan offers valuable sequences, probably comparable with those of Canada, with Ammonoidea more common, and Fusulinacea apparently absent. A number of inconsistencies arise from the correlations preferred by Menner *et al.* (1970), especially amongst the Ammonoidea, compared with ranges in the Urals. Of genera found in the Verchoyan Suite, *Paragastrioceras* characterises midAsselian faunas of the Urals, *Neoglaphyrites* disappeared at the end of the Asselian, but *Uraloceras* did not appear until the Tastubian (Ruzencev, 1952), yet all are found together in north-east Siberia. *Kochiproductus* characterised Asselian beds, but *Attenuatella* is recorded well below in the ?Middle Carboniferous Suyorgan Suite, with *Noeggerathiopsis* that is also usually regarded as no older than Permian. Admittedly this material has not been described, and could have been misidentified. But it must raise the possibility that *Attenuatella* did enter Carboniferous successions, as is possibly the case also for Spain and Austria. Equally it must raise the possibility that the Verchoyan sequences have been miscorrelated, Asselian rocks and faunas having been referred by Menner *et al.* to the Late Carboniferous. Certainly, in this regard, many of Menner's Lower Permian faunas are Sakmarian rather than Asselian, which would allow a basal Permian rather than Late Carboniferous age for some of their pre-Sakmarian suites.

Options over the Carboniferous-Permian boundary

From the foregoing review, it would appear that we face several difficulties in adjudicating a boundary. Overall, post-Moscovian faunas are fairly similar until the end of the Sakmarian Stage, and there is, apparently, no one indisputable key, plant or animal, that offers a widespread guide to the base of the Permian System. Fusulinacea have assumed the prime position in the Ural Mountains. But they were not particularly widespread, formed several contemporaneous provinces, and the nomenclature for the key genera are tangled in a bewildering maze at the moment. Ammonoidea would appear to be only slightly less provincial, and there is a critical apparent gap in the sequence in the Urals for the basal Asselian. Perhaps we should ignore Fusuline evidence, and allow the base of the Permian to coincide with the entry of 'basal Permian ammonoid genera' in the mid-Asselian. But we know of other instances where ammonoid genera are missing or belonged to a local and unusual community, and cannot judge yet the significance of the absence of Asselian ammonoids from the basal Asselian. Clearly Ruzencev (1952, 1965) considered that the absence was not significant, and gave greater weight to the Fusulinacea. The Brachiopoda at this stage are no more useful. Although they are much more widespread, and therefore less affected by environmental parameters, they are poorly known for the critical sequences of the Urals, especially for the Asselian and Sakmarian Stages. It is thus impossible to finally correlate better known brachiopod sequences. But enough is known to offer several alternative models for correlation, pending the overdue revision of the brachiopod faunules.

Option 1, Fig.12

In Option 1, reliance is placed on the ranges of brachiopods as in Cooper & Grant (1973), with an attempt to synchronise the incomings of such genera as *Kochiproductus* and *Teguliferina*, renewal of *Tomiopsis* and renewal or incoming of *Attenuatella* as marking the base of the Permian Period. This yields an impressive array of first beginnings, for the Fusulinacea show similar significant incomings with Schwagerinids (in the Gaptank) and '*Pseudofusulina*' (as variously understood, including the Carnian Alps and Soviet Union), and the gastropod *Omphalotrochus*, and bivalve *Eurydesma* (except for a report of an earlier form in Argentina by Gonzalez, 1973), and probably the bivalve *Atomodesma*. The overall picture is reasonable, because it suggests that the Permian Period commenced with glaciation, recorded by the Seaham deposits in New South Wales, Australia, which coincided with the widespread introduction or reinvigoration of 'cool-water' genera such as *Eurydesma*, and the brachiopods *Kochiproductus*, *Tomiopsis*, and *Attenuatella*, and the evolution in palaeotropics of many new Fusulinacea and Brachiopoda. Correlation is sustained between the Gaptank and Orenburgian on the basis of ammonoids, but the Suren fauna, with its indistinctive ammonoids, is relegated to an insignificant part of the basal Asselian. As a variation, the Gaptank might be solely Orenburgian, not Suren, and the range of *Uddenites* and *Prouddenites* should be reduced accordingly. The Fusulinacea suggest that the Surenan Substage is more significant than this, but they may have been of only local importance. '*Pseudofusulina*' s.l. assumes high value as a Permian index, though there is evidence, discussed previously, that at least some species perhaps mistakenly ascribed to that genus entered the Pamirs earlier. If the Seaham flora of Australia were regarded as Stephanian C rather than A as in Helby (1969), and were basal Permian in age, we would have a complete floral succession.

Although we need not discuss the Siberian faunas, it appears probable under this scheme that several of the faunas assigned to the Late Carboniferous by Likharev (1966) would also be Permian in age.

There are some objections, but none are firm. My overall impression of at least the Gshelian brachiopods is that they are very close to those of the underlying Kasimovian faunules, whereas the Surenan brachiopods in the Urals see the introduction of numerous *Juresania* (though not limited to this horizon), and *Tomiopsis*. A further objection lies in the treatment of *Pseudofusulina*. It appears very difficult to enforce a Permian age for this genus or at least species so named in the Pamirs, south Fergana, where associated brachiopods appear to be very close to late Moscovian species (Volgin, 1960), but perhaps the species concerned should be reassigned.

The range of *Duartea* deserves more study. This distinctive genus disappeared at the start of the E faunas in Canada, and is replaced by *Yakovlevia*. *Duartea* could be represented in Gshelian faunas by '*Muirwoodia*' *pseudoartiensis*.

Option 2, Fig.13

High value is placed on ammonoid distribution as interpreted by Ruzencev (1965) and Furnish (1973) with the boundary placed at the base of the Asselian, and above the upper Gaptank fauna. The Canadian Eka fauna is lowered, with its supposedly correlative faunas of Spitsbergen, Kazakhstan, and Austria to match the Orenburgian, and retain links with the Gaptank (chiefly through the incoming of *Kochiproductus*). This disperses a number of entries that coincided in the previous model, and makes *Schwagerina* (s.l.) and *Pseudofusulina* (s.l.) pre-Permian, and opens up a gap in the record of characteristic ammonoids. Brachiopods from Kazakhstan and Austria and Spitsbergen do show a number of Orenburgian affinities, but cannot be assessed as discriminating between correlative, or sequential relationships until the Orenburgian brachiopods are revised. If the correlation scheme were correct, it would appear that there is much to be gained from lowering the Permian boundary, so that it matches significant Fusulinacean and brachiopod incomings, instead of being represented by an ammonoid 'gap'. From the account in Cooper & Grant (1973) it appears unlikely that a gap is really present in the Glass Mountains column at the position shown in the figure.

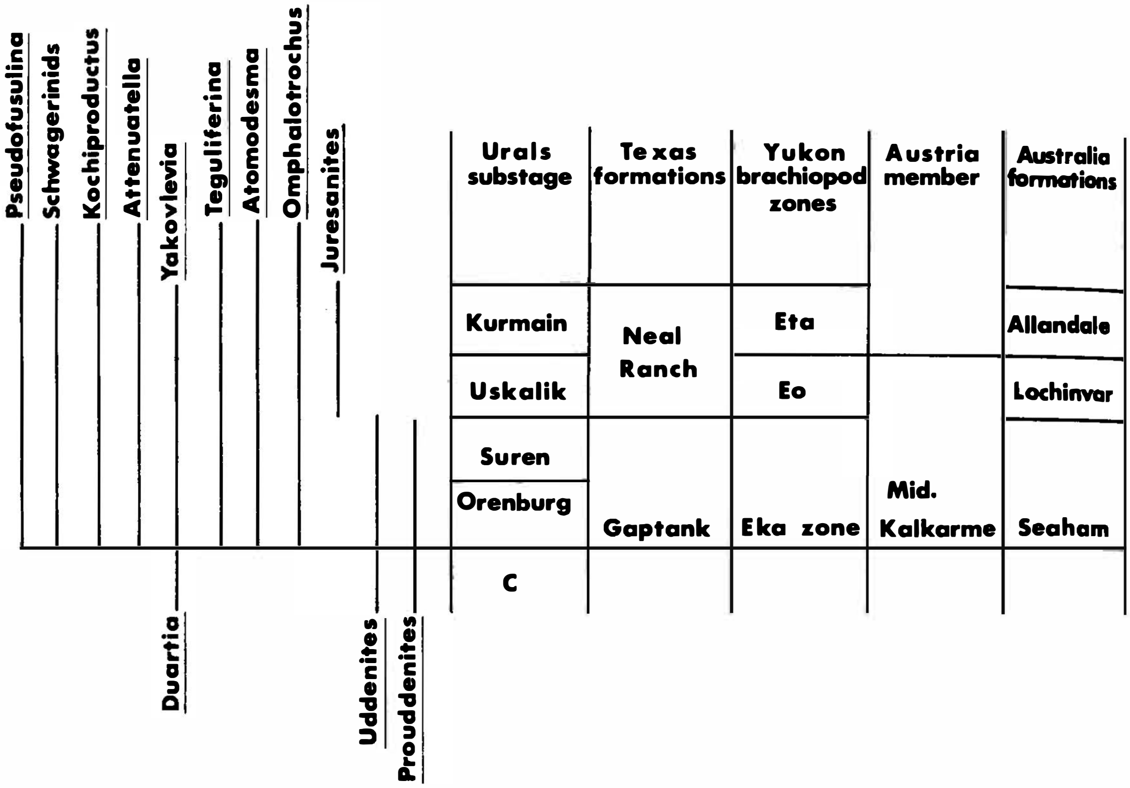


Fig. 12. One optional scheme for correlation of basal Permian sequences.

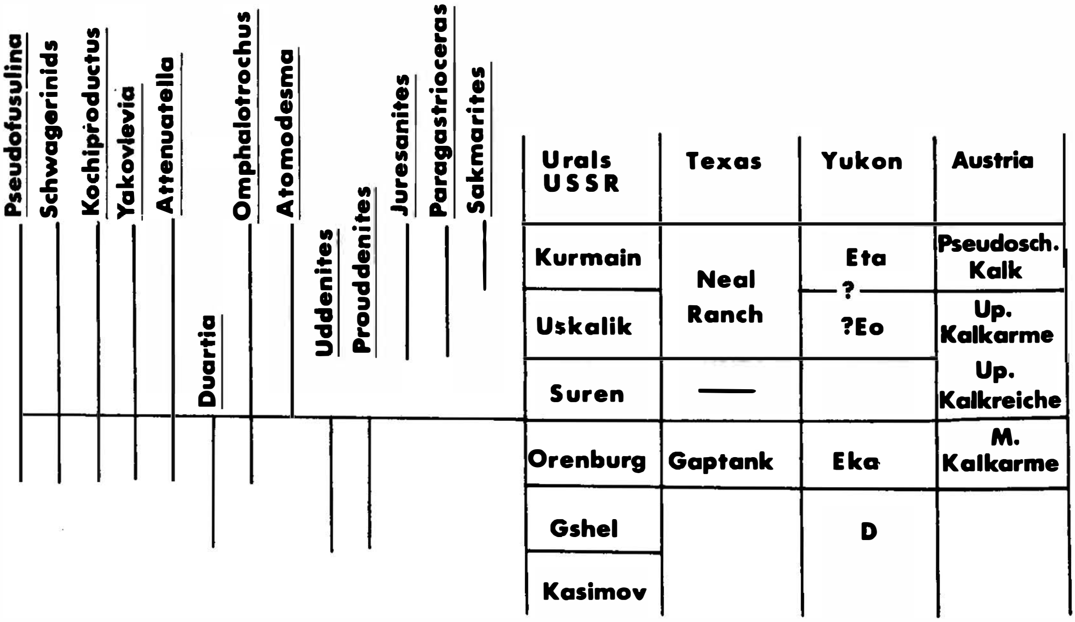


Fig. 13. Alternate option for basal Permian correlations.

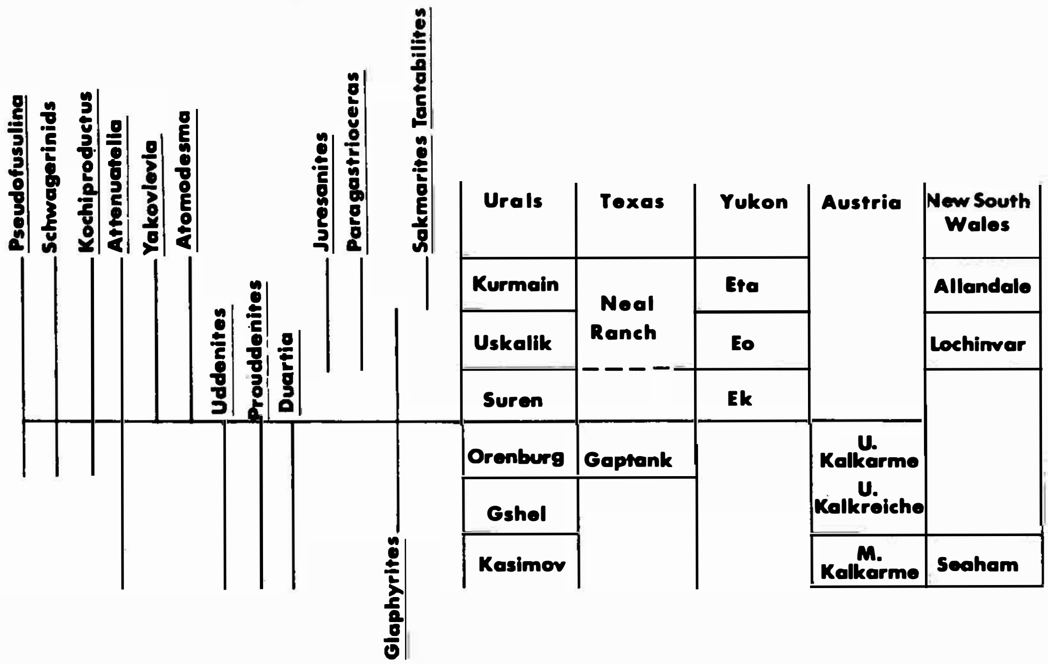


Fig. 14. Alternate option for basal-Permian correlations.

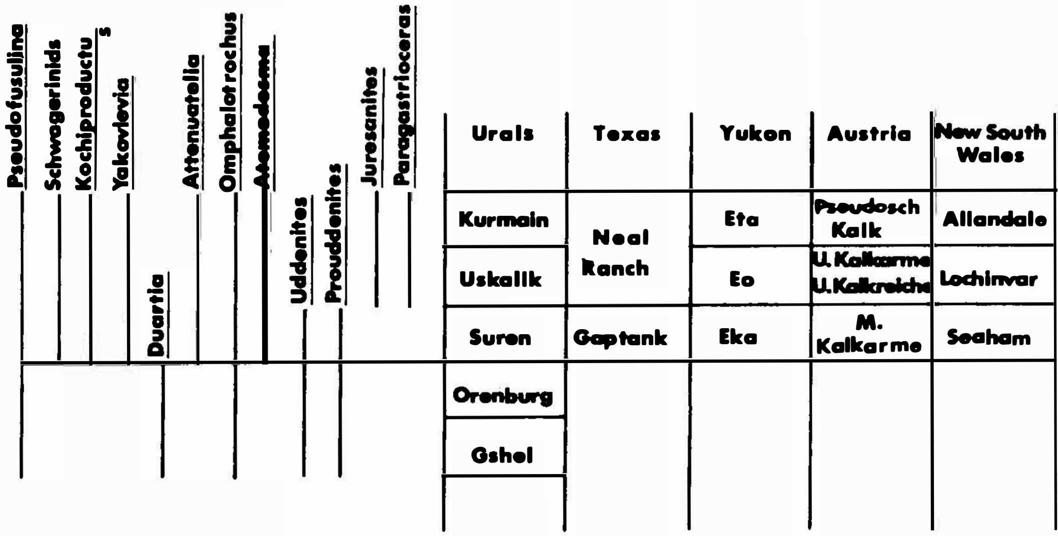


Fig. 15. Preferred option for correlation of basal Permian sequences.

Option 3, Fig.14

In the third scheme, the Canadian sequence is matched more closely with the Soviet sequence on the basis of brachiopods, the Eka zone with the Surenan Substage on the basis of *Tomiopsis*, and the D faunas with the ?Orenburgian to Kasimovian brachiopods. But the Gaptank and Orenburgian are intercorrelated by means of ammonoids. This appears to leave the brachiopod and Fusulinacean incomings in disarray and the positive links of the Orenburgian ammonoids are not reinforced by any notable entries of new forms at the start of the Permian. As a variation from previous charts, the traditional correlations of the Austrian and Australian sequences are shown as Late Carboniferous, i.e. Kasimovian. The scheme may well prove to be the right alternative, for it has essentially extended the column. This would accommodate well a Carboniferous age for *Attenuatella* in Verchoyan (Menner *et al*., 1970). But as a result, lengthy unconformities have opened up in the Glass Mountains and Australia, and no confirmation is yet known of three rather than two cold episodes in the Late Carboniferous and Early Permian. Nonetheless, I incline to this view.

Option 4, Fig.15

The fourth alternative will be the one adopted herein. It shows the Gaptank as correlative with the Surenan Substage, and delineates a fairly well defined Carboniferous-Permian boundary, marked by the incoming of Schwagerinids (but not perhaps *Pseudofusulina*), with the incoming brachiopod *Kochiproductus*, renewal or incoming of *Attenuatella*, and the renewal of *Tomiopsis*. Further support from the brachiopods appears to be provided from the underlying faunas, which through their characteristic suite of *Duartea, Kozlowskia, Brachythyris, Choristites, Krotovia* etc., form a general Late Carboniferous suite, involving the Missourian faunas of United States, the Kasimovian-Gshelian faunas of Russia and D faunas of Canada. As in other interpretations, the position of the Seaham beds in Australia is difficult to resolve, and not entirely relevant to the problem. They could be fitted into the Early Permian, at the entry of *Eurydesma* in Australia, and shortly before the entry of *Glossopteris*. And part of the debated Austrian succession, though shown as Permian, could be Late Carboniferous without critically affecting other correlations.

This scheme seems to fit best with most evidence, and of course requires least change in world correlations, or the Permian-Carboniferous boundary, except for the United States, where the Virgilian Stage may need to be treated as Permian, following Cooper & Grant (1973). But the Orenburgian could still be Permian.

The proposed solution is of course tentative, and it must be emphasized, needs verification from modern studies of brachiopods from the Urals. The data agree well with those adduced by Russian experts, including Ruzencev (1952), and also agrees with early conclusions by Miller (1931, p.384, 385) in which he accepted a Permian age for the *Uddenites* shale, and allowed that nearby *Prouddenites* faunas could be slightly older, as Late Carboniferous. But an intriguing paper by Miloradovich (1940) underlines the need for caution. He showed that Brachiopoda, Foraminifera, and Bryozoa declined sharply in numbers at the *Pseudofusulina** horizon, (?Orenburgian) which could imply onset of glaciation, and the start of a new period, supporting Option 1 of this discussion. Unfortunately, the Asselian values were not broken down into zones by Miloradovich (1940), so that their numbers may have been inflated.

4. Biochronology for the Marine Permian

ASSELIAN STAGE

Urals

The Asselian Stage of Ruzencev (1937, 1952) marks the commencement of the Permian Period. It is based on rocks and faunas exposed in the Ural Mountains of Russia near the Rivers Kiya, Sintas, and Dombas, in a variety of sedimentary rock types, ranging from thick shale and flysch, to polymict conglomerate with large broken blocks of reefs and bioherms. Ruzencev (1952) relied primarily on the incoming of four ammonoid families Perrinitidae, Metalegoceratidae, Popanoceratidae, and Paragastrioceratidae, to distinguish the Asselian faunas from the underlying Orenburgian faunas at the top of the Carboniferous Period. Three successive assemblages were recognised. The basal horizon is characterised by numerous species of *Glaphyrites*, a genus common also in the underlying Carboniferous, and the absence of many younger genera typical of the Permian Period. In the middle horizon *Juresanites* (Metalegoceratidae) and *Paragastrioceras* (Paragastrioceratidae) appeared for the first time. In the upper Asselian the genera *Sakmarites*, *Tabantalites* and *Protopopanoceras* made first appearances with a number of other species, and *Glaphyrites* and *Neoglaphyrites* disappeared.

This three-fold division of the Asselian is also reflected by faunal divisions based on Fusulinacea, abundant Schwagerinids being the most conspicuous and diagnostic fossils of the stage in the Ural Mountains. Rauser-Chernossova (e.g. 1937, 1940) recognised three zones on the Russian Platform:

(Top) 3. *Schwagerina* sphaerica* Raus.-Chern. & Schwerb., *Pseudofusulina* firma* Sham.
2. *Schwagerina* moelleri* Raus.; *Pseudofusulina* fecunda* Sham. & Schwerb.
1. *Pseudofusulina* vulgaris* (Schell.) and *Schwagerina* fusiformis* Krot.

This three-fold subdivision is best expressed by use of the names of the horizons within the Asselian beds, following Likharev (1966):

(Top) 3. Kurmain—Kurmaian Substage.
2. Uskalik—Uskalikan Substage
1. Suren—Surenan Substage

The three-fold subdivision may be traced widely around the world, and it is proposed that the three be elevated to substage rank, within the Asselian Stage.

The brachiopod faunules of Asselian age in the Ural Mountains are very large, and have been described as part of the Uralian assemblage in numerous studies, notably by Chernyshev (1902) and Stuckenberg (1898), as summarised by Miloradovich (1949) and Stepanov (1951). Genera include *Enteletes*, *Orthotichia*, *Derbyia*, *Meekella*, *Kochiproductus*, *Linoproductus*, *Ambocoelia*, *Phricodothyris* and *Tomiopsis*. Unfortunately they have not been re-examined for many years, and we do not know details of the faunal succession within the Asselian Stage. Indeed it is scarcely possible to discriminate Asselian brachiopods from those of Sakmarian age, perhaps because of difficulties for me in coping with Russian literature. Therefore it has been necessary to rely on other brachiopod sequences, correlated directly or indirectly with the type Asselian by means of Fusulinacea, Ammonoidea, or successional detail.

Many world sequences show a three-fold subdivision, which is assumed to match

Fig. 16. Distribution of Permian strata in the Soviet Union, summarised from Likharev (1966, table 1).

the three-fold subdivision found in Ammonoidea and Fusulinacea in the Urals. The basal and topmost subdivision, assigned to Asselian 1 and 3, are characterised widely by *Attenuatella*, and frequently are accompanied by *Kochiproductus* and especially *Tomiopsis* and Licharewiid genera, particularly in the later Asselian or Kurmaian Substage. Such genera, especially *Tomiopsis*, are suggestive of Australian-type faunas, and so indicate cool conditions (Waterhouse, 1971). The intervening faunas, believed to be equivalent to the Uskalikian Substage, have various genera also found in the Carboniferous, such as *Orthotichia* and *Kutorginella*, and have large coral reefs suggestive of warm-water conditions.

Donetz Basin, North Russia, Siberia

To the south of the Urals a sequence chiefly of carbonates up to 3000m thick in the Donetz Basin near the Don River (Fig.16) contain the Schwagerines typical of the Asselian Stage, with brachiopod faunas described and listed by Yakovlev (1912) and Grabau (1931, p.450). A three-fold division is recognised: the Kartamish Suite, with plants, and correlative Kalitven Suite, with marine faunas, perhaps equivalent to the Surenan Substage; the Pokrov Suite, and overlying Vrynetzev Suite, perhaps of Kurmaian age. Detailed ages are not clearly established, pending full analysis, which requires re-examination of the faunas. According to Likharev (1959), small Foraminifera suggest a middle and upper Asselian age, but this is not sustained by Likharev (1966). Some discussion has centered around the age of the underlying so-called Araucaria Suite, with plant remains, and the Fusulinacean *Triticites* and *Pseudofusulina**, regarded as Permian by some authorities, but now generally classed in the Carboniferous by Russian workers. The presence of saline and copper deposits in this sequence suggests the possibility of a basal Permian age, correlative with the basal Permian ice-sheets of Gondwana, by analogy with the copper beds and salt deposits that formed in the Zechstein Group during episodes of mid-Permian glaciation.

From Timan, north of the Urals, the Indiga Limestone about 30m thick is correlated with the Surenan Substage and the Nenetz beds are correlated with the Uskalikian and Kurmaian Substages on the basis of Fusulinacea (Barkhatova, 1964). Brachiopods were listed and described by Barkhatova (1964, 1968).

At Pai Hoi, east of the Petchora Basin and west of the Ob River the Yunargin Series contains the Zaostren Horizon at the base (Table 14), with *Pseudofusulina* krotowi* (Schell.) and *Schwagerina* fusiformis* Krot., indicative of an Asselian age, with several brachiopods, including *Spiriferella mica* Barkhatova. The overlying Sezim Suite, 6 to 40m thick, has a rich brachiopod fauna with *Neoglaphyrites* and *Glaphyrites*, suggestive also of an Asselian age, supported by *Yakovlevia*, *Brachythyris ufensis* Chernyshev, and *Uraloproductus stuckenbergianus* (Krotow). However the Sezim Suite was assigned to the Sakmarian Stage by Likharev (1966).

From Taimyr Peninsula (Fig.16), the faunas of the Turuzov Suite, described by Ustritsky and Chernyak (1963, 1967), contain *Glaphyrites*, with *Linoproductus achunowensis* Stepanov (also in the Sezim beds of Petchora), *Licharewia*, *Paeckelmanella* and *Tomiopsis*, to suggest a probable early or perhaps late Asselian age (Table 14), for at least part of the beds. Menner *et al.* (1970) showed most of the Turuzov Suite as Late Carboniferous (Table 15). At the Haraulakh region near the mouth of the Lena River, the Tiksin Suite, although assigned to the Permian in Likharev (1966, p.343), has ammonoids of Carboniferous aspect, including *Eoshumardites* and *Owenoceras*, with *Spiriferella gjeliensis* Stepanov, which, if correctly identified, is chiefly Carboniferous (especially Kasimovian-Gshelian), but ranges into Asselian deposits. The Tiksin Suite was shown as principally Lower Carboniferous, ranging up to Middle Carboniferous, by Menner *et al.* (1970), as in Table 16.

The Djuptagin Suite of Set Davan contains small faunas with *Jakutoproductus* and

Stage or Substage		Series	Beds	
			Petchor 1100 - 3300 m	
	Ufimian	VORKUT	Intin Suite 270 - 1100 m	
	Nevolin		Levorknt Suite	Rudnitz subsuite 150 - 500 m
Irenian				Ayachargin subsuite 250 - 700 m
		YUNARGIN	Undifferentiated	
?Filippovian Krasnoufimian			Talatin Suite 450 m	
Sarginian			Belkov Subsuite 450 - 800 m	
?Aktastinian			Upper 500 m Lower 40 m	Gusin Suite
Sakmarian			(=Glini Suite)	
?Kurmaian			Sezim Suite 40 m	
?Surenan			Zaostren Suite 30 - 150 m	

Table 14. Correlation of Permian at Pai Hoi, north Russia (Likharev, 1966, Table 9) Northwest Petchora Basin

Cancrinella, correlated with the Irbichan and upper Turuzov faunas by Abramov (1970).

Part of the Verchoyan Suite would appear to be Asselian, as Menner *et al.* (1970) recorded *Neoglaphyrites*. The bulk of the faunas, judged from lists in Likharev (1966), would appear to be Sakmarian.

In North Verchoyan, the rocks assigned to the Verchoyan Suite includes *Kochiproductus porrectus* (Kutorga), with *Jakutoproductus verchoyanicus*, and other wide-ranging species such as *Cancrinella janischewskiana* (Step.), *Neospirifer subfasciger* (Likharev), *Pseudosyringothyris inopinatus* Sol. and ammonoids *Uraloceras simense* Ruz., *Paragastrioceras* and *Neopronorites*. Some of the brachiopod species persist into the overlying Megen, Echi and Haldjin Suites, of Sakmarian age.

The Imtandjin Suite of south-east Verchoyan contains indecisive brachiopods such as *Jakutoproductus*, *Cancrinella*, *Pseudosyrinx* (Kashirtsev, 1959), and the ammonoids *Somoholites* and *Shumardites*. It is not possible to be certain of the age—from mid Carboniferous, to as young as upper Asselian—Menner *et al.* (1970) preferred a middle Carboniferous age. The Ekachan Suite of Set Davan at first sight appears to be Asselian, with *Kochiproductus*, *Tomiopsis*, and *Uraloproductus*, allied to a late Asselian species of Oregon and Yukon Territory, Canada, and ammonoids *Owenoceras*, *Somoholites* and *Stenopronorites ekatshanensis* Popov, unlikely to be as young as Kurmaian age. The beds were regarded as Late Carboniferous by Menner *et al.* (1970), and this may be correct because '*Kochiproductus*' is incorrectly identified by Abramov (1970, pl.13, fig.1-5).

Further east in the Kolyma River—Omolon Plateau region (Table 15), the Paren Horizon, 25-1000m thick, is likely to be upper Asselian, judged from the brachiopods *Attenuatella omolonensis* Zavodowsky and '*Pterospirifer*' *terechovi* Zavodowsky, with *Paeckelmanella*, *Tornquistia*, *Anidanthus*, *Linoproductus*, *Jakutoproductus*, and *Martiniopsis*. The fauna could be as young as Sterlitamakian, within the Sakmarian Stage as shown by Likharev (1966) or Zavodowsky (1970), but it seems unlikely. Underlying the Paren Horizon is the Burgali Horizon or Suite, containing a generalised Permian-type brachiopod fauna, with *Tomiopsis*, but without *Attenuatella*. The presence of a marginiferid, *Septacamera* and Choristitinids, together with the ammonoid *Owenoceras* suggests that the fauna could be Late Carboniferous, if *Omphalotrochus* can be taken as that old. A *Stepanoviella*-like form described by Zavodowsky (1968, 1970) as *Linoproductus popowi* Zav., *Sajakella zyriankensis* Zav. like a Spanish species, together with many *Tomiopsis* and *Brachythyris ufensis*, on the other hand allow a Permian age, both early and middle Asselian. Unfortunately, the report of *Kochiproductus* by Zavodowsky (1970) fails to finally confirm a Permian age, because *Kochiproductus levinsonlessingi* Zav. is far from typical of the genus.

Other small Permian faunas that are likely to be of Early Permian age in east Siberia were described from east Zabaikal by Kotlyar & Popeko (1967) in the Shazagaitui Suite. Brachiopods could prove to be Permian, though correlated with the Carboniferous by these authors, perhaps correctly if they were right in identifying *Levipustula*, for this has been assumed to typify early Moscovian faunas in both hemispheres. The fauna is somewhat like that of the Burgali Suite of the Kolyma River region, sharing *Jakutoproductus*, *Cancrinella cancriniformis* (Chernyshev), *Orulgania*, *Tomiopsis*, and *Taimyrella*. Andrianov (1963, 1966) correlated the fauna with those of the Uchagan beds of west Verchoyan which include supposed '*Ambocoelia*', an ally of *Attenuatella*. Further links to Orulgania (Ypenchin, Suyorgan, and Haldan Suites) and Haraulakh (Tugasir Suite) are suggested by ammonoids. The Chiron Suite of this area contains Early Permian brachiopods (Kulikov, 1959, 1965a, b), including *Martiniopsis* and other forms suggestive of an Asselian age. The Hiposhin Suite of Zabaikal has *Anidanthus* indicating an Asselian or Sterlitamakian age (Kotlyar & Popeko, 1967, p.22). West Zabaikal yielded a small fauna in the Chikoiskogo Suite, possibly as young

World Standard Substage	Central Taimyr Peninsula	SW Verchoyan		E Verchoyan Set-Davan	Kolyma, Omolon
(Dorashamian Stage)	Lower Tufolavov beds			Imtachan Suite 300 700 m	
(Djulfian Stage)					
Chhidruan	Chernoyar Horizon		?Dulgalach Suite 600 - 1600 m		Hivach Horizon 200 - 2000m
Kalabaghian	Upper Baikur Horizon				Gijigin Horizon 70m
Sosnovian	Lower Baikur Horizon	Endibal Series		Chambin Suite 500 - 100m	Omolon Horizon 100 - 1000m
Kalinovian			Delenjin Suite 600-700m	Menkechen Suite 900 1100 m	
Irenian					Djigdalin Horizon
Filippovian					
Krasnoufimian	Sokolin Horizon		Tumarin Suite 500 700 m	Dibbin Suite 500-700m	Djeltin Horizon 40m
Sarginian				(Tiri Basin)	
Aktastinian	Birrang Horizon	Tompin Series			Munugudjak Horizon 35 - 60 m
Sterlitamakian			Echi Suite 200-900 m	Kukkan Suite 1100-1300 m	Yasachnin Horizon 110m -
Tastubian	(?Evenk Horizon W. Taimyr)		Kigiltass Suite 600-1100m	(Tompo Basin)	Irbichan Suite 800 1000m
Kurmaian					Paren Suite
Uskalikian					Burgali Suite 200m
Surenan	Turuzov Horizon = 1		Imtandjin Suite 900 - 1200 m		
Carboniferous			Tiksin Suite 2000 - 3000 m	?Ekachan Suite	

Table 15. Correlation of Siberian sequences (see Fig. 16).

		Haraulakh	Orulgania	W Verchoyan	Set Davan	Taimyr
PERMIAN	UPPER	Haraulakh	Dulgalakh	Dulgalakh	Imtachan	Chernoyar
			Syuren Haldjin	Delenjin	Chambin	Baikur
					Menkechen	
				Tumarin		
	LOWER	Verchoyan			Dibin	Sokolin
				Echi		
						Birrang
			Echi			
						Turuzov
			Megen		Kukkan	
				Kigiltass		
CARBONIFEROUS	UPPER		Haldan	Solonchan	Surkechan	
					Ekachan	
			Suyorgan			
						Makarov
				Imtandjin ?	Hatalin	
	MIDDLE	Soybol				
			Yupenchin			
					Hatinakh	
		Tiksin	Setachan			
					Oblachan	Lower Carboniferous
	LOWER		Bilikat			

Table 16. Correlation of Late Palaeozoic suites in Siberia after Menner *et al.* 1970, Table 2, p. 54. "Upper Permian" commences at Kazanian Stage.

as Sakmarian (Kozubova & Kulikov, 1958; Kulikov, 1969; Maslennikov, 1957). *Odontospirifer* is present with *Jakutoproductus.*

In summary, most of these faunas from Siberia are difficult to correlate, partly because of the high northern palaeolatitude, and partly because the Late Palaeozoic rocks and faunas of Baikal are still incompletely monographed. It must be recalled that most of the extensive studies commenced only in the last few years, and may require revision through more refined collection from more closely controlled stratigraphic horizons. Thus the recognition of the Paren fauna in Zavodowsky (1970) marked a considerable improvement over slightly earlier work.

From Kazakhstan the large Kokpecten fauna described by Sarytcheva *et al.* (1968) is judged to be early Asselian in age, with *Attenuatella* and *Tomiopsis*, although it retains many Gshelian-Orenburgian genera. In south Fergana the very rich Karachatirian faunas fall into three divisions f, g, and h, possibly correlative with the three Asselian substages (Table 17), both on the basis of Fusulinacea and Brachiopoda (Likharev, 1946), with additions from Likharev (1966). However the faunas were shown as Sakmarian by Ustritsky (1971). The basal horizon f has Buxtoniids, *Scacchinella* and *Martinia*; the middle horizon is rich in *Enteletes*, *Meekella*, *Isogramma*, *Teguliferina*, *Hustedia*, and *Notothyris*, suggestive of warm waters; the upper horizon

Local Stage	Suite		World Standard
Pamirian	Chapsai Suite, 100m Shakharsev Suite 400m		?Djulfian
Murgabian	Iollikhar Suite 20-2000m		?Kazanian
Darvasian	Gundarin Suite 30-700m		Baigendzinian
	Safetdaron Suite 30-1500m		Aktastinian
	Chelamchin Suite 200-400m		?Sterlitamakian
	Zigar Suite 150-1200m		Tastubian
Karachatirian	Karachatirian Suite 150-1000m	Upper	Kurmaian
		Middle	Uskalikian
		Lower	Surenan

Table 17. Darvas Permian, South Fergana (Likharev 1966, Table 14).

includes more Buxtoniids, *Linoproductus*, *Martinia* and lacks such notably warm-water genera as *Scacchinella* and *Teguliferina*. Fusulinacea are highly significant, with *Rugosofusulina complica* (Schell.), *Pseudoschwagerina* ex gr. *uddeni* (Beede & Kniker) from the basal Karachatirian; *Paraschwagerina pseudomira* Mikl.-Makl., and *Robustoschwagerina tumidiformis* Mikl.-Makl. from the middle Karachatirian and *Sphaeroschwagerina carnica* (Schell.) and !*Pseudofusulina*[*] ex. gr. *vulgaris* (Schell.) from the upper Karachatirian fauna.

Volgin (1960) has also described a Karachatirian faunule from south Fergana. The underlying Late Carboniferous Dastar horizon $C^{2}{}_{3}$ includes *Rugosofusulina moderata* (Raus.) and *R. alpina* (Schell.) as if to suggest a possible Early Permian age also, by comparison with the Carnian Alps of Europe, with possible *Sajakella* ('*Muirwoodia*') *aurita* (Volgin) and *Spiriferella asiatica* Volgin like an Asselian species of Canada. Otherwise the Dastar fauna does not resemble Asselian faunas very closely. Underlying beds contain an echinoconchid very like a Missourian-Moscovian species from Canada and the United States.

From Pasha Asha, Tian (or Tien) Shan (Fig.17), comes another brachiopod fauna here correlated with the late Asselian on the basis of *Cancrinella*, *Martiniopsis*, *Martinia*, *Brachythyris* and *Linoproductus* species (Likharev, 1946). Hayasaka (1922, p.16) and Keidel (1906) discussed faunas of the Koktan Ridge, south Tien Shan, and Loweneck (1932) recorded several collections including a large fauna from Kukurtuktal in the Tien Shan, with supposed *Pseudoschwagerina princeps*, *Rhipidomella*, and numerous other brachiopods like the Asselian faunas of the Urals.

Karakorum Range, Tibet

Karakorum faunas to the south are somewhat similar. A fauna at Gilgal Camp, Gasherbrun, was recorded by Merla (1934) and redescribed by Sestini (1965d, p.167). It is likely to be either late Asselian (probably) or Sterlitamakian, judged from *Tomiopsis sokolovi* (Chernyshev), *Crurithyris*, regarded as an ecologic and temporal as well as morphologic ally of *Attenuatella*, syringothyrinids; and a general similarity to the Pasha Asha fauna of the Tien Shan. Species are allied to those of the Kalkarme beds of Austria, to favour a possible Asselian age. On the other hand the fauna differs from the Shaksgam Valley faunas of the Karakorum, described by Renz (1940a, b), here believed to be of definite Asselian age. The Shaksgam faunas are very large and accompanied by Fusulinacea identified as *Triticites*, *Pseudofusulina*, and *Pseudoschwagerina*. A middle or late Asselian age seems likely, in view of the presence of *Linoproductus cora* (d'Orb.), *Cancrinella cancriniformis* (Chernyshev), *Ambocoelia*, and *Martinia*.

Nearby in Tibet, north of the Tsang Po or Indus suture (lat. 31° 10' N; long. 87° E), Reed (1930) described Early Permian faunas in black limestones with Fusulinacea, including recorded but not illustrated '*Pseudoschwagerina princeps*' and '*Schwagerina fusiformis*', the latter typical of the basal and middle Asselian according to Likharev (1966). The collections, examined by the writer at the Geological Survey of India, Calcutta, include *Attenuatella*, described as *Dielasma* cf. *plica* not Kut. by Reed (1930, pl.1, fig.19). The brachiopods have much in common with species from Kokpecten, Kazhakstan, Gilgal Camp of Gasherbrun, and Shaksgam Valley.

Mongolia, China

Chao (1965) recorded an Asselian fauna from Mongolia that included *Triticites*, *Schwagerina*, and *Quasifusulina*, with possible *Attentuatella* figured as *Crurithyris*. Specific affinities amongst the brachiopods lie to some extent with middle Karachatirian; but chiefly with the upper Karachatirian faunas, and a late Asselian age is most likely.

System	Series	Formation	Rock Character	Fusulinid zones	Standard Stages
Trias	Lower		Thin-bedded limestone or shales	(As in Sheng)	?
PERMIAN	Lopingian	Changsing Limestone	Grey to deep grey thick-bedded, finely crystalline limestone with chert nodules 95-105m	*Palaeofusulina* Zone *Palaeofusulina* *Reichelina* *Nankinella*	Dorashamian
		Wuchiaping Limestone	Grey, thick-bedded subcrystalline limestone, seldom with chert nodules or cherty bands 370-330m	*Codonofusiella* Zone *Codonofusiella* *Reichelina* *Nankinella* *Sphaerulina*	Djulfian
	Yangsinian	Maokou Limestone	Light grey massive limestone with some chert nodules 35-172m	*Yabeina* Zone *Yabeina* *Neoschwagerina* *Neomisellina* *Kahlerina* *Chusenella* *Lantschichites*	Punjabian
			Light grey, thick-bedded limestone intercalated with siliceous limestone 190-265m	*Neoschwagerina* Zone *Neoschwagerina* *Verbeekina* *Sumatrina* *Afghanella* *Pseudodoliolina* *Chusenella* *Schwagerina* *Pseudofusulina*	Kazanian
			Grey to deep grey thick-bedded, finely crystalline limestone 237-305m	*Parafusulina* Zone *Cancellina* Subzone *Cancellina* *Yangchienia* *Parafusulina* *Verbeekina* *Russiella* *Pseudofusulina* *Chusenella* *Schwagerina* *Pseudodoliolina*	Kungurian
		Chihsia Limestone	Deep grey massive cherty limestone 124-280m	*Misellina* Subzone IV *Misellina* *Parafusulina* *Schwagerina* III *Toriyamaia* *Nagatoella* II *Staffella* *Nankinella* *Pseudofusulina* I	Baigendzinian Sakmarian
Carboniferous	Upper	Maping limestone	Whitish grey massive limestone 200m	*Pseudoschwagerina* Zone	Asselian

Table 18. Sequence of Permian in South China, following Sheng (1963, p. 142).

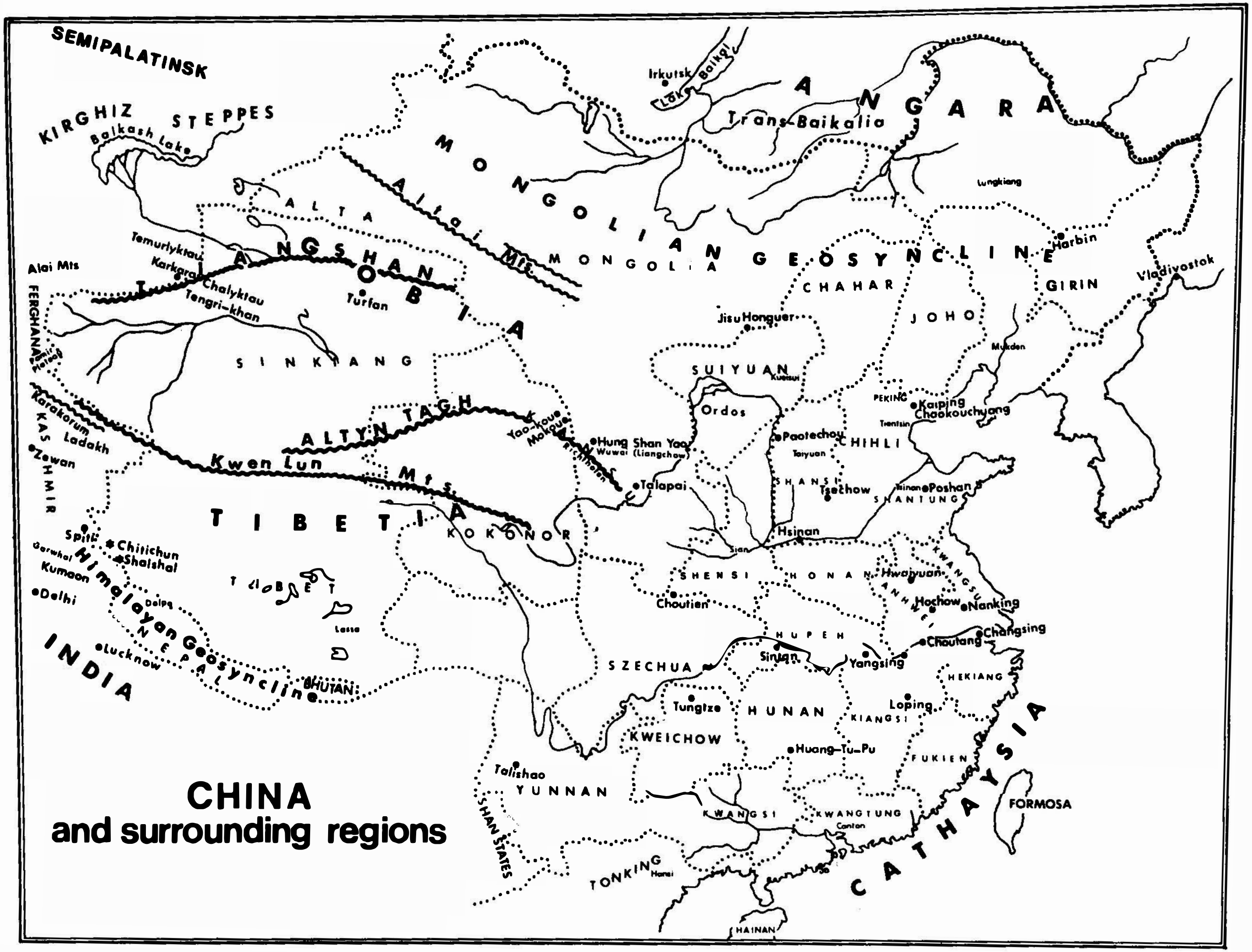


Fig. 17. China and surrounding regions, redrawn from Grabau (1924, pl. 4).

The Maping Limestone of China is a white, massive pure limestone with chert horizons, about 200m in thickness (Table 18). The formations contain Schwagerinids in three zones named as follows by Chan (1963):

(Top) 3. *Paraschwagerina inflata* (Chan)
2. *Pseudofusulina*('*Leeina*') *valida*(Lee)
(Base) 1. *Pseudoschwagerina parasphaerica* (Chan)

Both Chan (1963) and Sheng (1964) referred the formation to the Carboniferous on the basis of *Pseudoschwagerina*, but this is a matter of definition, not an alternative correlation. Several monographs have described the brachiopods (Chao 1927b, 1928; Huang, 1932b, 1933; Grabau, 1934, 1936), with the latter work devoted largely to species from the Maping Formation, which had previously been regarded as young Permian, chiefly in the Kwangsi and Kiangsi provinces (Fig.17). About fifty species are shared with Uralian faunas. Other large faunas come from the Payu Limestone and Lungli Limestone of Kweichow with more chonetids and fewer Productacea, originally described by Huang (1933) and Grabau (1934). The faunas are close to the upper Karachatirian faunas of Fergana (twelve restricted species), and less to the middle Karachatirian (eight restricted species) and also there are similarities to the Shaksgam faunas of the Karakorum. In addition a number of species are shared with the faunas of Tibet and the Gilgal Camp of Gasherbrun. The faunas came chiefly from the middle Maping Limestone according to Huang (1933), and as they do not have late Asselian key genera, may be middle Asselian.

From north China, Chao (1927) described part of the brachiopod faunules from the Taiyuan Limestone in Kansu and Shansi, probably correlative with the Maping Limestone. Further affinities are equally divided between Karachatirian horizons f and g, though considering only key species, most affinities lie with the f faunas, five species, against two for Karachatirian g.

In Manchuria, beds more or less equivalent to the Taiyuan Formation near Shih-pu-tsui have yielded a fauna probably incompletely listed by Ozaki (1931), and large but similar faunas are listed from near Poshan City by Ozaki (1931, p.10), and Hayasaka (1922). The preponderance of choristitinids (*nikitini*, *baschkirica*) from the Poshan beds suggest a possible Sakmarian age. Meagre faunas are found with '*Pseudoschwagerina*' (s.l.) in the Koten 'Series' of Korea.

South-east Asia, Japan

Further large Asselian faunas are found in south-east Asia, including Fusulinacea and Brachiopoda from Kham Kheut, and Muong Thé, and other localities in Laos and Tonkin (Mansuy, 1913, 1919, 1920) as set out in Table 19. A small fauna at Tran-ninh lies at the base (Mansuy, 1913; Deprat, 1913, p.74), but is judged to be of the same zone as the others by Waterhouse (1973a). The faunas are associated with supposed *Pseudoschwagerina princeps* (not Ehrenburg (=*S. moelleri* Raus.?) thought to be *Zellia* by Kahler & Kahler (1966). They were regarded as late Asselian or Kurmaian (Waterhouse, 1971), on the presence of *Crurithyris*, Licharewiinids, *Martiniopsis*, and *Tomiopsis*. From Thum Nam Maholan, central Thailand, a somewhat similar fauna was thought to be as young as Artinskian by Yanagida (1966), but Waterhouse & Piyasin (1970) preferred an Asselian age. Other faunas likely to be of identical age are mentioned by Gobbett (1968, p.19) from the Kinta Valley of central Malaysia.

In the Sakamotozawan Series or Stage at the base of the Permian in Japan, Fusulinacea identified as !*Pseudofusulina** *vulgaris* (Schell.) and *Robustoschwagerina schellwieni* (Yabe) in the middle of the stage are accompanied by a few brachiopods (Morikawa, 1967; Kanmera & Nikami, 1965) which are incompletely described, or very poorly preserved (Table 20). A brachiopod faunule has been recorded from south-west Japan in the Nakakubo Formation by Yanagida & Hirata (1969), with several

Standard Substage	Salt Range Formations	Timor Faunal Horizons	Thailand brachiopod & fusulinid localities	Cambodia Sisophon Ishii *et al.* (1969)	Laos Deprat 1913	China Ftm
Griesbachian						Changsing
Obginan						
Vedian						?
Baisalian						Wuchiaping
Urushtenian	Kathwai Member					
Chhidruan	Chhidru Fm	Amarassi		Member D	Luang Pradang	?
Kalabaghian	Kalabagh Member	Basleo	Petchabun	Member C	Level 7 6	
Sosnovian	Middle			Member B	Level 5	Maokou
Kalinovian	Wargal Fm				Level 4 Level 3	
Irenian	Lower	?Tae Wei	Khao Phrik		Level 2	
Filippovian	Basal	Bitauni	Khao Phlong Prab	Member A	Level 1	?
Krasnoufimian	Amb Fm					Chihsia
Sarginian						
Atkastinian	Sardi, Warchha Fm					
Sterlitamakian	(*Conularia* beds)					
Tastubian						
Kurmaian	(*Eurydesma* beds) Talchir Fm	Somohole	Thum Nam Maholan Noankowtok		Muong Thé Kham Kheut	Maping
Uskalikian						
Surenan						

Table 19. Permian correlations for south-east Asia, based on Waterhouse (1973 a).

Fm - Formation

species shared with the Maping and Taiyuan beds of China. Accompanying Fusulinacea are correlated with the *Pseudoschwagerina minatoi* Kanmera Subzone or Zone of the Yayamadake Formation of Kyushu, allotted a vague Sakmarian-Asselian age, but most likely mid-Asselian.

Turkey, Austria, Spain

A fauna described by Enderle (1901) from Balia Maaden, north-west Turkey, included fusulines identified as *Pseudoschwagerina princeps* though the brachiopods suggest only a general Asselian-Sakmarian age.

In Austria (Table 23) the base of the Permian has been assumed to lie at the base of the Rattendorfer beds (Kahler & Pray, 1963), but underlying faunas of the Auernig complex contain some brachiopods of Permian aspect. However plants and Fusulinacea are usually judged to indicate a Carboniferous age.

Pasini (1963) showed that there are three Fusuline communities in the Auernig beds, a basal faunule with *Pseudostaffella*, *Ozawainella*, *Fusulinella*, *Wedekindellina*, and *Quasifusulinoides*, indicating a Moscovian or more probably Kasimovian age, a much higher faunule with *Quasifusulina longissima* (Moeller), *Triticites*, and *Pseudofusulina* (*Daixina*) *alpina alpina* (=*Rugosofusulina* in Kahler & Kahler), classed as Gshelian, and a topmost faunule with *Nankinella*, *Sphaerulina*, *Fusulinella*, *Quasifusulina* and *Pseudofusulina*, classed as Orenburgian or probably Permian. The latter faunule occurs in bed n of Frech (1894), in the upper kalkreiche beds. The middle faunules occur in beds g-i at the base of the upper kalkreiche beds, and the basal faunule occurs below bed a of Frech (1894). The stratigraphic position of the latter fusulines is not entirely clear—probably at the base of the middle kalkarme beds, or in the underlying horizon.

From the accounts in Heritsch (1934) and Kahler & Pray (1963), the Auernig is subdivided into several units, especially well displayed along the Garnitzer ridge. The lower kalkarme beds with the Waidegger fauna is stated to be Moscovian (Mayachkovian-Samaran), although the abundance of marginiferids suggests to me a possible Kasimovian age. From the overlying lower kalkreiche beds, Heritsch (1933, p.166) recorded *Pseudofusulina* and *Triticites* with various choristitinids that point to a Carboniferous rather than Permian age. Many compound rugose corals are also present, with *Quasifusulina tenuissima* (Schellwien). The middle kalkarme beds contain large brachiopod faunules, including *Neochonetes*, *Chaoiella*, *Linoproductus*, and 'horizon a' is correlated with the Krone bed 6 containing the *Spirifer* fauna of Schellwien, including *Attenuatella frechi* (Schell.), *Plicatocyrtia zitteli* (Schell.), *Sergospirifer carnicus* (Schell.), choristitinids and *Martinia, with Stenoscisma alpina* (Schell.). Apart from *Attenuatella*, the brachiopods would appear to have a Late Carboniferous rather than Early Permian aspect, but this judgement is not based on intimate knowledge of the species. They apparently overlie the basal Fusuline fauna described by Pasini (1963). Wagner & Prins (1970, p.503) stated that this horizon a of Frech and Krone bed 6 contained the Moscovian-Kasimovian Fusulinacea described by Pasini (1963), but from the account in Heritsch (1934) I would gather that the brachiopod faunas were slightly higher in the Auernig sequence. This would seem to be confirmed from the overall stratigraphic columns and thicknesses involved. Overlying Fusulines *Pseudofusulina* (*Daixina*) *longissima alpina* (Schell.) with *Triticites* and *Quasifusulina longissima* (Moeller) at the g horizon, or base of the upper kalkreiche group suggest, as in Pasini (1963), a probably Gshelian age, but an early Asselian age could not be ruled out.

The overlying upper kalkreiche beds appear, from data in Heritsch (1933, 1934), to match beds 1-n up to bed r of the Monte Auernig section, and thus include the highest Fusuline faunule described by Pasini (1963). This could be Permian in age, and

		Standard Section	Fusulinid Subzone	South Kyushu Kuma Massif (composite)	Kwanto Massif	Iwaizaki	Kitakami Massif	
Lower Triassic							Inai Gp	
	Upper	Kuman	*Yab. yasubaensis* *Lep. toriyamai*	Kuma Fm			Toyoma Gp	Usuginu Cgl
	Middle	Akasakan	*V. verbeeki - shiraiwensis*	Kozaki Fm	Kamikuzu Fm	Iwaizaki Limestone	Yukisawa Gp	
			Ns. craticulifera		Asakaido Fm			
		Nabeyaman	*Ns. simplex*		Shimokuzu Fm			Kanokura Fm
	Lower		*Paf. kaerimizensis*	Shimodake Fm	Hanagiri Fm			Sakamotozawa Fm
		Sakamotozawan	*Pss. morikawai*	Yayamadaka Lmst				
Carboniferous	Upper	Hikawan						

Table 20. Permian of Japan, following Takai *et al.*, 1963, fig. 3a.

Cgl - conglomerate; Fm - Formation; Gp - Group; Lmst - Limestone.

Fig. 18. Distribution of Permian rocks at Spitsbergen, simplified from Gobbett (1964, fig. 1, p. 18).

contains *Pseudofusulina*. The brachiopods from the upper kalkreiche beds are very like those of the middle kalkarme beds, according to Heritsch (1934) who lists a number of species, including *Attenuatella frechi* (Schell.). Plants and compound rugose corals are present, with *Rugosofusulina alpina communis* (Schell.) and other Fusulines, and the age may be as young as Early Permian, as suggested by Pasini (1963), to Orenburgian. The presence of *Attenuatella* might be taken to imply that these beds belonged to the same zone as either the underlying middle kalkarme beds (more likely in view of overall faunal similarities) or with the overlying *Pseudoschwagerina* beds, but detailed study is required to verify the exact age. We know so little of the range and communal and ecologic associations of the key species that we cannot rule out an Uskalikian age for the upper Kalkarme, which might be supported simply from stratigraphic and sequential evidence.

At the top of the Auernig sequence the upper kalkarme beds contain numerous compound rugose corals, and plants assigned to Westphalian E(Reichardt, 1932). But evidence for a Late Carboniferous age is weak, and the beds could be as young as Uskalikian. The lower 'Pseudoschwagerinakalk', 135m thick, of the basal Rattendorfer beds contains rare *Pseudoschwagerina alpina* (Kahler & Kahler) and various brachiopods and is here considered Asselian. The writer found *Attenuatella* at this horizon at the Tresdorfer höhe, to increase the likelihood of a Surenan or Kurmaian age. Various faunas have been described (Schellwien, 1892; Seelmeier, 1937; Metz, 1935; Heritsch, 1935; Gauri, 1965). Auernig-type brachiopod faunas are recorded from Yugoslavia (Croatia) by Simic (1937) with '*Ambocoelia*', *Choristites fritschi*, *Brachythyrina carnicus* and *Stenoscisma alpina*.

From the supposedly Stephanian A Branosera Formation at Barruelo de Santulla, province of Palencia, north-west Spain, Wagner & Prins (1970) have recorded a mid-Auernig fauna, including *Attenuatella* cf. *frechi* (Schell.), and *Karawankina* (initially described from the Trogkofel of Yugoslavia), with some species identified with shells from the Miaohou Limestone at the base of the Taiyuan 'Series' in north China. The fauna is obviously close to that of the 'Spiriferenschicht' and layer 6 of Schellwien in the Carnian Alps, including such species as *Attenuatella frechi* (Schell.), *Plicatocyrtia zitteli* (Schell.), *Choristites fritschi* (Schell.), *Martinia karawanica* Volgin, *Brachythyrina carnica* (Schell.), and others. Many of these forms are shared with, or are closely allied to Kasimovian, Gshelian, and Asselian species.

Spitsbergen, Canada, United States

A large brachiopod faunule from the Treskelloden beds of Hornsund, west Spitsbergen (Fig.18, Table 25) was ascribed by Czarniecki (1969) to the Gshelian Stage, but the fauna could be of basal Asselian age, judged from *Tomiopsis petrenkoi* Czarniecki and *T. lata* Czarniecki, species which closely resemble *T. ovulum* Waterhouse in the Asselian of the Yukon Territory, as well as *Crurithyris*, or a broad *Attenuatella*, and *Linoproductus coralineatus* Ivanov. *Orthotetes* and *Krotovia* suggest an Orenburgian age, but may have persisted into the Surenan Substage, as did a number of brachiopod species in the Kokpecten fauna of Kazakhstan. The fauna is likely to to be correlative with the *Attenuatella frechi* fauna in the Auernig beds of Austria.

The *Triticites* Zone of the Cadellfjellet Member in the lower Wordiekammen Limestone on Bunsowland (inner Isfjorden), Spitsbergen, has yielded *Pseudofusulina* together with a modest brachiopod faunule of general Permian aspect assigned to the Orenburgian by Cutbill & Challinor (1965, p.19), but herein regarded as Permian, perhaps basal Asselian. The middle member, or Brucebyen beds of the Nordenskioldbreen Formation has a marginiferid, and the upper '*Pseudoschwagerina* Limestone' or Tyrellfjellet Member is possibly late Asselian, but likely to be Sakmarian, as in Cutbill & Challinor (1965), judged from the brachiopods recorded by Gobbett

Garnitzer Profile	Auernig Sequence	Faunal Sequence (in part)	Pasini 1963 - ages	Kahler & Pray 1963	Possible age minimum	Possible age maximum
Rattendorfer Beds	Frech 1894	*Pseudoschwagerina alpina*		Permian	Kurmaian	?Asselian
Upper Kalkarme Beds	s r				Uskalikian	
Upper Kalk-reiche beds	n g-i	*Quasifusulina*, *Pseudofusulina* *Quasifusulina longissima*, *Rugosofusulina alpina*	Permian Gshelian		Surenan	Gshelian
Middle Kalkarme Beds	f a	*Attenuatella frechi* etc. *Wedekindellina*, *Quasifusulinoides* *Pseudostaffella*	Kasimovian-Gshelian Moscovian-Kasimovian			?Kasimovian
Lower Kalk-reiche beds	?	? ? *Quasifusulina tenuissima*			?Gshelian	
Lower Kalkarme beds		"Waidegger" fauna		Moscovian	?Kasimovian	Moscovian

Table 21. Auernig sequence in Carnian Alps, Austrian-italian border

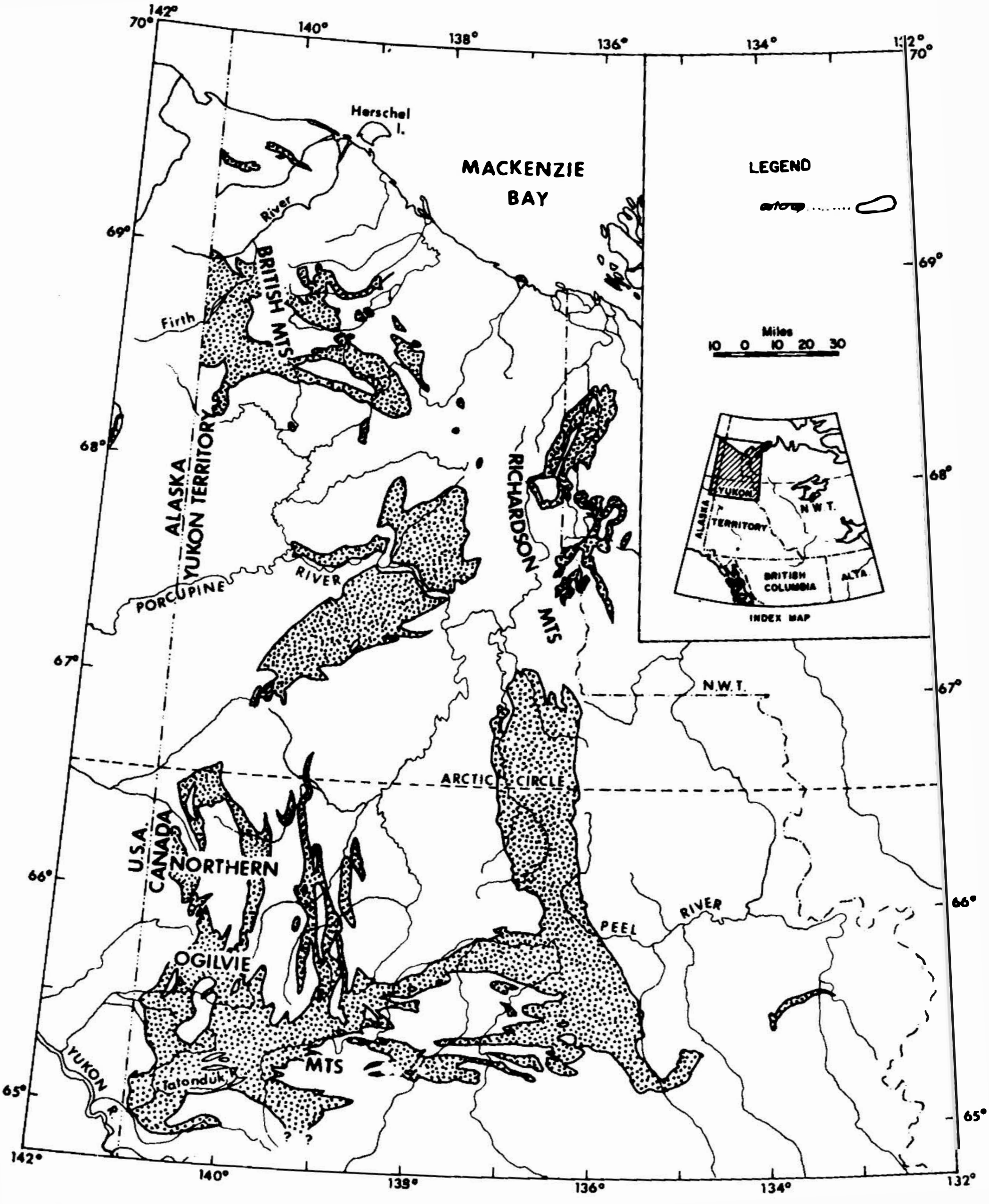


Fig. 19. Location of Carboniferous and Permian outcrops, north Yukon Territory. From Bamber & Waterhouse (1971, fig. 2).

(1964, p.20), apart from *Linoproductus dorotheevi* Frederiks, a form typical of late Asselian faunas in Canada.

A small ammonoid faunule has been described from the Hare Fiord Formation of Ellesmere Island by Nassichuk & Spinosa (1972), with *Somoholites* cf. *artus*, *Kargalites*, *Neopronorites*, and *Agathiceras* indicating an Asselian-Sakmarian age. Accompanying Fusulinacea were assessed as Asselian-Wolfcampian by Wilde (in Nassichuk & Spinosa, 1972, p.538) with *Pseudofusulinella* and *Schwagerina*, apparently like forms from the lower McCloud Limestone of California. As yet undescribed Brachiopoda listed by Waterhouse in Nassichuk & Spinosa (1972) might be as old as Uskalikian, to Tastubian, in age.

The three Asselian substages are well represented by brachiopods in northern Yukon Territory (Fig.19) in the Jungle Creek Formation (Bamber & Waterhouse, 1971): Table 22. The basal Eka Zone has *Attenuatella* and *Kochiproductus* (Sarytcheva & Waterhouse, 1972), overlain by a thick sequence of clastics with *Orthotichia*, *Kutorginella*, and other species, (Eo Zone), followed by the *Attenuatella-Tomiopsis* (Eta) Zone of Bamber & Waterhouse (1971). The latter zone is accompanied by ammonoids *Neopronorites* and *Somoholites*. The *Attenuatella-Tomiopsis* Zone is judged to be of Kurmaian age, and extends widely to the south in the Rocky Mountains (Waterhouse, 1971) into the Telford Formation of Alberta and eastern British Columbia (Logan & McGugan, 1968).

Further south in Oregon State the Coyotte Butte Formation, 300m thick, yielded a large brachiopod fauna which, although assigned to the Word (mid-Permian) by Cooper (1957), is partly upper Asselian in age (Bamber & Waterhouse, 1971). There is strong faunal support for correlation with the Kurmaian *AttenuatellaTomiopsis* Zone of the Jungle Creek Formation in the Yukon Territory from *Dyoros*, *Tubersulculus*, *Anidanthus minor* Cooper, *Kochiproductus transversus* Cooper, *Yakovlevia*, and *Attenuatella* as '*Crurithyris*' sp. *Spiriferella draschei* (not Toula) of Cooper, and *S. parva* Cooper, both allied to or identical with *S. pseudodraschei* Einor, support a Sakmarian age. Wilde (1971) assigned Coyotte Butte Fusulinacea to the Decie Ranch—Skinner Ranch faunas of Texas, believed to be of Sakmarian age. Detailed stratigraphic analysis is required to disentangle the mixed faunas.

From south-east Wyoming the Casper Formation has yielded a silicified fauna in limestone (Pederson, 1954), including *Triticites ventricosus* (Meek) found in the Neal Ranch Formation of Texas. A Surenan or Uskalikian age is likely, depending on the identity of '*Composita ovata*' Mather, which looks somewhat like an Ambocoelid. Ross (1963, p.49) concluded that primitive *Schwagerina* indicated a pre-Neal Ranch correlation, equivalent to bed 2 of the grey limestone member in the upper Gaptank of the Glass Mountains, Texas, likely to be of Surenan age.

The Earp Formation of south-east Arizona consists of shales, siltstones and limestones close to the Carboniferous-Permian boundary. Brachiopods and other fossils are listed in Gilluly *et al.* (1954), and Ross (1973) recorded Early Permian *Pseudoschwagerina uddeni* (Beede & Kniker), and species of *Triticites* and *Schwagerina*, overlain by a further *Schwagerina-Triticites* assemblage that indicated a middle or early late Wolfcampian (presumably Sakmarian) age.

In the Glass Mountains, west Texas (Fig.23, Table 26), the base of the Permian is taken as the *Uddenites*-bearing shale member of the Upper Gaptank Formation, hitherto often assigned to the Pennsylvanian Period. The problem is carefully discussed by Cooper & Grant (1973, p.366), who point to many Permian elements amongst the brachiopod component, including the first appearance of *Kochiproductus*. In addition, Bostwick (1962) recorded *Schwagerina* from the shale, and Douglass (in Mudge & Yochelson 1963, p.120) recorded *Pseudofusulina*. The overlying Neal Ranch Formation of Ross (1963) consists of about 16 cyclothems of shale passing up to calcarenite and shell debris, 120 to 150m thick, with the brachiopod fauna summarized by Ross

World Standard Substage		Brachiopod Biozones	Symbol	North Yukon Formation	Archipelago Formation
Kalinovian		*Cancrinelloides*	Gc		Trold Fiord
Ufimian Elkin	Irenian	-		Tahkandit	?-
Nevolin		*Lissochonetes*	Fl		Van Hauen
Filippovian		*Neochonetes* *=Pseudosyrinx*	Fn Fps		Assistance
Krasnoufimian		*Sowerbina*	Fs	Jungle Creek	Belcher Channel
Sarginian		*Antiquatonia*	Fa		
Aktastinian		*Jakutoproductus*	Ej		
Sterlitamakian		*Tornquistia* *Attenuatella*	Et Ea		
Tastubian		*Yakovlevia*	Ey		
Kurmaian		*Tomiopsis* *Attenuatella*	Eta		
Uskalikian		*Orthotichia*	Eo		
Surenan		*Kochiproductus* *Attenuatella*	Eka		

Table 22. Permian correlations for Arctic Canada, based principally on Bamber & Waterhouse (1971), and Sarytcheva & Waterhouse (1972). The formations of the Arctic Archipelago are complexly interrelated, with facies transgressing time, so that the Van Hauen Formation for instance, is older as well as younger than the typical Assistance Formation at Blind Fiord (Dr W.W. Nassichuk, pers. comm.).

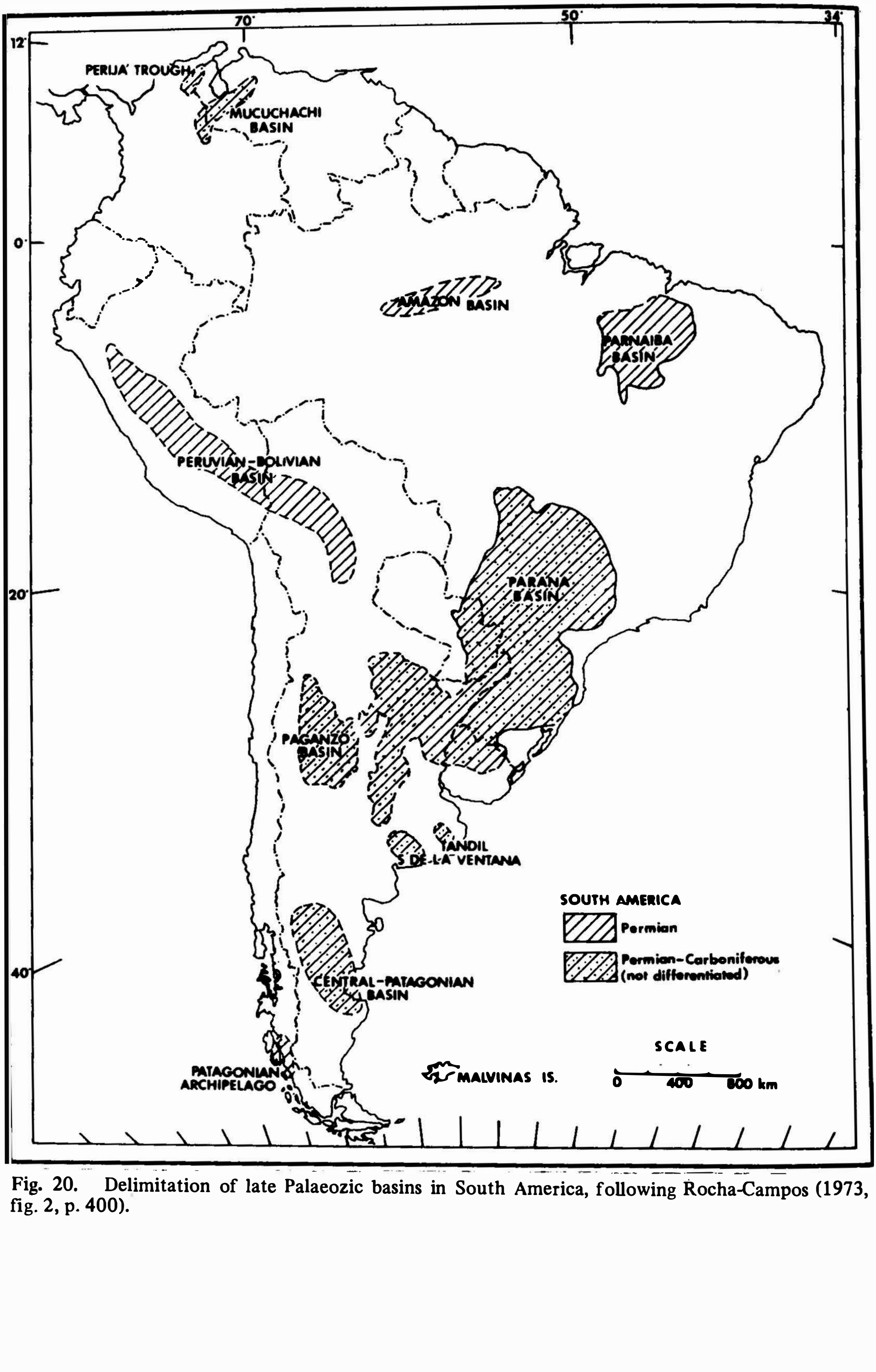


Fig. 20. Delimitation of late Palaeozoic basins in South America, following Rocha-Campos (1973, fig. 2, p. 400).

(1963) from various descriptions, chiefly in R.E. King (1931). Further species and genera are described or listed by Cooper & Grant (1969, 1973). The complete redescriptions of Glass Mountain brachiopods of Permian age by Drs G.A. Cooper and R.E. Grant are now in press, and will substantially increase understanding of these faunas. The presence of *Orthotichia*, *Derbyia*, Marginiferids, and *Hustedia* in the Neal Ranch faunas suggest possible correlation with the Eo (Uskalikian) faunas of the Yukon Territory in Canada. Unlike many regions, there is no clearly established three-fold faunal division for the Early Permian in the Glass Mountains but, until the brachiopods are described, it is difficult to ascertain if a substage is missing. On present evidence, the Kurmaian Substage may be absent, and Furnish (1973) also noted that only part (unspecified) of the Asselian appeared to be represented by the Neal Ranch ammonoids. On the other hand Wilde (1971) reported two Fusulinacean zones in the Neal Ranch Formation, which might suggest that the Uskalikian and Kurmaian Substages are present.

In Kansas, as summarized by Mudge & Yochelson (1963), the Permian System commences within the Admire Group, with *Pseudofusulina* entering the Five Point Limestone. Various thin carbonates and shales contain scattered brachiopods, including *Crurithyris*. Wilde (1971) matched the Admire Group with the Gaptank, and the Chase-Council Grove Groups with the Neal Ranch Formation of west Texas (Table 24).

Various other Early Permian faunas have been described in the mid-continental stages of Oklahoma, Kansas and Texas, in the Luta Limestone of the Summer Group or Big Blue 'Series' of Kansas, and in Nebraska (Dunbar & Condra, 1932). Cooper & Grant (1973) provided evidence that the Virgilian Stage may prove to be Permian.

Bolivia, Peru

The Copacabana Group in the Peruvian-Bolivian basin (Fig.20) has yielded large brachiopod collections described chiefly by D'Orbigny (1842), Kozlowski (1914), and Samtleben (1971). Four zones through some 300m to 3,000m of carbonate with minor shale were recognised by Newell *et al.* (1953), the *Silvaseptopora* Zone, the *Triticites opimus* (Dunbar & Newell) Zone, the *Pseudoschwagerina uddeni* (Beede & Kniker) Zone, followed by barren shales and then in south central Peru by the *Parafusulina* Zone of Sakmarian or Baigendzinian age. The earliest zone contains *Pseudoschwagerina broggii* (Roberts), indicative of a Permian age, with *Peruvispira delicatula* Chronic, member of a gastropod genus very widespread in the Early Permian faunas of Gondwana. A brief field trip to the area by the writer yielded a Late Carboniferous fauna with *Duartia*, but this fauna does not seem to have been described as yet. The overlying *Triticites* Zone is accompanied by *Pseudofusulina* and *Pseudoschwagerina* with a few brachiopods, followed by the *Pseudoschwagerina uddeni* Zone, based on a species also found in the Neal Ranch Formation of the Glass Mountains. Once again a three fold zonation is present, suggesting that all three Asselian substages might be present, but little is known of the association of brachiopods within each of these zones. A few faunas of possible Permian age are recorded in Branson (1948) from Brazil, (e.g. Oliviera, 1936), but some of the better known brachiopod faunas, as described by Derby (1874) and Mendes (1947) are clearly of Late Carboniferous age, with brachiopod genera *Duartia* and *Brasilioproductus*. Early Permian *Pseudofusulina* and *Schwagerina* are recorded from Madre de Dios, Chile, by Douglass & Nestell (1974).

Pakistan, India, Himalayas, Afghanistan

Widespread but small late Asselian (Kurmaian) faunas are known from various segments of Gondwana, as summarized by Waterhouse (1971). They share the bivalve

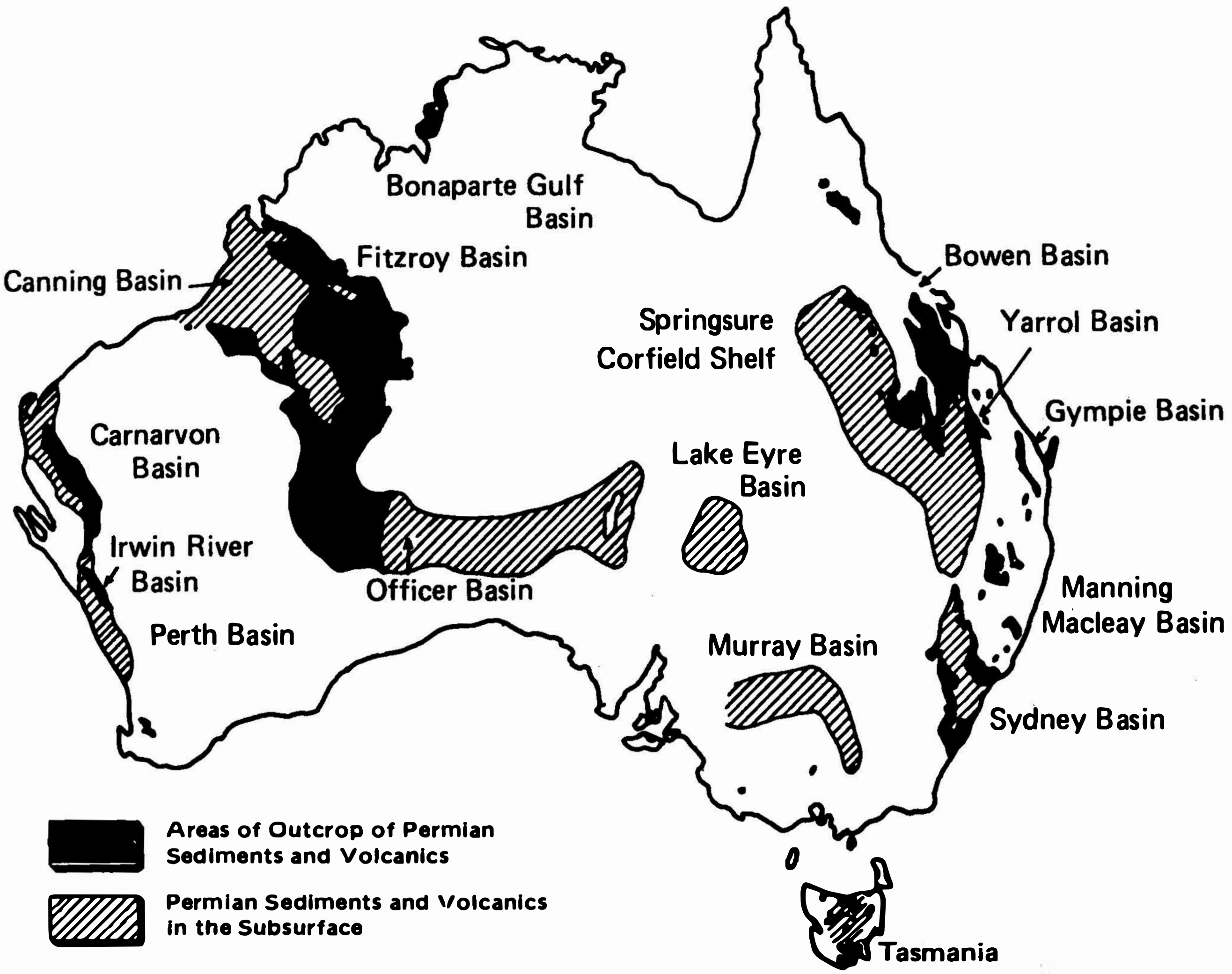


Fig. 21. Distribution of Permian strata in Australia, from Brown *et al.* (1968, fig. 7, 2, p. 181).

Eurydesma, the gastropod *Peruvispira* and brachiopod *Tomiopsis*, and are associated with tillite and other glacigene rock, having lived in cold waters probably around the edge of glaciers, or in areas previously occupied by ice-sheets. In the Indian subcontinent *Eurydesma* faunas occur below the Speckled or Warchha Sandstone above the Talchir Conglomerate in the Salt Range, Pakistan (Waagen, 1891; Reed, 1936) Table 27; in the *Eurydesma* beds of Bren Spur, Kashmir (Reed, 1932; Waterhouse, 1970a); in north Sikkim of the Himalayas (Sahni & Svrivastava, 1956) and in central India at Manendragargh (Sahni & Dutt, 1959).

Asselian faunas are found in the lower part of shales and sandstones and a carbonate bank, in all totalling about 1 km in thickness near Wardak (Table 28) south of Kabul, Pakistan (Termier *et al.* 1974). The fossils include *Tomiopsis* close to *T. ovulum* Waterhouse, though identified with *T. angulata* (Campbell) by Termier *et al.* (1974), together with *Punctocyrtella nagmagensis* (Bion), and the significant bivalves *Eurydesma mytiloides* Reed, *Atomodesma*, and *Heteropecten.* A late Asselian age seems likely, in view of the strong cold-water and Gondwanan affinities.

South Africa, Argentina, Australia

The upper Dwyka Tillites of South Africa have yielded the characteristic *Eurydesma* bivalve fauna, with other Mollusca including an ammonoid identified as *Glaphyrites*. This would permit an Asselian age though interpreted as Carboniferous by Martin *et al.* (1970). In the Sierra de la Ventana, Argentina (Fig.20), Harrington (1955) described faunas from the Bonete Formation, which appear to be early Permian rather than the mid-Permian age preferred by Amos & Rocha-Campos (1971). Other meagre faunas, including *Attenuatella*, come from Brazil (Fig.20) within the diamictite complex of the Parana Basin (Rocha-Campos, 1971), but these occurrences could be as young as Sakmarian. The fauna described by Reed (1927b) from the Andean foothills at Barrealas, Argentina, is considered to be Carboniferous rather than Permian, because it contains the Moscovian genus *Levipustula*.

In Western Australia (Fig.21), late Asselian faunas are found in the upper Lyons Group and Carrandibby Shale of the Carnarvon Basin (Dickins & Thomas, 1959; Konecki *et al.*, 1958; Thomas, 1959, 1967; Coleman, 1957; Thomas & Dickins, 1954, pp.73-4); Table 29. In eastern Australia the Allandale Formation of the Hunter Valley, north Sydney Basin, and Conjola Formation of the south Sydney Basin also contains the same *Eurydesma* fauna (Runnegar, 1969a; Waterhouse 1971d): Table 40. *Tomiopsis* is present, allied to Asselian species from the northern hemisphere (Waterhouse, 1971). Maxwell (1964) has described a somewhat richer fauna from the Burnett Formation of the Yarrol Basin, Queensland, of Kurmaian and perhaps greater age (Table 35). The Kurmaian Quamby Group of Tasmania also has a few brachiopods (Banks, 1961, 1962; p.198): Table 40.

Earlier Asselian deposits appear to be rare in Gondwana, possibly because of cannabalisation of early Asselian deposits by late Asselian glaciation (Burke & Waterhouse, 1973), and partly because some early Permian deposits may have been misdated as Late Carboniferous. Meagre warm-water faunas from the middle Lyons Group of Western Australia (Thomas, 1958) suggest a mid-Asselian Uskalikian age and the Lochinvar Formation with scattered fossils in the Hunter Valley, New South Wales, may also be Uskalikian from sequential evidence. The barren Joe Joe Formation of the Springsure Shelf of Queensland is also likely to be Early Permian. It is noteworthy that *Eurydesma* has been recorded at Stanhope, Hunter Valley, just above the Seaham varves and tillites, which though assigned to the Carboniferous in Packham *et al.* (1969, p.252), could prove to be of early Asselian age.

No Asselian brachiopods are known in New Zealand. The Croisilles Volcanic Complex of an ophioloid suite of ultramafics, tholeiites, and volcanic-derived sediment over 1000m thick near Nelson city, contains the bivalve *Atomodesma*, and a gastropod near the top considered to be of late Asselian age by Waterhouse (1969b).

SAKMARIAN STAGE

Urals

The Sakmar Substage of Ruzencev (1952) is based on fine sediment passing up to coarser sediment in a sequence about 800m thick in the Aktyubin region of the Urals (Table 12). Fine sandstone and shale are common, with some carbonate and coarser detritus. According to Ruzencev (1952), the Sakmarian is subdivided into the Tastubian, first used by Rauser-Chernossova (1940) and Sterlitamakian (Rauser-Chernossova, 1937). However, it is here proposed to modify the stage by incorporating the overlying Aktastinian Horizon or Substage of Ruzencev (1934, 1956), exposed near the Aktasty River, south Urals, in 800m of clastic sediment with thin fossiliferous carbonates, called the Burtsev and Irgin beds.

The placement of the Aktastinian Substage in the Sakmarian Stage rather than Artinskian Stage differs from some Russian usage, and is based primarily on the interrelationships between brachiopods. Aktastinian brachiopods from most world faunas are very close to those of Sterlitamakian and Tastubian age, and differ from those of Baigendzinian age (Bamber & Waterhouse, 1971). It is considered that the sheer numerical preponderance and wide geographic distribution of brachiopods makes them of prime significance in deciding where stage boundaries should be drawn. After detailed assessment of the very rich faunas of the Glass Mountains, west Texas, Cooper & Grant (1973) also drew the Wolfcamp-Leonard boundary, equivalent of the Sakmarian-Baigendzinian boundary, in what I take to be the same position.

Aktastinian ammonoids indicate a different pattern. They include three distinct genera, and share fourteen new genera with the Baigendzinian Stage. The Aktastinian Substage also sees the introduction of '*Parafusulina*' s.l., also characteristic of the Baigendzinian faunas, but Rauser-Chernossova (1949) initially classed the Aktastinian fusulines with Sterlitamak Fusulinacea. Moreover, the 'classical' Artinskian, of the Arti region, is entirely Baigendzinian (Ruzencev, 1956). According to Dunbar (1940), 'Artinskian' is largely a facies term, and varies in age in different areas, so that its passing from chronologic literature need not cause regret.

The following ammonoid horizons were recognised by Ruzencev (1952, 1956).

(top) 6. Aktastinian: characterised by entry of three new ammonoid genera, *Aktubinskia*, *Agathiceras*, *Neoshumardites*. (Presumably the significance of *Agathiceras* is local, or climatic, for it started in the Moscovian Stage).

5. Sterlitamakian: ammonoids the same as those in upper Tastubian, no new genera. Five species only persist into Artinskian. Ammonoids do not define this substage clearly.

4. Upper Tastubian: First appearance of many new genera, such as *Synartinskia*; *Medlicottia*; *Metalegoceras*; *Uraloceras*; *Propopanoceras*. Only two species persist from underlying lower Tastubian fauna.

Lower Tastubian: or Karamurum 'Series', with *Juresanites karakhorum*, an advanced member of the genus, and many Asselian survivors. It is hard to see why this is not Asselian on ammonoid evidence. Once again as for the Asselian Stage, the Fusulinacean—not the Ammonoidea—seem to have been decisive, in Ruzencev's delineation of boundaries.

Nautiloidea are also useful in distinguishing the faunal horizons. The Aktastinian Substage includes various *Pseudofusulina**, such as *P.* karogasensis* Raus., *P.* paraconcessa* Raus., and the first appearance in the Urals of *Parafusulina* (s.l.).

Sterlitamakian Fusulinacea include _Pseudofusulina_* _verneuili_ (Moell.), _P._* _devexa_ Raus., _P._* _bashkirica_ Korzh., and Tastubian faunas include _Pseudofusulina_* _verneuili_ (Moell.), !_P._* _moelleri_ (Schell.) and _Rugosofusulina serrata_ Raus. _Schwagerina_ and allies are missing, but this is apparently only a local phenomenon.

Brachiopod faunas are very extensive and diverse, but have not been comprehensively revised in recent years. To judge from summaries by Miloradovich (1949), Stepanov (1951), and Likharev (1966), the Tastubian brachiopods include _Schizophoria juresanensis_ Chernyshev, species of _Isogramma_ and _Reticulatia_, _Rhynchopora nikitini_ Chernyshev, _Septacamera krotovi_ (Chernyshev), _Cyrolexis superstes_ (Verneuil) and species of '_Spirifer_' and _Martinia_. The Sterlitamakian Substage has a very large fauna with a number of unique species including _Rhipidomella uralica_ Chernyshev, _Aulosteges uralicus_ Chernyshev, _Derbyia_, many Productacea, _Camerisma sella_ (Kutorga), _Martiniopsis orientalis_ Chernyshev, and several licharewinid or Spiriferid species.

Various faunas have been recorded from the general Urals region. Mironova (1960) described a small Sakmarian-Artinskian fauna from the Glini beds of Petchora-Pai Hoi; and Frederiks (1926) provided a faunal list from sandy argillites of the River Kejim-Terovey, considered to be Aktastinian because of the presence of '_Chonetes_' _solida_ Krotow, _Medlicottia_ and certain bivalves. Further Sakmarian (Tastubian) brachiopods were described from two horizons in the Ishimbaevo oilfield by Kulikov (1938).

North Siberia, Pamirs

A number of faunas have been described from Novaya Zemlya by Likharev & Einor (1939) and Miloradovich (1935). They are judged to be Sakmarian on the basis of their affinities to faunas from the Urals and Yukon Territory in Canada, and lack of Asselian key species, but little data is available on their stratigraphic interrelationships. A late Asselian age is possible for some of the faunas, i.e. from Cape Loushkin, in the Sedov and Barentz 'Series', but these are more likely to be Sakmarian, with species of such genera as _Orthotichia_, _Derbyia_, _Juresania_, _Waagenoconcha_, _Kochiproductus_, _Linoproductus_, _Anidanthus_, _Yakovlevia_, _Septacamera_, _Pterospirifer_, _Phricodothyris_ and _Choristites_, the latter showing a resurgence in Sakmarian times, after the Carboniferous. A Sakmarian age is supported by specific comparisons amongst species of the genus _Spiriferella_ for several of the localities.

In central and west Taimyr Peninsula (Table 15), the Birrang Horizon was correlated with the Sakmarian and Artinskian Stages by Ustritsky & Chernyak (1967) and with the early Lower Permian by Menner _et al._ (1970). The upper part includes _Jakutoproductus_, _Rhynchopora_, _Attenuatella_, _Taimyrella_ and _Tomiopsis_ (Ustritsky & Chernyak, 1963), suggestive of a Sterlitamakian or even Kurmaian age. This horizon is perhaps preceded by a fauna listed as Evenk and Upper Turuzov in beds 850-1100m thick from east Taimyr by Ustritsky & Chernyak (1963), containing such species as _Echinalosia delicatula_, _Rugivestis_ species, _Yakovlevia_ species and _Rhynchopora nikitini_ which suggest a Tastubian age, by comparison with faunas of the Yukon Territory, Canada, discussed below. A large Sakmarian fauna was described from west Taimyr by Einor (1939, 1946).

In the thick terrigenous sequences of the Verchoyan Mountains in north-east Siberia the lower part of the Tompin Series yields faunas of Sakmarian age. In the Haraulakh area near the mouth of the Lena River, the Verchoyan Suite, 650m to 2,000m thick, contains Sakmarian brachiopods such as _Yakovlevia mammatiformis_ (Fred.), _Waagenoconcha_, _Jakutoproductus verchoyanicus_ (Fred.) and _Spiriferella saranae_ (Verneuil) with the ammonoids _Paragastrioceras jossae subtrapezoidalis_ Max. & Chern., _Uraloceras_ ex. gr. _belgushkense_ Ruzh. and other species (Likharev, 1966).

Menner *et al.* (1970) reported *Neoglaphyrites* which would suggest an Asselian age in part, with *Agathiceras uralicum* (Karpinsky). In a closely divided sequence of southeast Verchoyan (Table 14), the Kigiltass Suite 600-1100m thick includes *Rhynchopora nikitini* Chernyshev with *Derbyia*, *Jakutoproductus* and linoproductinids, followed by thin argillites of the Echi horizon, 100m thick, containing numerous *Jakutoproductus* and other distinctive brachiopods with the ammonoids *Paragastrioceras* and *Neoshumardites triceps hyperboreus* Ruzh. These faunas are clearly Sakmarian, by superposition and general faunal affinities. In the Kolyma River and Omolon Plateau, the Irbichan, Munugudjak, and Yasachnin Horizons (Table 15), are likely to be Sakmarian, though referred to the Artinskian by Likharev (1966). The Irbichan Horizon appears to be Tastubian, or at least correlative with the *Yakovlevia* Zone of the Yukon (Bamber & Waterhouse, 1971). It includes *Yakovlevia mammatiformis* (Frederiks), *Cancrinella cancriniformis* (Chernyshev) and species of *Jakutoproductus*, *Anidanthus* and *Tomiopsis*. The overlying Yasachnin Horizon has a few different species with *Martinia* and *Spiriferella*, in some 100m of sediment. Although no direct connection with the Yukon or Urals sequence is apparent, its stratigraphic position would suggest a Sterlitamakian age. The overlying Munugudjak Horizon, 35-60m thick, contains *Tornquistia*, *Jakutoproductus* and *Anidanthus* to suggest correlation with the higher Yukon faunas, of approximately Aktastinian age. Evidence for correlation is not strong, but is consistent with stratigraphic position, and there is no contrary evidence. Faunas have been described chiefly by Zavodowsky (1968, 1970).

From the Ungadu Suite, 800-1300m thick, in the Chiron area of west Baikal, Kulikov (1959) listed a small brachiopod fauna of Sakmarian age, with species allied to Verchoyan forms, such as '*Chonetes*' *paraconvexa* Maslennikov and *Cyrtospirifer khauraulakhensis* Frederiks. The beds overlie the Chiron Suite.

In the northern Pamirs, especially Darvas, the upper part of the Lower Permian is referred to the Darvasian Stage with four subdivisions (Table 17). The Zigar Horizon at the base has fusulines *Pseudofusulina kraffti* (Schell.) and *!P.* vulgaris* (Schell.) and *Parafusulina ferganica* (M.Makl.) and ammonoids *Propinacoceras*, *Popanoceras* (supposedly limited to the Artinskian), and *Metalegoceras*. A number of Russian experts have placed the Zigar faunas in the Aktastinian Substage and the slightly older Karachatirian faunas in the Sakmarian (i.e. lower Sakmarian) Stage. However, the Zigar Horizon is here regarded as early Sakmarian on the basis of sequence and fossils present. *Parafusulina* enters the Lenox Hills Formation of west Texas at a comparable early Sakmarian age, as shown by Cooper & Grant (1973), assuming identifications are correct. The presence of a few persistent ammonoids through thick sections with several brachiopods or fusuline zones strongly suggests that the ammonoids were, as usual, long ranging, and slightly different in age from the Urals, of a different palaeogeographic realm. It seems most unlikely that the Zigar, with overlying faunas, are all Aktastinian in age.

The overlying Chelamchin Suite of the same region has *Pseudofusulina kraffti* and *Misellina*. A large brachiopod fauna is listed by Likharev (1966) for the succeeding Safetdaron unit with numerous Fusulinacea, *Nankinella*, *Pseudofusulina* ('*Leeina*') *exigua* (Schell. & Dyhr.), *Pseudofusulina kraffti*, *Chusenella*, and *Parafusulina* aff. *japonica* Gumb. Kalmikova (1967, p.142) described a large fauna from Tangi-Gor, Darvas, in the Safetdaron Suite, with *Schwagerina crassitectoria* Dunbar & Skinner (found also in the Decie Range Member of west Texas), *Schwagerina* fusiformis* (Schell.) and *!Pseudofusulina* vulgaris* (Schell.). The brachiopods include numerous overtoniids, *Camerisma sella* (Kutorga), many *Choristites*, and *Martinia*, and are regarded as Aktastinian, with warm waters suggested by the presence of *Parakeyserlingina*. On the other hand *Schwagerina crassitectoria* is more likely to be Sterlitamakian in the Glass Mountains and Hueco Mountains of Texas as discussed below. Ammonoids in the overlying Gundarin Horizon include *Medlicottia* aff. *artiensis*

Substage/ or Stage	S W Pamirs			
	Pamir Stage	TAKTABULAK SUITE	Upper	
Baisalian Subst.			Middle	- - - - ? - - - - - - - *Codonofusiella*, *Reichelina*, *Palaeofusulina*, *Colaniella*
Urushtenian Subst.			Lower	
?	Murgab Stage	GAN SUITE	Lower	*Codonofusiella Reichelina*
Punjabian Stage				*Neoschwagerina margaritae*, *Yabeina archaica*
?Kazanian Stage			Lower	*Neoschwagerina schuberti*
Kungurian Stage	Darvasian Stage	Kubergandin Suite		*Neoschwagerina simplex*
Baigendzinian Stage				*Cancellina*
				Misellina
Aktastinian Substage		KIZILDJILGIN SUITE	Upper	*Misellina Darvasites*
			Middle	——— ? ——— *Pseudofusulina Parafusulina?*
			Lower	
Sterlitamakian Substage		Bazardarin Suite		

Table 23. Permian succession in Fergana, from Grunt & Dimetriev (1973).

timorensis Han. and *Propinacoceras bornemani* Toum., here judged to be of Baigendzinian age.

Grunt & Dimetriev (1973) described the early Permian Bazardarin Suite in the Pamirs (Table 23) with a relatively rich ammonoid faunule, including *Metapronorites timorites* Haniel, *Synartinskia*, *Agathiceras*, *Tabantalites*, *Marathonites* and *Waagenina dieneri* Smith, and a modest brachiopod component including *Derbyia grandis* Waagen, *Taeniothaerus rusticus* Grunt, *Cancrinella*, and *Punctocyrtella spinosa* Plodowski. These brachiopod species are strongly reminiscent of Gondwanan faunas of early Sakmarian age, and differ from those of the nearly Safetdaron fauna, believed to be slightly younger. Grunt & Dimetriev (1973) assigned a Sakmarian-lower Aktastinian age (Table 23).

The overlying Kizildjilgin Horizon in Grunt & Dimetriev (1973) is of early Darvasian age, with *Pseudofusulina* and *Parafusulina*, overlain by beds with *Misellina* and *Darvasites*. The lower part of the formation includes brachiopods identified as *Globiella rossiae* Sestini, supposed *Lamnimargus himalayensis* (Diener), *Martinia*, and *Camerisma murgabica* Grunt and a species of *Spiriferella*, unnamed, but close to *Spiriferella salteri* Chernyshev from the Sakmarian Stage and *S. waageni* (Chernyshev) from the Artinskian facies of the Urals. Compound rugose corals and Artinskian ammonoids such as *Agathiceras mediterraneus* Toum., *Gaetanoceras martini* (Han.), *G. timorensis* (Han.), *Perrinites* and *Marathonites* also occur. Several of these ammonoids persist from the underlying faunule into the middle Kizildjilgin faunas, with *Monodiexodina*. The upper Kizildjilgin faunas, in 20-120m of sediment, include *Pseudofusulina*, *Parafusulina* and *Misellina*. The faunas are here judged to be Aktastinian from brachiopods, but perhaps they are Baigendzinian.

Europe

In the Carnian Alps of Austria, Italy and Yugoslavia, the Grenzland band of the middle Rattendorfer beds may be early Sakmarian in age, with a few brachiopods including *Isogramma paotechowensis* Grabau, many compound rugose corals, indicative of warm waters, and *Pseudoschwagerina extensa* Kahler & Kahler, *Pseudoschwagerina turbida* Kahler & Kahler, and notably *Rugosofusulina alpina* (Schell.). The upper '*Pseudoschwagerina* limestone', totalling with the Grenzland beds about 65m in thickness has *Pseudoschwagerina pulchra* Kahler & Kahler, and *Schwagerina** *nitida* Kahler & Kahler, with a number of compound rugose corals. The faunas are here regarded as Sakmarian (Table 24).

The overlying Trogkofel beds are also probably Sakmarian, possessing the ammonoid *Medlicottia* and a rich brachiopod faunule including *Enteletes*, *Meekella*, *Scacchinella*, overtoniids, *Camerisma sella* (Kut.), *Licharewia carnicus* (Schell.) and *Brachythyrina*, described by Schellwien (1900) and Heritsch (1938), with close general similarities to the Safetdaron fauna of the Pamirs and Sakmarian faunas of the Urals. Fusulinacea suggest correlation with the upper Sakamotozawan Stage of Japan. The age may be as young as Aktastinian, although Tastubian affinities may also be noted. Kahler & Prey (1963, p.44) placed the fauna in the middle Permian. Ramovs (1963) described Productida including *Karavankina* and *Scacchinella* from the Trogkofel beds in Yugoslavia. According to the correlation proposed herein the Tarviser Breccia in the Carnian Alps lies at the same horizon as great breccias in the Hueco Mountains in Texas (Cooper & Grant, 1973), suggesting the possibility of a sharp fall in sea-level at this time, related to glacio-eustatic fall of sea-level, or widespread orogenic spasm.

Armenia, Iran Afghanistan, Karakorum, Chitral

The Davalin Suite of Armenia (Table 45) contains *Nankinella* and may be as old as Sakmarian, with *Schwagerina** aff. *fusiformis* (Schell.); !*Pseudofusulina** ex gr.

Stage	Substage	Group	Unit
Scythian	Dienerian	?Werfer-(Servino) Ftm. ? ?	
Dorashamian	Griesbachian		
	Ogbinan	Bellerophon Limestone 200m	
	Vedian		
Djulfian	Baisalian		
	Urushtenian		
Punjabian Kazanian Baigendzinian		?Grodener 30-40m	
Sakmarian	Aktastinian Sterlitamakian	Trogkofel 200-400m	
	Tastubian	Rattendorfer 70m	Upper *Pseudoschwagerina* limestone
			Grenzland bänke
Asselian	Kurmaian	Auernig 200m	Lower *Pseudoschwagerina* limestone
	Uskalikian		Upper kalkarme beds Upper kalkreiche beds Middle kalkarme beds
	Surenan		
ate Carboniferous Period			?Middle kalkarme beds Lower kalkreiche beds Lower kalkarme beds

Table 24. Correlation of Permian sequence in Carnic Alps, Austria, assessed from Kahler & Prey (1963). The Auernig beds are retained partly as in the German for the sake of brevity.

vulgaris (Schell.) and *Triticites* (Arakelyan *et al.* 1964, p.124). *Nankinella* also occurs in the Aktastinian faunas of the Safetdaron Suite of Darvas and the Chihsia Limestone of China.

Douglas (1936, 1950) listed and partly described a small brachiopod faunule from south-west Iran, indicative of an Asselian-Sakmarian age, including *Schizophoria juresanensis* Chernyshev of Tastubian age in the Urals, and *Cancrinella cancriniformis* (Chernyshev). The fauna is overlain by beds with *Pseudofusulina*, !_Pseudofusulina_* _vulgaris_, *Triticites simplex* (Schell.) and *Rugosofusulina alpina* of Sakmarian age.

From north Iran Sestini (1966) described the Geirud Member D fauna in cherty limestone, shown by Waterhouse (1970a) to be probably Sterlitamakian on the basis of brachiopods (Table 31). The fauna, not fully collected according to Dr R. Assereto, University of Milan (pers. comm., 1971), includes such Sakmarian, and especially Sterlitamakian keys as buxtoniid *Reedoconcha iranicus* Sestini, *Stepanoviella*, widespread in beds of this age throughout Gondwana (Waterhouse, 1970a), *Punctocyrtella*, found also in the Pamirs, and *Martiniopsis orientalis* Chernyshev, also found in the Urals.

From the Haushi Formation over 200m thick at Haushi and Wadi Lusaba, Saudi Arabia, Hudson and Sudbury (1959) described another apparently Sterlitamakian fauna with *Licharewia* and *Juresania*, correlative with the Geirud D fauna (Waterhouse 1970a). The ammonoid *Metalegoceras* is found just above. An overlying fauna in the Lusaba Limestone 33m thick is more diverse with *Juresania* and marginiferids, and may, from superposition and its warm water affinities, be as young as Aktastinian. *Parafusulina* beds lie above.

To judge from preliminary accounts by Siehl (1967) and Karanatev & Leven (1973), there are extensive fossiliferous sequences of Permian carbonates in Afghanistan, rich in Fusulinacea and Brachiopoda. Partially described brachiopod faunules from central west Afghanistan include spiriferids such as *Orulgania*, *Permospirifer* and *Punctocyrtella* (Legrand-Blain, 1968; Plodowski, 1970), like species from the Haushi and Geirud D faunas. They may be Sterlitamakian, although the report of *Haydenella* suggests a younger, Aktastinian age, by comparison with the Lusaba fauna, with its marginiferids and Chonetenellids. According to Termier *et al.* (1974, pp.39,40), Sakmarian faunas near Wardak south of Kabul, Pakistan, (Table 35) include a lower fauna with *Stepanoviella umariensis* (Reed), also found in the Umaria fauna of the Indian Peninsula, *Tomiopsis*, *Martiniopsis* and other forms, and an upper fauna with *Neochonetes*, *Taeniothaerus* (or *Reedoconcha*) *permixtus* Reed, *Punctocyrtella spinosa* Plodowski, and *Tomiopsis* related to Kashmir species from the Agglomeratic Slate. Both faunas may be of Sterlitamakian age, in view of the presence of *Tomiopsis*, or the lower faunas may prove to be as old as Tastubian.

The Aktastinian Substage may be represented in Afghanistan by black carbonates with Fusulinacea including *Parafusulina ferganica* Mikl.-Makl., and _Pseudofusulina_* _procera_ Leven, with brachiopod species of *Karavankina*, *Sergospirifer* and *Notothyris*, and the gastropod *Bellerophon*. Species of the latter two genera were ascribed, probably mistakenly, to forms named from the Middle and Upper Productus Limestones of the Salt Range in Pakistan.

From the Shaksgam Valley, Karakorum Range, Renz (1940b) and Sestini (1965d) recorded a few so-called upper Uralian species, too few and nondescript to date accurately, but likely to be Lower Permian, and probably Sakmarian in age. The species show little in common with the faunas from Iran, Afghanistan, or Kashmir, but orthotetids, *Krotovia* and marginiferids suggest some approach to the Lusaba brachiopods of Arabia, and so are perhaps of Aktastinian age.

Early Permian faunas in quartzites and limestones from Chitral, Pakistan, especially near Baroghil Ailak, contain Schwagerinids, supposedly *Pseudoschwagerina princeps* (Ehrenberg?) and _Schwagerina_* _fusiformis_ Krot. pointing to an Asselian age

(Reed, 1925). They probably require revision and were not figured. Accompanying *Kochiproductus* and *Crurithyris* also suggest an Asselian or mid Sakmarian age, and numerous specimens of *Spiriferella* look like *Spiriferella saranae* (Verneuil) or *S. kolmaensis* Zav. from Sakmarian faunas of the Yukon, Canada and Siberia. Perhaps this younger age is supported by the presence of so-called *Parafusulina* (=*Praeparafusulina*) cf *lutugini* (Schell.), and shells allied to *Stepanoviella*, as if the faunas were Sterlitamakian and Aktastinian. The faunas were collected mostly from loose blocks with poor stratigraphic control and could have come from two or more substages.

China, Japan

In China, the Chihsia Limestone is a black thick bedded limestone 120-300m thick, shaly near the base, lying over shale with *Propopanoceras* (Table 18). Four Fusulinid zones were recognised by Chan (1963):

Baigendzinian	7-8	*Schwagerina* (=*Pseudofusulina*) *chihsianensis* Lee—*Rugosofusulina multiseptata* (Schell.)
Sakmarian	6	*Nankinella orbicularia* Lee—*Mufushanella mufushanensis*
Sakmarian	5	*Misellina claudiae* (Deprat)
Sakmarian	4	*Pseudofusulina** *tschernyschewi* (Schell.)

These zones probably embrace the Sakmarian and Baigendzinian Stages, although fusuline correlations are not entirely clear, for *S. chihsianensis* at the top of the Chihsia beds is reported also from the mid-Karachatirian faunas, regarded as Asselian in age. However *Misellina claudiae* is widespread in Artinskian faunas and *Nankinella* enters the Safetdaron fauna of the Pamirs, regarded as Aktastinian. The distribution of brachiopods within the Chihsia Limestone is poorly known, and has not been studied in relationship to the Fusulinacea (Grabau, 1931; Ching, 1963; Chao, 1927, p.178; Huang, 1933, p.96). *Orthotichia* suggests a general Sakmarian age, and correlation with the Safetdaron and Trogkofel faunas is supported by *Phricodothyris waageni* and *Martinia*.

In Japan the upper Sakamotozawan Stage of Toriyama (1967), with the !*Pseudofusulina** *vulgaris* Zone (Table 20,p.121), overlain by the *Pseudofusulina ambigua* Deprat Zone = *P. kraffti* locally, is approximately Sakmarian in age, though !*Pseudofusulina** *vulgaris* also characterises the middle Maping Limestone. Kanmera (1963) matched the two zones with a lower *Misellina* Zone, followed by an upper *Misellina claudiae* Zone. Ueda (1963) listed some brachiopods from the Nishikori Formation with Fusulinacea that appear to belong to the *P. ambigua* Zone.

Spitsbergen, Canada, Alaska

From Spitsbergen, Bunsowland (inner Isfjorden on Fig.19), the upper Wordiekammen Limestone or Tyrellfjellet Member of the Nordenskioldbreen Formation in the *Pseudoschwagerina* Zone is correlated with the Asselian-lower Sakmarian by Cutbill & Challinor (1965) and with the Asselian-Orenburgian by Czarniecki (1969, p.256). Perhaps the fauna is Uskalikian in age, or more likely Tastubian (Table 24), in view of the absence of *Attenuatella* and *Tomiopsis*. The upper 'Gypsiferous Series' has similar species (Gobbett, 1964).

Permian brachiopods have also been identified by Gobbett (1964) from the Cora Limestone in Bjørnøya, allegedly below the *Pseudoschwagerina* beds. Cutbill & Challinor (1965) assigned this limestone to the Sakmarian and Upper Wolfcamp *Monodiexodina* Zone which overlaps with *Parafusulina* and showed it to be younger than the Nordenskioldbreen Formation. The brachiopod genus *Tityrophoria* is found in the fauna, suggesting an Aktastinian age by correlation with faunas in the Yukon Territory, Canada (Bamber & Waterhouse, 1971). *Parafusulina* has been reported by Forbes *et*

Bjørnøya	Hornsund	Billefjorden				Substage
		Forbes *et al.*, 1958		Cutbill and Challinor		
	Brachiopod Limestone	Brachiopod Cherts	Upper	Kapp Starostin Formation	Hovtinden Member	?Kalinovian
			Middle		Svenskeegga Member	Irenian (Nevolin)
Spirifer Lmst.			Lower Limestone		Vøringen Member	Filippovian
Cora Lmst	?Cancrinella Lmst	Upper Gypsiferous Series		Gipshuken Formation		Aktastinian
Fusulina Lmst	Treskelloden beds	Wordiekammen Limestone	Limestone B	Nordenskioldbreen Formation	"Limestone B"	Sterlitamakian
			Upper		Tyrellfjellet Member	?Tastubian
			Mid		Brucebyen Beds	?Uskalikian
			Lower		Cadellfjellet Member	?Surenan
			Black Crag		Black Crag	
					Minkinfjellet Member	Carboniferous

Table 25. Permian rocks of Spitsbergen and Bjørnøya.

al. (1958) and Ross (1965), though doubted by Cutbill & Challinor (1965) and Czarniecki (1969). The Cancrinella Limestone, above the Treskelodden beds of west Spitsbergen, has a small fauna of possible Sterlitamakian, or Kurmaian age, with *Paeckelmanella.*

Four Sakmarian brachiopod zones have been recognised in the Yukon Territory of Canada by Bamber & Waterhouse (1971). The *Yakovlevia* (Ey) Zone lies at the base (Table 22), correlated with the Tastubian Stage, and accompanied by rare *Metalegoceras.* The overlying *Attenuatella* (Ea) and *Tornquistia* (Et) zones, better considered as subzones, for they are clearly of two communities in different facies, are judged to be Sterlitamakian in age. Ammonoids include *Eoasianites*, *Tabantalites bifurcatus* Ruz. aff. *trapezoidalis* Max., *Properrinites*, *Somoholites* cf. *belvensis* (Haniel), *Prothalassoceras*, *Medlicottia* and *Uraloceras.* Although these were assessed as Tastubian in age by Nassichuk (1971), Furnish (1973, p.531) preferred a Sterlitamakian age as supported by the brachiopods (Bamber & Waterhouse, 1971). The *Jakutoproductus* (Ej) Zone has various species related to Siberian species, especially *Jakutoproductus* as in the Echi faunas of Verchoyan, *Anidanthus*, *Yakovlevia*, and notably *Martinia*, so common in Aktastinian faunas. *Alaskanella yukonensis* (Skinner & Wilde) from the *Jakutoproductus* Zone has been interpreted as indicating correlation with the Lenox Hills Formation by Ross (1967a), and Tastubian Substage by Mamet & Ross (in Bamber & Waterhouse, 1971), but it is here considered that brachiopods and stratigraphic position above Sterlitamakian brachiopods and ammonoids require an Aktastinian correlation. Brachiopods of the *Jakutoproductus* Zone are also found in Bjorne Peninsula, southwest Ellesmere Island, Canadian Arctic Archipelago, in beds perhaps erroneously referred to the Assistance Formation by Thorsteinsson (1974). The brachiopods are found with ammonoids *Neoshumardites* cf *sakmarae* (Ruzh.), *Uraloceras*, and *Paragastrioceras* aff. *jossae* (Vern.) which were regarded as late Sakmarian (Sterlitamakian) or Aktastinian, by Nassichuk *et al.* (1965). Accompanying Fusulinacea support an Artinskian age, and an Aktastinian age is likely. Lengthy faunal lists, compiled chiefly by G.H. Girty, suggest that Sakmarian faunas are widespread in Alaska, for example in the Chitina Valley of south-east Alaska (Moffitt, 1938a) and in the upper Copper River District and east Alaska Range (e.g. Moffitt, 1938b).

Fusulinacean and brachiopod faunules from the upper Telford Formation, and from the Ross Creek Formation of South-east Alberta near Crowsnest have been discussed by Logan & McGugan (1968), and assigned a general Sakmarian age.

A briefly described fauna from the Buttle Lake Formation of Vancouver Island (Yole, 1963) is probably Sakmarian, judged from brachiopods *Horridonia*, *Spiriferella* and *Tomiopsis* like Tastubian forms of the *Yakovlevia* Zone in the Yukon Territory, Canada. *Schwagerina* and *Pseudofusulinella* are present, the latter known from high Wolfcamp (i.e. Lenox Hills) and Leonard according to Monger & Ross (1971).

United States

In south-east Arizona, the upper Earp Formation has Sakmarian Fusulinacea, as discussed by Ross (1973), and higher beds contain an ammonoid *Perrinites* or *Properrinites* indicating a Wolfcamp or Leonard correlation. The overlying Colina Formation contains gastropods that suggest a late Wolfcampian age according to Knight in Gilluly *et al.* (1954), but brachiopods were interpreted as showing a mixture of affinities. It seems likely that at least the lower fauna may be approximately equivalent to the Skinner Ranch Formation of the Glass Mountains, and roughly Aktastinian or Sterlitamakian in age or both. Perhaps the upper beds are as young as the Cathedral Mountain Formation of the Glass Mountains (i.e. Baigendzinian), but with the faunas not described, and revision of the Glass Mountains brachiopods pending, it is difficult to be sure.

Stage	Substage		Guadalupe Mountains		Delaware		Sierra Diablo		Glass Mountains
Djulfian	Urushtenian?	Guadalupe			Lamar	Bell Canyon			
Punjabian			Capitan		McCombs Rader Pinery Hegler				Capitan
Kazanian	?Sosnovian		Goat Seep Getaway		Manzanita Southwells	Cherry Canyon	Goat Seep ?	WORD	Vidrio Appel Ranch
	Kalinovian		Sandstone Tongue				Ss Tongue		Willis Ranch
Kungurian	Nevolin						Brushy Canyon		China Tank
	Filippovian	Leonard	Cutoff				Cutoff		Road Canyon
Baigendzinian			Victorio Peak Bone Spring		"Cutoff" Bone Spring		Victorio Peak Bone Spring		Cathedral Mountain
									Wedin
Sakmarian	Aktastinian	Wolfcamp			Hueco Mountains		Lower Massive	Skinner Ranch	Sullivan Peak Dugout Mtn Poplar Tank Decie Ranch *S. crassitectoria*
	Sterlita-makian			Hueco Group	Alacran Mountain		Bone Spring		
	Tastubian				Cerro Alto Hueco Canyon Powwow Cglm		Hueco Group Powwow		Lenox Hills
Asselian	?Kurmaian Uskalikian Surenan								Neal Ranch *Uddenites* Shale
					Magdalena		(Ordovician)		Gaptank

Table 26. Early & Middle Permian correlations in west Texas, based on Cooper & Grant (1973, fig. 2), with tentative world correlations. In my view, the Leonard Guadalupe boundary should lie below the Road Canyon Formation, as in King 1931.

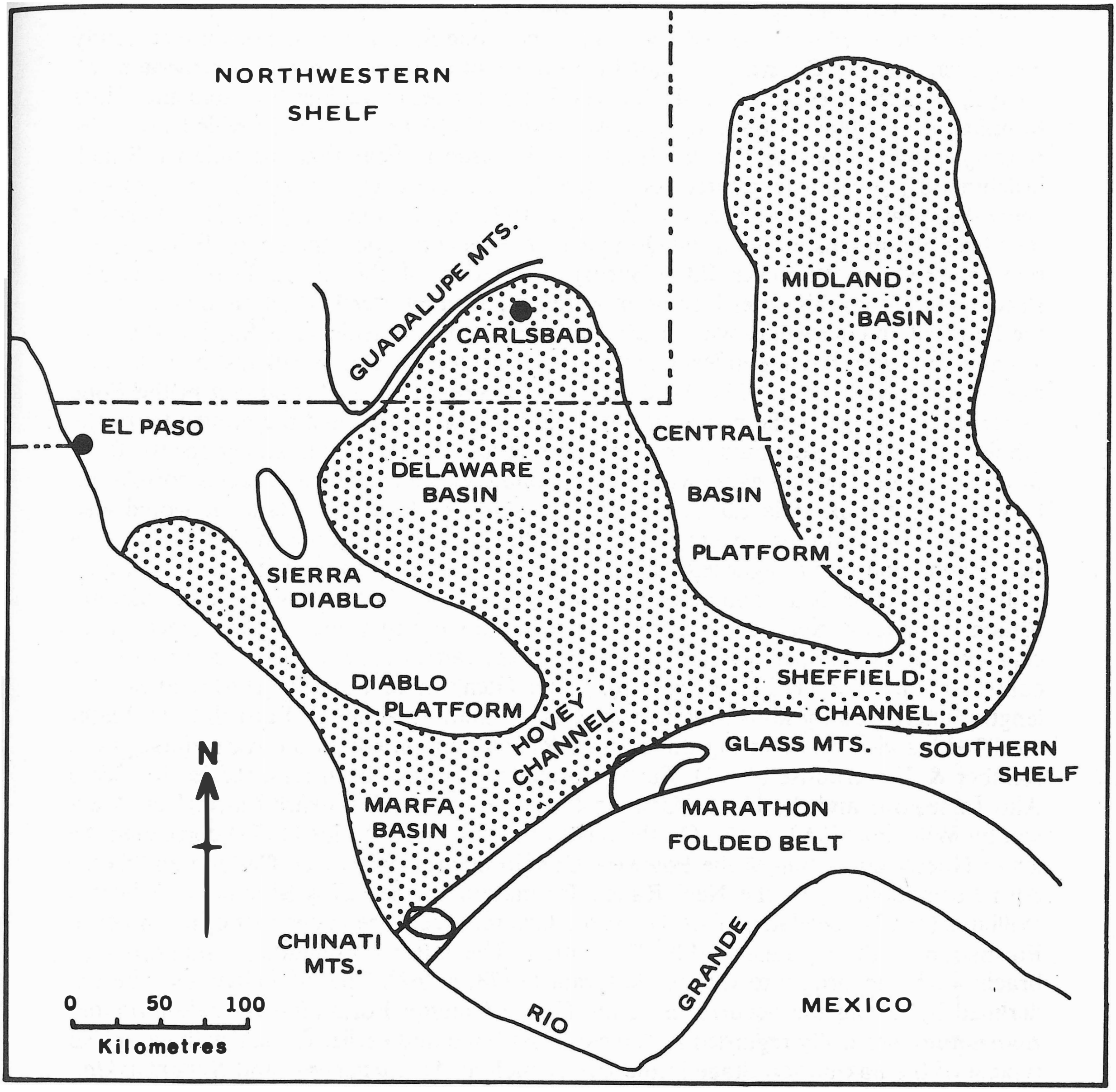


Fig. 22. Palaeogeographic setting of the Permian in west Texas, according to Cooper & Grant (1973a, fig. 27, p. 97). Reproduced with permission of authors.

West Texas provides superb faunal sequences (Table 26). The Lenox Hills Formation of the Glass Mountains (Fig.22) includes *Pseudoschwagerina* and *Monodiexodina* with a number of Ammonoidea, such as *Metalegoceras*, *Properrinites*, *Eoasianites* and *Artinskia*, and Brachiopoda listed in part by Ross (1963). Ross (1963, p.43) matched the Lenox Hills Formation with the Asselian Stage, on the basis of *Pseudoschwagerina* which persists to the top of the formation. Yet *Parafusulina* is also present in the upper Lenox Hills beds. As here interpreted, the ranges of both these genera overlapped in faunas of Sakmarian age, though not in the Urals.

The Lenox Hills, Skinner Ranch, Hess and Bone Spring brachiopods are currently being restudied by Cooper & Grant (in press) and it is not possible to provide a full analysis until the survey is published. A few initial studies in the Sierra Diablo and Glass Mountains by Stehli (1954), Cooper & Grant (1969) and others provided no wide-ranging correlations. Cooper & Grant (1973) made it clear that the Skinner Ranch brachiopods, previously treated as Leonard, were close to the Wolfcamp forms in general appearance. Cooper & Grant (1964, 1973) have shown that the Hess facies of the Glass Mountains matches the Decie Ranch beds and in part the Lenox Hills Formation, as well as the lower Bone Spring Formation of the Sierra Diablo (Fig.22). Brachiopods from this latter formation were described by Stehli (1954), and assigned to the Leonard, in conformity with interpretations based on Fusulinacea, Stehli making no attempt to assess the age independently. But brachiopods clearly suggest a Wolfcamp age (Cooper & Grant, 1973). To the writer, the presence of *Attenuatella* in the Bone Spring fauna suggests the possibility of a Sterlitamakian age, and the remainder of the brachiopods described would permit this correlation. A Sterlitamakian age for the Bone Spring basal beds would agree with the ammonoid evidence, which suggests correlation between the Lenox Hills Formation and *Tornquistia* Zone of Canada. It would also agree fairly well with the position of the Safetdaron fauna in Darvas, mid Asia, where a rich brachiopod fauna regarded by the writer as most likely to be Aktastinian but possibly slightly older is accompanied by *Schwagerina crassitectoria* of the lower Skinner Ranch Formation. Such an interpretation would appear to agree with the general concept implied by Cooper & Grant (1973) that the faunal succession is continuous. By contrast, Ruzencev (1952), Ross (1963), and Glenister & Furnish (1961) indicated a lengthy unconformity above the Lenox Hills Formation, although Furnish (1973) later modified his view by referring the Skinner Ranch ammonoids to the Aktastinian, as in Bamber & Waterhouse (1971). Further brachiopods have been reported in the Cerro Alto Limestone and the Hueco Canyon Formation of the Delaware Basin, New Mexico, by Williams (1963, p.17). On the basis of Fusulinacea, Wilde (1971) correlated the lower Hueco, consisting of the Powwow Conglomerate, and Hueco Canyon and Cerro Alto Formations, with the Neal Ranch Formation of the Glass Mountains, whereas Williams (1963) correlated all of the Hueco Group, except the upper part of the Alacran Formation, with the Lenox Hills Formation. The latter correlation is supported by brachiopods, according to Cooper & Grant (1973, p.368). The difficulties may be underlined by noting the occurrence in the Hueco Canyon Formation of the ammonoid *Eoasianites*, generally regarded as typical of Asselian and earlier faunas, with genera so typical of the Sakmarian Stage in the Urals, such as *Metalegoceras* and *Synartinskia*.

Brachiopods from the light grey limestone of the Alacran Mountain Formation were listed by Williams (1963), and correlated with the *Schwagerina crassitectoria* bed of the Decie Ranch Member at the base of the Skinner Ranch Formation in the Glass Mountains.

Wilde (1971) correlated the Summer Group of Kansas with the Lenox Hills and lower Skinner Ranch formations of west Texas on the basis of Fusulinacea, and matched the overlying Stone Coral Formation and Nippewalla Group with the upper Skinner Ranch beds. The *Schwagerina crassitectoria* horizon was considered to be missing here, but was observed at the base of the Clyde Formation of north-central Texas.

McCloud Ls Fusulinid Zones	Glass Mountains West Texas	North-Central Texas	Kansas	"Series"
H	Skinner Ranch Formation (restricted) *Schwagerina crassitectoria*	Clyde Formation *S. crassitectoria* ?	Nippewalla Gr Stone Corral Formation	Leonardian
G	Decie Ranch Member Skinner Ranch Formation	Belle Plains Formation ?	Summer Group	Wolfcampian
F	Lenox Hills Formation	Admiral Formation		
E	Basal Lenox Hills Congl.			
D	Neal Ranch Formation	Moran & Putnam Formation	Chase-Council Grove Groups	
B-C	King's Bed 3 ?	Salt Creek Bend Shale	Eskridge Shale	
A	King's Bed 2 of "Gray Limestone"	Pueblo Formation	Admire Group	

Table 27. Correlation of McCloud fusulinid zones of California with other lower Permian sequences of United States, following Wilde (1971, fig. 8).

In the same region the Belle Plains Formation and Admiral Formation were referred to the Lenox Hills and lower Skinner Ranch beds, as shown in Table 27. Ammonoids as summarized by Furnish (1973) support these correlations well, with *Properrinites boesi* (Plummer & Scott) and *P. denhami* (Miller & Furnish) from the Admiral Formation, considered to be at a Tastubian phase of evolution. From the Clyde Formation, species of *Medlicottia*, *Metalegoceras*, *Popanoceras* and *Metaperrinites* suggest an Aktastinian age. None of the species are identical with Russian forms, but they are judged to be at the same stage of evolution.

Bolivia, Madagascar, India

In south central Peru the upper Copacabana Group contains primitive *Parafusulina* with a few brachiopods, too few to provide any meaningful analysis (Newell *et al.*, 1953).

The Sakoa Group of the Onilahy region in south-west Madagascar commences with tillite of Kurmaian age, followed by coal beds, red sandstones and clays, and then the Vohitolia marine limestones with a few productids, apparently of Sterlitamakian age judged from *Brachythyrina rectangulus* (Kut.). The fauna is too incomplete to analyse properly.

Elements of the preceding faunas have been traced widely through the southern hemisphere by Waterhouse (1970a) as the *Stepanoviella-Taeniothaerus* (or *Reedoconcha*) fauna, already briefly discussed for Iran, Saudi Arabia and Afghanistan. The *Conularia* beds, 25m thick, in the Salt Range, Pakistan, may belong here (Table 18) with *Discinia*, *Neochonetes*, *Sulciplica*, and *Tomiopsis*, though the fossils are so few that they could be as young as Sterlitamakian or as old as Kurmaian. The Sakmarian Stage is well represented in the *Taeniothaerus* or *Reedoconcha* faunas of the Agglomeratic Slate of Kashmir, including Bren Spur (Bion, 1928; Reed, 1932; Kotlyar, 1964; Waterhouse, 1970a), with '*Streptorhynchus*' *bioni* Reed, *Neochonetes* spp., *Stepanoviella*, *Punctocyrtella nagmagensis* (Bion), and *Tomiopsis* spp., suggesting a Sterlitamakian age.

Elements of the same Sakmarian fauna appear at Subansiri in Sikkim (Sahni & Srivastava, 1956; Singh, 1973). From Peninsula India Reed (1928) described a small fauna at Umaria, regarded as Sterlitamakian in age by Waterhouse (1970a) because of the presence of *Stepanoviella*, *Tomiopsis* and rare specimens of the bivalve *Eurydesma*, which also appeared at this horizon in New South Wales. A similar fauna was found in western Rajasthan by Sastry & Shah (1964), sharing species found at Nagmarg and Yal Nal, Kashmir, recorded by Bion (1928). Spores also correlate the *Conularia* beds of the Salt Range with the Umaria beds (Ghosh & Basa, 1969, p.407), within the lower 'Karhabari floral zone'.

Australia, New Zealand

In Western Australia (Fig.21) the Beckett Member of the Holmwood Shale, Perth Basin (Table 29) has a Tastubian ammonoid fauna (Glenister & Furnish, 1961) with *Juresanites jacksoni* (Etheridge) and a small distinctive brachiopod fauna (Waterhouse, 1970a) allied to those of the *Conularia* beds in the Salt Range and Subansiri, Sikkim. The slightly younger Callytharra Formation of the Carnarvon Basin, Western Australia, possesses a large brachiopod fauna (Dickins & Thomas, 1959; Thomas, 1958, 1967; Coleman, 1957; Prendergast, 1943; Campbell, 1965), with related faunas in the Nura Nura Member of the Poole Sandstone in the Fitzroy Basin. Various ammonoids from the Nura Nura Member, including advanced *Propopanoceras rhuzencevi* (Glenister & Furnish) and *Metalegoceras*, were assigned to the Sterlitamakian Substage by Glenister & Furnish (1961). Correlative faunas are found in the Fossil Cliff Sandstone of the Irwin or Perth Basin. Overlying faunas are meagre, but are so close to the

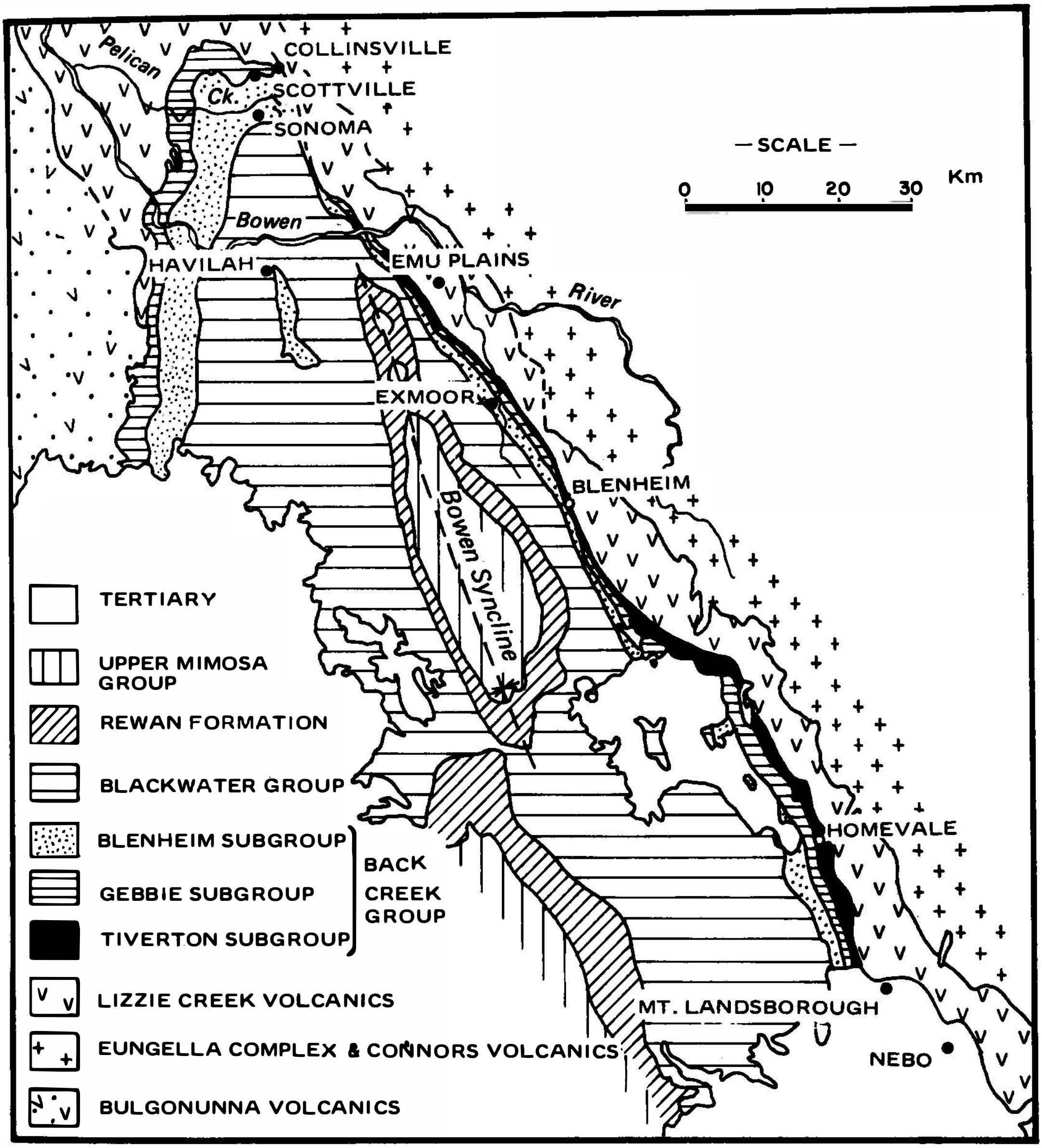


Fig. 23. North Bowen Basin, from Dear (1972, fig. 1).

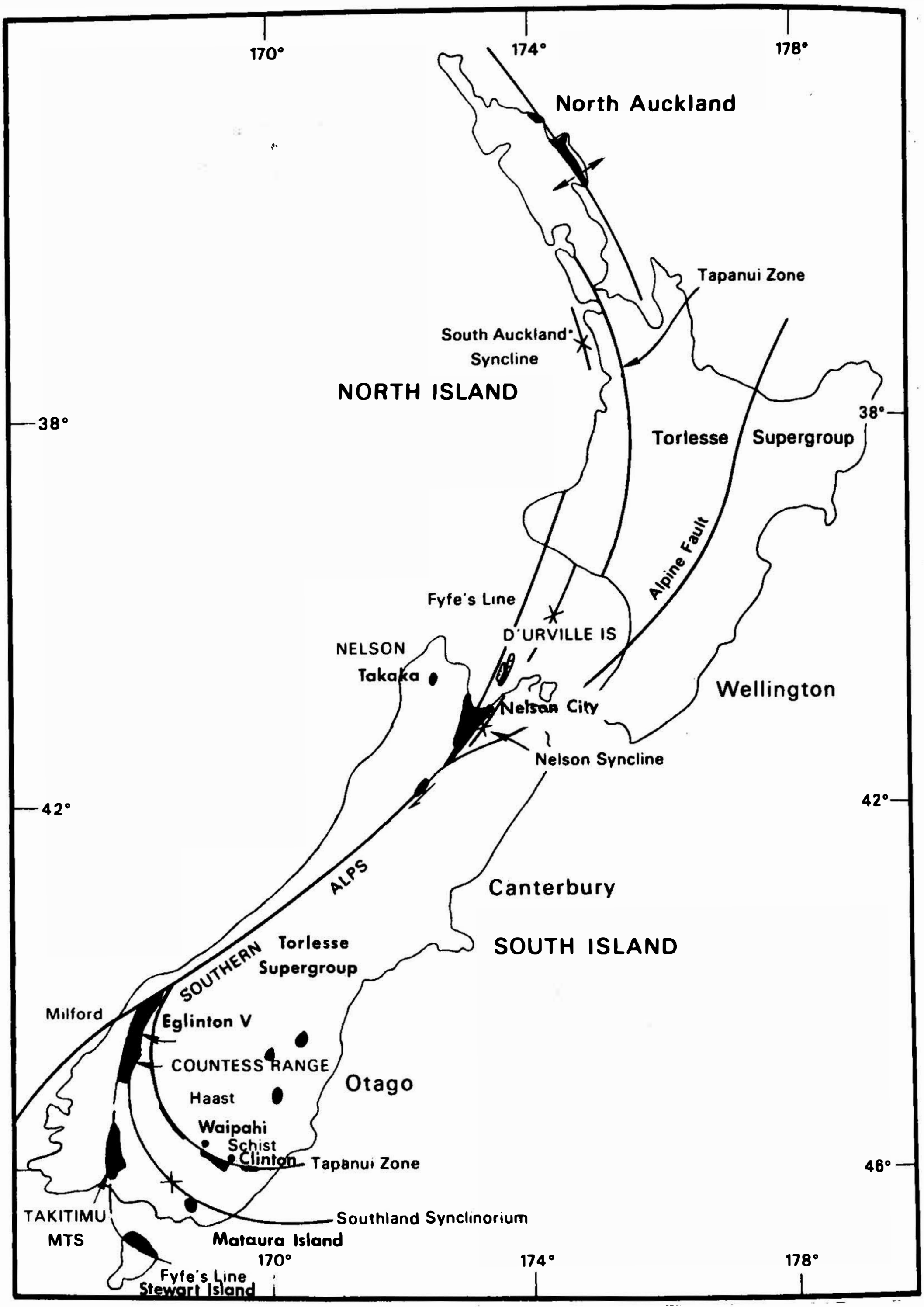


Fig. 24. Distribution of Permian in New Zealand, on a craton at Takaka, along a volcanic arc and trough (arc-trench gap) in between Fyfe's Line and Tapanui Zone in the South Auckland-Nelson and Southland synclinorium, a mid-geosynclinal ridge of Clinton-Waipahi, and sporadically in a trough (with Fusulinacea more common) containing the Torlesse deposits in Otago and North Auckland. From Waterhouse (1973d, fig. 2, p. 35). The Alpine Fault transects the Permian, and is of late Tertiary – Recent age.

Callytharra faunules that they are likely to be Aktastinian in age (Waterhouse, 1970a). The largest of these faunas comes from the basal siltstone member of the One Gum Formation in the Wooramel Group, Carnarvon Basin (Dickins in Konecki *et al.*, 1958, p.33), characterised by *Stepanoviella flexuosa* Waterhouse.

Sakmarian fossils are widespread in eastern Australia. In Queensland (Table 36), Fauna 1 of Dickins (in Malone *et al.* 1967, p.70) in the Lizzie Creek Volcanics in north Bowen Basin (Fig.23) could be Tastubian, though lumped with Fauna II by Runnegar (1969a). There is one distinctive species of *Notospirifer*. The Cattle Creek Formation of the Springsure shelf area, the Tiverton Formation of the Bowen Basin and the Yarrol Formation of the Yarrol Basin (Maxwell, 1964) have yielded large correlative faunas, including ?*Lissochonetes yarrolensis* Maxwell, *Echinalosia preovalis* (Maxwell), *Anidanthus springsurensis* (Booker), *Terrakea pollex* Hill, *Attenuatella australis* Armstrong & Brown; syringothyrinids and *Tomiopsis* spp. (see Etheridge, 1892; Campbell, 1960, 1961, 1965), here judged to be chiefly of Sterlitamakian age (Table 36). *Eurydesma* occurs in some of the faunas, suggesting cold waters. Species of *Uraloceras*, vaguely located in the stratigraphic column, were assigned by Armstrong *et al.* (1966) and Dear (1969) to the Aktastinian Substage, but this age requires verification from the associated faunas, which are yet to be described. The upper Cattle Creek Shale and Sirius Shale of the south-west Bowen Basin are possibly as young as Aktastinian, as the brachiopods differ slightly from those of the Tiverton faunas, and match those faunas in New Zealand (Waterhouse, 1964, 1969c). The Buffel Formation of south-east Bowen Basin is conceivably of the same age.

Moderately rich brachiopod faunas of much the same age as the Tiverton faunas are found in the Farley Formation in the Hunter Valley, Sydney Basin, of New South Wales (Table 40) with '*Uraloceras*' characterised by an unusual suture. Somewhat allied faunas are found in the Ravensfield Sandstone, at the base of the Farley Formation. The underlying Rutherford Formation yields faunas too meagre to be assessed but, from stratigraphic position, could be Tastubian. Much the same fauna is found in the Golden Valley Group, Tasmania, with small Foraminifera studied by Crespin (1958) and brachiopods summarized in Banks (1961, p.333; 1962, p.199), Johnston (1888), and Waterhouse (1970d).

In the Takitimu Group of southern New Zealand (Table 38), the Telford Stage has two brachiopod zones containing such species as *Echinalosia preovalis* (Max.); and *Terrakea pollex* Hill, closely allied to those of the upper Cattle Creek Shale of Springsure, Queensland, and tentatively considered to be of Aktastinian age (Waterhouse, 1964, 1968, 1969b, 1973c). The faunas are found in volcanic breccias, 1000m thick (Fig.24).

BAIGENDZINIAN STAGE

Urals

The classical section of the Arti region in the Urals (Nalivkin, 1949; Miloradovich, 1949; Stepanov, 1951), commences with the Belokatai Suite of polymict conglomerates, 600-1000m thick, and the overlying Gabrashitov or Kashkabash Suite 100-200m thick, both containing upper Artinskian ammonoids (Ruzencev, 1956). To the south in the Ishibeisk pre-Urals the Burtsev and Irgin limestones with Aktastinian ammonoids are overlain by the Baigendzinian beds of coarsely fragmental limestone, and much argillite, also containing ammonoids. Characteristic ammonoid genera include *Sakmarites*, *Propinacoceras*, *Waagenina* and *Neocrimites* with several other genera appearing for the first time. *Metalegoceras* and *Paragastrioceras* are especially abundant. Baigendzinian Fusulinacea include *Pseudofusulina** *insignita* Viss., and *Praeparafusulina* *lutugini* (Schell.), first appearing in the Burtsev Suite. Miloradovich (1949) recognised 137 species of brachiopods, of which 100 persisted from the Aktastinian Substage, and 37 appeared for the first time. However there have been no modern studies.

Two major divisions are recognised in the Baigendzinian Stage, the Sarginian followed by the Saranin (Nalivkin, 1949; Likharev, 1966, Table 4). The Sarginian, here treated as a substage, is characterised in part by *Parafusulina solidissima* Raus., *Pseudofusulina* makarovi* Raus., *Cyrtella kulikiana* Frederiks and several ammonoid species, including *Medlicottia orbignyana* Vern., and *Waagenina subinterrupta* Krotow. The Saranin is characterised by *Parafusulina solidissima* Raus., *Chonetina artiensis* (Krot.), other chonetids, and *Muirwoodia artiensis* (Chernyshev). Miloradovich (1949) called the upper part Krasnoufimian after Frederiks (1932), and this name is preferred for a substage over Saranin as the Krasnoufimian area yields a large brachiopod fauna (Frederiks, 1934a), including some overtoniids, *Uraloproductus stuckenbergianus* (Krot.), marginiferids, *Reticulatia*, many *Cancrinella*, *Anidanthus*, *Yakovlevia*, *Cleiothyridina*, *Purdonella*, *Martinia* and *Spiriferella*. Judged from charts, there seem to be virtually no Saranin or Krasnoufimian ammonoids. Ruzencev (1956) dismissed the significance of the subdivisions, yet had no supporting evidence one way or other from ammonoids. Little value can be placed on such procedures.

From supposed Kazanian beds of the Aktubin Urals, Lipatova reported brachiopods that appear in fact to be of Kungurian or Baigendzinian age (Kulikov, 1960). A huge brachiopod fauna from the Kolwa River region described by Stepanov (1934, 1937b) appears to be Krasnoufimian in age, judged from the presence of species of *Reticulatia*, *Uraloproductus stuckenbergianus*, *Cancrinella*, *Martinia*, *Spiriferella pseudotibetana* and other species. In Pai Hoi, Petchora, the Gusin Suite at the base of the Yunargin Series has a few brachiopods, of perhaps early Artinskian age (Table 13). The overlying Belkov Suite (450-750m) has brachiopods, Sarginian in aspect, including *Uraloproductus stuckenbergianus* (Krot.), *Waagenoconcha irginae* Stuck., *Spiriferella pseudotibetana* etc. and various ammonoids, especially *Waagenina* supporting a Baigendzinian age (Solomina, 1960). Ifanova & Semenova (1972) also recorded *Chonetina artiensis* (Krot.). The overlying Talatin Suite (350-700m) has similar faunas apparently correlative with the Krasnoufimian Substage. There are many links to the Bardin faunas associated with the Manchez reefs of Krasnoufimian age in the Ufimian amphitheatre. Species include many members of *Streptorhynchus*, *Derbyia regularis* Waagen, *Chonetina* spp., *Kochiproductus*, *Waagenoconcha irginae* (Stuck.), large *Linoproductus*, *Reticulatia*, *Chaoiella*, *Sowerbina*, *Yakovlevia*, and *Cyrtella kulikiana* (Fred.). The middle Talatin fauna is correlated with the basal Saranin (Krasnoufimian) by Gorsky & Guseva (1973, p.170). However Ustritsky (1971) referred the Talatin Fauna to the Kungurian Stage. Perhaps the Filippovian Substage may be represented in the upper Talatin faunas because *Spiriferella keilhavii* (von Buch) in the fauna is typical elsewhere of Kungurian deposits, and ostracods support a Kungurian age (Gorsky & Guseva, 1973), as do some of the brachiopods, such as *Pseudosyrinx kolymensis* Tolm. However a Kungurian correlation is not confirmed from recent studies by Ifanova & Semenova (1972), who showed the Talatin Suite as Artinskian.

North Siberia, Pamirs, Afghanistan, Armenia (Table 15)

Beds are thick but not very fossiliferous in south-east Verchoyan, Siberia. The lower Endibal Series or Tumarin Suite, 1,300m thick, contains such ammonoids as *Neouddenites adrianova* Ruz. and *Popanoceras tumarense* Ruz. (Likharev, 1966, p.348). In the Tompo Basin of east Verchoyan the Kukkan Suite, 1,100-1,300m thick, is followed by the Dibin Suite (500-700m) with '*Chonetes*' *brama* Frederiks, *Stepanoviella*, *Jakutoproductus* and *Spiriferella*, apparently Baigendzinian in age.

In the Kolyma River sequence the Djeltin Horizon of plant beds or equivalent Kuktui beds may be correlative, with *Horridonia* and *Spiriferella vaskovskii* Zavodowsky, the latter also found in Baigendzinian beds of Canada. Zavodowsky (1970) assigned the beds to the Kungurian Stage.

The middle Darvasian Stage of the Pamirs and south-central Asia is approximately Baigendzinian, on the basis of *Parafusulina* and stratigraphic position. The Gundarin Horizon is Baigendzinian (Dronov & Leven, 1961; Likharev, 1966) with *Nankinella*, *Pseudofusulina* vulgaris*, *Triticites contractus* (Schell.), *Pseudofusulina krafſti* (Schell.), *Parafusulina*, and *Misellina* and brachiopods *Derbyia regularis* Waagen, *Marginifera* and *Choristites*. Kalmikov (1964) described two zones in the Darvas region, the lower zone with Fusulinacea *Pseudofusulina krafſti* (Schell.) and *Parafusulina*, and Ammonoidea *Propinacoceras bornemani* Toum., *Medlicottia* cf *artiensis timorensis*, *Agathiceras uralicus* Karp., and *Popanoceras lahuseni* Karp., the upper zone with *Misellina claudiae* (Deprat) and *Parafusulina* (Table 17).

Part of the Kubergandin Suite of the south-west Pamirs, some 50- 100m thick, includes *Popanoceras* and *Metalegoceras*. Grunt & Dimetriev (1973) recorded a species of *Terrakea*, but it is too poorly preserved and decorticated to compare with Australasian species. It would well be as young as Kungurian (Table 22), for *Terrakea* is principally, though not exclusively a cold-water genus (Waterhouse, 1971), and so may be expected to appear in paleotropical realms during the cold Kungurian Stage. Moreover Kubergandin Fusulinacea described by Leven (1967) are of Kungurian age.

In Afghanistan south of Kabul (Termier *et al.*, 1974), the black carbonates have yielded *Parafusulina ferganica* Mikl.-Makl., and could be as young as Baigendzinian. From Mt Bamyan, Termier & Termier (1970) have described *Bamyaniceras bornemanni* (Toum.) with *Artinskia*, and *Popanoceras* and *Perrinites hilli afghana* Termier & Termier.

In Armenia the Sasnian Horizon, 80-150m thick may be of Baigendzinian age but could be Kungurian (Table 44). It contains *Pseudofusulina** aff. *gregaria* (Lee), *Nankinella caucasica* Dutk., and compound rugose corals. The Armin Horizon, 80-200m thick, is lithologically the same with *Nankinella*, *Sphaerulina* and corals like those of the Sasnian faunas. Brachiopods are few and have not been described, so that correlation must depend on Fusulinacea, with support from corals.

China, Japan

In China, the fourth and uppermost Fusulinacean zone of the Chihsia Limestone (Table 18) has *Pseudofusulina chihsianensis* (Lee) and *Rugosofusulina multiseptata* (Schell.) of possible Baigendzinian age (Chan, 1963), above a zone with *Nankinella orbicularia* Lee, and below the Maokou Limestone of Kungurian age. The upper part of the Chihsia Limestone in the Tianwo district of northern Kwangsi yielded *Artinskia*, *Neocrimites* and *Agathiceras* (Chao, 1966, p.1815). But as shown below, at least part of the upper Chihsia Limestone is definitely Kungurian in age.

The Nabeyaman Stage of Japan, based on black or dark grey carbonates with shale in the Yamasuge Member of the Aso Group in Kwanto Province, coincides with the *Parafusulina yabei* Hanzawa Zone, containing *Pseudoschwagerina* and *Pseudofusulina* krotowi* (Schell.) (Toriyama, 1967; Fujimoto, 1961). Various fusulinid biofacies are recognised (Igo, 1964), with a few brachiopods (Hayasaka, 1922, 1923, 1925).

Canada, United States, Mexico

In Canada, the Baigendzinian Stage is represented by the *Antiquatonia* brachiopod Zone in the basal 20m of the Tahkandit Formation (Table 22), with *Derbyia* cf *grandis*

Waagen, huge *Linoproductus* and *Cyrtella*, followed by the *Sowerbina* Zone at 70-100m above the base with *Muirwoodia* cf *artiensis* (Krotow) found in the Urals. *Bathymyonia sterlitamakensis* (Stepanov), *Reticulatia uralensis* (Likharev), *Linoproductus*, *Spiriferella pseudotibetana* Step., *S. vaskovskii* Zav. and *Cyrtella* species are allied to species in the Talatin beds of Petchora. The brachiopods differ considerably from those of underlying Yukon zones in the absence of Overtoniids and other early Permian species and genera. Ross (1967a) correlated *Schwagerina* from the *Antiquatonia* Zone with Lenox Hills or late Wolfcampian specimens of Texas. This age seems too great. But *Alaskanella yukonensis* (Skinner & Wilde), from the slightly younger *Sowerbina* Zone was correlated, correctly in my opinion, by Ross (1967a) with the upper Leonard, i.e. Cathedral Mountain Formation of the Glass Mountains. The Tastubian age assigned to the same Fusulinacea by Mamet & Ross (in Bamber & Waterhouse 1971) cannot be reconciled with brachiopod evidence and stratigraphic position above Sakmarian brachiopods and ammonoids. *Neouddenites caurus* Nassichuk *et al.* (1965, p.41) from northern Yukon Territory possibly came from beds of the same age, and was compared with *N. andrianovi* Ruzencev from the Endibal Series (Baigendzinian-Kazanian) of Verchoyan.

Similar brachiopods are found in the Belcher Channel Formation of Devon Island and elsewhere in the Sverdrup Basin, Canadian Arctic Archipelago, accompanied by *Schwagerina hyperborea* (Salter). This species was matched with *Praeparafusulina lutugini* by Harker & Thorsteinsson (1960) and was regarded as early Artinskian (i.e. Aktastinian), but *P. lutugini* ranges into the Baigendzinian Stage.

Fairly large brachiopod faunas have been collected from the Halleck Formation of the Alaska Panhandle, in dark-grey calcareous siltstone and calcareous sandstone, with detrital chert and volcanics (Buddington & Chapin, 1929; Muffler, 1967). The brachiopods were assessed as 'Leonardian' by Dutro in Muffler (1967), and *Parafusulina* has been reported, but a more precise determination must await description of the faunas.

The Grandeur Member of the Park City Formation in Wyoming, United States, may be of Baigendzinian age, with Productacea such as *Squamaria ivesi* (Newberry), *Rugatia occidentalis* (Newberry), and other species pointing to correlation with the Cathedral Mountain Formation of the Glass Mountains in west Texas (Yochelson, 1968).

A moderate sized brachiopod fauna from the Toroweap Formation of Arizona (McKee, 1938; McKee & Breed, 1969) may be correlative with the Cathedral Mountain Formation, though it has many links to the younger faunas of the Word. According to Gilluly *et al.* (1954), faunas of at least the upper part of the Colina Formation in south Arizona might be Leonardian. Fossils listed from the overlying Epitaph Dolomite are somewhat non-descript but may from stratigraphic position be correlative with the Cathedral Mountain Formation of west Texas, and the Toroweap Formation of north Arizona.

The Cathedral Mountain Formation of the Glass Mountains, west Texas, is up to 500m thick, and highly siliceous, with orange-coloured shale and thick sandstone near the top, bearing scattered bioherms (Fig. 29, Table 26). It is characterised by the brachiopod *Institella leonardensis* (King), and coincides with the fusulinacean zones proposed by Ross (1962), based on *Parafusulina spissisepta* Ross and *P. durhami* Thompson & Miller (Cooper & Grant, 1964). A number of brachiopods are described by R.E. King (1931) and Cooper & Grant (1969), but the bulk awaits publication in a major revision by Cooper & Grant (in press). A few known species are comparable to those of the lower Tahkandit beds in the Yukon Territory of Canada (*Antiquatonia bassi* McKee, *Anemonaria 'pseudohorrida'* (not Wiman) and *Anidanthus*), and the Cathedral Mountain faunas show the same disappearance of early Permian genera (Cooper & Grant, 1973) as in the Yukon. Typical ammonoids include *Medlicottia* *costellifera* Miller & Furnish; *Neocrimites newelli* (Miller & Furnish), and *Perrinites vidriensis* Böse. Various other Baigendzinian ammonoid faunas are recognised by Ruzencev (1956) in the Blain Formation, north-central Texas; and San Andreas Formation, New Mexico, with *Perrinites*, *Eumedlicottia*, *Agathiceras*, and *Stacheoceras*, differing from the Urals faunas. Some brachiopods are known (Clifton, 1961). As the brachiopods await publication by Cooper & Grant (in press), it is not possible to see if they show a two fold subdivision like those of most regions, and it is not clear if both Baigendzinian substages are present. However Ross (1962) did report two Fusulinacean zones.

The lower part of the sequences of lavas, conglomerates, limestones and clastics making up the Las Delicias Syncline in western Coahuila, Mexico, (King *et al.* 1944) may be of Baigendzinian age (Table 35). A few brachiopods are listed by King, but await description. Ammonoids include *Bitaunioceras*, *Perrinites* and *Medlicottia* in 'beds' or bands 20 and 18 of the Difunta sections, and *Parafusulina sellardsi* Dunbar & Skinner occurs in 'bed' 14.

Pakistan, Australia, New Zealand

In the Salt Range of Pakistan, the Lower Productus Limestone or Amb Formation, up to 50m thick, contains a *Monodiexodina* fauna near the base, recently revised by Douglass (1970). It may be allied to the *Parafusulina* faunas in Saudi Arabia discussed by Hudson & Sudbury (1959). Two faunas may be recognised by analysis of the Amb brachiopods described by Reed (1944, p.374) Table 28. The lower fauna is like those of the *Antiquatonia* fauna of Canada, and lower Talatin fauna of Pai Hoi, Russia, in the abundance of dictyoclostids, numerous *Streptorhynchus* and *Lissochonetes*, with *Marginifera* in place of the closely related genus *Anemonaria*. The upper fauna differs more and has no specific links. A general Baigendzinian age is suggested by *Derbyia regularis* Waagen, *Rhynchopora variabilis* Stuck., *Lissochonetes*, *Cleiothyridina semiovalis* (Waagen), *Spiriferella*, *Pterospirifer*, and *Neospirifer marcoui* (Waagen), with *Chaoiella* as in the Baigendzinian sequences of the Yukon Territory.

Correlative faunas of Western Australia are represented in the Lower Byro Group of the Carnarvon Basin (Waterhouse, 1970c, d), corresponding to Fauna D 1 of Dickins (1963). Two distinct faunas are recognised by analyses of the descriptions and distributions in Prendergast (1943), Thomas (1958, 1967), Coleman (1957), Campbell (1965), and other works mentioned by these authors (Table 29). The lower faunas, notably from the Madeline and Coyrie Formations, include *Wyndhamia*, *Kiangsiella*, *Cancrinella*, *Licharewia*?, *Neospirifer*, *Taimyrella*, and *Martiniopsis*. The upper fauna, in the Bulgadoo, Cundlego, Wandagee, and Quinnanie Formations, has *Streptorhynchus*, strophalosiids including *Echinalosia prideri* (Coleman), many Aulostegids, including *Aulosteges ingens* Hosking, *Taeniothaerus*, various Productacea, *Cleiothyridina*, *Fusispirifer*, and Dielasmatidae. The two faunas thus match the two-fold subdivisions of faunas in the Urals, Canada and Pakistan. Thomas & Dickins (1954) have stressed brachiopod and bivalve links with the Amb Formation of Pakistan. These include, from the writer's studies, rare Overtoniids, *Costiferina*, *Pterospirifer*, and *Neospirifer marcoui* (Waagen). The Bulgadoo Shale, Quinnanie and Wandagee Formations include a few ammonoids with Baigendzinian affinities (Glenister & Furnish, 1961).

Probably Fauna IIIa of Dickins (in Dickins, 1964; Runnegar, 1969a) in Queensland is Baigendzinian. It is found in the lower Gebbie Formation (Fig. 22) of the Bowen Basin (Table 36), and contains a few brachiopods including *Terrakea dickinsi* Dear, bivalves, and the ammonoid *Neocrimites* aff. *fredericksi* (Emel.) of Baigendzinian age. A large fauna is found in the Berriedale Limestone of Tasmania (Table 40), correlated with the lower Byro Group of Western Australia by means of *Taeniothaerus*

Stage	Substage	Group	Formation		Earlier Names
(Triassic)			Mianwali Formation	Narmia Member	Topmost Limestone Dolomite
				Mittiwali Member	Ceratite Beds
Dorashamian? or Djulfian	Urushtenian			Kathwai Member	Upper Productus Limestone
Punjabian	Chhidruan	ZALUCH 50-300m	Chhidru Formation		
	Kalabaghian		Kalabagh M.		Middle Productus Limestone
Kazanian Kungurian			Wargal Limestone (plant beds)		
Baigendzinian	Krasnoufimian		Amb Formation		Lower Productus Limestone
	Sarginian				
Sakmarian		NILAWAN 200-300m	Sardi Formation		Lavender Clay
			Warchha Sandstone		Speckled Sandstone
					Conularia beds *Eurydesma* beds
Asselian	Kurmaian		Tobra Formation		Talchir Boulder Beds

Table 28. Permian and Triassic Formations, Salt Range, Pakistan.

World Substages		Dickins' Faunal Stages		Perth Basin (Irwin River Area)	Carnarvon Basin (North end of Kennedy Range)		Canning Basin (Fitzroy River Area)
Griesbachian							Kockatea Shale
Ogbinan							
Vedian							
Baisalian							
Urushtenian							
Chhidruan		F					Upper marine beds incl. Hardman Member
Kalabaghian		E			Kennedy Gp	Binthalya Fm.	Liveringa Fm
Sosnovian						Mungadan Ss	middle
Kalinovian							
(?Ufimian Elkin)	Irenian	-				-	
(Nevolin)		D	2			Coolkilya Gw	Lightjack & Balgo Members
Filippovian						Baker Fm	
Krasnoufimian			1	Wagina Ss	Byro Gp	Nalbia Gw Wandagee Fm Cundlego Fm Bulgadoo Shale	Noonkanbah Fm
Sarginian				Mingenew Fm		Mallens Gw Coyrie Fm	
Aktastinian		C		Carynginia Fm Irwin River Coal Measures High Cliff Ss		Wooramel Gp	Poole Ss (upper part)
? Sterlitamakian		B		Fossil Cliff Fm		Callytharra Fm	Nura Nura Member of Poole Ss
Tastubian		A		Holmwood Shale			Grant Fm
Kurmaian				Nangetty Glacial Fm		Carrandibby Fm	
Uskalikian						Lyons Gp	
Surenan							

Table 29. Permian correlation for Western Australia, emended from Dickins 1967, Table 1.
Fm = Formation; Gp = Group; Gw = Greywacke; Mem = Member; Ss = Sandstone.

subquadratus (Morris) and ?*Wyndhamia jukesi* (Eth.) by Waterhouse (1969b, 1970d). Runnegar (1969a) referred the fauna to the Sakmarian Stage, equivalent to the Farley and Tiverton Fauna II, by using a very crude subdivision of time and faunas, but the fauna is definitely younger than Fauna II, and roughly equivalent to Fauna IIIa of Queensland. It is one of the most diverse of Permian faunas found in Tasmania, and oxygen isotope values suggest temperatures of up to 18°C (Dorman & Gill, 1961). World evidence also suggests warming during this time. However, Tasmania lay so close to the South Pole that its fauna was still of low diversity, and the value does seem high.

The Mangapirian faunas of New Zealand, found in the upper Telford Group of the Takitimu Mountains, Southland, have two divisions (Table 38). On the whole, the lower fauna, found in volcanogenic sandstones and conglomerate 7,000m thick, suggests correlation with the Berriedale Limestone of Tasmania, and the basal Byro Group of Western Australia through *Wyndhamia jukesi* (Etheridge), and *Taeniothaerus subquadratus* (Morris) and is considered to be Sarginian in age. The upper fauna in volcanogenic sandstones and siltstones 8,000m thick has affinities with higher Byro faunas with *Echinalosia prideri* (Coleman), *Taeniothaerus* aff. *miniliensis* Coleman and *Aulosteges ingens* Hoskings, and is considered to be Krasnoufimian in age (Waterhouse, 1973c).

KUNGURIAN STAGE

Russian Platform, Urals

Ammonoid workers in North America such as Glenister & Furnish (1961) and Nassichuk (1970; *et al.* 1965) have regarded the Kungurian as part of the Artinskian Stage. This cannot be sustained from detailed faunal studies. The Kungurian Stage has distinctive brachiopods and bivalves and correlative faunas have distinctive ammonoids. It is true that Ruzencev (1956) mentioned the possibility that the Kungurian ammonoids belonged to the Baigendzinian Stage, but he pointed out that no final judgement could be based on ammonoids, as they were so few in the type Kungurian Stage.

A second source of discussion concerns the general relationships of the Kungurian faunas. Russian, and recently, some North American workers, have classed the Kungurian, or early Word (that is Road Canyon) equivalents in North America, with the early Permian, on the basis that so many Baigendzinian forms persisted into the Kungurian Stage or in the case of west Texas, basal Kungurian (i.e. Filippovian) Stage. However all stages contain species surviving from underlying stages. What is more significant is the entry for the first time in the Kungurian of many forms that characterised the Middle Permian Series. As Stepanov (1973, p.125) wrote, the faunas were rejuvenated. Other workers thoroughly experienced with the Kungurian faunas came to the same conclusion, including Gerassimov (1956). Brachiopod species are characteristic and significant Fusulinacea such as Neoschwagerinids (see Waterhouse, 1973a, p.188) entered palaeotropical waters, with the first members of the ammonoid family Cyclolobidae (Waterhouse, 1972a).

Stratigraphy and faunas of the Kungurian Stage have been summarized by Zolotova *et al.* (1966). The type sections are in the Kama River region, on the Russian Platform and eastern rim of the sub-Urals depression (Gorsky & Guseva, 1973). Other stages have been proposed as substitutes for the Kungurian, including the Svalbardian Stage, based on Spitsbergen, by Stepanov (1957), and the Paikhoyan Stage based on outcrops and faunas in Pai Hoi, by Ustritsky (1971). The Svalbardian Stage appears to be of Kungurian to Kazanian age, though intended for pre-Kazanian rocks and faunas. It is incomplete, or not thoroughly studied, so that Elkin and Ufimian faunas have not been detected. A name to cover the Kungurian to Kazanian faunas would be useful but better based on Russian rather than Spitsbergen outcrops. The Paikhoyan Stage is richly fossiliferous and well controlled, though Filippovian and Kazanian faunas appear to be poorly represented. It is not clear why it is needed as a substitute, even though the Paikhoyan faunas are rich at some horizons. Another name that appears to have been largely ignored is the Kamian Stage, proposed by Zalessky (1930) for the Kungurian plus Ufimian. The Kungurian and Ufimian Stages are combined herein, as proposed by Gorsky & Guseva (1973), following Russian workers who appear to prefer to emend the Kungurian Stage rather than allow the name to lapse.

At the base of the Kungurian Stage, the Filippovian Horizon has a distinctive fauna that can be traced around the world, and so may be elevated to the status of a substage. It is formed in the type area of limestone, dolomite and sandstone, and has few Ammonoidea and no Fusulinacea. Small Foraminifera and Brachiopoda are diagnostic, with the first entry of species characteristic of the early mid-Permian, up to and including the overlying Kazanian Stage, such as *Streptorhynchus pelargonatus* (Schloth.), *Neochonetes variolata* (Vern.), *'Marginifera' septentrionalis* Chernyshev, *Spiriferellina cristata* (Schloth.) and *Dielasma elongatum* (Schloth.). The fauna changed sharply after the underlying Baigendzinian, reflecting increased salinity and lowered sea-level that led to the death of Baigendzinian coral reefs (Kulikov, 1943), suggesting onset of mid-Permian glaciation, revealed by cold water genera in Australia.

The overlying Irenian subdivision, here emended and elevated to a substage, is composed of salts, sulphates and carbonates. The lower horizon, the Nevolin, provides a distinctive and rich fauna in dolomite, with *Pseudofusulina*, and species of *Derbyia*, *Chonetinella*, *Paeckelmanella expansa* (Chernyshev), *Cleiothyridina pectinifera* (Sow.), *Horridonia borealis* (Haughton), *Anemonaria* species, and the ammonoid *Paragastrioceras kunguriensis* Mirsk. The fauna is very diverse, and involved the return of a number of Baigendzinian genera, and development of new species.

Overlying dolomites and limestones contain the meagre Elkin fauna, with a distinctive fauna of small Foraminifera, including the unique genus *Kunguria*. Many brachiopods disappeared. A few characteristic species include *Reticulatia uralicus* (Chernyshev) and *Horridonia pseudotimanicus* Gerassimov and distinctive nautiloids. Basically the fauna is an impoverished Nevolin fauna. It has been difficult to recognise elsewhere in the world, and may be of negligible significance, perhaps a local facies. However, the fauna was so short-lived that it will be discovered only by very careful work, and of course, might easily be represented in many sequences by unconformity, or barren beds. Waterhouse (1973a, c) has suggested that correlative horizons exist in south-east Asia, east Australia and New Zealand. The horizon has not been recognised in the Arctic, where there may have been a sedimentary hiatus during this time.

Above the Elkin horizon comes the Ufimian unit, elevated to full stage status by Likharev (1966, p.71), but difficult to recognise without detailed study. It has distinctive conchostracans and small Foraminifera, and is here placed in the Irenian Substage of the Kungurian Stage. Admittedly elements of its micro- and macro-faunas are Kazanian in aspect, but by retaining it in the Kungurian Stage, entry of the Kazanian brachiopod fauna remains a distinctive and useful time-line, a practise also supported by Stepanov (1973, p.126), and Gorsky & Guseva (1973). Alternative procedures would involve either the naming of a new unit for Irenian plus Ufimian, or, the recognition of Ufimian as a substage of the Kazanian Stage (Table 30). The Ufimian Horizon commences with the Solikamian salt deposits, about 200m thick, followed by the Shishmin Horizon with faunas towards the top, including *Cancrinella koninckiana* (Keys). Ostracods link the Solikamian to the rest of the Ufimian Horizon.

Kungurian brachiopods have been studied chiefly during the last century. More recently, a large fauna from the west slope of the Urals was listed by Kulikov (1947); Chalishev (1966) recorded faunas from the northern Urals, and Likharev (1913) redescribed a fauna from Kirillow. Grabau (1931) reported species from near

Adopted herein for mapping and simplicity*			Priority of Nomenclature emphasised		Faunal affinity emphasised	
Stage	Substage	Horizon		Substage	Stage	Substage
KAZANIAN	Sosnovian			Sosnovian	Kazanian Stage	Sosnovian
	Kalinovian			Kalinovian		Kalinovian
KUNGURIAN	Irenian	Ufimian	New Name Needed	Ufimian		Ufimian
		Elkin		Irenian	Kungurian Stage	Irenian
		Nevolin				
	Filippovian			Filippovian		Filippovian

Table 30. Alternative procedures for nomenclature of early Middle Permian units

Novgorod, with the significant species *Crurithyris clannyana* (King). *C. acutirostris* (Krot.) has been listed by Likharev (1966, p.226) in the Southern Urals, possibly but not certainly from Nevolin faunas. Ammonoids are rare in the Russian Kungurian, but include *Neopronorites permicus* Chernow, *Uraloceras suessi* (Karp.), *Artinskia artiensis* (Gruen.) and *Bitaunioceras krotowi* (Dewing).

Kanin Peninsula, Pai Hoi, Kolyma, Sikhote Alin

Small Kungurian faunas were described from Kanin Peninsula by Frederiks (1934a) with typical *Streptorhynchus*, *Echinalosia*, *Aulosteges* and *Tomiopsis*. Kungurian beds are also known in Pai Hoi (Table 13) in the Vorkut Series described in part by Solomina (1960) and Mironova (1960). The faunas were correlated with the Upper Artinskian and Kungurian by Likharev (1966), and revised by Ifanova & Semenova (1972). The lower Levorkut Suite is subdivided into the Ayachyargin beds with *Neopronorites permicus* (Chernow) and *Artinskia artiensis* (Gruen.) and brachiopods such as *Arctochonetes postartiensis* (Ustrit.), *Horridonia borealis* (Haughton) and *Paeckelmanella expansa* (Chernyshev), overlain by the Rudnitz Horizon, that shares many species with the Ayachyargin beds, especially chonetids. To the writer the two faunas look essentially similar, and are considered to be Nevolin in age. Ustritsky (1971) however placed the entire Vorkut Series in the Ufimian Stage. A Nevolin age would suggest that the Filippovian Substage was either missing, or represented by the meagre faunas of the underlying beds over the Talatin faunas with no distinctive species. Perhaps this is supported by a preponderance of linoproductids, and by the opinions of Mironov, Ustritsky and others as summarized by Likharev (1959) that the upper Talatin beds with *Chonetina artiensis* (Krot.) and *Pseudosyrinx kolymensis* Fred. are Kungurian (=Filippovian?). It would also explain why nearby supposedly correlative beds contain *Licharewia* ex gr. *rugulatus* (Kut.) and *L. stuckenbergi* (Nechaev). These are normally Kazanian, but are here considered to be Nevolin, for the Licharewiinae also enter the Nevolin Substage in New Zealand and Australia (Waterhouse, 1968). The Intin beds, 250-1, 100m thick, overlie the Rudnitz beds, and are dated as Ufimian by conchostracans.

A small fauna from the south island of Novaya Zemlya, described by Miloradovich (1936), appears to be of Kungurian age but one species *alferovii* Miloradovich may be *Monticulifera* (=*Cancrinelloides*), a genus more typical elsewhere of the Kazanian Stage, unless it is *Terrakea*, which is widespread in faunas of Kungurian age. In central-west Taimyr Peninsula the Sokolin Horizon, 500-800m thick, has a small brachiopod fauna (Ustritsky & Chernyak, 1963), assigned to the Ufimian but perhaps older Kungurian. The Sokolin fauna includes *Tomiopsis mergensis* Chernyak that resembles *Tomiopsis* from Nevolin beds in Arctic Canada and east Australia (Waterhouse, 1971) and from Ufimian faunas in New Zealand (Clark *et al.* 1967). The Sokolin fauna also contains *Chonetina*, suggesting a Nevolin to Elkin age, Elkin being preferable. The underlying Efremov Suite of east Taimyr is approximately Kungurian, with a fauna so small that it is difficult to correlate: it includes *Chonetina*, permitting a Nevolin age.

In the Verchoyan Mountains of north-east Siberia the Dibin Suite, 500-700m thick, has Baigendzinian or Kungurian faunas to north and south, including *Jakutoproductus* and *Tornquistia*, found also in north Russia. To the south supposedly correlative beds also include *Stepanoviella corcodonensis* Likharev, member of a genus common in the Kazanian and Baigendzinian Stages. Indeed, one accompanying species *Spiriferella saranae* (Vern.), if correctly identified, suggests a Baigendzinian age, although the typically Kungurian '*Chonetes*' *brama* Fred. is also reported.

In the Kolyma River area (Fig. 16) of north-east Siberia (Table 15) the Djigdalin Horizon a few metres thick has Kungurian brachiopods recorded in Likharev (1966) and Zavodowsky (1968, 1970), with the age discussed by Waterhouse (1969c). *Tornquistia* perhaps favours a Nevolin age, supported by ammonoids *Strigogoniatites zavodowskii* Popov and '*Altudoceras*' cf. *roadense* Böse. The Berein fauna of the Chiron district in Zabaikal is possibly of Nevolin age, with *Pterospirifer alatus* (Sow.), *Pseudosyrinx*, *Tomiopsis* and *Licharewia* (Kulikov, 1965). But *Neospirifer profasciger* Likharev was also listed, perhaps incorrectly, for this species was recorded by Kotlyar & Popeko (1967) in faunas that appear to be of middle Carboniferous age.

A fauna from Cape Kalouzin, Sikhote Alin (Fig. 16) in the Kalouzin Suite, 800m thick, studied by Frederiks (1925) was assigned to the Late Permian by Likharev (1966), but is more likely to be Nevolin in age (Waterhouse, 1973a, p.200). It has '*Chonetes*' *brama* Fred., '*Anidanthus aagardi gallatinense* Girty' which is close to *Chianella chianensis* (Chao) of China, and several species related to Nevolin species of Arctic Canada, including *Timaniella harkeri* Waterhouse, identified as *S. vercherei* not Waagen by Frederiks, *Chonetina*, *Terrakea kozlowskianus* (Fred.) cf *T. arcticum* Waterhouse, and *Echinalosia* cf *E. maxwelli* (Wat.) of Elkin age in New Zealand.

A fauna from nearby Ussuriland (Frederiks, 1924) has been less well illustrated, but shares some species, and is said to contain *Pterospirifer alatus* (Sowerby), which if correctly identified, indicates a likely Nevolin age. Moreover *Spiriferella lita* Frederiks is apparently allied to *Spiriferella loveni* (Diener), an early Kungurian species, chiefly of Filippovian age, from the Arctic. This Ussuriland fauna occurs in sandstone and siltstone, 500-700m thick, of central Sikhote Alin, shown as approximately Kazanian in Likharev (1966, Table 18). Underlying plant beds were assigned to an approximately Kungurian age, forming an extensive horizon in west Sikhote Alin, but may prove to be Baigendzinian. In turn they overlie Sakmarian Fusulinacean faunas in the Sibaigou Suite with *Pseudofusulina*, *Parafusulina*, ?*Triticites*, and *Misellina claudiae* (Deprat), (See Table 42).

Pamirs, Afghanistan, Iran

In the Pamirs of central Asia (Table 23) the Kungurian Stage is best displayed by Fusulinacean faunules described by Leven (1967, p.23). The upper Kubergandin Formation of limestone and shale 100-150m thick contains a faunule of *Pseudofusulina chihsianensis* Lee, *Parafusulina* spp., *Maklaya pamirica* (Leven), *M. cutlaensis* (Leven) and *Cancellina primigena* (Hayden), overlain by beds with *Pseudodoliolina*, and then by beds with *Maklaya cutlaensis* and *M. pamirica*. These faunas were referred by Waterhouse (1973a, p.320, Table 3) to the Filippovian Substage. The overlying Gan Limestone, 10-120m thick, contains *Neoschwagerina simplex* Ozawa and *Neofusulinella lantenoisi* Deprat, according to Leven (1967), and was tentatively correlated with the Nevolin horizon by Waterhouse (1973a). The Gan beds are overlain in turn by beds of presumably Kazanian age with *Neoschwagerina craticulifera* (Schwager). Grunt & Dimetriev (1973, Table 1) presented an amended sequence, as in Table 23. Certainly east Asian Fusulinacea suggest fine zonation comparable with that of the type Kungurian foraminiferal and brachiopod faunules (Waterhouse, 1973a), but it is not possible yet to securely match Asian with Russian zones, because Asian brachiopods, although listed, have not been described. Moreover the zonation is so fine that faunas were possibly mixed through sedimentary reworking or faulty collecting. Chief question must concern the age of *Neoschwagerina craticulifera*, or specimens so identified. Is the species early Kazanian as generally supposed, or did it enter in the Kungurian, especially the Irenian (?Nevolin) Substage?

Possibly the *Terrakea* species described from the Pamirs by Grunt & Dimetriev (1973) came from Kungurian beds. The species looks moderately like *T. concavum* Waterhouse in shape, but is so decorticated that the crucial spine pattern cannot be ascertained.

Reed (1931b) described a fauna from Afghanistan near the Khojagar Dara Dam with Overtoniids, many spiriferids such as *Martinia* and *Martiniopsis*, and *Neoschwagerina craticulifera* (Schwager), presumably indicative of a Kazanian age, although Waterhouse (1973a, p.200) preferred a Nevolin correlation. Indeed, nearby *Cancellina primigena* (Hayden) points to a Kungurian age, and also '*Fusulina*' or *Polydiexodina elongata* (Shumard) occurs with *Neoschwagerina craticulifera.* Other fusulines, described by Thompson (1946) in the Bamian Series of Afghanistan, include *Afghanella schencki* Thompson and so-called *Cancellina*, referred to *Maklaya* aff. *sethaputi* by Kanmera & Toriyama (1968), regarded as early Kungurian by Waterhouse (1973a). As a slight adjustment, perhaps *Neoschwagerina* commenced in the Ufimian Horizon, and *M. sethaputi* Kanmera & Toriyama should be regarded as Elkin, or mid-Irenian.

A fusuline fauna from Afghanistan, at Tezak south of Kabul, with *Neoschwagerina simplex* Ozawa, *Polydiexodina*, *Pseudodoliolina*, *Russiella pulchra* Mikl.-Makl., and other species occurs in fine-grained quartz with calcareous cement, and includes brachiopods identified with *Enteletes conjunctus* Reed, and *Purdonella semiovalis* (Reed) (originally described as *Elivina*), the former from the Wargal Formation of the Salt Range, Pakistan, the latter also occurring in the Chhidru beds of the Salt Range (Termier *et al.*, 1974, p.114). The basal beds contain *Cancellina dutkevitchi* Leven, with *Stacheoceras rothi* Miller and Furnish; followed by beds with *C. dutkevitchi*, *Armenina asiatica* Leven, *Neofusulinella lantenoisi* Deprat; and finally by a late Kubergandian fauna with *Cancellina pamirica* Leven, *C. dutkevitchi*, *Armenina asiatica*, and a number of ammonoids that show links with the Sosio fauna of Sicily. Species include *Daraelites meeki* Gemm., *Paranorites konincki* Gemm., *Propinacoceras beyrichi* Gemm., *Neogeoceras trautscholdi* (Gemm.), *Eoglyphioceras meneghinii* (Gemm.), *Stacheoceras mediterraneum* Gemm. and *Popanoceras*. The uppermost beds have yielded *Neofusulinella lantenoisi*, *Praesumatrina neoschwagerinoides* (Deprat) and *Neoschwagerina simplex* Ozawa (Termier *et al.*, 1972).

Small Permian faunas from scattered localities in south-east Iran were described by Douglas (1936, 1950), with *Polydiexodina persica* ('*Skinnerina*?) below ?Kazanian or late Kungurian beds with *Neoschwagerina craticulifera* and *Cancellina primigena.* To the writer some brachiopods listed by Douglas (1950, p.5) appear consistent with a Nevolin age, in view of the presence of *Lissochonetes* which is widespread in world faunas of Nevolin age; supposed *Mentzelia*, which might be allied to an Arctic Nevolin species *Spirelytha schei* (Chernyshev & Stepanov, 1916), *Spirigerella* and *Leptodus.* Species from the Baktibari Range, south Iran, include *Costalosia argentea* Waterhouse & Shah from Malakabad which is allied to a Burmese species *C. bifurcata* Waterhouse & Shah, that is accompanied by *Polydiexodina.* Other brachiopods are allied to species from the lower Wargal Limestone of Pakistan, and *Cancrinella* resembles an Arctic species of Filippovian age. *Neochonetes deremsii* (Douglas) suggests a possible Filippovian or Ufimian age. The fauna is overlain by beds with *Neoschwagerina craticulifera* and *Cancellina.*

From north Iran the Dorud fauna of the upper Djadjerud and Lar Valleys may be correlative (Table 31) but is so small and seems to have such an unusual combination of genera that certainty is lacking whether it is Kungurian or Kazanian. It underlies the Ruteh Formation of Punjabian age, with which it shares five of eight species, to perhaps support a Kazanian or early Kalabaghian age. Although it has *Orthotichia indica* (Waagen) and marginiferids like the south Iranian faunas, *Neochonetes* is present (typically Filippovian and lower Kazanian), with *Orbicoelia*, typical of Nevolin and younger faunas. On the whole the evidence suggests a lower Kazanian age. Sestini (1965c) assigned the fauna to the Darvasian Stage (Sakmarian, Artinskian).

Substage	Iran, Elburz Mts
Ogbinan	-
Vedian	-
Baisalian	Upper Nesen Ftm
Urushtenian	-
?Chhidruan	? Ruteh 5
Kalabaghian	Ruteh 1, 2
Sosnovian	-
Kalinovian	Dorud?
Krasnoufimian	-
Sarginian	-
Aktastinian	-
Sterlitamakian	Geirud D

Table 31. Faunas in Elburz Mountains, north Iran.

China, Japan, south-east Asia, Pakistan

In China, the Maokou Limestone above Chihsia Limestone consists of light grey thick bedded limestones 400-675m thick, (Table 18) devoid of ammonoids, but rich in fusulines, corals and brachiopods. There are three fusuline zones, of which the lowest is the *Cancellina* Zone, or *Cancellina* subzone in the *Parafusulina* Zone (in Sheng, 1964) of approximately, or at least in part, Kungurian age. It is associated with *Yanchienia*, *Verbeekina*, *Pseudodoliolina*, and *Chusenella*, which entered the faunas for the first time with *Parafusulina*, and *Schwagerina*, which persisted from below. According to Sheng & Lee (1974) *Cancellina* occurs in the upper part of the Chihsia 'Stage', and is correlated with the *Neoschwagerina simplex* Zone of Japan. It seems possible that early Kungurian brachiopods are found at the top of the Chihsia Limestone of southern Anhui in the so-called upper 'lydite horizon'. Huang (1932a, p.26) and Chao (1927b, p.179) listed a distinctive fauna including so-called '*Plicatifera*' (=?*Overtoniina* perhaps, or *Neoplicatifera* according to Sheng & Lee, 1974) *huangi* Ustritsky, with *Tyloplecta nankinensis* (Frech), *T. yangzteensis* (Chao) and *Chianella chianensis* (Chao). The latter species recalls '*Anidanthus aagardi gallatinense*' (not Girty) of Frederiks (1925) from Cape Kalouzin. A slightly different fauna called the Hsiaochang fauna by Huang (1932b, p.96; Chao, 1927b, p.179) occurs in the lower Yangzte Valley, especially Kiangsi, southern Anhui, Szechuan and southern Kwangsu (Fig. 17). Key forms include *Chianella chianensis* (Chao), *Tyloplecta nankinensis* (Frech), and *Edriosteges medlicottianus* (Waagen). Grabau (1934) also noted *Ambocoelia* or *Crurithyris*, suggestive of a Nevolin age. The fauna is accompanied by the coral *Wentzelella subtimorica* Huang which forms a zone at the base of the Maokou Limestone. Yet a similar fauna was listed from the top of the Chihsia Limestone in west Szechuan by Huang (1932a, p.27). Chan & Lee (1962) described a related fauna from Shansi, north China, with *Orthotichia indica* (Waagen), *Chonetinella*, '*Neoplicatifera*' *huangi* (Ustritsky), *Krotovia janus* Huang, *Chianella chianensis* (Chao), *Monticulifera sinensis* (Frech), and *Crurithyris*. Underlying beds contain the Fusulinacea *Cancellina schwellwieni* (Deprat), (now = *Praesumatrina* Toumanskaya 1951) and *Neoschwagerina*, and overlying beds contain *Neoschwagerina*, *Verbeekina*, *Misellina*, and *Pseudodoliolina*. Waterhouse (1973a) suggested that the older lydite fauna might be Filippovian, the younger Hsiaochiang fauna Nevolin. The Shansi fauna was also considered Nevolin. But, with *Monticulifera sinensis* (Frech) which is closely allied to and probably congeneric with *Cancrinelloides* of the Arctic Kazanian, the fauna could be upper Kazanian: which would allow *Neoschwagerina* to be early Kazanian in age.

A large ammonoid faunule is found in the Kufeng Shale of central Kiangsi, containing two significant primitive cyclolobids, *Kufengoceras* and *Shengoceras*, marking the start of the Middle Permian Series (Waterhouse, 1972a). All are referred to the *Kufengoceras* Zone, correlated with the *Cancellina* Zone by Chao (1966), but with the *Yabeina-Neoschwagerina* Zones by Sheng & Lee (1974). Another ammonoid fauna occurs in carbonaceous shale of the lower Tingchiashan Formation of west Chekiang and north-east Kiangsi with *Daubichites shoutangensis* (Chao), *Waagenoceras* and *Mexicoceras*. '*Paragastrioceras*' or *Altudoceras roadense* Böse and other species have been recorded from much the same horizon. The faunas appear to be typically Kungurian, *Daubichites* being found in the Filippovian Assistance Formation of Canada, and *Mexicoceras* with *Waagenoceras* entering Nevolin faunas of west Texas.

A different suite of ammonoids was matched with the *Cancellina-Neoschwagerina simplex* Zone by Sheng & Lee (1974), with *Pseudohalorites*, *Artinskia* and *Neocrimites*. Amongst conodonts described by Ching (1960) from the lower Maokou Limestone, *Gondolella nankinensis* has also been reported by Clark & Behnken (1971) in the *Streptognathodus sulcoplicatus* and *Gondolella idahoensis* faunas of the Meade Peak Member in Idaho (of early Filippovian-Nevolin age). However Kozur (1974, p.49) and

Ching (1960) considered that the lower Maokou was older than basal Guadalupian, though this is difficult to reconcile with fusuline, coral, and brachiopod evidence.

As noted in discussion of the Punjabian Stage, the faunas of the lower Jisu Honguer beds in Mongolia may prove to be Kungurian.

In Japan, the *Neoschwagerina simplex* Zone is close to Filippovian or Nevolin in age, judged by its fauna and stratigraphic position (Table 17). It is classed by Toriyama (1967) as part of the Nabeyaman Stage, and was correlated with the *Cancellina* Zone of China. The Kozaki Formation includes *Skinnerella* cf. *sapperi* (Schell. & Staff.), *Verbeekina*, *Cancellina* and *Neoschwagerina simplex* Ozawa.

A Nevolin brachiopod fauna has been described from Khao Phrik, south Thailand, by Waterhouse & Piyasin (1970) and Yanagida (1970), with the age assessed on the basis of Brachiopoda by Waterhouse (1973a, p.194). Some of the species of *Streptorhynchus*, *Cleiothyridina*, and *Spiriferella* are even related to those of Russia, and *Orbicoelia* is closely allied to *Crurithyris* found in contemporary faunas. *Orthotichia indica* (Waagen), *Asperlinus asperulus* (Waagen), ?*Rugaria speciosus* (Wat. & Piyasin) and *Uncinella* are other significant species. Sakagami (1968) recorded *Ozawainella* and *Neofusulinella*, supposedly of early Artinskian age, but this age is not acceptable.

Mansuy (1914) recorded a number of brachiopods from Cambodia (Table 19) with some definite Kungurian — probably Nevolin — forms at Phnom Miai such as *Uncinella* shared with Khao Phrik and the Wargal Formation, Salt Range. A fauna from Phnom Ta Maol is either Filippovian or Nevolin, and others may be slightly younger, as at Phnom-Tu-Kreem. Some of the Cambodian brachiopods, *Orthotichia indica* (Waagen), ?*Chaoiella margaritatus* (Mansuy), *Tyloplecta nankingensis* (Frech), *Urushtenia costulata* (Thuan) and *Chroistites* are also found at Level A of Sisophon, Cambodia, at the base of the sequence discussed by Ishii et al. (1969), accompanied by *Parafusulina padangense* (Lange), and *Pseudodoliolina pseudolepida* (Deprat), of Kungurian age.

Several faunas from the Tonbo Limestone, Shan States, Burma, may be approximately of this age, judged in part by brachiopod affinities (Waterhouse, 1973a), though revision is needed to clarify the identities. One fauna was recorded from Namun, Shan States, with both *Neochonetes* and *Lissochonetes*, *Orthotichia indica*, mid-Permian *Neospirifer*, and ?*Krotovia*, of perhaps late Kungurian age. A larger fauna from Kehsi Mansam (Diener, 1911, p.68) has *Orthotichia indica*, *Krotovia burmana* Diener, *Costalosia bifurcata* Waterhouse & Shah, *Martinia*, *Martiniopsis latouchei* Diener and other typically Kungurian species, accompanied by '*Polydiexodina*' *elongata* (Shumard), regarded as early mid-Permian by Douglas (1936, 1950). The species may be *Skinnerina* according to Skinner (1971), but is regarded as typical *Polydiexodina* by Dr D.J. Gobbett (pers. comm.). A Nevolin age appears likely. A related fauna from Mong Pawn, Burma, has some similar species with *Rugaria* as at Khao Phrik, Thailand, and *Polydiexodina* (Diener, 1911).

In the Salt Range, Pakistan, the lower Wargal Limestone has a meagre fauna that includes *Uncinella* (Table 28). Most other species persist into higher stages, but *Uncinella* apparently indicates a Kungurian and perhaps chiefly Nevolin age. Other taxa include *Rhipidomella*, *Streptorhynchus*, ?*Rugaria strophomenoides* (Waagen) (like the Khao Phrik species), *Richthofenia*, *Spiriferella*, *Composita*, and rare *Hustedia*. The basal coaly shales of this unit contain an even more impoverished fauna including species of *Orthotichia*, *Streptorhynchus*, *Aulosteges*, *Cleiothyridina* and *Dielasma*, generically quite close to the early Kungurian of Russia. It could be Filippovian, judged from faunal summaries based on Reed (1944) and Waagen (1891), but revision is needed to confirm the species ranges and identifications.

North-west Europe

In northern Europe (Fig. 25), the faunas of the lower Zechstein or Werra Formation in Germany and Lower to Middle Magnesian Limestone in England have been

		Standard Section	Tamba Zone Akasaka	Chugoku Region			
				Akiyoski		Tsune Mori	Atetsu
L. Triassic							
Permian	Upper	Kuman		Akiyoshi Limestone Gp	Ota Gp	Shiraiwa Fm	Terauchi Fm
	Middle	Akasakan	Akasaka Limestone			Tsune-Mori Fm	Atetsu Limestone Gp
	Lower	Nabeyaman				Aigyo Fm	
		Sakamotozawan	Samegai Fm				
Carboniferous	Upper	Hikawan					

Table 32. Permian correlations for northern Japan, following Takai *et al.* (1963, Chart 3a).

Fm = Formation Gp = Group

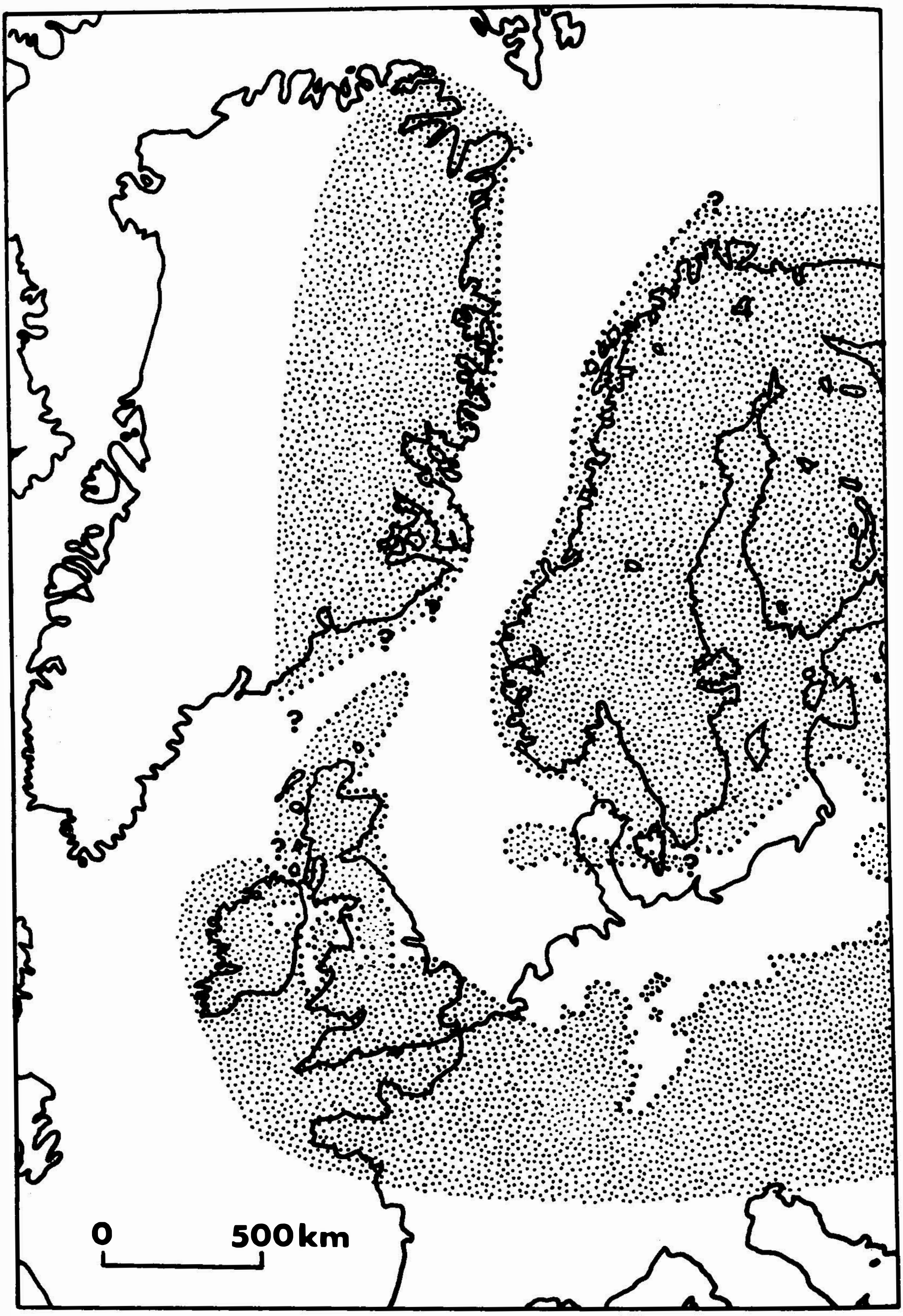


Fig. 25. The late Permian Zechstein Sea in north-west Europe. Stippled areas, land. After Pattison *et al.* (1973, fig. 1).

studied by many authors, including King (1850), with useful summaries in Mahlzahn (1937), Pattison (1970), Pattison *et al.* (1973), and Jordan (1969). The basal meagre fauna of the Zechstein is possibly Filippovian, and the well developed overlying Werra faunas of the Zechsteinkalk appear to be Irenian (Table 33) and specifically Nevolin by direct comparison with the sequences of Russia and the Canadian Arctic. *Streptorhynchus pelargonatus* (Schloth.), *Horridonia horrida* (Sow.), *Cleiothyridina pectinifera* (Sow.), *Crurithyris clannyana* (King), *Spiriferellina cristata* (Schloth.), and *Dielasma elongatum* (Schloth.) and many other species are found. The lower and middle Magnesian Limestones of England appear to have much — but not completely — the same faunas. There is one anomaly, in the presence of *Neochonetes* in the Magnesian Limestone, which might indicate an Ufimian age. Although it is here preferred to regard the occurrence as exceptional, due to unusually high salinity, an Ufimian correlation was strongly and perhaps correctly urged by Frebold (1933) and Likharev (1959). The age of the overlying Zechstein beds cannot be established by brachiopods but the rhythmic cycles of evaporites suggest a climatic control which it should be possible to match with the glacial cycles of Gondwana and Siberia, to facilitate good correlation. There are no known Fusulinacea or Ammonoidea.

In recent years the faunas have been assigned a much later age, as Kazanian, or even Tatarian, but the positive identifications suggest a Kungurian age, as also concluded by Likharev (1959) from a thorough comparison with the Russian faunas. Certainly this appears to be supported by the absence of well established Kazanian key genera, such as *Cancrinelloides* and *Licharewia.* A Kungurian age lies in sharp disagreement with spore studies summarized by Visscher (1973), who argued for a Tatarian age for the entire Zechstein Group. The upper Zechstein may well be late Permian in age, for marine faunas provide no control. But such a young age for the early faunas seems unacceptable. Although one must grant the possibility of error in interpreting marine faunas it must be pointed out that Palaeozoic spore correlations are not always well founded. For instance, an even greater margin of error has been documented for floras of the Canadian Arctic, in which numerous spore samples of indisputably Carboniferous age were confidently and quite wrongly assigned to the Permian Period, as pointed out by Bamber & Waterhouse (1971). Presumably insufficient account was taken of different floral biomes and provinces. Support for the Kungurian age of the early Zechstein here adduced is provided by several Russian experts, including Gerassimov (1956), Stepanov (1957) and Likharev (1959).

Conodont authorities have also claimed a late Permian age for the entire Zechstein, but their correlations seem extremely ill-founded, too deferential, as Grant & Cooper (1973) devastatingly commented, to the one school of correlation that claims *Cyclolobus* was limited to the late Permian (e.g. Kummel & Teichert, 1964 ff.) Conodont species are apparently shared between the Zechstein and east Greenland beds (Kozur, 1974), as would be expected, and this has been thought to require a late Permian age. On the contrary, the brachiopods and bivalves of Greenland show a Kungurian age. Moreover, a key species *Neogondella divergens* (Bender & Stoppel) from the basal Zechstein is also found in the upper Gerster beds of north-east Nevada, of Kungurian-Kazanian age, but wrongly assumed to be Capitan by Clark & Behnken (1971) — as discussed previously (Table 7). Conodonts are so widespread that they hold very high promise for correlation, but studies are just commencing, and, with so many apparently long-ranging species, cannot as yet match the degree of refined correlation achieved through study of Fusulinacea, Mollusca or Brachiopoda.

Spitsbergen, Greenland

Faunas somewhat related to those of the Zechstein Sea are found in the Spirifer Limestone or Voringen Member of the Kapp Starostin Formation, Spitsbergen, es-

	East and South Durham		Northern Germany
	Bunter		Buntsandstein
	Sandstone		Zechsteinletten
	Permian Upper Marls Upper Anhydrite	Aller Series (Z4)	Lagenanhydrite/Grenzanhydrit Unnamed Mudstone Aller Salze
	Upgang Carbonate		Pegmatitanhydrit Unnamed Carbonate-Rich Zone
	Rotten Marl		Roter Salzton
	Middle (Boulby) Halite	Leine Series (Z3)	Leine Salze
	Billingham Main Anhydrite		Hauptanhydrit
Upper Magnesian Limestone	Seaham Beds		Plattendolomit Grauer Salzton
	Seaham Residue	Strassfurt Series (Z2)	Evaporites
	Hartlepool and Roker Dolomite Concretionary Lst.		Haup Dolomit-Stinkschiefer
	Hartlepool Anhydrite	Werra Series (Z1)	Werra-Anhydrit
	Middle Magnesian Limestone		Werra-Dolomit
	Lower Magnesian Limestone		Zechsteinkalk
	Marl Slate		Kupferschiefer
	EARLY		PERMIAN

Table 33. Permian and early Triassic sequences in the Zechstein Sea Basin from Pattison *et al.*, 1973, p. 226.

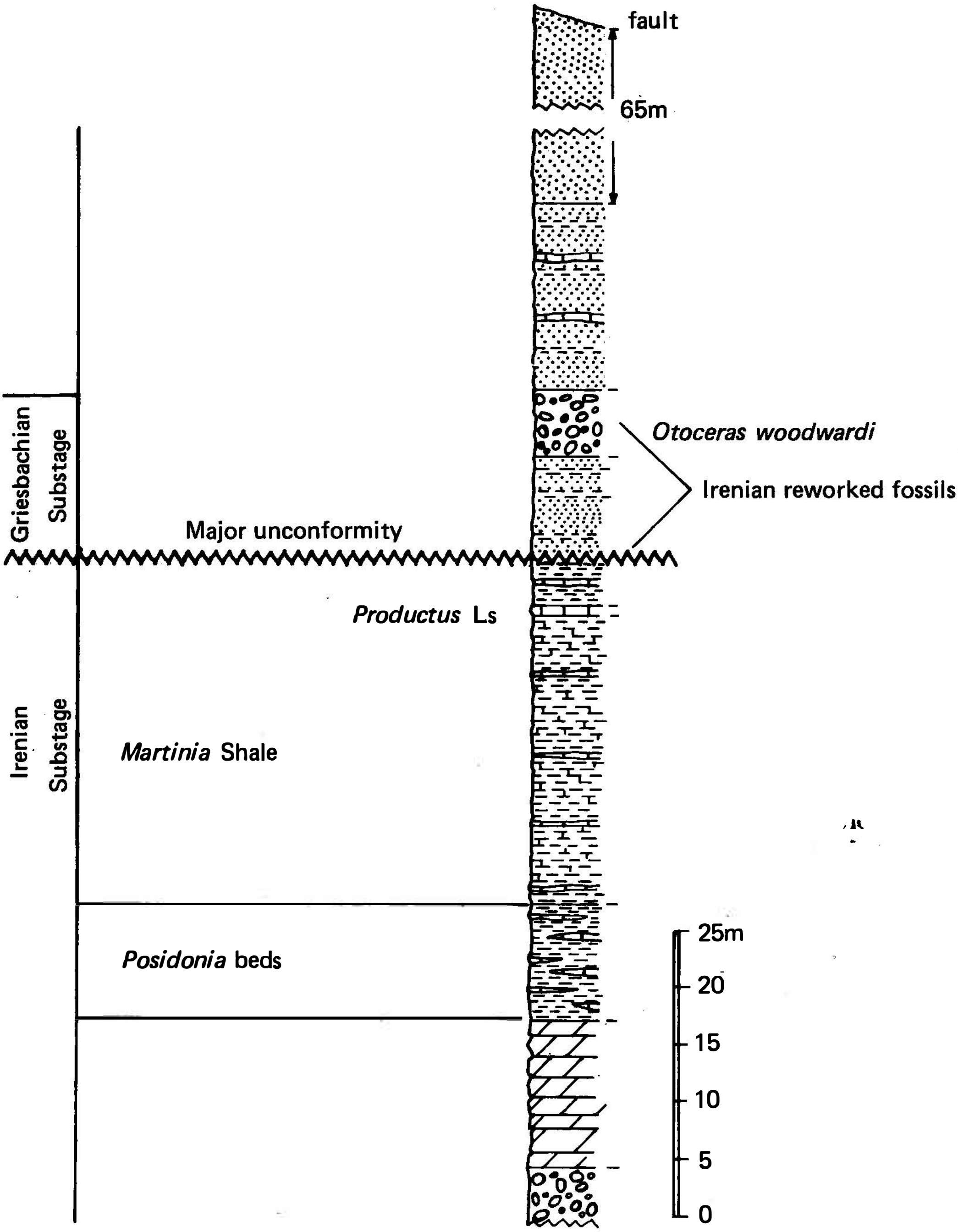


Fig. 26. Permian and Triassic section at River 14, east Greenland, (Permian after Maync, 1942; Triassic from Teichert & Kummel [1973, fig. 4, p. 282]).

pecially at Bunsowland (Table 25), in grey or black limestone with sandstone and at Miseryfjellet, south-east Bjørnøya (Fig. 18) see Gobbett (1964, p.38) & Grabau (1931). A number of species are shared with the well dated Assistance Formation of the Canadian Arctic Islands to suggest a Filippovian age, including *Arctitreta triangularis* (Wiman), *Grumantia* (or *Arctitreta*) *kempei* (Andersson), *Waagenoconcha*, *Thuleproductus arcticum* (Whitfield), *Spiriferella loveni* (Diener), *Pseudosyrinx wimani* Gobbett, and *Neospirifer striatoplicatus* (Gobbett). There is no clear development of any younger Kungurian fauna, but it is possible that horizons have been mixed, for several key Nevolin species are present, especially the smooth chonetids and Licharewiids, either allegedly from the Spirifer Limestone, or more usually from the overlying lower and middle Brachiopod Chert or upper Kapp Starotsin Formation. Even Elkin or Ufimian faunas may be present, but these particular substages lack distinctive key species, and will only be detected by study of stratigraphically well controlled collections.

The rich brachiopod fauna from the Foldvik Creek Formation at Cape Stosch, east Greenland (Fig. 26), occurs in 200-300m of interdigitating facies. It has been fully described by Dunbar (1955) to demonstrate a close similarity with Zechstein faunas of Europe. Significant genera and species include *Arctitreta kempei* (Andersson), widespread in Kungurian faunas of Arctic Siberia and Canada, *Lissochonetes toulai* Dunbar, as in Nevolin faunas elsewhere, *Cancrinella*, *Liosotella*, *Craspedalosia pulchella* Dunbar, *Krotovia licharewi* Frebold, *Odontospirifer mirabilis* Dunbar, *Spiriferella keilhavii* (von Buch), *Sowerbina*, and *Neospirifer striatoparadoxus* (Toula), which is the same as a Spitsbergen species, and differs from the Filippovian form *N. striatoplicatus* (Gobbett). The fauna is Nevolin in age, by direct correlation with the type Russian sequences, and also with Canadian faunas. A Cyclolobid species is found, (e.g. in Nassichuk *et al.*, 1965) and has been interpreted as of very late Permian age — 'Chhidruan' (Furnish, 1966), but the brachiopods incontrovertibly suggest an early mid-Permian age. Waterhouse (1972a) considered that the Cyclolobid was primitive, and used the generic distinction *Godthaabites* Frebold for species with such a simple cyclolobid suture. Conodonts of the *Neogondolella rosenkrantzi* (Bender & Stoppel) Zone are found in the Posidonia Shale, Productus Limestone and Martinia Shale, (Sweet, 1973, p.641), with species known to range from Kungurian to Kazanian. Several brachiopod species from Nathorsts Fiord, northern Greenland, recorded by Frebold (1931), were considered by Dunbar (1955, p.18) to belong to the same fauna.

Canada

The brachiopods and molluscs from the green sandstones of the Assistance Formation at Grinnell Peninsula, Devon Island, Canadian Arctic Archipelago (Table 22) were initially described by Harker in Harker & Thorsteinsson (1960). More brachiopods have been described by Waterhouse (e.g. 1969a; 1971; Bamber & Waterhouse, 1971, and Sarytcheva & Waterhouse, 1972). Several species, including *Arctitreta pearyi* (Whitfield), *Neochonetes*, *Thuleproductus arcticum* (Whitfield), *Muirwoodia mammatus* (Keys.), *Pseudosyrinx*, *Spiriferella loveni* (Diener), and *Neospirifer striatoplicatus* (Gobbett), suggest a Filippovian age, as confirmed by stratigraphic position, and by the sudden disappearance of Fusulinacea, as in Russia. Ammonoids described by Nassichuk (1970; *et al.* 1965), and correlated with the Road Canyon Formation of Texas, include *Daubichites fortieri* (Harker), *Sverdrupites harkeri* (Ruz.), *Synartinskia belcheri* Nassichuk, and *Popanoceras* cf *sobolewskyanum* (Vern.). Although Nassichuk (1970) favoured an Artinskian age, as well as a Road Canyon correlation, an analysis of the ammonoid affinities shows a wide range of possible correlation, from Sakmarian to Kazanian, and closest resemblances lie with Kungurian genera (*Daubichites*, *Popanoceras*, and *Sverdrupites*) in China, Russia and Western Australia.

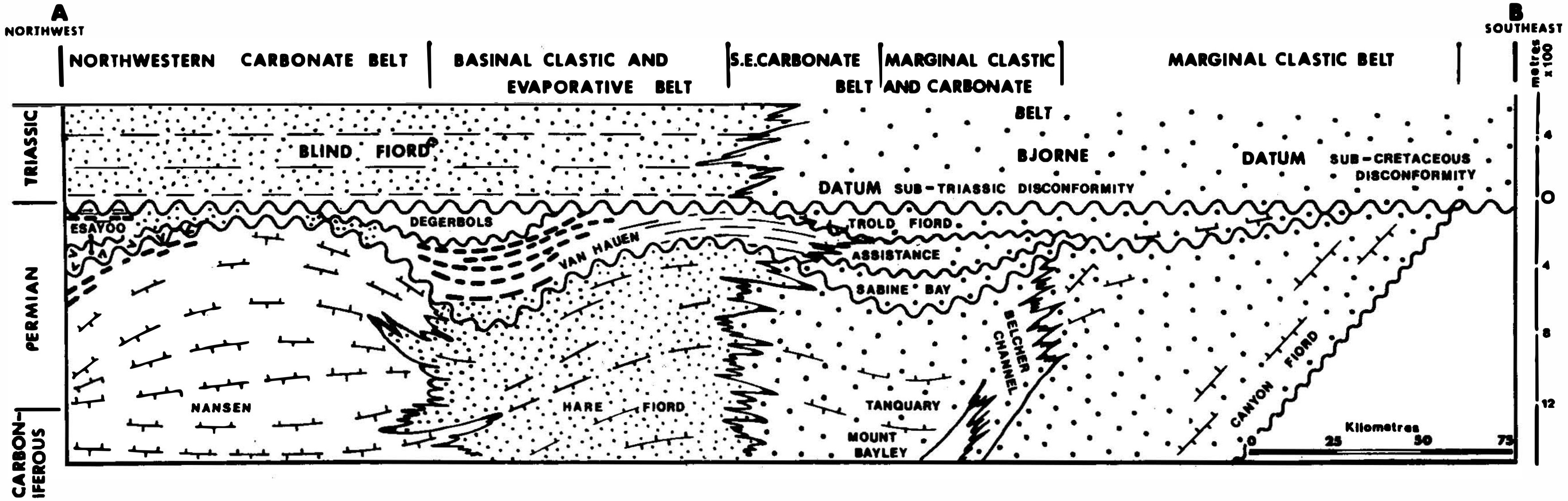


Fig. 27. Permian formations of the Canadian Arctic Archipelago, from Nassichuk *et al.* (1973, fig. 2, p. 288). Redrawn with permission of authors.

Nevolin faunas are also widely present in the Arctic (Fig. 27) especially in the Van Hauen Formation, and part of the Degerbols Formation on Ellesmere and Axel Heiberg islands. The fauna is characterised by a new species of *Thuleproductus*, *Pterospirifer alatus* (Sow.), *Chonetinella*, *Lissochonetes*, and various other species. One well preserved brachiopod faunule was described by Whitfield (1908), another by Stehli & Grant (1971) from somewhere (not known) on Svartevaeg, Axel Heiberg Island, with no stratigraphic detail provided. The age was stated to be Kazanian by Grant & Cooper (1973), but this is in error: the fauna is Kungurian. Possibly the fauna recorded from Great Bear Cape by Chernyshev & Stepanov (1916) is correlative, bearing the typical Nevolin species of *Thuleproductus*. Although the presence of Overtoniids point to a greater age, such have also been reported from Pai Hoi.

The middle Tahkandit Formation exposed near the Arctic Circle in Yukon Territory has two Kungurian brachiopod zones in rubbly limestones and breccias, and allied faunas are found to the north in the Richardson Mountains (Bamber & Waterhouse, 1971). The lower zone includes the widespread key *Neochonetes*, *Cancrinella phosphatica* (Girty) allied to an Iranian species, *Thuleproductus arcticum* as in Arctic faunas, *Anidanthus* cf *eucharis* (Girty), *Pseudosyrinx* and *Neospirifer striatoplicatus* (Gobbett), and other species shared with Kungurian faunas of the Arctic. The overlying fauna includes *Timaniella harkeri* Waterhouse as in the Kamchatka fauna of Frederiks (1926), and *Lissochonetes* and *Crurithyris* as in many Nevolin faunas over the world.

Various lists of faunas by Girty in Mertie (1930) and Brabb & Grant (1971) suggest that the Kungurian Stage is represented in the Tahkandit Formation of Alaska, though no detailed age studies have yet been published. From the Alaska Panhandle the Pybus Formation of chert and dolomitic limestone has yielded brachiopods listed by Girty in Buddington & Chapin (1929) and assessed as Roadian (=Filippovian) by Grant (1971, p.316), which would be in conformity with the presence of *Septacamera*, so far not reliably known in younger rocks. However Loney (1964, pp.95-96) recorded ?*Licharewia* and ?*Crurithyris* to suggest a Nevolin age.

A few brachiopods in the Ranger Canyon Chert in the Rocky Mountains of west Alberta indicate a possible Kungurian age, with *Anidanthus*, *Cancrinella* and *Terrakea* species like those of the Tahkandit Formation, Alaska-Yukon, and the Phosphoria complex in north-west United States (Logan & McGugan, 1968).

The Cache Creek Group of central British Columbia is thick and contains a number of Fusulinacean zones, including a well defined *Yabeina* assemblage of Chhidruan-Kalabaghian age in the Marble Canyon limestone (Monger & Ross, 1971, p.270). The only sizable brachiopod faunule from near Kamloops, as described by Crockford & Warren (1935), is probably of Nevolin age, judged from examination by the writer. The fauna is like that of south Iran, with *Juresania*, marginiferids, and two Spiriferellinids of Kungurian age in ?*Timaniella* cf *harkeri* Wat. from the Canadian Arctic and *Spiriferella* cf *supplanta* Wat. from New Zealand. Accompanying ammonoids were assessed as Word 2 or 3 (China Tank and Willis Ranch Members) i.e. early Kazanian, late Kungurian by Dr W.W. Nassichuk, Geological Survey of Canada, Calgary, pers. comm. The fauna lacks *Leptodus*, unlike a tiny (?Punjabian) faunule recorded by Kindle (1926) from elsewhere in the Cache Creek Group.

United States, Guatemala

From the Nosoni Formation of northern California, Coogan (1960) recorded advanced *Parafusulina* and *Monodiexodina* with *Lissochonetes*, *Chonetinella*, *Crurithyris* and *Cancrinella phosphatica* (Girty), all showing specific links with the Nevolin faunas of the Canadian Arctic.

Mills & Davis (1962) recorded a few brachiopods in Washington State, including

Anidanthus minor (Cooper) in siltstone and limestone, with *Pseudofusulinella*, *Schwagerina* and *Parafusulina antimonionensis* Dunbar, suggestive of an approximately Kungurian age.

The Phosphoria Rock Complex of Idaho, Wyoming, and Montana, (Table 34), has yielded small correlative brachiopod faunas described by Girty (1910, 1927), Branson (1930) and others, as summarized by Yochelson (1968) and McElvey *et al.* (1959). A number of species range from the Arctic to this region, such as *Lissochonetes ostiolatus* (Girty), *Cancrinella phosphatica* (Girty), *Anidanthus eucharis* (Girty), *Yakovlevia geniculata* (Girty), and *Crurithyris arcuata* (Girty). The Meade Peak member is probably Nevolin judged from the presence of *Lissochonetes* and *Crurithyris*. Furnish (1973, p.354) referred the Meade Peak faunas to the slightly older 'Roadian Stage', i.e. Filippovian, on the basis of *Glassoceras bransoni* (Miller & Cline) and *Spirolegoceras fischeri* Miller *et al.* Furnish (1973) also referred Verchoyan ammonoids to the same fauna, but associated Verchoyan brachiopods are clearly Kazanian in age, suggesting that the ammonoids are long ranged from Filippovian through Irenian to Kazanian. The Rex Chert just above the Meade Peak unit could be either Nevolin or Elkin — its fauna is not large, and includes *Kochiproductus*, *Anidanthus* and *Muirwoodia*, all suggestive of a cool episode and impoverished fauna, as in the Elkin faunas of Russia, Australia and New Zealand. The lower Shedhorn Sandstone of a correlative but different facies has a meagre fauna with *Neospirifer pseudocameratus* (Girty) that resembles early mid-Permian *Neospirifer* (*fasciger* type) rather than the *moosakhailensis* type, and so likely to be Baigendzinian or Kungurian. Accompanying species on the whole suggest an Elkin age. The fauna from the Retort Member has a small fauna with no obvious keys, and could be Ufimian or lower Kazanian. However, there is little value in these correlations, for the faunas need to be revised, and then compared with the Glass Mountain faunas, which await publication.

The Franson Member in the middle of the Park City Group (Yochelson, 1968; Williams in McKelvey *et al.* 1959) is not easy to date. It intertongues with the Meade Peak and Rex Chert beds, and its fauna shows a mixture of affinities, with *Derbyia magna* Branson, *Sphenosteges hispidus* (Girty) and *Sphenalosia smedleyi* Muir-Wood and Cooper, related to Kazanian specimens in the high Ranger Canyon beds of Alberta and Trold Fiord beds of the Canadian Arctic. On the other hand *Neospirifer pseudocameratus* (Girty) is like *N. striatoplicatus* (Gobbett) from the Filippovian, and *Cancrinella phosphaticus* appears to be typical of the Meade Peak or Nevolin fauna. This mixture of affinities suggests an age somewhere between that of the Meade Peak and perhaps Rex Chert on the one hand, and the Tosi Chert on the other. Moreover a few species, such as *Antiquatonia* cf. *sulcatus* Cooper are shared with the Rex and Retort members. The overlapping ranges of the species suggest an Ufimian age, but further study is needed to determine limits closer than late Kungurian or early Kazanian.

The Kaibab Formation of north Arizona has a number of species said to be identical with Cathedral Mountain forms, such as *Dyoros*, *Quadrochonetes* and *Peniculauris bassi* (McKee) but the fauna is apparently to be correlated with the Road Canyon Formation, according to McKee & Breed (1969). *Peniculauris bassi* is also present with other key brachiopods in the Concha Formation of south Arizona (Williams in Gilluly *et al.* 1954).

The lower middle part of the Las Delicias Permian in Mexico is probably Kungurian with *Bitaunioceras* (King *et al.* 1944). Dating is not under good control as yet, but it appears likely that 'beds' 8, 11, 12 and 14 of the Malascachas sections are approximately Kungurian in age (Table 35). Bed 14 with *Parafusulina sellardsi* Dunbar & Skinner could be correlative with the Cathedral Mountain Formation. By comparison with other faunas, Bed 11 could be Filippovian, as it contains *Neochonetes* and *Bitaunioceras*, and shares several species with underlying 'Cathedral Mountain' or

Standard		Phosphoria Complex		Park City Formation
Kazanian Stage	Sosnovian Substage Kalinovian Substage	Upper 20m	Tosi Chert Member 30-50m 20m cherty shale member	Ervay Member 5-30m
Irenian Substage	?Ufimian	Shedhorn	Retort Phosphatic Shale Member 20-30m	Franson 10-70m Member
	?Elkin	Sandstone lower 15m	Rex Chert Member 6m-20m	
	Nevolin		Meade Peake Phosphatic Shale Member 30-65m	
?Filippovian Substage		lower ? ?	Lower Chert Member	Grandeur Member 15-125m
Baigendzinian Stage				

Table 34. Tentative correlations of the Phosphoria Rock Complex of Idaho, Wyoming, Montana.

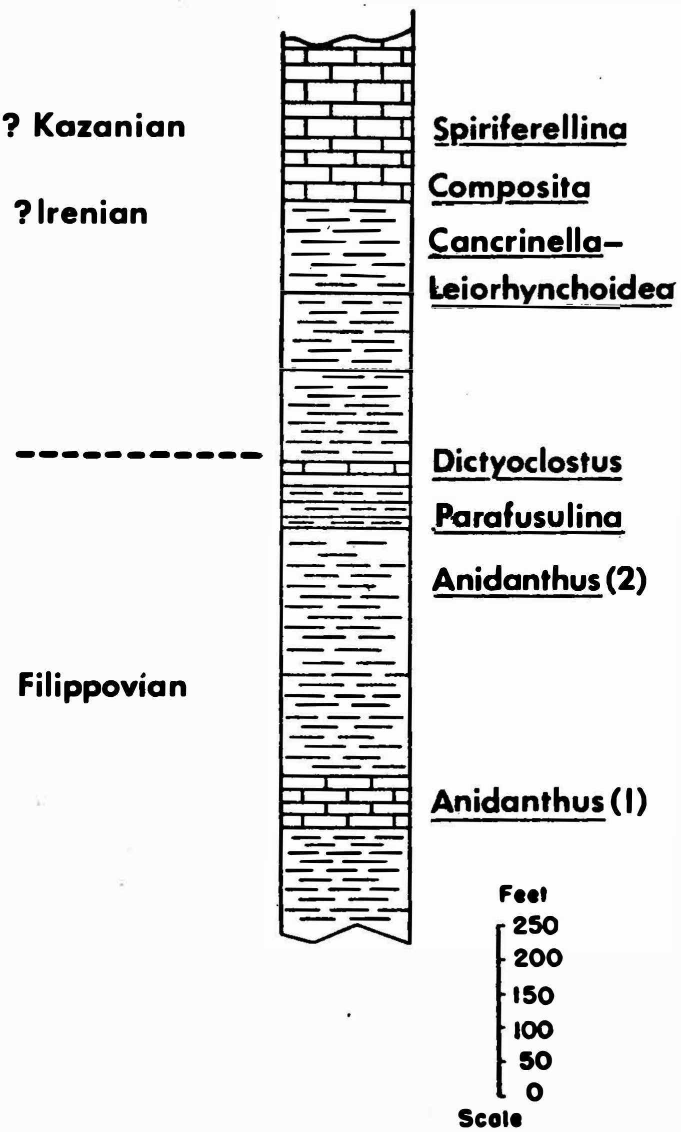


Fig. 28. Columnar section of the upper part of the Permian strata in the Monos Hills, El Antimonio, Mexico, from Cooper *et al.* (1953, fig. 3), with principal genera. Age tentative.

Baigendzinian faunas in bands 12 and 14. Description of the Las Delicias faunas and comparison with the Glass Mountain faunas may establish that a full Kungurian sequence is present.

At El Antimonio, Mexico (Fig. 28), 500m of shales and limestones of the Monos Formation are in part Kungurian (Cooper *et al.* 1953), with a sequence of brachiopod faunas outlined by Cooper. The basal *Anidanthus* Zone might be of Filippovian age, perhaps with the overlying *Dictyoclostus* Zone, which has *Neochonetes* and *Anidanthus. Muirwoodia* and *Cancrinella* occur in the *Dictyoclostus* and overlying *Cancrinella* Zones. Species of *Spiriferella* appear to be typically early Middle Permian, with *Spiriferella scobinoidea* Cooper from the *Anidanthus* Zone resembling the Arctic *S. keilhavii* (von Buch) and *Spiriferella* sp. B from the *Cancrinella-Leiorhynchoidea* Zone like the Arctic *S. loveni* (Diener). *Neospirifer* from the latter zone has high sharply defined plicae as in Arctic and other *Neospirifer* of Kungurian age. Perhaps the *Cancrinella* and *Composita* Zones are late Kungurian, i.e. Irenian in age, but detailed correlation must await description of the nearby brachiopod faunules from the Glass Mountains. Large *Parafusulina* occurs just above the *Anidanthus* Zone.

The Road Canyon Formation of Texas, named by Cooper & Grant (1964, 1966) for Limestone no. 1 at the base of the Word Formation of P.B. King (1931) is probably Kungurian, possibly Filippovian, to judge from Fusulinacean and ammonoid studies (Table 26). It has an early Cyclolobid ammonoid genus called *Glassoceras* and advanced *Parafusulina.* Other ammonoids include *Eumedlicottia burckhardti* (Böse) and *Perrinites hilli* (Smith). Some brachiopods have been described by Muir-Wood & Cooper (1960) and Cooper & Grant (1969, 1973), pending publication of Cooper & Grant (in press). Conceivably the overlying Word Limestone no. 2 or China Tank Member is Nevolin, but few brachiopods have yet been described (see Cooper & Grant, 1973).

The Chochal Limestone of Guatemala has yielded a modest brachiopod fauna, correlated with the Cathedral Mountain or Road Canyon Formation by Stehli & Grant (1970). On the whole detailed affinities, especially for *Edriosteges*, suggest a Road Canyon age, as reinforced by discussion with Dr R.E. Grant, Smithsonian Institution. A number of species do suggest a slightly greater age (*Echinauris*, *Hercosestria*, *Hercosia*, *Peniculauris*, and *Chonosteges*), but the latter occurs in the Nevolin fauna of Thailand (Waterhouse & Piyasin, 1970). Fusulinacea indicate a Leonard or possibly Word age — the very indecision pointing to a Road Canyon correlation.

Sumatra, Timor

From the Djambi tuffs, andesitic lavas and limestones of Sumatra, faunas recorded by Roemer (1880, p.85), Fliegel (1901) and Lange (1925, see. p.281) include *Orthotichia*, *Tyloplecta sumatrensis* (Roemer) and marginiferids suggestive of a Kazanian or Kungurian age. The presence of *Crurithyris* in one list implies a Nevolin age (see Roemer, 1880, p.85). Fusulinacea include *Verbeekina verbeeki* (Geinitz). Brachiopods from two fusuline limestones in the Airkunung beds in the Djambi Residency of Sumatra (Marks, 1957) as described by Meyer (1922) could well be Nevolin in age, and are somewhat like those recorded by Roemer (1880).

The Bitauni fauna of Timor (Tables 19, 44) includes a number of brachiopod species (Broili, 1916; Hamlet, 1928) of Kungurian age, although retaining links with the Baigendzinian, such as '*Productella*' *patula* Hamlet (not Girty) which is an overtoniid (cf *Overtoniina*?) species allied to '*Plicatifera*' *huangi* from Kungurian faunas of China, *Stepanoviella* allied to species from the Arctic Kungurian (Waterhouse, 1970), *Trigonotreta* or Licharewiinid as *Spirifer simaanensis* Hamlet, and ?*Rugaria molengraffi* (Broili), perhaps a senior synonym of *R. speciosus* (Waterhouse & Piyasin) from Thailand. *Martinia* resembles Kungurian specimens described by Diener (1911)

Malascachas	Difunta	King *et al.* 1944		Difunta, Newell, 1957		Tentative Stage
Bed		Bed	Thickness in Metres	Bed	Thickness in Metres	
	1.	Volcanic rocks	320	59-64	280	?Djulfian
	2.	*Kingoceras* shale	70	57-58	110	?Djulfian
1	3.	Volcanic rocks	220	44-56	300	
2	4-7	*Timorites* shale	160	43	120	?Punjabian
3-17	8-24	*Waagenoceras* shale *Parafusulina* volcanic rocks	2130	1-42	1640+	?Kazanian -Kungurian
18-20	25-26	*Perrinites* shale	230			Baigendzinian
	27-33	Conglomerate and volcanic rocks	400			
		Total	3530		2450	

Table 35. Sequence at Las Delicias, North Mexico.

from Burma. A few species have Baigendzinian affinities such as *Costiferina spiralis* (Waagen) found also in the Amb Formation of Pakistan, and a dictyoclostid close to *Reticulatia callytharrensis* (Prendergast), chiefly from the Sakmarian and Baigendzinian beds of the Carnarvon Basin, Western Australia. Both Ruzencev (1956) and Glenister & Furnish (1961) preferred a Baigendzinian age on the basis of ammonoids *Agathiceras, Stenopronorites, Gaetanoceras timorensis* (Haniel), etc, but Ruzencev did allow that the beds might be Kungurian. As noted by Waterhouse (1970a), the only ammonoid to firmly point to a Baigendzinian age appeared to be *Propinacoceras*, a genus also known from Kungurian-Kazanian at Kamloops, British Columbia, and from the Kazanian of Sicily, according to Dr W.W. Nassichuk, pers. comm. Related faunas have been recorded from nearby Letti (Broili, 1915), including *Rugaria strophomenoides* (Waagen) of the lower Wargal beds in Pakistan. A similar fauna at Hato Dame, Portuguese Timor (Shimizu, 1966), includes so-called '*Plicatifera minor* (Schell.)' obviously close to '*Neoplicatifera*' or ?*Overtoniina huangi* (Ustritsky) of the Chinese Kungurian. A few other species, including *Stepanoviella*, were found at nearby localities. The overall age was discussed in relationship to other south-east Asian fauna by Waterhouse (1973a, p.194), who concluded that the faunas were most likely to be Filippovian or Nevolin.

Australia

The early mid-Permian sequence is more complete in the Carnarvon Basin of Western Australia (Fig. 20), where Fauna D2 of Dickins (1963) in the upper Byro Group (Table 29) records the disappearance of many genera, especially those indicative of warmer waters (Waterhouse, 1970c). Brachiopods include *Taeniothaerus*, and *Pseudosyrinx*, as discussed in Thomas (1958, 1967), Coleman (1957), Campbell (1965) and Waterhouse (1970d), but complete descriptions are not yet available, although it has been possible for the writer to examine faunas kept at the Bureau of Mineral Resources, Canberra. The faunal drop in diversity is most noticeable in the Baker (=Nalbia) Formation and Norton Greywacke. Diversity then increases again in the overlying Coolkilya Greywacke (Dickins, 1963). On the basis of bivalve studies these formations are considered Kungurian (Dickins, 1956), and the general faunal relationships and succession suggest that the Baker and Norton are possibly Filippovian and the Coolkilya with its more diverse fauna is Nevolin. *Spiriferella australasica* (Eth.) is allied to Kungurian species from the Arctic, such as *S. polaris* (Wiman) and other forms. A highly plicate *Cancrinella* from the Nalbia (=Norton) beds resembles *C. magniplica* Campbell (1953) from Nevolin beds of Queensland and New Zealand. Amongst species present in both Baker and Coolkilya faunas, *Undulomya* suggests correlation with Malbina A of Tasmania, and *Atomodesma exaratum* Beyrich is shared with Fauna 111b (Filippovian) of Queensland. In reviewing the few ammonoids found in the extensive Coolkilya Formation as proposed by Teichert, prior to a precise definition by Condon (1967), Glenister & Furnish (1961) assigned the upper Coolkilya to the Wordian. *Propinacoceras australe* Teichert is present, member of a genus regarded as key to the Baigendzinian in the Urals, but also occurring in 'Wordian' strata elsewhere (Dr W.W. Nassichuk, Geological Survey of Canada, pers. comm.). *Paragastrioceras* is found also in the Coolkilya Formation. It is typical of Baigendzinian or earlier faunas in Siberia and Canada. Glenister & Furnish referred the lower 100 ft. of the Coolkilya (=Baker, see Dickins, 1963) to the Baigendzinian Stage. *Helicoprion* is present, found widely in Kungurian beds of Russia and North America. In fact the ammonoids show a very wide scatter of ages, leaving one free to choose what seems the most significant. Nassichuk *et al.* (1965) pointed to significant similarities between '*Pseudogastrioceras*' *goochi* (Teichert) (now assigned to *Daubichites* — pers. comm., Dr W.W. Nassichuk) and *Daubichites fortieri* (Harker) of the Assistance Formation,

World Substage		Yarrol Basin	Gympie Basin	Bowen Basin			
				North		Springsure south-west	south-east
Ogbinan					?	?Rewan	?Rewan
Vedian					Upper Bowen Coal Measures	upper Black water	Baralaba Coal Measures
Baisalian							
Urushtenian			?Tamaree Fm			Black Alley Shale	Gyranda Fm
Chhidruan			South Curra Limestone	Blenheim Subgroup	?Havilah Fauna		Flat Top Fm
Kalabagh							
Sosnovian					Pelican Creek Fauna		Barfield Fm
Kasimovian					Scottville Fauna	Peawaddy Fm	
Irenian	Ufim				Exmoor Fauna		
	Elkin Nevolin			Gebbie Group	IIIC		
Filippovian					Glendoo Member IIIB	Ingelara Shale	?Oxtrack Fm
Krasnoufimian						Freitag Fm	
Sarginian					IIIA	Aldebaran Fm	
Aktastinian		Owl Creek Volcanics				Sirius Shale Staircase Ss	
Sterlitamakian		Yarrol Fm	?South Curra Limestone		Tiverton Subgroup	Stanleigh Fm	?Buffell Fm
Tastubian			Rammutt Fm		Lizzie Creek Volcanics		Camboon Andesite
Kurmaian		Burnett Ftm Youlambie Conglom.?				Orion Shale	?
Uskalikian						?	
Surenan		Rands Fm?				Joe Joe Fm	

Table 36. Tentative correlations for Queensland.

Fm = Formation; Ss = Sandstone.

Canada, indicative of a 'Road Canyon' or Filippovian correlation. This is confirmed by the bivalves and brachiopods, and stratigraphic position.

The Lightjack Member of the Lower Liveringa beds of the Fitzroy Basin, Western Australia, shares fifteen species with the Coolkilya and only four with the Baker, though Dickins (1963) preferred a Baker correlation. *Daubichites goochi* is also found in the Lightjack Member. '*Propinacoceras*' has been reported from nearby, but may have come from the underlying Nooncanbah Formation.

In Queensland, Fauna 111b of Dickins (1964; Runnegar, 1969a) is tentatively considered to be Filippovian, on the basis of stratigraphic position, and indications of cold water, which would explain the wide-spread reduction in faunal diversity observed in Asia, the Arctic, and Western Australia. The fauna is best represented in the Glendoo Member of the Gebbie Formation of the Bowen Basin (Table 36). The Eurydesmatid bivalve *Glendella* Runnegar is present, with a few brachiopods including *Wyndhamia dalwoodensis* Booker and *Aperispirifer wairakiensis* (Waterhouse). *A. wairakiensis* is closely related to shells from Kungurian faunas of New Zealand, Timor, and Burma, and is close to the Arctic species *Neospirifer striatoplicatus* (Gobbett). Fauna 111c of Queensland, also incompletely described, may be equivalent to Irenian faunas of Russia. It possibly includes part of the Ingelara fauna of Campbell (1953), in which the species from the sandstone are perhaps ?Filippovian and the species from the overlying fine calcareous argillite may be Nevolin or younger Irenian.

A few occurrences of the ammonoid *Neocrimites* are recorded by Armstrong *et al.* (1967), regarded by them as Baigendzinian, but age and faunal relationships remain to be clarified. The use by these authors and Runnegar (1969b) of a mere 3 or 4 subdivisions for the entire Permian of eastern Australia provides only an extremely crude correlation.

Long studied faunas and rocks of the Hunter Valley, New South Wales, suggest a fairly complete Kungurian sequence (Table 40). Basal Kungurian, probably Filippovian, faunas are found in the Elderslie Sandstone, now called the Cessnock Sandstone at the base of the 'Upper Marine' or Branxton Group (see Packham *et al.* 1969). These and subsequent faunas are assessed chiefly from collections by the author and from collections at the Bureau of Mineral Resources, Canberra, as listed in Waterhouse (1970d). Significant species include *Wyndhamia dalwoodensis* Booker, *Aperispirifer wairakiensis* (Wat.), and *Echinalosia maxwelli* (Wat.), all indicative of a Kungurian age, with *Eurydesma*. In opposition, Dickins (1968) and Runnegar (1969b) considered these Kungurian faunas to be of the same general age and faunal unit as the underlying Farley (Sterlitamakian) faunas, based chiefly on the occurrence of a few bivalves, such as *Eurydesma*. In my opinion the brachiopods differ considerably and consistently, and should be granted prime value in assessing correlation and differentiation. *Neocrimites meridionalis* Teichert & Fletcher from the Elderslie Formation did not indicate any precise age, according to Glenister & Furnish (1961, p.689).

The overlying Fenestella Shale in the Hunter Valley contains a distinctive *Neospirifer* found also in an Irenian faunal unit in New Zealand, believed to be possibly Ufimian in age. In the south Sydney Basin the Wandrawandrian Siltstone at Ulladulla (see Campbell in Packham *et al.* 1969, p.362; Dickins *et al.* 1969) or 'Ulladulla mudstone' contains good indices for an Irenian age in *Echinalosia maxwelli* (Wat.), *Anidanthus solita* Wat. and *Terrakea concavum* Wat. with *Sulciplica*, and members of the Licharewiinid suite, that by comparison with the Pai Hoi and New Zealand Permian suggest a Nevolin age. Other Kungurian faunas are likely to be discovered when the sequence is studied palaeontologically.

In Tasmania (Table 40), the upper Grange Mudstone has *Eurydesma* as in the Cessnock Sandstone of New South Wales, and may be Filippovian in age. Overlying faunas from Malbina A and B beds, as well as the Dabool Sandstone, and Mistletoe Sandstone, all units proposed by Banks (see 1962), have Irenian faunas, assessed by the writer from collections either kept at the University of Tasmania, Hobart, or made by the writer. Species include *Echinalosia maxwelli* (Wat.), *Wyndhamia dalwoodensis* Booker, *Terrakea concavum* Wat., etc. *Licharewia clarkei* (Koninck) enters Malbina A and Dabool beds, suggesting direct correlation with the Nevolin faunas of northern Russia, which also contain *Licharewia* (Likharev, 1966).

New Zealand

The Kungurian Stage is well represented in the foothills of the Takitimu Mountains, New Zealand (Fig. 23), although there are hazards in assessing faunas so remote from the northern hemisphere (Table 37). As a consequence we have to rely heavily on stratigraphic sequence and general indications of faunal diversification or impoverishment akin to those of the northern hemisphere, discussed as 'Faunal Signature' in Chapter 1 (see Fig. 7). Even so, some Productid genera (*Wyndhamia*, *Echinalosia*, *Terrakea*) and some spiriferid genera (*Licharewia*, *Spiriferella*, ?*Aperispirifer*, and *Tomiopsis*) are closely allied to species in the Canadian and Siberian Arctic. A small fauna in the uppermost Takitimu Group of southern New Zealand may be of Filippovian age (Waterhouse, 1969b) with *Terrakea dickinsi* Dear and *Notospirifer*, unless it is infaulted (Mutch, 1973). Overlying beds include thick and large tilloidal breccia conglomerate. A moderately rich fauna at the base of the overlying Productus Creek Group is comprised chiefly of brachiopods with *Spiriferella supplanta* Wat. allied to *S. keilhavii* (von Buch) of Arctic Kungurian faunas. A number of species are shared with east Australian faunas, especially *Wyndhamia dalwoodensis* (Booker), *Cancrinella magniplica* Campbell, *Terrakea concavum* Wat., *Tomiopsis* and *Aperispirifer wairakiensis* (Wat.). Licharewiniids suggest a likely Nevolin age. The succeeding faunas, exceptionally well-preserved in favourable mudstone facies, partly as *Echinalosia* bioherms, were of low diversity, with a number of species shared with underlying faunas. The fauna includes species allied to northern forms (*Echinalosia*, *Tomiopsis*) and is regarded as possibly Elkin, by superposition. Succeeding collections from sandstone include *Neochonetes*, and also coral bioherms with a distinctive *Neospirifer* found also in the Fenestella Shale of the Hunter Valley. This small fauna is correlative with a more complete fauna from the Flowers Formation of the Parapara Group near Takaka in north-west Nelson (Clark *et al.*, 1967) (Table 40). Both are regarded as Ufimian in age. The Flowers fauna contains many Irenian species mixed with several species that flourished in Kazanian faunas of east Australia and New Zealand, thus supporting Russian evidence for placing the Ufimian Horizon with the Kazanian Stage. But, as discussed previously, it may prove easier to *map* the start of the Kazanian Stage at the start of the Kalinovian Substage.

KAZANIAN STAGE

Russian Platform, Urals, north Russia

The Kazanian Stage is one of the long-established units of the Russian Permian, and can be recognised with relative ease by means of its brachiopods, and some extent, bivalves in high latitudes, but not so readily in the palaeotropics. Probably the conodonts, ostracods and small Foraminifera will also prove useful. The type sequences lack ammonoids and Fusulinacea, and have no marine top. The succession is composed chiefly of limestones a few hundred feet thick, with a lower fauna dominated by brachiopods, and an upper fauna dominated by bivalves. Although this division is clearly due to ecological controls, well exposed and complete Kazanian faunas elsewhere in the world show a similar two-fold subdivision, as yet without any formal names. The names Kalinov and Sosnov applied to lithological and faunal divisions for the Kazanian

World Substages		Takitimu Mts.	East Nelson (and Gore, in part)	Faunal Zone
Dienerian		Wairaki Breccia 200m		*Wairakiella rostrata*
Griesbachian		?		
Ogbinan			upper Stephens Fm 500-700m	-
Vedian		Hawtel Fm 250 m	lower Stephens Fm 200m (Tilloid) Waiua Ftm 700m	*Aperispirifer nelsonensis*
Baisalian			(AG6) 200m Greville Fm 700-5000m	*Durvilleoceras woodmani*
Urushtenian			Little Ben Ss-(AG5) 200m	*Spinomartinia spinosa*
Chhidruan Kalabaghian		Glendale Lmst 350m sandstone 100m	(AG4 Lmst 170m) Wooded Peak Lmst 200-1200m	*Plekonella multicostata* *Martiniopsis woodi*
Sosnovian		Weetwood Tuff 100m Mangarewa Fm 220m	Patuki Volcanic Melange 0-300m	*Terrakea brachythaerum*
Kalinovian			Dun Mountains Ultramafics 0-1500m	*Echinalosia ovalis*
Ufimian	Irenian	Letham Fm 70m	Patuki Volcanic Melange 2000-3000m	*Notospirifer spinosa* *Aperispirifer sp.*
Elkin				*Echinalosia maxwelli*
Nevolin				*Spiriferella supplanta*
Filippovian		(conglomerate tilloid) Takitimu Group 16,000m		*Terrakea exmoorensis*
Krasnoufimian			Rai Sandstone 200-600m	*Echinalosia prideri*
Sarginian				*Martinia adentata*
Aktastinian			Croisilles Volcanic Complex 2000-3000m	*Notostrophia homeri* *N. zealandicus*
Sterlitamakian Tastubian				*Atomodesma?* *Mourlonia impressa*
Kurmaian				
Uskalikian				-
Surenan				*Atomodesma*

Table 37. New Zealand correlations
Fm - Formation; Lmst - Limestone; Ss - Sandstone.

of the Russian Platform are here proposed as substages. The Kalinov Suite has Productida dominated by *Aulosteges* and *Stepanoviella* as significant genera and its Spiriferida are characterised by members of the Licharewiinâe, such as *Licharewia* and *Permospirifer* (Slusareva, 1960; Grigorieva, 1962). The overlying Sosnov Suite is dominated by bivalve faunas including *Procrassatella*, *Stutchburia* (*Netschajewia*), and *Pseudomonotis*, with brachiopods *Cancrinella*, *Aulosteges* and *Cleiothyridina*. It may be noted that the nomenclature needs clarification and modification, because a thin intervening Godrohimiches Suite is present between the two, barren, and not faunally significant. In my view it should be treated as a member of one or other horizon after study of the microfossils. The correlative Yardren dolomite has Productacea in common with both suites, but is close to the upper or Sosnovian Substage in lacking Spiriferida. In other basins, as in that of the Mezen and Kulor Rivers, *Blasispirifer blasii* (Vern.) is present in the Sosnov beds. The same faunal subdivisions persist north into Timan, where the lower Kazanian faunas are found in the Chevyu Horizon and overlying upper Kazanian faunas in the Vesliyan Horizon.

Faunal descriptions of brachiopods are provided especially by Nechaev (1911). A so-called 'Zechstein' fauna recorded by Mirchink (1938) from Pinega River is clearly Kazanian. Other somewhat incomplete faunas are recorded from northern Russia by Likharev (1931) at Vologrod and Archangel, and from west pre-Timan by Plotnikov & Molin (1969).

Northern Siberia, Caucasus, Crimea, Afghanistan

The same Kazanian suite of brachiopods extends across the Arctic in Siberia and North America. Several such faunules were recorded from the Barents and Sedov Series of Novaya Zemlya, as at Russian Harbour and Borzov Bay (Likharev & Einor, 1939). In Taimyr (Table 15), the Baikur Horizon of Ustritsky & Chernyak (1963) has somewhat the same faunas in two levels, as in other Kazanian faunas. However so-called *Neospirifer bambadhuriensis* (Diener) and *Brachythyrina* suggest a younger, Kalabaghian age for the upper zone (Waterhouse, 1969c), which lacks a number of species present in the lower fauna, notably *Attenuatella stringocephaloides* (Likharev & Chernyshev). Moreover the lower fauna has *Chonetina*, not *Neochonetes*, which is otherwise common in lower Kazanian faunas. Ustritsky (1971) referred the lower fauna to the 'upper Ufimian Stage', and the upper to the lower Kazanian, but his Late and even Middle Permian are so compressed, as discussed previously, that his correlations must be set aside. Earlier, Ustritsky & Chernyak (1963) had assigned the lower beds to the Kungurian Stage.

Allied faunas occur in the Barain Series of the Verchoyan Massif east of the Lena River (Likharev, 1966, p.349), in the lower Haraulakh Suite (1,000-1,900 m thick) in the north, and upper Endibal Series or Delenjin Suite (600-700 m thick) to the west. The latter has yielded the ammonoid *Spirolegoceras*, compared by Nassichuk *et al.* (1965) with a Filippovian species from the Canadian Arctic, but it must be considered that the ammonoid was long-lived, for the upper Endibal faunas are clearly post-Kungurian. The Menkechen Suite (900-1,100 m) of east Verchoyan has *Licharewia*, and the overlying Chambin Suite has *Cancrinelloides*, suggestive at least in a general way of the Kalinov and Sosnov subdivisions of the Kazanian in the Russian Platform. Unfortunately the faunas are rather small, and no more precise correlation is yet possible.

A fine fauna occurs to the east in the Omolon Horizon of the Kolyma River and Omolon Plateau region (Zavodowsky, 1970, p.19), including the *Licharewia* complex, smooth chonetid (*Lissochonetes*) and *Attenuatella* as in the lower Baikur beds of Taimyr Peninsula. The overlying Gijigin Suite is of considerable interest, because it includes a tillite according to Ustritsky (1973). The accompanying fauna is very small, Zavodowsky (1970) recording *Tornquistia* and *Licharewia*, which suggest a Kazanian

World Standard		Dacht-e-Nawar and Tezak	Wardak
Stage	Substage		
Dorashamian		- ? - Pamiran	
Djulfian			
Punjabian	Kalabaghian	*Alatoconcha vampyra* beds	*Marginifera typica* beds
Kazanian			*Permundaria sisophonensis* beds
Kungurian	Irenian Filippovian	Kubergandian *Parapronorites*	*(Neoschwagerina)* *(Cancellina)*
Baigendzinian or Aktastinian			"Artinskian"
Sakmarian	Sterlitamakian	Doni Yarchi Series	*Taeniothaerus permixtus* horizon
	?Tastubian	Bini Darzak Horizon *Stepanoviella umariensis*	*Tomiopsis* sp
Asselian	Kurmaian	Bokan Series *Cancrinella lyoni*	Horizon with *Eurydesma mytiloides*
Late Carboniferous			*Asyrinx*

Table 38. Upper Palaeozoic sequence of Afghanistan, after Termier *et al.*, 1974 (see Fig. 4).

age. But a Kalabaghian age seems possible, as discussed above for the upper Baikur Horizon.

Similar Kazanian faunas extend into east and west Baikal at Lake Chironskogo (Maslennikov, 1960; Kotlyar & Popeko, 1967, p.10) and are represented in the Haranor Suite (1,600-1,700 m thick) of the Borzin region, with *Licharewia* and other forms (Likharev, 1966).

In the Murgab Stage of the Greater Caucasus, the Gutan (8-28 m) and Nikitin (7-30 m) Horizons include *Tyloplecta yangtzeensis* (Chao), *Leptodus nobilis* (Waagen) and other species, with *Palaeofusulina nana* Likh. and *Reichelina cribroseptata* Erk. To the south correlative beds contain *Neoschwagerina margaritae* (Deprat), and *Nankinella orientalis* Mikl.-Makl. These beds are equivalent to brachiopod Horizon A of Likharev (1937). Brachiopod species belong to *Derbyia*, *Meekella*, *Scacchinella*, (Waagen), marginiferids, with *Chonetella nasuta* Waagen, *Linoproductus lineatus* (Waagen) and *Leptodus nobilis* (Waagen) found also in the Wargal Formation, Salt Range, and *Tyloplecta yangtzeensis* (Chao) from the Maokou beds of China. A related fauna from the Crimea Peninsula has many of the same species, but also has *Cancellina*, perhaps indicative of a slightly greater age.

A large fauna has been described as lower Murgabian by Termier *et al*., (1974) from Afghanistan south of Kabul (Table 38) in bioclastic carbonates and shaly limestone, called the *Permundaria sisophonensis* beds. Numerous brachiopods include *Rugaria simulata* (Reed), (Amb or Wargal), species of *Waagenoconcha*, *Permundaria*, *Kutorginella*, *Chonetella nasuta* Waagen, *Costiferina redacta* (Reed), *Paeckelmanella* (=*Pterospirifer*?), *Purdonella lunwalensis* Reed, spiriferellids and *Martinia* sp., many also found in the Wargal Formation of the Salt Range. Correlation with the lower Wargal appears acceptable. None of the typical Arctic Kazanian species are present, underlining the need for clarification of which brachiopod species typified warm-water tropical faunas of the Kazanian Stage. For the Afghanistan fauna the age appears confirmed by stratigraphic position over Kungurian Fusulinacea, and below Punjabian brachiopods. Nearby in the Tazak section, Sosio ammonoids have been discovered (Termier *et al*., 1974, p.114), but these seem to be late Kungurian.

China, Japan, south-east Asia

The *Neoschwagerina* Zone in China (Table 18) is the middle of three Fusulinacean zones in the Maokou Limestone, above the *Nankinella-Cancellina* Zone, and below the *Yabeina* Zone (Sheng, 1964). Associated Fusulinacean genera include *Verbeekina*, *Pseudodoliolina*, *Sumatrina*, *Chusenella*, and *Parafusulina*. *Cancellina* and *Yangchiena* are no longer present. Sheng (1964) matched the fauna with that of the lower Nikitin Formation of the Rek Basin in the northern or Greater Caucasus. A few brachiopods have been recorded from the zone by Huang (1932a), including species of *Haydenella* and *Marginifera* as in Sisophon member B of Cambodia (see below).

As noted previously, Chao (1966) recorded an ammonoid fauna with possibly *Daubichites*, *Waagenoceras* and *Mexicoceras* from the carbonaceous shale in the lower Tingchiashan Formation of western Chekiang and north-east Kiangsi, indicative of the *Waagenoceras* ammonoid Zone and correlated with the *Neoschwagerina* Zone. This is probably of Kazanian age, although the close comparison between one ammonoid *Daubichites* and a Canadian Arctic species of *Daubichites* (Nassichuk *et al*., 1965) suggests the possibility of a Kungurian age. However Dr W.W. Nassichuk pers. comm. considers the Chinese '*Daubichites*' could be *Altudoceras*. The other genera *Waagenoceras* and *Mexicoceras* occur in the Word Limestone no. 2, of Nevolin age in the Glass Mountains, Texas, as well as in higher Kazanian faunas of the Word in Texas.

Reed (1927a) described several collections from green shales and fine sandstone in Yunnan, southeast China, of which one at Tai-li-shao (see Fig. 17) is large enough to tentatively assign to the Kazanian Stage or perhaps Kalabaghian Substage, on the presence of *Neochonetes*, *Stepanoviella*, and *Martiniopsis talishaoensis* Reed. Reed (1927a, p.164) recorded *Elivina tibetana* (Diener) nearby with *Stepanoviella*, possibly suggestive of a Kalabaghian age, if *Elivina* is correctly identified. A few other species from the Tai-li-shao fauna also suggest a Kalabagh age, such as *Brachythyrina*, *Martinia semiplana* Waagen and *Tschernyschewia*, whereas *Spirifer peregrinus* Reed looks like *Sulciplica*, a genus widespread in the Kazanian and Kungurian Stages.

The upper Jisu Honguer faunas of Mongolia could be of Kazanian age, as discussed later.

In Japan (Tables 20, 32), the *Neoschwagerina margaritae* Zone of the Akasaka Stage, typified by massive light and dark grey limestone, is regarded as Kazanian. The key species is locally replaced by *Neoschwagerina douvillei* Ozawa, and is underlain by the *Neoschwagerina craticulifera* Zone, also classed in the Akasaka Stage. A few brachiopods in sandstones of the Tenjinnoki Formation, 150 m thick, in the southern Kitakami Mountains (Ueda, 1963, p.150) are accompanied by *Monodiexodina matsubaisha* (Fujimoto), and regarded as correlative with the *Neoschwagerina* fauna.

In Sisophon member B of Ishii *et al.* (1969) in western Cambodia, brachiopods of the *Tyloplecta nankinensis* Zone are somewhat like those of the Kungurian member A (Table 19). They include *Chonetinella*, *Costiferina* cf *indica* (Waagen), *Tyloplecta nankinensis* (Frech), *Leptodus*, *Choristites* and a distinctive dictyoclostid ?*Chaoiella margaritatus* (Mansuy), with *Marginifera* and *Haydenella* related to Maokou species of China. Fusulinacea seem to form two zones or communities, the lower beds with *Nankinella*, *Schubertella*, and *Chusenella* species, the upper with *Neoschwagerina douvillei* Ozawa, *N.* aff. *margaritae* Deprat and *Yabeina asiatica* Ishii. *Yabeina asiatica* is generally considered to be a primitive *Yabeina*, descended from *Neoschwagerina douvillei* according to Ishii (1966, p.132). It perhaps indicates a late Kazanian or early Kalabaghian age. From the generalised column in Deprat (1913, p.76) as repeated in Table 42 herein, level 3 with *Spiriferella* and Licharewinid and level 4 bearing Fusulinacea are likely to be Kungurian. Level 5 at Lang-nac has *Neoschwagerina margaritae* Deprat and *N. megasphaerica* Deprat, of Kazanian age, conceivably high Kazanian as *N. craticulifera* normally precedes this zone. Level 7 at Pong Oua has Kazanian-Kalabaghian species of *Orthotetes*, *Leptodus*, *Linoproductus*, and *Neoschwagerina margaritae* and *Yabeina* cf. *globosa* (Yabe), which is also found in the overlying horizon. Other brachiopods described by Mansuy (1912) from Phom-Ta-Kreem and Phnon-Ta-Maio may be roughly Kazanian in age. It is not clear whether the faunas with *Y. globosa* are late Kazanian or early Kalabaghian, but Japanese workers regard *Y. globosa* as indicative of their lower Kuman (Kalabaghian-Chhidruan) Stage. Unfortunately there are few accompanying brachiopod or ammonoid faunules to test various possible correlations, and at present we are faced with several alternatives:

1. that *Neoschwagerina craticulifera* is Kungurian (as seems likely in Iran and Pamirs), and *N. margaritae* and even *Y. globosa* are Kazanian;
2. that *N. craticulifera* and *N. margaritae* are Kazanian and *Y. globosa* is early Kalabaghian;
3. that *N. craticulifera* and *N. margaritae* are Kazanian, and *Y. globosa* forms a third zone between Kazanian and Kalabaghian;
4. that *Y. globosa* is insignificant, and overlaps with either *Yabeina* or *Neoschwagerina* to indicate a Kalabaghian or Kazanian age.

Similar problems concern the age of *Yabeina asiatica*. In the present account, high value is given to Japanese studies on the Fusulinacea, which would suggest that *Yabeina globosa* is Kalabaghian, and *Neoschwagerina margaritae* is Kazanian. *Yabeina asiatica* is tentatively regarded as Kazanian, but the relationship between the late Kazanian and Kalabaghian is under poor control, and there might well be a zone not as yet well delineated, typified in part by *Yabeina asiatica*. *Neoschwagerina craticulifera* or shells so-called, though regarded as typically lower Kazanian, also appears in faunas of Kungurian age. This being so, it may be that primitive *Yabeina* (=*asiatica*), and allies

Chi-Thuan 1961		Ishii *et al.* 1969	
		Member D	muddy limestone and limestone
Bed 5	siliceous black carbonates	Member C	red = bed 5-7 of Saurin.
Bed 4	siliceous carbonates		red nodular mudstone.
Bed 3	red shale, not fossiliferous		red shale.
Bed 2	red carbonates, with *Yabeina Lepidolina*		*Yabeina, Neoschwagerina*
Bed 1	crinoidal limestone, grey marl.	Member B	crinoidal limestone
		Member A	tuff

Table 39. Comparison of Sisophon mid-Permian sequences, from Waterhouse (1973a, Table 27).

typify the later Kazanian. Such speculation underlies the need for detailed analysis of palaeotropical brachiopods, for which there are few modern studies available.

Large brachiopod faunas from Sisiphon and especially Phnom Tup are described by Chi-Thuan (1961) with ?*Chusenella* aff. *tunetana* (Douville), and *Yabeina johannis* Saurin (Table 19). Overlying beds contain chiefly *Lepidolina multiseptata* Deprat and *Yabeina* aff. *khmeriana* Saurin. As shown by Waterhouse (1973a, p.196), there are difficulties in reconciling Chi-Thuan's account of the stratigraphy with that outlined by Ishii *et al.* (1969). Chi-Thuan's fauna appears to have come from the upper part of the B member, and so may be late Kazanian or early Kalabaghian age. I prefer the latter. Chi-Thuan herself stated that the faunas came from two horizons, but made no separation of localities in the text; she further stated that the faunas came from the *Yabeina* Zone below *Lepidolina multiseptata.* Many of her species are recorded in Ishii *et al.* (1969) in Sisophon member C, which would agree with many of the known species ranges elsewhere. Yet *Costalosia*, *Waagenites*, *Uncinella*, and *Spiriferella cambodgensis* point to a Kungurian correlation, whereas *Brachythyris*, *Tyloplecta*, and *Monticulifera* are perhaps younger Kazanian. Still others of the species identified, perhaps incorrectly, by Chi-Thuan, suggest a Kalabaghian age by correlation with the faunas of Basleo, Himalayas, and Salt Range. The problem is insoluble at present, but it appears likely, if we can accept the identifications, which are frequently dubious and not supported by illustrations, that the collections have unwittingly crossed two or even three condensed zones, of Kungurian, Kazanian and even Kalabaghian age.

Pakistan, Iran, Mediterranean

The middle part of the Wargal Formation of the Salt Range, Pakistan (Table 28), has a fauna distinguished by a number of species of *Enteletes*, *Orthis*, *Streptorhynchus*, *Derbyia*, chonetids, *Echinalosia indica* (Waagen), *Choristitella wynnei* (Waagen), '*Spirifer*' *oldhamianus* Waagen, *Martinia semiplana* Waagen and a few other forms, according to Waagen (1891, p.111, 200). Some ranges have to be amended, especially on the basis of the work by Reed (1944), but there appear to be Kazanian faunas at this position, below the Kalabagh Member at the top of the Wargal Formation. The fauna is richer than the lower Wargal faunas, thought to be of Kungurian age, and less diverse, but with fewer cool-water elements than in the Kalabaghian faunas. There are virtually none of the species and genera that characterise Arctic or Australian faunas, so that the stratigraphic limits of the fauna await detailed study. No Fusulinacea or significant Ammonoidea are found.

A Permian fauna from south Iran described by Douglas (1936, 1950) includes *Neoschwagerina craticulifera* (Schwager), *Cancellina primigena* (Hayden), *Verbeekina verbeeki* (Gein.) below a fauna with *Yabeina inouyei* Deprat and above a fauna with *Polydiexodina* (=*Skinnerina*?), but the fauna could be as old as Nevolin, in having the brachiopods *Lissochonetes* and *Mentzelia.*

Part of what promises to be a very rich fauna has been described or listed chiefly as new Aulostegid genera, *Leptodus*, *Oldhamina*, *Derbyia*, and *Orthotetes*, from Hydra in the Aegean Sea by Grant (1972). *Neoschwagerina craticulifera* and *Verbeekina verbeeki* are known widely in this area.

A huge fauna has been recorded from the Sosio beds of Sicily, by Gemmellaro (1899), Greco (1942, 1947), Gregorio (1930) and Rudwick & Cowen (1968) with the ammonoid *Waagenoceras*, and Neoschwagerinid Fusulinacea regarded as keys to palaeotropical equivalents of the Kazanian Stage. The writer has examined little of the actual material, and so is not sure if the Kazanian age is completely correct. There are many species of *Enteletes*, and *Martinia*, with *Scacchinella*, *Streptorhynchus*, Leptotid, richthofeniids, spiriferinids, a few choristitinid and syringothyrinid forms, and many terebratulids, such as *Heteralasma*, *Jisuina* and *Notothyris.* The fauna is in general rather like those of the Sakmarian Trogkofel Formation of Austria, but also resembles the Kazanian 'Horizon A' brachiopods from the north Caucasus (Likharev, 1932), which probably occupied a similar palaeotropical station. But a high Kungurian age cannot yet be ruled out.

Spitsbergen, Greenland, North America

The Brachiopod Chert of Isfjorden and Hornsund, Spitsbergen (Table 25) has yielded large brachiopod faunules that share many species with Kazanian faunas of Russia and Siberia, such as *Cancrinelloides* and *Licharewia.* The lists are summarised from various authors by Gobbett (1964). However, it must be noted that stratigraphic details are not well controlled, and it appears likely that Nevolin (Irenian) faunas, though not described from any clearly distinguished horizon, may well be present, and have been intermixed with genuine Kazanian horizons. Such forms as *Chonetina superba* Gobbett, and *Pterospirifer cordieri* (Robert) suggest the likelihood of Nevolin equivalents. This seems to be counter-balanced by the report of *Licharewia* (Gobbett, 1964), but we do not know if this is an early appearance of the genus, as in Nevolin faunas of Timan and New Zealand, or due to mixture of Nevolin and Kazanian faunas. The Ufimian and Elkin Horizons, requiring careful field collecting and subtle faunal analyses, have not been recognised but may well be present. This failure to distinguish the Nevolin level may have led to misleadingly high faunal diversities.

Brachiopods briefly described and listed from Horizons G and H from Amdrupsland, north Greenland by Frebold (1950) may be of Kazanian age, but could also be Kungurian. So few species are figured, and so many assignments are dubious, that it is difficult to tell.

Kazanian faunas with *Cancrinelloides* and *Licharewia* are widespread through the Canadian Arctic Islands (Fig. 27), in the Trold Fiord green sandstones, and the coarsely granular limestones of the Degerbols Formation, as well as in sandstones of the Richardson Mountains, and cherts and limestones of the upper Tahkandit Formation (Table 22) in northern Yukon Territory (Waterhouse, 1969a; Bamber & Waterhouse, 1971). Only one zone is present, presumably of lower Kazanian or Kalinovian age. Nassichuk *et al.* (1965) described *Neogeoceras macnairi* from the Trold Fiord Formation and assigned a general Guadalupian (=basal Kungurian to Urushtenian) age. The same typically Kazanian fauna is found in the upper Tahkandit Formation of Alaska (Brabb & Grant, 1971). To the south allied faunas occur in the Fantasque Chert of British Columbia and the upper Range Canyon Chert in Alberta as reviewed by Logan & McGugan (1968).

In the Phosphoria Rock Complex of Idaho, Montana, Wyoming, and Utah (Table 34) the Tosi Chert Member has *Lissochonetes*, *Sphenosteges*, *Echinauris* and *Leptodus* of apparent Kazanian age, though thought to be possibly younger by Yochelson (1968). Several species are shared with the Ervay Carbonate Rock Member at the top of the nearby Park City Group. Conceivably *Lissochonetes* implies a late Kazanian age. In northern Utah, the topmost unit of the Park City Group consists of the Gerster Formation (the Kaibab lies at the base), with a modest brachiopod faunula, including *Sphenosteges hispidus* (Girty), *Waagenoconcha montpelierensis* (Girty), *Bathymyonia nevadensis* (Meek), *Muirwoodia multistriata* (Meek) and *Neospirifer pseudocameratus* (Girty). The fauna was correlated by Dr G.A. Cooper with the Appel Ranch Member at the top of the Word, that is, late Kazanian or Sosnovian (Bissell, 1973, p.324). The Gerster in places overlies the Rex Chert, which is here regarded as Elkin in age, to imply that the Ufimian and lower Kazanian are missing.

Brachiopods from the Word and equivalents of the Glass Mountains, Texas (Table 26), have been described by R.E. King (1931), Muir-Wood & Cooper (1960) and Cooper & Grant (1969). Horizons include the Appel Ranch and Willis Ranch Limestone Members of the upper Word in the Glass Mountains (Fig. 29), and the

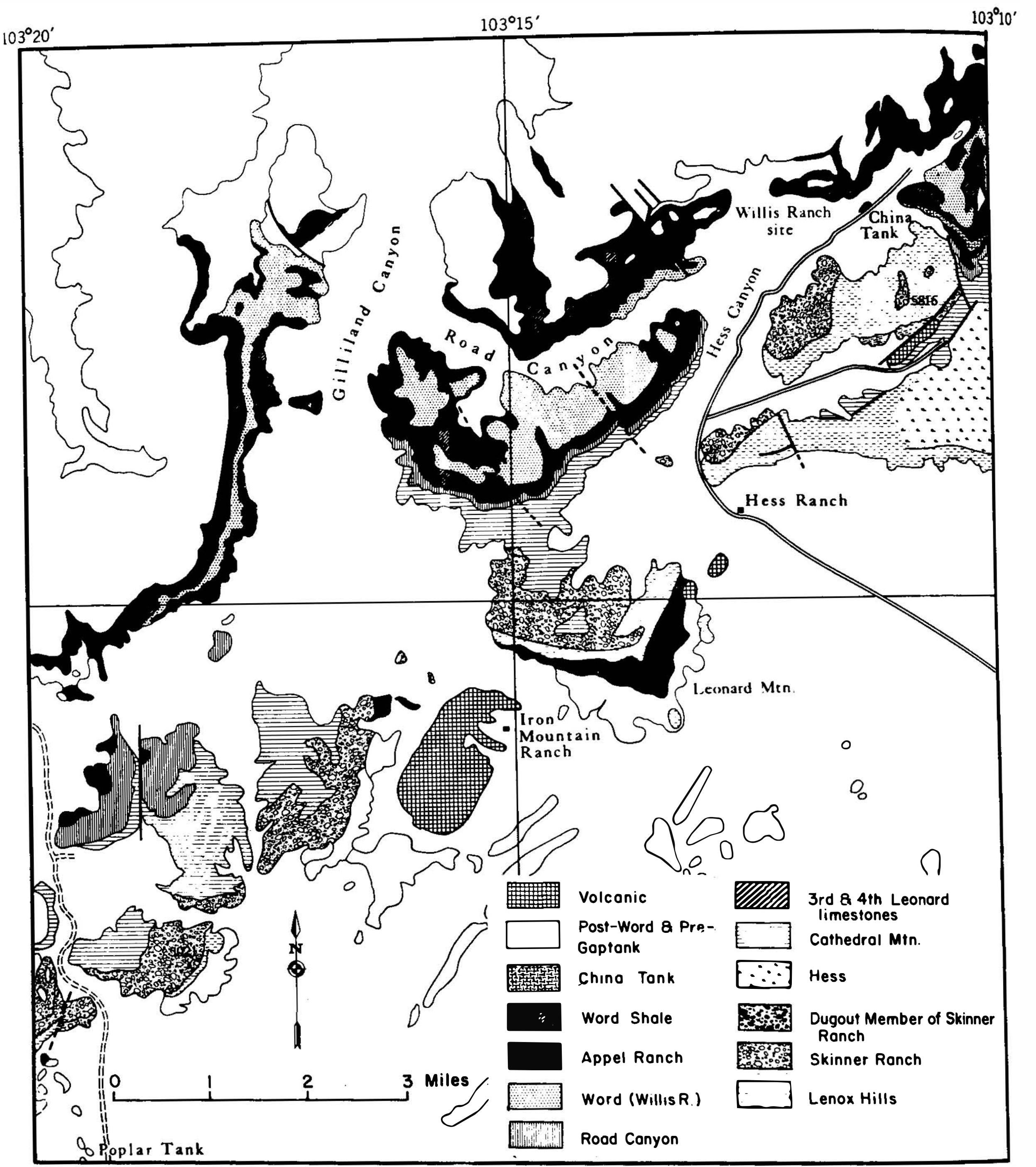


Fig. 29. Geological map of part of the Galss Mountains, west Texas, from Cooper & Grant (1973a, fig. 25, p. 73). Reproduced with permission of the authors.

Getaway and Cherry Canyon Formations of the Guadalupe Mountains and Sierra Diablo. It is impossible to fully comprehend the faunal affinities until the brachiopod descriptions are published by Cooper & Grant (in press), but large '*Grandaurispina*' (=*Terrakea*) from locality 706e at the top of the Willis Ranch Member for example suggests correlation with the Kazanian Stage of Australia and New Zealand. The report of *Spiriferinaella* in the Appel Ranch Member (Cooper & Grant, 1973) probably implies an upper Kazanian age. Ammonoids are present in the Wordian by the hundreds according to Furnish (1973), and include species of *Waagenoceras*, *Agathiceras*, *Popanoceras*, *Stacheoceras*, *Neocrimites* and *Propinacoceras*. Apparently no detailed zonation has been achieved for ammonoids, the faunas from Nevolin to upper Kazanian, i.e. China Tank to Appel Ranch Members all being treated as one unit.

Clastics, carbonates and lavas of probably Kazanian age in the Las Delicias syncline of north Mexico (Table 35) include faunas in the dark shale of Band 5 in the Malascachas section (King *et al.*, 1944, p.10) and in shale, greywacke, and limestone of beds 14, 15 and ?15 in the Difunta section (King *et al.*, 1944, p.14). *Parafusulina deliciasensis* Dunbar & Skinner occurs with *Meekella*, *Neochonetes*, *Prorichthofenia*, *Leiorhynchoidea*, *Paranorella*, *Waagenoceras dieneri* Böse, *W. guadulupensis* Girty, *Epithalassoceras ruzencevi* Miller & Furnish, *Stacheoceras gemmellaroi* Miller and other species.

The *Spiriferellina* Zone at the top of the Monos Formation, north Mexico (Fig. 28), is probably Kazanian in age with a brachiopod faunule described by Cooper (1953). The faunule is too small to decipher with confidence, but contains *Neochonetes* which might suggest an Ufimian or lower Kazanian age. Also the low interarea and shape of a strophalosiid recall *Echinalosia minima* (Maxwell) of Kazanian and Ufimian age in Australia and New Zealand (Dear, 1971; Waterhouse & Vella, 1965). *Waagenoceras dieneri* is present.

Timor, Australia, New Zealand

No well established brachiopod fauna of Kazanian age is known from Timor (Table 16, Table 44). The *Waagenoceras* ammonoid fauna from Tei Wei was placed in the Baigendzinian Stage by Ruzencev (1956) and Glenister & Furnish (1961), but is probably late Kungurian or Kazanian.

Kazanian faunas are widely represented in eastern Australia where they are called Fauna IV by Dickins (1964; Runnegar, 1969b). An outstanding summary of the Queensland successions by Dear (1971, 1972) goes far beyond the crude recognition of Fauna IV, and names four successive faunas, the Exmoor, Scottville (=Peawaddy Formation), Pelican Creek (=*Streptorhynchus pelicanensis* bed) and Havilah faunas in the Blenheim Subgroup of the north Bowen Basin (Fig. 23, Table 36, Table 40). From superposition and correlation with New Zealand faunas, the Exmoor fauna is here considered to be Ufimian, the next two faunas Kazanian, and the Havilah fauna may be post-Kazanian. The Kazanian age is based on superposition, reinforced by the presence of a number of brachiopod genera and species found in the Arctic, such as *Wyndhamia*, *Terrakea*, *Cancrinella*, etc., and members of the Licharewiinae. Allied Kazanian faunas are found in the Muree beds and Mulbring (at least lower Mulbring) Subgroup of the Hunter Valley, New South Wales, and in Malbina D-E and lower Ferntree and correlative beds of Tasmania (Table 40).

In New Zealand two brachiopod teilzones are found in the Takitimu foothills, the *Echinalosia ovalis* Zone, followed by the *Terrakea brachythaerum* Zone, both with well developed Kazanian faunas (Table 36), and many forms shared with eastern Australia, especially Queensland (Waterhouse, 1964, 1973c). Thus the two-fold division suggests likely correlation with the Kalinovian and Sosnovian Substages of the standard Kazanian of the Russian Platform. The lower zone includes such species as *Grumantia*

World Substage		New Zealand Formations, Nelson (upper), Southland	Tasmania Hobart, Poatina	New South Wales Hunter Valley	Queensland Bowen & (Gympie) Basins	Western Australia Carnarvon Basin
Griesbachian		Stephens		?Clifton Subgroup	?Brooweena Blackwater	Kockatea Shale
Ogbinan						
Vedian		Waiua	Cygnet Coal Measures		(?Traveston)	
Baisalian		Greville		Newcastle Coal Measures	Black Alley	
Urushtenian		Little Ben		Tomago Coal	(Tamaree)	(Hardman Member)
Chhidruan		Wooded Peak Lmst			•Flat Top & upper S. Curra	(Liveringa)
Kalabaghian		lower Elsdun	Ferntree Group	Measures	Barfield	
		?				
Sosnovian		Mangarewa		Mulbring Ss		
Kalinovian			?Risdon Ss Malbina D, E	Muree Ss Member Wollong Ss Member	Peawaddy	
Ufimian	Irenian	Letham	Malbina C	Fenestella Siltstone Member	Catherine Ss	
Elkin						
Nevolin			Malbina B, A	?	Ingelara Shale	Coolkilya
Filippovian			Grange Ms	Cessnock Ss Member	Freitag	Baker
Krasnoufimian		Takitimu	Berriedale Lmst	Greta Coal Measures	Aldebaran Ss	Wandagee, Quinnanie ?Bulgadoo Cundlego
Sarginian						Coyrie, Mallens
Aktastinian			Nassau Sls	?	Cattle Creek	Wooramel Group
Sterlitamakian		Group	Faulkner Group Bundella Ms	Farley	?Reids Dome beds	Callytharra Lmst
Tastubian			Darlington Lmst	Rutherford	=Lizzie Creek Volcanics (part)	Beckett Shale
Kurmaian			Quamby Ms Wynyard Tillite	Allandale	Burnett	Lyons Group
Uskalikian				Lochinvar		
Surenan				Seaham		

Table 40. Intercorrelations between New Zealand and Australian Formations. Ms mudstone; Ss - sandstone; Sls - siltstone; Lmst - Limestone.

Table 41. Correlation of Queensland Permian according to Dear, 1972, Table 1, p. 4. 71

Faunal Subdivision Dickins 1964	Faunal Subdivision		North Bowen Basin	South-west Bowen Basin Springsure An.	Southeast Bowen Basin	Yarrol Basin	Gympie Basin	Sydney Basin Hunter Valley	Sydney Basin South Coast	Faunal Subdivision Runnegar 1969
			Upper Bowen Coal Meas.	Black Alley Shale	Gyranda Formation	Unconformity	Tamaree Formation	Tomago Coal Meas.	Cumberland Subgroup	
Fauna IV	Havilah Fauna	Back Creek Group	Blenheim Sub-Group	Peawaddy Formation	Flat Top Formation			Mulbring Formation		Fauna IV
	Pelican Creek Fauna			Catherine Sandstone					Gerringong Volcanics	
				Ingelara Formation	Barfield Formation		South Curra Lime-stone		Berry Formation	
	Scottville Fauna			Freitag Formation				Muree Formation	Nowra Formation	
	Exmoor Fauna			Upper Aldabaran Sandstone	Oxtrack Formation					
Fauna III	Fauna III		Gebbie Subgroup	Lower Aldebaran Sandstone	Disconformity			Upper Branxton Subgroup	Wandrawandian Sandstone	Fauna III
Fauna II (Incorporating Fauna I)			Tiverton Subgroup	Sirius Formation				Fenestella Shales	Ulladulla Mudstone	Ulladulla Fauna
	Homevale Fauna			Staircase Sandstone				Lower Branxton Subgroup	Conjola Formation	Fauna II
					Buffel Formation			Greta Coal Meas.		
	Lizzie		Lizzie Creek Volcanics and Carmila Beds	Stanleigh	Camboon	Owl Gully Volcanics	Rammutt Formation	Farley Formation		
								Rutherford Formation		
						Yarrol Formation		Allandale Formation		Allandale Fauna
				Orion Shale	Andesite	Burnett Formation	Highbury Volcanics	Lochinvar Formation	Unconformity	
								Seaham Beds		

pelicanensis (Flet.), *Neochonetes beatusi* Wat., *Lethamia ligurritus* Wat., *Terrakea elongatum* (Eth. & Dun), *Plekonella southlandensis* (Flet.), *Aperispirifer lethamensis* Wat. and *Tomiopsis mantuanensis* (Campbell). The upper zone includes *Wyndhamia clarkei gattoni* (Max.), *Plekonella acuta* Campbell, and *Tomiopsis costata* Wat.

PUNJABIAN STAGE

Pakistan

The Punjabian Stage contains the youngest widespread and richly fossiliferous rocks of the Permian Period, characterised by the *Yabeina-Lepidolina* fusulinacean assemblage, the *Timorites-Cyclolobus* ammonoid suite, and an array of brachiopod species varying in different palaeolatitudes. Stepanov (1973) revived the name Punjabian Stage originally proposed by Schenk *et al.* (1941) for this part of the column. Stepanov (1973) showed the Punjabian Stage as pre-Djulfian, and partly Guadalupian. It is adopted herein, and divided into the Chhidruan and Kalabaghian Substages, as defined by Waterhouse (1972a). This Punjabian Stage is the same as the Chhidruan Stage of Furnish (1966), and Glenister & Furnish (1970), in which the initial Chhidruan Stage of Furnish & Glenister (1961) was expanded beyond the faunal and lithostratigraphic limits of the Chhidru Formation to incorporate the underlying Kalabagh Member of the Wargal Formation. Here it is preferred to retain the original definition of Chhidruan as in Furnish & Glenister (1961), and allow the substages to agree in name with their lithological units. A Chhidruan Stage as in Furnish & Glenister (1970) that differs so much from its original definition, and incorporates a Chhidru Formation *and* Kalabagh Member can only confuse.

The Chhidruan and Kalabaghian Substages are based on exposures in the Salt Range of West Pakistan (Table 28) and as such have been assessed as Late Permian (Miller & Furnish, 1940; Glenister & Furnish, 1961; Schindewolf, 1954; Ross, 1967b; Kummel & Teichert, 1964; Teichert *et al.*, 1973; Ruzencev & Sarytcheva, 1965). Waterhouse (1966) and Grant (1968) showed that this was not correct, as reinforced by ammonoid studies (Tozer, 1969; Chao, 1966; Furnish, 1966, 1973; Spinosa *et al.*, 1970) and fusuline studies of important sequences in China (Sheng, 1964). It may well be time to abandon the Kalabaghian and Chhidruan Substages, for they have occasioned a regrettable diversion of opinion over correlation that may take years to resolve. Other than for the Salt Range sections, there is virtually no disagreement whatsoever between brachiopod and ammonoid correlations — for instance, between such important sequences as those of west Texas, Mexico, China, Armenia, and Timor. But because of the Salt Range names, this close measure of agreement is not apparent. If, for example, we used Gnishik and Hachik as the basis for substages, our correlation tables would agree well except for the disputed Salt Range column, which after all, is only one of many sequences. Then also we would have a number of substages and stages in sequence, and thus reduce correlation problems, and allow one country to be custodian for standard sequences of the Permian Period.

Kozur (1974) has also avoided the difficulty, by using the Guadalupian 'Stage' with Wordian and Capitanian substages as world standards. In a considerable improvement over earlier summaries (e.g. Kozur, 1973a, b), the Kalabaghian is shown as equivalent to low Capitanian, and the Chhidruan as equivalent to upper Capitanian, largely following Waterhouse (1972b), but he also correlated the Chhidruan with the 'Araksian' (=Baisalian of Waterhouse, 1972b, not Araksian of Furnish, 1973), passing up to early Dorashamian. In an appendix, Kozur (1974, p.50) preferred correlation at least in part with the Abadehian Substage of Taraz (1973).

The upper division of the Wargal Formation, called the Kalabagh Member by

Waagen (1891), (see Teichert, 1965, p.12), contains a fauna that can be distinguished from the faunas above and below. Waagen (1891) recorded several distinct species, *Enteletes laevissimus* Waagen, *Enteletina latisinuatus* Waagen, *Megasteges dalhousei* (Dav.), *Terebratuloidea depressa* Waagen, *Spirigerella alata* Waagen, *Notothyris lenticularis* Waagen, and several nautiloids. Waagen (1891, pp.198-200) listed some 18 species that appeared last in the member and some 18 species that entered the sequence, including *Derbyia hemisphaerica* Waagen, *Waagenoconcha purdoni* (Dav.), (assigned to a new genus *Septiconcha* by Termier *et al.*, [1974]), '*Rhynchonella*' *wynnei* Waagen, *Uncinunellina theobaldii* (Waagen), *U. jabiensis* (Waagen), *Spirigerella hybrida* Waagen, *S. ovoidalis* Waagen, *Notothyris subvesicularis* (Dav.), and *Spiriferellina multiplicata* (Sow.). Most persisted into the Chhidru beds.

The fossil lists from the Wargal Limestone in Reed (1944) cover 80 pages and are detailed, but provide little stratigraphic information, apart from an indication of basal faunas, and topmost faunas. Intermediate faunas are seldom described, and other faunas are described as 'upper' in contrast to 'top'. Subject to this reservation, the topmost Wargal beds are very rich compared with the middle Wargal, with numerous *Enteletes*, no *Orthotichia indica* (?) or other *Orthotichia* except *derbyi*, *Meekella punjabica* Reed, a number of *Streptorhynchus*, *Schuchertella*, *Kiangsiella*, *Derbyia*, *Waagenites*, *Tschernyschewia*, Lyttoniids as in lower beds, restricted *Megasteges dalhousei* (Davidson) (as in Waagen, 1891), *Chonetella* and *Marginifera* as in upper beds, restricted 'Dictyoclostid' *celsus* Reed; Anidanthinid '*weyprechti* (Toula)', ?*Stepanoviella lahuseni* (Likharev), *S. kulikii* (Fred.) and *Compressoproductus mongolicus subcircularis* (Reed), *Wellerella* spp. *Pugnoides*, ?*Purdonella scopulosus* (Reed), *P. limitaris* Reed, *P. conformis* Reed, *Tomiopsis punjabica* (Reed), and species of *Martinia*, *Dielasmina* and *Notothyris*. A number of coolwater genera are present, including numerous linoproductinids, *Tomiopsis*, *Martinia*, and *Dielasmina*, which is related to *Fletcherithyris* of Australia. Perhaps this cooling was contemporaneous with the Gijigin tillite of north-east Siberia.

The overlying Chhidru Formation, previously called the Upper Productus Limestone, is 90 m thick, and composed chiefly of limestone and sandy limestone (Teichert, 1965). Compared with the underlying Kalabagh Member, Chhidruan faunas have fewer *Enteletes*, no *Streptorhynchus*, *Plicatoderbyia*, *Chonetina*, *Aulosteges*, fewer *Tschernyschewia*, no *Juresania*, ?*Chianella*, *Stepanoviella*, *Compressoproductus*, *Uncinunellina*, *Hustedia*, *Tomiopsis*, *Heterelasma* or *Gefonia*. New genera include *Sphenalosia*, *Tyloplecta*, *Fredericksia*, and *Cryptacanthia* — new, that is, for the Salt Range, but found in older beds elsewhere. New species include '*Chonetes*' *squama* Waagen, *Strophalosia blandfordi* Reed, *Sphenalosia salmunensis* (Reed), and *Costiferina aratus* (Waagen). Thus even basing an assessment of faunal studies more than 30 years old it is possible to distinguish the two faunas.

No Fusulinacea are present in either Kalabagh or Chhidru faunas, but the significant ammonoids *Xenodiscus* and *Cyclolobus* are present although discrimination between the substages does not appear possible (Furnish & Glenister, 1970), perhaps because specimens are so few. Just how extensively these ammonoids, particularly *Cyclolobus*, enable correlation has been debated. It appears probable that *Cyclolobus* of this age lived in a geographically restricted area, around the margin of the present Indian Ocean, now separated as the Himalayas, Salt Range, Timor and Madagascar (Waterhouse, 1972b). Even the Himalayan correlation has now come into question from Grant & Cooper, 1973 (see Table 9), though their view is not supported by brachiopod evidence.

Himalayas

According to most published studies, Punjabian faunas are wide-spread in the Himalayas of Kashmir, Kumwaon, Nepal and southern Tibet, as reviewed and summarized by Waterhouse (1972a).

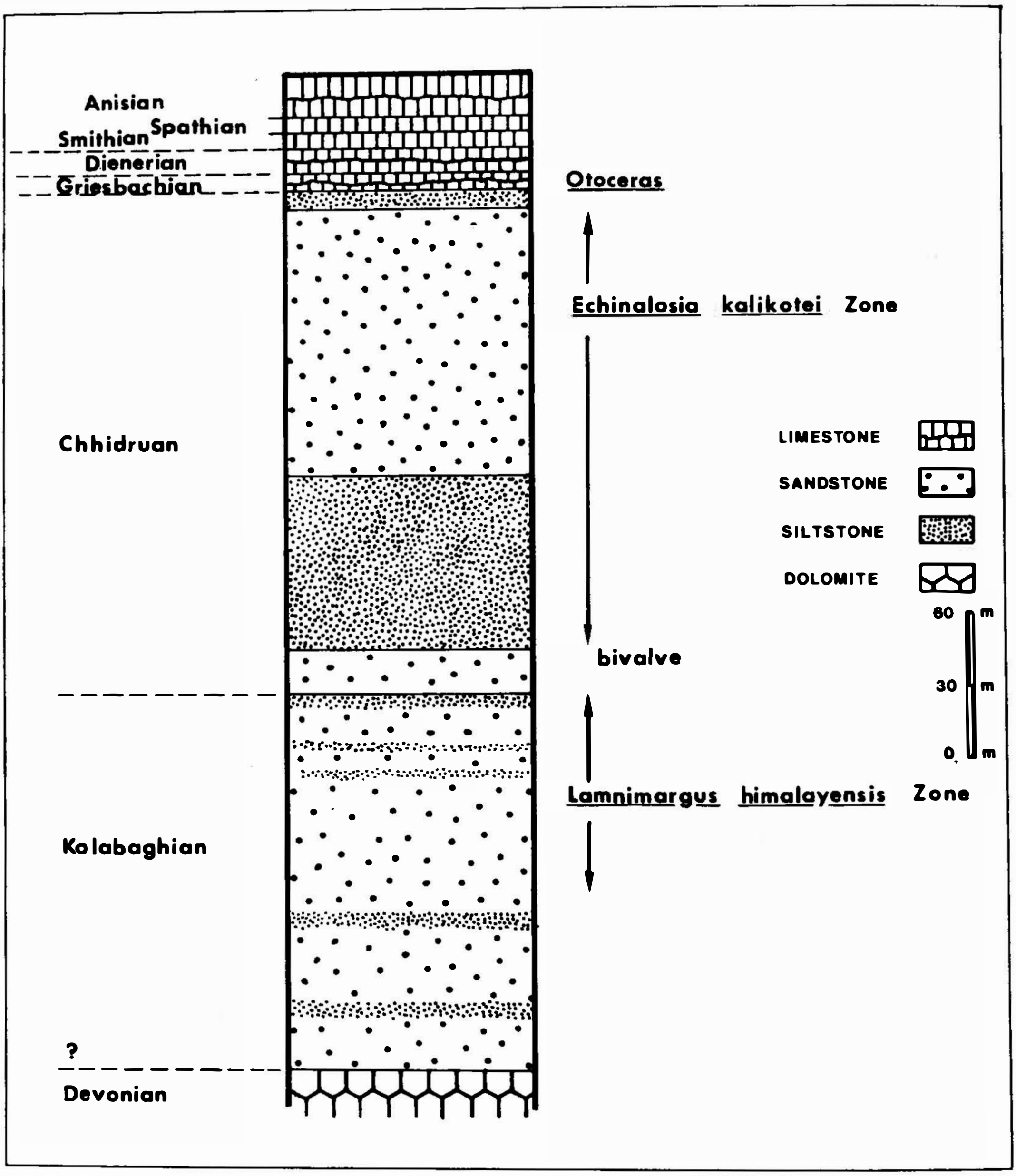


Fig. 30. Simplified stratigraphic column of Permian and Triassic beds in Panjang Kola, Dolpo District, north-west Nepal, from field work by the writer. Ages for the *Otoceras* and *Lamnimargus himalayensis* beds are well established, but the ages of the intervening bivalve (*Pyramus*) and '*Echinalosia*' *kalikotei* faunas require further study.

The fullest Punjabian sequences apparently occur in the Dolpo district of northwest Nepal (Fig. 17, 30) judged from field work and preliminary laboratory studies as yet unpublished by the writer, within the broadly defined Chini-Thu Formation of Fuchs (see Waterhouse, 1966). Micaceous dark silty shales and quartzites of the lower part of the group contain *Lamnimargus himalayensis* (Diener), *Marginifera typica* Waagen, *Costiferina alatus* Waterhouse, *Anidanthus fusiformis* Wat., and *Fusispirifer nitiensis* (Diener) and other brachiopod species. The *Lamnimargus himalayensis* Zone is also found in sandstone of the Lachi Group of North Sikkhim (Muir-Wood & Oakley, 1941), in the Selung Group on the Tibetan side of Mt Jomlo Lungma (Everest) (Mu Antze *et al.*, 1973), and the Productus Shales in the Lissar Valley (2 miles south of peak Darma no. X1) (Diener, 1903), and the Productus Shales of Byans (Diener, 1903). Other localities in the Productus Shales lack the key species, but on the whole share more species with the *Lamnimargus himalayensis* Zone, than with the *Echinalosia kalikotei* Zone, discussed below. However the beds at the Kiunglung camping ground (Diener, 1897b, 1903) could be slightly younger. The zone is well represented at Spiti in the Kuling Shale, of calcareous sandstone at the base and chiefly shale. Underlying sandstone has yielded few fossils.

The brachiopods of the Zewan beds of Kashmir have been described principally by Davidson (1862) and Diener (1899, 1915). Diener (1915) arranged the faunas into six horizons, of which the lower two have few brachiopods, and may be little older than the overlying horizons. They contain *Spinomarginifera*? and *Leptodus*, but do not share significant species with the lower Spiti sandstone. Underlying beds contain *Glossopteris* plants. The main fossiliferous horizons are those of Zewan 3 and 4, essentially similar to each other. The lower horizon contains *Lamnimargus himalayensis* and various dictyoclostid and retariid Productacea. The overlying horizon is dominated by *Spiriferella rajah*, but has no unique species. Zewan 5 is a minor horizon. In short, Zewan 3-5 are a complex of several communities dominated by different species at different levels, but all apparently belong to one *Lamnimargus himalayensis* Zone. The topmost or Zewan 6 fauna is provisionally assigned to the uppermost Permian, as discussed later. A number of species from Zewan 3-5 are shared with those of the Kalabagh Member of the Wargal Formation in the Salt Range (Diener, 1903, 1915; Waterhouse, 1966, 1972a).

No Fusulinacea are known, but ammonoids are found at several localities. Furnish *et al.* (1973) have recorded *Cyclolobus walkeri* Diener from some 20 m below *Otoceras* beds at Guryul Ravine in the Zewan beds of Kashmir. Diener (1903) also recorded species of *Cyclolobus* and *Xenaspis* (=*Xenodiscus*) from the Kuling Shale, some 10 m below the *Otoceras* beds, and other specimens have been collected by a Danish expedition. All are referred to *Cyclolobus walkeri* Diener by Furnish & Glenister (1970, p.165), thus suggesting correlation with the Chhidruan fauna of the Salt Range, which contains *C.* cf. *walkeri.* Diener referred some of the species *kraffti* Diener and *haydeni* Diener from the Kuling Shales to a new subgenus or genus *Krafftoceras*, on the basis of a complexly ramnified siphonal saddle, but this is discounted by Furnish & Glenister (1970), and Furnish (1966) synonymised *Krafftoceras* with *Cyclolobus.*

A number of tiny ammonoids are found at Lilinthi in the Productus Shales of Byans, identified by Diener (1903, p.115) as *Hyattoceras* n. sp. ex aff. *H. cumminsi* White, *Gastrioceras* sp. ind. ex aff. *G. marianum* Vern., *Lilinthiceras* n. gen. sp. ind., and *Nomismoceras smithii* Diener. They include a form ascribed to *Hyattoceras*, now generally synonymised with *Waagenoceras*, but suggested to be possibly of Kungurian rather than Kazanian age. *Lilinthiceras*, with no species named, is said to be close to Triassic forms in shape and sculpture. Presumably the Byans ammonoids were essentially contemporaneous with *Cyclolobus* from the Kuling Shales, as *Waagenoceras* is known elsewhere to occur with *Timorites*, in United States, and with *Cyclolobus* in Timor.

Amongst Permian faunas of the Himalayas, the richest comes from a limestone crag Chitichun no.1 in southern Tibet, chiefly from talus at the base, thus precluding any detailed stratigraphic study (Diener, 1897a, 1903). The crag itself is part of the topmost nappe of the Himalayas, and is believed to have travelled southwards with enclosing ultramafics from the vicinity of the Indus suture. The outstanding fossils are *Strophalosiina tibetica* (Diener) and *Elivina tibetana* (Diener), also reported from faunas of apparent Punjabian age in south-east Asia, especially Cambodia, and Timor, but not known in the 'Tibetan' Zone or nappe of the Himalayas. Other important forms include *Chaoiella chitichunensis* (Diener) and '*Spirifer*' *wynnei* Waagen. Many species were identified by Diener (1903) with shells from the Sosio beds, of supposed Kazanian age, but it must be noted that internal details were seldom available in Chitichun material, so that identifications, especially generic, lack certainty. Moreover, faunas like those of the Sosio beds also occur in slightly younger faunas, believed to be of Punjabian age on the basis of *Attenuatella* and *Yabeina*, in Tunisia. Diener (1903, p.53) argued that the fauna was to be correlated with the Wargal, and especially Kalabaghian Member of the Salt Range, on the basis of some 27 species. Of these 23 were also shared with the Chhidru Formation, but four were exclusive to the Wargal. Although some of the identifications may be questioned, this still appears to be an acceptable conclusion. But some reservation must be retained because stratigraphic control within the crag has not been achieved; and the overall geological setting of the limestone points to possible origin from a carbonate bank on a guyot or mid-oceanic ridge, under conditions of slow sedimentation and high likelihood of faunal condensation or intermixing. Such can be resolved only by re-examination of the fauna, with attention to internal detail. Strong support for a Punjabian age for the Chitichun no. 1 fauna is offered by the ammonoid *Cyclolobus walkeri* Diener at Chitichun no. 1, which Furnish & Glenister (1970, p.172) have recognised as *C.* cf *walkeri* in the Chhidru Formation of the Salt Range

In north-west Nepal, the *Lamnimargus himalayensis* Zone is overlain by some 100-200 m of calcareous sandstones, coquinites, shales and other lithologies with rich brachiopod faunas of the *Echinalosia kalikotei* Wat. Zone (Fig. 30). Some species are shared with the underlying zone, but many additional species appear as well in a complex of lithotopes and communities, including new species of *Rugaria*, *Krotovia*, *Cancrinella*, *Platyconcha grandis* Waterhouse, *Quinquenella glabra* Waterhouse, *Megasteges nepalensis* Wat., *Transennatia gratiosus* (Waagen), *Pterospirifer*, abundant *Spiriferella rajah* (Salter), and *Neospirifer ravana* (Diener). The zone lacks ammonoids apart from fragments of what appear to be *Xenodiscus*, but there are some strong faunal links with the underlying *Lamnimargus* Zone, that the zone is conceivably only slightly younger, and therefore upper Punjabian or Chhidruan in age. This appears to be reinforced by the presence of some Chhidruan species, as well as the absence of any Djulfian key species and genera. Thus the Nepalese succession provides some support for the assertion by Grant (1968, 1970) and Waterhouse (1972a) that the Kalabaghian and Chhidruan faunas are closely related, but show zonal differences, as expressed herein by the use of substages for the two units, placed in one stage.

In the Thakkola region of north-east Nepal, Bordet *et al.* (1971) assigned almost 600 m of coarse and fine clastics with some carbonate to the Chini Thu Formation, overlying early Carboniferous carbonates of the Tilicho Lake Formation. The topmost fauna contained *Spiriferella rajah*, suggestive of a Punjabian and perhaps Chhidruan age, but the lack of accompanying fossils prevents assignment to one of the zones found in west Nepal. Fossils from the underlying beds display, from the lists in Bordet *et al.* (1971), a bewildering array of affinities and ages, so that assessment must await formal description. It was suggested that the beds represent in part the great unconformity between Chini Thu and Ice Lake beds to the west (Bordet *et al.*, 1971, p.116). The spiriferids, as provisionally identified by Mme Legrand, suggest a lower Permian age, or even correlation with the Fenestella Shales of Kashmir. The accompanying Productida were provisionally identified by Mme G. Termier with early Middle and early Carboniferous genera, and the Permian genus *Stepanoviella*. The faunal sequences promise to be of high value when described.

The upper faunas from the Selung Formation of south-west Tibet north of Mt Jomlo Lungma include *Neochonetes*, *Chonetella nasuta*, *Transennatia*, *Stenoscisma gigantea* (Diener), and *Phricodothyris* (Mu An-tze *et al*., 1973) which may be of Chhidruan age.

It would thus appear that modern studies have on the whole reinforced early work by Diener (1903, 1915), with the recognition of two major faunas, rather closely allied, as in Waterhouse (1972a).

Grant & Cooper (1973, fig. 4, see Table 9 herein) offered another view, showing the Kuling Shales (with *Cyclolobus*) as very late Permian (or Changshingian Stage i.e. Dorashamian), the Productus Shales (with *Waagenoceras*?) as Capitan-Word (i.e. Kazanian-Punjabian), and the entire Zewan fauna (with *Xenodiscus*, *Cyclolobus*) as approximately Kungurian-Baigendzinian (Leonardian). Yet all fall in one *Lamnimargus himalayensis* brachiopod zone.

Karakorum, Afghanistan

Several faunas from the Karakorum Range are similar. From the upper Hunza Valley Sestini (1965b) recorded two small faunas as probably Lower Permian in age. They include *Neochonetes*, *Linoproductus lineatus* (Waagen), *Elivina tibetana* (Diener) and *Fusispirifer nitiensis* (Diener) as in the lower Punjabian faunas of the Himalayas.

From the Camp Staghar glacier in the Karakorum Range, Merla (1934) and Sestini (1965d) recorded a fairly large brachiopod fauna in white fine limestone, supposedly of Lower Permian age, and with a number of early Permian species, but also with many Salt Range Wargal species. Merla (1934) called the fauna 'Lopingian'. Renz (1940b, p.277) described another large fauna from the Shaksgam Valley of the Karakorum, assigning it to the Upper Artinskian. But brachiopods, even though in need of revision, and including many tiny specimens, strongly suggest a Kazanian or Kalabaghian age, probably confirmed by accompanying large *Parafusulina*. The fauna includes *Compressoproductus*, *Choristitella wynnei* (Waagen), *Martinia*, ?*Chaoiella margaritatus* (Mansuy) and ?*Attenuatella*. *Attenuatella* occurs in Chhidruan faunas of Mexico, New Caledonia, New Zealand and Australia and in ?Kalabaghian or late Kazanian faunas of Tunisia and perhaps Taimyr Peninsula. On the whole the fauna would appear to be late Kazanian or Kalabaghian in age. Sestini (1965d, p.168) added various species, including some Sosio forms, and others found in the Wargal Formation of the Salt Range, such as *Marginifera typica* Waagen and *Costiferina spiralis* (Waagen). There are further species in common with Himalayan forms, such as *Anidanthus fusiformis* Waterhouse, *Megasteges dalhousei* (Dav.) and *Stenoscisma purdoni* (Dav.). *Parafusulina* and *Pseudofusulina* occur rather than *Neoschwagerina* or *Yabeina*, perhaps as in the *Leptodus* beds of Japan. However there is some doubt over the correlation. Whilst it is true that there appear to be strong faunal links with the Wargal Formation, and few with the Amb Formation, the illustrations, descriptions, and especially stratigraphy are not well enough established to allow confidence, and few of the species identifications can be sustained without re-examination of the material. At a generic level, the faunas approach the late Sakmarian faunas of the Trogkofel Limestone of Austria, and Safetdaron fauna of Fergana. It is considered that the similarity is due to similar palaeogeographic conditions, but further study is needed.

Carbonates in the upper part of the Permian sequence described by Termier *et al.* (1974) from south of Kabul, Afghanistan, are likely to be of Kalabaghian age, with *Marginifera typica* Waagen.

Southeast Asia, China, Japan

Levels 7 and 8 of Cammon, Cambodia, as set out by Deprat (1913), contain *Yabeina globosa* (Yabe) and may be Kalabaghian, or perhaps late Kazanian, as discussed previously. A Kalabagh age is preferred from Japanese evidence.

Member C of Ishii *et al.* (1969) at Sisophon, west Cambodia (Table 38) contains *Yabeina asiatica* Ishii and *Lepidolina multiseptata* (Deprat), with a fairly large brachiopod faunule of Kalabaghian age, including species typical of the Himalayan faunas, such as *Strophalosiina tibetica* (Diener), *Lamnimargus himalayensis* (Diener) and *Elivina tibetana* (Diener). A number of species occur in common with the Kalabagh fauna of the Salt Range (see also Waterhouse, 1972a, 1973a). Many of the species recorded by Chi-Thuan (1961) from supposedly slightly older beds are listed in Member C. Allied faunas were recorded by Deprat (1913) for Indochina, with *Lepidolina multiseptata* found at level 9 at Sisophon (Table 19, Table 42).

The high level 10 recorded by Deprat (1913) is typified by distinctive brachiopods from Luang Prabang described by Mansuy (1912), including ?*Monticulifera* (or *Choanoproductus*) *paviei* (Mansuy), ?*Krotovia nystianus* (De Kon.) and *Stepanoviella mekongensis* (Mansuy). These in turn are overlain by bivalve beds with *Liebea*, and similar brachiopod species at level 11, possibly also Chhidruan in age on the basis of superposition and world brachiopod distributions. Similar brachiopods occur at Bannahai (Mansuy, 1919, p.91). At Sisophon, the correlative *Permophricodothyris grandis* Zone, or Member D of Ishii *et al.* (1969, p.48) is typified by *Echinauris khmerianus* (Mansuy), and possibly identical '*Monticulifera*', identified by Ishii *et al.* (1969) with *sinensis* (Frech), a species from the mid-Maokou Limestone of China. *Permophricodothyris grandis* (Chao) is found as in the Chhidru and Choutang beds. Fusulinacea include species of *Parafusulina*, with *Lepidolina multiseptata gigantea* (Gubler), and *Yabeina minuta* Thompson and Wheeler.

From black argillites in Quang Tri, central Vietnam, Chi-Thuan (1962) recorded a small fauna that included several chonetid species originally described by Chao in the Wuchiaping and Changsing beds of China. A nearby richer fauna of Vietnam included *Leptodus nobilis*, *Schuchertella semiplana*, alleged *Lamnimargus himalayensis*, *Uncinunellina jabiense* and a Changsing species *Spinomarginifera kweichowensis* Huang. The latter fauna appears to be Kalabaghian and several of the species are identified with species found at Horizon C of Sisophon. But the argillite may be as young as Djulfian.

A small Punjabian collection described from Petchabun, Thailand, by Yanagida (1964), includes species of *Orthotichia*, *Orthotetina*, *Tyloplecta nankinensis* (Frech), *T. yangtzeensis* (Chao), *Marginifera banphotensis* Yanagida, and *Haydenella kiangsiensis* (Kayser) (Table 19).

From Bukit Tengku Lembu, Perlis, Malaysia, Ishii *et al.* (1972) recorded sandstones with the chonetid *Micraphelia*, known also in Guadalupian faunas of Texas, and *Monticulifera*, with a few other forms. Correlation with Member D of Sisophon, as suggested by Ishii *et al.* (1972), seems eminently acceptable, and helps correlate the Chhidruan Substage with part of the Guadalupian succession of Texas.

From Htam Sang in Burma, Reed (1933) described a fauna that may be approximately Punjabian in age with *Martiniopsis* and Leptotids, and a number of Chhidru as well as Kalabagh species. The record of *Krotovia*, *Martinia*, *Phricodothyris*, *Martiniopsis* and several *Notothyris*, mostly not figured, so not available for assessment, suggests a Kalabaghian age as most likely, without being able to rule out a mid-Kungurian age. Another Wargal equivalent is reported by Reed (1933) from the road to Tuang-gyi, Mong Pawn, with *Strophalosiina* cf. *tibeticus* (Diener), typical of the lower Himalayan fauna, and *Schuchertella semiplana* (Waagen).

The *Yabeina* Zone is well developed in the upper Maokou Limestone of China, overlapping the range of *Neoschwagerina*, and accompanied by *Verbeekina*, *Chusenel-*

Level	Fauna, locality	Correlation
11	Luang-Prabang greywackes, ?*Krotovia nystianus* (De Kon.) *Liebea*	Chhidruan Substage
10	*Monticulifera paviei* (Mansuy), ?*Krotovia nystianus* (De Kon.)	
9	*Lepidolina multiseptata* (Deprat), Sisophon	Kalabagh Substage
8	Pong Oua Limestone, *Yabeina globosa* (Yabe)	early Kalabaghian?
7	Pong Oua Limestone, Laos, *Neoschwagerina margaritae* Deprat *N.* cf *globosa* (Yabe), *Leptodus*, *Linoproductus* dielasmatids	upper? Kazanian Stage
6	Black limestone, Cammon, *Pseudofusulina subcylindrica* (Deprat)	
5	Langnac carbonate *Neoschwagerina margaritae* Deprat	Kazanian Stage
4	Limestone, *Neomisellina lepida* Schwag.; *Verbeekina verbeeki* (Gein.), *Neofusulinella lantenoisi* Deprat	Ufimian level
3	Limestone, *Spiriferella*, Licharewiniid	?Elkin level
2	Limestone at Cammon, *Neofusulinella lantenoisi* Deprat, *Parafusulina richthofeni* (Schwag.)	?Nevolin level
1	Carbonate at Cammon and Cambodia, *Uncinunellina timorensis* (Beyrich), *Chaoiella sumatrensis cambodgensis* (Mansuy); *Spiriferellina* ?*Septacamera garoudi* (Mansuy)	?Filippovian Substage

Table 42. Sequence in Indo-China, simplified from Deprat (1913, p. 76)

la, *Neomisellina*, *Kahlerina*, *Lantschichites* and *Wutuella*. No associated ammonoids are found. Only a few brachiopods were mentioned by Huang (1932a,b; 1933, p.97), reflecting the small amount of study on the faunas. The species may indicate a general correlation with the Kalabaghian of the Salt Range and Himalayas, for they include *Neochonetes*, *Waagenites*, *Compressoproductus mongolicus* (Diener), *Hustedia grandicosta* (Dav.), *Terebratuloidea depressa* Waagen, *T. davidsoni* Waagen, *Phricodothyris* and *Martinia*, with *Krotovia janus* Huang.

Although Sheng & Lee (1974) appear to provide a disconcertingly different account of the faunas, showing *Yabeina* to be correlative with faunas containing *Kufengoceras*, *Mexicoceras*, *Altudoceras* and brachiopods *Neoplicatifera huangi* and *Cryptospirifer*, the correlations may be lumping ammonoid and brachiopod faunas. Their text does not explain the position of *Kufengoceras*.

The Kuman Stage of Toriyama (1967) is found in clastics and black limestone some 900 m thick (Table 20, Table 32), structurally complicated and represented by several 'biofacies' or communities. The lower part of the Kuman Stage, as herein restricted to exclude the Gujo fauna following Waterhouse (1969b), is equivalent to the Punjabian Stage. This involves the *Lepidolina toriyamai* Zone and elsewhere the *Yabeina shiraewensis* Zone, both said to overlap somewhat with the *Yabeina globosa* Zone. Not all faunas can be dated accurately, but most show a general Punjabian appearance, Shimizu (1963) recording upper Wargal brachiopod species from the Mitsu area, and Yanagida (1958) recording a few brachiopods in the Mizukoshi Formation in shales about 100 m below the top of the upper member, just above an assemblage with *Lepidolina toriyamai* and *Yabeina* cf *gubleri*. A number of brachiopods have been described from the Kitakami massif, where the upper Kanokura 'Series' has been subdivided into lower *Lyttonia* (=*Leptodus*) and upper *Lepidolina* faunas (Kanmera, 1953). *Timorites* occurs low in the Kanokura beds (Furnish, 1966; Waterhouse, 1972a) to suggest a Captanian (=Punjabian) age. The Katchizawa Member has *Monodiexodina* persisting from older rocks with *Leptodus richthofeni* Kayser and other brachiopods (Minato *et al*., 1954; Nakamura, 1959). It is correlated with a *Neoschwagerina* fauna in the Kamiyase-Kesenmura area by Onuki (1956), who records other brachiopods also in the Maiya area. The overlying Iwahata Limestone has the *Lepidolina multiseptata* fusulinacean assemblage with compound rugose corals. Hayasaka (1925; 1963, p.753) also reported on the Lyttonid beds and brachiopods in the southern Kitakami region and from the Kamiyase region in the Shigejizawa Sandstone Member, with *Yabeina* (*fide* Murata, 1964, p.21), *Verbeekina*, and *Parafusulina*, and a somewhat non-descript ammonoid fauna of early mid-Permian appearance, including *Propinacoceras* and *Stacheoceras*, like the Iwaizaki Limestone which has *Yabeina shiraiwensis*, with *Propinacoceras* and *Stacheoceras* (Murata, 1964, p.23). The Shigejizawa brachiopods include *Leptodus richthofeni* Kayser and others in some need of revision (Hayasaka, 1960). Another *Leptodus richthofeni* fauna was described by Imamura (1953) in the largely clastic Karita Formation, lithologically like the Maizuru Group. From the Maizuru Group, Shimizu *et al*. (1962) recorded a *Lepidolina toriyamai* Kanmera fauna or *Lepidolina kumaensis* — *L. multiseptata* according to Kanmera & Nakazawa (1973, p.104). Sandstones and shales of about the same age contain the Kawahigashi brachiopod faunule (Shimizu, 1961a), with some brachiopod species of the Chhidruan Substage, including *Derbyia altestriata* Waagen, *D.* cf. *grandis* Waagen, *Lissochonetes bipartita* (Waagen), *L. morahensis* (Waagen), *Hustedia indica* Waagen, a Wuchiaping species *Haydenella kiangsiensis* (Kayser) and *Megasteges dalhousei* (Dav.), which is found in Punjabian faunas of the Himalayas and Pakistan.

Kalabaghian brachiopods are found in the Takauchi fauna of the Maizuru Zone (Shimizu, 1961a) with undoubted Himalayan affinities displayed by *Strophalosiina tibetica* (Diener), *Schuchertella semiplana* (Waagen), and *Martinia elegans* Diener.

Leptodus richthofeni Kayser is also present, providing a link to other Japanese faunas.

In summary, it appears that at least two faunas are present. The lower *Yabeina shiraiwensis* Ozawa fauna (Yabe, 1964), perhaps represented elsewhere by the *Leptodus richthofeni* brachiopod faunule, is overlain or partly overlapped by the *Lepidolina toriyamai* Kanmera — *L. kumaensis* Kanmera subzone or communities, associated with Chhidruan brachiopods. But this is a very coarse simplification, because many Fusulinacean communities were present, with complex and overlapping interrelationships.

South Primoyre, Kolyma River

In south Primoyre of western Siberia, the Chandalaz Suite, 700-800 m thick, is likely to be of Punjabian age, with *Verbeekina verbeeki* (Gein.), *Yabeina*, *Lepidolina ussurica* (Dutk.), and species of *Enteletes*, *Prorichthofenia*, *Tyloplecta yangtzeensis* (Chao) and stenoscismatids (Likharev, 1966, table 18).

In the same general region at Kur Ufiimsk the Cereduchin Suite (950-1000 m) is of Kalabaghian age, with the ammonoid *Timorites* and a few brachiopods overlying the Babstov Suite of Kazanian and Kungurian age with a few more listed brachiopods in beds 190 m thick (Table 43). The Tirin Horizon of north and west Verchoyan, 100-700 m thick, may be Punjabian in age (Likharev, 1966, p.351), containing numerous *Atomodesma variabilis* Wanner and *A. costata* Popov, reminiscent of the Puruhauan faunas of New Zealand and Basleo — Amarassi faunas of Timor. *Atomodesma* and *Kolymia* also occur in the Chenoyar Suite of Taimyr Peninsula (Likharev, 1966). Conceivably the underlying upper Baikur horizon of Taimyr Peninsula is as young as Kalabaghian, in view of supposed *Neospirifer bambadhuriensis* (Diener) identified by Ustritsky & Chernyak (1963), and other species, as discussed previously.

The Gijigin fauna of the Kolyma River area may be Kalabaghian, as outlined above. Perhaps the youngest Arctic faunas of Permian age are found in north-east Siberia (Likharev, 1966; Zavodowsky, 1968, 1970) in the Hivatch Suite 164 m thick in Omolon, 2000 m thick in the Kolyma River area (Table 15). The fauna is moderately large, with species of '*Strophalosia*', *Linoproductus*, *Stepanoviella*, *Chivatschella*, and *Neospirifer*, but as the fauna is younger than any other large fauna of northern latitudes there is no basis for comparison, and little evidence about its upper age limits. It may be Punjabian, even as old as Kalabaghian, but could be even late Permian. *Kolymia inoceramiformis* Likh. is present, as in many Punjabian and/or Djulfian faunas of Siberia, Timor, Australia and New Zealand, with other members of the Atomodesminae that are too poorly figured to allow close comparison. However *Etheripecten volucer* (Likharev) is very close to *E. striatura* Waterhouse of New Zealand, suggesting a possible Chhidruan age, and perhaps a Chhidruan age is supported by the large Strophalosiid species, such as *S. chivatschensis* Zavodowsky, like *Echinalosia kalikotei* Wat. from Chhidruan beds of north-west Nepal. On the other hand the numerous linoproductinids suggest a Kalabaghian age.

Mongolia, Pamirs, Armenia, Iran

The young Permian faunas of Mongolia from the Jisu Honguer Formation were assessed as allied to both the Wargal faunas of the Salt Range, and the Lopingian of China (Grabau, 1931). The writer has not seen the collections, and can offer no final decision, but as a suggestion, it appears possible that the lower beds are Punjabian, and the upper faunas are Djulfian, as discussed later, in fair measure of agreement with Grabau.

The lower faunas, believed to be Punjabian, come from localities 1190 and 1192, and have numerous *Enteletes*, *Geyerella*, *Aulosteges*, *Kochiproductus*, *Yakovlevia-Muirwoodia*, *Compressoproductus*, *Leptodus nobilis*, *Spiriferella* including a transverse

Stage	Kur Ufim			Significant Fossil
Punjabian		Cereduchin Suite 950-1000m		*Timorites*
Kazanian		Upper middle		
Kungurian	Peschanik Suite =	Babstov Suite lower		
?Baigendzinian		Ungun Suite 750-800m		
		Canar Suite 1700-1800m		
Sakmarian-		Kukan Suite 800m	=?Sibaigou Suite	*Pseudofusulina kraffti* *Cancellina* *Misellina claudiae*
Asselian		Ulkuk Suite 1120-1150 m	=Kavalerov Suite	*Schwagerina* fussiformis*, *S.* moelleri*

Table 43. Correlation of Permian at Kur Ufim, Sikhote Alin (from Likharev, 1966, Table 18).

form like *S. turusica* Einor, and *Notothyris*. The Linoproductids with *Kochiproductus* suggest cool water faunas, as in the Kalabaghian Substage. A number of species range higher, but younger faunas lack the distinctive productids, except in the immediately overlying locality 1196 (Table 46) which might be high Punjabian, as it lacks significant Linoproductidae.

The basal faunas with Linoproductinids are followed by faunas in cherty limestone, some 275m higher at localities 1205-1210 (Table 47). Here *Spiriferella mongolica* Grabau is abundant, a distinctive form ascribed to various species by Grabau, with projecting ventral umbo, long concave posterior walls, simple plicae, and closely costate dorsal fold. This species is difficult to match with other known forms, and may be post-Chhidruan or late Chhidruan in age. Rare shells like *Spiriferella rajah* are found also, suggesting a late Punjabian age, almost exactly comparable in position to late Chhidruan *Spiriferella rajah* communities in Nepal, but perhaps the *Spriiferella mongolica* community is slightly younger. Other species, including Linoproductids, *Marginifera* and *Streptorhynchus*, are rare.

However, I am not satisfied that the preceding ages have been finally established. There is the disconcerting occurrence of what appears to be *Timaniella*, a Kungurian-Kazanian genus, at locality 1209 in the *Spiriferella* bed. The shell was misidentified by Grabau (1931, pl. 23, fig. 5a-c) as *Neospirifer moosakhailensis*, and indicates an Irenian-Lower Kazanian age. If this horizon were really Nevolin (Table 47), the underlying faunas with *Kochiproductus* and Yakovleviinae at loc. 1192 would be Filippovian, and the overlying faunas at loc. 1193 and 1194 with numerous *Leptodus* and *Martinia* would compare with the Sosio fauna. That so great a range of possibilities is still open underlines the need for detailed and specific re-examination of the faunas of the Jisu Honguer beds.

Punjabian faunas appear to be scarcely represented in the Pamirs, north Caucasus or Crimea Peninsula (Table 18). Grunt & Dimetriev (1973, table 1, p.21) showed *Yabeina archaica* Dutk. with *Neoschwagerina margaritae* near the top of the Murgab Stage and *Yabeina* has been recorded from the uppermost Murgabian beds above the Nikitin (Kazanian) faunas of the Greater Caucasus (Likharev, 1966, p.394).

Iran and Armenia offer thin beds with significant faunas of Punjabian age (Table 46). On the Armenian side of the border at the Araxes River (Ruzencev & Sarytcheva, 1965; Waterhouse, 1972a) the Gnishik Horizon contains a number of Fusulinacea, including *Polydiexodina persica* Kahler, *Verbeekina*, *Nankinella*, *Chusenella*, and *Pseudofusulina* and many brachiopods such as *Edriosteges*, *Orthotetina*, *Leptodus richthofeni* Kayser, *Richthofeni lawrenciana* (Koninck), *Phricodothyris indica* (Waagen), and *Terebratuloidea* species in common with the Wargal Formation, and Japanese faunas of Kalabaghian age. Various other species indicate a more general Punjabian age (*Haydenella tumida*, *Leptodus nobilis*). The only puzzling occurrence is that of *Martiniopsis inflata* Waagen, which typifies the Chhidruan Substage in the Salt Range. But an allied Kalabaghian form occurs in New Zealand, suggesting that reexamination of the specimens may change the identification or extend the time range. Similar faunas are found on the Iranian side of the border at Kuh-e-Ali Bashi (Stepanov *et al.*,1969).

The overlying Hachik Horizon of shales and limestone 70-100 m thick has many of the same species, with only four distinct—*Rhipidomella vediensis* Sok., *Orthotetina arakeljani* Sok., *O. dzhulfensis* Sok. and *Septospirigerella megridagica* Grunt. On the Iranian side of the border *Martiniopsis* ex. gr. *inflata* is found at Kuh-e-Ali Bashi (Stepanov *et al.*, 1969, pp.22, 23) at unit 23 and unit 28. The Hachik fauna is likely to be of Chhidruan age, chiefly from its place in the stratigraphic column and the distinctiveness of its fauna from the Gnishik or Kalabaghian fauna. My Armenian colleagues are convinced that the Hachik and Gnishik faunas are more distinct than suggested by the studies in Ruzencev & Sarytcheva (1965).

Over fifty species of Brachiopods, Bryozoa and Mollusca have been described from the Ruteh Formation (Table 31) of the Elburz Mountains, north Iran, by Sestini (1965a). Almost 40% are found also in the Wargal Limestone of Pakistan. Nine species from Ruteh carbonates at levels 1 and 2 suggest or permit a Kalabaghian age, including *Derbyia altestriata*, *Schuchertella semiplana*, species of *Cleiothyridina*, and the presence of *Stepanoviella* and *Compressoproductus*. A few species are also found in the Himalayas. Level 5 has species identified as *Marginifera typica* Waagen and *Costiferina indica* (Waagen), which would suggest a Kalabaghian age if correctly identified, but the stratigraphic position of level 5 is not clear. There is little in common with the faunas described by Douglas (1936) from south Iran, presumably because the ages differ.

The Permian of Djebel Tebaga, Tunisia, (Glinzboeckel & Rabate, 1964) has a brachiopod fauna of modest size high in the Permian sequence in carbonates, clays and grits, with *Yabeina syrtalis* (Douville) and *Yabeina globosa* Yabe, suggesting a horizon close in age to Punjabian faunas of south-east Asia, and Japan. This does not accord well with the very large number of Sosio brachiopod species recorded by Termier & Termier (1957) which would imply a slightly earlier Kazanian age, but the Djebel fauna does have an Ambocoeliid ?*Attenuatella* unknown at Sosio, implying a late Kazanian or Kalabaghian age by analogy with occurrences in Taimyr Peninsula and Omolon-Kolyma River, or even Chhidruan age by analogy with Mexico and New Zealand. Unfortunately the Tunisian brachiopods are sketched, not photographed, so that it is difficult to check identifications. Renewed study of the mid-Permian brachiopods from the Mediterranean, including Sicily, Tunisia, and the Aegean is required to clarify the sequences and correlations. Miller & Furnish (1957) recorded various ammonoids, including *Agathiceras*, *Popanoceras*, *Peritrochia* and probable *Stacheoceras* from essentially the same horizon. They assigned an early Guadalupian age, and considered the fauna to be correlative with that of Sosio, as most of the brachiopod identifications would also suggest. But the presence of *Yabeina* and ?*Attenuatella* appear to be decisive in suggesting a slightly younger age. It is interesting to note the generic similarity of the ammonoids to those described from the Shigejizawa beds of Japan, of Kalabaghian age.

United States, Mexico

The Capitanian Stage of the Guadalupian Series is mostly of Kalabaghian and Chhidruan age (Table 26). Faunas are restricted largely to the Delaware Basin and Guadalupe Mountains (Fig 21). Fusulinacea as summarized by Ross (1967b, p.1352) are typified by advanced *Polydiexodina* with rare but advanced *Yabeina* (Ross & Nassichuk, 1970) as well as *Leella*, *Codonofusiella*, *Reichelina*, *Lantschichites*, etc., most of them known also in older rocks. Brachiopods collected from the middle Capitan of Guadalupe Peak were listed as the typical Guadalupian fauna by Girty (1909, p.16), with a few additional forms since described by Cooper & Grant (1969) and others. It is not possible to assess faunal assemblages or precise age until the redescriptions are published by Cooper & Grant (in press). Noteworthy is the presence of *Orthotetina* (as in Armenia), and supposed *Elivina* (as in the Himalayas), together with *Oldhamina*, Aulostegiids, many linoproductinids, including *Compressoproductus* and *Anidanthus*, various *Wellerella*-like forms, *Crurithyris*, *Martinia* and *Heterelasma*. The ammonoids are referred to *Timorites*, *Medlicottia*, *Kingoceras*, *Xenodiscus*, *Xenodiscites*, *Strigogoniatites*, *Waagenoceras*, *Epadrianites*, and first appearance of *Episagiceras*. Furnish (1973, p.539) included the Manzanita Member at the top of the Cherry Canyon Formation, and the Hegler Member at the base of the overlying Bell Canyon Formation, with most of the rest of the formation up to the Lamar Member, through some 300m of strata, in a restricted *Timorites* or Capitan Zone.

At Las Delicias, west Coahuila (Table 35), Mexico, brachiopods have been described by Cloud (in King *et al.*, 1944). No specific age limits were provided by Cloud, but it is likely that the ammonite shale of band or 'Bed' 5 of King (1944) in the Difunta section is Punjabian, with *Neochonetes*, *Prorichthofenia*, *Leiorhynchoidea*, *Paranorella* and *Attenuatella attenuata* (Cloud). Band 2 has a Buxtoniid and *Leptodus*, with Fusulinacea *Polydiexodina capitanensis* Dunbar and *Rauserella erratica* Dunbar. Band 7 of King (1944, p.14) with *Polydiexodina shumardi* is at the same horizon, according to Spinoza *et al.* (1970). Ammonoids include *Timorites schucherti* Miller & Furnish, *Strigogoniatites kingi* Miller, *Stacheoceras toumanskiae* Miller & Furnish, and *Waagenoceras dieneri* Böse. The ammonoids are regarded as correlative in a general way with those of the Hegler Limestone in the Capitan of the Guadalupe area by Spinoza *et al.* (1970).

Attenuatella attenuata (Cloud) from Mexico is closely allied to *A. incurvata* Wat. of Chhidruan and Urushtenian age in New Zealand (Waterhouse, 1964) and especially to *Attenuatella convexa* Waterhouse (1967b) not Armstrong (1968) from New Caledonia in beds close to the boundary between *Atomodesma trechmanni* (Marwick) and *Atomodesma* cf *trabeculum* Waterhouse. These two species are restricted in New Zealand to the Chhidruan and Urushtenian Substages respectively, and their occurrence together in New Caledonia suggests faunal intermixing, either by collecting or sedimentation, at a time close to the Punjabian-Djulfian boundary. The Mexican species is possibly of the same age, i.e. about late Chhidruan.

Madagascar, Timor, Australia, New Zealand

In north Madagascar, Astre (1934) described a small fauna from the 'Productus limestones' of the lower Sakamena Group. The fauna has various brachiopods suggestive in a general way of a Punjabian or younger age, including a number of supposedly unique species of *Enteletes*, *Liosotella*, *Uncinunellina*, and *Spiriferellina*, with *Neospirifer moosakhailensis* (Dav). and other forms. Overlying shaly sandstones contain two additional brachiopod species, including a sub-species or variety of *Waagenoconcha abichi* (Waagen), a species which is especially characteristic of Chhidruan faunas, and the ammonoids *Cyclolobus walkeri* Diener and supposed *Xenodiscus carbonarium* Waagen (see Waterhouse, 1973b)

Two rich faunas come from Timor, but unfortunately exposures are poor and the structure complex (Table 19, Table 44). The lower or Basleo fauna is clearly Kalabaghian in age (Waterhouse, 1972a), with such diagnostic species as *Strophalosiina tibetica* (Diener), *Megasteges dalhousei* (Davidson), *Chonetella nasuta* Waagen, *Chaoiella chiticunensis* (Diener), *Spiriferella rajah* (Salter), and *Elivina tibetana* (Diener), all identical with Himalayan species, together with the additional species of note, *Camarophoriina antisella* (Broili). The faunas are described chiefly by Broili (1916), Hamlet (1928) and Wanner & Sieverts (1935). The ammonoid *Timorites* is present. Furnish (1973) also stated that 'Wordian' (that is Nevolin to upper Kazanian) ammonoids were present in the Basleo collections. Whether this means that the ammonoids were long ranging, or that the Basleo faunas include two horizons, as could easily be the case, is not clear.

The Amarassi faunas, described by Rothpletz (1892), Broili (1916) and Hamlet (1928) are fairly close to those of the Basleo faunas, but show more affinities with the Chhidru and fewer with the Kalabagh faunas of the Salt Range. However the fauna is not clearly Chhidruan and has few distinctive species (*Timoriina broili*; *Orthotetina altus* Hamlet), leading Waterhouse (1972b) to suggest that it was early Chhidruan in age. Many of Rothpletz's species were not mentioned by Hamlet (1928) and it is not certain whether they were discounted, or as seems more likely simply not rediscovered. An unusual ammonoid *Cyclolobus persulcatus* Rothpletz is found in the Amarassi fauna, with *Timorites*. Spinoza *et al.* (1970, p.731) correlated the Amarassi fauna by means of *Stacheoceras* cf. *tridens* Rothpletz with the Lamar Limestone at the top of the

Stage	Substage	Fauna	
		Brachiopods	Ammonoids
Dorashamian		-	
Djulfian		-	
Punjabian	Chhidruan	Amarassi	Amarassi
	Kalabaghian	Basleo	Basleo
Kazanian			Basleo
Kungurian	Irenian		?Tei Wei
	Filippovian	Bitauni	
Baigendzinian			Bitauni
Sakmarian	Aktastinian		Bitauni
	Sterlitamakian	-	
	Tastubian		Somohole
Asselian			

Table 44. Correlation of faunas from Timor, with occurrences of ammonoids recorded by Furnish (1973, p. 524). See Table 19.

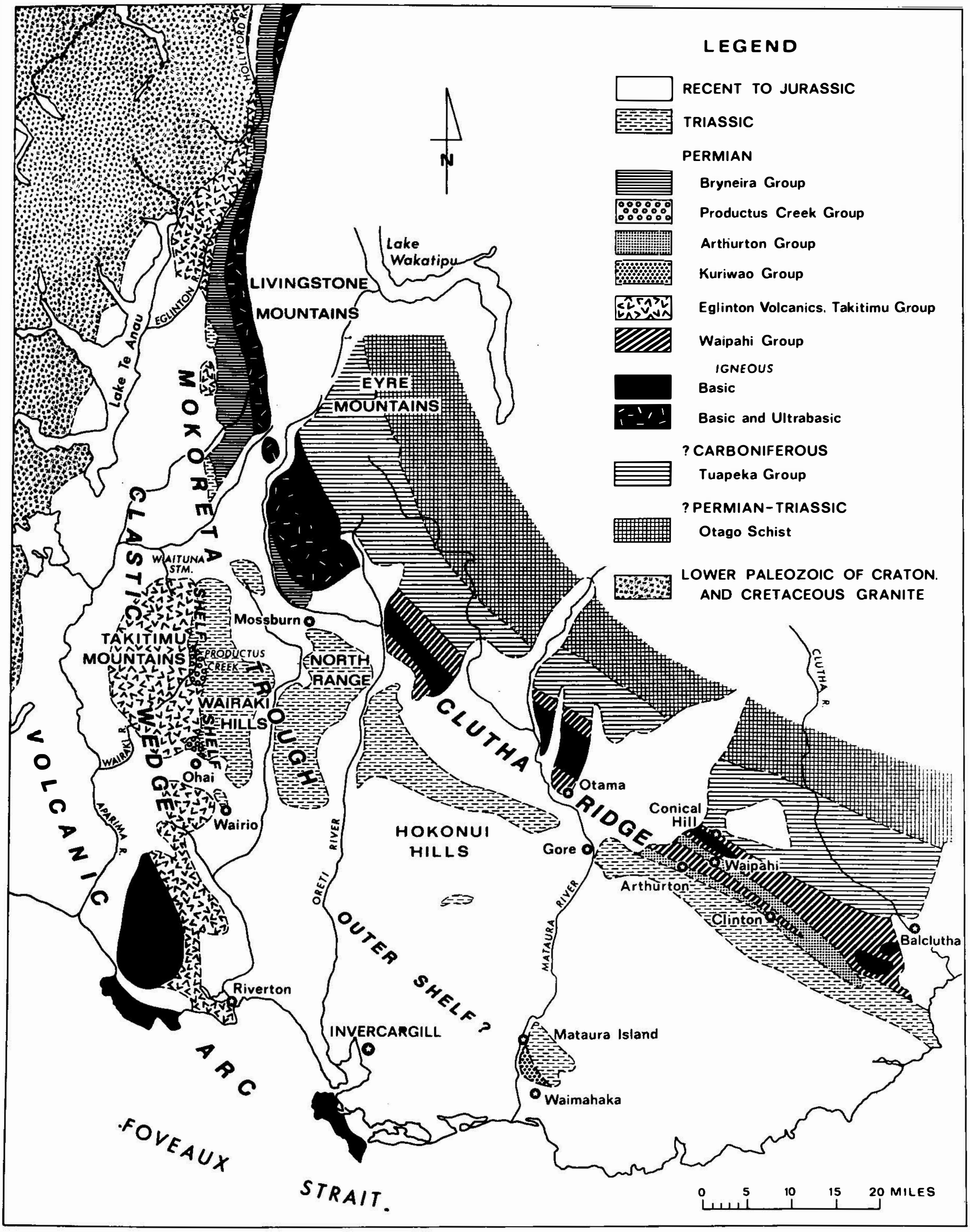


Fig. 31. Geological map of Southland, New Zealand, showing distribution of Permian rocks and formations, with facies that changed during the period. From Waterhouse (1973c, fig. 3, p. 36). Reproduced with permission of Dr W. Tovell, Director, Royal Ontario Museum.

Capitan in Texas—New Mexico and the upper La Colorada beds of Mexico, but it is believed that the beds in North America, at least those of Mexico, may be slightly younger, for they contain primitive Araxoceratidae, suggesting a post-Chhidruan age (Waterhouse, 1972a).

In Western Australia the sequence is largely terrestrial in the middle and late Permian, but a small fauna from the Hardman Member at the top of the Liveringa Formation in the Fitzroy Basin is probably Chhidruan (Table 29), containing *Derbyia grandis* Waagen, *Waagenoconcha imperfecta* Prendergast, *Cleiothyridina gerardi* (Diener), and *Neospirifer ravana* (Diener) according to Thomas (1967). Dickins (1963, p.67) recorded the Amarassi bivalve *Atomodesma undulatum* Rothpletz in the upper Liveringa beds, and Muir-Wood & Cooper (1960) compared *Waagenoconcha imperfecta* to the Amarassi species *W. waageni* Rothpletz). Two small faunas are known from the Port Keats area in the Bonaparte Gulf, northwest Australia (Thomas, 1957, p.181). Fauna C of Thomas has *Martiniopsis* and *Neospirifer*, perhaps suggesting a Kalabaghian age, pending full description, and the overlying Fauna D may be Chhidruan, with *Waagenoconcha imperfecta* and *Leptodus nobilis*, amongst other species yet to be described.

In eastern Australia a Chhidruan fauna appears to be present as Fauna V of Waterhouse (1969c), in the middle Flat Top Formation and upper South Curra Limestone of the Bowen and Gympie Basins, Queensland (Table 38, Fig. 21). Characteristic species include *Capillonia brevisulcus* (Waterhouse), *Plekonella multicostata* Wat., *Stenoscisma papilio* Wat. and *Attenuatella incurvata* Wat., (Runnegar, 1969b; Dear, 1969; Runnegar & Ferguson, 1969), all found as well in a fuller stratigraphic sequence in New Zealand. Runnegar (1969b) correlated the fauna with the Kazanian Fauna IV, but this is not acceptable, because many new species are present in addition to some species lingering on from the underlying stage. However the limits of the faunas are not clearly established as yet (Dear, 1972). Conceivably the Havilah fauna, with *Tomiopsis havilensis* (Campbell) is of this age or slightly older (?Kalabaghian).

New Zealand faunas of Kalabaghian and Chhidruan age are widespread in thick sequences, especially well exposed around the coast-line (Waterhouse, 1973c). Fig. 31. The sequence is as follows:

Age	Formation	Faunal Zone	Thickness
Urushtenian	Little Bed Sandstone	*Spinomartina spinosa*	100 - 700 m
Chhidruan	Tramway Sandstone	*Atomodesma trechmanni*	150 - 700 m
Chhidruan	Wooded Peak & Upper Glendale limestones	*Spiriferella* (subzone)	? + I m
Chhidruan	upper AG4 Formation	*Plekonella multicostata*	50 m
Kalabaghian	lower AG4 Formation	*Martiniopsis woodi*	30 m

The limestone containing the three lower zones varies from 50m to 1,000m in thickness.

Brachiopods within the *Martiniopsis woodi* Wat. Zone (Table 37) are rather few in number, perhaps because diversity was inhibited by flourishing bioherms of rugose corals (in North Auckland) and stenoporid Bryozoa. They are accompanied by

Fusulinacea, including *Neoschwagerina margaritae* Deprat, *Yabeina*, and *Lepidolina multiseptata* (Deprat) (see Waterhouse, 1964, p.13). As *L. multiseptata* is generally regarded as an advanced *Yabeina* a slight unconformity or barren interval may separate the fauna from the underlying *Terrakea brachythaerum* Zone of late Kazanian age. The immediate overlying faunas are more diverse and widespread, with several Kalabaghian and a few Chhidruan links, especially displayed by *Cleiothyridina laqueata* Wat., Rhynchonellid aff. *wynnei* Waagen, and *Tomiopsis parallela* (Wat.) like *T. punjabica* (Reed) from the Salt Range. *Filiconcha* n. sp. is close to *Monticulifera* from the Chhidruan Pong Oua and Luang Prabang faunas of southeast Asia. *Attenuatella incurvata* Wat. entered the sequence, and is found in faunas of Punjabian age in New Caledonia and Mexico, and perhaps in Tunisia, as well as Queensland.

Above this fauna in New Zealand comes *Spiriferella* representing a late Chhidruan community or subzone. *Spiriferella* is also particularly characteristic of what appear to be late Chhidruan faunas in the Himalayas at least in north-west Nepal. Its age in New Zealand, though not finally established, could be identical.

DJULFIAN STAGE

Armenia, Iran, Caucasus

The Djulfian Stage of various authors is redefined following Waterhouse (1972a) to embrace two substages, characterised by Araxoceratidae and by the presence of *Codonofusiella*, persisting from older faunas, and absence of Neoschwagerininae. For the lower of these substages, the name Urushtenian Substage is used, based on faunas and outcrops in the Northern or Greater Caucasus. The name is only provisional, on the basis that it has long been applied to the most diverse faunas yet described. No designated type section is offered until the Russians decide if they want the name. Taraz (1971) has proposed the Abadehian Stage, based on outcrops and faunas in central Iran, which correspond to the same interval. Since the Abadehian unit does not appear to be so richly fossiliferous, its use is deferred pending international discussion, but the name has advantages of being associated with faunas close to those of the overlying type Baisalian and younger beds, and also enjoys priority. The substage overlying the Urushtenian = Abadehian is the Baisalian unit as defined by Waterhouse (1972a) with faunal content described by Ruzencev & Sarytcheva (1965), and type section offered by the section of Djulfa Gorge, Armenia.

In the Greater Caucasus, the Urushtenian Horizon, 12-128 m thick, has very large brachiopod and fusuline faunas described in part by Likharev (1932, 1937) and treated as lower Pamiran by Likharev & Mikluko-Maklay (1964) for their faunal subdivisions in central Asia. Small Foraminifera include *Reichelina minuta* Erk., *Cribrogenerina permica* Lange, and *Pachyphloia paraovata maxima* Mikl.-Makl. Brachiopods of Horizon B of Likharev (1932, 1937) include Punjabian species *Leptodus richthofeni*, *Strophalosiina tibetica*, *Stepanoviella*, *Compressoproductus*, and *Echinauris opuntia* reinforced by *Ombonia* and *Dorashamia* to suggest the likelihood of an early Djulfian age. One of the most characteristic species is *Crurithyris* (=*Orbicoelia*) *tschernyschewi* Likharev. Ruzencev & Sarytcheva (1965, table 2, opp. p.32) showed the Urushtenian as lower Djulfian on the basis of Fusulinacea, and the brachiopod faunas support this correlation.

In the Armenian region, the Urushtenian Substage is poorly represented by *Codonofusiella* (Ruzencev & Sarytcheva, 1965). Arakeljan *et al.* (1964) and Stepanov *et al.* (1969, p.27) however argued strongly to include this band in the upper Hachik horizon. The overlying faunas of the Baisalian Substage are well represented in Armenia

Stage	Substage	Unit Thickness	Significant Fossils
Dorashamian	Griesbachian		*Claraia*
	Ogbinan	20m	*Paratirolites*
	Vedian	4.5m	*Comelicania, Janiceps, Phisonites*
Djulfian	Baisalian	47m	*Haydenella, Vedioceras,* *Dzhulfoceras, Oldhamina* *Araxilevis, Araxoceras, Vescotoceras*
	Urushtenian	?	(upper Hachik, lower Djulfian of Ruzencev and Sarytcheva, 1965) *Codonofusiella Reichelina*
Punjabian	Chhidruan	Hachik beds 70-100m	
	Kalabaghian	Gnishik beds 70-100m	
Kazanian		Armik	*Chusenella, Nankinella*
Kungurian		Asni	*Nankinella*
Baigendzinian		-	*Pseudofusulina, Parafusulina*
Sakmarian		Davalin	
Asselian			

Table 45. Sequence in Armenia, Djulfa Gorge, Dorasham Siding II

World Standard	Ruzencev & Sarytcheva 1965	Furnish 1973
Ogbinan	*Paratirolites*	Changhsingian
	Bernhardites	
	Dzhulfites	
	Tompophiceras	
Vedian	*Comelicania-Phisonites*	Chhidruan (including Kalabaghian)
Baisalian	*Haydenella-Vedioceras*	
	Oldhamina-Araxoceras	*Cyclolobus* Araxian
	Araxilevis	
?Urushtenian	*Codonofusiella*	not stated
Chhidruan	Hachik	
Kalabaghian	Gnishik	

Table 46. Correlation of Armenian sequence proposed by Furnish (1973).

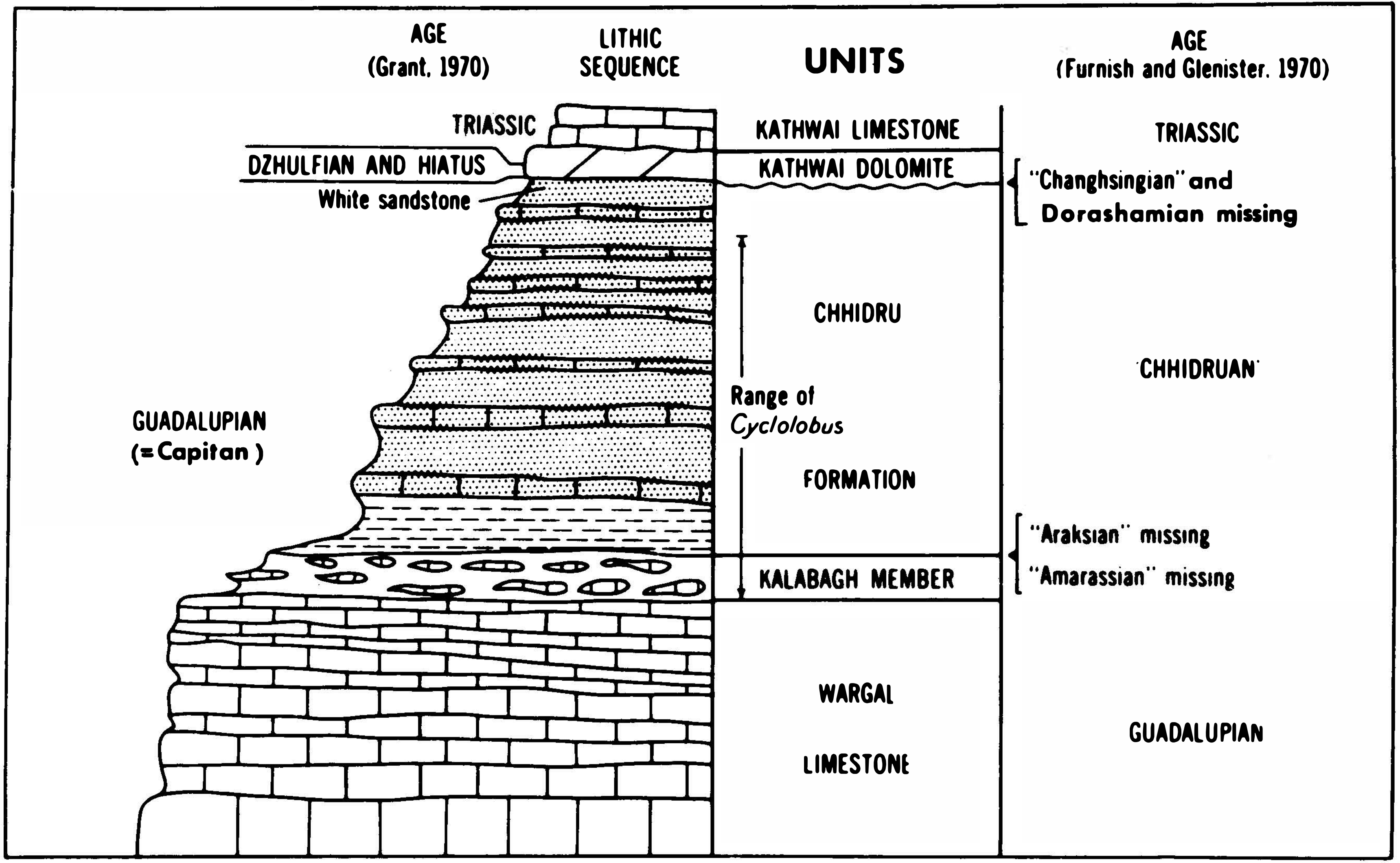


Fig. 32. Diagrammatic comparison of the interpretations of the upper part of the Salt Range sequence offered by Grant (1970) on the left side, and by Furnish & Glenister (1970) on the right side. The centre part is a sketch of the lithic sequence, and the stratigraphic nomenclature; the vertical arrow depicts the range of the ammonoid *Cyclolobus*. From Grant & Cooper (1973, fig. 3, p. 581). Reproduced with permission of the authors.

(Table 45, p.272) as elaborated by Ruzencev & Sarytcheva (1965). Characteristic ammonoids include *Vedioceras* and *Araxoceras*, and correlative zones are recognised across the border in northern Iran by Stepanov *et al.* (1969) with an additional *Tyloplecta* Zone. The same brachiopod faunas range westwards into the Bellerophon Limestone faunas of Yugoslavia and Austria, described by Heritsch (1934), Simic (e.g. 1935b), Stojanovic-Kujenko (1963) and others, with the report of *Crurithyris* to suggest Urushtenian as well as Baisalian faunas. In central Iran, Taraz (1971) has recorded Djulfian faunas, and proposed an Abadehian Stage for the lower faunas between the Hachik and later Djulfian. His unit 6 (Taraz, 1971) contains *Eoaraxoceras* and *Kingoceras* (Furnish, 1973, p.542), indicative of an Urushtenian = Abadehian age.

Furnish (1973) offered a different interpretation of these faunas (Table 10, Table 46). The lower and middle Baisalian faunas were assigned to an Araksian Stage and separated from the overlying *Vedioceras-Haydenella* fauna although there is no significant faunal distinction that I can discern, indeed as Stepanov *et al.* (1969) also confirmed. The *Vedioceras-Haydenella* fauna was regarded as one with the overlying *Comelicania-Phisonites* fauna, although in fact the brachiopods and ammonoids are very different. Species of *Xenodiscus* from the Chhidru Formation, Pakistan, were matched by Furnish with species from the *Phisonites* Zone, and *Vedioceras* was correlated with a fauna of no clear stratigraphic position in China (Chao, 1966), and with the Amilobé beds of Madagascar. The *Vedioceras* correlations are acceptable, but not stratigraphically significant, and the link proposed by *Xenodiscus* seems dubious, for *Xenodiscus* is a long ranging genus (Middle Permian into Triassic), and cannot be reliable except at specific levels.

Djulfian faunas are well established in the Elburz Mountains of north Iran (Table 31). A small fauna described from level 3 and ?3 in carbonates by Sestini (1965a) is Urushtenian judged from brachiopods, including *Orthotetina* and *Orbicoelia tschernyschewei* (see Waterhouse, 1972a). Level 5 of Sestini (1965a), p.24) could be Baisalian, for its stratigraphic position is not certain, but its species suggest a Punjabian age, as discussed previously. A typical Baisalian brachiopod faunule has been described from 'bed 8' of the upper Nesen Formation in the same region by Sestini & Glaus (1966).

Pakistan

Elements of the same Urushtenian fauna, including *Orthotetina* cf *arakeljani* (low in the Djulfian of Armenia), *Chonetella*, *Spinomarginifera*, *Crurithyris*, (?*Orbicoelia*) *extima* Grant, and *Martinia* are found in the basal Kathwai Member of the Mianwali Formation of the Salt Range, Pakistan (Fig. 32), immediately above the Chhidru Formation (Table 28). The brachiopods are clearly Permian in age, as well demonstrated by Grant (1970), and Grant & Cooper (1973). These authors assigned a latest Permian ('Changhsingian') age, or earlier late Djulfian age. This could be correct, but not on the bases so far published. Waterhouse (1972a) pointed out that this late age was based on misinterpretation by Grant (1970) of the Ruteh faunas set out by Sestini (1965a). My preference for a lower Djulfian age is based primarily on the occurrence according to Grant (1970) of *Orthotetina* cf. *arakeljani* like a Urushtenian or early Baisalian species from Armenia, *Crurithyris* or *Orbicoelia*, widespread in Urushtenian faunas, and *Martinia* like a late Lamar Limestone species (?Urushtenian) of New Mexico. If these have been misidentified, the age could be younger, perhaps as young as late Dorashamian, i.e. Griesbachian, for *Crurithyris* and possible *Orthotetina* have been found by the writer above *Otoceras* in north-west Nepal. A Changhsingian age (= ?Vedian) would seem less likely, as it would imply that the Kathwai unit was bounded above and below by paraconformities, but Grant (1970) noted a strong resemblance of Kathwai *Crurithyris* to *C. speciosa* Wang from the Changhsingian faunules of China.

The Kathwai fauna has occasioned violent debate about its age, particularly from

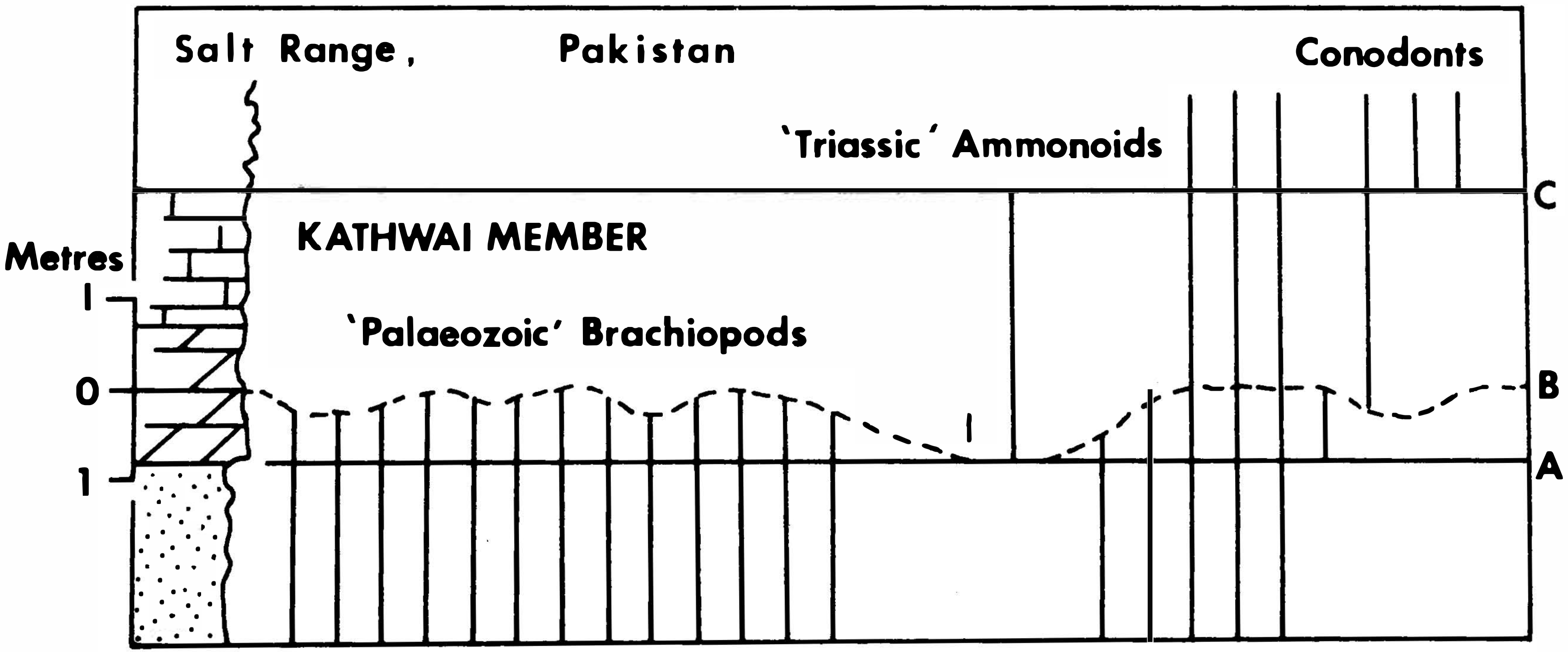


Fig. 33. Permian – Triassic boundary beds in the Salt Range, West Pakistan, with three interpretations of the best placement of the boundary. A. Boundary selected by Kummel & Teichert (1970); B. Interpretation of Grant (1970); C. Permian at the top of the Kathwai member. From Newell (1973, fig. 2, p. 6). Reproduced with permission from Dr N. D. Newell.

Kummel & Teichert (1964, 1973 and other papers of similar content), who have strongly stated that the brachiopods are Triassic in age, and attacked the integrity of opposition to their view. Kummel & Teichert (1973, p.23) stressed that underlying white sandstone had similar brachiopods, and deduced that this implied a Triassic age for the overlying dolomite, without demonstrating why this does not suggest that the white sandstone is also Triassic, or alternatively, ensure a Permian age for the brachiopod faunules. According to Grant (in Kummel & Teichert, 1970, p. 35), the white sandstone brachiopods are Chhidruan, not Kathwai, in affinity. Conodonts however range through both units. The brachiopod faunule is so convincingly Permian that one must wonder why a Triassic age should ever have been entertained. The reason is provided by the discovery by Schindewolf (1954) of a well preserved specimen of *Ophiceras connectens* Schindewolf, with no accompanying bracniopods, and various poor moulds (Kummel, 1970) suggestive of *Ophiceras* and alleged *Glyptophiceras* in the lower Kathwai beds. *Ophiceras connectens*, it was believed, demanded an early Triassic age for the entire Kathwai fauna; though even the ammonoid evidence is not totally convincing (Newell, 1973), especially since the discovery of *Durvilleoceras woodmani* Waterhouse, with an Ophiceratid suture in rocks of Permian age in New Zealand (Fig. 29). Perhaps the readiest solution to the problem is to consider that the brachiopods were of one age, and the ammonoid of another, and that the two have been mixed (though not occurring together), by reworking of sediment and faunas near wave-base, as suggested by Waterhouse (1972a, b). But the most competent analyses of the problem are provided by Grant & Cooper (1973) and Newell (1973) who have carefully discussed alternative hypotheses to explain the apparent concurrence of fossils of conflicting age implications, making no prior assumptions, unlike their colleagues. They concluded that the ammonoid, at least the only well-preserved one, was probably 'precocious'. They further noted that both the Chhidruan and dolomitic beds lay within one conodont zone (Sweet, 1970). The whole question of whether brachiopods and ammonoids occur in the same unit underlines the need for modern field mapping, careful collecting and up-to-date carbonate studies in the Salt Range. (Fig. 33).

Pamirs, Mongolia, China

The Pamiran Stage of the Pamirs and Fergana has *Palaeofusulina*, *Reichelina* and *Codonofusiella*, with large brachiopod faunules recently described by Grunt & Dimetriev (1973) in two zones, presumably equivalent to the Urushtenian and Baisalian Substages (Table 23). The lower Taktabulak Suite includes restricted species of *Notothyris*, with *Martinia* and *Permophricodothyris*, and shares several species with the middle Taktabulak Suite, *Haydenella tumida* (*Waagen*), *Parenteletes ruzhencevi* Sok., and *Stenoscisma armenica* Sok., found in the Baisalian faunas of Armenia. Middle Taktabulak species include *Richthofenia caucasica* Likharev, *Strophalosiina multicosta* Likh. and *Krotovia jisuensiformis* Sarytcheva, as a mixture of Urushtenian and Baisalian species, with supposed *Enteletes dzhalgrensis* Sok. of Obginan age in Armenia. The claim by Taraz (1973) that the Pamiran 'Stage' is pre-Djulfian cannot be sustained.

In the Jisu Honguer beds of Mongolia (Grabau, 1931), the younger faunas with *Spiriferella rajah* may be late Punjabian in age, as outlined previously. A still younger fauna at localities 1211, 1193, 1194 from carbonate lenses in shales, has numerous *Martinia* and *Derbyella*, and is quite possibly Djulfian in age. Slight support is offered from the second highest fauna by *Martinia mongolica* Grabau, which was also identified by Waterhouse (1964) from a fauna in New Zealand that is now thought to be lower Djulfian, i.e. Urushtenian in age. *Codonofusiella* has also been recorded in the Jisu Honguer beds, supporting a Djulfian age. But a Kazanian age cannot be ruled out, as discussed previously.

Locality	Fauna and Lithology	Possible Age Following Grabau	Greater Possible Age
1186	*?Waagenoconcha*, limestone bed in shale	?	
	(150 m approx.)		
1211, 1193, 1194	*Enteletes* sp.; *Derbyella*, *Leptodus nobilis*, *Spinomarginifera jisuensis*, *Martinia mongolica*, *Martinia* spp. limestone beds in shale	Urushtenian	
	(70 m interval approx.)	-	
1205- 1208	*Orthotetina*, *Spinomarginifera*, *Spiriferella* aff.*mongolica*, *S.* aff *"rajah"* in thick limestone	Urushtenian or late Punjabian	
	(200 m interval approx.)	-	
1209, 1210	*Linoproductus*, *Compressoproductus*, *Spiriferella mongolica* in dark cherty limestone	Urushtenian or late Punjabian	?Nevolin (*Timaniella*)
	(70 m interval approx.)	-	
1196	*Enteletes*, *Richthofenia*, *Spinomarginifera Hemiptychina* in carbonate beds in sandstone	?Punjabian ?Chhidruan	
	(200 m interval approx.)	-	
1190, 1192	*Orthotetina*, *Geyrella*, *Richthofenia*, *Leptodus nobilis*, *Kochiproductus*, *Muirwoodia*, *Compressoproductus*, *Spiriferella "rajah"*, *Phricodothyris indica* carbonate reefs in sandstone	Punjabian -?Kalabaghian	?Filippovian

Table 47. Sequence of faunas in the Jisu Honguer Formation, Mongolia, summarized from Grabau (1931), with alternative correlations.

In China the Wuchiaping Limestone above the Maping Limestone is richly fossiliferous and is correlated with sandstone, shale and coal measures of the lower Yangtse Valley. It contains the *Codonofusiella* Fusulinacean Zone of Sheng (1964). Characteristic Baisalian ammonoids such as *Vescotoceras*, *Araxoceras*, *Prototoceras*, and *Pseudogastrioceras* occur especially in the upper Laoshan Shale, in the Loping Coal Measures (Chao, 1966). Large brachiopod faunas have been described from the Choutang Limestone, and Wuchiaping Limestone (Huang, 1933), and Sheng & Lee (1974) listed as characteristic *Edriosteges poyangensis* (Kayser), *Rugaria soochowensis* (Chao), *Tyloplecta yangtzeensis* (Chao), and *'Squamularia' grandis* (Chao), approaching or identical to Armenian forms. Overall the faunas look like those of the Kalabaghian and Chhidruan Substages, perhaps due to failure to correctly assess the faunas, which probably need re-evaluation from first-hand examination. Alternatively, the Choutang Limestone is really Chhidruan, or the Chhidru faunas persisted in this region. Some caution must be retained over the stratigraphy, which involves considerable facies changes. Chao (1966, p.1818) noted that diagnostic ammonoids were missing from the Wuchiaping Limestone, and rare in the Hoshan Limestone. He further noted that the Loping Coal Measures rested disconformably on Maokou Limestone with *Verbeekina* and *Neoschwagerina*, as if to imply that the *Yabeina* Zone was missing, or conceivably represented by Early Lopingian beds (Chao, 1947).

From Jinxian, Anhui, Zhang & Ching (1961) recorded a brachiopod faunule from low in the Upper Permian (i.e. post Maokou) that is typically Djulfian, and includes *Crurithyris* or *Orbicoelia*, suggesting an Urushtenian age.

Japan, south-east Asia

It seems likely that at least meagre Djulfian faunas are present in Japan (Table 48). Toriyama (1973, p.509) suggested that the *Lepidolina kumanensis* Zone with *Lepidolina multiseptata* of the Kuman Stage was Djulfian. It includes highly evolved Neoschwagerinids and Verbeekinids with *Codonofusiella*, *Reichelina* and *Dunbarula*. Kanmera & Nakazawa (1973) agreed, and noted that horizons of probable correlative age included *Palaeofusulina* in the Maizuru belt. The Kawahigashi brachiopod faunule of Shimizu (1962) was regarded as Lopingian. Unfortunately, *Codonofusiella*, *Reichelina* and *Palaeofusulina* do not offer indisputable evidence of age, for all three genera are widespread in older deposits, as discussed by Toriyama (1973), and they are valuable only through the absence of other forms. The presence of *Yabeina* and *Lepidolina* would suggest to the writer that some of these beds are pre-Djulfian, as seems to be confirmed by the brachiopods. But higher faunas are found, and these appear to be of genuinely Djulfian age, as in the upper part of the Kuma Formation (see Kanmera & Nakazawa, 1973, p.105) with Wuchiaping Fusulinacea, and perhaps the Mitai Formation, with *Codonofusiella* near the base and *Palaeofusulina* above. The Tsukumi Limestone Group is also possibly Djulfian. Unfortunately, no significant brachiopods are found with these faunas.

It seems highly likely that Djulfian faunas will be discovered, or rather recognised as such in south-east Asia. Kanmera & Nakazawa (1973, p.113) have pointed to the likelihood of Djulfian or Dorashamian fossils in the Jenka Pass region of Malaysia, where Nakazawa (1973) identified a distinctive transverse *Orthotichia* with *O. dorashamensis* Sok. from the mid-Baisalian Substage of Armenia. A number of bivalves are also present. The fauna lies in purplish shale over plant beds, in turn above beds with brachiopods including *Spinomarginifera* likely to be of Punjabian age. Nearby limestones contain *Yabeina asiatica* Ishii. Thailand and Vietnam (cf Chi-Thuan, 1961) may well have such Lopingian faunas. Kanmera & Nakazawa (1973) implied that *Lepidolina multiseptata* faunas at the top of the Sisophon sequence were of Djulfian age, but this is unlikely.

United States, Mexico

Beds of possible, but rather uncertain Urushtenian age are present in Mexico and upper Capitanian of Texas and New Mexico. Spinosa *et al.* (1970) described a primitive Araxoceratid from the upper La Colorada beds of Las Delicias as *Eoaraxoceras ruzhencevi* Spinosa *et al.*, which may signify an Urushtenian age (Waterhouse, 1972a). It is accompanied by *Stacheoceras* cf *tridens* Rothpletz, *Timorites*, *Episagiceras* cf *nodosum* Wanner and *Kingoceras kingi* Miller. To judge from descriptions by Newell (1957), this appears to be approximately the topmost shale of the sequence, in 'Bed 1' of King *et al.* (1944, p.13) of the Difunta section (Table 34). *Polydiexodina mexicana* Dunbar is present, with *Chonetina* and an overtoniid, together with a few brachiopods as yet undescribed, the writer collecting *Leiorhynchoidea* for instance. Spinosa *et al.* (1970) correlated the fauna with the Amarassian beds of Timor, which was considered to be younger than the typical Capitan, as represented by the Hegler Limestone. Only one ammonoid species with Amarassian affinities is found in Texas, in the Lamar Member, called *Strigogoniatites fountaini* Miller & Furnish.

The Lamar Limestone (Table 26) at the top of the Capitanian, may be as young as Urushtenian, for Grant (1970) stated that a peculiar species of *Martinia* in the Kathwai fauna of Pakistan closely resembled a peculiar species from the Lamar Limestone. The correlations should become clear when the brachiopod descriptions are published by Cooper & Grant (in press), but Furnish (1973) has added strong support for the La Colorada-Lamar correlation from ammonoid evidence.

The Rustler Formation in the Delaware Basin of Texas has yielded a small brachiopod faunule (Walter, 1953), but there is little evidence for age, pending revision, for none of the genera that characterise late Permian faunas of Asia are known. The fauna is correlated by means of bivalves with the Whitehorse Sandstone of the mid-continent in Kansas, Nebraska, Oklahoma and Texas (Newell *et al.*, 1940), with a few brachiopods, including the unusual Dielasmatid *Pseudodielasma* Brill. Newell *et al.* (1940) were undecided whether the Whitehorse faunas were correlative with or younger than the Capitan. But the Rustler fauna lies well above Capitanian faunas, and is probably no older than Djulfian and possibly as young as Dorashamian.

New Zealand, Queensland

In New Zealand, the AG 5 sandstone of Wood (1956) near Clinton, Southland (Fig.24), contains brachiopods of the *Spinomartinia spinosa* Zone, and elements of the fauna are found widely throughout the South Island, in the Little Ben Sandstone near Nelson City, the upper Annear Sandstone of Eglinton Valley, and Pine Bush Formation of Mataura Island, Southland, the fauna being one of the most widespread of Permian faunas in New Zealand (Table 37, Fig. 24, 31). *Crurithyris* suggests a direct link with the Urushtenian, Ruteh 3 and Kathwai faunas, as confirmed by stratigraphic position. *Martinia* cf *mongolica* Grabau supports correlation with the upper beds of Mongolia described by Grabau (1931). *Atomodesma trabeculum* Waterhouse is found also in New Caledonia (Waterhouse, 1967b). The overlying Greville Formation has scattered occurrences of the ammonoid *Durvilleoceras woodmani* Waterhouse 1973b, probably of Baisalian age.

In the Gympie Basin of Queensland (Fig. 21), the Tamaree Formation contains a gastropod figured as *Platyteichum* sp. by Runnegar & Ferguson (1969, pl.3, fig. 15-16) that might be *Ananais campbelli* Waterhouse. This species is characteristic of the Urushtenian in New Zealand, and occupies a similar stratigraphic position in Queensland (Table 36).

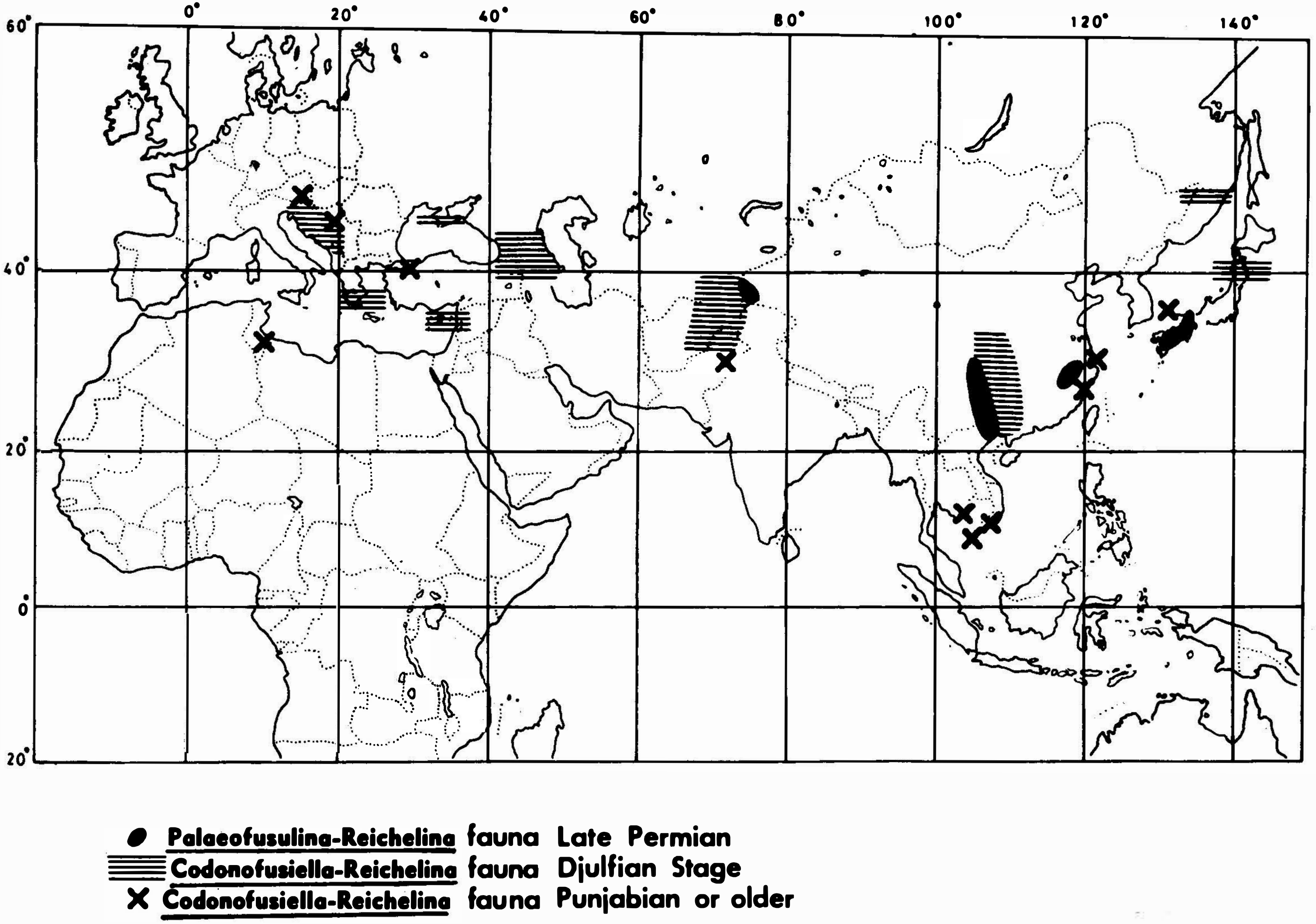


Fig. 34. Distribution map of *Palaeofusulina, Reichelina* and *Codonofusiella* in the Middle and Late Permian of the Tethys, redrawn with permission from Toriyama (1973), fig. 1, p. 499).

DORASHAMIAN STAGE

Vedian and Ogbinan Substages

Armenia, Iran

The Dorashamian Series of Rostovtsev and Azaryan (1973) includes the upper part of the former Djulfian Stage or Series, and is here treated as a stage, with two or three substages, the Vedian at the base, the Ogbinan, and perhaps the Griesbachian, or part thereof, at the top. Two distinct faunas, here treated as substages, were recognised for the lower part by Waterhouse (1972a) on the basis of work by Ruzencev & Sarytcheva (1965) from sequences of south Armenia, and by Stepanov *et al.* (1969) in northern Iran. The type section is offered by Dorasham Siding II for the Vedian Substage (see both papers) and for the Ogbinan Substage by the Djulfa Gorge (Waterhouse, 1972a) though Rostovtsev & Azaryan (1973) suggested the Dorasham II section. The stage has been referred entirely (Stepanov *et al.*, 1969), or partly (Ruzencev & Sarytcheva, 1965; Glenister & Furnish, 1961, 1970) to the Triassic, in the face of a Permian age clearly indicated by brachiopods, as sustained by Yakovlev (1931), Chao (1966), Waterhouse (1967a, 1969b) and Tozer (1969).

The Vedian Substage is exposed in red shales and dark red limestone up to 5 m thick (Table 45). It is characterised by the ammonoid *Phisonites*, and the brachiopod genera *Comelicania* and *Janiceps*. *Phisonites* and *Comelicania* are also found across the border in Iran in beds 5 m thick (Stepanov *et al.*, 1969). Perhaps only the brachiopods will prove diagnostic, for Rostovtsev & Azaryan (1973, p.91) considered that *Phisonites* was only a compressed *Xenodiscus*.

The Ogbinan Substage has species of brachiopod genera *Orthotichia*, *Enteletes* and *Araxathyris* with characteristic ammonoids *Dzhulfites* and *Paratirolites*. Rostovtsev & Azaryan (1973) synonymised *Dzhulfites* with *Paratirolites*. *Pleuronodoceras*, *Pseudotirolites* and *Pseudostephanites* were recognised by Teichert *et al.* (1973) in the late Ali Bashi Formation of Kuh-e-Ali Bashi, Iran. Somehow Teichert *et al.* (1973) failed to find the critical *Phisonites-Comelicania* Zone, even though it was recognised in the area by Stepanov *et al.* (1969), to imply that the ranges of the species they did find lack a rigorous stratigraphic framework.

Much the same faunal sequence is found at Abadeh in central Iran (Taraz, 1971, 1973, fig.3, p.1128), with *Dzhulfites* (Vedian) beds overlain by beds with *Paratirolites* (Ogbinan).

Europe

A limestone fauna in the upper Permian of the Bukk Mountains of Hungary (Shreter, 1963) has *Martinia* and *Comelicania*, with many Djulfian species as well, including Licharewinids and even *Crurithyris*. Whether collections have spanned some interval of time, as seems likely, or come really from only one zone cannot be ascertained but Assereto *et al.* (1973) considered these faunas were mostly older than the faunas of the Carnian Alps. The same key brachiopods *Comelicania* and *Janiceps* are found in the upper Bellerophon Limestone (Table 24) of the south Tyrol close to the Italian, Austrian and Yugoslav borders (Stache, 1878; Diener, 1910; Merla, 1931; Accordi & Loriga, 1968; Assereto *et al.*, (1973). These faunas are accompanied by a very large molluscan element, including *Paraceltites sextensis* Diener, but chiefly gastropods and bivalves (Gortani, 1906a, b, etc.).

China, Japan

The Dorashamian Stage is represented in south China by the Changsing

Limestone (Table 18), a light grey well bedded limestone 25-100 m thick in Chekiang, north-west Kweichow, Kwangsi and Szechuan, above rocks of Djulfian age (Sheng, 1964; Chao, 1966). *Palaeofusulina* is a predominant foraminifer and may be accompanied by *Codonofusiella* (Wang, 1966). *Pseudotirolites* and *Pseudogastrioceras* occur in the lower part, and *Changhsingoceras*, *Trigonogastrites*, *Stacheoceras* and other genera in the upper part. There are many brachiopods, few obviously distinctive, and many like those of the underlying Wuchiaping fauna, including *Anidanthus sinosus* (Huang) and ?*Rugaria soochowensis* (Chao). Sheng & Lee (1974) listed *Crurithyris speciosa* Wang and *Araxathyris araxensis* Grunt. Other ammonoids and brachiopods are found in the limestones, shales and sandstones of the Talung Formation in south China in Kwangsi and southern Kuiechow. The Talung Formation is either correlative with or slightly younger than the Changsing Limestone. Further ammonoid species were listed by Chao (1966) in northern Szechuan. *Palaeofusulina* (Fig. 34) is also found in the Liangfengpo Shale in western Kueichow. No fauna clearly correlative with the Vedian Substage has yet been recognised, but stratigraphic and faunal relationships are not under satisfactory control, so that it is not certain whether the Vedian Substage is missing, or has not been recognised. Indeed there is the possibility that it is represented by the upper Changsing Limestone. This contains the Cyclolobid ammonoid *Changhsingoceras* Chao, which is related to *Godthaabites* and *Cyclolobus*, genera that are on the whole typical of temperate latitudes. So the presence of *Changhsingoceras* in south China, which occupied the palaeotropics during the Permian (Waterhouse & Bonham-Carter, 1972, 1975), might indicate Vedian temperatures which were cooler than normal. This might be supported by the record of *Eurydesma inflatum* (author not stated) in Sheng & Lee (1974), for *Eurydesma* is otherwise restricted to faunules known to have been cold-water.

Faunas of Japan may be correlative but there are problems, for only Fusulinacea are abundant, and those of late Permian age are survivors from earlier faunas. However, *Palaeofusulina* and *Codonofusiella* occur in the lower to middle part of the Mitai Formation (Kanmera & Nakazawa, 1973, p.107) and may well be lower Changhsingian, whatever that be.

The Gujo bivalve fauna, described by Nakazawa & Newell (1968) is probably Vedian in age because a number of the bivalves which dominate the fauna are obviously closely related to bivalves from the upper Bellerophonkalk of Europe, as first pointed out by Waterhouse (1969b). Few brachiopods are present (Shimizu, 1961b). Table 48.

Madagascar, New Zealand

The ammonoid *Paratirolites* has been found in beds of otherwise uncertain age in north Madagascar (Tozer, 1969). Near Nelson City, New Zealand, (Fig. 24, Table 37), the local Waiitian faunas belong to the Vedian Substage, with brachiopod faunas described by Waterhouse (1964, 1967a). The faunas occur in extensive carbonate lenses varying from a few metres to 700 m in thickness, above the Greville Formation with the Baisalian ammonoid *Durvilleoceras*. The fauna is correlated chiefly by stratigraphic position and evidence of cooling, for no well dated faunas of comparable age are known from such high latitudes in the late Permian. However a species of the gastropod, *Spirovallum* Waterhouse is close if not identical to a species from the Gujo fauna of Japan (Waterhouse, 1969b). Underlying red and green shales and siltstones probably belong to the same stage, and were apparently deposited in shallow cold waters. Overlying beds include tilloidal rock, and slump breccias suggestive of sharply lowered sea level (Burke & Waterhouse, 1973), implying glacio-eustatic influence.

Breccias and carbonates with scattered fossils from the Takitimu foothills, Southland, New Zealand, in the Hawtel Formation, are likely to be correlative. No well-established Ogbinan fauna is found in New Zealand.

Waterhouse (1969b) drew attention to possible tillite in the upper Ferntree Form

	Northeast Japan		South-west Japan						
			Inner Zone		Outer Zone				
	Kitakami		Maizuru		Chihibu belt				
					Kuma		Tsukumi		Takachiho
Hiraiso Fm		Yakuno Fm		Kuma Fm	Triassic	Tsukumi Limestone		Kamura Fm	
	Leiophyllites		*Nuculana nogamii* (?)		f				f *Meekoceras* Bivalves
	Meekoceras		*Pseudosageceras* *Meekoceras*						
	Glyptophiceras		*Neoschizodus Claraia*				*Bakaviella*		
Toyoma Fm	*Leptodus*	Maizuru Gp	Gujo fauna *Palaeofusulina sinensis* *Colaniella*		f (fossils not found)		*Staffella Nankinella*	Mitai Fm	*Staffella Nankinella*
Kanokura Fm	*Lepidolina multiseptata*		*Palaeofus minima* *Reichelina* *Lepidolina kumaensis* *Codonofusiella*		*Codonofusiella*		*Palaeofusulina* cf *sinensis* *Reichelina changhsingensis* *Codonofusiella* *kueichowensis*		cf *sinensis* *changhsingensis* *Codonofusiella* *kueichowensis*
	Lepidolina multiseptata shiraiwensis				*Lepidolina kumaensis* *Codonofusiella* *Reichelina*				f
			Lophophylloid coral	Yonagu Fm	f *Yabeina globosa katoi*		f *Yabeina globosa*	Iwato Fm	f *Yabeina katoi* *Neoschwagerina margaritae*
					Neoschwagerina margaritae		*Neoschwagerina*		*Neoschwagerina*

Table 48. Correlation of Upper part of Permian, and Lower Triassic of Japan and some other areas of the Tethys region by diagnostic genera or species. (From Kanmera & Nakazawa, 1973, p. 115, fig. 6.)

f - fault Fm - Formation Gp - Group

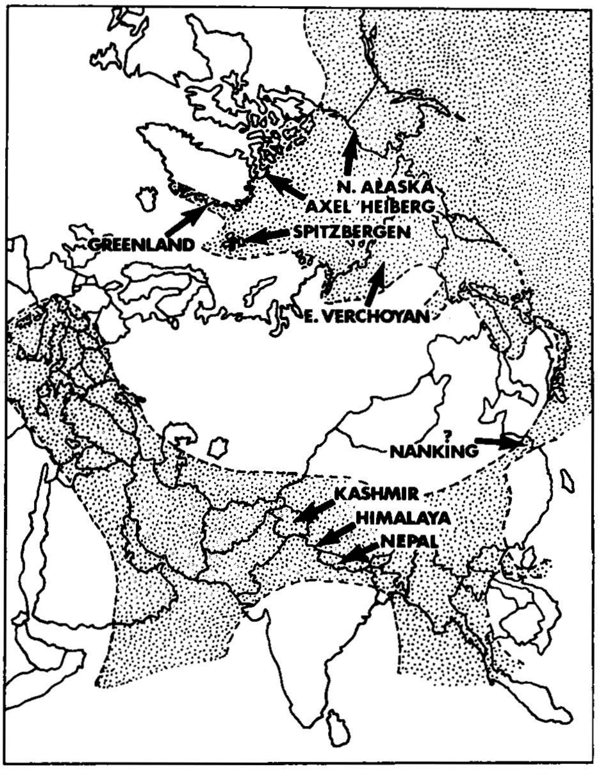


Fig. 35. Present geographic distribution of the ammonoid genus *Otoceras*, emended from Kummel (1973, fig. 5, p. 568).

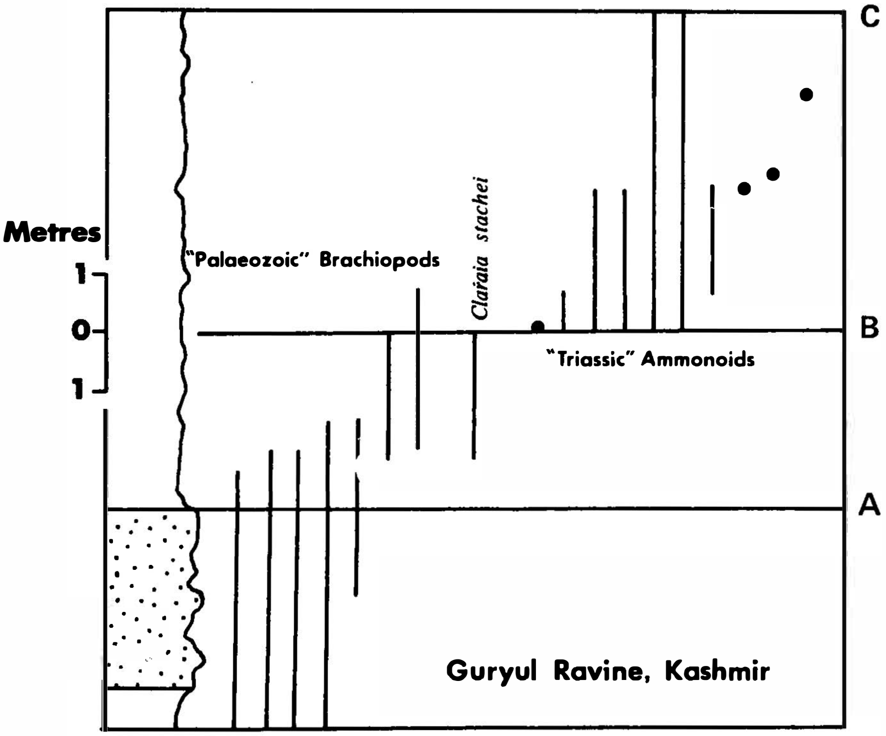


Fig. 36. Permian – Triassic boundary beds in Guryul Ravine, Kashmir. A, the boundary drawn by Nakazawa *et al.* (1970) below the first occurrence of *Claraia stachei*. B, an alternative boundary at the base of a stratum bearing the *Otoceras* – *Ophiceras* assemblage; C, boundary favoured by Newell (1973) and the writer (Waterhouse, 1973), at the top of the ammonoid genus *Otoceras* with *Ophiceras* transitional between Permian and Triassic. Dots represent single occurrences of ammonoid genera. Redrawn with permission from Newell (1973, fig. 3, p. 7).

Group, and to the possible presence of *Tomiopsis* like a late Permian species from New Zealand, and supposed *Eurydesma.* Clarke (1973) strongly doubted the presence of tillite or glacial sediment, but other accounts record at least ice-rafted pebbles (Jago, 1972). Unfortunately we still await clarification of the Ferntree correlation. Clarke (1973) asserted most strongly that the fauna was identical in age with that of the late Malbina Formation, but his lists provide little indication of any positive age or basis for correlation. Not even a refined age for the Malbina E is provided, other than 'Kazanian', which in the terminology of Clarke (1973), following Runnegar (1969b), ranges from Nevolinian (Kungurian Stage) to Vedian (Dorashamian Stage).

Dulhunty & Packham (1962) have described glacial sediments near Mudgee, New South Wales, regarded as correlative with the late Middle Permian Capertree Group = Wandrawandrian beds or even ?Late Permian Lithgow Coal Measures.

Griesbachian Substage

Rocks and faunas generally referred to the basal Triassic, or what used to be called the Scythian Stage, contain Permian-type brachiopods, associated with the ammonoids *Otoceras* and *Ophiceras*, and the bivalve *Claraia* (Waterhouse, 1973b). The basal unit of the Scythian, called the Griesbachian Stage by Tozer (1967), based on outcrops and faunas of the Canadian Arctic Archipelago, should almost certainly be placed in the Permian Period where we use faunal affinities rather than historical precedence as the guide. *Otoceras* itself at the base of the Griesbachian Stage is distinctly Permian in affinities, and even *Ophiceras* is morphologically close to the Permian genus *Durvilloceras* Waterhouse (1973b). Waterhouse (1973b) suggested that the boundary should possibly be drawn in the Dienerian Stage, but this is subject to further enquiry.

Kozur (1973a) has argued strongly that the *Otoceras* faunas, or basal Griesbachian or Tozerian Stage should be treated as topmost Permian. The overlying upper Griesbachian and Dienerian Stages were referred by Kozur (1973a) to a new Brahmanian Stage, typified by ammonoids of Triassic aspect, including *Ophiceras.* In 1974 Kozur showed the top of the Permian to be represented by the *Otoceras concavum* and *O. boreale* zones, underlain perhaps by the *Hypophiceras martini* and *H. triviale* zones of Greenland, in a Gangetian Substage, above the Dorashamian. The zone of *Ophiceras commune* was assigned to the Ellesmerian Substage at the base of the Triassic Period. Newell (1973) has suggested drawing the boundary at the top of the Griesbachian Stage, that is, taking in the *Ophiceras* as well as *Otoceras* beds (see Fig. 36).

Clearly the decision must be by international agreement, after general discussion. What is apparent is that we may now delineate an overall geological picture after a decade of confusion caused by the allegation that 'Permian-type brachiopods' survived only locally in rocks crudely dated as Triassic or 'Scythian' by Kummel & Teichert (1964, 1970, 1973) and their colleagues. The late Permian—early Triassic involved a succession of faunas and geological events, commencing with world-wide basal Griesbachian, or Gangetian transgression after long emergence, with faunas characterised in part by *Otoceras*, closely related to Permian Otoceratidae, the bivalve *Claraia*, closely related to the Permian genus *Pseudomonotis*, and various brachiopod families, identical with preceding Permian families. The later Griesbachian apparently saw the disappearance of *Otoceras*, and supposed incoming of *Ophiceras* and otherwise little change amongst the macro-invertebrates. During the Dienerian 'Stage', the ammonoids developed from upper Griesbachian forms. Brachiopods changed drastically within the Dienerian, as far as can be ascertained, from those of Permian type, to those of the more restricted Triassic type. Overlying ammonoids and brachiopods of the Smithian Stage were typically Triassic in appearance. The Smithian ammonoids are obviously close to Dienerian and Griesbachian forms, whereas the Smithian brachiopods represent an enrichment of only some of the families present in Griesbachian and possi-

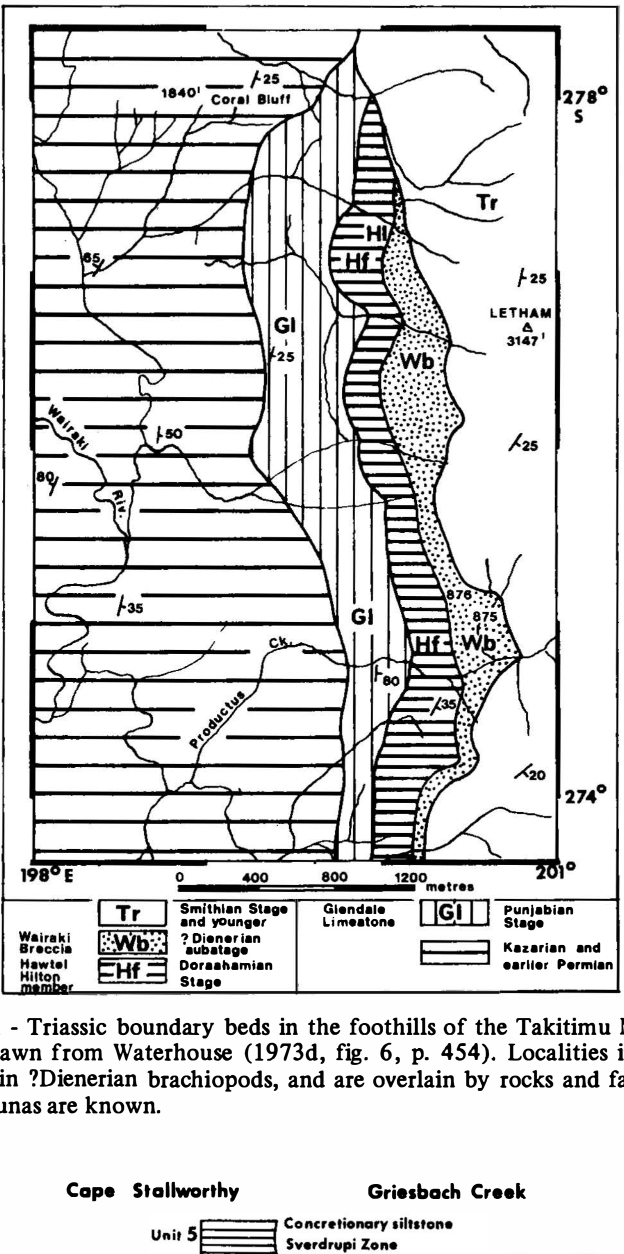


Fig. 37. Permian - Triassic boundary beds in the foothills of the Takitimu Mountains, Southland, New Zealand, redrawn from Waterhouse (1973d, fig. 6, p. 454). Localities in the Wairaki Breccia (black spots) contain ?Dienerian brachiopods, and are overlain by rocks and faunas of Smithian age. No Griesbachian faunas are known.

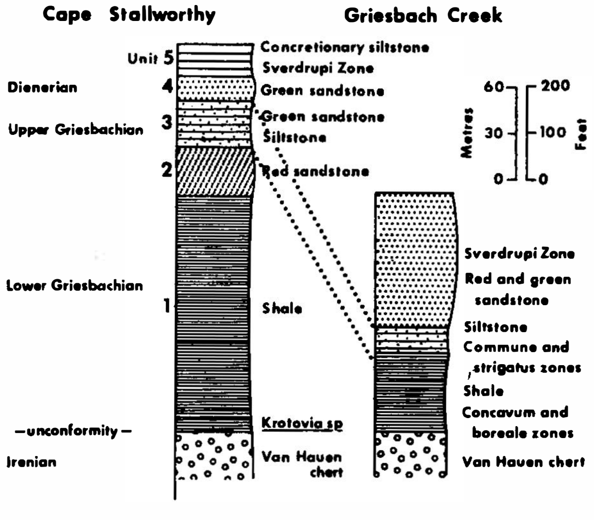


Fig. 38. Stratigraphic columns of the Blind Fiord Formation on Axel Heiberg Island, Canadian Arctic Archipelago, traditionally regarded as basal Triassic, but here considered Late Permian in part. Redrawn from data supplied by Dr E. T. Tozer in Waterhouse (1972b).

ble early Dienerian faunas; other typically 'Palaeozoic families' have essentially vanished.

Faunistically one may argue for placing the boundary at the incoming of *Ophiceras*, or the incoming of Triassic brachiopods especially in the Smithian Stage. Or we may emphasise the disappearance of *Otoceras*, or disappearance of Permian brachiopod families. From the viewpoint of mapping a boundary, the base of the Griesbachian, or base of the Smithian are generally easy to recognise. The last appearance of *Otoceras* is particularly difficult to map, judged from my own experience in the Himalayas. *Otoceras* was very widespread, but is comparatively rare in various regions, possibly because its shell was easily destroyed. The ammonoid data summarised by Waterhouse (1973b) from Tozer (1967, 1971) suggests that the commencement of the Smithian Stage would offer a good and easily recognisable base for the Triassic Period, but it now appears that the ranges of a number of ammonites have to be extended downwards (Kozur, 1973a, b; Dr E.T. Tozer, Geological Survey of Canada, pers. comm.).

In the meantime, only one modest brachiopod fauna has been completely described, by Waterhouse (1967a) from the Wairaki Breccia, Takitimu Mountains, Southland (Fig. 31, 36), above Vedian rocks and faunas, and below Smithian (i.e. upper Scythian) faunas (Table 37). It is thought by Waterhouse (1973b) to be as young as Dienerian, in view of the absence of key Permian families, but its genera are still of Permian type, so that faunistically it possibly lies right at the top of the Permian, or base of the Triassic: historically it is Triassic. Other modest brachiopod faunules are found, none described fully. In the western United States, the Dinwoody Formation with *Claraia* (Newell & Kummel, 1942) contains numerous scattered brachiopods including Leptodidae, Overtoniidae, Ambocoeliidae and Dielasmatidae, with other taxa (Waterhouse, 1973b; Grant & Cooper, 1973), some misidentified as Triassic by Kummel (in Newell & Kummel, 1942).

Another extensive fauna has been found in north-west Nepal by the writer in 1973, with Orthotetacea, Chonetidae, Strophalosiidae, Productacea, Rhynchonellida and Ambocoeliidae. All await determination and description. They are found with numerous 'early Triassic' ammonoids, including rare *Otoceras* (Fig. 30).

Other approximately correlative faunas are scattered through the Himalayas, as reviewed in Waterhouse (1973b), including briefly documented occurrences in the Pahlgam-Aru basin, and in Indochina (Waterhouse, 1973b, p.311).

The topmost zone of the Zewan sequence in Kashmir, named the lamellibranch zone by Diener (1915) (Fig. 31), or Zewan 6, is found two miles north of Barus and in the Guryul Ravine. Diener (1915) recorded *Xenodiscus* cf. *carbonarium* and so-called *Pseudomonotis* and *Eumicrotis* that might prove to be *Claraia* with such typically mid-Permian brachiopods as *Lamnimargus himalayensis* and *Costiferina* with *Lissochonetes*. Nakazawa *et al.* (1970) listed other Permian brachiopods, including '*Pustula*', with *Claraia* and Griesbachian ammonoids such as *Ophiceras*. We await description of the fauna to see if it was reworked, at least in part, from underlying Zewan faunas, or represented new Griesbachian brachiopods of Permian aspect. Furnish *et al.* (1973) have shown that so-called *Xenaspis* cf. *carbonaria* is likely to be an indeterminate Triassic ophiceratin, possibly *Glyptophiceras*, and have considered that so-called *Popanoceras* of Diener (1915) is a Triassic genus.

Permian Overtoniid brachiopods occur at comparable horizons in Japan (Nakazawa, 1971) and the Canadian Arctic (Waterhouse, 1972b) (Fig. 38) and Rhynchonellids are found in Spitsbergen, Greenland. A few species are reported from the Werfener beds of Austria and especially Italy (Sherlock, 1955). Here the barren Tesero Horizon of oolitic limestone and marly micrite up to 6 m thick is overlain by the Mazzin Member of marly micrite 30 - 70 m thick, with *Bellerophon vaceki* Bittner, also found in the *Otoceras* beds of Shalshal Cliff; and conodonts *Anchignathodus typicalis*

Sweet and *Ellisonia teicherti* Sweet that are especially typical of Griesbachian faunas. *Claraia* enters the overlying Siusi Member, and was assumed to indicate an upper Griesbachian age by Assereto *et al.* (1973, p.190). Kiparisova *et al.* (1973, p.141) recorded *Crurithyris* and *Fletcherithyris* with such bivalves as *Atomodesma* in the early Triassic of the Soviet Union, without specifying locality.

Various faunas are discussed by Tozer (1967). Dickins & MacTavish (1963) recorded 'Otoceratan' fosils in the Kockatea Shale of the Perth Basin.

Conodonts are of high promise for recognition of the *Otoceras* and allied horizons, but the exact range of key species is not clear. *Anchignathodus typicalis* Sweet and *Ellisonia teicherti* Sweet are significant species of the lower Kathwai Member of the Salt Range, that range down into the overlying white sandstone at the top of the Chhidru Formation (Sweet, 1970b). These species are also found near the Permian boundary in Guyrul Ravine (Sweet, 1970a), and in the matrix of *Otoceras* specimens from Spiti. But, as shown by Grant & Cooper (1973), the range at Guyrul is so great that the species appear to be both Permian (apparently Middle Permian) and Triassic, wherever the boundary is drawn, and species with shorter ranges would be more useful. Sweet (1973) has also recorded the two species in the Djulfian Ali Bashi Formation of north-west Iran, so that the species clearly range from the Punjabian to late Dorashamian.

Note added in proof.

During September, 1975, I attended the Carboniferous Congress at Moscow, to learn that the "Orenburgian Stage" was under severe criticism from stratigraphers and palaeontologists. Some would deny its validity as a unit, others maintained that it formed the base of the Permian System as a distinct unit, or as part of the Asselian Stage.

It is a pleasure to draw attention to the text Gondwana Geology, Australian National University Press, 1975, edited by Dr K.S.W. Campbell. Amongst other articles of value, M.J. Clarke and M.R. Banks in their article "The stratigraphy of the Lower (Permo-Carboniferous) parts of the Parmeener Super-Group, Tasmania" (pp.453-467), have listed faunal distributions for the Permian of Tasmania. Moreover, Runnegar and McLung (1975, p.431) in the article "A Permian time scale for Gondwanaland" (pp. 425-441), have abandoned attempts to subdivide the east Australian Permian through bivalves, and used brachiopods instead, following Campbell (1953), Maxwell (1954), Dear (1971, 1972) and other workers. They have thus provided valuable data in support of the refined classification in this text.

5. Summary of Permian Stages and Substages: Problems and Proposals

Asselian Stage (Table 49)

As summarized in Chapter 3, difficulties still beset the base of the Permian Period, because it may be fixed at various levels. The full range of critical Fusulinid genera, *Schwagerina*, *Pseudofusulina*, and *Pseudoschwagerina* has not been established and the problem is exacerbated by nomenclatural confusion. Yet we have been forced to rely on Fusulinacea, because the 'type Asselian' abounds in these fossils, and they have been closely studied. The Fusulinacea show a three-fold zonation which appears to be reflected widely by Fusulinacea and Brachiopoda over the rest of the world. But many sequences lack Fusulinacea, and the brachiopod faunas, though widespread and moderately well-known, cannot be accurately matched with those of the Urals, because there have been few modern Russian studies. The solution to most of our problems for the early Permian lies in the provision of brachiopod studies from the type and nearby Asselian Stage. Key brachiopod genera may include *Kochiproductus*, *Muirwoodia-Yakovlevia* and perhaps *Attenuatella*. The genus *Attenuatella* is especially widespread, but has been reported from deposits of Spain, Austria, and Verchoyan which may prove to be late Carboniferous. Ammonoidea play a curious role in defining the Asselian Stage. Although mid and late Asselian genera and species are characteristic, early Asselian, or Surenan Ammonoidea differ little from underlying Ammonoidea (Ruzencev, 1952), and so suggest that the basal Asselian may differ little from the Orenburgian, unless the Ammonoidea failed to change with the rest of the faunas. This means that the base of the Permian has to be assessed from other fauna, particularly Fusulinacea and Brachiopoda. We still wait for this clarification.

Marine rocks of the Asselian Stage were widespread in all continents save the Antarctic, and record one of the most widely distributed glacial episodes known, in the late Asselian Kurmaian Substage. Faunal evidence strongly suggests that the period commenced with Gondwanan glaciation, and relicts of such glaciation are possibly found in eastern Australia, with rare fossils, though the beds have usually been interpreted as Carboniferous (eg. by Runnegar, 1969b).

Intervening beds and faunas, and world-wide correlative faunas suggest warm conditions, so that the Asselian may record two glacial episodes, with an intervening warm episode. If so, the Permian Period, although at first sight arbitrarily delimited, may have commenced at the onset of very widespread climatic cooling that must have strongly affected rocks and life more or less simultaneously (within the limits of monitoring Permian time), as the first extensive glaciation to follow the early Moscovian or Bashkirian glacial episode (see Bamber & Waterhouse, 1971).

Sakmarian Stage (Tables 49, 50)

Fusuline, brachiopod and ammonoid species and genera delineate three substages for the Sakmarian Stage, in good and widespread agreement. The only question lies in treatment of the Aktastinian Substage, which is classed with the younger Baigendzinian Stage on ammonoid evidence, and with the Sakmarian on brachiopod evidence. Fusuline authorities initially supported the latter position in Russia and now follow the former classification. The difference may surely be resolved by discussion, and is not critical: I have based the assessment on brachiopods because they were most

Substage	Fusulinacea	Brachiopoda	Bivalvia	Ammonoidea
Tastubian	*Rugosofusilina* spp. *Pseudofusulina* spp.	first *Spiriferella pseudodraschei* first *S. salteri Notospirifer*		start of *Synartinskia* *Medlicottia* *Metalegoceras* *Uraloceras* *Propopanoceras*
Kurmaian	*Schwagerina* *Pseudofusulina* spp.	widespread *Attenuatella* *Tomiopsis*	*Eurydesma* *Deltopecten*	first *Sakmarites* *Tabantalites* *Protopopanoceras*
Uskalikian	*Schwagerina* *Pseudofusulina* spp.	*Orthotichia* *Kutorginella*		first *Juresanites* *Paragastrioceras*
Surenan	*Schwagerina* *Pseudofusulina* *Pseudoschwagerina* spp.	first *Kochiproductus Yakovlevia* revival or first *Attenuatella* revival *Tomiopsis*	*Eurydesma*	*Glaphyrites* sp.

Table 49. Some significant marine invertebrate genera and species for Early Permian.

Substage	Fusulinacea	Brachiopoda	Bivalvia	Ammonoidea
Krasnoufimian	*Alaskanella yukonensis* *?Misellina claudiae*	*Echinalosia prideri* *Aulosteges ingens* *Uraloproductus stuckenbergianus* *Sowerbina* fauna		
Sarginian	*?Parafusulina solidissima* *Pseudofusulina makarovi* *Parafusulina* spp. *Monodiexodina* spp.	*Chonetina artiensis* *Wyndhamia jukesi* *Institella* *Antiquatonia* fauna *Muirwoodia artiensis* *Spiriferella saranae*		*Waagenina* spp. *Medlicottia* spp. *Perrinites* *Propinacoceras* *Sakmarites* spp.
Aktastinian	entry of *Praeparafusulina lutugini* *Schwagerina crassitectoria* *Pseudofusulina* spp.	*Scacchinella* chonetellids *Krotovia* marginiferids *Stepanoviella flexuosa* *Tityrophoria* *Martinia*		*Properrinites boessi* *Agathiceras* spp. *Aktubinskia*
Sterlitamakian	*Pseudofusulina*	*Echinalosia preovalis* *Reedoconcha* *Anidanthus springsurensis* *Attenuatella* *Punctocyrtella nagmagensis* *Tomiopsis*	*Eurydesma*	

Table 50. Some significant marine invertebrate genera and species of the Early Permian Period.

widespread. Faunal difficulties that beset Sakmarian species are much the same as those interfering with our understanding of the Asselian Stage. Fusulines have nomenclatural problems, and ranges vary locally. Brachiopoda have not been recently monographed from the type Sakmarian and there are no widespread typical new genera, and Ammonoidea show changes slightly out of phase with benthos, in that the lower Tastubian beds of the Urals have few outstanding species and no new genera, and the Sterlitamakian ammonoids are not very distinct. But these difficulties appear to have been overcome, to judge from the widespread agreement over correlation.

Sakmarian marine rocks and faunas are almost as widespread as those ot Asselian age. They are more definitely established in north-east Siberia, but somewhat less extensive in parts of Gondwana, notably South Africa and South America and central Asia.

Faunal evidence based on the appearance of *Licharewia*, *Tomiopsis*, *Attenuatella*, and the bivalve *Eurydesma* in the Sterlitamakian interval suggests a mid-Sakmarian cooling, but evidence for this in eastern Australia is restricted to occasional ice-rafted boulders, with no well developed tillite or varves as far as I am aware. Tillite has been reported from Sakmarian beds (sl.) in Verchoyan (Ustritsky, 1973). It appears that the Sakmarian Stage witnessed extensive cooling during the Sterlitamakian Substage, but was on the whole warmer than the Asselian Stage, leading to the return and proliferation of some late Carboniferous genera, such as Choristitinids. Reduced glaciation allowed isostatic emergence of parts of Gondwana, leading to terrestrial conditions and formation of some coal measures.

Baigendzinian Stage (Table 50)

The Baigendzinian Stage delimits a distinctive phase of earth history, marked by withdrawal of the seas from extensive regions, especially over Gondwana, with the development of widespread coal measures and terrestrial sediments. Coarsening of sediments or unconformity also occurred in tropical and northerly realms, including the Glass Mountains of Texas, and northern Yukon of Canada. The climate appears to have been relatively warm, with evidence of glaciation restricted to Tasmania, which then lay very close to the South Pole (Waterhouse, 1974a). Under warm conditions, Fusulinacea became widespread, and new lineages developed amongst Brachiopoda.

Kungurian Stage (Table 51)

Because of recent Russian studies the Kungurian Stage is relatively well controlled for faunas and rocks of the northern, Arctic, and southern hemisphere. That there has been controversy over the stage cannot be denied, but this has stemmed partly from the paucity of ammonoids in the type Kungurian, and partly from a historical development that failed to understand the uniqueness of Kungurian faunas. It is now well recognized by many authorities that the Kungurian Stage saw the revival of many early Permian genera, and entry of many new and widely dispersed brachiopod species, coinciding with the appearance of new Fusuline genera in the palaeotropics. These new faunas coincided with a new widely transgressive phase that commenced during the basal Kungurian and continued until the late Kazanian Stage. Understanding of critical Fusulines and Ammonoidea is still incomplete. On the whole, evidence suggests that *Neoschwagerina craticulifera* may be as old as Irenian, or upper Kungurian, and that *Waagenoceras* may be as typical of Irenian faunas as of the Kazanian. In earlier literature these forms are widely regarded as 'Wordian', a very broad and long-ranging time span, or sometimes as Kazanian, which may be imprecise.

Substage	Fusulinacea	Brachiopoda	Bivalvia	Ammonoidea
Sosnovian	*?Neoschwagerina margaritae*	*Grumantia pelicanensis* ?smooth chonetids *Tomiopsis costata*	*Stutchburia*	
Kalinovian	*?Neoschwagerina craticulifera*	*Neochonetes* *Aulosteges* *Cancrinelloides* *Stepanoviella* *Licharewia* *Aperispirifer lethamensis*		*Neogoceras* *Stacheoceras*
Irenian	*Polydiexodina elongata* *Neoschwagerina simplex?*	*Lissochonetes* and smooth chonetids *Echinalosia maxwelli* *Chianella chianensis* *Anidanthus eucharis, solita, minor* *Terrakea concavum* *Uncinella* *Crurithyris* *Pterospirifer alatus* *Paeckelmanella*		first appearance *Godthaabites* *Maxicoceras* *Waagenoceras*
Filippovian	first appearance *Chusenella* *Cancellina* *Verbeekina* *Maklaya*	*Streptorhynchus pelagonartus* *Neochonetes* *Thuleproductus arcticum* *Terrakea dickinsi Chianella* *Cleiothyridina pectinifera* *Pseudosyrinx* *Spiriferella polaris, S. loveni, keilhavii* *Timaniella harkeri* *Spiriferellina cristata* *Dielasma elongatum*	*Glendella*	first appearance *Daubichites* *Sverdrupites*

Table 51. Some significant invertebrate (marine) genera and species of the early Middle Permian Period.

As noted previously, nomenclature for the upper Kungurian is not fully established, and should receive attention from the Permian Subcommission, as several horizons have been only provisionally incorporated into one improperly named substage in the present study.

Climatically, the early Kungurian appears to have been cold, with evidence for glaciation in New Zealand and south-east Australia. This is supported by worldwide evidence for cool-water faunas. The later 'Irenian' Substage commenced with very much more diverse faunas rather allied to those of Baigendzinian age, and probably warm-water in relative attributes. Slightly later (Elkin and Ufimian) faunas were somewhat impoverished, with suggestions of moderate withdrawal of epicontinental seas.

Kazanian Stage (Table 51)

The Kazanian Stage is well defined in rocks and faunas from high and temperate Permian latitudes by a suite of brachiopod species, but is not so well controlled in palaeotropical regions. The subdivision into two stages rests almost entirely on Brachiopoda; and Ammonoidea provide little evidence for subdivision as far as is known. Fusuline evidence is not clear: there are suggestions of a two-fold zonation, but correlation is not finally established. Mid-Permian transgression continued into the lower Kazanian or Kalinovian Substage, and widespread withdrawal of seas ensued in the Sosnovian or upper Kazanian Stage, starting in the Arctic. Climates are not clearly delimited, but the presence of glacial erratics in south-east Australia, and some worldwide faunal attributes suggest a moderately cool, but not strongly glaciated, episode. Both substages were somewhat similar in this regard.

Punjabian Stage (Table 52)

The Punjabian Stage is characterized principally by *Yabeina* and *Lepidolina* amongst the Fusulinacea, *Cyclolobus* and *Timorites* amongst the Ammonoidea, and numerous brachiopod species. The claim that the Punjabian Stage lay at or close to the top of the Permian Period is now abandoned, except by a few ammonoid specialists, but problems remain, particularly with regard to the age of Siberian faunas, regarded as either Kazanian or Kalabaghian (i.e. basal Punjabian), as well as certain palaeotropical faunas with primitive *Yabeina.*

Climatically, the Punjabian Stage is not well understood. The Kalabaghian faunas frequently include brachiopod genera of cold-water attributes, to suggest a cold episode possibly correlative with Gijigin tillite reported from Verchoyan Mountains, north-east Siberia, but the tillite could be as old as upper Kazanian: this marks a prime question to be resolved. The Chhidruan Substage appears to be relatively warm, but there is evidence for several horizons still awaiting discrimination, with evidence over parts of Asia and New Zealand for a distinctive late Chhidruan fauna. Depending on correlations, it appears that withdrawal of seas continued extensively, especially after the Kazanian or Kalabaghian in north Siberia. But a Kalabaghian transgression invaded much of the Himalayas prior to widespread Chhidruan emergence, and a Chhidruan transgression overlapped Kazanian sediments and faunas in Queensland, Australia.

Djulfian Stage (Table 52)

Fusulinacea and a number of brachiopod families began to diminish severely just before or within Djulfian Stage, but new ammonoid genera and families were generated. Long established brachiopod and fusuline families assumed new importance. There is fair uniformity over the classification of the stage, though the names are still to be

Substage	Fusulinacea	Brachiopoda	Bivalvia	Ammonoidea
Gangetian	none known	various Productacea	*Claraia*	*Otoceras*
Ogbinan		Productid species		*Paratirolites*
Vedian	*Palaeofusulina*	*Comelicania*, *Janiceps* widespread *Tomiopsis*	*?Eurydesma*	*Phisonites* *?Changhsingoceras*
Baisalian	*Codonofusiella*	*Araxilevis*		*Araxoceras* *Vedioceras* *Durvilleoceras*
Urushtenian	*Polydiexodina mexicana*	*Crurithyris* *Spinomartinia* *Martinia* spp.	Atomodesminae	*Strigogoniatites* *Eoaraxoceras*
Chhidruan	*Lepidolina* *Yabeina*	*Terrakea multispinosa* *Monticulifera-Filiconcha* *Attenuatella incurvata* *Spiriferella rajah* *Martiniopsis inflata*	*Atomodesma trechmanni*	*Cyclolobus* *Timorites*
Kalabaghian	*Lepidolina* *Yabeina*	*Megasteges dalhousei* *Strophalosiina tibetica* *Leptodus richthofenii* *Elivina tibetana* *Martiniopsis woodi*	*A. woodi*	*Cyclolobus* *Timorites*

Table 52. Significant (marine invertebrate) genera and species of Re Late and late Middle Permian.

resolved, as a relatively minor problem involving a choice between Urushtenian and Abadehian, and between Baisalian and Araksian. Climatically, there is no known evidence for glaciation, from either sedimentary or faunal analyses, and the climate may be assumed to have been warm. The Urushtenian or Abadehian Substages witnessed the cessation of deposition in Nepal-Tibet, the last major marine deposition in Texas, Mexico, Mongolia, and arguably in the Salt Range of Pakistan, but Djulfian marine sediments are widely developed in China, New Zealand, perhaps Queensland, Pamirs, Armenia, Iran, and were extensively transgressive in Yugoslavia-Italy-Austria. Coal measures possibly developed extensively in eastern Australia, but are poorly dated.

Dorashamian Stage (Table 52)

The Dorashamian Stage commenced with the highly distinctive Vedian Substage characterized by the brachiopods *Comelicania* and *Janiceps*, and various species, and by the ammonoid *Phisonites.* Faunas of the overlying Ogbinan Substage are less distinctive but include the ammonoid *Paratirolites*, and brachiopod species rather like those of Baisalian age apparently, though few have yet been described. Younger horizons are still in a state of nomenclatural flux, because studies were up till recently, uncritically based on ammonites and historical interpretation, with little consideration for overall faunal affinities. New names proposed by Kozur (1973b) better express the faunal subdivisions, and there can be little question that the Gangetian 'substage' or horizon faunally belongs to the upper Dorashamian Stage, characterized as it is by *Otoceras*, and various Permian-type brachiopod species as yet undescribed. Only arguments based in historical usage can be offered against treating the Gangetian as Permian. But the position of the overlying upper Griesbachian and Dienerian units, or Brahmanian 'Stage' is still not clear, and requires further faunal studies before international discussion is worth undertaking.

Both the Vedian and Ogbinan Substages were virtually as restricted in distribution as the Baisalian Substage, being limited largely to a 'Tethyan' belt from the south-east Mediterranean through Armenia-Iran-Pamirs, south China, and New Zealand, with other reports not yet substantiated. Apparent tillite is found at the Vedian horizon in New Zealand, and would support faunal evidence for climatic cooling at this time (with a sharp fall in temperature affinities even for Armenia shown by Waterhouse & Bonham-Carter, (1975), and the record of *Changsingoceras* and even *Eurydesma* (?!) in China. Later horizons appear to have been warm (Waterhouse, 1973d).

The Gangetian horizon saw the start of world-wide transgression that was most noticeable in the Arctic in covering marine beds as old as Kungurian-Kazanian, and also transgressed large tracts of North America, Himalayas, north Siberia, and elsewhere. Transgression appears to have continued into the Triassic Period.

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Stratigraphic and Biostratigraphic Index

The standard substages and stages appear on most tables and are omitted from the index. Variations in nomenclatural hierarchy, used by different authors, are generally not recorded.

Systematic Index for Genera and Species