The Divisions of the Upper Cretaceous and Tertiary in New Zealand.

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THE system of New Zealand stage names at present in use was introduced by J. A. Thomson (1916). Other stages have been added from time to time, and a summary of those proposed, with discussion of the type localities, has been given by Dr. R. S. Allan (1933). This excellent paper gives full stratigraphical data or references for the various stages discussed and details of previous work. The present paper deals with the palaeontological side much more exhaustively, but elaborates the stratigraphy only where necessary.

CONCEPTION OF CHARACTERISTIC OR KEY FOSSILS.

Common forms.

In his 1933 paper Allan advocated the use of " characteristic fossils " for correlating, his belief being that, " For practical purposes a characteristic fossil of a given horizon and facies is one which is there abundant. It is not necessary to know the complete fauna, nor is it vital to determine the exact range of any individual species." We disagree fundamentally with each of these dicta, our own opinion being that a fossil should be designated as characteristic only when approximately limited to a particular horizon or stage, that the more completely a fauna is known the more cross-bearings for correlation are available, and that it is vitally necessary to determine individual ranges. Some of the " characteristic fossils " of Allan are probably no more than paleic indicators (see Allan, 1936, p. 384), species significant only as a guide to paleo-ecology. Our experience is that Allan's method is not practicable, and that the common constituents of the New Zealand faunas frequently mask the rarer, but much more significant species. It is the nature of some gregarious genera to occur in great abundance or not at all, and many of the commonest of our Tertiary species have so long a range (due to the equable climatic conditions in our early and middle Tertiary) as to be useless for exact stratigraphic work. For example, a mollusc collection from Moutara Point, Poverty Bay, consisted of abundant specimens of *Callusaria callosa, Verconella grandis, Polinices huttoni, Manaia* cf. *huttoni, Eucrassatella ampla,* and *Acominia hendersoni,* all prominent and common species of the basal Tutamoe, and on Allan's dictum it would be so placed. But the accompanying microfauna contained *Bolivinita* and other forms demonstrating a Taranakian age. Amongst the common molluscs occurred one specimen each of *Pelicaria, Ellicea,* and *Waitara,* and it was these rare but really characteristic elements which also proved the molluscan fauna to be not only Taranakian but Urenuian.

Faunal Communities.

Nor do we feel that Allan's concept of the " faunal community " as of prime importance is justified. A stage is a large unit and must contain many communities, and it is not any single one of these that is characteristic and of over-riding importance, but a judicious selection of short-ranging species from each of them. It is only thus that the correlation of a stage is made possible with beds remote from the type locality, or of widely differing facies. It is these criteria that have been used in selecting the diagnostic fossils given in this paper. The inability of these two concepts (the characteristic-common species and the primely important faunal community) to produce correlation results has been indirectly noted by other New Zealand writers. Powell, for example, has pointed out (1931, p. 90) that the Waitotaran faunas of Waihi and Waipipi, easily correlated by key species, are from not dissimilar lithologies and differ but slightly in depth, yet have only one of their most abundant species in common; the same author (1934, pp. 261, 262) has convincingly correlated the highest Pliocene beds of Landguard Bluff and Cape Runaway entirely by consideration of rather uncommon key species, noting that the faunal communities and common species differed; the same author again (1937) has shown how faunal communities and ecologic controls can be rightly used and interpreted when applied to a single basin of known age uniformity.

Not that it is here intended to discount the importance of facies, faunal communities, or ecology. The principal underlying H. G. Schenck's definition of *homeotopic* and *heterotopic* faunas (1928, p. 164), namely, the control of the environment (as expressed by facies) on the generic and specific constitution of a faunule, is one of the first lessons a collector learns. Most species imply, by their very presence, a certain range of environmental conditions, all the more important because they represent *positive* evidence. Until the many faunal communities have been clearly designated, however, the *absence* of given species must be used with extreme caution. In these faunal community studies the importance to the palaeontologist of the dead shells as well as the live ones should not be forgotten, for shells are often transported from their own environment and buried in another. This would have a bearing on the " synecological studies " suggested by Thalmann (1936, p. 364), which are interesting in conception, but largely impossible of fulfilment.

As has often been remarked, the different environmental stations are very unevenly represented in the fossil record. Littoral species of both Foraminifera and Mollusca are rare. Infra-tidal, shallow water Mollusca are much better known, but not the corresponding Foraminifera. The off-shore faunas, from, say, 5–100 fathoms are perhaps the best known, also the yet deeper water Foraminifera. The deep water molluscs, being more dispersed and generally of fragile build, are difficult to collect, and tend to be poorly preserved through distortion by compaction of the fine sediments enclosing them. Indeed, a considerable difference in the preservation of these two phyla is often apparent, and it is not rare to find (e.g., at Hampden, in the Maheno and Burnside marls, etc.) that squeezed, broken, and unrecognisable Mollusca are accompanied by the unharmed, fragile, and hollow tests of Foraminifera, perfectly preserved in every detail. Due allowance must be made for this caprice and its bearing on apparently different accounts of the same geological story.

Studies of faunal communities may be useful in the case of such a clear-cut section as Castlecliff, but they are not usually so feasible elsewhere in the Dominion Tertiary (where the lateral gradation of fossiliferous sediments is seldom seen) ; no one to our knowledge has yet demonstrated in practice their superior usefulness in exact correlation. The acid test of any criticism of old methods is a demonstration of greater efficiency by the new.

Micro-Faunas.

Since Allan's paper appeared much light has been thrown on correlation problems by intensive study of the Foraminifera. The well-known advantage of this group is that excellent faunas can frequently be obtained from important localities poor in or lacking macro-fossils. The result is that where, before, we had relatively few abundant mollusc or brachiopod faunas, unequally distributed, we now have hundreds of rich rhizopod faunas covering almost the whole Tertiary, and can observe and separate faunal changes due to the time factor in a way previously impossible. Although the stratigraphic implications of the Foraminifera have received special attention for several years, the systematic descriptions are only now being published. In the first of these papers to appear, a revised classification of New Zealand stages has been put forward, based on both macro and micro-faunas (Finlay, 1939A, p. 531). This is the table adopted here, with the exception that the Upper Cretaceous is added, and the two divisions of the Taranakian have been reinstated for reasons given later.

TABLE OF NEW ZEALAND STAGES.

PLIOCENE	Upper	Castlecliffian (Thomson)	
	Middle	Nukumaruan (Morgan)	
	Lower	Waitotaran (Thomson) Opoitian (Finlay)	
MIOCENE	Upper	Urenuian (Henderson) Tongaporutuan (Marwick)	(Taranakian)
	Middle	Awamoan (Thomson)	
	Lower	Hutchinsonian (Thomson)	
OLIGOCENE	Upper	Waitakian (Park) [includes Duntroonian (Allan)]	
	Middle	Whaingaroan (Finlay)	(Ototaran)
	Lower	Kaiatan (Morgan) [includes Waiarekan (Thomson)]	
EOCENE	Upper	Tahuian (Allan)	(Waimatean)
	Middle	Bortonian (Park)	
	Lower	(present but not named)	
CRETACEOUS	Danian	Wangaloan (Morgan)	
	Maestrichtian	?	
	Campanian	" Mangatu "	(Piripauan)
	Santonian	" Tapuwaeroa "	
	Coniacian		
	Turonian		(Clarentian)
	Cenomanian	" Raukumara "	
	Albian		
	Aptian	" Taitai "	

Tabulation of stage names in a list such as this would seem to imply that they are of subequal value in time. Actually, this is far from being so, but they *are* subequal from the point of view of practical use and ease of recognition through palaeontology. The great discrepancies in duration involved, and the fact that breaks occur in almost any area, can give an impression of regional gaps in the sequence that is not necessarily valid when the whole Dominion is under review. Allan's summary, on p. 103, includes seven gaps in the table of stages, the implication being that the New Zealand scheme of useable stages is very far from complete. But his evidence, on p. 104, is based on faunal gaps which totally disregard facies and on breaks which have not been more than locally established. In adopting the present table we have been guided by positive faunal evidence in recognising useable units, rather than on field breaks which often have but slight biologic significance. Different blocks must have been differently affected by earth movements, and what seems a striking physical break in one particular district does not necessarily extend throughout the Dominion. Conversely, important faunal breaks are frequently concealed because of similar lithologies and poor exposures at critical contacts. A very important physical movement may take place in a relatively short space of time, while a long period of non-deposition may leave but little evidence in the field. Note, for example, the *erosional* break (unaccompanied by a faunal one) within the Opoitian (unpublished), within the Tutamoe (the conglomerates are not always at the base), within the Waitakian (Thomson, 1926A, p. 156), within the Duntroonian (Thomson, *l.c.*, p. 158); and the *faunal break* (unaccompanied by any obvious physical one) within the Point Elizabeth beds (unpublished).

It should also be borne in mind that though the suggested European equivalents have been divided into "Upper, Middle, and Lower," these are relative terms only, and are not meant to apply exactly.

OUTSIDE MACRO-FAUNAL CORRELATIONS.

In spite of the difficulty of using the European time scale in a country so distant, there is evidence available to show that the suggested correlation is not merely guess-work. Some of it is direct, some indirect.

Finlay (1939A) pointed out in his original table two outside levels—"Middle Eocene age for the Bortonian, because of the occurrence of *Discocyclina* and *Asterocyclina*, and Lower Miocene age for the Hutchinsonian, because it is almost without exception the horizon of *Nephrolepidina* spp. and *Miogypsina*, and correlates with the Australian Janjukian already referred to that age." The "almost" can now be omitted, as the supposed examples in thin sections made from Mokau limestone have turned out to be *Cycloclypeus*. A Middle Eocene age for the Bortonian was arrived at independently from the molluscan evidence by Finlay and Marwick (1937, p. 14).

CRETACEOUS.

The divisions in the Cretaceous are much more a matter of doubt than in the Tertiary. Only the System names Kaitangatan, Piripauan, and Clarentian, and the stage name Wangaloan have yet been proposed. The Oamaruian System begins with the Bortonian, and the Piripauan does not take in the highest Belemnite horizon known (the so-called " *Teredo* limestone " at Amuri Bluff), so that the Wangaloan and at least one lower stage are not placed in any system. Nor have the separable faunal divisions of the Piripauan and Clarentian yet received stage names, but to make the tabulation more useful and easily followed we have included in their stead four local formational names. Until the ranges of the Foraminifera and Mollusca are more accurately known from sections now being studied, it would be premature to propose Cretaceous stage names.

The oldest post-Hokonui formation for which a definite Cretaceous age has been established is the Taitai Series of Ongley and Macpherson (1928). These rocks, once thought to be in normal position, are now generally regarded as overthrust (Ongley, 1930B). They have yielded the two molluscs *Maccoyella* and *Aucellina*; the representative of the former especially is of considerable interest as indicating by its advanced development an Upper Aptian age (Marwick, 1939, p. 462) and correlation with the Roma Series of Australia (Whitehouse, 1926, p. 276).

Clarentian.

The Clarentian System (Thomson, 1917, p. 408; 1919, p. 311) has been defined as " all those Notocene rocks in the Middle Clarence Valley lying below the flint-beds at the base of the Amuri limestone," and at its type locality consists of about 8000 feet of sediments, divisible on lithological and faunal bases into several units. The three lowest units (basal conglomerate, Wharf mudstone and Wharf Gorge sandstone) contain nothing distinctive except *Aucellina*, and may be considered together as a single division. The next unit, however, (Cover Creek mudstones) contains *Inoceramus concentricus* Woods and *Turrilites circumtaeniatus* Kossmat, which induced Woods (1917, p. 2) to suggest correlation with the Lower Utatur, referred by Kossmat to the Cenomanian. This has not been questioned by later workers. In the succeeding unit (Nidd alternating mudstones and sandstones) occurs *Inoceramus bicorrugatus* Marwick (1926B, p. 379), which Heinz (1928, p. 123) has recorded also from the Upper Turonian of Luneburg. That Heinz's results cannot be accepted unreservedly has been pointed out by Marwick (1931A, p. 54), who mentioned discrepancies in the New Zealand occurrence of species regarded by Heinz as of zonal value. Nevertheless, the occurrence of these strongly folded Inocerami at restricted Upper Cretaceous horizons in Europe and South America (*andinus* Wilck.), as well as in New Zealand, is of considerable import. In view of this, it seems that Woods's identification of the Cenomanian *Gaudryceras sacya* Forbes from the highest Clarentian unit (Sawpit Gully mudstone) is questionable; indeed, Marshall (1926, p. 145) has already pointed out that Woods's specimen differs from true *sacya* and is very close to *subsacya* Marshall from a higher horizon. Considering all these points, and the faunas of the overlying Piripauan, we now suggest that the four divisions of the Clarentian outlined may be tentatively regarded as covering the period Albian to Coniacian. It is of interest that *Belemnites superstes* Woods is known only from the lower part of the Clarentian, and this species has been placed by Whitehouse (1924, p. 412) in *Dimitobelus,* known in Australia only from the Upper Albian.

Piripauan.

The Piripauan at its type locality ("beds at Amuri Bluff below the *Teredo* limestone"—Thomson, 1917, p. 409) consists of the following units:—basal sandstone with calcareous bands containing Mollusca, "sulphur sands," black grit with shark teeth, and concretionary glauconitic sandstone ("saurian beds"). A detailed account has been given (Thomson, 1920, p. 341) of a similar succession in the not far distant Middle Waipara area, where basal coal-measures and *Ostrea* beds are followed by "saurian beds" and then by Waipara greensand; the occurrence of *Cimoliosaurus australis* (Owen) in the two latter, and of *Pacitrigonia* Marw. and *Conchothyra* Hutt. in the former, confirms the association with the type Piripauan. This is mentioned, since good micro-faunas have been obtained from the Mid-Waipara, but not as yet from Amuri Bluff. The Piripauan cannot be divided into several Cretaceous stages as conveniently as the Clarentian. It is only about 1000 feet thick and possibly covers a much shorter period of time. Most of its important Mollusca come from the basal beds, while Foraminifera are known only from the top of the "saurian beds" and basal Waipara greensands. Although the Clarentian and Piripauan are nowhere known to be in contact, the presence of different Inocerami in each, and the absence of any faunal agreement between the topmost Clarentian and any part of the Piripauan indicates that the two systems do not overlap. The characteristic Belemnite of the basal Piripauan, *B. lindsayi* Hector, has been made by Whitehouse (1924, p. 414) the monotype of *Cheirobelus,* as distinct from the Clarentian *Dimitobelus*; in the absence of related forms he accepted for it Woods's determination of a Senonian age.

The characteristic Inocerami of the Piripauan are *australis* and *pacificus,* both of Woods, but Heinz's work (1928) on these is somewhat contradictory. They occur together in the basal conglomerate, and black grit, and are certainly younger than the Clarentian forms, yet Heinz divided them into four different species, characterising four horizons from Cenomanian to Lower Emmscherian. Two other molluscan genera are of importance. *Pacitrigonia* Marwick (1932, p. 505) is a group apparently confined to the Upper Senonian of the Southern Hemisphere, while *Conchothyra* Hutton (see Finlay and Marwick, 1937, p. 64) has no outside close relatives, is limited in its type species to the Piripauan, but extends as another species to the Danian Wangaloan.

The North Island Tapuwaeroa Formation, from its rich micro-faunas may certainly be correlated with some part, if not all, of the Piripauan. It is therefore significant that at Mataikona, north of Castle Point, Tapuwaeroa beds with their index mollusc, *Ostrea lapillicola* Marwick (1926B), overlie a mudstone (probably the Mangaotane) carrying *Inoceramus bicorrugatus* Marwick, the index mollusc of the Clarentian Nidd mudstones; to the south-west of this, at Bush Grove Stream, beds similarly mapped as Tapuwaeroa contain the ammonite *Parapuzosia* aff. *haughtoni* Spath (1935, p. 11); this and other ammonites from the overlying Waipawa Series (Thomson, 1926B, p. 349) were referred by him to Senonian and Upper Senonian, but Whitehouse (1926, p. 279) has quoted *Parapuzosia* as indicative of a Lower Santonian age for the West Australian Gingin Chalk. The argillitic Whangai (= Waipawa) Series (see later) overlying the Tapuwaeroa is still intimately connected with it in micro-fauna, but not at all with the Eocene Bortonian (Wanstead and Upper Mangatu of North Island), so that it seems reasonable to refer both of these to the Piripauan, with a possible combined age of Santonian-Campanian.

“ *Teredo Limestone.*”

It seems, however, that there are still higher horizons in the Cretaceous than any in the Piripauan System, the upper limit of which was inadvertently left open to confusion by Thomson. He defined it as including all beds below the “ *Teredo* limestone,” but there are two *Teredo* limestones described (as Upper and Lower) by McKay (1877, p. 181) from the type locality. The upper of these is more persistent and constant in character, the lower being sometimes absent or overlooked when its facies changes to calcareous sandstone. Since McKay conceived these and the intervening greensands as a unit distinct from the underlying formation, the upper limit of the Piripauan is here fixed as the concretionary greensands below the Lower *Teredo* Limestone (see McKay's table, *op. cit.*, p. 178). This definition is necessary since Belemnites have been collected by the Geological Survey not far south of Amuri Bluff, from the greensands four feet below the Upper *Teredo* Limestone. These are small and quite distinct from the Piripauan *Cheirobelus,* and presumably indicate a still higher stage, perhaps the Maestrichtian. At Shag Point Professor Park collected a few Belemnites from near the base of the Katiki Series (see Brown, 1938, p. 11); these are also small, but distinct from those at Amuri; the accompanying micro-fauna contains *Dorothia elongata* Finlay, characteristic of the Piripauan. Between this horizon and the Eocene Hampden section are the Katiki-Moeraki beds, whose micro-faunas have a pre-Tertiary aspect and little affinity with the overlying Bortonian, yet lack the characteristic Cretaceous species of the Piripauan—a description which has already been applied by Finlay and Marwick (1937, p. 7) to the Molluscan fauna of the Wangaloan. These beds may be approximately coeval, therefore, with either the Lower *Teredo* Limestone or the Wangaloan, neither of which has yet yielded a micro-fauna.

Approximate correlatives of these high Cretaceous horizons occur in the North Island, and have generally been referred to the Mangatu Series of Henderson and Ongley (1920, p. 34) and the Otamatea Series of Ferrar (1934, p. 25). The former name has been widely employed for formations ranging from Lower Piripauan to Upper Oligocene, and is too wide in application. It is at present being re-investigated and the type locality systematically collected for micro-faunas. Restriction and use of the name should await results from these. Because of this uncertainty, the term Whangai was proposed by Quennell (1937, p. 3) for the argillitic series of Hawke's Bay. It is equivalent in part at least to the Mangatu and perhaps partly to the Tapuwaeroa, but is also being re-investigated at present. Chocolate shales occurring above the Whangai have a micro-fauna comparable with that of the Moeraki beds, and are similarly overlain by a formation (Wanstead whitish mudstones) with Bortonian faunas, both Lower and Upper.

Kaitangatan and Wangaloan.

One other System-Name, the Kaitangatan, needs mention. Thomson proposed it to include the Kaitangata upper and lower coal-measures as described by Park (1911) and the intermediate marine horizon, but excluded the Oamaruian coal series and overlying Oamaruian marine rocks. He did not know this section at first hand, and accepted Park's sequence; Ongley (1926, p. 7, and 1939), however, has shown that the " intermediate " marine horizon really overlies both coal-measures (see also the columnar sections comparing Kaitangata, Brighton, and Boulder Hill in Finlay and Marwick, 1937, Pl. 18). The coal-measures with quartz conglomerate may be the same age in the various localities, but whether this is so or not, at Brighton the overlying marine horizon contains Belemnites, while at the other two places the Danian Wangaloa beds (without Belemnites) overlie the coal measures. The Belemnites belong to the Dimitobelidae and are very poorly preserved; they were thought by Whitehouse to be possibly Albian (which would mean a Clarentian age), but the subsequent finding of *Pacitrigonia* Marw. and *Venericardia* Lamk. in the Brighton Limestone (Ongley, 1939, p. 55) makes correlation almost certain with the Piripauan. Two very different horizons are concerned, the Wangaloan being much younger and either equivalent to the mudstones above the Belemnite bed containing *Lahilleona* Marw., or even higher. It is, however, obvious that most of the Kaitangatan System below the actual Wangaloan is Piripauan or older and, since the Kaitangatan can hardly be thus restricted to one stage, it has to be dropped entirely from the column of marine stages. The Dimitobelid Belemnites in the Brighton Limestone place it below the *Teredo* Limestone, while the Wangaloan itself, from the absence of Belemnites, etc., must be younger; the evidence for a suggested Danian age has been presented by us previously (1937). Chapman (1934, p. 119) has reported the Upper Cretaceous fish genus *Portheus* from the glauconitic mudstone overlying the Brighton Limestone at Abbotsford. From shaft spoil in the neighbourhood, McKay collected *Lahilleona, Trigonia* cf. *waiparaensis* Woods, and *Dentalium morganianum* Wilck.; these were considered by Grange (see Ongley, 1939, p. 56) to be from the glauconitic mudstone, and, if so, show that in part at least this formation is older than Wangaloan. Dr. Benson's statement to Chapman and to us, however, is that the *Portheus* came from some 500 ft. above assumed Wangaloan, and that McKay's fossils were probably from a facies of the Brighton Limestone.

TERTIARY.

(a) Bortonian.

The indirect biological and stratigraphical evidence for a Mid-Eocene age has been presented by Finlay and Marwick (1937, p. 14). Direct evidence in the same publication is afforded by the recording of the early Eocene genus *Priscoficus* (pp. 75, 119). At Kakahu also occurs an undescribed species of *Paryphostoma* Bayan, very close to the Middle and Upper Eocene *minus* Deshayes. The striking Turrid genus *Speightia* (Finlay, 1926B, p. 252) is similar to a number of puzzling species of early Eocene occurrence in various parts of the world, and in particular to the Middle and Lower Eocene *Andicula* Olsson from Peru. The Bortonian Volute *Notoplejona* (Marwick, 1926C, p. 262) has its nearest relatives in the Middle and Upper Eocene, and no close ones in the Cretaceous.

(b) Ototaran.

The molluscan faunas here are so poor that reference is made only to that of Lorne (type of Waiarekan zone, see Marwick, 1926A, and Finlay, 1939A, p. 530). This contains the genus *Semitriton* (see Marwick *l.c.*, p. 315) characteristic of the Lower Aldinga beds of South Australia, for which Singleton (1937) suggested a pre-Janjukian age, i.e., Oligocene. It is also the only known locality for *Siliquaria senex* Marwick, which is undoubtedly an *Agathirses,* a group recorded only from the Mid-Eocene Lutetian.

(c) Waitakian.

With the Waitakian may be treated the Duntroonian, which on account of micro-faunal similarities, Finlay (1939A p. 530) has considered merely a basal zone. There are sufficient differences in the Mollusca from certain localities to suggest separate treatment as perhaps substages, but there is also palaeontological, stratigraphic, and faunal evidence from several areas supporting the idea of their very close relationship. We have presented the faunal evidence in this paper under the separate names, but considering the Tertiary of the Dominion as a whole we do not feel that more than one stage can usefully be recognised between Whaingaroan and Hutchinsonian, and for this we have here adopted Waitakian as the best name. This is pre-eminently the horizon for fossil Cetacea in New Zealand; Benham has lately described several important forms and discussed their age implications. *Microcetus* is noted by him (1935, p. 242) from the Marewhenua limestone and the Upper Oligocene of Germany; while the presence of both Squalodonts (elsewhere Miocene) and Zeuglodonts (elsewhere Eocene) (1937, pp. 7 and 15) in these beds at Waihao and Wharekuri suggested a Lower Miocene age.* Of the important

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* Oligocene *s.l.* would seem a better compromise.

Brachiopods here, the *Pachymagas huttoni* Th. series has been compared (Thomson, 1927, p. 287) with the Patagonian Oligocene-Miocene *venter* Iher., while *Murravia catinuliformis* (Tate) is restricted here to the Duntroonian and in Australia to the Janjukian-Balcombian, regarded as Upper Oligocene-Lower Miocene. All these factors point to a horizon somewhere about Aquitanian, whose Upper Oligocene-Lower Miocene age has been similarly debated (Schenck, 1935, p. 521). Note especially in this connection the remarks made later regarding the occurrence and range of *Miogypsinoides* Y. and H.

(d) Hutchinsonian.

One of the few identical molluscs in the New Zealand and Australian Tertiary is *Typhis maccoyi* Ten.-Woods, which is known from the Janjukian-Balcombian and the Hutchinsonian-Awamoan (see Marwick, 1924A, p. 328). An interesting point is that in New Zealand an ancestral form appears at an earlier horizon (Duntroonian). A somewhat comparable case amongst the brachiopods is the distribution of *Neobouchardia minima* Th., known in New Zealand from Whaingaroan to True Hutchinsonian, but in Australia only from Janjukian (Allan, 1940, p. 285). The distribution of *Bathytoma* (s.str.) is pertinent; the large compact *cataphracta* type does not seem to antedate the Aquitanian, and the earliest record in New Zealand is from the Waitakian, though the group is not common till the Hutchinsonian. A similar form occurs in the Upper Oligocene or Lower Miocene of Bouton, West Indies (Martin, 1933, p. 21). The curious Triviid genus *Willungia* (Powell, 1938, p. 370) ranges from the lower Aldinga beds of Australia to the Awamoan of New Zealand, but of the various species the nearest related are the Janjukian *tasmanica* Powell and the Hutchinsonian *fracta* Tomlin.

(e) Awamoan.

The general similarities of these faunules to the Hutchinsonian make additional comparisons difficult. but attention may perhaps be drawn to *Zelandiella* Finlay (see Finlay and Marwick, 1937, p. 77). This Neptunid genus is conspicuous in the New Zealand Middle Tertiary, lasting till the Lower Pliocene, but apparently beginning suddenly in the Awamoan (the species recorded from the Wangaloan must be held suspect—none are known from the long gap between these horizons). The lineage is unknown in Australia, but in the Patagonian Miocene occurs *Austrocominella* v. Ihering (see Steinmann and Wilckens, 1908, p. 60) which is extremely similar or perhaps identical.

(f) Tongaporutuan.

The molluscan faunules, compared with those of most of the other stages, are small, and represent no great range in station. The sediments are rather uniform argillaceous sandstones, and do not provide rich macro- or micro-faunas. Among the molluscan genera practically all are Awamoan, but there are marked specific differences in most lineages, indicating some lapse of time. The only fossil of significance for outside correlation is *Aturia,* which has been collected at three different localities, and is an undoubted member of the fauna. Schenck (*Univ. Cal. Bull. Geol.,* vol. 19, No. 19, p. 439,

1931) has shown that throughout the world, except the Austral-New Zealand region, *Aturia* last appeared in the Middle Miocene, and some doubt may therefore arise as to whether the Tongaporutuan is really Upper Miocene. As noted later, the larger Foraminifera offer strong grounds for correlating the Hutchinsonian with the Lower Miocene, while there are indications that the Waitakian is Aquitanian. If, then, the Tongaporutuan were taken as Mid-Miocene, the Awamoan would have to be included with the Hutchinsonian in the Lower Miocene because of important lineage differences from the Tongaporutuan. On the other hand, because of its strong specific resemblances, the Urenuian must be included with the Tongaporutuan —if in the Middle Miocene, then the Upper Miocene receives the Opoitian. This seems to be rather crowding the Lower Miocene at the expense of the Upper, and a better balance is preserved by regarding —as the writers do here—the Tongaporutuan (and the Urenuian) as Upper Miocene, the Awamoan as Middle Miocene, and the Hutchinsonian as Lower Miocene. The greater probability then appears to be that *Aturia* lasted in New Zealand until Upper Miocene, a probability all the more strengthened by Chapman's record of the genus from the Australian Kalimnan (Lower Pliocene) *(Proc. Roy. Soc. Vict.*, vol. 34, pt. 1, 1921). A range to the Upper Miocene in Java has just recently been recorded by J. W. Durham (1940, *Journ. Pal.*, p. 160).

(g) Urenuian.

Many important lineages undoubtedly show close specific agreement with the Tongaporutuan, so that there is some justification for those who have favoured uniting the two in one Taranakian stage. Nevertheless, the important genera *Pelicaria, Heligmope, Ellicea,* and *Waitara* appear for the first time in the Urenuian—quite an imposing array considering their wide distribution in New Zealand and the small fauna known from this stage.

The Turrid genus *Waitara* Marwick apparently has a very short range in New Zealand, appearing in the Urenuian and not lasting beyond Opoitian, thus being restricted here to Upper Miocene–Lowest Pliocene (the species *generosa* Marwick must be neglected, as its horizon is quite uncertain). The range of *Waitara* elsewhere is not known, but should be investigated; rather similar shells are the Recent and Upper Tertiary *Thatcheria* Angas from Japan, and a form from the Lower Miocene of the Dutch East Indies described as *Cryptoconus carinatus* Martin (1933, p. 18). The Janthinid genus *Heligmope* Tate was also common from Urenuian to Waitotaran time, and has been the subject of a paper (Finlay, 1931, p. 1) suggesting a possible correlation with Australia, since this pelagic genus also occurs in the Kalimnan there. The Struthiolarid group *Pelicaria* Gray has its inception here in the Urenuian, while the earliest Australian member seems to be *P. marwicki* Fin. *(Trans. N.Z. Inst.*, vol. 62, p. 17, 1931), from the Abattoirs Bore beds of South Australia, whose age is still debated, but is probably Upper Miocene or Lower Pliocene.

(h) Pliocene.

The Lower Pliocene is marked in New Zealand chiefly by the disappearance of Miocene lines, presumably due to a cooling climate, and no particular introductions are known until the Castlecliffian. Even at Castlecliff the only strikingly new additions occur well up in the series. The large Pectinid *Notovola* (Finlay, 1930, p. 51), the Indo-Pacific *Eunaticina* (Powell, 1934, pp. 268, 269), and *Leucotina* A.Ad. *(s.str.)* are all marked new-comers, conspicuous in the Pliocene of Japan, and all of very short life here, except *Notovola*, which is still common. The Glycimerid group *Glycimerula* Finlay and Marwick (1937, p. 23), which is also characteristic of the Japanese Pliocene and Recent, reached New Zealand somewhat earlier, probably at the beginning of the Pliocene. Even later immigrations have occurred, perhaps in the Pleistocene, in the form of *Anadara trapezia* L. (Powell, 1932, p. 70) and some Cymatiidae (Finlay, 1926B, p. 398, etc.; Powell, 1933, pp. 156–159), and are still occurring at the present time; e.g., *Gadinia conica* Angas, *Hydatina physis* (Linné), *Recluzia lutea* (Bennett) (Powell, 1924, p. 282), *Polinices simiae* (Desh.) (Powell, 1934, p. 156).

OUTSIDE CORRELATIONS BY FORAMINIFERA.

In the absence of comparative specimens and much literature, it is difficult to give an adequate survey of extra-limital microfaunal affinities. Most of those noticed are shown by the older faunas, but even here one is greatly hampered by what are perhaps depositional or regional peculiarities—there are extremely few New Zealand faunas that bear an obvious resemblance to any outside fauna considered as a unit. Perhaps the vagaries of range and distribution of the smaller Foraminifera explain this, but even in the Cretaceous we have nothing so easily comparable with the illustrated American faunas as is that of the West Australian Gingin Chalk. This is not satisfactorily explained by our lack of sufficiently calcareous facies—there are whole groups of otherwise world-wide index lineages apparently missing from the New Zealand faunas. In the Cretaceous there is as yet no trace of *Pseudotextularia, Ventilabrella, Eouvigerina, Pseudouvigerina, Bolivinita (eleyi* Cush.) and, most surprising of all, *Globotruncana**. Only odd specimens of *Gümbelina* have been found; a large species *(panikauia* Finlay) is abundant at one Piripauan locality, but otherwise that genus is common here (as a tiny form) only in the Oligocene. The two latter genera are extremely abundant in the West Australian Cretaceous, and Thalmann (1935A, pp. 598–601) has commented on the finding of *Globotruncana* in so many countries that its extreme rarity in New Zealand is surprising. In our Eocene an equally conspicuous absentee is *Camerina* (*Assilina* has been recorded in sections—see Chapman, 1932, p. 484). In one Lower Oligocene (Kaiatan) fauna there is a form, evidently near

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* Since this was written, rare specimens of two species have been found by J. M. Dorreen in the Clarentian Puketoro beds and the Piripauan Rakauroa formation.

Camerina, with complex strong reticulate sculpture; but it is the sole New Zealand representative of its Family as yet. In the Miocene the index Australian and Dutch East Indies genus *Trillina* is not known here.

Nevertheless, there are present in our faunas a sufficient number of genera and species of restricted occurrence elsewhere to indicate a number of correlations, and these may be classified by the main epochs.

CRETACEOUS.

The top of the Raukumara Formation is at present the oldest bed yielding a micro-fauna, and here also is the only horizon with abundant *Globigerina cretacea* d'Orb.; the accompanying *Globigerinella aspera* (Ehrenberg) ranges somewhat higher in the section, into Piripauan. The former has been erroneously recorded from numerous higher horizons; in America it is still common in the Texan Navarro (Campanian), but is in New Zealand extremely rare or absent in beds of approximately that age, being replaced by a form close to the Navarro *rugosa* Plummer. This and the absence of typical *Globotruncana,* etc., could easily suggest that the New Zealand Upper Cretaceous stages are even younger than considered here. In Mexico *Globotruncana* is similarly absent in the Velasco, though very characteristic of the Mendez, considered by Thalmann (1935B, p. 371) to be Paleocene and Santonian respectively. There is little in the rest of the Raukumara fauna to throw light on its age at present, though it has some general resemblance to the Albian faunas figured by Eichenberg (1935, p. 389) from the North German oil-fields, and on the whole is remarkably similar to a fauna just lately figured by Tappan (1940, *Journ. Pal.,* vol. 14, no. 2, pp. 93–126), from the Grayson formation of Northern Texas, and placed as Upper Albian. Ornate Epistominas are lacking, but the Frondicularians and allied forms, though not particularly like the illustrated species of the Texan Taylor (Santonian), have much less in common with the Navarro than have the Piripauan species.

The evidence of these latter seems fairly strong, for the Piripauan Rakauroa formation contains species of *Palmula* very close to *reticulata* (Reuss), *semireticulata* (Cushman and Jarvis), and *primitiva* Cush., a *Frondicularia* like *dimidia* Bagg, and a *Planularia* close to *simondsi* (Carsey)—all prominent Navarro species. The restricted Cretaceous genus *Bolivinoides* (as *dorreeni* Finlay, of the *delicatula* Cush. group) also occurs at this horizon, while above it in the section occurs *Nuttallides alatus* (Marsson), also known from high in the Cretaceous of Rügen, Germany, Arkansas, and Trinidad. The allied and older *N. micheliniana* d'Orb. so common in the Craie Blanche of Europe, Middle Taylor of America, and White Chalk of Antigua (see discussion in Cushman, *Contrib. Cush. Lab. Foram. Research,* vol. 7, pt. 2, pp. 34 and 45, 1931; and *Journ. Pal.* vol. 6, No. 4, p. 342, 1932) has not been found here in typical form, but has a representative *(tholus* Finlay) in the Lower Piripauan showing the same evolutionary differences as the form in the Trinidad Upper Navarro called by Cushman (*Proc. U.S. Nat. Mus.,* vol. 80, p. 48, 1932) "*Pulvinulinella alata* Marsson." In the latter fauna and the

Saratoga Chalk, also of Navarro age (see Cushman, *Journ. Pal.*, vol. 5, No. 4, p. 310, 1931), is the conspicuous species *Gyroidina globosa* v. Hag.; this is equally conspicuous in almost every Piripauan fauna, but absent above and below, and does not seem to be in the American Taylor or Midway. *Rotamorphina cushmani* Finlay is known only from our Upper Piripauan and this same Upper Navarro Trinidad horizon. The Trinidad fauna has very much in common with our highest Piripauan, and has been regarded by Cushman as most similar to the Mexican Velasco (Tamesí of Muir) and equivalent to the Texan Navarro, but many micro-palaeontologists, including Thalmann, Plummer, and Dorr, regard it as younger—even Paleocene. The late J. M. Muir stated in a personal letter discussing the problem that " The Tamesí is certainly post-Maestrichtian and definitely pre-Midway (of Texas). The inference is that the beds are probably Danian."

An important connection is furnished by the extreme similarity of some Piripauan faunas to those of the Burdwood Bank Uppermost Cretaceous described by Macfadyen (1933, p. 4). All the species he figures (except *Pseudotextularia*) are conspicuous in, and all but one limited to, the Piripauan. Of particular interest is the genus *Rzehakina* Cushman (see Finlay, 1939B p. 534), which is abundant in and highly characteristic of the North Island Piripauan (the Tapuwaeroa and restricted Mangatu formations); the known occurrences of *R. epigona* (Rzehak) in the Middle and Upper Velasco of Mexico, the Upper Navarro of Trinidad, the Maestrichtian and Danian of French North Morocco, and the "Alttertiar " of Austria (which Glaessner has shown to be really late Cretaceous) support a conclusion that the age of such New Zealand beds must be close to the Tertiary boundary; certainly no older than Santonian (if as old), and no younger than Danian.

Geographically the nearest Cretaceous faunas comparable to those of New Zealand are in the different Gingin horizons in West Australia, which Whitehouse (1926, p. 279) refers to the Lower Santonian, though Crespin (1938, p. 395) thinks that the full range from Cenomanian to Campanian may be present. These faunas in their species of *Globotruncana, Gümbelina, Clavulina, Bolivinita, Eouvigerina,* and *Frondicularia* are much more directly comparable with those of the Selma and Annona chalks of the American Taylor, and are more obviously Cretaceous than much of the Piripauan—it is indeed very possible that some of them correlate better with the top of the Clarentian between the Raukumara and Tapuwaeroa. The highest parts of our Cretaceous (Wangaloa beds, Amuri " *Teredo* Limestone ") have yielded no micro-faunas at their type localities.

TERTIARY.

(a) Eocene.

No Lower Eocene has been recognised in New Zealand. A sharp change is already visible in the Lowest Bortonian, and there are no Cretaceous lingerers as in the Texan Midway. A form deceptively like *Eouvigerina* does occur, but is a more advanced development, and has been separated as *Zeauvigerina* Finlay (1939B, p. 541).

The large ornamented Frondicularians have all gone, there are no Planularias, and the Palmulas are of altogether different and Tertiary types. The Lower Eocene Midway fauna is as closely related to our Upper Piripauan as to any of our Eocene faunas, being in many features " midway " between the two. The most significant New Zealand micro-fossils from this aspect are *Assilina*, *Discocyclina* and *Asterocyclina* (Chapman, 1932, p. 483); the last has been quoted as restricted to Upper Eocene, but is given by Galloway and by Vaughan as also Middle Eocene; it occurs in the Dutch East Indies and Australia (Chapman and Crespin, 1935, p. 60) as characteristic of " stage b " (of van der Vlerk and Umbgrove, 1927) placed as Middle—Upper Eocene. In a recent tabulation by Senn (1935, Pl. 9) *Assilina* is given a range of only Lower—Middle Eocene (just into Upper Eocene in Egypt), while *Asterocyclina* is confined to Upper Eocene in America and Venezuela, but also reaches Middle Eocene in Morocco and Europe. This would seem definite evidence that the Upper Bortonian at least is Middle Eocene.

Of other restricted genera *Hantkenina* is the most impressive. *H. australis* Finlay (1939B, p. 538), a species close to the genotype, has been found at several localities in the Upper Bortonian; since it was recorded, specimens have been found also in the Kaiatan (Kaiata mudstone of Westland and Maheno chalky clays of North Otago), here referred to the Lower Oligocene. This is the same range as that of the genotype in America; while the nearest relatives to the New Zealand shell, *alabamensis* Cush. and *brevispina* Cush., have also been recorded from the Upper Eocene and Lower Oligocene of French Morocco (Rey, 1938, p. 331). Cushman (1939, p. 38) has reported that no authentic species of *Elphidium* is known below Middle Eocene; the genus is absent from our Cretaceous and Lowest Bortonian (which may be Lower Eocene), but two typical species occur in the Lower and Upper Bortonian respectively, already referred to Mid-Eocene by Finlay. There are also some striking affinities with the Eocene of Mexico, particularly the Lower Eocene Aragon formation. *Nuttallides* Finlay of the *trümpyi* type is not uncommon throughout our Bortonian (but absent from the Tahuian, Uppermost Eocene) and extends down to the Upper Piripauan; in Mexico it extends similarly throughout the Eocene, while in French Morocco it is dominant in the Middle Eocene, but also extends halfway through the Upper (Ostrowsky, 1938, table opposite p. 352). *Globorotalia crater* Finlay, so characteristic of our Lower Bortonian, is close to the Mexican *crassata* Cush. and *aragonensis* Nuttall (from the Aragon formation, classed as upper part of Lower Eocene), and less like the Danian *velascoensis* Cushman, while the Bortonian genus *Aragonia* Finlay (of *Bolivinoides* affinity) has close Mexican allies in the Velasco and esecially Aragon, and is unknown above the Eocene. *Marginulinopsis asperuliformis* Nuttall, an index species of the Aragon (see Nuttall, 1930, pp. 277, 282) is extremely close to the Lowest Bortonian *M. waiparaensis* Finlay, while the Middle and Upper Eocene Californian *M. nudicostata* (C. and H.) is just as close to our Lower Bortonian *marshalli* Finlay. The French Cretaceous genus *Citharinella* Marie (see *Bull. Soc. Geol. de France,* ser. 5, vol. 8, p. 99; 1938) has been seen in the Piripauan Rakauroa Series; the Tertiary species *tenuissima* Hantken is known from the Upper Eocene of South America and Europe and lasts to the Oligocene, just as in New Zealand, where it is in the Upper Bortonian and Whaingaroan.

The Claiborne and Jackson Eocene faunas are of semi-tropical coral reef type and have no particular affinity with what is here regarded as New Zealand Eocene, nor has the West Australian fauna recently described as Upper Eocene by Parr (1938, p. 69), but the latter has striking and curious affinities with both the Upper Piripauan and Lowest Oligocene of New Zealand.

Chapman (1926, p. 16) regarded the age of the Tahuian Burnside Marl micro-fauna as " Upper Eocene probably," but has lately (1934, p. 120) stated that it exactly agrees with the Goon Nure Bore of Gippsland, below 2020 feet, thought to be Upper Oligocene. In this case his first location was better, but it would be unreasonable to expect any outside worker to place the Tahuian fauna without intimate knowledge of how the Bortonian and Ototaran also compared with the Gippsland faunas.

(b) Oligocene.

Perhaps the most striking genus here is *Rotaliatina* Cush. (see Finlay, 1939B, p. 539); this is present also in the Upper Bortonian, increases in abundance till the Whaingaroan (Mid-Oligocene), and then becomes extinct—this is a longer range than given by Nuttall (1930, p. 272) for the Mexican formations, where the genus is restricted to Middle and Upper Eocene, common only in the latter. A striking feature of the Lower Oligocene in New Zealand is the abundance of several species of *Asterigerina;* elsewhere this ranges to Recent, but is particularly common in the Oligocene (see, for example, the four species of the Upper Vicksburg described by Cushman and McGlamery, 1938, p. 111). *Amphistegina* begins to replace it in the Whaingaroan (a single specimen seen in Kaiatan) by an uncommon *hauerina* form, but does not occur in abundance and typical *lessoni* type until the Hutchinsonian–Taranakian period, supporting the reference of these stages to Miocene in the broad sense. From the basal Oligocene have been described *Robertina lornensis* and *Ceratobulimina lornensis,* both closely related to external Lower Oligocene or Eocene species.

(c) Miocene.

Miogypsina appears for the first time, and is abundant in, and limited to, the Hutchinsonian. This also applies to our various species of *Lepidocyclina,* which are all Nephrolepidine. Crespin (1936, p. 11) has noted that all the Victorian Lepidocyclines are also Nephrolepidine, and that in the Dutch East Indies and New Guinea these have their greatest development in the early part of stage " f," which is equivalent to the Middle Miocene, a few of the species ranging up from the Lower Miocene stage " e."

Some interesting faunal connections can be traced through these orbitoid forms, as follows:—Pakaurangi Point has a well-known and truly Hutchinsonian Molluscan fauna (Laws, 1939, p. 466) and an abundance of the Upper Aquitanian-Lower Helvetian ***Miogypsina irregularis*** Mich.; its micro-fauna is almost duplicated at a Poverty Bay locality, which also contains *Nephrolepidina tournouri* L. and D., *marginata* Mich., *borneensis* Provale and *sumatrensis* Brady (with var. *mirabilis* Y. and H.), together with *Amphistegina lessoni* d'Orb. and *Gypsina howchini* Chap. Equivalent horizons in the Waitemata beds of Auckland, the basal Mahoenui of Taranaki, and the lower " Blue Bottom " of the South Island West Coast contain *Carpenteria rotaliformis* Chapman and Crespin, *Calcarina mackayi* (Karrer) and *Nephrolepidina orakeiensis* (Karrer) (probably a synonym of *martini* Schlumb.). This horizon certainly corresponds with those from the Australian Janjukian containing these same orbitoids and referred to high in the Lower Miocene between stages " e " and " f," by Crespin (*l.c.*, p. 12). Below it, in New Zealand, but still placed in the Lower Miocene, is the Lower Hutchinsonian, discussed later.

The correlation of the Hutchinsonian as a whole with the Janjukian-Balcombian is confirmed by many other species. Because of the few Australian faunas seen, however, and their considerable specific difference and distinctive facies from ours, it is not yet possible to say which divisions of about Lower Miocene age more nearly correspond across the Tasman. The restricted genus *Victoriella* Chap. and Cresp., hitherto known only from the Oligocene of Hungary and the Lower Miocene of Australia, has been found in the Caversham sandstone at Burnside as a new species close to *plecte* (Chap.). The index New Zealand species *Calcarina mackayi* (Karrer) (see Finlay, 1939A, p. 527) is known only from our " true " Hutchinsonian (for remarks on this and possibly " false " or Lower Hutchinsonian, see later in this paper), and is common in the Janjukian, but replaced by a distinct form (*verriculata* Howchin and Parr) in the slightly higher Balcombian—both formations being referred to the Lower Miocene by Singleton (1935, p. 130; 1937, p. 442). *Pavonia triformis* Parr (1933, p. 29) is a rare and distinctive form previously confined to the Janjukian and Balcombian and the Miocene of Java; it is not uncommon in the true Hutchinsonian of Pakaurangi Point, but absent elsewhere in New Zealand. *Planorbulinella plana* (H.-A. and E.) is known only from these Australian horizons and the true Hutchinsonian of Nelson (Takaka), Westland (Marsden), and Taranaki (Mahoenui). *Cerobertina* Finlay (1939B, p. 118) ranges from Mid-Eocene to Recent in New Zealand, but only the true Hutchinsonian *bartrumi* compares with the Australian forms seen; it is very close to the Janjukian-Balcombian *dehiscens* H.-A. and E. The allied *Ceratocancris* Finlay (1939B, p. 117) has a restricted true Hutchinsonian range and appears to be recorded only from the Australian Balcombian; a very closely allied species is in the Vienna Miocene. The index genus of the Australian Balcombian, *Hofkerina* Chapman and Parr (1931, p. 237), is known in New Zealand only from the true Hutchinsonian of Pakaurangi Point by a species apparently identical with *semiornata,* the genotype. It would take too long to detail completely the many other described Janjukian and Balcombian species that occur, or have allies, in our Hutchinsonian—the microfaunal affinity between these stages is stronger than any other trans-Tasman link in the Tertiary. Allan (1940, p. 280) has recently written that " it is probable that the Hutchinsonian stage . . . is older than the Janjukian beds," but gives no evidence or reference to others' opinions to support this assumption.

Chapman (1932B) made the important discovery of *Miogypsinoides* Y. and H. in New Zealand, in slides sent him by Speight from the Mount Somers district. *M. nitidula* Chap. was found at three localities (Chapman Creek, Bland's, and Stavely limestone); from the first two Marwick and Allan (in Speight, 1938, pp. 61, 62) have recorded Lower Hutchinsonian brachiopods and molluscs, and Allan (*l.c.,* p. 91) has given a Hutchinsonian age for the latter, so that the horizon here of *Miogypsinoides* seems to be entirely Lower Hutchinsonian. Chapman's supposition that it came partly from (and proved the Lower Miocene age of) the Ototaran is erroneous. The importance of these records lies in the fact that the genus is known elsewhere only in the top of the Dutch East Indies stage " e " and base of " f "—Aquitanian and basal Burdigalian. This corresponds excellently with the Lower Miocene age Finlay allotted to the Hutchinsonian (its lower part would then be basal Miocene), with the Duntroonian-Waitakian Aquitanian.

A few links are known with faunas still further afield. Some matrix examined from the Burdigalian of France contains a species of *Virgulopsis* Finlay very close to the index species *pustulata* Finlay, limited to the New Zealand true Hutchinsonian and Awamoan. *Hopkinsina notohispida* Finlay (not below Awamoan) and *Siphogenerina ongleyi* Finlay (not below Whaingaroan) both seem to occur in the Miocene of French Morocco (Lacoste and Rey, 1938, chart, opp. p. 320 and Pl. 21) not below the Burdigalian. *Operculina,* so useful in Australia and America, is known here only from a distinct species at one locality, referred to Lower Miocene by Chapman and Parr (1938, p. 288), but probably older; of all the Austral and Indo-Pacific species they discuss it is the closest related to the French *complanata* Defr., known from Aquitanian to Lower Burdigalian in Europe and French Morocco (Lacoste and Rey, 1938, *l.c.*).

A rich fauna has been examined from the base of the Ouba series of New Guinea (basal " g " stage, regarded as Upper Miocene); a surprising similarity to our Taranakian is evident, almost all our Upper Miocene key-species being represented by close allies. Another fauna from the Upper Mena series (upper " f " stage—Middle Miocene) is even closer in a most striking fashion, to our Tutamoe (Awamoan) especially as developed in Hawke's Bay.

On the other hand extremely little relationship exists between figured faunas of the American Miocene and any New Zealand fauna placed here within the range Lower Oligocene-Pliocene.

(d) Pliocene.

The widely recorded *Uvigerina pigmea* d'Orb. has been restricted by Cushman to forms agreeing with the Italian Plaisancian type, and Finlay (1939C, p. 102) has noted that of the numerous forms met with in New Zealand, only those from the Lower Pliocene Wairoa formation are exactly similar. From the same Italian stage d'Orbigny described *Bulimina echinata;* this distinctive and uncommon form occurs in the North Canterbury Bourne Sandstone, of Lower to Middle Pliocene age, and has recently been recorded by Parr (1939, p. 67) as restricted in Australia to the Kalimnan (Lower Pliocene). Parr also records *Rectobolivina striatula* Cushman as ranging from Kalimnan to Recent; in New Zealand, too, it covers this range, but extends down to the Uppermost Miocene, a horizon doubtfully recognised in Australia. In the Opoitian (Lowest Pliocene) also a modern Globigerinid assemblage appears for the first time, characterised by *Globigerinoides rubra* (d'Orb.), *G. sacculifera* (Brady), *Globorotalia truncatulinoides* (d'Orb.) (none of which are known elsewhere before late Tertiary), *Globorotalia inflata* (d'Orb.), and *G. crassula* Cush. and Stewart.

(e) Anomalies.

There are also some important genera whose ranges in New Zealand are apparently not the same as elsewhere, but the anomalies concerned almost disappear when the facts are closely examined. The most striking are ***Flabellamina*** Cush. and ***Frankeina*** C. and A., regarded as zonal indicators in the American Cretaceous; here they are rare in the Cretaceous and Eocene, but often abundant and of large size in the Oligocene (especially Whaingaroan) and Miocene (especially true Hutchinsonian). This anomaly is not as great as it seems, however, for the Recent *Verneuilina variabilis* Brady (*Chall. Rep.*, vol. 9, p. 385; Pl. 47, figs. 21–24; from deep water off Fiji) is evidently a *Frankeina. Halkyardia* H.-A. and E. has previously been recorded only from the Middle Eocene and with doubt from the Mexican Oligocene. It has been reported by Parr (1934, p. 144) in what was regarded as a Middle Tertiary Waitematan (Hutchinsonian) fauna, and again later (Chapman and Parr, 1938, p. 288) from the "Lower Miocene" of Kawakawa; abundant large forms of this genus mark the Omotumotu beds of Westland, corresponding in fauna to the Waiarekan zone of the Lower Oligocene; the specimens seen by Parr are of questionable age and may turn out also to be Kaiatan. *Sphaeroidinella* Cush. is known here as the primitive *disjuncta* Fin. in the true Hutchinsonian and Awamoan and becomes quite characteristic in the Taranakian, a succession exactly paralleled in the New Guinea Miocene; the genus is quoted only as Recent by Cushman, but Oligocene-Recent by Galloway.

SOME GENERAL ASPECTS OF CORRELATION.

Conflict of Evidence.

The opinion has sometimes been expressed that different groups of organisms are likely to conflict in their evidence of geological age or correlation; we doubt this, and believe that any supposed clashes are more likely to be due to insufficient data or misinterpretation of evidence. One of us has had considerable personal experience in using and gauging the value of three major phyla—Mollusca, Brachiopoda, and Foraminifera. Certain conclusions have inevitably been drawn as to their respective usefulness in correlation, ease of discrimination of the genera and species, reliable identification of these in our Tertiary deposits from both perfect specimens and fragments, and availability in the maximum number of localities and lithologies. This is not the place to discuss these conclusions, but it has also been observed that there is no discrepancy in their evidence, if due regard is paid to biological principles and imperfections in the fossil record—the former affecting them equally, the latter unequally. In every case where discord seemed present at first, consistency resulted from fuller investigation.

Recurrence of Faunas.

Another opinion that has gained some mention in literature is that identical faunas might appear in different horizons if lithologies were similar, and thus upset correlations. This would leave the way open for much fanciful speculation about surface geology, but statements such as "determinations of micro-faunas in Arkansas afford other examples of recurrence of faunas" (Stephenson, *Bull. Am. Assoc. Pet. Geol.*, vol. 11, p. 12, 1927) are obsolete in micropalaeontology. A much more modern conception and treatment of this problem of unvarying sediments has been finely presented by Hedberg (1937) in dealing with the massive Carapita formation of Venezuela. There is no example in New Zealand remotely suggestive of recurrence of *identical* faunas, though similar backgrounds of hardy long-ranging species are of course common. There is always a difference if the age is different; if there is no difference in faunas of reasonable size their age is the same.

Post-Jurassic Complexity.

The problem of dividing up our Cretaceous and Tertiary beds into well defined stages is much more difficult than the subdividing of the Triassic and Jurassic. In these the faunules are small, uniform throughout the country, and they occur in easily defined, strictly limited succession. For instance, when one finds the widely spread Carnic *Maoria problematica* (Zitt.), one can be reasonably certain of finding the Noric *Monotis richmondiana* (Zitt.) a few hundred feet higher in the section, each species practically comprising the whole faunule. Similarly, no trouble has been found in accepting the range of *Pseudaucella marshalli* (Trech.) as about the middle of the Liassic; it has never been found in any embarrassing company, and *Inoceramus haasti* Hoch. is not encountered until several hundred feet higher in the beds. Obviously we are dealing with entirely different conditions from those of the Tertiary, where the trouble inclines to be a plethora of riches. The time and labour involved in winnowing the grain has naturally led some workers to seek a simpler way out, and the suggestion has been made, apparently by analogy with the old faunas, that only the common species need to be considered. Substitute " characteristic " for " common " and we agree; synonymise the two and we disagree.

Probably owing to unfavourable stations, our Cretaceous molluscan faunas are few in number; but, as far as can be seen, they tend to show the diversity characteristic of the Tertiary faunas.

Whether these observed differences in the straightforwardness of the fossil record are due to general climatic change is too large a question for discussion here, but it seems significant that they apparently synchronise with the world revolution in the vegetation so markedly initiated between Lower and Upper Cretaceous. Whatever the cause, it soon becomes evident to the practical palaeontologist that stimulating and successful methods of dealing with ancient faunas and strata have to be modified or even discarded in a study of the Tertiary.

Percentage of Recent Species.

The writers have not given the percentage of Recent species associated with each stage. It would involve, for present or future correlation, the naming of total faunas, of which a large proportion will consist of non-significant species. The percentage method of estimating the age of Tertiary faunas is of little or no value in defining or correlating stage divisions (see, for example, Laws's difficulties with regard to Kaawa Creek; 1936, pp. 39–42). Of course, the nearer a given fauna is in age to the Recent, the more it is likely to have in common, so that a general indication as to early, middle, or late Tertiary age can be obtained. It is significant, considering the very extensive use now made of micro-faunas in correlation by that severest taskmaster of stratigraphy—the Oil Company—that the writers can recall only a single mention of " percentage of Recent species " in connection with Foraminifera—that of Vaughan as far back as 1923.

Specific divisions are so unequal in value that mathematical statements based on them assume an analogy with unit numbers that does not really exist. The very basis, therefore, of the method is unsound. If the results agree with the other evidence, they are generally regarded as confirming it, but if they disagree, they are always readily explained away as due to differences in rate of evolution, contact with or isolation from other faunas, and so on. In such a realm as palaeontology, the writers are inclined to look askance at too much application of statistical methods; the " unknowns" and " controls " seem to them too debatable and too likely to vitiate the outcome. In practice the principle of key species and delimitation of ranges appears to give superior results, and has been used throughout this paper. The method has for some time been used in guiding the palaeontological work of two major oil companies, and the results obtained over wide areas have been entirely satisfactory.

Type and Standard Sections.

Allan (1933) has drawn attention to the need of a better stratigraphical basis for the New Zealand stages, and has more accurately defined the limits of several of them. There still remains, however, much to be done, especially more detailed field work at the type localities.

Palaeontologists, schooled as they are in the value of type selection in zoological procedure, may be biassed in its favour, but is seems likely that, in the end, uniformity and precision of usage can be achieved only by this means.

Considerable divergence of opinion prevails among stratigraphers, not only as to the need of type localities for stage (and series) names, but also as to the manner in which these types should be designated. The terms type locality, type section, unit type, standard locality, standard section, control section, and reference section are all in use, but uniformity in their application is lacking. The general practice, no doubt, is to regard the " type " as something fixed and not subject to change, but that this is not always so is shown by A. J. Butler's " type section " of the Wenlock Limestone (1939, *Q.J.G.S.*, vol. 95, p. 41), which " is used for convenience to denote the complete reference-section . . . . and, of course, bears no significance of priority over sections described by earlier authors."

There has also been much criticism as to the poorness of some type sections, and refusal to recognise any merit in their use. Objection to the use of types probably has arisen through confusion of two separate processes—(1) stabilising the stage or series name by fixing it to a physical entity; (2) selection of the best all round section (at least at the time of selection) as a basis of comparison with other localities in order to determine their age. The writers propose to keep the two underlying ideas quite distinct by applying the terms Type Locality and Type Section to the former, and the terms Standard Locality and Standard Section to the latter. The term reference section can be regarded as practically synonymous with the Standard, but J. E. Eaton's " control section " (1931, *Bull. Amer. Assoc. Pet. Geol.*, vol. 15, No. 4, p. 372) represents rather a number of type sections or of standard sections combined into one standard column.

The terms type section and type locality, then, should be rigidly applied, permanent, and reasonably subject to the law of priority.

The terms standard section and standard locality should be applied to the best section that, with the available data, can be confidently correlated with the type, where the two are necessary. If additional evidence upsets this correlation, then a new stage name or a new standard section must be selected.

This use of the standard, as distinct from the type, section will secure the results aimed at by Allan regarding the Bortonian and the Awamoan, while avoiding complications with regard to the validity of type designations and the accuracy of stage definition.

The writers have found some difficulty in evaluating the Bortonian and Hutchinsonian, and in fitting the faunal facts into the conventional usage, so that their treatment of these stages may seem unduly involved. The foraminiferal evidence suggests that the Bortonian, as represented at Hampden and elsewhere can be subdivided, while both molluscs and forams indicate that a new stage or stages may be necessary between the Bortonian and Wangaloan. This should await the elaboration of field evidence brought to light during the recent survey of the Hampden district by D. A. Brown. Owing largely to facies differences, the exact relationship of the Waitakian to what is here called Lower Hutchinsonian is not yet clearly understood, nor is the best section of the Lower Hutchinsonian yet determined to serve as a standard. The position has been purposely left vague until further faunules have been collected or new stratigraphic evidence brought to light.

Scope of Lists.

The following lists are concerned mostly with restricted species and first and last appearances of important fossils. In the case of the molluscs, records of shallow-water and rock forms and the very small shells, such as Rissoids and Liotids, have mostly been omitted as too sporadic and uncertain. Except in the case of some outstanding genera, only described species are dealt with, but many index new species are known.

The Foraminifera so far validly known from the Dominion have been fairly fully dealt with here, and the ranges include the latest information on all the species discussed so far by Finlay in the " Key Species in Stratigraphy " papers, most of the species described by Stache and Karrer in the " Novara " volume, all Kreuzberg's new species from the Ihungia of Whakatu Stream, most of Parr's new forms in various recent papers and of Chapman's in *Pal. Bull. 11,* and a number described by Cushman and collaborators. Records of mollusca are not nearly so complete as regards the very many fossil species now described by Zittel, Hutton, Suter, Wilckens, Trechman, Woods, Marshall, Murdoch, Marwick, Finlay, Powell, Allan, Laws, King, and others; but are reasonably complete in the case of genera of any significance. Records of the brachiopods have been taken from the published papers of Thomson and Allan and from personal knowledge.

It would not, in any case, have been practicable to present as full a specific account of the Mollusca and Brachiopoda as has been done with the Foraminifera. There are so very many cases of " species groups "—closely allied forms which have been named as distinct in the literature, coming from different localities of about the same age and certainly in the same Stage. Even within the same district, the diversity of species of such genera as *Turritella, Pelicaria, Verconella, Parvimitra,* Volutid genera, *Pachymagas, Rhizothyris, Liothyrella,* etc., sufficiently indicate the multiplicity of local faunules, which have not much real bearing on Stage correlation. Marwick and Thomson have frequently referred to this. It is then the *group* of species rather than the single name which becomes important, and it is not possible to delimit all these except in a check-list. Subdivision of the foram species may not have been so minutely attempted (though the personal equation should be absent here), but it is likely that their abundance has allowed of more accurate estimation of variability, with the consequent suppression of over splitting. Perhaps because of this, perhaps because their record is much fuller, perhaps because molluscs are more highly organised and therefore show evolutionary (or benthic?) change more rapidly, the micro-" species " may be on a slightly different footing from the macro- ones, and appear on the whole longer ranging. But if the larger fossils were as thoroughly known and locality variants less taken into account, less difference would appear in the respective numbers of species limited to one, two, or more Stages. With the fine divisions in use in our Mollusca, it is easy to find numbers of " species " apparently limited to one or at most two Stages, and these are readily designated " characteristic " or " index." This usage has also been employed by Finlay for very distinctive Foraminifera. But so many of the common micro-species range over several Stages that an implied distinction has been made in the term " Key-Species." This has tacitly been used for any forms whose ranges have been definitely or very nearly determined (the overlaps of several long ranges often providing the required age estimation); a certain proportion of these have short ranges, and are then regarded as of characteristic or index value.

DESCRIPTION AND CHARACTERISTIC FOSSILS OF THE STAGES.

Wherever no author's name has been appended to a foraminiferal genus or species in the following lists, it is to be understood as described by Finlay. To save repetition, Mollusca are designated by (M), Brachiopoda by (B), and Foraminifera by (F). Species marked with an asterisk occur actually at the type locality, but any similar attempt to mark facies indicators would inevitably have led to complexity and confusion.

Pre-Clarentian (Taitai Series).

Type Locality:—Not designated. At Taitai by tautonymy; the fossils mentioned do not come from here, but from Koranga Survey District.

Sediments:—Igneous conglomerate and indurated mudstone, 2000+ feet thick, apparently overthrust on Raukumara and Tapuwaeroa beds (Ongley, 1930B).

Fauna:—Molluscs very rare.

Correlatives:—(By lithology). Beds in Wairoa Subdivision and in Eketahuna Subdivision (see Ongley, 1935, p. 3).

RESTRICTED FORMS:—

(M) *Maccoyella magnata* Marw. (1939, p. 462).

FIRST APPEARANCE OF:—

(M) *Aucellina* Pompeckj (aff. *gryphaeoides* Sow.).

Clarentian. *(a) Typical, South Island.*

Type Locality:—Coverham, Clarence Valley (Thomson, 1919, p. 312).

Sediments:—Conglomerates, mudstones, sandstones, 8000 feet thick, resting unconformably on old basement rocks. Overlain with apparent conformity by flint beds at the base of the Amuri Limestone.

Fauna:—Molluscs; an Annelid.

Correlatives:—(By molluscs) East Wellington (indurated mudstone); Hawke's Bay (indurated mudstone with concretions and forams); Raukumara Pensinula (Raukumara Series—see Ongley and Macpherson, 1928, p. 20—indurated alternating sandstones and mudstones; near top is Mangaotane Mudstone with forams).

RESTRICTED FORMS:—

(M) **Aucellina euglypha* Woods (1917, p. 9), **Inoceramus concentricus* Park, **I. (Callistoceramus) bicorrugatus* Marw. (1926B, p. 380), *Trigonia glyptica* Woods, *T. meridionalis* Woods.

(M: Cephalopoda) **Turrilites circumtaeniatus* Kossm., **Gaudryceras* cf. *subsacya* Marsh., *Dimitobelus superstes* (Hect.) (Whitehouse, 1924, p. 412).

(Annelid) **Serpula wharfensis* Woods.

(b) Raukumara Series, North Island.

Type locality not designated; base not known. Overlain unconformably by Tapuwaeroa or Mangatu, or by overthrust Taitai.

RESTRICTED FORMS:—

(M) *I. (Callistoceramus) bicorrugatus* Marw.

(Annelid) *Serpula wharfensis* Woods.

(F) *Globigerina cretacea* d'Orb., *Lingulina* of *pygmaea* Reuss line, *Globotruncana* cf. *arca* (Cush.).

FIRST APPEARANCE OF:—

(F) *Karrerulina clarentia, Globigerinella aspera* (Eh.). Other genera dating back to these earliest micro-faunas yet known in New Zealand are *Recurvoides* Earland, *Ammobaculites* Cush., *Pseudoclavulina* Cush., *Quinqueloculina* d'Orb., *Ramulina* Jones, *Bolivina* d'Orb., *Nodosarella* Rzehak, and *Allomorphina* Reuss.

Glomospira corona Cush. and Jarv. (common in Piripauan, dying out in Bortonian), *Ammodiscus glabratus* Cush. and Jarv. (abundant to Lower Bortonian, grading in Upper Bortonian to *archimedis* Stache), *Marssonella* cf. *oxycona* (Reuss).

Piripauan.

(a) Typical, South Island.

Type Locality:—Amuri Bluff, North Canterbury (McKay, 1877, p. 181; Thomson, 1917, p. 409).

Sediments:—Sands with calcareous bands and concretions, grits, greensands, 1000 ft. thick, unconformable on old basement rocks; upper limit here fixed as the concretionary greensand below the Lower *Teredo* Limestone.

Fauna:—Molluscs (especially Belemnites) not uncommon in lower part. Radiolaria abundant.

Correlatives:—(By molluscs) Otago (Brighton Limestone, Horse Range Breccia); North Canterbury (Waipara River, Malvern Hills, Waimakariri Gorge, Selwyn Rapids); East Wellington, Hawke's Bay, Poverty Bay, East Cape (including Whangai, Tinui, Lower Mangatu, and Tapuwaeroa Series); North Auckland (Otamatea = Batley Series, rich in Ammonites; see Marshall, 1926). Rich foram faunas from Waipara, Hawke's Bay, and Poverty Bay.

RESTRICTED FORMS:—

(M) **Pacitrigonia* Marw. (1932, p. 507), **Protodolium* Wilck. (1922, p. 18), *Trigonia waiparaensis* Woods (1917, p. 23), **T. pseudocaudata* Hect., **Inoceramus australis* Woods, **I. steinmanni pacificus* Woods, **Eriphyla meridiana* (Woods), **Anthonya elongata* Woods, **Callistina wilckensi* Woods and *thomsoni* Woods (see *Tikia* Marw., 1926D, p. 595), **Conchothyra parasitica* Hutt., **Dentalium morganianum* Wilck.

(M: Cephalopoda) **Madrasites haumuriensis* (Hect.), **Cheirobelus lindsayi* (Hect.).

(F) *Spiroplectammina piripaua, Gaudryina healyi, Dorothia biformis* and *elongata, Palmula* cf. *primitiva* Cush. and *rakauroana, Pseudoglandulina parallela* (Marss.), *Buliminella sauria, Patellina piripaua, Gyroidina globosa* (v. Hag.), *Anomalina piripaua, Pulvinulinella creta* and *acutimarginata, Planulina rakauroana, Allomorphina whangaia;* (from the upper part alone, Waipara greensands) *Planularia whangaia, Bolivina incrassata* Reuss, *Elongobula creta.*

FIRST APPEARANCE OF:—

(M) **Cucullaea* Lamk., **Cucullastis* F. and M., **Lahilleona* Marw., *Glycimerita* F. and M., **Conchothyra* Hutt., **Struthioptera* F. and M. (1937, p. 61), *Lunatia* Gray (*selwyniana* Wilck.), **Maoricrypta* (*hochstetteriana* Wilck.).

(B) *Aetheia* Th.

(F) *Gaudryina* d'Orb., *Dorothia* Plummer, *Pseudoglandulina* Cush., *Buliminella* Cush., *Chilostomella* Reuss, *Ellipsonodosaria* Silv. (of *verneuili* d'Orb. type), *Patellina* Will., *Pulvinulinella* Cush., *Pullenia* P. and J.

Nodosaria longiscata d'Orb. and cf. *filiformis* Reuss, *Bulimina* of the *pupoides* d'Orb. line (as *quadrata* Plummer), *Gyroidina* of the *zelandica* line.

(b) Tapuwaeroa Series, North Island.

Type locality not designated; by tautonomy should be somewhere in Tapuwaeroa Valley (see Ongley and Macpherson, 1928, p. 23), but insufficient macro- and micro-faunas are known from here as yet. The formation rests unconformably on the Clarentian Raukumara beds, and is overlain by unconformable Mangatu or by overthrust Taitai.

The Whangai (Quennell, 1937, p. 3) is not here faunally separated, as there are few macro-fossils, the micro-faunas are poor, and the line of division uncertain. Some of the Foraminifera quoted below will probably be restricted later to a horizon above Tapuwaeroa —possibly a reconstituted Mangatu. Of this the Waipara greensands may be a South Island equivalent.

RESTRICTED FORMS:—

(M) **Ostrea lapillicola* Marw. (1926B, p. 381).

(F) *Ammodiscoides* Cush. (reappears in Recent fauna), *Conotrochammina* (as *whangaia*), *Rzehakina* Cush. (as *epigona* Rze.), *Bolivinoides* Cush. (as *dorreeni*), *Rotamorphina* (as *cushmani*), *Globotruncana* n.sp.

Spiroplectammina steinekei, Vulvulina büningi, Gaudryina whangaia, Eggerella columna, Matanzia simulans, Palmula rugosa d'Orb. and *thalmanni, Frondicularia mucronata* Reuss, *teuria,* and *steinekei, Planularia rakauroana, Pseudoglandulina cylindracea* (Reuss), *Gümbelina panikauia, Bulimina rakauroana, Nonionella tamumua, Eponides infrafossa, Nuttallides alatus* (Marsson) and *tholus, Globotruncana* n.sp., *Globigerina circumnodifera;* together with all the South Island species except *Patellina.*

FIRST APPEARANCE OF:—

(F) *Bolivinopsis* Yakov. (as *spectabilis* Grzyb.), *Vulvulina* d'Orb., *Matanzia* Palmer, *Tritaxilina* Cush. (as n.sp.), *Clavulinoides* Cush. (of *instar* line), *Citharinella* Marie, *Gümbelina* Egger, *Nonionella* Cush., *Nuttallides* (several species), *Parrella, Quadrimorphina* (as *allomorphinoides* Reuss), *Discorbis* of *bertheloti* (d'Orb.) line (as n.sp.).

Trochamminoides irregularis White, *Cyclammina* cf. *pusilla* Brady, *Karrerulina aegra, Pseudoclavulina* cf. *anglica* (Cush.), *Bulimina bortonica, Anomalina aotea* and *eoglabra, Eponides ecuadorensis* (G. and M.), *Nuttallides subtrümpyi* (small specimens), *Cibicides* of *perforatus* Karrer line, *Allomorphina trochoides* (Reuss), *Globorotalia* of *dehiscens* C., P., and C. line (as n.sp.), *Globigerina linaperta.*

LAST APPEARANCE OF:—

(M) **Aucellina* Pompeckj (in Tinui Series), **Ammonites,* and **Inoceramus.*

(F) *Rzehakina* Cush. (as *epigona* Rze.; abundant), *Planularia* Defr. (until the Recent *spinipes* Cush.).

Karrerulina clarentia, Marssonella cf. *oxycona* (Reuss), *Globigerinella aspera* (Ehrenb.).

Post-Piripauan.

The Amuri "*Teredo* limestone" has yielded no fossils as yet, except the little Belemnites, and cannot be discussed faunally.

Wangaloan.

Type Locality:—Mitchell's Point, Wangaloa (Ongley, 1939, p. 56).

Sediments:—Concretionary zone in sandstone, 50 + ft. thick, overlying Taratu and Kaitangata coal measures, the latter resting on schist. Overlain by unfossiliferous sandstone.

Fauna:—Molluscs abundant.

Correlatives:—(By molluscs) Otago (Boulder Hill, Dunedin); (by stratigraphical position between Bortonian and Piripauan) North Otago (? Katiki-Moeraki Series, with good foram faunas but only arenaceous species).

RESTRICTED FORMS:—

(M) The following genera of Finlay and Marwick, 1937; **Cucullona,* **Dosinobia,* **Leptocolpus,* **Colposigma,* **Kaitangata,* **Amauropsona, Spirogalerus,* **Microfulgur, Tudiclana,* **Fyfea, Taieria,* **Proficus,* **Taioma, Antepepta, Coptostomella,* **Pristimerica,*

**Campylacrum*, **Tholitoma*, **Ongleya*; also **Marwickia* Finlay, *Drepanochilus* Meek, **Heteroterma* Gabb, **Paleopsephaea* Wade. All of the species are restricted.

FIRST APPEARANCE OF :—

(M) **Electroma* Stol., **Limopsis* Sassi, **Venericardia* Lk. (*s.l.*), *Milthoidea* Marw., **Pteromyrtea* Fin., **Dosinia* Scop. (as *Dosinobia* F. and M.), **Wangaloa* Fin., **Globisinum* Marw., **Polinella* Marw., **Spelaenacca* Fin., *Zexilia* Fin., **Pseudofax* F. and M., *? Insolentia* Fin., **Marshallaria* F. and M., **Priscaphander* F. and M., **Acteon* Mont., **Tornatellaea* Con., *Lornia* Marw.

LAST APPEARANCE OF :—

(M) **Spineilo* F. and M., **Cucullastis* F. and M., **Lahilleona* Marw., **Proscala* Cossm., **Bittiscala* F. and M., **Conchothyra* Hutt., **Struthioptera* F. and M.

No micro-fauna is present at the type locality, but in the probably equivalent Katiki-Moeraki Series *Ammobaculites* Cush., *Ammomarginulina* Wiesner, and *Karreriella aegra* are common, *Pseudoclavulina* cf. *anglica* Cush. is last seen, and *Textularia* cf. *eocenica* Gümbel and *Bolivinopsis* aff. *rosula* (Ehren.) first appear.

Bortonian.

Type Locality:—Black Point, Borton's, Waitaki Valley (Allan, 1933, p. 87). The actual type locality is so unsatisfactory that Allan has suggested that a palaeontological basis be given to the Bortonian by the well-preserved molluscs from Waihao Downs. Since a better sequence of beds and much richer micro-faunas (in addition to numerous molluscs) are available at Hampden, this may be regarded at present (in preference to the Lower Waihao suggested by Allan) as the standard section for correlation until the Borton's–Ngapara area is closely examined.

Sediments:—Glauconitic sandstone 50± ft. thick, poorly exposed over a small area, overlying quartz conglomerates (coal measures) that rest on semi-schist. At Hampden, glauconitic mudstones and greensand rest on the Moeraki black mudstones, and are overlain conformably by a less glauconitic bed with a Tahuian micro-fauna. The lower part of the Moeraki Series (Brown, 1938) is of approximately Wangaloan age, but the upper part, separated by a greensand band, has a definite Eocene microfauna, and is here temporarily included with the Bortonian as Lower Bortonian.

Fauna:—Badly preserved molluscs, but the index genera *Monalaria, Notoplejona,* and *Fascioplex* present.

Correlatives:—South Otago (Castle Hill shaft; see Finlay and Marwick, 1937, p. 95); North Otago (glauconitic sandstone covering many square miles in Ngapara district); South Canterbury (Waihao Valley, Raincliff district, Kakahu, Ashburton River); Westland ("Island Sandstone" of Ten Mile Bluff near Greymouth). At all these localities the beds have definitive molluscan faunas and rest on coal measures overlying old rocks. In North Canterbury, Hawke's Bay, Poverty Bay and North Auckland, argillaceous and calcareous beds, in places glauconitic or sandy at the base, contain rich foram faunas but no molluscs. In Canterbury they rest on marine Upper Cretaceous beds without noticeable angular unconformity, but with a sharp sedimentary change or phosphatic zone. The connection between the former set of localities and the latter is supplied at Hampden, North Otago (mudstones, glauconitic at base) and Pahi, North Auckland (greensands and conglomerate) where the Bortonian has rich mollusc and foram faunas and (at Hampden) rests on Upper Cretaceous to Paleocene mudstones. In Hawke's Bay, the Wanstead series (Ongley, 1936) is at its type locality entirely Upper Bortonian, though Lower Bortonian is known nearby. In Poverty Bay both divisions are present.

At Hampden, all the macro-fossils have come from a small part of the coastal section between Kakaho Creek and a greensand some 25 chains south, *i.e.* from only the lower part of Brown's Hampden Series. The micro-faunas, however, show that a considerable extent of the section north of Kakaho Creek must be included with this as Bortonian; all this is termed here the Upper Bortonian. Though a distinctive fauna occurs below this in the upper part of the Moeraki Beds, it is so intimately connected with the Bortonian as a whole that it is included here in that stage and referred to as Lower Bortonian. Radiolaria are frequently abundant in this stage, especially in the Lower Bortonian.

(a) Key fauna of Lower Bortonian.

RESTRICTED FORMS:—

(F) *Hormosina* cf. *globulifera* Brady, *Cyclammina grangei*, **Vulvulina* cf. *advena* Cush., *Eggerella decepta*, *Gaudryina reliqua*, **Marginulinopsis marshalli* and *waiparaensis*, **Sigmoidella bortonica*, **Buliminella browni*, **Elphidium hampdenensis*, **Globorotalia crater*. *G. reliqua* and *M. waiparaensis* are diagnostic of the Lowest Bortonian zone.

FIRST APPEARANCE OF:—

(Ostracoda.) An assemblage different from that in the Piripauan appears, and lasts with little apparent specific change (but occasional additions) to the Awamoan or later.

(F) **Karreriella* Cush. (as *novozealandica* Cush.), **Marginulinopsis* Silv., *Lagenoglandulina* Silv., **Sigmoidella* C. and O., *Sigmomorphina* C. and O., *Zeauvigerina*, *Aragonia* (as *zelandica*), **Rectobolivina* Cush. (as *bortonica*), **Hopkinsina* H. and W. (as *wanzea*), **Angulogerina* Cush. (as *australis* H.-A. and E.), **Trifarina* Cush. (as *bradyi* Cush.), *Cassidulina* d'Orb. (as *subglobosa* Brady), **Nonion* Mont. (as *maoricum* Stache), *Notorotalia* (as tiny species).

**Bolivinopsis cubensis* (C. and B.), *Textularia zeaggluta*, *Karrerulina bortonica*, **Pseudogaudryina proreussi*, *Clavulinoides instar*, **Dorothia agrestis*, *Marssonella* cf. *indentata* (C. and J.), **Sigmoilina tenuis* (Czjzek), **Vaginulina* cf. *elegans* Cush., *Zeauvigerina parri*, **Bulimina truncanella* and *pahiensis*, **Cerobertina kakahoica*, *Ellipsoglandulina subconica* (Kreuz.), **Ellipsonodosaria globulifera* (Kreuz.) (of *verneuili* line), **Nonion iota*, **Nonionella zenitens*, *Notorotalia* aff. *alabamensis* (C. and McG.), **Pulvinulinella* *tenuimarginata* C., P., and C., *Anomalina visenda* and **eosuturalis*, **Cibicides parki* (rare and small till Upper Bortonian), *tholus*, and **collinsi*, **Discorbis appositus*, **Globorotalia collactea.*

LAST APPEARANCE OF:—

(F) *Karrerulina aegra, Allomorphina trochoides* (Reuss).

(b) Key fauna of Upper Bortonian.

RESTRICTED FORMS:—

(M) **Crassatellites* Krug. (s. str.), **Monalaria* Marw. (1924B, p. 173), *Paryphostoma* Bayan, **Fascioplex* Marw. (1934, p. 15), *Priscoficus* Con. (see Fin. and Marw., 1937, p. 75), **Notoplejona* Marw. (1926C, p. 270), *Marwickara* Laws (1935, p. 28), *Speightia* Fin. (1926B, p. 25).

**Glycimerita subglobosa* (Sut.), *Lopha gudexi* (Sut.), *Duplipecten waihaoensis* (Sut.), *Venericardia acanthodes* Sut., **Dosinia mackayi* Marw., **Carinacca allani* (Marw.), *Spirocolpus rudis* (Marsh.), *Mathilda prima* Laws, *Galeodea modesta* (Sut.), *Dicroloma zelandica* Marsh., *Waimatea amplexa* Fin., *Waihaoia thomsoni* Marw., *Mauia biconica* (Sut.) and *curvispina* Marw., *Marshallena serotina* (Sut.), *Insolentia sertula* (Sut.), *Zemacies torticostata* (Marsh.), "*Hemifusus*" *goniodes* Sut.

(F) *Assilina* d'Orb., *Discocyclina* Gümbel, *Asterocyclina* Gümbel, *Plectina* Marss. (as *quennelli* and *agrestior*).

Vulvulina cf. *colei* Cush., *Siphotextularia acutangula, Palmula marshalli, Lagena* n.sp. aff. *orbignyana* Seg. (with pustuled centre), *Zeauvigerina zelandica, Siphogenerina prisca, Elphidium saginatum, Nuttallides subtrümpyi* (large specimens), *Discorbis jugosus.*

FIRST APPEARANCE OF:—

(M) *Lentipecten* Marw., *Serripecten* Marw., *Pleuromeris* Say., *Spissatella* Fin., *Senectidens* Ired., *Gari* Schum., **Notocorbula* Ired., **Marama* Marw., *Hina* Marw., **Offadesma* Ired., *? Risellopsis* Kest., **Carinacca* Marw., *Magnatica* Marw., *Friginatica* Hed., *Taniella* F. and M., **Spirocolpus* Fin., *Zeacolpus* Fin., *Austrosassia* Fin., *Galeodea* Link, **Euspinacassis* Fin., **Ficus* Roed., *Niso* Risso, *Tioria* Marw., *Falsicolus* Fin., *Austrofusus* Kob., *Poirieria* Jouss., *Waimatea* Fin., *Waihaoia* Marw., *Mauia* Marw., **Baryspira* Fischer, *Marginella* Gray, *Anapepta* Fin., *Bonellitia* Coss., *Zemacies* Fin., *Marshallena* Fin., *Borsonia* Bell, *Zeacuminia* Fin., *Gemmula* Weink., *Superstes* F. and M.

(M: Cephalopoda) *Aturia* Bronn.

(F) *Frankeina* C. and A. as large forms, *Arenodosaria* (as *antipoda* Stache), *Spiroloculina* d'Orb. (as n.sp.) *Plectofrondicularia* of *vaughani* Cush. line (as *whaingaroica* Stache), *Astrononion* C. and E. (as n.sp.), *Cancris* Mont. (as *compressus*), *Laticarinina* G. and W. (as *halophora* Stache), *Epistomina* Terq. (as cf. *elegans* d'Orb.), *Hantkenina* Cush. (as *australis*), *Globigerinoides* Cush. (as *index*).

Ammodiscus archimedis (Stache), *Vulvulina pennatula* (Batsch), *Listerella levis, Marginulinopsis hochstetteri* (Stache) and *spinulosa* (Stache), *Palmula bivium, Citharinella tenuissima* (Hantken), *Hopkinsina bortotara, Bulimina forticosta, Rotaliatina sulcigera* (Stache), *Gyroidina scrobiculata, Anomalina semiteres.*

The following have their earliest occurrence in the Eyre River *Asterocyclina* bed (see Speight, 1928, pp. 413–419), which seems to form the base of the Upper Bortonian, but whose faunal facies is very different from that of any other Bortonian locality, and more like that of the Waiarekan zone of the Kaiatan:—*Verneuilina* d'Orb. (as aff. *novozealandica* Cush.), *Asterigerina* d'Orb. (as n.sp.), *Eponides concentricus* (P. and J.), *Calcarina* d'Orb. (as aff. *mackayi* Karrer), *Discorbis* of *pulvinatus* (Brady) line, *Heronallenia* C. and P. (as *wilsoni* H.-A. and E.), *Vagocibicides* (as primitive n.sp.), *Planorbulina* d'Orb. (as n.sp.).

LAST APPEARANCE OF:—

(M) *Electroma* Stol., *Perissoptera* Tate, *Pseudofax* F. and M.

(F) *Recurvoides* Earl., *Glomospira* Rzehak (as *corona* C. and J.), *Zeauvigerina, Aragonia* (as *zelandica*), *Nuttallides* (as *subtrümpyi*), *Quadrimorphina* (in any abundance, *allomorphinoides* very rare in Kaiatan).

Ammodiscus glabratus C. and J., *Trochamminoides irregularis* White, *Bolivinopsis spectabilis* (Gryzb.) and aff. *rosula* (Ehrenb.), *Textularia* cf. *eocenica* Gümbel, *Pseudogaudryina proreussi, Dorothia agrestis, Zeauvigerina parri, Rectobolivina bortonica, Hopkinsina wanzea, Bulimina quadrata* Plummer, *bortonica,* and *pahiensis, Anomalina visenda, Notorotalia* aff. *alabamensis* C. and McG., *Cibicides tholus, Globorotalia collactea.*

Tahuian.

Type Locality:—McCullough's Bridge, Waihao River, South Canterbury (Allan, 1933, p. 93).

Sediments:—Greensand, 50 ft. thick, outcropping over only a few square chains; rests conformably on Upper Bortonian (by micro-fauna) but is separated by a phosphatic zone. Overlain apparently conformably by glauconitic marl with Duntroonian micro-fauna.

Fauna:—Molluscs rich (see Allan, 1926, p. 291); forams well preserved but uncommon and difficult to extract. Dr. C. O. Hutton, of the Geological Survey, has recently successfully removed the glauconite from such samples with an electromagnet.

Correlatives:—Several Tahuian molluscs in an old collection of T. Esdaile were labelled as from Waiareka Valley, North Otago (see Marwick, 1926A), but the locality has not been confirmed, and the specimens were probably from McCullough's Bridge. No other Tahuian locality has been recognised by means of molluscs. Forams indicate correlation with highest bed of Hampden mudstone, the "Burnside Marl" (very rich), and a Mid-Waipara zone below Amuri Chalk Marls.

RESTRICTED FORMS:—

(M) **Neverita* Risso, **Cordieria* Rouault.

**Limopsis waihaoensis* Allan, **Carinacca waihaoensis* (Sut.), **Eulima waihaoensis* Allan, **Waimatea inconspicua* (Hutt.), **Waihaoia allani* Marw., **Conospirus tahuensis* (Allan), **Marshallena formosa* (Allan), **Gemmula bimarginata* (Sut.), **G. complicata* (Sut.), **G. duplex* (Sut.), **Parasyrinx finlayi* (Allan), **Cordieria rudis* (Hutt.), **Zeacuminia sulcata* (Hutt.).

(F) *Palmula bensoni.* This is very rare, and at present no other limited species is known, the chief distinction of the stage being the absence of important forms of underlying and overlying horizons (e.g., *Pseudogaudryina proreussi, Gümbelina ototara, Zeauvigerina, Bolivina anastomosa, Bulimina bortonica, Nonion* of *pompilioides* line, *Nuttallides, Cibicides pseudoconvexus*).

First Appearance of:—

(M) *Callolima* Bartsch, **Tanea* Marw., **Spelaenacca* Fin., **Eulima* Risso, **Coluzea* Fin., **Proximitra* Fin., **Parvimitra* Fin., **Conospirus* de Greg., **Parasyrinx* Fin.

(B) **Aetheia gualteri* (Morris).

(F) **Pseudogaudryina reussi* (Stache), **Arenodosaria robusta* (Stache), *Plectofrondicularia whaingaroica* (Stache) striate form, **Bulimina pupula* Stache, *Eponides umbonatus* (Reuss).

Last Appearance of:—

(M) **Carinacca* Marw.

(F) **Palmula bivium*, **Globorotalia* cf. *dehiscens* C., P., and C.

Kaiatan.

Type Locality:—Kaiata district, Greymouth Subdivision, North Westland (Finlay, 1939A, p. 531; Allan, 1933, p. 91).

Sediments:—Mudstone, 2000–3000 ft. thick, outcropping over many square miles in Westland, resting apparently conformably on the Island Sandstone of Bortonian age (see Henderson, 1929, p. 284). The Tahuian has not beeen recognised there, and seems absent, the lowest Kaiata Mudstone being apparently still Ototaran in the wide sense. The Kaiatan is overlain conformably by the upper Point Elizabeth beds, of Whaingaroan age.

Fauna:—Molluscs extremely rare (a small **Spirocolpus* is the only one of note); forams everywhere abundant.

Correlatives:—(By forams) the Lower Ototaran of Oamaru district (limestone with brachiopods, diatoms, sponge spicules locally abundant), basal tuffaceous part of same, and tuffs of Lorne (type of Waiarekan zone, with distinctive molluscs), covering many square miles in North Otago; Omotumotu beds and lower Point Elizabeth beds in the type area. In North Island known only in Elsthorp district of Hawke's Bay, but probably fragments elsewhere.

The molluscan fauna is taken almost entirely from the Waiarekan zone (see Marwick, 1926A, p. 307), all other facies of the Lower Ototaran being poor in macro-fossils.

The micro-faunas plainly indicate a definite two-fold division of the Ototaran, with a few possible zones of lesser importance. The molluscs have not shown this before simply because they are generally so rare and poorly preserved in this period. The three or four-fold division on brachiopod faunules suggested by Thomson (1926A, p. 152) and Allan (1933, p. 92) is not confirmed by the Foraminifera, and is in any case impracticable outside the Oamaru coastal area, for the assemblages occur hardly anywhere else separately and nowhere else in sequence. They cannot, for example, be applied to divide and correlate the great thickness of Ototaran *s.l.* in Westland (though the various micro-faunas from here exactly correspond with those of the Oamaru formations), thus indicating once again the uncertainty of isolated brachiopod faunules for long-distance correlation.

RESTRICTED FORMS:—

(M) *Danilia* Brus. (as *neozelanica* Laws), *Agathirses* Mont. (as *senex* Marw.).

Fossularca januaria Marw., *Chlamys venosus* (Hutt.), *Serripecten enfieldensis* (Marw.), *Spissatella media* (Marw.), *Venericardia benhami.* Thomson, *Argalista proimpervia* Laws, *Incilaster marshalli* (Thomson), *Spirocolpus tophinus* (Marw.), *Semitriton revolutum* (Fin.), *Erato vulcania* Marw.

(B) *Liothyrella pulchra* Th., *Stethothyris uttleyi* Th., *Terebratella totarensis* Th.

(F) Probably **Halkyardia* H.-A. and E. (as *bartrumi* Parr, 1934, p. 144; and undescribed species), and probably *Operculina* d'Orb. (as *kawakawaensis* Chap. and Parr).

Bolivina pontis, Siphogenerina postprandia, **Robertina lornensis,* **Eponides lornensis,* **Asterigerina waiareka* and *lornensis,* **Cibicides pseudoconvexus* Parr (common, very rare in Whaingaroan).

FIRST APPEARANCE OF:—

(M) *Grandaxinea* Ired., *Trichomusculus* Ired., *Pedalion* Huddesf., *Ascitellina* Marw., *Nemocardium* Meek (large forms), *Emarginula* Lamk., *Semitriton* Cossm., *Mayena* Ired.

(B) *Liothyrella* Th. (as *boehmi* Th., *oamarutica* Boehm, and *pulchra* Th.), *Stethothyris* Th. (as *uttleyi* Th., and *tapirina* Hutt.).

Terebratulina suessi (Hutt.).

(F) *Wiesnerella* Cush. (as n.sp.), **Polymorphina* d'Orb. *s.str.* (as n.sp.), **Reussella* Gal. (as n.sp.), **Angulogerina* of the *rugoplicata* Cush. line (except for one record in Upper Bortonian), **Parvicarinina* (as *altocamerata* H.-A. and E.), **Carpenteria* Gray (as *rotaliformis* Chap. and Cresp. and other species).

**Textularia cuspis,* **Siphotextularia heterostoma* (Forn.), *Gaudryina minuscula,* **Marginulinopsis asprocostulata* (Stache), **Gümbelina ototara,* **Bolivina anastomosa,* **Buliminella* of *elegans* d'Orb. line, **Patellina corrugata* Will., **Nonion* of *pompilioides* F. and M. line, **Astrononion* cf. *australe* C. and E., **Notorotalia* large species, **Cibicides perforatus* (Karrer) and *verrucosus.*

LAST APPEARANCE OF:—

(M) None known as yet.

(F) **Asterigerina* d'Orb. (as large forms; several species; a rare and tiny undescribed species in Duntroonian and Lower Hutchinsonian), **Hantkenina* Cush. (as *australis*), **Globigerinoides* Cush. (as *index*; genus re-enters in Pliocene).

**Listerella levis,* **Karrerulina bortonica,* **Plectofrondicularia whaingaroica* (Stache) striate form, **Hopkinsina bortotara* (rare specimens in Whaingaroan), **Nonion iota,* **Gyroidina scrobiculata,* **Anomalina semiteres,* **Cibicides parki,* **Globigerina linaperta.*

Whaingaroan.

Type Locality:—Whaingaroa Harbour, Huntly-Kawhia Subdivision (Whaingaroa Beds of Henderson and Grange, 1926, p. 46).

Sediments:—Calcareous mudstone, 100 + ft. thick; rests on coal measures, and these on old basement rocks. Overlain, apparently conformably, by Te Kuiti limestone, of Waitakian age.

Fauna:—Molluscs insignificant; forams abundant.

Correlatives:—(By forams entirely.) Many square miles of calcareous claystone in Huntly-Kawhia Subdivision and southward into Te Kuiti Subdivision, forming the basal marine Tertiary and marking a wide transgression. Scattered areas in Poverty Bay of more or less glauconitic sandy marl. Light coloured, fine to sandy marls, Hawke's Bay, Weber Series (Ongley, 1935). Upper Ototaran of North Otago, North Canterbury, and Westland, mostly more highly calcareous facies (Kakanui, Oxford, Upper Amuri, and Cobden limestones, etc.), generally resting conformably on Kaiatan beds or intervening tuffs.

This stage more than any other depends on Foraminifera for its palaeontological basis; the Kaiatan mostly does also, but has a zone with a molluscan fauna. Brachiopods are locally abundant in the North Otago correlatives of these stages, but are so discontinuous and sensitive to environment that their practical use in correlation is limited. Too little is known of their ranges in most cases,† and though many are useful in the Oamaru district, the possibility that they are largely paleic indicators must not be overlooked. In thus stating our views we are not disparaging the usefulness of brachiopods; any organism that gives any clue to the age of strata must be considered, and this phylum can be of great local use (perhaps of even zonal value in the Hutchinsonian). But it has obvious limitations in the gregarious nature and sporadic occurrence of its members (see Thomson, 1926A, p. 151) and experience has shown that for correlation throughout the Tertiary much greater reliance has to be placed on the Mollusca and Foraminifera. The absence of particular brachiopod faunules furnishes only "negative evidence," and should be used very cautiously in correlation and in postulating sequential gaps.

RESTRICTED FORMS:—

(M) **Janupecten polemicus* Marw. and *uttleyi* Marw.

(B) *Tegulorhynchia sublaevis* Th. and *squamosa* (Hutt.), *Liothyrella gravida* (Suess), *concentrica* (Hutt.), and *kakanuiensis* (Hutt.), *Terebratella radiata* Hutt., *Terebratulina oamarutica* Boehm, *Lingula waikatoensis* Pens.

(F) **Sigmoilina* cf. *edwardsi* Schl., **Lagena* n.sp. aff. *orbignyana* Seg. (with vertically ribbed centre), **Polymorphina lingulata* Stache, **Uvigerina maynei* Chap., **Notorotalia stachei*, **Globigerina angipora* Stache.

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† Compare Allan's surprise (1937, p. 150) at the extension of the range of his *Rhizothyris labiata*, a distinctive post-Hutchinsonian species at Clifden, but Hutchinsonian elsewhere in Southland.

FIRST APPEARANCE OF :—

(M) *Janupecten* Marw., *Crenostrea* Marw., *Atamarcia* Marw.

(B) *Neobouchardia* Th. (as *minima* Th.), *Tegulorhynchia depressa* Th.

(F) **Technitella* Norman (common; very rare in Tahuian), **Flabellamina* Cush. as large forms, **Semivulvulina* (as *capitata* Stache), **Bigenerina* d'Orb. (as n.sp.), **Haeuslerella* Parr (as *textilariformis* Stache), **Lingulina* d'Orb. as large forms of *costata* d'Orb. line, **Plectofrondicularia* Liebus s.str. (as *parri*; extremely rare till Hutchinsonian), **Bolivinella* Cush., **Cassidulinoides* Cush., **Pseudononion* Asano, **Siphonina* Reuss, **Amphistegina* d'Orb. (extremely rare in Kaiatan), **Chilostomelloides* Cush.

**Dorothia minima* (Karrer), *Listerella weymouthi*, **Verneuilina novozealandica* Cush. (= *browni* Fin.), **Gaudryina* cf. *quadrangularis* Bagg, *Liebusella bradyi* (Cush.), **Robulus haasti* (Stache), **loculosus* (Stache), **vortex* (F. and M.), and **dicampylus* (Franz.), **Marginulina* of *costata* Batsch line, **Vaginulina* of *legumen* line (as *cristellata* (Stache), **Lagenonodosaria* of *scalaris* (Batsch) and **hirsuta* (d'Orb.) lines, **Palmula taranakia*, **Bolivina lapsus* (not common till Hutchinsonian), **Siphogenerina striatissima* (Stache), *Bulimina* cf. *spiniscens* Brady and *scobinata*, *Cassidulina* cf. *oblonga* Reuss, **Elphidium ornatissimum* (Karrer), **Gyroidina zelandica*, *Planulina* aff. *wuellerstorfi* (Schw.), **Anomalina vitrinoda*, **Cibicides thiara* (Stache), **Globorotalia* of *scitula* Brady line.

LAST APPEARANCE OF :—

(M) None known as yet.

(B) *Liothyrella oamarutica* (Boehm).

(F) **Citharinella* Marie (as *tenuissima* Hantk.), **Gümbelina* Egger (as *ototara*), **Rotaliatina* Cush. (as *sulcigera* Stache).

**Textularia zeaggluta* and **cuspis*, **Karreriella novozealandica* Cush., **Pseudogaudryina reussi* (Stache), **Spiroloculina* n.sp. of Bortonian, **Marginulinopsis hochstetteri* (Stache), **asprocostulata* (Stache), and **spinulosa* (Stache), *Bulimina forticosta*, **Cerobertina kakahoica*, **Cancris compressus*, **Anomalina eosuturalis* and *eoglabra*, *Discorbis* of *pulvinatus* (Brady) line and **appositus*, *Cibicides collinsi*.

Duntroonian.

Type Locality:—North (or left) branch of Landon Creek, North Otago (Allan, 1938, p. 89).

Sediments:—Glauconitic sandstone, 4 ft. thick, resting conformably on Whaingaroan limestone. Overlain by unfossiliferous nodular limestone apparently similar to the basal Hutchinsonian conglomerate, followed by sandstone with Lower Hutchinsonian brachiopods (*Pachymagas hectori* Th., etc.).

Fauna:—Brachiopods abundant (see Thomson, 1926A, pp. 152–154); forams a few.

Correlatives:—(By brachiopods.) Lower part of Duntroon and Ngapara limestones (glauconitic), and the Waihao, Cave, Otaio, and Weka Pass limestones and Stavely greensand of Canterbury. Forams in these locally abundant, enabling correlation with Chatton sands (Southland) and upper Wharekuri greensands (North Otago) (both with molluscs abundant), and with Te Kuiti Limestone (lower part at least) of North Island.

RESTRICTED FORMS:—

(M) *Trigonostoma* Blainv.

Neilo sinangula Fin., *Glycimerita thomsoni* (Marw.), *Chlamys compitum* (Marw.), *Spissatella subobesa* (M. and M.), *Pyrazus sutherlandi* Marw.

(B) **Liothyrella landonensis* Th., *"*Waiparia*" *elliptica* (Th.), *Murravia catinuliformis* (Tate), **Rhizothyris* undescribed dwarf spp.

(F) *Pseudogaudryina anachrons, Lingulina semilineata* Chap., *Elongobula chattonensis* and *lawsi, Nonion* aff. *chapapotensis* Cole.

FIRST APPEARANCE OF:—

(M) *Veletuceta* Ired., *Gigantostrea* Sacco, *Athlopecten* Marw., *Lima* Brug. (*s.str.*), *Cyclocardia* Con., *Notomyrtea* Ired., *Gonimyrtea* Marw., *Finlayella* Laws, *Raina* Marw., *Fossacallista* Marw., *Bassina* J.-B., *Eumarcia* Ired., *Myadora* Gray (as small forms), *Salaputium* Ired., *Solecurtus* Blainv., *Zeminolia* Fin., *Neojanacus* Sut. (Laws, 1935, p. 33), *Sinum* Roed., *Maoricolpus* Fin., *Notacirsa* Fin., *Struthiolaria* Gray, *Pyrazus* Mont., *Zefallacia* Fin., *Pareora* Marw., *Trichosirius* Fin., *Xymenella* Fin., *Typhis* Mont., *Clifdenia* Laws, *Procominula* Fin., *Cominista* Fin., *Baryspira* Fisch. (with heavy callus), *Alcithoe* Sw., *Spinomelon* Marw., *Metamelon* Marw., *Teremelon* Marw., *Austrotoma* Fin., *Comitas* Fin., *Scaphander* Mont., *Ringicula* Desh.

"*Cardium*" of *spatiosum* Hutt. line, *Polinices huttoni* (v. Iher.), *Globisinum crassiliratum* Fin.

(B) *Pachymagas* Th. (as *huttoni* line), **Rhizothyris* Th. (as dwarf species; see Thomson, 1926A, p. 149), **Tegulorhynchia masoni* Allan.

(F) *Polymorphina* d'Orb. very elongate species, *Pseudopolymorphina* C. and O. (both smooth and striate species), *Ceratobulimina* Toula (as *kellumi*).

Matanzia mahoenuia, Karreriella cushmani, Sigmoilina of the arenaceous type (as sp. aff. *celata* Costa), *Lenticulina mamilligera* (Karr.), *Marginulina allani, Cassidulina pacifica* Cush., *Ellipsonodosaria verneuili* (d'Orb.), *Pseudononion stachei* (Cush.), *Astrononion* of *novozealandicum* C. and E. line, *Nonionella magnalingua, Cancris lateralis, Notorotalia serrata, tenuissima* (Karr.), and large forms of *spinosa* (Chap.) line, *Eponides* cf. *broeckhianus* (Karr.), *Gyroidina allani, Anomalina miosuturalis, subnonionoides, pinguiglabra,* and *macraglabra, Cibicides novozelandicus* (Karr.), *catillus,* and *ihungia, Discorbis turgidus, Globorotalia dehiscens* C., P., and C., *Globigerina bulloides* d'Orb. (typical).

LAST APPEARANCE OF:—

(M) *Janupecten* Marw., *Niso* Risso.

(B) **Stethothyris tapirina* (Hutt.), **Tegulorhynchia depressa* Th.

(F) *Pseudogaudryina* of *reussi* line (as *anachrons*), *Marginulinopsis* of *hochstetteri* (Stache) line (as n.spp.), *Vaginulina cristellata* (Stache), *Siphogenerina striatissima* (Stache), *Cibicides thiara* (Stache).

Waitakian.

Type Locality:—Waitaki limestone and Otiake beds, Waitaki Valley, North Otago (Allan, 1933, p. 97; Park, 1918, pp. 25, 83).

Sediments:—Arenaceous limestone, 150 + ft. thick, resting on greensands (with Duntroonian micro-fauna, but without the characteristic brachiopods, which are abundant in greensands in the same valley not far away). Overlain by river gravels.

Fauna:—Molluscs abundant (generically like those of Wharekuri and Awamoa, but specifically mostly different from either); brachiopods mainly of *Pachymagas huttoni* line, but also grading to *parki* types; forams abundant, but of few species and indicating an uncommon facies.

Correlatives:—(By molluscs and lithology.) A similar limestone across Waitaki River in South Canterbury, and also at Wharekuri, North Otago. Probably calcareous sandy mudstones in Waipawa area, Hawke's Bay, and Huntly-Kawhia area.

RESTRICTED FORMS:—

(M) **Fossacallista watti* Marw., **Dosinula uttleyi* Marw., **Waimatea transilis* Fin., *"*Turris*" *uttleyi* Sut.; many new species as yet unnamed.

(B) **Pachymagas huttoni* Th. typical (with allied species verging towards *parki* series).

(F) ? **Guttulina yabei* C. and O., ? **Pseudopolymorphina doanei* (G. and W.), *Uvigerina dorreeni*. These and other forms common in Waitakian may extend down to Duntroonian; even the slight differences recorded here in the faunas may be due, not to time, but to the distinct facies involved, the Duntroonian being mostly much more glauconitic and coarser in sediment. Allan (1938) mentions several lithologies, however, and it will be necessary to collect micro-faunas from each of these for comparison, also systematic collections throughout the type Waitakian.

FIRST APPEARANCE OF:—

(M) **Divaricella* v. Mart., **Uberella* Fin., **Proterato* Schild. (*s.str.*), **Eucominia* Fin., **Neocola* Fin., **Inglisella* Fin., **Rugobela* Fin., **Cryptomella* Fin., **Pervicacia* Ired.

(B) **Pachymagas* approaching *parki* series (similar types).

(F) **Semivulvulina waitakia, Plectofrondicularia awamoana* (rare till Awamoan), *Uvigerina* of *canariensis* d'Orb. line, *Siphogenerina ongleyi, Bulimina miolaevis, Cassidulina cuneata, Cibicides mediocris*.

LAST APPEARANCE OF:—

(M) **Athlopecten* Marw., **Spirocolpus* Fin.

(B) **Pachymagas* of the *huttoni* Th. series.

(F) **Polymorphina* d'Orb.

**Haeuslerella textilariformis* (Stache), *Bulimina scobinata*, **Gyroidina allani* (possibly in Lower Hutchinsonian), *Cibicides verrucosus*, *Marginulina allani.*

Hutchinsonian.

Type Locality:—Hutchinson's quarry, Oamaru (see Allan, 1933, p. 88).

Sediments:—Greensands, 20 ft. thick, with basal conglomerate; unconformably overlying current-bedded tuffs, limestone, and glauconite, which in turn rest on more tuffaceous sediments. Overlain by calcareous glauconitic sandstone with an Awamoan mollusc fauna.

Fauna:—Brachiopods very abundant, advanced types of *Pachymagas* and *Rhizothyris*; molluscs practically absent; forams fairly abundant, good faunas obtained from several of the lithologies present at the type locality.

Correlatives:—(By brachiopods.) Southland limestone at Clifden and other localities); North Canterbury (Main Mt. Brown limestone of Weka Pass). No other localities with the true Hutchinsonian brachiopod fauna are yet known (except possibly in the Trelissick Basin).

Thomson (1926A, pp. 149–151) and others have classed here the *Pachymagas* greensands in North Otago district, resting with basal conglomerate on eroded phosphatised surface of Kakanui limestone (Whaingaroan), but these contain (e.g., at All Day Bay, Deborah, Devil's Bridge, Rifle Butts, Landon Creek, and Mt. Somers district) less advanced brachiopods, and were considered by Finlay (1939A, p. 530) to represent an older horizon, which is here termed Lower Hutchinsonian. At All Day Bay this horizon, with abundant *Pachymagas marshalli,* etc., and a basal phosphatic zone containing *Isis* and *Mopsea,* rests on eroded Kakanui limestone; it is overlain by a sandstone zone with *Waiparia* (but no *Pachymagas*), and this in turn by argillaceous sandstones with Awamoan macro- and microfauna.

Thomson (*l.c.*) has argued that "the contemporaneous existence of species in different stages of evolution is known, and brachiopods are known to be local in their distribution, so that until the two faunules are found in some locality in sequence it is unsafe to conclude that they are not of the same age." The species of *Pachymagas* and *Rhizothyris* erected by Thomson are so very similar *inter se* and so variable in shape that the actual species present in these various greensands appear to be much less important than the state of evolution of the genus as a whole; simple types certainly accompany the advanced *parki* and *rhizoida* in the true Hutchinsonian (as is to be expected), but the really important point is that *only* the simple types exist in the Lower Hutchinsonian, the later division being marked by the *advent* of the advanced types. As regards the sequence of the faunas, we believe that *Waiparia* s.str. is always an age equivalent of the advanced *Pachymagas* and *Rhizothyris,* and either exists with or entirely replaces them; if this is correct, the All Day Bay strata provide the sequence Thomson required.

In the typical fauna at Mt. Brown occur *Magadina* and the restricted *Waiparia intermedia-abnormis;* the latter species-group is here used to correlate with this the *Waiparia* zone at All Day Bay, the *Waiparia*-bearing Caversham sandstone of Dunedin district (Thomson, 1918, p. 197), and the Middle Ihungia brachiopod horizon of Poverty Bay (again with *Waiparia* abundant, but no *Pachymagas*). From the three last-named, good foram faunas have been obtained, but the molluscan fauna comes chiefly from the beds above the limestone at Clifden, the Pakaurangi Point beds, the Mahoenui and Ihungia mudstones (deeper water), and the Waitemata Oneroa beds (shallow water, with *Magadina*) (Powell and Bartrum, 1929, p. 395). Forams also allow correlation with the Lower " Blue Bottom " of Marsden and other localities in Westland, where there are no molluscs or brachiopods.

Although the molluscan beds at Clifden lie above the *parki* limestone, faunal comparisons between them (up to as far as the "*Stethothyris* zone "), and the Middle and Upper Ihungia and Pakaurangi Point beds indicate that they still fall within the Hutchinsonian. When the Tertiary as a whole is considered, a separate division of stage value does not appear to us to be warranted for these beds. Finlay (1939A, p. 530) mentioned that a small new stage might be needed here, but much additional information from micro-faunas, accumulated since, negatives the idea. Allan (1940, p. 289) has again suggested that this horizon merits a stage name, but no definite correlation can be made with it elsewhere, and it would have to be postulated as missing or unrecognisable in all other, apparently normal, sections. Such theoretical " stages," based on rather thin deposits in the South Island, do not merit serious consideration unless they can be usefully employed in connection with much thicker and more continuous beds in the North Island.

For a number of cogent reasons, no new stage name is here proposed for Lower Hutchinsonian as distinct from the True Hutchinsonian, but for convenience the faunal analyses are presented separately. The term " True " is used rather than " Upper " Hutchinsonian to avoid confusion with Park's usage of the latter.

(a) Key fauna of Lower Hutchinsonian.

RESTRICTED FORMS:—

(M) None known as yet, the molluscs of this horizon being either very poorly preserved or but little collected.

(B) *Pachymagas haasti* Th., *marshalli* Th. (and similar large forms with primitive folding and cardinalia), *Rhizothyris* simple species (rare till true Hutchinsonian).

Tegulorhynchia antipoda Th. and aff. *coelospina* C. and C., *Campages neozelanica* Allan.

(Corals) *Isis dactyla* T.-W., *Mopsea hamiltoni* Th. (*Isis* has been found in the basal Ihungia—see Marwick, 1931B, p. 38.)

(F) *Haeuslerella hectori, Victoriella* aff. *plecte* (Chap.).

FIRST APPEARANCE OF:—

(M) None known as yet.

(B) *Pachymagas hectori* Th. (as large forms; smaller ones in Waitakian and Duntroonian), *Rhizothyris curiosa* Th. (and other simple species), *Terebratella* aff. *sanguinea* Leach.

(F) *Ehrenbergina* d'Orb. (as *marwicki*), *Büningia* (as *creeki*), *Vagocibicides* typical (as *maoria*).

Siphotextularia awamoana (not common till Awamoan) and *kreuzbergi, Spiroloculina rotundata* Kreuz., *Varginulina legumen* L., *Lingulina avellanoides* (Kreuz.), *Plectofrondicularia parri* (in abundance), *Bolivina* cf. *pusilla* Schw. and *lapsus* (large and abundant), *Rectobolivina maoriella, Uvigerina miozea, Siphogenerina rerensis* and *vesca, Cassidulina* cf. *carinata* Cush., *Amphistegina lessoni* d'Orb. typical and abundant, *Anomalina parvumbilia, Planulina* cf. *sinuosa* Side. (extremely rare in Kaiatan), *Globorotalia miozea.*

Last Appearance of:—

(M) *Pleurotomaria* Defr., *Semitriton* Cossm., *Superstes* F. and M.

(B) *Liothyrella boehmi* Th., *Tegulorhynchia masoni* Allan.

(F) *Marginulinopsis* Silv. (as n.sp.), *Arenodosaria robusta* (Stache), *Notorotalia serrata, Discorbis turgidus.*

(b) Key fauna of True Hutchinsonian.

Restricted Forms:—

(M) *Spondylus* L., *Bembicium* Phil., *Paracominia* P. and B., *Coralliophila* H. and A. Ad., *Oniscidia* Sw., *Lyria* Gray, *Atys* Mont.

Grandaxinea finlayi Laws, *Venericardia subintermedia* Sut., *Euspinacassis muricata* (Hect.), and *pollens* Fin., *Neocola alpha* Fin., *beta* Fin., and *flexuosa* (Marsh.), *Nassicola nassa* Fin., *Verconella parans* Fin., "*Murex*" *komiticus* (Sut.), *Mitra elatior* Fin., *Waihaoia phymatias* (Fin.).

(B) *Waiparia intermedia* Th. and *abnormis* (Th.), **Pachymagas parki* (Hutt.) (and similar advanced species such as **cottoni* Th., *bartrumi* Th., *macdowelli* Allan), **Rhizothyris rhizoida* (Hutt.), **scutum* Th., **elliptica* Th., *longitudinalis* Allan, *flexa* Allan, *labiata* Allan, etc., *Liothyrella elongata* Allan, *Terebratella clifdenensis* Allan.

(F) *Miogypsina* Sacco (as *irregularis* Mich.), *Nephrolepidina* Douv. (as *orakeiensis* Karr., *tournouri* L. and D., *marginata* Mich., and other species), *Pavonina* d'Orb. (as *triformis* Parr), *Tubulogenerina* Cush. (as *mooraboolensis* Cush.), *Ceratocancris* (as *clifdenensis*), *Calcarina* d'Orb. (as *mackayi* Karr.), *Hofkerina* C. and P. (as *semiornata* How.).

Vulvulina jablonskii, Textularia marsdeni, Siphotextularia ihungia, Eggerella ihungia, Dorothia hayi (Karrer), *Clavulinoides olssoni, Gaudryina fenestrata, Arenodosaria elegans* (Karr.), *Robulus dorothiae, Cassidulina arata, Cerobertina bartrumi, Ellipsonodosaria aequalis* (Karr.), *Cancris brevior, Notorotalia powelli, Cibicides amoenus,* "*Discorbis*" aff. *palmarealensis* (Nuttall), *Planorbulinella plana* (H.A. and E.), *Elphidium* cf. *howchini* Cush.

FIRST APPEARANCE OF:—

(M) *Linucula* Marw., *Ledaspina* Marw., *Zealeda* Marw., *Cratis* Hed., *Ctenamussium* Ired., *Dimya* Rouault, *Chama* L., *Eucrassatella* Ired., *Bartrumia* Marw., *Hyphantosoma* Dall, *Lutraria* Gray, *Periploma* Schum., *Tugalia* Gray, *Antisolarium* Fin., *Tropicolpus* Marw., *Ataxocerithium* Tate, *Pakaurangia* Fin., *Cheilea* Modeer, *Hipponyx* Defr., *Proxicharonia* Powell, *Waikura* Marw., *? Willungia* Powell, *Nassicola* Fin., *Acominia* Fin., *Mirua* Marw., *Olivella* Sw. (as *Lamprodomina* Marw.), *Hiwia* Marw., *Waipaoa* Marw., *Eubela* Dall, *Kaitoa* Marw.

(B) *"Neothyris" anceps* Th., *novara* (Iher.), *iheringi* Th., *Stethothyris epsilon* Allan.

(F) **Virgulopsis* (as *pustulata*), *Globobulimina* Cush., *Planorbulinella* Cush., *Sphaeroidinella* Cush. (as *disjuncta*), **Orbulina* d'Orb. (as *universa* d'Orb.; rare, suddenly common in Awamoan).

**Textularia miozea, Sigmoilina schlumbergeri* Silv. and *asperula* (Karr.), *Nodosaria subtetragona,* **Sigmoidella kagaensis* C. and O., *Guttulina regina* (B., P., and J.), *Rectobolivina maoria* and *parvula, Bulimina senta* and *bremneri, Cerobertina mahoenuica* and *crepidula, Nonion* cf. *simplex* (Karr.), **Nonionella novozealandica* Cush., **Cancris amplus,* **Notorotalia spinosa* (Chap.), **Eponides repandus* (F. and M.), *Parvicarinina deflata, Globigerina triloba* d'Orb., *Pseudogaudryina crespinae* Cush.

LAST APPEARANCE OF:—

(M) *Callolima* Bartsch, *Crenostrea* Marw., *Clifdenia* Laws, *Lornia* Marw.

(B) **Aetheia* Th. (as *gualteri* Morris), *Neobouchardia* Th. (as *minima* Th.), *Waiparia* Th.

Terebratulina suessi (Hutt.).

(F) *Flabellamina* Cush., *Frankeina* C. and A., *Semivulvulina* (as *capitata* Stache and *waitakia*), **Arenodosaria* (as *antipoda* Stache), *Büningia* (as *creeki*).

Verneuilina novozealandica Cush., *Gaudryina minuscula, Matanzia mahoenuia, Sigmoilina* aff. *celata* (Costa), *Robulus haasti* (Stache), **Marginulina* of *costata* Batsch line, *Palmula taranakia, Siphogenerina rerensis* (rare in basal Tutamoe and Mokau), *Bulimina miolaevis* (very rare in Tutamoe), **Cibicides perforatus* (Karr.), **Carpenteria rotaliformis* C. and C.

Awamoan.

Type Locality:—Awamoa Creek, North Otago (by tautonymy) (see Marshall and Uttley, 1913, p. 299; Marwick, 1931, p. 35; and Allan, 1933, p. 85). Allan's designation of " Rifle Butts " is undesirable and here held invalid.

In making the statement that " no type locality was cited by Thomson " Allan (*l.c.*) seems to have overlooked the deliberate intention clearly expressed in Thomson's paper (1916). It is sufficient to quote the following phrases (italicised words are ours):— " compare the rocks of other *localities* with those chosen as types for the various stages " (p. 29), " in choosing *localities* and rocks *to* *serve as types, and to give names* to the various stages " (p. 29), " I select Ngapara as the *type locality* " (p. 35), " I propose, therefore, to *base its name* on Castlecliff . . . limits must be left vague " (p. 36), " the *localities chosen as the types for stages* " (p. 39). If these are read in their context, in conjunction with the paper as a whole, it becomes evident that Thomson quite deliberately formed his " ian " stage names from special localities which in every case he also chose as the type. The localities mentioned by him in connection with his stages are therefore Type Localities by both tautonomy and original designation.

Actually, the Rifle Butts, chosen as type locality by Allan, is not so great an improvement on Awamoa Creek as to warrant a change. Macro-fossils are always easily obtainable at Awamoa, but sea encroachment has practically eliminated this possibility as concerns the upper beds at Rifle Butts.

Finally, Park's recognition (1918, p. 86) of Thomson's intention is plainly shown by his words, " the typical locality at the mouth of Awamoa Creek."

Sediments:—Sandstones, 50 + ft. thick, with shell-bed at base; overlain by river silts.

Fauna:—Molluscs very abundant; brachiopods very rare; forams rich.

Correlatives:—(By molluscs.) Southland (sandstones of upper Clifden beds—bands 7 and 8); North Otago (All Day Bay, Target Gully, Ardgowan, Pukeuri); South Canterbury (Mt. Harris, Pareora, Sutherland's); North Canterbury (View Hill, Lottery Creek); Westland (main mass of " Blue Bottom "—molluscs here are rare but forams, abundant everywhere, fix the age); East Wellington, Hawke's Bay, Poverty Bay (Tutamoe beds; sandstones and mudstones unconformable on Cretaceous or older rocks, disconformable or in some places conformable on Ihungia); North Taranaki (Mokau beds; sandstone in places unconformable on Mahoenui; overlain, disconformably on coast, by poorly fossiliferous Mohakatino beds, included at present with Mokau).

The uppermost Mt. Brown beds of Weka Pass and the few other places with the *Stethothyris epsilon* brachiopod fauna are here referred to Awamoan (see Finlay, 1939A, p. 530); there is no proof as yet that the presence or absence of these brachiopods depends on age rather than on ecology. The mollusc and foram faunas contain some index fossils of the Awamoan, and as a whole do not appear to be distinctively older; when Tertiary faunal evolution and sections are considered throughout the Dominion, there is no room for a division of stage value between true Hutchinsonian and Awamoan (which are themselves very similar), and no evidence apart from the sporadic brachiopods for its necessity. Allan, while previously of the opinion that these were sufficient to justify stage rank, has lately expressed doubts (1940, p. 289). It is noteworthy that specimens considered by Thomson and Allan to be *epsilon* are abundant in the Takaka limestone *below* marly beds with rich micro-faunas containing an overwhelming number of true Hutchinsonian index species, most closely related to the faunas of Pakaurangi Point and Westland Lower " Blue Bottom " (with *epsilon*), and not at all like Awamoan faunas from similar facies. The Takaka brachiopods are also not far above a horizon with *Athlopecten,* not known above Waitakian.

RESTRICTED FORMS:—

(M) **Hinnites* Defr., **Zafra* A. Ad., **Maorivetia* Fin.

Glycimerita robusta (Marw.), **Limopsis zealandica* Hutt., **Venericardia awamoaensis* Harris and *monsadusta* Marw., *Spissatella scopalveus* Fin., **Proximitra apicalis* (Hutt.), **Parvimitra pukeuriensis* Fin., *Waimatea othoniana* (Fin.), **Egestas fenestrata* (Sut.), **Zelandiella subnodosa* (Hutt.), **Nassicola contracta* Fin., *Alcithoe scopalveus* Fin. **Spinomelon parki* (Sut.), *Metamelon reverta* Marw., *Bathytoma haasti* (Hutt.), and many others.

(B) **Tegulorhynchia* aff. *nigricans* (Sow.), *Cancellothyris* cf. *hedleyi* Fin.

(F) **Cornuspiroides* Cush.

**Textularia awazea, *Siphotextularia awamoana* (in abundance; rare in Hutchinsonian), *? Amphicoryne prora, *Nonionella satiata, *Discorbis scopos.*

FIRST APPEARANCE OF:—

(M) *Manaia* F. and M., *Myllitella* Fin., *Semeloidea* B. and P., *Amphidesma* Lamk., **Tawera* Marw., *Austrovenus* Marw., **Cleidothaerus* Stutch., *Paraclanculus* Ired., *Callusaria* Fin., **Egestas* Fin., **Zeapollia* Fin., *Glaphyrina* Fin., **Zelandiella* Fin., *Cronia* H. and A. Ad., *Pachymelon* Marw., **Leporemax* Ired., **Oamaruia* Fin., **Phenatoma* Fin.

(B) *Neothyris* Douv. (typical), *Tegulorhynchia* of *nigricans* line.

(F) *Migros* (as *medwayensis* Parr), *Orbulina* d'Orb. in abundance (large forms of *universa* d'Orb.).

*Bolivina affiliata, Uvigerina mioschwageri, Hopkinsina notohispida, Siphogenerina pohana, *Cassidulinoides orientalis* (Cush.), *Ehrenbergina osbornei, Gyroidina orbicularis* d'Orb. and *stineari.*

LAST APPEARANCE OF:—

(M) *Serripecten* Marw., **Cyclocardia* Con., **Spissatella* Fin., *Bartrumia* Marw., *Hyphantosoma* Dall., **Hina* Marw., *Nemocardium* Meek (large forms), *Pyrazus* Mont., *Zefallacia* Fin., *Spelaenacca* Fin., *Tropicolpus* Marw., **Willungia* Powell, **Proterato* Schild., **Ficus* Roed., **Galeodea* Link, *Proxicharonia* Powell, *Waimatea* Fin., *Zexilia* Fin., **Nassicola* Fin., **Mirua* Marw., *Mauia* Marw., *Metamelon* Marw., **Conospirus* de Greg., *Borsonia* Bell., **Rugobela* Fin., **Insolentia* Fin., *Zemacies* Fin., **Parasyrinx* Fin., *Cosmasyrinx* Marw.

**Zeacolpus pukeuriensis* Marw.

(B) *Rhizothyris* Th., *Pachymagas* Th., *"Neothyris" anceps* Th., *novara* (Iher.), and *iheringi* Th., *Stethothyris epsilon* Allan.

(F) *Chilostomelloides* Cush.

Siphotextularia kreuzbergi, Karreriella cushmani, Dorothia minima (Karr.), *Clavulinoides instar, Lingulina avellanoides* (Kreuz.), **Plectofrondicularia parri* and **awamoana, *Virgulopsis* *pustulata*, **Bolivina anastomosa*, **Rectobolivina maoriella*, *Siphogenerina vesca* and *ongleyi*, *Bulimina* cf. *spiniscens* Brady and *bremneri*, *Ehrenbergina marwicki*, *Cerobertina mahoenuica* and *crepidula*, *Nonion* aff. *pompilioides* F. and M. (large inflated forms), **Pseudononion stachei* (Cush.), **Nonionella novozealandica* Cush. and **zenitens*, **Cancris lateralis*, **Notorotalia spinosa* (Chap.), **Anomalina miosuturalis* and *aotea*, **subnonionoides*, **pinguiglabra*, and **macraglabra*, **Cibicides mediocris*.

Tongaporutuan.

Type Locality:—Coast, Tongaporutu, North Taranaki (Grange, 1927, p. 27; Allan, 1933, p. 94).

Sediments:—Argillaceous sandstones, 1400 ± ft. thick, resting conformably on Mohakatino. Overlain unconformably by Urenui beds.

Fauna:—Molluscs not abundant; brachiopods absent; forams locally fair, often very poor. Specific change from Awamoan considerable in molluscs, distinct but not so marked (except for *Bolivinita*) in forams.

Correlatives:—(By molluscs and abundant forams.) North Canterbury (Shell-beds, East and West Grey Stream, and Lower Waipara Gorge, Jedburgh marls, etc.); Marlborough (Medway Series —see King, 1934, p. 10); Westland (Callaghan's Creek "Blue Bottom"); Hawke's Bay and Poverty Bay–East Cape district (mudstones, sandstones, and tuffs, conformable on Tutamoe; these have usually been referred to as Mapiri, which is certainly Tongaporutuan in part, and probably extends to Urenuian).

RESTRICTED FORMS:—

(M) *Leptomya simplex* Marw., *Kereia cottoni* Marw., *Eumarcia thomsoni* Marw., **Polinices mucronatus* Marw., *Zelandiella fatua* Fin., **Marginella whitecliffensis* Marw., **Waipaoa cristata* Marw.

(F) **Haeuslerella morgani* (Chap.), **Siphotextularia subcylindrica*, *Massilina subaequalis* (Parr), **Plectofrondicularia fyfei*, *Ehrenbergina fyfei*.

FIRST APPEARANCE OF:—

(M) **Neilo waitaraensis* Marw. and **sublaevis* Marw., **Manaia rapanuiensis* Marw., *Marama hurupiensis* Marw., **Zeacolpus* cf. *vittatus* (Hutt.), **Neocola cliftonensis* (Marw.).

(F) **Bolivinita* Cush. (as *pohana*).

**Karreriella cylindrica*, *Pseudogaudryina kingi* (Parr), *Nodosaria sinalata*, *Vaginulina* cf. *margaritifera* (Batsch), **Plectofrondicularia pohana*, **Bulimina elegans* d'Orb., **Pseudononion parri* (Cush.), **Anomalina spherica*, **Cibicides deliquatus*.

LAST APPEARANCE OF:—

(M) **Nucula* of *sagittata* Sut. line, *Ledaspina* Marw., *Periploma* Schum., **Pakaurangia* Fin., **Hiwia* Marw., *Waihaoia* Marw., *Teremelon* Marw.

(M: Cephalopoda) *Aturia* Bronn.

(F) *Migros* (as *medwayensis* Parr), *Clavulinoides* Cush., *Planorbulinella* Cush.

**Textularia miozea, Listerella weymouthi, Clavulinoides virilis,* **Robulus loculosus* (Stache), **Nodosaria subtetragona,* **Vaginulina legumen* (L.), **Bolivina lapsus, Rectobolivina parvula, Uvigerina mioschwageri* and **miozea,* **Siphogenerina pohana,* **Angulogerina australis* (H.-A. and E.), **Bulimina senta* and *truncanella, Ehrenbergina osbornei, Ceratobulimina kellumi, Nonion maoricum* (Stache), **Notorotalia tenuissima* (Karr.), **Planulina* aff. *wuellerstorfi* (Schw.), **Anomalina vitrinoda,* **Cibicides novozelandicus* (Karr.) and *catillus, "Discorbis"* aff. *saulcii* (d'Orb.), *Parvicarinina deflata,* **Globorotalia dehiscens* C., P., and C. and **scitula* (Brady), **Sphaeroidinella disjuncta.*

In view of the uncertainty in distinguishing the Urenui micro-faunally at present, and the lack of knowledge of its various facies, these " last appearances " are for the Taranakian as a whole, and no separate list is presented for the Urenuian. All these species seem to disappear before the Pliocene; some probably vanish during the Tongaporutuan, and others certainly persist to Urenuian, but a more accurate list must await further collecting.

Urenuian.

Type Locality:—Coast, Urenui Stream, North Taranaki (Grange, 1927, p. 31; Allan, 1933, p. 94).

Sediments:—Argillaceous sandstones, 1500 ft. thick, on coast angularly unconformable to Tongaporutuan (Grange, *l.c.,* p. 32). Overlain by volcanic deposits. In the Wairoa syncline, mudstones with an upper Mapiri (probably Urenuian) micro-fauna are overlain disconformably by Opoiti beds.

In Finlay's previous list of stages (1939A, p. 531), the Urenuian was merged with Tongaporutuan in a single Taranakian stage. This was an unavoidable conclusion if only the micro-faunas then available were considered, for supposed Urenui beds had provided no characteristic forms to allow of separation; faunas from a few other localities (from matrix of the molluscan collections) have since then indicated that there may be some distinctive assemblages at least, and it appears premature to suppress the Urenuian. This policy has accordingly been reversed in the present paper, mainly because of the evidence of the mollusca, the thickness of strata involved, and the unconformable relation between the two as shown on the coast. It should be understood that the few foraminifera provisionally quoted here as characteristic are really from the upper Mapiri beds, stratigraphically probably equivalent, but much less sandy and representing deeper water. Micro-faunas from typical Urenui matrix containing *Ellicea, Waitara,* and *Pelicaria* are still definitely Taranakian in the broad sense, and not yet Opoitian.

Fauna:—Molluscs often rather common, usually poorly preserved, not much specific change from Tongaporutuan in the case of lineages common to both; forams uncommon in Taranaki, abundant in Hawke's Bay and Poverty Bay.

Correlatives:—(By molluscs and forams.) East Cape district, Waiapu Subdivision (sandstones generally unconformable to Lower Taranakian); Hawke's Bay and Poverty Bay (probably some of the Upper Mapiri mudstones).

RESTRICTED FORMS:—

(M) *Pakaurangia waitaraensis* Marw., **Magnatica nuda* Marw., *Struthiolaria praenuntia* Marw., *Pelicaria nana* (Marw.), *Heligmope pehuensis* (Marw.), *Falsicolus tangituensis* (Marw.), *Lithoconus* large species.

(F) *Bolivinita compressa, Rectobolivina hangaroana, Bulimina mapiria;* undescribed species of *Bolivina* and *Loxostomum.*

FIRST APPEARANCE OF:—

(M) *Heligmope* Tate, *Pelicaria* Gray, **Ellicea* Fin., *Austromitra* Fin., *Waitara* Marw.

(F) *Rectobolivina striatula* (Cush.), **Sphaeroidinella dehiscens* (P. and J.).

LAST APPEARANCE OF:—

(M) **Nucula* Lamk. large species, **Linucula* Marw., *Lentipecten* Marw., *Notomyrtea* Ired., *Kuia* Marw., *Fossacallista* Marw., **Magnatica* Marw., *Euspinacassis* Fin., *Pakaurangia* Fin., *Falsicolus* Fin., **Neocola* Fin., *Baryspira* Fisch. (with heavy callus), **Bathytoma* H. and B.

**Neilo waitaraensis* Marw. and *sublaevis* Marw.

(F) Some of the species in the Tongaporutuan list will be found to extend to Urenuian when the faunas are better known.

Opoitian.

Type Locality:—Northern Hawke's Bay, Wairoa Valley, Opoiti Series of Ongley (1930A, p. 8) (Finlay, 1939A, p. 530).

Sediments:—Argillaceous sandstones and tuffs, 4000 ft. thick, disconformable on Mapiri mudstones, covering a wide area. Overlain unconformably by the Waitotaran Wairoa Series.

Fauna:—Molluscs (good faunules); brachiopods (*Neothyris* locally common); forams abundant. Many mollusc and foram lingerers from the Miocene disappear here (see Laws, 1936, p. 38, and Finlay, 1939A, p. 530), and new Pliocene lines enter.

Correlatives:—(By forams and some molluscs.) Westland (Upper "Blue Bottom"); Marlborough (probably the Upton Series of King, 1934, p. 13); Raukumara Peninsula (sandstones; part at least of Tokomaru Series of Ongley and Macpherson, 1928; Taranaki (conglomerates and shell sands previously referred to Waitotaran—see Morgan and Gibson, 1927, pp. 41–43); South-West Auckland (Kaawa Creek ?. Laws, 1940, considers the Kaawa beds as Waitotaran in age).

RESTRICTED FORMS:—

(The Hawke's Bay molluscs have not yet been described. and many restricted Kaawa Creek species—see Laws, 1936 and 1940—have not yet been found elsewhere.)

(M) *Sectipecten* Marw. (s.str.; as *wollastoni* Fin., etc.), *Tasmatica* F. and M., **Kaweka* Marw.

**Xenophalium kaawaensis* (B. and P.), *Zelandiella kaawaensis* (Bart.).

(F) *Nodosaria* (?) *multicostales*, **Rectobolivina striatula* (Cush.) (in abundance is characteristic of this and Waitotaran), *Anomalina semipunctata* (Bailey).

FIRST APPEARANCE OF :—

(M) *Glycimerula* F. and M., *Dacrydium* Torell, *Phialopecten* Marw., *Verticipronus* Hed., ? *Longimactra* Fin., *Gomphinella* Marw., *Notirus* Fin., *Myadora* Gray (of large size), *Montfortula* Ired., **Stiracolpus* Fin., *Microvoluta* Ang., *Glabella* Sw., *Splendrillia* Hed. (large forms such as *aoteana* Fin.), *Awateria* Sut.

"*Sectipecten*" *crawfordi* (Hutt.), *Pteromyrtea dispar* (Hutt.), *Nerita melanotragus* Sm., **Polinices waipipiensis* Marw., **Poirieria zelandica* (Q. and G.).

(F) **Patellinella* Cush. (as *inconspicua* Brady), *Streblus* Fischer (as *aoteanus*).

**Siphotextularia wairoana*, **Bigenerina pliocenica*, **Haeuslerella parri*, **Robulus costatus* (F. and M.), **Lagena squamosa* Mont., **Plectofrondicularia pellucida*, **Bolivinita pliozea*, **Bulimina aculeata* d'Orb., **Ehrenbergina mestayeri* Cush., *Elphidium novozealandicum* Cush., modern Globigerinidae including *Globigerinoides rubra* (d'Orb.) and *sacculifera* (Brady), **Globorotalia inflata* (d'Orb.), **crassula* C. and S., and *truncatulinoides* (d'Orb.).

LAST APPEARANCE OF :—

(M) *Cucullaea* Lamk., *Ctenamussium* Ired., *Semeloidea* B. and P., *Salaputium* Ired., *Finlayella* Laws, *Solecurtus* Blainv., *Pareora* Marw., *Polinella* Marw., *Hipponyx* Defr., *Cheilea* Modeer, *Callusaria* Fin., *Notacirsa* Fin., **Typhis* Mont., **Waikura* Marw., *Parvimitra* Fin., *Pachymelon* Marw. (*s.str.*), ? *Spinomelon* Marw., **Inglisella* Fin., **Waitara* Marw., **Eubela* Dall.

Marama hurupiensis Marw., *Polinices propeovatus* Marw., *Poirieria primigena* Fin., *Austrotoma minor* Fin.

(F) *Hopkinsina* H. and W. (as *notohispida*), **Vagocibicides* (as *maoria*; not seen later except in one Recent sample off Otago Heads).

**Textularia* of *miozea* line, **Pseudogaudryina kingi* (Parr), **Spiroloculina rotundata* Kreuz., **Lenticulina mamilligera* (Karr.), **Plectofrondicularia pohana*, *Rectobolivina maoria*, **Cassidulina cuneata*, **Ellipsonodosaria globulifera* (Kreuz.), **Cancris amplus*, **Nonion* cf. *simplex* (Karr.), **Elphidium ornatissimum* (Karr.), **Gyroidina zelandica*, *Pulvinulinella tenuimarginata* C., P., and C., **Planulina* cf. *sinuosa* (Side.), **Cibicides ihungia*. All these are conspicuous Miocene lines.

Waitotaran.

Type Locality:—Coast, Waitotara River to Waingongoro (Allan, 1933, p. 102).

Sediments:—Argillaceous sandstone with shell limestone at top, 1500 + ft. thick, base not exposed on coast; unconformably resting on Opoiti in Wairoa Surv. District. Overlain apparently conformably by sandstones and limestones with Nukumaruan macro-fauna.

Fauna:—Molluscs abundant, brachiopods few, forams moderate.

Correlatives:—(By molluscs.) North Canterbury, Marlborough, and Westland (conglomerate and sandstones with good molluscs and forams, generally unconformable on different underlying formations); East Wellington and Hawke's Bay (wide areas of barnacle limestones and sandstones with *Neothyris,* many good mollusc faunules, generally unconformable on any older beds down to greywacke), isolated patches on greywacke of Ruahine and East Kaimanawa Mountains to 3000 ft.; North Wellington to Taranaki (wide area of argillaceous sandstones with shell limestone), Ruapehu (sandstones round Hauhangatahi at 3000 ft.).

RESTRICTED FORMS :—

(M) *Trachycardium* Mörch, **Dimidacus* Ired.

**Manaia manaiaensis* Marw., **Veletuceta waipipiensis* (Marw.), **Lima waipipiensis* M. and M., **Raina waipipiensis* Marw., **Phialopecten triphooki* (Zitt.), **Tawera errans* Marw., **Myadora waitotarana* Pow., **Pholadomya waitotarana* Pow., **Maurea hawera* Oliver and **granti* Pow., **Polinices ovuloides* (Marw.), **Pelicaria zelandiae* (M. and M.), **rugosa* Marw., and **incrassata* Pow., **Zelandiella pliocenica* Pow., **Verconella haweraensis* Pow., **Coluzea spectabilis* Pow., **Alcithoe gatesi* Marw., **whakinoensis* Marw., and **haweraensis* Marw., **Marshallena austrotomoides* Pow., **Comitas declivis* Pow., **Zeacuminia murdochi* Pow.

(F) *Uvigerina pigmea* d'Orb. (*s.str.*), *Bulimina echinata* d'Orb.; fauna similar to Opoitian except for absence of many Miocene elements.

FIRST APPEARANCE OF :—

(M) **Phacosoma* J.-B., **Barytellina* Marw., *Talabrica* Ired., **Striacallista* Marw., *Zethalia* Fin., *Proxiuber* Pow., *Zephos* Fin., **Zeatrophon* Fin., *Xymene* Fin.

**Gigantostrea ingens* (Zitt.), **Mantellum marwicki* (Pow.), **Pedalion zelandicum* (Sut.), **Lutraria solida* Hutt., **Kereia greyi* (Zitt.), **Raina nukumaruensis* Marw., **Marama murdochi* Marw., **Eumarcia plana* Marw., **Atamarcia benhami* Marw., *Zethalia zelandica* (H. and J.), **Zeatrophon bonneti* (Cossm.), **Alcithoe larochei* Pow., *Epideira murdochi* (Fin.).

(F) *Angulogerina* cf. *spinipes* Cush., *Bolivina spinescens* Cush.

LAST APPEARANCE OF :—

(M) *Zealeda* Marw., **Manaia* Marw., **Phialopecten* Marw., *Chama* L., **Eucrassatella* Ired., **Milthoidea* Marw., *"*Cardium*" of *spatiosum* Hutt. line, **Pholadomya* Sow., **Polinices* Mont. (large species), **Friginatica* Hed., **Sinum* Roed., **Heligmope* Tate, **Austrofusus* of *pagoda* Fin. line, **Zelandiella* Fin., **Olivella* Sw. (as *Lamprodomina* Marw.), **Marshallena* Fin., **Austrotoma* Fin., **Zeacuminia* Fin., *Scaphander* Mont.

(B) *Neothyris obtusus* Th.

(F) *Bigenerina pliocenica, Karreriella cylindrica, Sigmoilina schlumbergeri* Silv., *Robulus costatus* (F. and M.) and *dicampylus* Franz., *Nodosaria holoserica* Schw., *longiscata* d'Orb., cf. *filiformis* Reuss, and *sinalata*, **Rectobolivina striatula* (Cush.) (in abundance), *Uvigerina* of *miozea* line, *Ellipsonodosaria verneuili* (d'Orb.), *Nonionella magnalingua, Eponides ecuadorensis* (G. and M.), *Gyroidina orbicularis* d'Orb. and *stineari, Cibicides deliquatus, Globorotalia miozea* and *crassula* C. and S.

Nukumaruan.

Type Locality:—Nukumaru Coast, west of Wanganui (Allan, 1933, p. 102).

Sediments:—Sandstones, 500 ft. thick. At Rangitoto, south of Takapau, Nukumaruan beds (Petane Series) with the characteristic mollusc *Tawera subsulcata* (Sut.) rest with angular unconformity on Waitotaran beds (Te Aute Series) with the equally characteristic mollusc *Phialopecten triphooki* (Zitt.) (see Quennell, 1938, p. 3). Overlain disconformably by the Okehu shell conglomerate with a Lower Castlecliffian macro-fauna.

Fauna:—Molluscs abundant; forams common (no muddy or deep water facies seen).

Correlatives:—(By molluscs entirely.) East Wellington and Hawke's Bay (wide areas of Petane Sandstone, with shell limestone, unconformable or apparently conformable on Waitotaran; rich faunas).

RESTRICTED FORMS:—

(M) *Taxonia* Fin.

**Cosa trigonopsis* (Hutt.), *Veletuceta shrimptoni* (Marw.), **Amphidesma crassiforme* M. and M., **Mactra crassa* Hutt., **Austrodosinia horrida* Marw., **Tawera subsulcata* (Hutt.), **Struthiolaria frazeri* Hutt., *Pelicaria convexa* Marw. and *fossa* Marw., *Coluzea espinosa* Fin., *Cominula hamiltoni* (Hutt.), *Murexsul espinosus* (Hutt.), **Xymene drewi* (Hutt.), **Alcithoe detrita* Marw., *Antizafra pisaniopsis* (Hutt.).

(F) None known as yet.

FIRST APPEARANCE OF:—

(M) **Cosa* Fin., **Aeneator* Fin., *Iredalina* Fin., **Axymene* Fin. **Paphirus largillierti* (Phil.), **Austrovenus stutchburyi* (Gray), *Inquisitor wanganuiensis* (Hutt.), *Melatoma buchanani* (Hutt.), *Leucotina ambigua* (Hutt.).

(F) *Pulleniatina* Cush.

? *Buliminoides williamsonianus* (Brady) (rare in New Zealand), *Notorotalia zelandica* (large, typical forms).

LAST APPEARANCE OF:—

(M) *Veletuceta* Ired., *Limopsis* Brocchi, **Gigantostrea* Sacco, *Lima* Brug. (*s.str.*), *"*Sectipecten*" Marw. (as aberrant *crawfordi* Hutt.), **Pedalion* Huddesf., **Pteromyrtea* Fin., **Lutraria* Gray,

**Raina* Marw., **Eumarcia Ired.*, **Atamarcia* Marw., **Taniella* F. and M., *Ellicea* Fin., *Pachymelon* of *bulbus* Marw. line, *Awateria* Sut., *Comitas* Fin.

**Pedalion zelandicum* (Sut.), **Lutraria solida* Hutt., *Marama murdochi* Marw.

(F) *Haeuslerella* Parr (as *parri*), *Pseudogaudryina* Cush. (as *kingi* Parr).

Siphotextularia wairoana, Plectofrondicularia of *whaingaroica* (Stache) line, *Bolivina affiliata, Bolivinita pohana, Uvigerina* of *canariensis* line, *Cassidulina pacifica* Cush., *Anomalina parvumbilia.*

Castlecliffian.

Type Locality:—Landguard Bluff to Butler's (Ototoka) Creek, west of Wanganui (Allan, 1933, p. 101).

Sediments:—Argillaceous sandstones, shell beds, pumiceous sands, 1200 ± ft. thick, disconformable on Nukumaru beds at east end of Nukumaru beach, containing one strong and other less marked intra-formational disconformities. Overlain unconformably by the Pleistocene Hawera Series.

Fauna:—Molluscs very rich; brachiopods (Recent species) common in some beds; forams abundant.

Correlatives:—(By molluscs entirely.) Bay of Plenty (Cape Runaway; only highest Castlecliffian—Powell, 1934, p. 261); possibly Hawke's Bay (Cape Kidnappers).

RESTRICTED FORMS:—

(M) **Eunaticina* Guild. (as *cincta* Hutt.), **Capulus* Mont. (as *uncinatus* Hutt.).

**Cosa wanganuica* Fin., **Notovola tainui* Fin. and **marwicki* Fin., **Amphidesma pliocenica* Oliver, **Tawera wanganuiensis* Marw., **Zelippistes perornatus* (M. and M.), **Glaphyrina progenitor* Fin., **Evarnula striata* (Hutt.), **Pterochelus zealandicus* (Hutt.), **Iredalula striata* (Hutt.).

(B) **Neothyris ovalis* (Hutt.).

(F) **Siphotextularia wanganuia.*

FIRST APPEARANCE OF:—

(M) **Notovola* Fin., **Liratilia* Fin., **Iredalula* Fin.; many Recent species.

(F) **Triloculina oblonga* d'Orb., **Miliolinella oblonga* (Mont.) and *circularis* (Bornem.).

LAST APPEARANCE OF:—

(M) **Barytellina* Marw., **Leucotina* A. Ad. (large species).

**Mantellum marwicki* Powell, **Tellinella eugonia* (Sut.), **Maorimactra acuminella* Fin., **Zeatrophon bonneti* (Cossm.), **Inquisitor wanganuiensis* (Hutt.), **Melatoma buchanani* (Hutt.).

(F) **Plectofrondicularia pellucida,* **Bolivinita pliozea,* **Uvigerina* of *pigmea* line (in lower part, the Kai-Iwi beds; no Uvigerinas seen in true Castlecliff beds).

Recent Faunas.

(M) Quite a number of Australian and Indo-Pacific immigrants have been reported in various papers by Finlay, Oliver, and especially Powell, and there are numerous living species not yet reported from the Tertiary—many of these probably did occur, in habitats unsuitable for sedimentary preservation. Laws's recent work, especially on the smaller molluscs of the Pliocene, has extended many ranges downwards.

(F) The Recent fauna strikingly differs even from the highest Pliocene in possessing *Nouria* H.-A. and E., *Nevillina* Side., *Parrina* Cush., *Reophax advena* Cush. and *scorpiurus* Mont., *Ammodiscoides mestayeri* Cush., *Textularia stricta* Cush., *Siphotextularia catenata* (Cush.), *Biloculinella globula* (Bornem.), *Planularia spinipes* Cush. (*tricarinella* auct.), *Loxostomum karrerianum* (Brady), *Uvigerina proboscidea* Schw., *Siphogenerina raphanus* P. and J., *Cancris maoricus, Streblus aoteanus* in abundance, *Parvicarinina planoconcava* (Parr), *Discorbis dimidiatus* (P. and J.), and *Globigerinella aequilateralis.*

REVIEW OF RESULTS.

Agreement of Evidence.

The foregoing lists show, when different facies are taken into account, a remarkably close agreement between the behaviour of the molluscs and of the forams, with this difference, however, that more *genera* of molluscs are mentioned than of forams. This is perhaps to be expected from their higher organisation, but it may also be due to the more continuous record of foram faunas. The fact that important first and last appearances of foram species coincide quite closely with those of mollusc groups is clearly established, with the exception of the Pliocene mollusc disappearances.

Stages Most Striking Faunally.

The Bortonian and Hutchinsonian are notable not only because of the relatively large number of restricted genera, but also because of the important number of new additions to the fauna. Other stages showing important entries are Whaingaroan (mostly forams), Duntroonian (basal Waitakian) and Opoitian, but many of the Duntroonian molluscs probably entered during the Whaingaroan.

The stages notable because of the last appearance of genera are Awamoan, Tongaporutuan plus Urenuian (considered together), Opoitian, Waitotaran (molluscs), and Nukumaruan (molluscs).

Thus the most important additions to our fauna have been made in the early half of the Tertiary, and the latter half has shown a marked extinction of molluscan genera, probably in large part due to cooling seas (Powell, 1931, p. 90; Laws, 1936, p. 43, etc), the foraminifera being apparently less sensitive to this factor.

This faunal survey shows clearly that the Pliocene stages still depend principally on molluscs, and have much less distinctive microfaunas than those before them. Nearly all the pre-Pliocene stages are now seen to have a solid palaeontological basis of both large and small fossils, and the time is rapidly approaching when we can make our Tertiary divisions in terms of ranges of organisms (multiple biochrons). The two exceptions are the Tahuian and the Duntroonian and it is plain that these are less important and less definable than the others, and may not really merit stage rank. It is difficult, however, at the present time to merge Tahuian with either Upper Bortonian or Kaiatan, but unless additional evidence of its distinction is found it may in the future be regarded as a basal zone of the latter. Waitakian has priority over Duntroonian, which also seems to be only its basal zone, just as Waiarekan is a doubtfully separable zone of the larger Kaiatan—though here the priority is reversed. There would appear to be too many divisions of *stage* value in the period Duntroonian-Waitakian-Lower Hutchinsonian, but the most suitable telescoping is still a matter for debate and research. The importance of the break between the Amuri Limestone (Whaingaroan at the top) and the Duntroonian Weka Pass Stone has been the subject of one of New Zealand's longest geological controversies. The absence of distinctive fossils always checked progress in the discussion; but now that the micro-faunas are adequately known, the break assumes new importance, not so much in time as in the fact that the real faunal severance from the earlier Tertiary, though initiated in the Whaingaroan, seems to occur here. The Duntroonian introduces many of the features of the comprehensive Hutchinsonian-Awamoan-Taranakian era, and it is to be suspected that the differences here recorded between the Duntroonian-Waitakian and the Lower Hutchinsonian periods will be minimised as further facies and collections become available. It is so difficult to apply these divisions to the altogether different sediments of the North Island that it seems best to use Waitakian there as a comprehensive name for any strata or faunas definitely post-Whaingaroan and pre-Mahoenui.

Conclusion.

A possible readjustment in value of some of these stages may slightly alter allocation to the European time scale, and the position of some first and last entrances is bound to shift with further knowledge. But the given ranges are probably fairly correct as regards occurrence in any abundance, and will serve as a basis to build on: according to their evidence and the correlation levels and hypotheses here adopted the suggested European equivalents of the New Zealand stages seem reasonable.

In conclusion, we take this opportunity of acknowledging much stratigraphical information personally communicated to us by officers of the Geological Survey, and of the different Oil Companies that have been operating in New Zealand recently. We have also to thank Dr W. N. Benson for reading an early draft of this paper and offering much helpful criticism.

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ADDENDUM.

Some extension of ranges and records has become known since the lists in this paper were set up in print. Their incorporation would mean so much alteration and expense that for sake of completeness they are presented together here:—

Trochamminoides irregularis.—White is not uncommon in some North Island Waitakian faunas.

A large new species of *Flabellamina* occurs in a North Island Piripauan fauna with *Gaudryina whangaia.*

Vulvulina jablonskii continues (rarely) to the Awamoan, and has been seen in several North Island Waitakian faunas.

Siphotextularia ihungia and *Sphaeroidinella dehiscens* (P. and J.) occur in a Tongaporutuan fauna.

A large ***Polymorphina***, very close to the Midway ***cushmani*** Plummer is in a North Island Piripauan fauna of unusual facies. In this same fauna ***Gyroidina nitida*** (Reuss) is common; it is restricted to Piripauan.

Angulogerina cf. ***oligocenica*** (Andreat) seems to be common in and perhaps restricted to the North Island Waitakian. ***Uvigerina dorreeni***, equally common here, is better referred to ***Siphogenerina***, the last chamber of adults being terminal. ***Siphogenerina vesca*** also appears to occur first in this Stage, ***striatissima*** not yet having been seen above Duntroonian.

Bulimina miolaevis is in several Tutamoe faunas.

Büningia creeki has been reported by J. M. Dorreen as common in the Poverty Bay Tongaporutuan in certain areas, together with ***Bolivinita***.

There is some evidence that ***Cibicides tholus*** may extend beyond Bortonian, perhaps even as high as Whaingaroan.

Pseudogaudryina kingi should be deleted from the Opoitian list of last appearances; it is already in the Nukumaruan list.