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The World Significance of New Zealand Permian Stages

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Abstract

THE pattern of Permian stages proposed by Waterhouse (1966a; 1967b) for New Zealand is traced over Australia and other southern realms, and into the Arctic deposits of Siberia and Canada. Three glacial episodes are recognised in Australia, with severe contemporaneous chilling in New Zealand, and in Siberia and Canada. Attention is given to queries by Runnegar and Armstrong (1969) who, with their corrections to the miscorrelations offered by Runnegar (1967), fall more into line with the view of Waterhouse (1963c; 1967b).

INTRODUCTION

IN a recent note Runnegar and Armstrong (1969) have expressed dissatisfaction with the local scheme of New Zealand Permian stages. To some extent their objections were based on misunderstandings which can be easily resolved, and to some extent they were simply repeating what has already been published, without acknowledging the fact, as though they were correcting New Zealand work when they were really agreeing with it. Most of the facts they presented are based on data I have published, though this has not been acknowledged, and they also appear to use opinions I had discussed with them in Brisbane during May, 1967. Their suggested correlations between Queensland and New Zealand now largely *agree* with what I have always proposed, and *conflict* strongly with the published views of Runnegar (1967) as shown in Table I. Presumably my discussions in Brisbane with Dr Runnegar confirmed his lack of faith in his own recorded views.

Table 1. East Australian and New Zealand correlations. (Note the divergent correlations of Runnegar (1967), now abandoned by Runnegar and Armstrong, who have moved closer to Waterhouse.)

New Zealand Stage	East Australian Correlations		
	Waterhouse	Runnegar & Armstrong	1967 Runnegar
Puruhauan	Fauna "V"	Fauna IV	Fauna IV
upper Braxtonian	Fauna IV		Fauna III
lower Braxtonian			
Mangapirian	Fauna III	Fauna III	
Telfordian	Fauna II	Fauna II	Fauna I

Apart from these minor matters, Runnegar and Armstrong have made two propositions that should receive closer attention. The first is that paleoclimatic

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interpretations based on molluscs and brachiopods are misconceived, and the second is that the New Zealand scheme of stages is simply a dubiously interpreted local phenomenon and of no world significance. I propose to examine these claims briefly, but must first endeavour to clarify some of the detailed misconceptions over the New Zealand Permian.

INTERNAL CORRELATIONS

Preservation and Distribution

Though they have never conducted field work in New Zealand, Runnegar and Armstrong (1969) refuse to accept the lithological correlations summarised by me from work by various colleagues of the New Zealand Geological Survey (Waterhouse, 1964b). They have offered no reasons for their scepticism, and so there appears to be nothing to answer. Nothing can combat a sceptical attitude that refuses either to check the propositions in the field and museum collections or to read the maps and papers. Assertions are made with greater truthfulness about poor preservation and paucity of numbers, for they repeat my observations. Fortunately such difficulties can be overcome, and, as shown below, the usefulness of the New Zealand material is proved by the application of conclusions based on it to the entire marine Permian of the world. Not all New Zealand material is badly preserved, as may be seen by comparing illustrations of New Zealand *Strophalosia* (*Echinalosia*) in Waterhouse (1964c, pls. 5, 6) with Queensland *Strophalosia* in Maxwell (1954) or New Zealand *Atomodesma* (Waterhouse, 1963b) with Queensland *Atomodesma* (Dickins, 1961). Some of the species yield more detail than even the silicified fossils of the Glass Mountains, Texas. Nor are faunas always sparse and geographically restricted. *Atomodesma* species occur in zones which extend from the southern South Island to New Caledonia, for a distance of over 2,500 miles (Waterhouse, 1967d). Numbers of species and genera are also misjudged by Runnegar and Armstrong. By selectively quoting my works they have given the impression that the Mangapirian Stage contained seven species. The stage has about 20 key species. Although this discrepancy, one of many, may or may not give some measure of the reliability of these authors, it is an unfortunate misrepresentation. New Zealand is small, and, occupying temperate latitudes, would not be expected to yield huge faunas. Its marine faunal diversity is modest, but the diversity is greater in some respects than that of Australia, in that it includes reef-building corals and fusulinids. It is still modest, however, and definitely inferior to that of South China or the Glass Mountains. A comparison may be made in terms of gastropods with New South Wales. Fletcher (1958) has recorded 32 species, distributed among 13 genera; Waterhouse (1963d) has recorded 35 species distributed among 18 genera. Both works may require revision, but the order of magnitude is probably correct.

Correlation of Species and Genera

In commenting on genera such as *Strophalosia* and *Neospirifer* Runnegar and Armstrong have repeated my own conclusions (for *Strophalosia* see Waterhouse 1964c, p. 28; 1966b, p. 12; 1967b, p. 167; for *Neospirifer* see Waterhouse 1968a, p. 82), but they have not acknowledged that their views coincide with mine. Another genus mentioned is *Platyteichum,* in which the species *spirolaxum* Waterhouse is compared with *P. johnstonei* Dickins. As far as age is concerned this similarity would be correct. As noted by Waterhouse (1963a, p. 130), however, the position of the selenizone on the whorl is very different in the two forms. Runnegar and Armstrong have possibly followed Dickins (1963) in this regard, attaching little significance to such a distinction and clinging to an outmoded classification much less developed than that in the *Treatise* by Knight *et al.* (1960), as noted by Batten (1967).

The genus *Attenuatella* supposedly commenced in the Artinskian, according to Runnegar and Armstrong. They have added " as Waterhouse points out ", but I am not able to find the source of my alleged support. I have always been sceptical about such a young beginning for this particular genus, as implied in my correlations. Recent advances have justified this caution, for the genus has been reported in pre-Artinskian (Sakmarian) deposits by Licharev (1966), Waterhouse (1967e), and Zavodowsky (1968). In fact the type species is probably Sukmarian. Runnegar and Armstrong (1969) and also Armstrong and Brown (1968, p. 59) do not appear to have kept up with recent advances.

CORRELATION WITH EASTERN AUSTRALIA

Correlation of Braxtonian and Puruhauan Stages

With two or three exceptions, the views on correlation between eastern Australia and New Zealand propounded by Armstrong and Runnegar (1969) follow those published in Waterhouse (1958; 1963c; 1964b; etc.) (cf. Table I). They have disregarded and abandoned the unwarranted miscorrelations offered by Runnegar (1967), a welcome step, for I have already tried to publish a rebuttal of these views in Australia, but have been refused the opportunity. We still differ over the three upper stages. Runnegar and Armstrong have suggested that the upper Braxtonian Stage and Puruhauan Stage should be correlated with Fauna IV of Queensland. It is difficult to find support for such a step. Runnegar (1967) listed only 26 species as characteristic of Fauna IV. Of these at least 17 are allied to or identical with species from the upper Braxtonian Stage of New Zealand. In fact, more species should have been added, especially from brachiopods, but brachiopods are somewhat ignored by Runnegar. Counting these as well, not one species typical of Fauna IV is found in the Puruhauan Stage. Fifty-one species of brachiopods, bivalves, and gastropods are known from the Puruhauan Stage. Not one occurs in the upper Braxtonian, although *Maorielasma* approaches *M. callosum* Campbell from the Ingelara and Flat Top beds. (This species was not listed by Runnegar.) The distinction between the two faunas could hardly be more pronounced.

Thus we have two faunas, the upper Braxtonian and Puruhauan, characterised by over 150 species of brachiopods and molluscs, completely different—without a species in common—merged by Armstrong and Runnegar into one fauna. The chief reason for their view appears to be that *two* species of the Puruhauan Stage are found with a Fauna IV in Australia, in the Barfield Formation. Even assuming that the species are correctly identified, and that the stratigraphy and structure are clear, we are faced with the interesting problem of whether these two species entered Queensland before they entered New Zealand, or whether the other associated species persisted in Queensland for a longer time than in New Zealand. Instead of trying to analyse the problem rationally, Armstrong and Runnegar have, however, jumped to the conclusion that merging of two stages provides the only solution. Little difficulty may be anticipated in resolving the problem by proper analysis, because the faunal boundary between the Braxtonian and Puruhauan is clearly defined; it can be traced through marine faunas over much of the globe—in Siberia and Canada, in the United States and China. The suggestion made by Runnegar and Armstrong that this clearly defined boundary should be disregarded and faunas above and below it be lumped together is unacceptable.

In passing it may be noted that Armstrong and Runnegar have erred in claiming that the Puruhauan is still based on a miscellany of faunas correlated largely by stratigraphy, lithology or international correlations. In fact, key brachiopod species are found not only in the type area but also in several others, including above the Braxtonian type section and with the fusulinid beds of North Auckland (Waterhouse, 1968a (cf. Table II).

Correlation of the Waiitian Stage

Runnegar and Armstrong (1969) have been unwilling to accept a Tatarian age for the Waiitian Stage. The reason for their attitude seems to have been that they were not able to correlate the fauna with any faunas known to them from eastern Australia. They were apparently unaware that a high Permian fauna is known in eastern Australia in a stratigraphic position comparable to that of the Waiitian Stage. The Tasman fauna occurs in a tillite horizon high in the Ferntree Mudstone of Tasmania, and I have collected from it specimens of *Ambikella* aff. *antesulcata* Waterhouse 1967b, key species to the Waiitian Stage. The Ferntree Mudstone overlies Malbina beds with upper Braxtonian faunas, and contains fragments of upper Braxtonian fossils near its base. It evidently ranges from Kazanian up into the Tatarian. It is overlain by the Cygnet Coal Measures at the top of the Permian.

COMMENTS ON WORLD CORRELATION

The only important difference between us over world correlations beyond Australia concerns the Waiitian and Makarewan Stages. Unwilling to acknowledge a Tatarian age, Runnegar and Armstrong have granted no more than " an upper Permian age ", and possibly believe that the faunas are about the same as Fauna IV of Queensland or the upper Braxtonian Stage of New Zealand, though their views have not been clearly stated. This supposition is disproved by a number of considerations apart from evolutionary development of the faunas, which Runnegar and Armstrong have misrepresented as providing the only " dubious proof " along with lithological correlations they have refused to take seriously. The following further points suggest that their assessment is incorrect (Table II).

(*a*) Waiitian key fossils are found in sequence above Puruhauan and Braxtonian faunas in the Takitimu Mountains, and therefore can be no older than Kazanian, the upper Braxtonian being Kazanian, as admitted by Runnegar and Armstrong, though tentatively opposed by Runnegar (1968).

(*b*) The type Waiitian faunas are found several thousand feet stratigraphically above *Xenaspis carbonarium* (Waagen) and another Xenodiscid which are Tatarian or at most uppermost Kazanian in age. In the writer's opinion there is no question that *Xenaspis* is post-Kazanian, but whether it is or not, the Waiitian is unlikely to be as old as Kazanian.

(*c*) Puruhauan key fossils, found below the Waiitian fauna in the Takitimu Range, occur also with a *Lepidolina* fauna in North Auckland. *Lepidolina* is possibly upper Kazanian, but is best regarded as basal Tatarian (Thompson, 1948; Hornibrook, 1951; Gobbett, 1967). If the Puruhauan Stage is Tatarian, the overlying Waiitian Stage must also be Tatarian (or younger).

(*d*) Other Puruhauan fossils, including species from the type section, show affinities with Hivatch beds of Kolyma River, in Siberia. The fauna is assigned to the Tatarian by Licharev (1966).

(*e*) The Waiitian faunas differ specifically from those of the Braxtonian Stage, or correlatives in eastern Australia or Siberia and Canada, and thus cannot be correlated with any known pre-Tatarian faunas. Special pleading to invoke peculiar facies, or other considerations is invalidated by the appearance of the fauna in Tasmania and by the stratigraphic relationships and the age of underlying faunas.

(*f*) The Makarewa rocks and faunas overlie the Waiitian Stage (as represented by rocks and faunas) and so must be younger.

Table 2. Tatarian age of Waiitian and Puruhauan Stages. Type sections indicated in parentheses.

World Stage	Takitimu Mts	Arthurton, Gore	Nelson	North Auckland	Japan	West Pakistan Salt Range	Siberia
Tatarian	(Makarewan Stage) Wairaki Breccia						
	Hawtel Fm. *N. nelsonensis*		(Waiitian Stage) *N. nelsonensis*		Gujo bivalve fauna		
	Elsdun Fm. *Terrakea* A, *N. arthurtonensis*	(Puruhauan Stage) *Atomodesma trabeculum, A. trechmanni, N. arthurtonensis, Terrakea A, Martiniopsis woodi*	*Xenaspis,* Xenodiscid, *A trabeculum, A. trechmanni*	*Yabeina* and *Lepidolina* *Martiniopsis woodi*	*Yabeina* and *Lepidolina* Kuman Stage	*Xenaspis* Chiddru Formation	Hivatch Suite *Atomodesma*
Kazanian	(Braxtonian Stage)	Lower Arthurton Group	Lee River Group	Volcanics	*Neoschwagerina* Akasaka Stage	Wargal Limestone	Gijigin and Omolon Suites

VALIDITY OF NEW ZEALAND PERMIAN STAGES

Runnegar and Armstrong have severely criticised my attempt to subdivide the New Zealand Permian sequence into stages. "At best," they claim, "the New Zealand Permian sequence is sparsely fossiliferous, with most of the faunas occurring in thin[1], restricted[2] rock units, and the stage boundaries are arbitrarily placed between successive fossil horizons . . . The Mangapirian Stage . . . [here follows the distorted summary of species numbers discussed above] . . . Ideally the fauna or sequence of faunas characteristic of a stage should be as diverse as possible, so that international correlations of the stage may be made with the type area."

It is clear that Runnegar and Armstrong hold a concept of stages very different from that held by world opinion as reflected in the International Code or the discussion circulated in 1967 by Dr Hollis Hedberg, Princeton University. This different approach is to some extent shown in Runnegar's (1967) repetition of the proposal by Dickins (1964) to subdivide the Queensland faunas into four or five horizons, with no type sections and no detail on relationship between zones. The critics also hold an unusual position on the distribution of fossils throughout rock sequences. Few workers in the Upper Paleozoic imagine that any sequence can be found with fossils occurring in every foot of vertical thickness; every upper Paleozoic sequence of any length has some barren intervals. Yet Runnegar and Armstrong have emphasised this deficiency for the New Zealand sequences, apparently in the naive belief that it is unique to New Zealand. There can be no objec-

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[1] Runnegar and Armstrong presumably include the Mangapirian Stage 30,000ft. thick, and the Telfordian and Puruhauan Stages each over 2,000ft thick, as "thin" stages.

[2] Some "restricted" rock units, e.g., Brook Street Volcanic Group and Tramway Sandstone as shown by Avias (1953) and Waterhouse (1964b; 1967b; 1967d) extend from southern New Zealand for 2,500 miles to New Caledonia.

tion to barren intervals, because such an objection would invalidate not only New Zealand type sections but every world type section. Nor is it fatal to a scheme to have type sections in different areas, for this is done for virtually every period in every part of the world, as is acknowledged by Dr Hollis Hedberg. It is wise to choose the most fossiliferous section as type, with the clearest stratigraphy and structure. Runnegar and Armstrong have claimed that type sections are to be chosen in order to make overseas correlations. By contrast, experienced stratigraphers such as Hornibrook (1966; 1967) have stated that local stages are based on local sections in order to make local correlations.

Statements about a " sequence of relatively small faunas whose preservation makes them difficult to correlate both on a local and an international scale " would appear to lack objectivity, for the opposite has already been established in various publications. In stating that they cannot identify New Zealand faunas Runnegar and Armstrong must lay themselves open to the question of whether it is the New Zealand material that is necessarily at fault. One of the authors has already erred considerably in his correlations (Runnegar, 1967), as now admitted with the partial corrections by Runnegar and Armstrong, and this error cannot be blamed on the fossils.

World and Local Correlations

The authors appear to have been unnecessarily apprehensive about the applicability of the New Zealand scheme on both the local and world scene. Locally, all of the New Zealand stages (except for the Makarewan Stage) have been recognised faunally in areas away from the type sections. On the world scene, in spite of " the sparsely fossiliferous sequences " and allegedly " poor preservation " it is possible to trace the New Zealand stages over much of the world—throughout Australia (more successfully than Runnegar's attempt), Timor, Siberia, Canada, and western United States (Waterhouse, 1968b; 1969a; 1969b). There is difficulty in penetrating the lower latitudes of Europe, Armenia, the Tethys, Salt Range, China, Japan, and south-west United States, but some horizons can be recognised. For all its shortcomings the New Zealand succession has provided the key to a breakthrough on world Permian correlations. Whereas it previously proved impossible to trace successfully more than four or five world divisions, largely restricted to the tropical and subtropical realms, it is becoming possible to recognise nine subdivisions, which not only cover the tropics but extend far into high latitudes, even where there are no fusulinids and no ammonoids. The reasons for this success include the following:

(*a*) The unusually full marine upper Permian sequence in New Zealand, like those of Armenia and South China in contrast with the non-marine, poorly fossiliferous sequences over much of the world.

(*b*) The fact that most of the New Zealand brachiopods and molluscs are recently described (or in press) and under tight stratigraphic control.

(*c*) The fact that brachiopods have been used as the most important guide, rather than fusulinids or ammonoids. The latter groups are too much restricted by facies and latitude, and possibly they evolved too slowly in the Permian to provide more than restricted and lengthy time-indices.

Age of Cyclolobus

Runnegar and Armstrong may be reluctant to accept these generalisations, for studies to substantiate them are still largely in preparation, apart from a handful of papers in press. But one test has already come into prominence. This has involved the entire understanding of the Upper Permian correlations of the world. According to general understanding based chiefly on ammonoid evidence, the youngest Permian stage was considered to have been typified by *Cyclolobus* (Miller and Furnish, 1940;

Glenister and Furnish, 1961; Thomas and Dickins, 1954; Schinderwolf, 1954; Kummel and Teichert, 1965; Teichert, 1965). Beds in which *Cyclolobus* occurred were correlated with the uppermost Permian, loosely called Tatarian or "Chiddruan" or "Djulfian". The view of the young age of *Cyclolobus* has been challenged by the New Zealand evidence. Implicit in my earlier works (Waterhouse, 1963c; 1964a; 1964b; 1964c) was the possibility that *Cyclolobus* and its Djulfian Stage were not uppermost Permian but were equivalent to the New Zealand Puruhauan, or dubiously Waiitian, Stage. The *Cyclolobus* equivalents were followed in New Zealand by one or two further Permian stages, and *Cyclolobus* was considered to come rather low in the Upper Permian. This opinion, based largely on New Zealand evidence, was explicitly stated in Waterhouse (1966b; 1967a; 1967b). The view ran completely against current opinion; yet it appears to have been correct. Chao (1965) has independently published a similar view from Chinese evidence. Furnish (1966) and especially Tozer (1967) have added strong ammonoid support for the likelihood that *Cyclolobus* did not occur at the top of the Permian; Grant (1968) has also supported the claim from brachiopod studies in the Salt Range. From this example it appears that the New Zealand faunas and sequences have some bearing on interpretation of world Permian and that the faunas, no matter how sparse and poorly preserved they are supposed to be by Runnegar and Armstrong, are of more than local significance.

PALEOCLIMATIC SIGNIFICANCE OF BRACHIOPODS

The most basic concept underlying the scheme for subdividing the New Zealand Permian is that the faunas alternated in their affinities between warm-water and cold-water forms. These alternations have suggested that there were three major Permian glacial episodes, followed by recovery and then warm phases (e.g., Waterhouse, 1964d; Brown *et al.,* 1968). Runnegar and Armstrong do not accept this concept. Their objection is not simply to suggest that the so-called warm- or cold-water affinities for certain genera must be revised, though this is obviously true. For instance, *Attenuatella,* because it was first named for Mexican and Texan species prior to its discovery in New Zealand, was thought to indicate warm-water affinities. It had not been found in eastern Australia (Waterhouse, 1964c). But it was I who then discovered the genus in eastern Australia (Waterhouse, 1967c) and then revised the climatic implication of the genus (1967d). To announce, as did Runnegar and Armstrong, the occurrence of *Attenuatella* in eastern Australia as though correcting my statement is less than truthfully summarising my work. The revision of affinities for a few genera (as in Waterhouse, 1969b) need not require abandonment of the concept that brachiopods were paleoclimatic indicators. But Runnegar and Armstrong have asserted that only fusulinids and reef-building corals can be so used in the New Zealand scheme—as warm-water indicators. This is not correct.

Underlying Principles for the use of Brachiopods and Molluscs as Paleoclimatic Indices

The Permian period was one of severe climatic contrasts, as evidenced by the sediment, which ranged from glacigene rock types to arid or salty sediment suggestive of high temperatures and low precipitation. Associated faunas differed correspondingly, and some genera are found almost only in sequences that included glacigene sediment, whereas others occur in sequences that lack glacigene sediment and in some cases have rock types and biota (such as compound-coral reefs) indicative of warm temperatures. It thus seems reasonable to conclude that some organisms were able to tolerate only cold waters, others only warm, and are thus potential indices of relative temperatures. *Eurydesma* was a characteristic cold-water genus. A far greater number of genera serve as warm-water indices, such as the Lyttoniacea, Richtofeniidae, etc. (Stehli, 1957).

A second principle concerns generic diversity. Faunas found in sequences that include glacigene rock types are individually numerous, generically few. Faunas found in coral reefs or other warm-rock types were individually more or less numerous, and generically numerous as well. Geographical plots of rock types and genera clearly show an increase in generic diversity away (e.g., northwards) from glacigene regions. In the case of eastern Australia the Permian faunas increased northward in diversity, implying that the south pole lay nearer to Tasmania than to New South Wales (Figs. 1, 2).

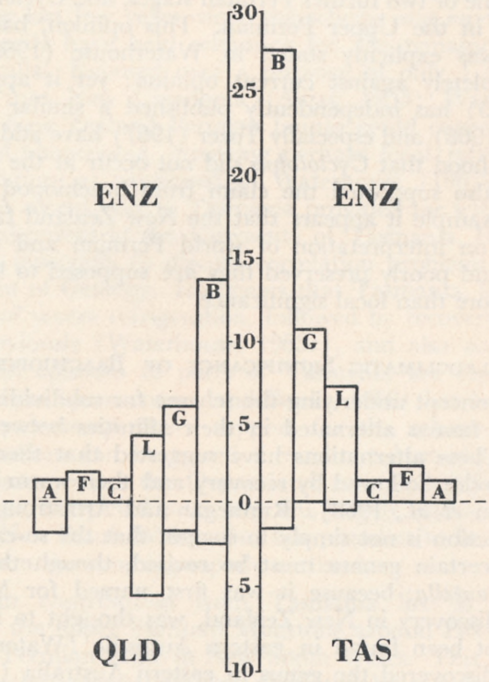

FIG. 1.—Numbers of Permian genera in Queensland, Tasmania and New Zealand, excluding West Nelson, which has a Tasmanian fauna (Waterhouse and Vella, 1965). On the left side the number of genera in various phyla and classes found in eastern New Zealand (ENZ) but not in Queensland (QLD) are compared with those found in Queensland but not in eastern New Zealand. On the right side the numbers of genera found in east New Zealand (ENZ) are compared with numbers found in Tasmania (TAS) but not in east New Zealand. To judge from data so far published, east New Zealand and Queensland had somewhat comparable diversities, whereas Tasmania was generically impoverished.

A, cephalopods; B, brachiopods; C, "warm-water" reef-building corals; F, fusulines; G, gastropods; L, bivalves.

These concepts find two independent lines of support. The first is that modern distributions of biota show the same increase in diversity away from the poles, culminating in the warmest region at the equator (Stehli *et al.*, 1967). The second is that paleomagnetic evidence shows that the Permian paleomagnetic pole lay essentially south of eastern Australia (Irving, 1964), as confirmed by more recent work. Combining these principles, Waterhouse (1969b) has plotted the distribution of productaceans in the Permian of eastern Australia to show how Queensland to the north possessed more genera than New South Wales and Tasmania. For instance Fauna II of Queensland includes *Taeniothaerus, Aulosteges, Krotovia, Horridonia, Cancrinella, Terrakea,* and *Anidanthus. Aulosteges, Krotovia* and *Horridonia* certainly did not penetrate Tasmania, where the only common productaceans were *Taeniothaerus* and *Terrakea* (Fig. 2). Although some genera were highly variable in toleration, most exhibited consistent tolerances with marked thresholds. *Cancri-*

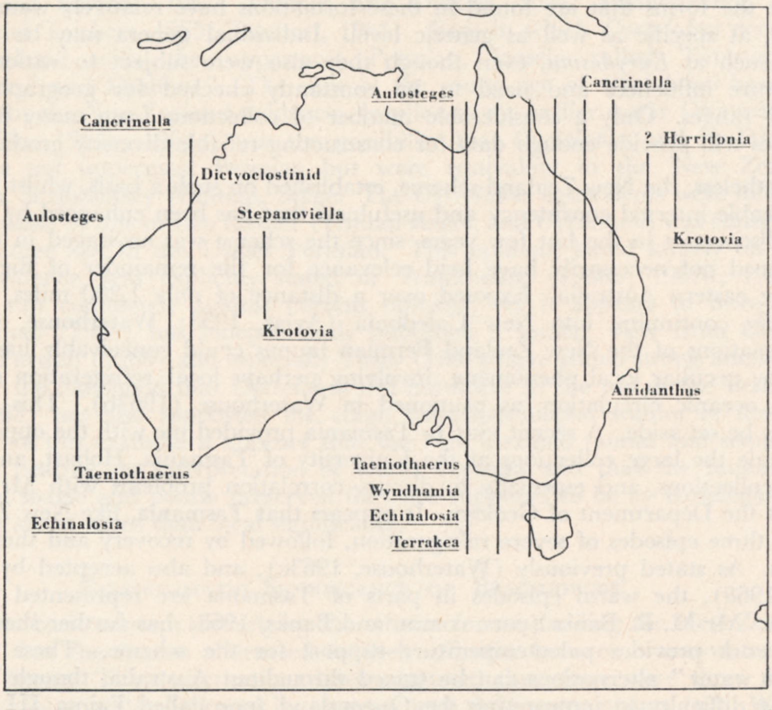

FIG. 2.—Distribution of Productida (Productacea and Strophalosiacea) in Australia during the late Sakmarian and early Artinskian (e.g., Callytharra Formation, etc., of Western Australia, and Fauna II of eastern Australia = Telfordian Stage in New Zealand), each genus represented by a line generalised to suggest latitudinal extent. Fewest genera occur in Tasmania, and the number increases northwards through New South Wales and Queensland. In Western Australia a Dictyoclostid is found, member of a family not known in eastern Australia, and *Wyndhamia, Terrakea,* and *Anidanthus* with others are apparently absent. *Strophalosia* has been inadvertently omitted from Western Australia.

nella for instance was widely tolerant, but was rare or absent in Tasmania and southern New South Wales, whereas *Terrakea* tolerated the cold of Tasmania better. *Horridonia* is found only in the north part of eastern Australia and in New Zealand, as well as the Arctic realm and Zechstein—but not in the very warm regions with sizeable compound-coral reefs. Thus individual genera, as well as generic diversities, reflect temperature control.

It is possible also to trace temperature changes through time. A fine example is offered in Western Australia, where the Lyons Group, with glacigene sediment, is overlain by the Callytharra Formation, with no glacigene sediment. The upper Lyons faunas have limited generic diversity, and many of the genera are characteristic of cold water—such as *Eurydesma*. The Callytharra faunas are far more diverse, enriched in genera known in Tethyan faunas but missing from the upper Lyons. Significantly *Eurydesma* is absent. An example is offered in New Zealand by the Braxtonian, Puruhauan, and Waiitian Stages. The Braxtonian Stage has only three productacean genera, *Krotovia, Cancrinella,* and *Terrakea*; the Puruhauan has *Waagenoconcha, Horridonia, ?Anidanthus, Cancrinella,* and *Terrakea,* signifying through its diversity a warmer-water fauna; the Waiitian has only *Sowerbina* and *Terrakea,* suggesting another cold- (or cool-) water fauna.

These data cannot, of course, be used uncritically. Allowances must be made for conditions of preservation, bottom facies, and other ecological conditions apart from temperature. The rapid deposition of the Greville Formation or the upper Takitimu Group of New Zealand obviously precluded rich faunas of any description, but the forms that are found in these formations have relatively warm-water affinities, at specific as well as generic level. Individual genera may be used as indices, such as *Eurydesma,* even though they also were subject to various non-temperature influences and need to be constantly checked for geographic and temporal ranges. Only a considerable number of collections from many different rock types will provide enough data for constructing reliable diversity gradients.

Nonetheless, the New Zealand scheme, established on such a basis, whilst holding a remarkable internal consistency and usefulness that has been enhanced by further faunal discoveries in the last few years, since the scheme was envisaged in the late 1950s, need not necessarily have held relevance for the remainder of the world, including eastern Australia. Exposed over a distance of only 1,200 miles, though admittedly continuing into New Caledonia (Avias, 1953; Waterhouse, 1967d), the alternations of the New Zealand Permian faunas could conceivably have been caused by peculiar local phenomena, involving perhaps local refrigeration or local shifts in oceanic circulation, as cautioned in Waterhouse (1967b). This caution may now be set aside. A recent visit to Tasmania provided me with the opportunity to examine the large collections at the University of Tasmania, Hobart, and make further collections, and especially to discuss correlation problems with Mr M. R. Banks at the Department of Geology. It appears that Tasmania, like New Zealand, suffered three episodes of severe refrigeration, followed by recovery and then warm intervals. As stated previously (Waterhouse, 1963c), and also accepted by Brown *et al.* (1968), the warm episodes in parts of Tasmania are represented by coal measures. Mr M. R. Banks (pers. comm. and Banks, 1968) has further shown that isotope work provides paleotemperature support for the scheme. These " warm and cold water " alternations can be traced throughout Australia, though there is still some difficulty in interpreting the Queensland zone called Fauna III, which, as described by Runnegar, is typified by a very few largely undescribed species that do not even range into New South Wales. But this promises to be only a temporary check, to be clarified when the zone is properly outlined.

The most significant contribution from Tasmania lies in the very young Permian tillite found in the upper Ferntree Mudstone around Hobart and probably correlative with a high Permian tillite in New South Wales. This proves that there was a late Permian glacial episode, as was predicted by me from New Zealand studies (Waterhouse, 1964b; 1964d). A small fauna in the tillite enables correlation with the New Zealand Waiitian beds.

Some such suggestion of alternations has long been held, with Gerth (1952), for instance, suggesting that the New South Wales coal measures represented warm wet intervals between refrigerated episodes. In this regard, the New Zealand contribution has been to provide faunal proof of this suggestion and also to indicate the occurrence of the third of the glaciations, which was largely overlooked until recently in Australia. Australian colleagues such as Dr K. S. W. Campbell and Mr M. R. Banks have always been sympathetic to the scheme, and possibly conceived it independently. But were the alternations limited to Gondwana? It has long been considered that the faunas of the northern realm were of warm-water affinities. This is not so. My examination of the huge collections made in the Yukon and Arctic by the Geological Survey of Canada, coupled with Yukon field-work, has shown that the Arctic realm also suffered alternating affinities. Cold-water faunas, characterised by such typical Australian genera as *Wyndhamia, Terrakea,* and *Ambikella* (or *Tomiopsis*), entered the Arctic realm in the lower and middle Permian (Waterhouse, 1968b; 1969a) at the same time as the southern glaciations reached their maximum, i.e., correlative with the Allandale and lower Branxton faunas of the Hunter Valley, for instance. At these times fusulinids and ammonoids vanished, with other warm-water genera, and the faunas were dominated by cool-water genera. A similar invasion of cool-water genera at the same time swept across

Table 3. World correlations between northern and southern hemispheres, based on the New Zealand scheme, with some uncertainty over Ural correlations. Brachiopod and molluscan indications of paleoclimate are noted where examined, showing how strongly the world faunas fall in one pattern of 3 glaciations, (centred near Tasmania as noted by "ice"), with cool faunas in correlative beds elsewhere, followed by a recovery period with "warming" temperatures, then by warm-water faunas.

New Stage	New Zealand	Tasmania	Western Australia	Siberia	Composite Canada	Ural Mts
9	Makarewan warm	Cygnet Coal Measures				
8	Waiitian cool	Ferntree ice				Tatarian
7	Puruhauan warm	Mudstone warm?		Hivatch horizon warm	?*Atomodesma* beds warm	
6	upper Braxtonian warming	Malbina E D		Gijigin Omolon warming	Ranger Canyon-Fantasque warming	Kazanian warming
5	lower Braxtonian cool	C ice (Grange) B A	? ?Coolkilya warming high Byro cool	Djigdalin cool	Assistance Fm. cool	?Ufimian
4	Mangapirian warm	Berriedale Limestone warm	lower Byro Group warm	Djeltin Munugdjak	upper Middle Recessive unit warm	Baigendzinian warm
3	Telfordian warming	Nassau Sls warming	Wooramel Gp warming Callytharra Fm.	Yasnachin	middle "Middle Recessive unit"	Artinskian ?Upper Sakmarian
2	*Mourlonia impressa* cool?	Quamby Mudstone ice Wynyard Tillite	Lyons ice	Irbichan cool	Ross Creek cool *Attenuatella* zone	Sakmarian
1	*Atomodesma* beds warm		Group warm	Burgali warm	*Reticulatia* zone warm	Asselian

Siberia. These invasions, coinciding in time with the southern glaciations, as we know from ammonoid and other evidence, must have reflected reduced temperatures in the northern polar regions (Table III). The scheme of alternating changes in temperature deduced from the New Zealand Permian faunas applies to faunas from high and temperate latitudes all over the world. The New Zealand scheme is not only internally consistent; it is relevant to the world. It would take very special pleading to escape the conclusion that the procedures for detecting the paleoclimatic significance of brachiopod and molluscan genera are essentially correct. Of course, it must be said that the methods are at present largely unpublished. It would seem to me pointless to bring out such studies in any depth before the systematic section of my work is completed. For the systematics, geographic distribution and age are fundamental. This is illustrated by the occasional error in my work, in prematurely trying to decipher the paleoclimatic range of a genus by way of illustrating a principle rather than being very serious about the particular details of the individual genus.

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