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Permian Brachiopod Correlations for South-East Asia

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Abstract: Permain Fusulinacea, Brachiopoda, and Ammonoidea from various parts of South-east Asia, including Burma, Cambodia, Indonesia, Malaysia, Laos, Thailand and Vietnam are correlated with world standard sequences in the Urals, Russian platform and Armenia, with reference also to sequences in the Salt Range of Pakistan. Early Permian faunas appear to be of late Asselian (Kurmain) age, and there are no significant brachiopod faunas yet described from Sakmarian or Artinskian beds. Middle Permain faunas are extensively developed and can be closely zoned by Fusulinacea and brachiopods, to replicate the three-fold zonation of the Russian Kungurian Stage. The overlying Kazanian, and early Tatarian faunas are also well developed, showing strong affinities with the Kalabagh Member and some with the Chhidru Formation of the Salt Range. No faunas are known to be as young as the Baisalian Stage or Dorashamian Series of Armenia, but some may yet be recognised.

INTRODUCTION

Permian faunas from South-east Asia have been studied for over a century—perhaps one of the greatest paleontological series ever published were the French memoirs of the Geological Survey of Indochina—and work on systematics and correlation is still being vigorously pursued. Unfortunately, the world standard subdivisions for the Permian, based largely on sequences in the Ural Mountains and Russian Platform, have not been easy to apply in south-east Asia. Two different faunal realms were involved, and Fusulinacea, of prime value for correlation in south-east Asia, are rare in the standard mid-Permian. Another source of difficulty lies in the crude nature of correlations attempted beyond narrow geographic limits. It was not difficult even in the first part of this century to establish a five-fold subdivision of the Permian period, in categories now termed Sakmarian, Artinskian, Kungurian, Kazanian and Tatarian. The current use of so few time-divisions is outdated, marking not only a failure to progress, but rendering detailed studies on sequences in South-east Asia by Deprat (1913), Kanmera and Toriyama (1968) and Ishii *et al.* (1969) meaningless in a world context. Fine Permian subdivisions have been initiated for ammonoid sequences by Ruzencev (1952, 1956) and Furnish and Glenister (1970), and late Permian in Armenia (Ruzencev and Sarytcheva, 1965; Stepanov *et al.* 1969). In the present work, the fine zonations of world standard and reference sequences are traced from the Soviet Union and Salt Range, Pakistan, into South-east Asia. The typical sequence is outlined, and then compared with the most detailed information available for the South-east Asian sequences. On the whole the world standard subdivisions can be traced successfully, though there are problems with some horizons, due in part to a lack of recent systematic work, or lack of control in the sequence of faunas.

Method of correlation

For correlating strata and faunas, reliance is placed on 1, stratigraphic succession, 2, the occurrence of short-lived "key species" which recur widely in identical sequences, and 3, rhythmic fluctuation of faunal diversity, in which minima can be correlated with glacial episodes in east Australia, and diversity maxima with warm episodes (Waterhouse, 1964, 1970b). Prime attention is focused on brachiopods,

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which in some instances have been reinterpreted generically from types or figures. Fusulinacea are listed from the literature.

DIVISIONS OF THE PERMIAN PERIOD

The two-fold division of the Permian Period in common use today is based largely on sequences of the Urals, Russian Platform and west Texas. The upper parts of these sequences lack marine fossils and so are virtually useless for late Permian correlations. In our view a three-fold division in which the so-called Upper Permian becomes Middle Permian is preferable, and agrees with recent usage in South-east Asia (eg. Jones *et al.* 1966). The Upper Permian, well represented in Armenia and Iran, has been virtually ignored until recently, and has sometimes been placed as Triassic (Ruzencev and Sarytcheva, 1965; Grant 1970). But it has typical Permian faunas of greater age than the beds long accepted as Triassic in Europe. Each of the three major Permian divisions started with glaciation, in the southern hemisphere at least, and ended with relative warm temperatures, and diverse faunas, so that the divisions are natural ones.

There has also been confusion about where the Middle Permian commenced. Many Russian authorities, on the basis of meagre faunas, have placed the top of the Lower Permian above the Kungurian Stage (Licharev, 1966). In North America, by contrast, the boundary has often been placed below Kungurian equivalents, correctly in the view of Stepanov (1957) and the writer. The Kungurian Stage saw the entry of various species of *Streptorhynchus*, *Cleiothyridina*, *Licharewia*, *Dielasma* and other forms characteristic of the early Middle Permian. In other regions correlative beds are further distinguished by the entry of the Neoschwagerinidae (Fusulinacea) and the Cyclolobidae (Ammonoidea) (Waterhouse, 1972b).

LOWER PERMIAN

Asselian

The Asselian Series or Stage is generally considered to be the base of the Permian Period. Three subdivisions are recognised, the Kurmain, Uskalik, and Suyren at the base. The exact faunal content is difficult to ascertain from the voluminous Russian literature, but the faunas appear to support a three fold subdivision. According to Ruzencev (1952) the basal Asselian ammonoids retained links with the underlying Carboniferous, judged from the presence of numerous *Glaphyrites*, but lacked many typical Carboniferous genera. At a higher level *Glaphyrites* diminished, and *Juresanites* and *Paragastrioceras* appeared. In the upper Asselian *Sakmarites*, *Protopopanoceras*, and *Tabantalites* appeared, with various other new species. Three Fusulinacean zones are also distinguished by Rauser-Chernysova over the Russian Platform and Bashkirian Urals (eg. in Licharev, 1966, p. 60):

c. (top) *Schwagerina sphaerica*, *S. fusiformis*, *Pseudofusulina firma*, *Ps.* ex gr *krotowi*

b. *Schwagerina moelleri*, *Pseudofusulina fecunda*, *Ps. krotowi*

a. *Schwagerina vulgaris*, *S. fusiformis*

Ruzencev (1952) strongly criticized the fusulinacean correlation and pointed out that certain key species ranged for much longer than the zone they supposedly characterized. Yet Barkhotova (1964) noted that Ruzencev (1952) himself relied primarily on Fusulinacea for establishing the ammonoid succession.

Unfortunately there has been no comprehensive modern work on the brachiopods. A characteristic "Uralian" assemblage contains various species of *Enteletes*, *Orthotichia*, *Derbyia*, Overtoniids, *Meekella*, *Kutorginella*, *Linoproductus*, *Kochiproductus ?Attenuatella* (or *Crurithyris*), Choristinids, *Phricodophyris*, *Tomiopsis*, *Martiniopsis*, *Brachythyris*, *Martinia*, and other genera, but the exact sequence, interrelationships, and identifications are uncertain. In a somewhat similar brachiopod sequence of the northern Yukon Territory of Canada there are three distinct brachiopod zones, which can be traced widely through Siberia as well. The basal zone is characterized by *Kochiproductus* and *Attenuatella*, the middle zone by *Orthotichia*, the upper zone by *Attenuatella* and *Tomiopsis* (Bamber and Waterhouse, 1971).

Timor

From Timor, the Somohole ammonoid faunas described by Haniel (1915) are referred to the Asselian and Sakmarian by Glenister and Furnish (1961, p. 681, table 2, p. 680), and include several characteristic Asselian genera.

Laos

Extensive Asselian fusulinacean and brachiopod faunas have been recorded from Laos, but uncertainties over stratigraphy and the need for modern revision render a more precise correlation difficult. According to Dassault (1919) the sequences are faulted and perhaps folded, but how this affects the sequence is not known. Oldest Permian faunas listed by Deprat (1913a, p. 63; 1913b, p. 76) include "*Fusulina*" *multiseptata* (Schellwien,) "*F.*" *complicata* (Schell.), *Quasifusulina? tenuistriata* (Schell.), *Schwagerina globosa* Deprat, S. *laosensis* Deprat, and rare *Pseudoschwagerina princeps* (Ehrenberg), from beds at Cammon. This fauna is possibly of early or middle Asselian age.

Pitakpaivan (1965, p. 59) described a related fauna from Noankowtok, Thailand, with *Schwagerina solida* Colani, *Pseudoschwagerina muongthensis rossica*, and *Pseudoschwagerina sphaerica*. *P. sphaerica* occurs in the "middle" *Pseudoschwagerina* Zone (i.e. Uskalik) of the Soviet Union according to Pitakpaivan (1965), but is typical of the topmost Asselian beds according to Rauser-Chernysova and Licharev. Various other occurrences in Sumatra and Borneo are summarised by Pitakpaivan (1965, p. 60).

The earliest Permian brachiopods are found just above the "*Fusulina*" *multiseptata* beds at Tran-ninh, Laos (Mansuy, 1913; Deprat, 1913b, p. 74). They include *Krotovia pustulosus* (Krotow), *Cancrinella rouxi* (Mansuy), *Linoproductus* and *?Brachythyrina*, in a fauna that looks much the same as the slightly younger and much larger fauna at Kham Kheut, Laos, especially as Mansuy (1913, Table 1) also listed *Tomiopsis sokolovi* from the same level. The brachiopod faunas from Kham Kheut, Laos and Muong Thé, Tonkin, as summarized by Mansuy (1913, p. 2, 3) include *Meekella*, *Enteletes*, *Neochonetes*, various Overtoniids, *?Urushtenia*, *Sowerbina*, many *Cancrinella* and *Linoproductus*, *Uncinunellina*, *Crurithyris*, *Spiriferella*, characteristic Asselian transverse spiriferids such as syringothyrinids, and *Tomiopsis* and *Martiniopsis*. A general upper Asselian correlation is indicated by *Neochonetes variolata*, *Juresania juresanensis*, *Krotovia pustulosus*, *Chaoiella gruenewaldti*, *C. boliviensis*, *Sowerbina timanicum*, *Uncinuellina*, *Ambocoelia ?*, *Syringothyris tastubensis*, *Eliva lyra*, *Phricodothyris rostrata*, *Purdonella nikitini*, *Tomiopsis quadriradiatus*, *Martiniopsis orientalis*, *Martinia triquetra*. Subject to the need for revised identifications and age ranges, these species are typical of upper Asselian faunas in South Asia, including Tibet (Reed, 1930), Gilga Signal Camp, Gasherbrun, Karakorum Range (Merla, 1934; Sestini 1965, p. 157), upper Karachaturian of Fergana (Licharev, 1946) and perhaps Mongolia, though the latter beds might be older by two stages (Zhao, 1965).

Even the Lower Rattendorfer fauna of the Carnian Alps in Austria shows similarities. In several of these localities *Crurithyris* is present, as at Laos, and this genus may prove to be a temporal and ecologic equivalent of the genus *Attenuatella*, which characterises more northerly faunas of basal and upper, but not middle Asselian age. *Tomiopsis sokolovi* (Chernyshev) recorded by Mansuy (1913) resembles *T. ovatum* from the upper Asselian beds of the Yukon Territory (Waterhouse, 1971). Laotian brachiopods allied to mid-Asselian species from the middle Karachaturian faunas of Ferghana and Shaksgam faunas of the Karakorum include *Chaoiella gruenewaldti*, *C. boliviensis*, *Eliva lyra*, *Neospirifer fasciger*, *Martiniopsis orientalis*, and *Martinia triquetra*. None of these species are restricted in age.

There are a number of species in common with the brachiopod faunas from the middle Maping Limestone of Kweichow and Kwangsi, China (Huang, 1933; Grabau, 1936), with a fairly similar overall content, notably in the presence of linoproductinids and *Spiriferella* and absence of Stophalosiacea. Affinities of the Maping brachiopods lie more with the Shaksgam fauna described by Renz (1940a, b), rather than with the upper Karachaturian and correlative faunas, suggesting that the Maping faunas are slightly older than the Laotian faunas.

Thailand

From Thum Nam Maholan, near Loei, Thailand, Yanagida (1966) described 26 brachiopod species with *Pseudoschwagerina*. Some genera from Loei such as *Striochonetes*, *Pirgulia* and *Compressoproductus* suggest that the fauna is possibly as young as the *Parafusulina* fusulinacean zone (Yanagida, 1966) but the fauna on the whole appears to be Asselian, and fairly close to faunas of Laos and Tonkin (Waterhouse and Piyasin, 1970, p. 87) although syringothyrinids are absent. *Juresania juresanensis*, *Uncinuellina* and perhaps *Phricodothyris asiatica* from Loei are found also in upper Asselian beds of Mongolia (Zhao, 1965), Tibet (Reed 1930), and upper Karachaturian of Fergana (Licharev, 1946). On the other hand *Rhipidomella pecosi* is reported from ?middle Asselian beds of the Calcarme beds of Austria. Other faunas likely to be of identical age are mentioned by Gobbett (1968, p. 19) from the Kinta Valley of central West Malaysia, west of Kampar.

Sakmarian

Like the Asselian Series, the Sakmarian Series is based on sequences of the pre-Urals of Russia, and its ammonoids and fusulinacea have been closely studied, in contrast to the neglected but abundant brachiopods. Ruzencev (1952) sub-divided the Sakmarian into the Tastubian and overlying Sterlitamakan horizons, which should be elevated to stage rank in the writer's view. The overlying Aktastinian horizon, formerly included in the Artinskian Stage, is tentatively incorporated here with the Sakmarian Series, because of the general brachiopod affinities of what are believed to be correlative faunas in North America and Australasia (Bamber and Waterhouse, 1971).

The Tastubian in the Urals, especially the upper Tastubian, is characterised by the appearance of many new ammonoid genera such as *Metalogoceras*, *Synartinskia*, *Uraloceras*, *Propopanoceras* and a distinctive species *Sakmarites postcarbonicus* with the fusulinacea *Pseudofusulina lutuginiformis* and *P. tastubensis*. The Sterlitamakian is characterised by somewhat similar ammonoids and various Fusulinacea such as *Pseudofusulina verneuili* (Moeller), and *Ps. devexa* Raus. The Aktastinian includes species of *Aktubinskia*, *Agathiceras* and *Neoshumardites*, with *Popanoceras* and *Propinacoceras* and Fusulinacea such as *Pseudofusulina* species and *Parafusulina lutugini*.

Neoshumardites is the last genus of the Somoholitidae, a family prominent in the late Carboniferous and early Permian.

The brachiopods are moderately like those of the Asselian Series, but differ specifically.

No Sakmarian brachiopods have been described as yet from south-east Asia, but Fusulinacea of possible Sakmarian age have been recorded from Malaysia (Gobbett, 1968, p. 19). It was noted by Jones *et al.* (1966, p. 328) that *Misellina claudiae* occurs above *Pseudofusulina kraffti* with a large fauna of gastropods and some brachiopods and ammonoids, according to Ishii (1966), but it may be premature to assign an Aktastinian age to the fauna without full study, as *Misellina* ranges well into the Middle Permian.

Baigendzinian

The Baigendzinian Series is based on Upper Artinskian sequences in the Urals region with characteristic Fusulinacea, including various species of *Parafusulina*, and the ammonoids *Sakmarites*, *Propinacoceras*, *Waagenina*, and *Neocrimites* (Ruzencev, 1956; and Licharev, 1966). Two distinct horizons are widely recognisable, the Sarginian, and Saraninian, the latter equivalent to the Krasnoufimian, which has a very rich brachiopod fauna. Two related brachiopod faunas are recognisable widely over the Arctic Canada, in Salt Range of Pakistan, Western Australia, and New Zealand. In these faunas the Overtoniidae became rare and dictyoclostids very prominent. *Taeniothaerus* was especially characteristic of southern faunas of the younger beds. A diverse fauna from Khao Phrik, Thailand, was assigned to the Artinskian by Yanagida (1970), but is younger, as discussed later.

EARLY MIDDLE PERMIAN

Kungurian

Ruzencev (1956) stated that the Russian Kungurian Stage possessed several ammonoid genera that were closely related to Baigendzinian forms. He hesitated to merge the two because specimens were too few, but Glenister and Furnish (1961) and Nassichuk (1970) combined them. To the writer this view is impractical and undesirable (Bamber and Waterhouse, 1971). Kungurian brachiopods differ from Baigendzinian brachiopods, and new fusulinacean and ammonoid families entered correlative beds all over the world, marking a significant change in marine faunas. It is true that other Baigendzinian biota persisted into Kungurian and younger times, but it is the entry of genera and species, rather than their disappearance, which is significant for correlation. Thus the Kungurian Stage is regarded as post-Baigendzinian.

In the Kama River region Zolotova *et al.* (1966) have recognised three divisions of the Kungurian Stage. The Filippovian Substage at the base records the entry of species widely characteristic of the mid-Permian, such as *Streptorhynchus pelargonatum*, *Cancrinella cancrini*, *Cleiothyridina pectinifera*, *Spiriferellina cristata* and *Dielasma elongatum*, as well as genera such as *Pseudosyrinx*, and *Tomiopsis* in Arctic latitudes. Throughout these regions there was a sudden drop in species diversity and disappearance of polythermal Fusulinacea and compound rugose corals, because of renewed glaciation in east Australia, where the cool-water bivalve *Eurydesma* flourished in the Cessnock Sandstone and Grange Mudstone of New South Wales and Tasmania.

The lower Irenian Substage, or Nevolin horizon, is characteristic by greater faunal diversity, with the replacement in the Arctic of *Neochonetes* by *Chonetina*, *Chonetinella* and *Lissochonetes*, and introduction of *Crurithyris*, *Paeckelmanella* and *Spiriferinaella*. *Permospirifer* and *Licharewia* appeared in Pai Khoi, northern Russia, and in east Australia and New Zealand.

The upper Irenian Substage, or Elkin Horizon is characterised by a decrease in brachiopod diversity in the Russian platform and New Zealand. It is a minor level, needing good preservation and refined work for its detection.

Ufimian

The Ufimian Stage is recognised from ostracods accompanied by fairly non-descript brachiopods, apart from "*Chonetes*" *solidus* (Licharev, 1966). An east Australian and New Zealand horizon corresponds in position with the Ufimian Stage, but there is no direct correlation.

Kazanian

The Kazanian Stage is characterised by the entry in force of *Stepanoviella*, *Cancrinelloides*, *Licharewia* and *Permospirifer* widely over Russia, Arctic Siberia and Canada. *Cancrinelloides* appeared synchronously in east Australia. In the type Kazanian the brachiopod horizon is succeeded by a bivalve horizon, obviously facies controlled and of uncertain age significance. But two brachiopod horizons can be distinguished widely in east Australia, New Zealand, and the Glass Mountains of Texas (Table 1).

Salt Range

A closer reference section for brachiopod faunas in the Salt Range of Pakistan, has yielded large faunas described by Waagen (1891) and Reed (1944). The Wargal Limestone lies above the Amb Formation, of Baigendzinian age. Its Filippovian faunas occur in the basal coaly shales, with *Orthotichia*, *Streptorhynchus*, *Aulosteges*, *Cleiothyridina*, *Dielasma*, followed by a richer ?Irenian fauna, with a number of species of *Streptorhynchus*, a few chonetids (*Waagenites compressa*, *W. strophomenoides*), *Aulosteges*, no *Waagenoconcha*, few productids other than *Costiferina* and *Linoproductus*, no *Stenoscisma*, *Uncinella indica*, rare *Hustedia*, many *Cleiothyridina*, *Composita*, *Spirigerella*, *Neospirifer*, no *Phricodothyris* or *Martinia*. *Stepanoviella* occurs at Bangshang, bed 2.

According to Waagen (1891, p. 199, 200) and Reed (1944) the middle Wargal fauna is richer than the underlying Wargal faunas. It does not appear to have the Kazanian genera characteristic of Arctic or Australian—New Zealand beds. Restricted species listed by Waagen included "*Choristitella*" *wynnei* and "*Spirifer*" *oldhamianus*, and *Martinia semiplana*. Productida include *Echinalosia indica*, *Haydenella*, *Chonetella*, *Compressoproductus*, many *Cleiothyridina*, *Elivina*, few *Martinia*.

Timor

From several parts of Timor brachiopods and ammonoids have been described as part of the "Bitauni fauna" (Broili, 1915, 1916; Hamlet, 1928; Shimizu, 1966). The ammonoids described by Haniel (1915), were stated to be Baigendzinian by Glenister and Furnish (1961), and Baigendzinian or possibly Kungurian by Ruzencev (1956). Some Bitauni brachiopods are close to early Permian species from the Carnarvon Basin, Western Australia, notably *Stepanoviella flexuosa* Waterhouse from

Table 1. Correlation of Permian world standard sequences with Permian beds, faunas or localities of south-east Asia. The columns of the Urals and Russian Platform are summarized from Licharev (1966) and Zolotova *et al.* (1966), and those from Armenia and the Salt Range from Waterhouse (1972b). For Laos, localities are shown from Mansuy (1912, 1913), and "levels" from Deprat (1913b).

URAL MTS, and RUSSIAN PLATFORM, "Stages" or Series	"Horizons"	ARMENIA IRAN "Horizons" and Stages.	SALT RANGE FORMATION	TIMOR faunal horizons	THAILAND brachiopod and fusulinid localities	CAMBODIA Sisophon (Ishii *et al.* 1969)	LAOS
		Ogbinan					
		Vedian					
		Baisalian					
		Abadehian	Kathwai				
TATARIAN		Khachik	Chhidru	Amarassi		?Member D	?Luang Pradang
		Gnishik	Kalabagh	Basleo	Petchabun	Member C	Level 7 6
KAZANIAN		Armik	Middle Wargal			Member B	Level 5
UFIMIAN							Level 4
KUNGURIAN	Elkin			?Tae Wei			Level 3
	Nevolin	Asnis	Lower Wargal		Khao Phrik		Level 2
	Filippovian	Devalin	Basal Wargal	Bitauni	Khao Phlong Prab	Member A	Level 1
BAIGENDZINIAN	Krasnoufimian		Amb				
	Sarginian			—			
SAKMARIAN	Atktastinian Sterlitamak Tastubian		Speckled (*Conularia* beds)				
ASSELIAN	Kurmain		(*Eurydesma* beds) sandstone	Somohole	Thum Nam Maholan Noankowtok		Muong Thé Kham Kheut
	Uskalisk						
	Suyren						

the Wooramel Group (Aktastinian), and *Reticulatia callytharrensis* (Prendergast) and *Camerisma crassa* (Hamlet) from the Callytharra Formation (Sterlitamakian). Baigendzinian links are suggested by *Lialosia* (Western Australia) and *Costiferina spiralis* (Salt Range). But the overall Bitauni fauna shows a low basic diversity, together with a newly introduced cool-water genus *Trigonotreta* (as *Spirifer simaanensis* Hamlet) to indicate possible correlation with the basal Kungurian glacial episode of east Australia. This would agree well with the ammonoid assessment by Ruzencev (1956). A general Kungurian age is suggested by brachiopods close to or identical with the Irenian *Aperispirifer wairakiensis* (Waterhouse) from New Zealand, and *Waagenites speciosa* from Thailand.

Broili (1915) described a Bitauni fauna from Letti with similar *Costiferina*, *Stepanoviella*, *Spiriferella*, and *Martinia*, accompanied by *Waagenites* identified with *W. strophomenoides* from the lower Wargal Formation (Kungurian) of the Salt Range. Bitauni-type faunas were described from Portuguese Timor by Shimizu (1966), with *Stepanoviella*, *Spiriferella* and "*Plicatifera minor* Schellwien", an overtoniid allied to and perhaps identical with "*Plicatifera*" *huangi* Ustritsky from the *Cancellina* Zone in the basal Maokou Limestone of China.

Tae Wei, Timor, has yielded ammonoids *Hyattoceras* and *Waagenoceras*. Ruzencev (1956) and Glenister and Furnish (1961, p. 683) assigned a Baigendzinian age, but Gerth (1950) and Furnish (1966, table 1) preferred a Sosio (Kazanian) correlation. In view of Gerth's statement that the sutures of *Hyattoceras* were more primitive than in Sosio *Hyattoceras*, the Tae Wei beds might be Irenian, perhaps Ufimian.

Sumatra

From Padang, west coast of Sumatra, a fauna described by Roemer (1880), Fliegel (1901) and Meyer (1922) includes *Verbeekina verbeeki*, *Orthotichia frechi* (Fliegel), *Rhipidomella*, *Marginifera*, *Tyloplecta sumatrensis* (Roemer), *Linoproductus lineatus* (Waagen), *Terebratuloidea davidsoni*, *Spirigerella* spp., *Cleiothyridina*, *Hustedia*, *Crurithyris* (or *Orbicoelia* as at Khao Phrik, Thailand), and *Vacunella padangense* (Roemer). A Kungurian age, probably Irenian (?Nevolin) seems likely in view of the presence of *Crurithyris*.

Thailand

A moderately large brachiopod fauna, dominated by chonetids and *Spiriferellina*, has been described by Yanagida (1970) and Waterhouse and Piyasin (1970) from Khao Phrik, south Thailand. Waterhouse and Piyasin (1970) argued for a mid-Permian age, because the brachiopods obviously included some of the lower mid-Permian suite of brachiopods or close allies, such as *Streptorhynchus pelagonartus* Schlotheim, *Spiriferellina cristata* superspecies and *Cleiothyridina pectinifera*. In deference to the view of ammonoid workers that the Kungurian was inseparable from the Baigendzinian, and in recognition that the Khao Phrik fauna was slightly younger than the Bitauni fauna of Timor, the writers referred the Khao Phrik fauna to the Kazanian Stage. But revision of the ammonoid ages requires revision of the Khao Phrik age, and an Irenian age appears preferable. The fauna is considered to be correlative with the lower Wargal Limestone of the Salt Range, Pakistan, with which there are nine brachiopod species in common—*Orthotichia indica* Waagen, *Marginifera typica* Waagen, *Asperlinus asperulus* (Waagen), *Wellerella naliensis* Reed, *Uncinella indica* Waagen, *Cleiothyridina pectinifera* (Sowerby), *Neospirifer moosakhailensis* (Davidson), *Phricodothyris attenuata*, Reed, *Notothyris praelecta* Reed. *Uncinella* is limited to the lower Wargal beds. *Orbicoelia* is related to and perhaps a geographic variant of *Crurithyris*, which is found in the lower Irenian beds of the Canadian Arctic, north Europe, Iran, and Sumatra.

Sakagami (1968) described bryozoa and fusulinaceans *Ozawainella* spp. and *Neofusulinella* sp from the north part of Khao Phrik. The Chondhurian Fusulinacea described by Pitakpaivan (1965) from mid-central Thailand were considered identical. These authors preferred an early Artinskian age, but evidence is not convincing, and an Irenian age is likely.

Burma

From the Shan States of Burma, Diener (1911) described a fauna from Kehsi Mansam dominated by brachiopods, and accompanied by "*Polydiexodina*" *elongata* (Shumard), which may be referable to *Skinnerella* Coogan according to Skinner (1971) and Wilde (1971). *Skinnerella* was initially described from Kungurian (Irenian) beds of California and older beds of Texas. Cool water indices are provided by *Costalosia*, *Aulosteges*, *Yakovlevia*, *Spiriferella*, *Martiniopsis latouchei* allied to *Tomiopsis confusa* (Waterhouse) from the Irenian beds of New Zealand, and *Martinia*, so-called *M. suborbicularis* Gemm. being moderately like the Bitauni *Martinia*. *Neospirifer fasciger* approaches Bitauni specimens of *Neospirifer*, and both show similarities to *N. wairakiensis* Waterhouse from the New Zealand Irenian. Affinities with the Khao Phrik fauna are suggested by *Rhipidomella*, *Orthotichia indica*, *Waagenites*, *Hustedia*, *Neospirifer* and *Notothyris*, and more generally by *Orthotichia*, *Streptorhynchus*, *Cleiothyridina* and *Spiriferellina*. Overtoniids are present but do not resemble "*Plicatifera huangi*". A Filippovian or more dubiously Elkin correlation seems favoured by *Polydiexodina* (=*Skinnerella*). The cool-water aspect of the brachiopods probably support a Filippovian age, but there are too few other Permian brachiopod faunas from Burma to allow adequate comparisons.

A fauna from Mong Pawn (Diener 1911) contains *Skinnerella elongata*, with *Orthotichia indica* and *Waagenites* allied to Khao Phrik and Bitauni species. *Neospirifer* is close to *Aperispirifer wairakiensis* in costation.

Cambodia

Near Sisophon, West Cambodia, invaluable work by Ishii *et al.* (1969) has established a sequence of four members in three zones, informally lettered A to D. Member A at the base contains *Pseudofusulina padangense* (Lange), *Pseudodoliolina pseudolepida* Deprat, and *P. dunbari* Gubler, with the brachiopods *Orthotichia*, Schuchertellid, "*Strophalosia*" (*Urushtenia?*) *costulata* Thuan, *Tyloplecta nankinensis* (Frech), *?Alexenia gratiosa* (Waagen), "*Dictyoclostus*" *margaritatus* Mansuy, *Stenoscisma* sp. and *Choristites* sp. There are a few similarities to the Khao Phrik fauna in *Orthotichia* and Schuchertellid. On the basis of stratigraphic position, the fauna may be Kungurian or Ufimian. Meagre brachiopod evidence would possibly favour the first alternative on present knowledge, because *Tyloplecta nankinense* is reported from the Kungurian "upper lydite" and Hsiaochiang fauna of China (see below). The species *margaritatus* is possibly allied to *Chaoiella sumatrensis* from Sumatra, of possible Irenian age.

Member B of Ishii *et al.* includes a lower unit, containing *Nankinella quasihunanensis*, *Schwagerina crassa*, *Chusenella* cf. *ishanensis* with *Pseudodoliolina pseudolepia*, *P. dunbari* and *Pseudofusulina padangensis* persisting from Member A. These species are joined near the top of the unit by *Sumatrina annae longissima*, *Neoschwagerina* *douvillei*, *N.* aff *margharitae*, and *Yabeina asiatica*. Ishii (1966, p. 132) considered that *Yabeina asiatica* was a primitive member of the genus, possibly descended from *Neoschwagerin douvillei*. If correct, the entry of the species possibly characterizes a horizon either very late in the Kazanian, or judged from brachiopods described by Chi-Thuan (1961) early in the Kalabaghian. The lower part of Member B may be essentially the same in age, or more likely, is slightly older. A diastem appears to lie between Member A and B, or more doubtfully, within B.

A few brachiopods are present, identified as *Chonetinella*, *Reticulatia*, *Costiferina indica* (Waagen). Several species persisted from A, such as *Urushtenia costulata*, *Tyloplecta nankinensis*, "*Dictyoclostus*" *margaritatus*, and *Choristites*. The stratigraphic position of the brachiopods as related to the fusulinids is not stated.

Apparently, Member B of Ishii *et al.* (1969) yielded the large brachiopod fauna described from Phnom Tup by Chi-Thuan (1961). Ishii *et al.* (1969) stated that their Member C corresponded with Beds 5 to 7 of Saurin, implying that their members A and B were equivalent, at least in part, to beds 1–4 of Saurin. Chi-Thuan (1961) described her brachiopods chiefly from bed 1, and also bed 2 of Saurin, together with *Parafusulina* aff *tunetana* Douville and *Yabeina johannis* Saurin. Table 2 shows the stratigraphic columns provided by the two papers. The table suggests that the red beds of Chi-Thuan's bed 3 and 2 might be equivalent to Member C of Ishii *et al.* but Chi-Thuan recorded few fossils from these beds, and Ishii *et al.* stated that Member C began higher in the section. Yet many of the species recorded by Chi-Thuan from bed 1 and 2 were reported from Member C by Ishii *et al.* (1969). Whether this means that the species have a long range, or that Chi-Thuan's collections were mixed, or that the Ishii identifications are tentative, is not clear. It is imperative to discover the exact horizons covered by the Chi-Thuan collection, and its relationship to Ishii's faunas. It seems possible that faunas are mixed, either by collecting, or condensation of sequences.

Within these limits, the fauna as described by Chi-Thuan (1961) is related to the Wargal faunas of the Salt Range, about ten occurring in the middle Wargal, and eleven in the topmost Wargal, or Kalabagh Member. A number of species are also found in the Chitichun No. 1 and Malla Sangcha faunas of the Himalayas (*?Retimarginifera himalayensis* and *Spiriferella rajah*), which are correlative with the Kalabaghian Member. There are also ten species in common with the Basleo fauna of Timor, most notably *Camarophoriina antisella* (Broili). On the other hand, *Monticulifera* is present, found in the Kungurian lower Maokou Limestone of China, and Chhidruan Kalabaghian beds of Luang Prabang (Deprat, 1913a); and related to the Kazanian genus *Cancrinelloides* of the Arctic and Australia. On the whole, the Chi-Thuan brachiopods appear to be Kalabaghian, as though in part at least from upper Member B.

Table 2. Comparison of Sisophon mid-Permian sequences.

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

Laos

From Cam-mon, central Laos, Deprat (1913b, p. 76) listed a lengthy sequence, which commenced with beds at "level 1" of probable lower Wargal, or Kungurian age, bearing *Waagenoconcha abichi*, *Costiferina gratiosus*, *Chaoiella sumatrensis cambodgiensis*, *Leptodus nobilis*, *Uncinunellina timorensis*, *Spiriferellina*, *Phricodothyris inaequilateralis*, and *Permophricadothyris indica*. "*Spirifer*" *frischi*, somewhat like *S. wynnei* from the Wargal Formation of the Salt Range, is possibly the choristinid reported from Sisophon Member A and B, and Member A also contains the ?dictyoclostid *gratiosus*. Overlying beds of level 2 according to Deprat contain the Fusulinacea "*Fusulina*" (*?Schwagerina*) *richthofeni*, "*Doliolina*" (=*Cancellina?*) *schellwieni*, *Verbeekina verbeeki*, and *Neofusulinella lantenoisi*, the latter also found at Chondhur of central Thailand, in beds thought to be correlative with the Khao Phrik fauna of southern Thailand (Sakagami, 1969). Possibly the fauna is lower Irenian, i.e. Nevolin. Two cool water genera, *Spiriferella rajah* and a syringothyrinid *lyddekeri* (specific identities not confirmed) lie above at level 3, suggestive of a cool episode, conceivably equivalent to the Elkin interval in the Russian Kungurian. Mansuy (1919, p. 91) indicated that these forms were likely to be of Uralian age, although this does not seem convincing. More fusulinid beds follow at level 4, with *Pseudoliolina lepida*, *Verbeekina pseudoverbeeki*, *Schwagerina mansuyi*, as well as species found in underlying beds (*S. richthofeni*, *V. verbeeki*) of late Kungurian or Ufimian age.

According to Deprat (1913) carbonates at Langnac are slightly younger at level 5, bearing *Neoschwagerina margharitae* and *N. megasphaerica* indicating a Kazanian (?Upper Kazanian) age. The brachiopod faunas listed by Deprat (1913b) seem to be the same as larger faunas listed from Phnom ta Kreem, Phnom Ta Maol, and Phnom Roang, of Cambodia and Cammon by Mansuy (1914). Mansuy considered the fauna to be lower or middle Permian, above the *Pseudoschwagerina princeps* beds. The faunas, if grouped, show most affinities with the Wargal Formation of the Salt Range, Pakistan (nine species, three exclusive) compared with six species in common with the Chhidru Formation, none exclusive. However, the ranges of several species do not coincide with what is otherwise known, and it seems possible that faunas of two ages at least have been mixed. The fauna from Phom Miai includes species of *Uncinella* very close to the lower Wargal and Khao Phrik species. It may therefore be lower Irenian. The faunas from Phom Ta Mao and Phnom ra Kreem are possibly younger, perhaps Kazanian, or middle Wargal. Indeed, the locality at Phnom Roang, near Sisophon includes *Echinauris khmerianus* (Mansuy) identified by Ishii *et al.* (1969) from Member D at Sisophon of Chhidruan age.

China

In China Kungurian horizons are poorly understood. From Szechuan Chao (1927, p. 179) and Huang (1932b, p. 96) listed brachiopods in the so-called Hsiaochiang fauna with *Edriosteges poyangensis medlicottianus* (Waagen) and *Tyloplecta nankinensis* (Frech) and *Argentiproductus chianensis* (Chao). "*Ambocoelia planoconvexa*" is probably *Crurithyris*, widespread elsewhere in deposits of lower Irenian age. The fauna is found widely in the Yangtze Valley in the *Wentzelella subtimorica* Zone at the base of the Maokou Limestone. A rather similar fauna was listed by Huang (1932a, p. 27) from the top of the Chihsia Limestone in west Szechuan.

According to Huang (1932a, p. 26) the Hsiaochiang fauna is equivalent to an "Upper Lydite" fauna of the Upper Chihsia Limestone in southern Anhui, (see also Chao, 1927 p. 179). This "Upper Lydite" is also characterised by "*Argentiproductus*" *chianensis*, *Tyloplecta nankinensis* and *T. yangzteensis*, with two significant additional species, *Monticulifera sinensis* (Frech) and "*Plicatifera*" *huangi* Ustritsky, allied to the Bitauni "*Plicatifera*". The two faunas are obviously close, but could be of slightly different ages, with the lydite Filippovian perhaps, and the Hsiaochiang fauna lower Irenian. However, Chan and Lee (1962) described a more complete fauna from Shansi with *Orthotichia indica* (Wargal, Khao Phrik), *Chonetinella plicatiformis* (aff Nevolin species), *Plicatifera huangi* (aff Bitauni species), *Krotovia janus*, *Argentiproductus chianensis*, *Monticulifera sinensis* (Frech) and *Urushtenia*. *Marginifera elongata* Huang (also Khao Phrik) and *Crurithyris* (Irenian widespread) are recorded also, possibly from a different locality. Underlying Fusulinacea include *Neoschwagerina* sp., *Misellina lepida*, *Cancellina schellwieni*, and overlying beds contain *Neoschwagerina*, *Pseudodoliolina*, *Verbeekina* and *Misellina*. The brachiopods appear to be of lower Irenian (Nevolin) age, and the *Cancellina* beds are the same or slightly older.

Of chief interest is the occurrence of *Monticulifera sinensis* (Frech). This genus is closely allied to, if not congeneric with and a senior synonym of *Cancrinelloides*, which is a key to the Kazanian Stage in Arctic latitudes of Canada and Siberia and also in Queensland, Australia. Apparently the genus evolved first in the paleotropics of China during the Kungurian, and migrated later into higher latitudes, becoming slightly altered either generically or specifically.

Brachiopods from the middle Maokou Limestone, characterized by *Neoschwagerina*, are few and in need of revision, as well as clarification of their stratigraphic position. According to Huang (1932a) they include *Haydenella kiangsiensis wengenensis*, and *Marginifera magniplicata*, also found at Sisophon (Member B?) by Chi-Thuan (1961).

Elsewhere in China the basal Kufeng beds of central Kwangsi contain primitive Cyclolobidae *Kufengoceras* and *Shengoceras* (Chao 1965; Waterhouse, 1972b), correlated with the *Cancellina* fusulinacean zone. In northeast Kiangsi and western Chekiang the lower Tingchiashan Formation includes *Mexicoceras* and *Waagenoceras*, two ammonoid genera characteristic of the Word Series in Texas (Furnish and Glenister, 1970). The upper middle part of the formation includes *Daubichites*, allied to but presumably slightly younger than a species from the basal Kungurian Assistance Formation of the Canadian Arctic (Nassichuk 1970).

Fusulinid zonation

Zonation of Fusulinacea promises to be most useful for gaining tight age control of paleotropical Permian faunas, similar to the fine brachiopod control applied in the Arctic, Australia and New Zealand. From the Khao Phlong Phrab section of central Thailand, Kanmera and Toriyama (1968) showed how *Misellina* diversified into *Cancellina*, *Verbeekina*, *Armenia*, and *Pseudodoliolina* in the early mid-Permian. One lineage was represented by *Maklaya*, which was probably ancestral to the *Neschwagerina* complex. In the Khao Phlong Prab section *Maklaya saraburiensis* appears above the *Misellina* Zone, and is followed by *M. pamirica*, then *M. sethaputi*, then *Neoschwagerina simplex* and *Cancellina tenuitesta* (Table 3).

From Japan, the *Neoschwagerina simplex* Zone is close in age to the Kungurian in Russia, judged by its faunal content and stratigraphic position. It is classed by Toriyama (1967) as part of the Nabeyaman Stage, and occurs with *Cancellina tenuitesta* in the Kozaki Formation, south Kyushu. It preceeds beds of the Akasaka Stage with *Neoschwagerina craticulifera* followed by *N. margharitae*.

Table 3. Intercorrelation of fusulinaceans from early mid-Permian of south-east Asia and other sequences. Asterisks mark occurrences of associated brachiopod faunas which help date Filippovian and Nevolin horizons. Age control is poor for *Neoschwagerina craticulifera* and *Nankinella* of Sisophon, and these beds could be pre-Kazanian.

Russian Platform	Japan	Pamirs	Bamian Afghanistan	South-west Iran	Sumatra	Thailand Khao Phrik Chondhur	Thailand Khao Phlong Phrab	Burma	Sisophon (Ishii *et al.* 1969)	Deprat 1913, central Laos
Kazanian	*Neoschwagerina margharitae* *N. craticulifer*	*N. craticulifera* *Afghanella* (or older)							*Nankinella* *Chusenella* * *P. padangenese*	*Neoschwagerina margharitae* *N. megasphaerica*
Ufimian										*Pseudodoliolina* *Verbeekina pseudoverbeeki*
Elkin										*
Nevolin	*Neoschwagerina simplex* *Cancellina tenuitesta*	*N. simplex* *Neofus. lantenoisi*		*Neo. craticulifera* *Cancellina primigena*	*Verbeekina verbeeki* *	*Neofusulinella lantenoisi* *Ozawainella* *	*Neschwagerina simplex* *Ozawainella tenuitesta*	*Cancellina*		*Schwagerina richthofeni* *Cancellina ?* *Verbeekina verbeeki* *Neofusulinella lantenoisi*
Filippovian		*Maklaya cutlaensis* *M. pamirica* *Pseudodoliolina ozawai* *M. pamirica* *M. cutlaensis* *Cancellina primigena*	*Maklaya sethaputi* *Neo. craticulifera haydeni* *Skinnerella afghanensis*	*Skinnerella persica*			*Maklaya ..sethaputi* *M. pamirica* *M. saraburiensis*	*Skinnerella elongata* *	*Pseudofusulina padangenese* *Pseudodoliolina* *Pseudolepida* *	*

In the Pamirs of central Asia Leven (1967, p. 23) showed that the upper Kubergand Formation contained a large fusulinacean fauna, including *Pseudofusulina chihsianensis*, *Parafusulina spp.*, *Maklaya pamirica*, *M. cutlaensis*, *Cancellina primigena*, *Armenina*, *Pseudodoliolina ozawai*, *Chusenella*. It is overlain by beds with *Maklaya cutlaensis* and *M. pamirica*, followed by the Gans Suite with *Neoschwagerina simplex*, and *Neofusulinella lantenoisi*, overlain by beds with *N. craticulifera* and *Afghanella*.

The Bamian sequences of Afghanistan are also relevant. Thompson (1946) described a fauna with "*Polydiexodina*" (*Skinnerella*) *afghanensis*, *Neoschwagerina craticulifera haydeni*, *Verbeekina verbeeki*, *Cancellina primigena*, and *Afghanella schencki*, with definite overlap between *Cancellina*, *Neoschwagerina* and *Skinnerella*. Kanmera and Toriyama (1968) considered that *Cancellina* was in fact *Maklaya*, close to *sethaputi* from the Thailand sequence. Earlier work established part of a sequence of faunas near Khojagar dara. Topmost beds contained "*Cancellina primigena*", underlain by faunas with "*Neoschwagerina craticulifera*", and a rich brachiopod fauna including "*Avonia*" *bamiensis*, *Linoproductus afghanensis* Reed, *Camerisma sella* (related to the Bitauni *Camerisma*), and *Martiniopsis convexa*. At the base beds contained further so-called *Cancellina primigena* and *Neoschwagerina craticulifera* (Reed, 1931, p. 2,3).

In the Iran sequence described by Douglas (1936, 1950) *Polydiexodina* (or *Skinnerella*) *persica* preceeds *Neoschwagerina craticulifera* with *Cancellina primigena*. The latter are accompanied by *Lissochonetes*, a key to lower Irenian beds in the Arctic Canada and Soviet Union, and by *Mentzelia*, a genus possibly related to *Spirelytha schei* (Chernyshev and Stepanov), known only from the lower Irenian of the Canadian Arctic. *Cancrinella* resembles a Filippovian species of Canada, and *Costalosia argentea* Waterhouse and Shah is moderately close to *C. bifurcata* found with *Skinnerella elongata* in Burma, but the exact stratigraphic relationships of the Iranian forms are not clear. Other species identified by Douglas suggest a mixture of ages, ranging from Baigendzinian to Kazanian but need re-examination. According to Douglas "*Polydiexodina*" lay above beds with *Parafusulina* which are related to species from the Sarginian or lower Baigendzinian Amb Formation of the Salt Range, Pakistan.

Thus, in summary, the *Skinnerella* and early *Maklaya* beds might be Filippovian, the earliest *Neoschwagerina simplex* beds lower Irenian, and *Cancellina* beds as young as late Irenian, or even Ufimian. The position of *Neoschwagerina* identified as *craticulifera* or *craticulifera haydeni* requires verificationi n a number of sequences. Possibly its range varied in different places, or there has been faunal mixing, possibly through slow deposition or reworking, for it must be noted that the time intervals were very brief. It has been assumed that *Neoschwagerinac raticulifera* is typically lower Kazanian, and *N. margaritae* upper Kazanian, but perhaps this is in error, and one or both zones may be slightly older.

One of the most useful mid-Permian faunas to link the paleotropical with northern faunas of paleotemperate latitudes from the Canadian and Siberian Arctic is the large brachiopod faunule described from Cape Kalouzin, Sikhote Alim, by Frederiks (1925). Though assigned to the high Tatarian by Licharev (1966), it is probably Kungurian in age, and more precisely lower Irenian. Links with the Canadian Arctic faunas are provided by *Chonetina*, *Waagenoconcha*, *Terrakea*, *Anidanthus*, *Yakovlevia*, *Timaniella* aff *harkeri* ("*Spiriferella* aff *vercherei*"), and with the Khao Phrik fauna by *Waagenites*, *Marginifera* and *Compressoproductus*. More general Kungurian affinities are provided by *Hustedia*, *Cleiothyridina*, *Neospirifer*, *Spiriferellina* and other genera.

MID MIDDLE PERMIAN

Kalabaghian and Chhidruan faunas.

The traditional world standard Tatarian Stage is a most unsuitable stratotype with no marine beds. Three stratotypes have been used instead from west Texas, Salt Range, and Armenia–Iran. In the Salt Range the upper Wargal Formation, or Kalabagh Member of Teichert (1966), immediately overlies ?Kazanian faunas of the middle Wargal Formation, and has a very rich brachipod fauna including numerous *Enteletes*, no *Orthotichia indica*, or other *Orthotichia* except *O. derbyi*, a number of *Streptorhynchus*, *Waagenites*, *Tschernyschewia* and Lyttoniids as in lower beds, restricted *Aulosteges dalhousei*, numerous *Waagenoconcha*, numerous *Haydenella*, *Chonetella* and dictyoclostids as in lower beds, and some characteristic linoproductids, such as *?Stepanoviella lahuseni*, and *?S. kulikii*, *Compressoproductus mongolicus subcircularis*, *?Anidanthus "weyprechti"*, restricted *Laevicamera* or *Camerisma*, *Spiriferella scopulosus*, *Ella blanfordi*, *Elivina interplicatus "bashkirica"* and *Elivina blasii* from older beds. *Purdonella conformis* and *P. limitaris*, both restricted, occur with longer ranging *"Choristitella" wynnei*, *C. interauritus*, and *Neospirifer*. *Tomiopsis punjabica* and several species of *Martinia* and *Dielasmina* are restricted.

The overlying Chhidru Formation has fewer *Enteletes*, no *Streptorhynchus*, *Chonetina*, *Aulosteges*, fewer *Tschernyschewia*, *Juresania*, *Argentiproductus*, *Stepanoviella*, *Tomiopsis*, *Uncinunellina*. New genera include *Sphenalosia*, *Tyloplecta*, *Fredericksia*, and *Cryptacanthia*. At the top comes the Kathwai Member of the Mianwali Formation with a small peculiar fauna, including *Orbicoelia*, *Orthotetes* and *Martinia*, described by Grant (1970). Overlying beds are either basal Triassic or late Permian (Waterhouse, 1972a, b).

Timor

Differing faunal lists have been presented for the large Basleo fauna from various localities in Timor by Broili (1916) and Hamlet (1928). Subject to this reservation the Basleo fauna is of Kalabaghian age, judged from such brachiopods as *Edriosteges dalhousei*, abundant *Spiriferella*, *Martinia* and *Uncinunellina*. Strong links to the Kalabaghian Chitichun 1 fauna of the Himalayas, described by Diener (1903) are suggested by *Strophalosiina tibetica*, *?Chaoiella chiticunesis*, *Uncinunellina timorensis* and *Spiriferella tibetana*. The Basleo fauna also contains *Calceolispongia* allied to a species from the Barfield Formation of Queensland, which has species in common with the lower Puruhauan fauna of New Zealand (Waterhouse, 1969). The lower Puruhauan Stage has *Lepidolina multiseptata*, and *Attenvatella* close to a species found with *Timorites* in Mexico.

Brachiopods from the Amarassi fauna of Timor include *Waagenoconcha abichi*, *W. waageni* (close to *W. imperfecta* Prendergast (Chhidruan) in Western Australia), *Richthofenia lawrenciana*, *"Rhynchonella" wichmanni*, *Hustedia tenuistriata*, *H. grandicostata*, *Cleiothyridina semiconcava*, *C. capillata*, *Sprierifella interplicata* and *Dielasma truncatum*, none apparently found in the older Basleo beds. Basleo brachiopods that did not persist included species of *Rhipidomella*, *Waagenites*, *Echinalosia*, *Aulosteges*, *Marginifera*, *Camerisma*, *Camarophoriina*, *Cardiocrania*, *Paralyttonia*, *Oldhaminella*. The Basleo fauna is equivalent to Kalabaghian. The Amarassi fauna, being slightly younger than the Basleo fauna, is possibly correlative with the Chhidruan Stage. The Amarassi brachiopods have a number of links to both the Kalabagh and Chhidruan faunas, and show the same disappearance of Kalabaghian genera as does the Chhidruan. This is not conclusive evidence for correlation, and there are in addition some confusing discrepancies in the various faunal lists by Hamlet (1928), Broili (1916) and Rothpletz (1892).

Numerous ammonoids are known from the two faunas. Gerth (1950, p. 256) assigned the Basleo fauna to the *Timorites* Zone of West Texas and Mexico (ie. Capitanian, which part unspecified) on the basis of *Timorites*, and assigned the Amarassi fauna to the *Cyclolobus* Zone, of the Chhidru Formation, "ohne zweifel". Spinosa *et al.* (1970, p. 731) stated that the Basleo ammonoids were correlative with the "*Timorites* shale" of Las Delicias, Mexico, and the Hegler Limestone of the lower Capitanian in west Texas. They compared *Strigogoniatites fountaini* Miller and Furnish from the upper Capitanian Lamar Limestone to *S. angulatus* (Haniel) from Amarassi. Furnish and Glenister (1970) considered the Chhidruan Stage to be much younger, whereas it is here believed to be correlative, from ammonoid evidence summarised by Gerth (1950) and Waterhouse (1972a), supported by brachiopod evidence summarised by Grant (1970) and Waterhouse (1966). The Amarassi fauna was also correlated with the upper La Colorada beds of Sonora by Spinosa *et al.* (1970) on the basis of *Stacheoceras* cf *tridens* (Rothpletz) and *Episageceras* cf *nodosum* Wanner. However the appearance of primitive Araxoceratidae in the Mexixan horizon would suggest to the writer that the La Colorada beds are slightly younger than the Amarassi–Chhidru beds.

From northern Pahang, at Sungei Remih, Igo (1964) recorded several dictyoclostids, *Neospirifer*, compared to *wynnei* Waagen, but probably closer to the *fasciger moosakhailensis* lineage, and *Spiriferellina cristata*, accompanied by *Wentzelella* and Fusulinacea of the *Yabeina* Zone. Jones *et al.* (1966, p. 329) also listed various brachiopods, including *Schellwienella ruber* (Frech) and *Spinomarginifera* cf *kueichowensis*, with Fusulinacea of the *Yabeina asiatica* Zone, probably of early Kalabaghian age, from Jengka Pass in Pahang.

Thailand

A small fauna described by Yanagida (1964) from Phetchabun, Thailand, is possibly Kalabaghian as it includes *Tyloplecta yangtzeensis*. But it also includes *T. nankinensis*, restricted to member A and B at Sisophon, Cambodia. Other brachiopods include *Orthotichia*, *Orthotetina*, *Haydenella*, *Linoproductus* and *Marginifera banphotensis* which was listed from Sisophon Member C with *Lepidolina multiseptata* by Ishii *et al.* (1969).

Burma

From the Shan States of Burma a fauna between Taung-Gyi and Mong Pawn includes "*Schuchertella*" *semiplana* and *Strophalosiina tibeticus* with *Cleiothyridina*, *Marginifera* and Chonetid (Reed, 1933). A larger fauna described by Reed (1933) from Htam Sang may be close in age, in possessing various *Streptorhynchus*, *Orthotetes*, "*Schuchertella*" *semiplana*, chonetid, *Krotovia janus* (found in the upper Maokou), *Notothyris exilis* (also Chitichun I and Sosio), and longer ranging *Spirigerella derbyi*, *Derbyia grandis* and *Leptodus nobilis*. *Martinia* and *Martiniopsis* are also present.

Cambodia

Of the zones recognised by Ishii *et al.* (1969) near Sisophon in west Cambodia, the "*Marginifera*" (*?Retimarginifera*) *himalayensis* Zone, or Member C has many links with the Himalayan and Timor faunas, including *Strophalosiina tibetica* (Basleo–Chitichun I), *Costiferina gratiosa* (Wargal), *?Retimarginifera himalayensis* (Chitichun I, Zewan–Chhidruan), *Neospirifer moosakhailensis* (widespread in Salt Range, Himalayas and Timor,) *Martinia nucula* (Basleo, Chitichun, Amarassi), *Hustedia grandicosta* (Amarassi), *Stenoscisma purdoni* (Chitichun I, and aff. Basleo species *fide* Hamlet, or Amarassi species *fide* Broili 1916), *Uncinunellina timorense* (Basleo, Chitichun I, Amarassi). Species shared with the Wargal Formation of the Salt Range include *Rhipidomella corallina*, '*Schuchertella*' *semiplana*, **Tschernyschewia typica*, *Alexenia gratiosa*, *Tyloplecta yangtzeensis*, *Anidanthus sinuosus**, *Leptodus nobilis*, **Stenoscisma purdoni*, *Terebratuloidea davidsoni*, *Hustedia grandicosta*, *Neospirifer moosakhailensis*, *Phricodothyris elegantulus*, **Martinia semiplana*. The asterisked species are characteristic of the Kalabaghian Member, but are not restricted. Only *R. corallina* suggests a middle Wargal age, and *T. yangtzeensis* is recorded from the upper Cliff Limestone rather than the topmost Wargal. *Edriosteges* from Member C may be related to the Kalabaghian species *E. dalhousei*.

Fusulinacea from Sisophon Member C include *Verbeekina verbeeki*, *Yabeina asiatica* and *Lepidolina multiseptata* correlative with the Kuman Stage of Japan, the upper Maokou Limestone of China, and the basal Puruhauan Stage of New Zealand (Toriyama, 1967; Sheng, 1964; Waterhouse 1969).

There is also a preponderance of affinities with the Kalabaghian faunas from Chitichun I and Malla Sangcha rather than the upper Zewan and Nepalese faunas of Chhidruan age. The species shared with the Amarassi and Ajer Mati faunas are slightly more numerous than those found in the Basleo faunas of Timor, and perhaps Imply that the Amarassi faunas are late Kalabaghian.

In Member D of the Sisophon sequence described by Ishii *et al.* (1969) many of the fusulinacea persist from Member C, with the addition of *Yabeina multiseptata gigantea*, *Y. elongata* Gubler and *Y. minuta* Thompson and Wheeler, as well as *Para fusulina*. The brachiopods differ considerably, and include *Echinauris khmerianus* (Mansuy), *Monticulifera sinensis* (Frech), *Oldhamina*, *Phricodothyris elegantulus* (Waagen), *Permophricodothyris grandis* (Chao). *P. elegantula* is found only in the Wargal beds of the Salt Range, and *P. grandis* in the Chhidru beds, and Choutang beds of China. *Monticulifera sinensis* is characteristic of slightly older, especially Kungurian faunas, but it or the closely allied genus *Cancrinelloides* persists into Kalabaghian equivalents in the Flat Top Formation of Queensland, and in the upper Baikurskian of Taimyr Peninsula. *Monticulifera* indicates cool waters. A cool-water fauna is also represented at approximately this horizon in the *Martiniopsis woodi* Zone of the Puruhauan Stage in New Zealand. However, it is still not possible to match this cool-water episode with any horizon in the Salt Range, Armenia, or west Texas with any certainty perhaps because insufficient detailed zonation has been attempted in these areas. By superposition, a late Kalabagh or Chhidruan correlation seems likely.

Laos

From Pong Oua, Laos, Deprat (1913b) recorded "level 7" with *Yabeina globosa*, *Sumatrina annae*, and *Schwagerina douvillei*, accompanied by brachiopods such as *Orthotetes*, *Linoproductus lineatus* Waagen, *Lyttonia tenuis* Waagen, *Dielasma grandi* Mansuy and *D. triangularis* Mansuy. Overlying carbonates also contained *Yabeina globosa*, and *S. annae*. These faunas are approximately correlative with the Kalafiagh Member of the Salt Range. According to Deprat (1914) *Yabeina globosa* typified a horizon immediately preceeding *Lepidolina multiseptata* beds, but there seems to be no conclusive confirmation for this. In Japan, it is generally held that the *Yabeina globosa* zone is approximately equivalent to the *Yabeina shiraiwensis* Zone, followed and partly overlapped by the *Lepidolina toriyamai* Zone (Toriyama, 1967, p. 50).

From greywackes of Luang – Prabang, Laos, Mansuy (1912) recorded *Krotovia nystianus*, *Monticulifera paviei*, and a linoproductinid *mekongensis*. *K. nystianus* and another overtoniid were also found at Ban-na-hai, with a Xenodiscid (Mansuy, 1919, p. 91). The faunas are correlative with that of Member D from Sisophon.

Vietnam

From Quang Tri, Central Vietnam, Chi-Thuan (1962) recorded several species found also in Sisophon Member C, including *Leptodus nobilis*, "*Schuchertella*" *semiplanus*, *?Costiferina gratiosus*, *?Retimarginifera himalayensis*, and *Spinomarginifera kweichowensis*. *?Chaoiella margaritatus* (Mansuy) from this horizon is found in Sisophon Member B, but ranges into the late Permian Choutang Formation of China. "*Schuchertella*" *semiplana* is found in the Wargal and Chhidru formations, and *Leptodus tenuis* and *Uncinunellina jabiensis* are restricted to the Wargal Formation in the Salt Range.

China

The upper Maokou Limestone of China is apparently characterised by a zone of "*Plicatifera*", presumably equivalent to the *Yabeina* beds. Other species described by Huang (1932 a, b, 1933, p. 97) include *Schizophoria tani*, *Streptorhynchus*, *Neochonetes*, *Waagenites*, *Waagenoconcha*, *Krotovia janus*, *Urushtenia*, an anidanthinid *fusiformis* Huang, *Compressoproductus* (also characteristic of the Kalabagh Member in the Salt Range), *Hustedia grandicosta*, *Terebratuloidea davidsoni*, *T. depressa*, *Phricodothyris* and *Martinia* spp. This list resembles various South East Asian lists, but the stratigraphy is not clearly explained, and the reader is left in doubt about the possibility of whether the fauna is in fact younger than the *Yabeina* Zone, or somewhat older, as suggested by the record of *Plicatifera huangi* (=*P. minor* of Huang, 1932b) in early Maokou beds by Chan and Lee (1962).

Japan

In Japan the *Yabeina* fusulinacean complex, summarised by Toriyama (1967), is accompanied by brachiopod faunas, some of which are correlative with the Kalabagh Member, such as the Takauchi fauna in the Yakuno district of south-west Japan, which includes the schuchertellid *semiplanus* and *Strophalosiina tibetica* and *Martinia elegans*.

A *Lepidolinatoriyama* fauna from the upper Maizuru Group of Japan (Shimizu, 1962) includes the Chhidruan species *Derbyia grandis* Waagen, *D. altestriata* Waagen, and various chonetids, including *Lissochonetes bipartita* Waagen. *L. cf avicula* (Waagen), with *Chaoiella margaritatus* (Sisophon Member A and B, younger beds from Vietnam), *?Edriosteges dalhousei*, and *Haydenella kiangsiensis*. This shows little resemblance to the faunas from Pong Oua or Sisophon Member D, and may be slightly younger.

East Siberia

The cool water fauna from Pong Oua, Laos, has a number of overtoniids, as in a fauna listed in Licharev (1966) from the Chandalaz suite of southern Primorye, east Siberia. Here *Yabeina*, *Lepidolina*, *Codonofusiella*, *Misellina* and *Verbeekina* are accompanied by two overtoniid species, with *Aulosteges*, *Haydenella*, *Eliva lyraeformis*, *Spiriferella* and richthofeniids.

LATE MIDDLE PERMIAN

No faunas of younger Permian age are known for certainty from south-east Asia, but various species have been identified with young Permian Wuchiaping and Changsing faunas of south China, eg. the chonetids from Quang Tri (Chu Thi-Chuan, 1962) and some of the faunas herein treated as Chhidruan or even Kalabaghian may be somewhat younger. Indeed various authorities still regard the Chhidruan as either very high, or at the top of the Permian (fc Furnish and Glenister, 1970; Nakazawa *et al.* 1970). But the Chhidruan and closely allied Kalabaghian faunas are followed by further faunas of undoubted Permian age. One of the most complete successions is provided by various sections in Iran and Armenia. Here the Kalabaghian fauna is represented by the Gnishik fauna, also found nearby in the Ruteh fauna, (level 1), of Sestini (1965), Iran. The Chhidruan fauna is represented in the Khachik beds, *Martiniopsis inflata* and corals providing a direct link. The upper Khachik, separated as a unit by Stepanov *et al.* (1969), characterised by *Codonofusiella*, and *Orthotetina arakeljani* is better developed in central Iran, where Taraz (1971) has proposed a new Abadehian Stage. This fauna is also developed in Ruteh 3 and 3a of the Elburz Mts, Iran, with *Orbicoelia*, and in the lower Kathwai fauna of the Salt Range, with *Orthotetina arakeljani* and *Orbicoelia* (Waterhouse, 1972a).

Overlying beds in the Armenian succession above the *Codonofusiella* beds were referred to the Baisalian Stage by Waterhouse (1972b), characterised by brachiopods *Dorashamia*, *Araxothyris*, and *Araxilevis*, and the ammonoid family Araxoceratidae. New cephalopod genera included *Vescotoceras*, *Vedioceras*, *Protoceras*, and *Pseudotoceras*. The same brachiopod fauna is found in the lower Nesen Formation of the Elburz Mountains, as restricted by Stepanov *et al.* (1969) and the lower Bellerophon beds of south Europe, especially in Yugoslavia and Hungary. The typical Baisalian ammonoids are found in the Laochan Shale of China, considered to be correlative with the Wuchiaping Limestone, and Choutang Limestone. This level is characterised by *Codonofusiella*, but no characteristic Baisalian brachiopods can be recognised from the various descriptions summarised in Huang (1932). The brachiopods look from figures to be very like those of the Kalabaghian and Chhidruan levels, but have not been examined for over forty years. Moreover it is likely that the sequence of faunas has not been subdivided as finely as for Armenia or in other recent studied regions. Grant (1970, p. 121) assigned these "Lopingian" faunas to the early Guadalupian, ie. Kungurian to Kazanian, or lower and middle Wargal, on the presence of *Waagenoconcha*, because this genus disappeared from the later Guadalupian faunas. However *Waagenoconcha* is widespread in late Guadalupian correlatives in Timor, Western Australia, New Zealand, and elsewhere.

UPPER PERMIAN

Above the Baisalian comes the Upper Permian Dorashamian Series, which commenced with the Vedian Stage of Waterhouse (1972b), characterised by Xenodiscid ammonoids, and the brachiopod *Comelicania*. The brachiopod is also found in the upper Bellerophonkalk of Austria–Italy, where a rich bivalve fauna is identical with that found in the Gujo fauna of the Maizuru Group, Japan (Nakazawa and Newell, 1968). No trace of this very characteristic fauna has been found in China or south-east Asia.

Above the Vedian Stage is the Ogbinan Stage, with various typical Permian brachiopod genera (*Orthotichia*, *Enteletes*, *Orthotetina* and *Terebratuloidea*) and characteristic ammonoids such as *Paratirolites*, and *Dzhulfites*. The Changsing beds of south China may be correlative. The youngest Permian is known only in New Zealand, where the Makarewan Stage has Permian brachiopod genera, and new genera in families that persisted into the Triassic, with no Productida or Orthotetida, or other groups that perished at the end of the Permian.

One important matter that requires clarification is the exact position of the Permian–Triassic boundary. It is generally assumed that *Otoceras*, followed by *Ophiceras*, mark the start of the Triassic period but these ammonoids are found with Permian type brachiopods in several regions. In some of these instances there has been some reworking, as in Greenland, but in other instances, fairly distinctive Permian brachiopods have been found, in the Griesbachian of Canada (Waterhouse, 1972b) and also in the Dinwoody Formation of Wyoming. Rostovtsev and Azarian (1971) have reported Permian brachiopods with *Otoceras* and *Glyptophiceras* in Armenia over *Paratirolites* beds, and occurrences of *Ophiceras* have been recorded from the Himalayas, generally with mid-Permian brachiopods that may have been reworked, unless grossly misidentified. Pascoe (1959, p. 712) noted an occurrence in Indochina of *Ophiceras* with a Permian ammonoid and brachiopods, so that South-East Asia apparently shows the same phenomenon. Possibly the Permian–Triassic contact has been misjudged, and should be placed above the Griesbachian. After all, *Ophiceras* is very closely related to the Permian ammonoid family Xenodiscidae, and is known in the mid Permian Katwhai Member of the Salt Range.

CONCLUSIONS

Studies of Fusulinacea and brachiopods show that upper Asselian, Kungurian, Kazanian, Kalabaghian and Chhidruan horizons are well developed in south-east Asia. Intervening rocks and faunas of Sakmarian and Baigendzinian age are less well known, and no younger Permian rocks are known for certain. It is possible to correlate the early middle Permian (Kungurian to Kalabaghian) sequences in fine detail with successions in the Russian standard, Arctic, Salt Range, Australasia and elsewhere. The order of appearance of the Fusulinacea *Neoschwagerina*, *Maklaya*, *Skinnerella* and *Cancellina* is not entirely clear, unless there are inconsistencies, but the scale of subdivision is now extremely fine. One outstanding problem of correlation lies in the age of the Sisophon Member D, with a cool water fauna that can be traced in south-east Asia, south Primoyre of Siberia, and New Zealand, but not yet in any of the standard sequences.

The present work underlines the importance of studies of faunas in sequence, such as those by Deprat (1913b), Mansuy (1919), Kanmera and Toriyama (1968) and Ishii *et al.* (1969). Studies of isolated faunas are virtually useless for correlation purpose unless they can be correlated with a zone in other sequences. Certainly the practice of referring isolated faunas to subdivisions as crude as the Sakmarian, Baigendzinian, Wordian, etc. marks no improvement over studies of the early part of this century.

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