On the System and Stage Names applied to Subdivisions of the Tertiary Strata in New Zealand.

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CONTENTS.

I.—INTRODUCTION.

THE nomenclature in use in the Dominion for the major subdivisions of the Tertiary rocks is an extension of the scheme proposed by J. Allan Thomson in 1916. Marshall's alternative classification (1916, 1919), based upon the percentage of Recent species, has not been adopted by subsequent workers. As well as the system and stage names of Thomson's classification there are a host of series names which are of local value only. The latter are not further considered here.

There is now a general consensus of opinion among those studying Tertiary problems that Thomson's scheme is not sufficiently detailed. Of this fact Thomson himself was fully aware. He wrote: "With the detailed palaeontological work on Tertiary Mollusca now being carried out by Marwick, Finlay, and others it is becoming evident that the stages of the Oamaruian as originally proposed by me (1916) are not, as was at first thought by other geologists, too numerous and small in content for classificatory purposes, but the reverse. Important faunas, such as that of Otiake and those of Clifden, while undoubtedly Oamaruian, do not appear to agree exactly with any of the stages in the Oamaru coastal district, and probably represent stages missing between Ototaran and Hutchinsonian, or between Hutchinsonian and Awamoan. If this is so there must be important unconformities or disconformities between these stages in Oamaru." (1926, p. 145.)

However, before introducing any new terms, it seems advisable to summarise what has already been done. Stage names have been introduced without adequate definition by more than one worker, and these should be carefully scrutinised, and, if necessary, defined accurately or else rejected.

It is well to bear in mind that a scheme of classification is but a means to an end. The various stage-names are primarily tools for the convenience of the stratigrapher. It is obvious that the better the tool the better will be the use of it in skilled hands.

The economic geologist and stratigraphical palaeontologist both demand that their units shall be accurately and clearly defined. Recent work in the British Isles has demonstrated very clearly that stratigraphy can be a very exact science.*

When the palaeontologist is able to study fossils which have been collected from well-defined units he is able, more often than not, to provide the stratigrapher with very accurate information as to age or correlation of the strata in question. The stratigrapher gains from his exact work. This is nowhere more apparent than in recent developments in oil-geology, and has a great economic significance.

It seems to the writer that the stage-names in New Zealand are imperfectly defined, with the result that, in spite of the palaeontological data now available, exact correlation is practically impossible in many cases.

Too much attention has been paid to individual fossils, their description, and the determination of their range in time. The tendency of modern palaeontology is towards (a) the study of restricted groups of organisms as they develop in time; and (b) the study of faunal communities or assemblages rather than of individuals.

Neither of these methods has yet been applied in the Dominion. The first means more than merely recording the succession of different forms in time. The object is to find the stratigraphical value of stages in development in particular lineages. The guiding principle is that stages of development in any one lineage are successive in time. This science of stratigraphical palaeontology demands of its devotees a greater knowledge of fossils in the field than do the older methods. The focus of modern work is in the field rather than in the museum. The significant changes in many lineages are so intimately related to changes in lithology or facies that they can only be appreciated fully in the field.

In a report on the Lower Devonian fossils of Reefton, soon to be published, the writer has attempted to show the value for purposes of correlation of faunal communities based upon characteristic fossils. It is not necessary, therefore, to provide full details of this type of study here. It will be sufficient to state that a given horizon of uniform facies can be treated in terms of its characteristic fossils alone. 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.

Fossil communities, in the same way as recent animal and plant communities, are bounded by certain physical conditions, and are constant only where the physical conditions are constant. A change in environment results in a change in the community as far as the characteristic members of it are concerned.

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* See for example W. D. Lang (and others). The Belemnite Marls of Charmouth, a Series in the Lias of the Dorset Coast. *Quart. Jour. Geol. Soc.* LXXXIV (2), 1928, pp. 179 *et seq.*

It is thus of great importance to realise that a community characteristic of a certain stage in the type locality will be characteristic of that stage only in areas where it is represented by strata of the same facies.

I would submit, therefore, that before correlation of faunas of distinct facies is possible one must understand clearly the characteristic fauna in its relation to the facies of the type area.

In very few cases is it possible in the Dominion to enumerate standard characteristic communities. This is because in most cases the type localities for our stages are not fixed, or because the fossils from type localities are imperfectly known. Until these deficiencies are made good it is impossible, in the writer's opinion, to expect to get any accurate data as a basis for sound correlation.

Before either of these methods, viz., the study of restricted groups of organisms as they develop in time, and the study of faunal communities based upon characteristic fossils, can be applied in New Zealand there must be a more rigorous definition of stratigraphical units. This is attempted in the sequel.

For each stage I propose to select a definite type locality which will form a standard for that stage. Each stage will be based upon definite lithological units which will be defined as accurately as possible. When they are known the most characteristic fossils will be listed. Stress will be laid upon the community rather than upon the individual.

In selecting type or standard localities the clearness of the section and the state of preservation of the fossils will receive consideration, but underlying the selection the law of the superposition of strata will be the guiding factor as far as it is applicable in any one area.

I should like to suggest that if the stages herein employed prove to contain more than one community in sequence in the standard area, then each might fittingly be spoken of as a zone. Each zone would be indicated by selecting an index-fossil, thus the " Zone of *Stethothyris sufflata* "; or, more simply, the *sufflata*-zone.

It is therefore possible, in some cases certain, that the stages will be subdivided into zones. This method is more convenient than the excessive introduction of stage or substage names. For gaps between the stages as herein defined, however, new stages will be both necessary and desirable. Such a scheme should make for permanence of nomenclature—a most excellent aim.

It appears to the writer that the first task of Dominion students is not to attempt correlation problems, but to study in detail the faunas of the standard areas. Only after these are thoroughly known in relation to their particular facies can correlation be attempted. Areas other than standards could well await study until knowledge of the standards is reasonably complete.

A second task concerns the study of changes in faunal assemblages in relation to changes in facies. This can only be attempted by palaeontological studies in the field after the standard faunas and facies are determined.

It will be obvious that the writer owes a great deal to the worthy pioneers of Tertiary stratigraphy in New Zealand, A. McKay, F. W. Hutton, James Park, and P. Marshall, but his indebtedness to the younger workers, J. Allan Thomson, G. H. Uttley, J. Marwick, L. I. Grange, H. J. Finlay, and others, will be equally apparent.

Dr J. Marwick* and Dr H. J. Finlay have both offered most helpful criticism of my manuscript. The latter's help in connection with lists of characteristic mollusca has been invaluable.

II.—REVISION OF SYSTEM AND STAGE NAMES.

The following names have been used for subdivisions of the Tertiary strata of New Zealand:—Atiuian, Awamoan, Awaterian, Bortonian, Brunnerian, Castlecliffian, Hutchinsonian, Islandian, Kaiatan, Kaitangatan, Mawheranuian, Ngaparan, Nukumaruian, Oamaruian, Onairoan, Ototaran, Paparoan, Pareoran, Petanian, Tahuian, Taranakian, Tongaporutuan, Urenuian, Waiarekan, Waimangaroan, Waimateian, Waipipian, Waitakian, Waitotaran, Wangaloan, and Wanganuian.

Of these the following are system or group names:—Kaitangatan, Mawheranuian, Oamaruian, Taranakian, Waimangaroan, and Wanganuian.

ATIUAN Stage.

Proposed by P. G. Morgan (1921, p. 101 and p. 103).

The name appears first in " Table I—Classification of Cretaceous and Tertiary Strata " and there covers (a) Part of Kaeo Series; hydraulic limestone (Northern Auckland); (b) Mangatu Series (East Coast of North Island); and (c) Amuri limestone (Marlborough and North Canterbury). In the " Remarks on Classification Table " Morgan wrote: " The adjective ' Atiuan ' [final ' i ' omitted] from Atiu Point, Kaikoura Peninsula, is intended to cover the Amuri limestone, for which a stage or alternative name, notwithstanding its poverty in fossils, seems desirable." (1921, p. 103.)

The fossils of the Amuri limestone are chiefly foraminifera, and F. Chapman (1926, pp. 10-11) has concluded that these organisms indicate a Danian (Upper Cretaceous) age. If this age be accepted the Atiuian need not be considered further in the classification of the Tertiary sequence.

Thomson's suggestion (1916) that the Amuri limestone is Cretaceous at the base but Tertiary at the top is not borne out by Chapman's studies of the foraminifera. (See Thomson, 1920, pp. 385-6.)

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* Since these notes were written Dr Marwick has published (*N.Z. Geol. Surv. Pal. Bull.* No. 13, 1931) a " Synopsis of the Commonly Used Stage Names of the New Zealand Tertiary." This synopsis is referred to where necessary in footnotes in the sequel.

AWAMOAN.

Proposed by J. A. Thomson (1916, p. 34) for the " Awamoa Beds " of the Oamaru district.

The name is based upon Awamoa Creek, but no type locality was cited by Thomson. The strata exposed at the mouth of Awamoa Creek are isolated from all other rocks of Oamaruian age (Park, 1918, p. 87); hence this area is not suitable for a standard. However, one wing of the syncline here developed is clearly exposed at the Rifle Butts, and there is available there a clear measured section (Park, 1918, pl. IV) which is here selected as the type locality of the Awamoan stage. Park gives the following sequence (in descending order):—

(a.) Blue sandy clays; 30 feet exposed.
(b.) Band of hard calcareous sandstone; 18 inches.
(c.) Blue sandy clays; 8 feet.
(d.) Band of hard calcareous sandstone; 16 inches.
(e.) Blue sandy clays; 43 feet.
(f.) Hard calcareous band; 18 inches.
(g.) Soft glauconitic sands; 9 feet.
(h.) Hard brown limonitic sandstone; 2 feet.
(i.) Glauconitic sandy shell-bed; 5 feet.
(j.) Greensands with *Pachymagas parki;* 5 feet.

Park placed beds (a.)-(f.) in the Awamoan; beds (g.) to (j.) (and certain lower horizons) in the Hutchinsonian. With regard to horizon (j.) there can be no dispute—it is definitely Hutchinsonian, but G. H. Uttley (1920 B, pp. 173-4) has argued, correctly, that bed (i.) is the equivalent of the shell-beds of Target Gully and Ardgowan which Park admits are basal Awamoan.

The Awamoan stage may be defined as the interval of time represented by the deposition of beds (a.) to (i.) in the standard section at the Rifle Butts, Oamaru, and as well such periods as may be represented therein by non-deposition or erosion. Two faunal communities may be recognised in the Awamoan period. The first is basal Awamoan, and is found in the shell-bed of the Rifle Butts, Target Gully, Ardgowan, etc. This faunule is best known at Target Gully, and a list of the characteristic mollusca found there by Dr H. J. Finlay is given below. The second faunule occurs in the blue clays of the Rifle Butts, Awamoa Creek, Pukeuri, All Day Bay, etc. As typical I list the characteristic mollusca from the type locality at the Rifle Butts.

The characteristic mollusca of the Target Gully shell-bed are:—*Acteon praecursorius* Suter, *Alcithoe compressa* Marw., *A. cylindrica* Marwick, *A. finlayi* Marwick, *Alocospira hebera* (Hutton), *Anomia trigonopsis* Hutton, *Argalista impervia* Finlay, *Ataxocerithium pyramidale* Finlay, *Austrodrillia callimorpha* (Suter), *Austrofusus spinifera* (Finlay and McDowall), *Austrotoma minor* Finlay, *Austrotriton maorium* Finlay, *Barbatia awamoana* Finlay, *Bullinella soror* (Suter), *Chathamina compacta* (Suter), *Cochlis notocenica* (Finlay), *Comitas oamarutica* (Suter), *Corbula pumila* Hutton,

Cryptomella excavata (Hutton), *Cucullaea australis* (Hutton), *Cymatiella octoserratum* (Finlay), *Dosinia (Raina) bensoni* Marwick, *Dosinula suboblonga* Marwick, *Egestas fenestrata* (Suter), *Eucominia intermedia* (Suter), *Eucrassatella attenuata* (Hutt.), *Eumarcia (Atamarcia) curta* (Hutton), *E. (A.) sulcifera* Marw., *Fissidentalium solidum* (Hutton), *Gari oamarutica* Finlay, *Glycymeris robusta* Marw., *Hima socialis* (Hutt.), *Hinnites trailli* Hutt., *Kuia vellicata* (Hutt.), *Limopsis zitteli* von Ihering, *Maoricolpus cavershamensis* (Harris), *Maoricrypta radiata* (Hutt.), *Maorivetia brevirostrus* (Hutt.), *Marginella conica* Harris, *M. harrisi* Cossm., *Mesalia striolata* (Hutt.), *Miopila fidicula* (Suter), *Monia incisura* (Hutt.), *Nassicola contracta* Finlay, *Navicula subvelata* (Suter), *Notocallista parki* Marwick, *Notacirsa oamarutica* (Suter), *Nucula sagittata* Suter, *Oamaruia suteri* (M. & M.), *Pachymelon firma* Marwick, *Pallium (Mesopeplum) burnetti* (Zittel), *Panope worthingtoni* (Hutt.), *Parasyrinx alta* (Harris), *Parvimitra scopi* Finlay, *Polinices huttoni* von Ihering, *P. lobatus* Marwick, *Procominula pukeuriensis* Finlay, *Proximitra rutidolomum* (Suter), *Pteronotus awamoanus* Finlay, *Rhizorus reflexus* (Hutt.), *Rugobela canaliculata* (Suter), *R. tenuilirata* (Suter), *Sigapatella maccoyi* Suter, "*Siphonalia*" *excelsa* Suter, *Spinomelon parki* (Suter), *Spissatella scopalveus* Finlay, *Struthiolaria subspinosa* Marw., *Tawera marshalli* Marwick, *Teredo heaphyi* Zittel, *Teremelon cognata* (Finlay), *Trichomya huttoni* (Cossm.), *Uromitra etremoides* Finlay, *Venericardia awamoaensis* (Harris), *Verconella marwicki* (Finlay), *Waimatea othoniana* (Finlay), *Xymenella lepida* (Suter), *X. minutissima* (Suter), *Zaclys aequicincta* (Suter), *Zeacolpus abscisus* (Suter), *Zeacrypta wilckensi* (Finlay), *Zeacuminia pareoraensis* (Suter), *Zeapollia acuticingulata* (Suter), and *Zenatia acinaces* Q. and G.

The characteristic mollusca in the blue clays at the Rifle Butts include:—*Alcithoe neglecta* Marwick, *Alocospira hebera* (Hutt.), *Austrodrillia praecophinodes* (Suter), *Austrotriton maorium* Finlay, *Bullinella soror* (Suter), *Chathamina protensa* (Powell), *Cochlis notocenica* (Finlay), *Coluzea dentata* (Hutt.), *Comitas oamarutica* (Suter), *Egestas fenestrata* (Suter), *Friginatica vaughani* (Marwick), *Hima socialis* (Hutt.), *Lima colorata* Hutt., *Limopsis zelandica* Hutton, *Marginella conica* Harris, *M. fraudulenta* Suter, *M. harrisi* Cossm., *Neilo awamoana* Finlay, *Parasyrinx alta* (Harris), *Parvimitra pukeuriensis* Finlay, *Procominula pukeuriensis* Finlay, *Proximitra apicale* (Hutt.), *P. tumens* Finlay, *Rugobela canaliculata* (Suter), *Spissatella trailli* (Hutt.), *Teremelon awamoanensis* Marw., *Uberella pseudovitrea* (Finlay), *Venericardia awamoaensis* (Harris), *Vesanula vegrandis* (M. & M.) and *Zeadmete miocenica* Finlay.

AWATERIAN.

Proposed by P. G. Morgan (1922, p. 52).

"In some parts of New Zealand there occur strata known by their stratigraphical position and molluscan fauna to be somewhat younger than the typical Awamoan, but not easily separable either from it or from the strata forming the lower part of the Wanganuian. These are the Awatere beds, and form what may perhaps

be called the Awaterian stage, which, however, is at present not clearly definable, and must simply be considered as intermediate between Awamoan and Wanganuian. In this category come not only certain strata in the Lower Awatere Valley, but portions of the strata in southern and central Taranaki that comformably underlie undoubted Wanganuian, together with the Ormond limestone and Tawhiti beds of the Gisborne district."

It is still impossible to define Morgan's term, and it should be allowed to lapse. The time interval between the Oamaruian and the Wanganuian is bridged by the Taranakian System of L. I. Grange.

The terms "Awaterian" and "Taranakian" are in part or completely synonymous, but there is nothing to be gained by the rejection of the latter on grounds of priority.

BORTONIAN.

Proposed by J. Park (1918, p. 25) as the lower substage of the Waiarekan as originally used by Thomson (1916).

Type locality: Near Borton's, in the Waitaki Valley, 24 miles from Oamaru.

Park (1918, pp. 33-4) gives the following sequence of strata in the type locality (in descending order):—

(a.) A yellowish-brown calcareous sandstone.
(b.) Glauconitic greensands; 5 feet.
(c.) Greyish sandy beds; 10 feet.
(d.) Brown sandy beds, slightly glauconitic; 130 feet.
(e.) Soft brown sandstone, interbedded with a band of hard calcareous glauconitic sandstone, 6 inches to 2 feet, 30 feet in thickness.
(f.) Coal-measures.

The Bortonian fossils occur in the hard band in horizon (e.). Allan (1927, pp. 284-90) has suggested that since the fossils at Borton's are poorly preserved, a palaeontological basis may be given the Bortonian by reference to the sequence developed in the Lower Waihao Valley. In this locality Bortonian fossils are beautifully preserved, and the relationship of the Bortonian fauna to overlying faunas is clear.

Allan gave the following sequence (in descending order):—

(a.) Waihao limestone	Ototaran		
			(disconformity)
(b.) Upper greensands	Tahuian	(diastem)*	Waimatcian.
(c.) Lower greensands	Bortonian		
(d.) Hard sandstones			
And			
(e.) Coal-measures.			

* According to Willis and Willis *Geologic Structures* (1929), a conformable contact between strata which are not separated by a notable time break is called a diastem. A conformable contact which is characterised by a notable lapse of time is called a disconformity.

If this suggestion be allowed, *the Bortonian Stage may be defined as the interval of time represented by the deposition of the lower greensands and sandstones in the Lower Waihao Valley, and as well such periods as may be represented therein by non-deposition or erosion.*

The top of the lower greensands is marked by a phosphatised surface at McCullough's Bridge.

The characteristic mollusca of the Bortonian, based upon personal observation, are:—*Carinacca allani* Marwick, *Cucullaea waihaoensis* Allan, *Friginatica prisca* (Marwick), *Fusinus bensoni* Allan, *Globisinum elegans* (Suter), *Insolentia sertula* (Suter), *Latirus neozelanica* (Suter), *Limopsis campa* Allan, *Marshallena serotina* (Suter), *Mauia curvispina* Marwick, *Monalaria concinna* (Suter), *Notoplejona necopinata* (Suter), *Pecten devinctus* Suter, *P. waihaoensis* Suter, *Speightia spinosa* (Suter), and *Venericardia acanthodes* (Suter).

BRUNNERIAN Stage. See Mawheranuian System.

CASTLECLIFFIAN Stage. See Wanganuian System.

HUTCHINSONIAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the " Hutchinson Quarry Beds " of the Oamaru Coastal District. " In the Hutchinsonian I would place all beds between the Ototaran limestone and the shell-bed at Target Gully, described by Marshall and Uttley (1913), the latter forming the base of the Awamoan." (Thomson, 1916, p. 35.)

The name is used by Thomson for a lithological unit, and a type locality, although not definitely stated, is implied in the name. Unfortunately the sequence of strata developed at and near Hutchinson's Quarry is somewhat obscure. Thomson's base line, the top of the Ototaran limestone, can be distinguished at the Quarry only with difficulty. Furthermore there is no clear contact in Target Gully between the greensands of Hutchinson's Quarry and the basal Awamoan shell-bed which is itself probably a very local deposit.

In fact Park (1918) has recognised fossiliferous strata between the greensands and the Awamoan shell-bed at Target Gully itself. This horizon, which has a moderately rich, well-preserved, molluscan fauna, was ignored by Thomson, and has been neglected by all subsequent workers.

If therefore the Hutchinsonian be interpreted by the sequence in Lower Target Gully, it contains three lithological units, each characterised by a distinct fauna:—

(a.) Glauconitic sands with mollusca and *Tegulorhynchia*— " Upper Hutchinsonian " of Park (1918).
(b.) Greensands with *Pachymagus parki.*
(c.) Phosphatic conglomerate with *Liothyrella boehmi.*

If, on the other hand, a standard locality be selected elsewhere in the Oamaru District, a further difficulty presents itself. The greensands of the Rifle Butts, Kakanui, Devil's Bridge, All Day Bay, and Deborah, i.e., correlatives according to Thomson and earlier workers, of the Hutchinson's Quarry Beds, contain a brachiopod assemblage distinct from that of Hutchinson's Quarry. In other words, the lithic boundary of the greensands appear to cut across the true time planes. The brachiopod evidence for this view is detailed by Thomson (1926, p. 150.)

It would seem to be obvious that a precise definition of the Hutchinsonian stage must await the detailed stratigraphical and faunal studies required to clear up the obscurity implied in the above statements.

In the meantime the Hutchinsonian may be defined as the period of time during which the Pachymagas parki *series of brachiopods were the characteristic fossils.*

As thus interpreted the Hutchinsonian includes, as well as the strata noted in Target Gully, the greensands of the Oamaru Coastal District (Rifle Butts. Deborah, etc.); the main Mount Brown limestone; the limestones of Winton and Clifden in Southland; and the greensands of the Curiosity Shop, Rakaia River.

From the faunal point of view more detailed subdivision is possible. The following faunules may be differentiated:—

(a.) A brachiopod faunule characteristic of the basal phosphatic horizon in the Oamaru Coastal District. (See Thomson, 1926, p. 150, Table I.) At this horizon *Mopsea hamiltoni* (Thomson) and *Isis dactyla* Tenison-Woods are also noteworthy.

(b.) The *Pachymagas parki* assemblage. Found in the greensands of Hutchinson's Quarry; in the main Mount Brown limestone, Weka Pass; and in the Clifden limestone. Characteristic brachiopods are *Pachymagas parki* (Hutton), *Rhizothyris rhizoida* (Hutt.), *R. scutum* Thomson, *R. elliptica* Thomson, *Waiparia intermedia* Thomson, and *Magadina browni* Thomson.

(c.) The *Pachymagas hectori* assemblage. This is restricted to the greensands of Deborah, the Rifle Butts, Devil's Bridge, etc., in the Oamaru Coastal District.
And

(d.) A molluscan faunule known only from Park's Upper Hutchinsonian of Target Gully. This faunule has not been critically examined.

Park (1918, p. 25) proposed the term Waitakian as an upper substage of the Hutchinsonian. This proposal is discussed in the sequel.

P. G. Morgan (1921, p. 103) suggested that the Hutchinsonian should be merged into the Ototaran; and (1922, p. 52) that it should be included in the Awamoan stage. Neither suggestion warrants serious consideration.

ISLANDIAN Stage. See Mawheranuian System.

KAIATAN Stage. See Mawheranuian System.

KAITANGATAN System or Group.

Proposed by J. A. Thomson (1917, pp. 410-11) for " the Kaitangata upper and lower coal-measures as described by Park (1911) and the intermediate marine horizon, but excludes the Oamaruian coal series and overlying Oamaruian marine rocks which rest unconformably, according to Park, on the Kaitangata coal-measures proper." (1917, p. 410.)

Recent work by M. Ongley (1926) would seem to show that the Kaitangatan of Thomson contains both Tertiary and Cretaceous rock units. Ongley shows that the Kaitangata coal-measures (stated to be of Upper Cretaceous age) are separated from the overlying Taratu coal-measures which include sandstones with marine fossils—the Wangaloa beds—by " a period of elevation, accompanied by tilting or folding and probably by faulting." (1926, p. 83.) These facts made it doubtful whether Thomson's system name should be retained. The matter may perhaps be left until after the publication of the Survey Bulletin dealing with this area. The only marine stage of the Kaitangatan is the Wangaloan, and this will be discussed in the sequel.

MAWHERANUIAN.

Proposed by P. G. Morgan (1918, p. 40; 1922, p. 52) as a group or system name to include strata developed typically in the Greymouth subdivision of North Westland.

Morgan (1911) gave the following sequence (in descending order:—

(a.) Kaiata Mudstone.		2000-3000 feet
(b.) Island Sandstone.		500 feet
(c.) Brunner Beds	i. Coarse sandstones, grits, and pebble-beds.	300-400 feet
	ii. Pebble-beds and conglomerates.	0-400 feet
(d.) Paparoa Beds	i. Upper sandstones and shales.	700-800 feet
	ii. Middle sandstones with minor shales.	500-600 feet
	iii. Lower sandstones and shales.	700-800 feet
	iv. Basal conglomerates with minor sandstones.	0-1000 feet

The coal-measures thus defined are the exact equivalent of Park's " Waimangaroa Series " (1910, pp. 101-7). Morgan (1922, p. 52) therefore proposed Waimangaroan or Mawheranuian. The two terms are exactly equivalent, and since one term only is necessary I select Mawheranuian for the reasons given by Morgan (1911, pp. 53-4). The Mawheranuian may be defined as the period of time represented by the deposition of the Paparoa, Brunner, Island sandstone, and Kaiata beds, together with such periods as may be represented therein by non-deposition or erosion.

Thomson (1916, p. 39) based the non-marine Paparoan Stage on the Paparoa Beds as defined by Morgan. The same author considered that Morgan's conclusion that the Mawheranuian as a whole was older than the Oamaruian, was not justified on palaeontological data, and, therefore, did not base stage names on the Kaiata mudstone, the Island sandstone, or the Brunner beds.

Morgan (1918, p. 40; and 1922, table I, p. 56), however, proposed the Kaiatan, Islandian, and Brunnerian stages for the horizons in question, and regarded the whole of the Mawheranuian as Eocene. The Brunnerian is a non-marine stage, but the Kaiatan and Islandian contain marine fossils which are never abundant.

It is still impossible to define these stages palaeontologically. Hence it is impossible to state that the Mawheranuian System is distinct from the Oamaruian System. It is probable that they are in part at least equivalent.

As regards the Kaiatan and Islandian marine stages it is impossible yet to determine their relationship to the lower stages of the Oamaruian System, viz., Waiarekan, Tahuian, and Bortonian* or to the Wangaloan marine stage of the Kaitangatan System.

In any scheme for the division of Tertiary marine succession in the Dominion, it would seem wisest to omit the Mawheranuian System from consideration until such time as its faunal succession is better understood.

It should also be pointed out that the group name Kaitangatan proposed by Thomson (1917, p. 410) is probably the equivalent of at least part of the Mawheranuian of Morgan, and should take priority.

NGAPARAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the coal-measures at the base of Oamaruian of the Oamaru District. Thomson suggested "that 'Ngaparan' should be restricted to coal-beds, and that a different stage name should be used for the normal marine beds of the same horizon." (1916, p. 35.) This stage name is not further considered in this summary.

NUKUMARUIAN Stage. See Wanganuian System.

OAMARUIAN System.

Proposed by J. Park (1910, pp. 108 et seq.), and used as the equivalent of his "Oamaru Series." The term was given its exact definition by J. A. Thomson (1916, p. 31), who employed it for "the whole Tertiary succession as developed at Oamaru, and its correlatives elsewhere."

As thus defined the Oamaruian includes the Ngaparan coal-measures. The writer prefers to omit this stage because it will be impossible to correlate any marine fossiliferous unit with it. It seems advisable to limit the Oamaruian by reference to marine strata.

* J. Henderson (1929, p. 284) stated, on the authority of J. Marwick, that the Island sandstone at Ten Mile Bluff contains Bortonian fossils.

The Oamaruian may be defined as the interval of time which commenced at the beginning of the Bortonian period and ended at the close of the Awamoan period. The stages so far recognised in the Oamaruian are, in descending order, Awamoan, Hutchinsonian, Waitakian, Ototaran, Waiarekan, Tahuian, and Bortonian.

ONAIROAN Stage. See Taranakian System.

OTOTARAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-5) for the Ototara limestone of the Oamaru District.

Type locality: The selection of a standard area for the Ototaran presents difficulties because the sequence of strata forming this stage has been variously interpreted by different authorities. The Ototaran contains several faunal communities, some definitely in sequence; others possibly facies variants. These are as yet imperfectly understood.

I believe that if one locality were selected as a standard, impetus would be given to the necessary research, and the problem would be considerably clarified. As a working hypothesis I suggest that the type locality for the Ototaran Stage be along the line of section exposed from Trig. V., near Totara, east through Flat Top Hill to Deborah Road.

J. Park (1918, map opposite p. 66) has provided a section along this line.

The sequence (in descending order) is:—

1. Greensands with *Pachymagas* of the *parki* series.

Disconformity.

2. Deborah (or Kakanui) limestone.
3. Deborah tuffs.
4. Oamaru stone.
5. Waiareka tuffs.

The Ototaran may be defined as the period of time represented by the deposition of beds 2 to 4 in the above sequence, and as well such intervals as are represented therein by non-deposition or erosion.

It is at present impossible to cite the characteristic fossils of the Ototaran Stage except in a very general way.

Thomson (1926, p. 152) reported that "at least four more or less distinct brachiopod faunas are found in the Ototaran of the Oamaru coastal district, of which three in the Kakanui neighbourhood are clearly in sequence, viz., those of (1) the calcareous tuffs of Trig. M. and the limestone of Fortification Hill; (2) the Kakanui tuffs; and (3) the limestones of Kakanui and Flat Top Hill (Deborah limestone of Park)." These three divisions apparently correspond to those noted in the type locality.

The brachiopod faunules have not been studied in detail.

The upper—that of the Kakanui or Deborah limestone—contains an abundance of *Liothyrella oamarutica* (Boehm), *Terebratulina oamarutica* Boehm, and *Tegulorhynchia depressa* Th., and *T. sublaevis* Thomson.

The second horizon at Everett's Quarry is the type locality for *Liothyrella boehmi* Thomson. While from the lowest member, the calcareous tuffs, Trig. M., Thomson described *Liothyrella pulchra* Th., and *Terebratella totaraensis* Thomson, both species being abundant.

A fourth brachiopod community—termed by Thomson the *Liothyrella landonensis* fauna—has a wide occurrence wherever the Ototaran presents a glauconitic facies, e.g., at Landon Creek, in the Lower Waihao Valley, etc. Thomson correlated the strata containing this fauna with Kakanui limestone.

The *landonensis* fauna includes *Liothyrella landonensis* Th., *Tegulorhynchia depressa* Th., *Murravia catinuliformis* (Tate), *Terebratulina suessi* (Hutton), *Stethothyris tapirina* (Hutton), and other species enumerated by Thomson (1926, Table II, p. 152).

The lists in Park's Bulletin (1918) show clearly that the Ototaran tufaceous horizons yield a moderately rich molluscan fauna. A revision of this material is very necessary to a complete understanding of the Ototaran period.

PAPAROAN Stage. See Mawheranuian System.

PAREORAN Stage.

Proposed by P. G. Morgan (1918, 1921) as a substitute for the Awamoan Stage of Thomson. The latter was particularly chosen so that " all ambiguity caused by the use of the terms " Pareora series," " Pareora fauna," etc., may be avoided . . ." (Thomson, 1916, p. 34). Morgan's suggestion, therefore, has nothing in its favour.

PETANIAN Stage.

Proposed by P. G. Morgan (1918, p. 40) for the " Petane beds," and placed between the Castlecliffian and Waitotaran. Later, Morgan (1921, pp. 98 and 101) used this term as the equivalent of the Castlecliffian. The Petane beds of Hawke's Bay are Nukumaruian. It is therefore possible to argue that Petanian should replace Nukumaruian.

In the writer's opinion Petanian should be dismissed; it is clearly desirable that the type localities for the divisions of the Wanganuian should be selected from units on the Wanganui Coast.

TAHUIAN Stage.

Proposed by R. S. Allan (1926, 1927) as the upper substage of the Waimateian Stage. It has been granted the rank of a full stage by Marwick (1927).

Type locality: McCullough's Bridge, Lower Waihao River, South Canterbury.

The sequence (in descending order) is:—

1. Waihao limestone.

Disconformity.

2. Upper greensands, 20 feet.

Diastem.

3. Lower greensands, with the upper surface phosphatised.

The Tahuian may be defined as the interval of time represented by the deposition of the upper greensand at McCullough's Bridge, and as well such periods as are represented therein by non-deposition or erosion.

The characteristic mollusca collected by Dr Finlay and the writer are:—*Baryspira morgani* (Allan), *Borsonia rudis* (Hutt.), *Carinacca haasti* Marwick, *C. waihaoensis* (Suter), *Friginatica suturalis* (Hutton), *Gemmula bimarginata* (Suter), *G. complicata* (Suter), *G. waihaoensis* Finlay, *Limopsis waihaoensis* Allan, *Marshallena formosa* (Allan), *M. neozelanica* (Suter), *Nuculana semiteres* (Hutton), *Parvimitra plicatellum* (M. & M.), *P. subplicatellum* Finlay, *Spirocolpus waihaoensis* (Marwick), *Waihaoia allani* Marwick, *Waimatea inconspicua* (Hutt.), *Zeacuminia tahuica* Finlay, and *Zexilia waihaoensis* (Suter).

TARANAKIAN.

Proposed by L. I. Grange (1926, p. 334) as a group name for the period between the Wanganuian and Oamaruian Systems; also as a stage name to include the Onairo beds and the Tongaporutu beds of Taranaki.

It should be noted first that P. G. Morgan had earlier proposed the term Awaterian for strata intermediate between the Wanganuian and the Awamoan, and this term covered " portions of the strata in southern and central Taranaki that conformably underlie undoubted Wanganuian . . ." (1922, p. 52.) Grange does not mention his chief's work, but the two terms are clearly synonymous. However, the strata deposited in the interval between the Wanganuian and the Oamaruian are very fully developed in Taranaki, whereas the sequence in the Awatere Valley is very incompletely known. For this reason the Taranakian is clearly a preferable term, and Morgan's Awaterian Stage should be dismissed.

One must question the wisdom of having a single term for both a group or system name and a stage name. Grange's reasons for the introduction of the term Taranakian are detailed in his report on " The Geology of the Tongaporutu-Ohura Subdivision." (1927.) He there states that the " Onairo beds " of his earlier paper (1926) include only a part of the Onairo Series of Clarke (1912), and this part is now distinguished as the " Urenui beds," a name already adopted by Morgan and Gibson. (1927, p. 32 et seq.)

J. Marwick (1924B) provided a stratigraphical table in which the new stage names Tongaporutuan and Onairoan were proposed, without definition, but obviously for the Tongaporutu and Onairo beds of Grange whose unpublished results were available to him. In a later paper (1926A) Marwick used the terms " Tongaporutuan " and " Urenui beds " for the same time interval. Again (1927) he

combined both series, and employed solely the stage name Taranakian. J. Henderson (1929), however, has used the term Urenuian, without definition, other than is implied in the name.

Judging from the lists of mollusca published by L. I. Grange (1927)* there would seem to be little palaeontological justification for subdividing the strata in question into two units.

The characteristic mollusca of the Tongaporutu beds appear to be:—*Amusium zitteli* (Hutt.), *Ancilla subhebera* Marwick, *Austrofusus cliftonensis* (Marwick), *Cominella hendersoni* Marwick, *Corbula canaliculata* (Hutt.), *Dentalium pareorense* Pils. and Sharp, *Fissidentalium solidum* Hutt., *Neilo sublaevis* Marwick, *Polinices scalptus* (Marwick), and *Zeacolpus vittatus* (Hutt.)

The characteristic mollusca of the Urenui beds appear to be:—*Ancilla subhebera* Marwick, *Austrofusus cliftonensis* (Marwick), *Dentalium otamaringaensis* Marwick, *Fissidentalium solidum* (Hutt.), *Glycymeris rapanuiensis* Marwick, *Neilo sublaevis* Marwick, *Streptopelma henchmani* Marwick, and *Zeacolpus vittatus* (Hutt.).

Of less importance but still apparently abundant are:—*Alcithoe solida* Marwick, *Cominella hendersoni* Marwick, *Divaricella cumingi* (Ad. and Ang.) *Friginatica vaughani* (Marwick), *Nucula otamaringaensis* Marwick, *Polinices propeovatus* (Marwick), *P. scalptus* (Marwick), and *Zeacrypta wilckensi* (Finlay).

It is only fair to state that these lists are not based upon personal observations in the field, but upon the frequency of occurrence in the many lists of fossils supplied by Grange. It is hardly necessary to state that a fossil recorded from numerous localities is not necessarily abundant at the horizon in question. If my lists do, in fact, include the characteristic fossils, or the majority of them, then the differences between the characteristic communities of the Tongaporutu and Urenui beds respectively are not of great importance. They may indicate a zonal distinction, but do not, in my opinion, necessitate the subdivision of these strata into two stages.*

In consideration of the above facts, and since the correlation of the whole of the strata in N.E. Taranaki is not definitely known, I would advocate that the term Taranakian be retained as a group or system name. *It may be defined as the time interval between the Oamaruian and Wanganuian periods as herein defined.*

As regards the stages to be included in the Taranakian System the position is admittedly difficult.

It is clear, however, that the interval represented by the deposition of the Tongaporutu and Urenui beds does not, even approximately, fill this gap.

The pre-Tongaporutu beds, namely, the Mahoenui, Mokau, and Mohakatino beds, may possibly be post-Oamaruian. Again Morgan and Gibson recorded that the Urenui beds " are succeeded disconformably or possibly with slight angular unconformity by beds assigned to the Waitotara formation." (1927, p. 33.)

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* The nomenclature is that of Grange's bulletin; some generic names require revision.

The strata referred to the Waitotaran by Morgan and Gibson " are known to belong to a lower horizon than the type Waitotara beds of the South Taranaki coast line." (1927, p. 43.) They are, therefore, not strictly Waitotaran. The mollusca cited, however, prove that the beds in question are more closely related in time to the Waitotaran than they are to the Urenuian.

Until the uncertainties implicit in this discussion are cleared up it seems best to employ the terms Tongaporutuan and Urenuian as stage names. If they prove to have identical characteristic fossils they should be combined, and a new term proposed. For this I would suggest a name based upon Rapanui Stream.

The type localities for both stages will, no doubt, be defined in terms of the coast sections between Kawau, Whitecliffs, and Waitara.

Summary:—

System.	Stage.
Wanganuian.	Waitotaran.
Taranakian.	(Possible new stage.) Urenuian. Tongaporutuan. (Possible new stage or stages.)
Oamaruian.	Awamoan.

TONGAPORUTUAN Stage. See Taranakian System.

URENUIAN Stage. See Taranakian System.

WAIAREKAN Stage.

Proposed by J. A. Thomson (1916, pp. 34-35) for the " Waiareka tuffs and Enfield-Windsor greensands = Ngapara greensands " of the Oamaru District. Thomson wrote: " Should this stage be too large in comparison with the others, the Waiarekan may be restricted to the tuffs themselves, and the underlying Windsor and Enfield beds may be made the type of a new stage." (1916, p. 35.)

Thomson's suggestion has, in the main, been carried out, for Marwick (1926 B) has restricted the Waiarekan to the tuffs, selecting Lorne as the type locality; and Allan (1926, 1927) based the Tahuian and Bortonian (of Park) upon greensands in the Waihao Valley which are almost certainly the correlatives of Windsor-Enfield-Ngapara greensands mentioned by Thomson.

Type locality: Marwick has proposed " that the hillside immediately west of Lorne be taken as the type locality " (1926 B, p. 307.) The geological details of this hillside are, judging from Marwick's sketch and from his short description, somewhat obscure, and the locality is hardly ideal for a standard.

Marwick*[1] did not state the relative abundance of the species, therefore the whole fauna is here listed (Marwick, 1926 B, p. 310) :— *Chlamys enfieldensis* Marwick*, *Clavatula humerosa* Marwick, *Diplodonta infrequens* Marwick, *Erato vulcania* Marwick, *Eucrassatella media* Marwick*, *Fossularca januaria* Marwick, *Glycymeris lornensis* Marwick, *Kellia antiqua* Marwick, *Limatula trulla* Marwick, *Lornia limata* Marwick, *Mantellum inconspicuum* Marwick, *Nemocardium semitectum* Marwick, *Polinices esdailei* (Marwick), *Semitriton revolutum* (Finlay), *Serpulorbis lornensis* Marwick, *Sigapatella vertex* Marwick*, *Siliquaria senex* Marwick, *Trivia pinguior* Marwick, *Turricula esdailei* Marwick, *Turritella lornensis* Marwick, *T. tophina* Marwick*, *Venericardia benhami* (Thomson), and *Vexillum lornense* Marwick.

From the nature of the lithology one may infer that this assemblage is a facies fauna, and before placing much value on the Waiarekan Stage one would like to know more of similar facies faunas intercalated with the Ototaran limestones. This fauna has never been recognised apart from its peculiar facies, and it may prove that the Waiarekan should be merged with the Ototaran Stage (cf. Henderson (1929), p. 273). This is another problem for future research*[2].

WAIMANGAROAN System. See Mawheranuian System.

WAIMATEIAN Stage.

Proposed by Allan (1926) for the pre-Ototaran marine beds in the Lower Waihao Valley, South Canterbury. It was subdivided into the Tahuian and Bortonian substages. The latter have since been granted the rank of full stages by J. Marwick (1927, p. 573); hence the term Waimateian may lapse.

WAIPIPIAN Stage. See Wanganuian System.

WAITAKIAN Stage.

Proposed by J. Park (1918, p. 25) as a substage of the Hutchinsonian Stage of Thomson, in the following words: " On palaeontological grounds the Hutchinsonian might be divided into two substages—the lower or true Hutchinsonian including the glauconitic greensands, the upper comprising the glauconitic calcareous sandstone that forms the Waitaki stone or Waitakian." (1918, p. 25.)

This definition, as a perusal of Bulletin No. 20 will show, implies the correlation of the Waitaki limestone with certain glauconitic sandy beds below the shell-bed at Target Gully, and these sandy beds

* Marwick (1931, p. 6) reaches a very similar conclusion.

*1 Marwick (1931, p. 4) cites four species of characteristic mollusca. These are followed by an asterisk in the above list.

*2 See Marwick (1931, p. 4).

overlie the Hutchinsonian *parki* greensands. The Waitaki limestone, on the other hand, is known to contain a brachiopod fauna which is definitely pre-Hutchinsonian. (Thomson, 1926.)

The term Waitakian, therefore, connotes two distinct stratigraphical units, and if it is to be retained must be restricted to one or the other.

It is rather doubtful whether a new division is required for the so-called Waitakian of Target Gully. The stratigraphy is not clear in the locality, and G. H. Uttley (1920 B) has argued that Park's Upper Hutchinsonian there is in fact Awamoan. In my opinion the area should be thoroughly reinvestigated before a decision can be reached.

On the other hand, a new or distinct term is certainly required for the Waitaki limestone and the overlying Otiake beds of the Waitaki Valley. Professor Park has spent many years in attempting to prove that the Waitaki limestone is distinct from the limestones of the Oamaru Coastal District, therefore it will be fitting to employ his term, Waitakian, for the former unit. The Waitakian may be granted the rank of a full stage intermediate in position between the Hutchinsonian and the Ototaran.

One may venture to hope that this decision, based upon the combined researches of J. Park, G. H. Uttley, and J. Allan Thomson, will bring to an end the somewhat lengthy controversy which has centred around the " two limestone theory " in the Oamaru District.

The Waitakian may be defined as the interval of time represented by the deposition of the Waitaki limestone and the Otiake beds of the Waitaki Valley, and as well such periods as may be represented therein by non-deposition or erosion.

It is difficult to select a locality in the Waitaki Valley which will provide a complete section of strata contained in the Waitakian Stage. Perhaps Trig. Z., Otiake, comes nearest to the ideal. I select that locality (see Uttley, 1920 A, Fig. 2 on p. 143) as type.

The brachiopod fauna of this stage cannot be listed in detail. It consists of species of the *Pachymagas huttoni* series. The Waitakian overlies strata containing the *Liothyrella landonensis* fauna, and does not contain any species referable to the *Pachymagas parki* series.

Mollusca are rare in the limestone, but very abundant in the overlying Otiake beds.

The characteristic mollusca, based upon collections made by Dr. H. J. Finlay and the writer, and named by the former, include:— *Alocospira hebera* (Hutt.), *Austrofusus affiliatus* Finlay, *Badenia zebina* Finlay, *Baryspira robusta* Marwick, *Cochlis inexpectata* (Finlay), *C. notocenica* (Finlay), *Corbula humerosa* Hutton, *C. kaiparaensis* Suter, *Cucullaea worthingtoni* Hutton, *Dosinula uttleyi* Marwick, *" Euthria " blandiata* Suter, *Fissidentalium solidum* (Hutt.), *Friginatica vaughani* (Marw.), *Gari oamarutica* Finlay, *Globisinum miocaenicum* (Suter), *Kuia vellicata* (Hutt.), *Lentipecten hochstetteri* (Zittel), *Macoma robini* Finlay, *Magnatica planispira* (Suter), *Marginella harrisi* Cossm., *Mesalia striolata* (Hutt.),

Metamelon inermis (Finlay), *Notocallista parki* Marwick, *Ostrea (Gigantostrea) wollastoni* Finlay, *Panope worthingtoni* (Hutt.), *Parasyrinx subalta* (M. & M.), *Poirieria primigena* Finlay, *Polinices obstructus* (Marw.), *Procominula densilirata* Finlay, *Proximitra armorica* (Suter), *Rugobela tenuilirata* (Suter), *Spinomelon residua* (Finlay), *Spissatella trailli* (Hutt.), *Teredo heaphyi* Zittel, *Teremelon tumidior* (Finlay), *Trachycardium waitakiense* Suter, *Waimatea transilis* Finlay, *Zeacrypta wilckensi* (Finlay), *Zeacuminia biplex* (Hutt.), *Zenatia acinaces* Q. & G., and *Zexilia dalli* (Suter).

WAITOTARAN Stage. See Wanganuian System.

WANGALOAN Stage*.

Proposed by P. G. Morgan (1918, p. 40) and employed by J. Marwick (1924 A, p. 172), in both cases without definition, but obviously based upon the " Wangaloa beds " of P. Marshall (1917, pp. 450-60).

Type locality: Wangaloa, Otago.

Precise stratigraphical details of the sequence at Wangaloa will no doubt be found in the forthcoming Survey Bulletin dealing with this area.

The fauna has been described by Marshall (1917), but the nomenclature needs considerable revision.

Recently H. E. Fyfe has discovered an identical fauna, well preserved, at Boulder Hill, near Dunedin. Material from this locality, as well as from Wangaloa, is being described by Dr. H. J. Finlay in collaboration with Dr. J. Marwick, and this report should be published in the near future.

Pending the information to be derived from the two sources indicated, it will be sufficient to state that the fauna of the Wangaloan Stage is the oldest Tertiary fauna known in New Zealand, and that its characteristic mollusca are almost entirely distinct from any that follow them in the Dominion.

Until Marshall's determinations are revised it would be premature to cite a detailed list of the mollusca. Those recently described by Marwick (1924, 1927) may be noted. All (except one) are confined to the Wangaloan Stage, but are not necessarily abundant. They are:—*Amauropsella major* (Marshall), *Dosinia (Kereia) ongleyi* Marwick, *D. perplexa* Marwick, *Finlaya parthiana* Marwick, *Globisinum spirale* (Marshall), *Monalaria minor* (Marshall), *Polinices finlayi* (Marwick), *P. (Euspira) fyfei* (Marwick), and P. *(E.) firmus* (Marwick).

The last named is also found in the Bortonian.

WANGANUIAN System.

Proposed by J. Park (1910) for the sequence of strata exposed on the sea coast between Wanganui and Patea, and adopted by J. A. Thomson (1916).

* Marwick (1931, p. 3) supplies additional data concerning this stage.

The sequence of strata on the Wanganui coast based on J. Park's survey (1887) is as follows, re-quoted from Thomson (1916, p. 36):—

Park, 1887.		Park, 1905.	Park, 1910.
(1.) Wanganui beds: Upper sandy beds. Lower blue clays.	Newer Pliocene.	Wanganui Series.	Petane Series.
(2.) Kai-iwi blue clays.			
(3.) Okehu pumice beds.			
(4.) Okehu sandy shell beds.			
(5.) Nukumaru Rotella beds.			
(6.) Nukumaru limestone—Older	Pliocene.		
(7.) Waitotara Coralline Series: Brown micaceous sandstone. Coralline beds. Yellowish-blue sand clays. Whenuakura blue clays.	Upper Miocene	Te Aute or Waitotara Series.	Waitotara Series.
(8.) Patea blue clays and brown sands.			Awatere Series.

Thomson (1916) based two stage names upon this succession, viz., Castlecliffian for the Wanganui beds and Kai-iwi blue clays, and Waitotaran, based oupon Park's "Waitotara Coralline series." The limit between these stages was purposely, and wisely, left vague.

Marshall and Murdoch (1920) published an excellent account of the faunal changes throughout the Wanganuian, but did not employ stage names.

In a table of classification of strata, prepared by P. G. Morgan (?) and published in a Bulletin by T. H. Withers (1924), it is stated that the Waitotaran "may be subdivided into Nukumaruian and Waipipian," and a footnote adds: "Probably the term 'Waitotaran' as a stage name will drop out of use, and the more exact terms 'Nukumaruian' and 'Waipipian,' based upon Marshall and Murdoch's work (1920) will take its place."

L. I. Grange (1926, p. 334, footnote) has pointed out that this is impossible since Thomson (1916) did not include the Nukumaru beds in his Waitotaran Stage. The Waipipian is the term which must drop out of use.

Marwick (1924 A) divided the Wanganuian into Waipipian, Nukumaruian, and Castlecliffian, but in a later paper (1924 B) Waitotaran was substituted for Waipipian. The same author (1926 A, p. 267) later separated off the Kai-iwi beds because "a preliminary survey indicates that a useful stage may be recognisable between the Nukumaruian and Castlecliffian." Thomson (1916), however, included the Kai-iwi beds in the Castlecliffian. Marwick's latest scheme (1927) distributed the stratigraphical units as follows:—

(a.) Castlecliffian, containing the Castlecliff, Kai-iwi, and Okehu beds.

(b.) Nukumaruian, the Nukumaru beds.

(c.) Waitotaran, all lower divisions on the Wanganui coast.

These various stage names, therefore, have been employed rather loosely, and should be redefined. It is generally admitted that three stages are represented in the sequence, and for these the terms Castlecliffian, Nukumaruian, and Waitotaran have found general acceptance. It is probable that future research will prove that each of these stages contains more than one faunal community. The exact range of these communities is not yet accurately known. However, the writer believes that it would be wise to define the three stages with reference to certain definite stratigraphical units. The minor faunal communities, when their range is established, can form the basis of zones within the major scheme here outlined.

*The Castlecliffian may be defined as the interval of time represented by the deposition of the Wanganui, Kai-iwi, and Okehu beds of Park (1887), and as well such periods as may be represented therein by non-deposition or erosion**.

Henderson (1929) has noted that the lowest beds of the Castlecliffian contain much pumice, and a seam of lignite. He believes that the Castlecliffian strata result from a minor sea transgression which followed uplift at the end of the Nukumaruian period. If this is so the Nukumaruian-Castlecliffian junction may conceal a considerable time interval.

The characteristic mollusca of the Castlecliffian based upon collections made by the writer, and further material in the Finlay collection, and determined by Dr. Finlay, are†:—*Acteon ambiguus* (Hutt.), (= *sulcata* Hutt.), *Aeneator marshalli* (Murdoch), *Alcithoe gracilis* (Swainson), *A. swainsoni* Marwick, *Alocospira novaezelandiae* (Sow.), *Amphidesma pliocenica* Oliver, *Antisolarium egenum* (Gould), *Arthritica bifurca* (Webster), *Astrea heliotropium* (Martyn), *Ataxocerithium huttoni* (Cossm.), *Austrodrillia wanganuiensis* (Hutt.), *Austrofusus glans* (Bolten), *Barbatia novaezelandiae* Smith, *Baryspira (Pinguispira) lata* (Hutton), *B. mucronata* (Sow.), *Cardita aoteana* Finlay, *Chlamys radiatus* (Hutton), *Cochlis australis* (Hutt.), *C. zelandica* (Q. & G.), *Coelotrochus huttoni* (Cossm.), *Coluzea spiralis* (A. Ad.), *Corbula macilenta* Hutt., *Cosa wanganuica* Finlay, *Divaricella cumingi* Ad. and Ang., *Dosinia (Phacosoma) wanganuiensis* Marwick, *Dosinula zelandica* (Gray), "*Drillia*" *buchanani* (Hutt.), *Estea impressa* (Hutt.), *E. semisulcata* (Hutt.), *Eucominia elegantula* Finlay, *Evarnula striata* (Hutt.), *Gari lineolata* (Gray), *Glaphyrina progenitor* Finlay, *Glycymeris laticostata* (Q. & G.), *Iredalula striata* (Hutt.), *Mantellum marwicki* Powell, *Maoricolpus roseus* (Q. & G.), *Maoricrypta costata* (Sow.), *Maurea hodgei* (Hutt.), *Melliteryx parva* (Deshayes), *Murexsul octogonus* (Q. & G.), *Myadora striata* (Q. & G.), *Nemocardium pulchellum* (Gray), *Notocallista multistriata* (Sow.), *Notolepton antipodum* (Filhol), *Nuculana bellula* (A. Ad.), *Ostrea sinuata* Lam.,

* In this connection see Marwick (1931, pp. 7-8).

† This list is characteristic of the Upper Castlecliffian only—records of common species at Kai-iwi are not available to me.

Pachykellya edwardsi Bernard, *Panope zelandica* Q. & G., *Paphirus largillierti (Philippi), Pelicaria vermis* (Martyn), *Phenatoma novaezelandiae* (Reeve), *Pleuromeris zelandica* (Deshayes), *Poirieria zelandica* (Q. & G.), *Pteronotus zelandicus* (Hutt.), *Saxicava australis* Lam., *Scalpomactra scalpellum* (Reeve), *Semicassis multisecta* (Finlay), *Sigapatella inflata* (Hutt.), *Splendrillia laevis* (Hutt.), *Stirocolpus symmetricus* (Hutt.), *Struthiolaria papulosa* (Martyn), *Tawera wanganuiensis* Marwick, *Tellina eugonia* Suter, *T. urinatoria* Suter, *Tugali pliocenica* Finlay, *Venericardia purpurata* (Desh.), *Verconella mandarina* (Duclos), *Xymene plebeja* (Hutt.), *Zeacolpus vittatus* (Hutt.), *Zeatropon ambiguus* (Phil.), *Z. bonneti* (Cossm.), *Zemitrella sulcata* (Hutt.), *Zemysia zelandica* (Gray), *Zenatia acinaces* Q. & G., and *Zethalia zelandica* (A. Adams).

The Nukumaruian may be defined as the interval of time represented by the deposition of the Nukumaru beds as exposed on the Wanganui coast, and as well such periods as are represented therein by non-deposition or erosion.

The characteristic mollusca of the Nukumaruian Stage, based upon personal collections from the type locality, Nukumaru, and determined by Dr. Finlay, are:—*Alcithoe detrita* Marwick, *A. nukumaruensis* (M. & M.), *Anomia undata* Hutton, *Austrovenus crassitesta* Finlay, *Baryspira (Pinguispira) lata* Hutt., *B. (P.) opima* Marwick, *M. mucronata* (Sow.), *Bassina yatei* (Gray), *Cominista obsoleta* Finlay, *Corbula macilenta* Hutt., *Cosa trigonopsis* (Hutt.), *Dosinia (Raina) nukumaruensis* Marwick, *Dosinula zealandica* (Gray), *Estea semisulcata* (Hutton), *Eucominia exoriata* Finlay, *Isognomon zelandicum* (Suter), *Lutraria solida* Hutt., *Maorimactra acuminella* Finlay, *Ostrea sinuata* Lam., *O. (Crassostrea) ingens* Zittel, *Pallium mariae* Finlay, *Pervicacia tristris* (Deshayes), *Pleuromeris zelandica* (Desh.), *Pteromyrtea dispar* (Hutt.), *Tawera subsulcata* (Suter), *Venericardia purpurata* (Desh.), *Verconella allani* Finlay, *Xymene drewi* (Hutt.) and *Zethalia zelandica* (A. Adams).

The Waitotaran may be defined as the interval of time represented by the deposition of the pre-Nukumaruian strata exposed on the Wanganui coast, and as well such periods as are represented therein by non-deposition or erosion.*

An incomplete list of the characteristic mollusca is as follows:—*Alcithoe gatesi* Marwick, *Cardium spatiosum* (Hutt.), *Cochlis haweraensis* (Marwick), *Dosinia (Raina) waipipiensis* Marwick, *Eumarcia plana* Marwick, *Fissidentalium solidum* (Hutt.), *Glycymeris manaiaensis* Marwick, *Lima waipipiensis* (M. & M.), *Miltha neozelanica* M. & M., *Olivella neozelanica* (Hutt.), *Ostrea (Crassostrea) ingens* Zittel, *Pallium mariae* Finlay, *Pelicaria zelandiae* (M. & M.), *Phialopecten triphooki* (Zittel), *Polinices ovuloides* (Marwick), *P. waipipiensis* (Marwick) and *Tawera errans* Marwick.

The stages of the Wanganuian are somewhat loosely defined. The writer believes that further research on this classic coast line

* See Marwick (1931, p. 7).

is necessary before greater precision can be obtained. A continuation of the excellent work carried out by Marshall and Murdoch is most desirable.

T. Wayland Vaughan (1921, p. 738) has suggested that the Wanganuian faunas might logically be discussed with reference to the disconformities noted near Kai-iwi, and at Nukumaru Beach, by Marshall and Murdoch (1920). This has not yet been attempted.

III.—SUMMARY OF CLASSIFICATION.

The classification resulting from the discussions detailed above may be summarised in table form. Diastems or disconformities are indicated by a dotted line (....). New stages may prove necessary at these intervals.

System or Group.	Stages.
Wanganuian.	Castlecliffian. .....(1) Nukumaruian. Waitotaran.
Taranakian.	.....(2) Urenuian. Tongaporutuan. .....(3)
Oamaruian.	Awamoan. .....(4) Hutchinsonian. .....(5) Waitakian. Ototaran. Waiarekan. Tahuian. .....(6) Bortonian.
Kaitangatan (pars).	.....(7) Wangaloan.

The following are non-marine stages:—Brunnerian, Ngaparan, and Paparoan.

The following terms are rejected as being unnecessary, imperfectly defined, or otherwise invalid:—Awaterian, Islandian, Kaiatan, Mawheranuian, Onairoan, Pareoran, Petanian, Waimangaroan, Waimateian, and Waipipian.

Some notes follow on the diastems and disconformities in the table. These are numbered 1 to 7, and will be considered in that order.

No. 1.: Between the Castlecliffian and Nukumaruian. Henderson (1929) believes that the junction of the strata referred to these stages in the type locality conceals a time break during which the main Kaikoura movements occurred.

No. 2.: Between the Waitotaran and the Urenuian. Morgan and Gibson (1927) record that the Urenui beds are succeeded disconformably by beds assigned to the Waitotaran, but these beds "assigned to the Waitotaran" "are known to belong to a lower horizon than the type Waitotara beds of the South Taranaki coast line." (1927, p. 43.)

No. 3.: Between the Tongaporutuan and the Awamoan. It may prove that part of the pre-Tongaporutuan beds of Taranaki are post-Awamoan.

No. 4.: Between the Awamoan and Hutchinsonian. Unpublished evidence proves that the Awamoan-Hutchinsonian boundary in the Oamaru Coastal District conceals a long time interval. The bulk of the Clifden beds, the Pakaurangi Point beds*, and other strata were deposited at this time. Further details will appear in a future paper by Dr. H. J. Finlay and the writer.

No. 5.: Between the Hutchinsonian and the Waitakian. This break is postulated because it is not certain that the Waitakian completely fills the interval between the Ototaran and the Hutchinsonian. No junction between strata of Waitakian and Hutchinsonian age is yet known.

No. 6.: Between the Tahuian and Bortonian. The phosphatised upper surface of the Bortonian greensands at McCullough's Bridge no doubt indicates a diastem. Judging by palaeontological evidence any break at this junction must be of small time significance.

No. 7.: Between the Bortonian and the Wangaloan. The mollusca of these stages have little in common. The inference is that a considerable time interval separates them.

IV.—SOME GENERAL CONCLUSIONS.

In an excellent summary of the Late Cretaceous and Tertiary Rocks of New Zealand, J. Henderson (1929) suggested that the strata in question "are divisible into three groups on diastrophic grounds. The youngest, deposited after the main Kaikoura movements had ceased, form the Castlecliff beds, and their correlatives in other parts of New Zealand. The other and much more important groups were laid down during the relatively quiescent period between the Hokanui and Kaikoura orogenies." (1929, p. 294.)

* Marshall. 1918.

If I understand it correctly, Henderson's thesis may be summarised as follows:—

1. Castlecliffian (minor sea transgression).
   .....main Kaikoura movements.
2. Hutchinsonian to Nukumaruian (period of sea retreat).
3. Late Cretaceous to Ototaran (period of sea transgression and base levelling).
   .....Hokanui movements.

Henderson stated that " the erosion interval above the Ototaran beds . . . is taken as separating one group of beds from the other " (i.e., two from three). The reasons are (1) that the Ototaran deposits are the most calcareous of any sets of beds; (2) that they were deposited during the period of maximum sea transgression; and (3) that a great change in the position of the areas where waste accumulated occurred after the close of the Ototaran. (1929, p. 294.)

These conclusions are open to serious criticism:—

(1.) Because they are based upon very questionable correlations.

(2.) Because the Waitakian Stage, intermediate between the Ototaran and Hutchinsonian, is not considered.

In the Hutchinsonian Henderson includes (a.) the Pakaurangi Point beds; (b.) the Mahoenui beds of Taranaki; (c.) the Ihungia Series of the East Cape; (d.) the Lower Mount Brown beds; (e.) the Hutchinson's Quarry beds; and (f.) the bulk of the Clifden beds.

Of these (d.) and (e.) are undoubtedly Hutchinsonian, but the others are all doubtful.

Henderson further included the Winton and Clifden limestones in the Ototaran, whereas both contain very typical Hutchinsonian brachiopod assemblages.

The bulk of the strata at Clifden, as well as the Pakaurangi Point beds, and the uppermost Mount Brown beds are post-Hutchinsonian, but pre-Awamoan.

I must conclude from these facts that the problem is much more complicated than Henderson infers. A single marine transgression and retreat with the Ototaran rocks representing the period of maximum transgression hardly meets the case.

In the South Island, at least, Hutchinsonian rocks are more widespread, and just as calcareous as the Ototaran.

Concerning the relationship of the Castlecliffian to the Kaikoura orogeny, the only evidence I can find in Henderson's paper follows from the correlation of the Waipaoa Series of the East Cape with the Castlecliffian.

The reason for this correlation is not given. Henderson and Ongley (1920, pp. 50-51) both regard the Waipaoa Series as Older Pleistocene*.

Additional details of the fauna and flora of the Waipaoa Series are provided by W. R. B. Oliver (1928). As far as the mollusca

* The latter authors add that this series belongs " perhaps to the Upper Pliocene."

are concerned the sole evidence for the Castlecliffian age of the series consists of the presence of *Acteon sulcatus* (Hutt.). From his palaeobotanical studies, however, Oliver concluded that the age of the Waipaoa Series was " not younger than later Pliocene." (1928, p. 288.)

This evidence appears to the writer to be altogether inconclusive. The correlation of the Castlecliffian and the Waipaoa Series upon the molluscan evidence—a single species—is most questionable. Correlation between these two units on palaeobotanical evidence is impossible. If Oliver's conclusion be accepted it does not follow that the two units are correlatives. Both could be " Upper Pliocene " without being equivalent.

Henderson's conclusion concerning the date of the Kaikoura orogeny can hardly be accepted on the data presented.

In this paper most weight has been given to the communities of mollusca and brachiopoda. The Tertiary foraminifera, shark's teeth, and cirripedes have been described, but as far as I can judge are not of much value for purposes of correlation. It is a matter of regret that the bryozoa, corals, and echinoderms are very imperfectly known. Bryozoa in particular are very abundant in our Tertiary rocks, and might well provide valuable data.

It may be suggested with some reasonableness that the adjectival form such as Ototaran, Tahuian, etc., should be reserved by stratigraphers for stage names. If, as has been the case, adjectival terms are used for local series, confusion will be inevitable.

Thus M. Ongley (1924, p. 171) has used the term Ihungian for the Ihungia Series of the Waiapu Subdivision. (Ongley and Macpherson, 1928, pp. 35-9.)

Finlay and McDowall (1924, p. 536) wrote " Mokauian " instead of Mokau beds.

Again Morgan (1921, p. 5), Powell and Bartrum (1929), and Henderson (1929, p. 277) have used the term " Waitematan " instead of " Waitemata beds."

None of the authorities cited intended to propose new stage names, but why add difficulties to what is already a sufficiently difficult matter?

Finally the writer puts forward a plea for greater accuracy in the use of stage names. These are scientific terms, and should have a precise meaning. In particular new stage names should not be proposed unless stratigraphical or palaeontological evidence demonstrates clearly that they are necessary.

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