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Standard Sections and Subdivisions of the Castlecliffian and Nukumaruan Stages in the New Zealand Pliocene.

By C. A. Fleming, N.Z. Geological Survey.

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Introduction.

The Castlecliffian Stage was proposed by Thomson (1916, p. 36) for the upper part of the continuous succession of beds exposed on the sea coast between Wanganui and Patea—the "Wanganui beds" and "Wanganui series" of Park (1887 and 1905). Thomson based the name on Castlecliff, "the point at which Park's section along the coast commences," and left the limit between the Castlecliffian and underlying Waitotaran vague, noting the possibility of an intermediate stage.

Influenced by Marshall and Murdoch's work on the Wanganui coast section (1920, 1921), Morgan (1924, p. 43, footnote to table) introduced the term "Nukumaruian" as a stage-name, without definition. Marwick, in his papers on the systematics of molluscan groups (1924A and B), continued the use of the Nukumaruian (emended to Nukumaruan, 1926) as a stage between the Waitotaran and Castlecliffian and later (1931, p. 7) indicated that the name was based on Marshall's (1919B) Nukumaru Series, from which Marshall and Murdoch (1920, p. 123) listed a fauna from beds outcropping on the coast "over a distance of one mile south" (really east) "from the Nukumaru boat-landing." Allan (1933) defined the Nukumaruian Stage as the "interval of time represented by the deposition of the Nukumaru beds on the Wanganui coast," naming Nukumaru the type locality.

The boundary between the two stages has, in general, been left vague. Marwick (1926A) kept the Kai Iwi beds separate from the Castlecliffian, but later reunited them, noting, however (1931, p. 78), strong physical and palaeontological evidence for an important break between the Kai Iwi and Castlecliff beds. He stated that the Kai Iwi fauna (in beds between Butler's Creek and the disconformity near Castlecliff) is more distinct from that of the Castlecliffian than the Castlecliffian is from the Recent, but included in the Castlecliffian all the beds "from the shell conglomerate at the eastern end of Nukumaru beach to Castlecliff," "until more field work has been done." Allan (*op. cit.*, p. 101) also accepted these provisional limits, defining the Castlecliffian as covering the period of "deposition of the Wanganui, Kai Iwi and Okehu beds of Park (1887)." The latter definition (which is a "time" rather than "stratigraphic" one) includes the Landguard Bluff, Putiki, Shakespeare Cliff, and other occurrences away from the coast section. Finlay and Marwick (1940, p. 128) quoted "Landguard Bluff to Butler's (Ototoka) Creek, west of Wanganui," as the type locality of the Castlecliffian.

Schenck and Muller (1941) have made a valuable contribution to stratigraphic terminology by emphasising that "stages" and similar terms used for correlation are used in a "time stratigraphic" sense. They defined time stratigraphic units (*loc. cit.*, p. 1423) as "material stratigraphic units consisting of sediments deposited during a given time interval" with "time boundaries only," "established primarily on a palaeontologic basis and, as a result . . . to a considerable degree subjective" and "more or less arbitrarily fixed." In spite of the subjective nature of stage limits, it is both customary and desirable to designate a type locality or type section for each stage, with the admission that the stage may include beds deposited either before or after those at the type locality, depending on the judgment of the worker. Thus, in the present instance, Thomson based Castlecliffian Stage on "the point at which Park's section along the coast commences," and explicitly excluded from the type locality Landguard Bluff and other localities, which, however, he, and all subsequent writers, embraced in the Castlecliffian Stage. It is desirable to adhere to Thomson's designation as future investigators may choose to split the Castlecliffian (as at present conceived) into two or more stages; the restricted Castlecliffian would then always apply to that part of the coast section nearest Castlecliff.

Contemporary usage of the term Castlecliffian, both in published papers and in the manuscript reports of oil companies, embraces not only the exact lateral equivalents of the sediments in the type locality, but also beds above and below them, represented in the Wanganui area by the Putiki-Landguard Bluff sequence and by the beds on the coast north-west of Castlecliff to the mouth of Butler's (= Ototoka) Creek. Similarly, the Nukumaruan, implicitly based on Marshall's Nukumaru Series (beds outcropping over a distance one mile east of Nukumaru boat-landing), is currently interpreted as including also the Nukumaru shell-limestone to the west and all beds between Nukumaru and Ototoka Creek to the east.

Laws (1940, p. 45) has recently extended the Nukumaruan still further to include beds stratigraphically below the Nukumaru limestone at Wilkie's Bluff and Mangapani, in the Waitotara Valley. In doing so, he noted that the Wilkie's Bluff beds were stated by Park (1887, p. 64) to be the finest exposure of his Coralline series, on which the Waitotaran Stage was based (Thomson, 1916, p. 36). Park's Coralline series included "the soft brown micaceous sandstones underlying the Nukumaru limestone, the coralline beds and yellowish-blue sandy clays at Waitotara, and the Whenuakura blue clays," but if any restriction within this series of sediments is warranted, it must be the "Coralline Beds," which are the essential part of the "Waitotara Coralline series," and must be included in the type beds of the Waitotaran stage. Laws has thus advocated the inclusion within the Nukumaruan of the beds which are the basis of the (prior) Waitotaran Stage, having shown by empirical analysis that the affinities of the Wilkie's Bluff fauna are with that at Nukumaru rather than with the Waipipi-Hawera faunas which have long but erroneously been considered "typical" Waitotaran. Solution of the problem is beyond the scope of this paper, but is mentioned as it has a bearing on the status of the beds in Southern Hawke's

Bay classified by the Geological Survey (Lillie and Fleming, 1941; Fleming, 1944), and independently, in the Manawatu basin, by Superior Oil Company (1943), as "Lower Nukumaruan." These beds were separated because of faunal differences from the underlying "Waitotaran" *(sic)* correlatives of the Waipipi-Hawera beds and from the overlying Nukumaruan beds. There may be direct continuity between the "Lower Nukumaru Formation" of Superior Oil Company and the "coralline" beds at Waitotara, so that solution of the Waitotaran-Nukumaruan problem must take into account these southern beds, with their distinctive cold-water fauna in Manawatu and southern Hawke's Bay.

This paper is not greatly concerned with the "time stratigraphic" stage concepts, but is an attempt to describe and classify, in more detail than has previously been done, the section along the coast from Nukumaru to Castlecliff (which includes the type localities of the Nukumaruan and Castlecliffian stages) and also those parts of the Castlecliffian sequence on the south-east bank of the Wanganui River which are not covered by the coast section.

In April, 1886, Professor James Park made the first systematic examination of the richly fossiliferous marine sediments of the coastal section between Wanganui and Waitotara, and based his classification of the late Tertiary rocks of West Wellington and Taranaki, in part, upon this section. In 1920, and again in 1921, Marshall and Murdoch published papers on the results of their collections of molluscan fossils from various points between Wanganui and Hawera. These papers have greatly influenced palaeontologists during the past two decades and it has been generally recognised that the coast section north-west from Wanganui offers opportunities unsurpassed elsewhere in New Zealand for detailed biostratigraphic studies. Allan (1932) pointed out the scope for study of faunal sequences, of lineage groups, of facies relations and for environmental reconstruction in the Wanganui section, and Powell (1929, p. 610) cited instances of the relevance of his classification of Recent bottom deposits and communities to the interpretation of Castlecliffian communities. Systematic and faunistic papers touching on parts of the sequence have been published by Marwick, Powell (1931), and Laws (1940).

Dr. J. Marwick, Professor R. S. Allan, and Mr. A. W. B. Powell have each independently done some field work to establish a sequence of faunal zones, but have so far published neither detailed stratigraphic descriptions nor faunal lists. Professor Allan's classification of the beds was published, in part, by Marwick (1938, p. 69). To enable correlation of his classification with the present one, Professor Allan's designations are noted in parenthesis at the head of the account of each bed, preceded by the initials R. S. A.

ACKNOWLEDGMENTS.

I am indebted to Professor R. S. Allan, Canterbury University College, Mr A. W. B. Powell, Auckland War Memorial Museum, and Dr. J. Marwick, New Zealand Geological Survey, for the benefit of discussion and advice on a subject they have each studied in the past. My thanks are due to the Trustees of the Alexander Museum, Wanganui, for generously providing accommodation for draughting

and for packing collections during the field season of 1945. I am grateful to the Director, Geological Survey, for permission to publish this paper.

FIELD WORK AND SCOPE.

In the summer of 1944-45 work on the regional survey of the Wanganui Subdivision by the New Zealand Geological Survey began with a measurement of the 11 miles of coastal section from Castlecliff to Nukumaru. At intervals along the coast, averaging 17 chains, stations were established and vertical sections drawn up by repeated reading of barometric heights at significant horizons on the cliffs. From the information thus obtained, a diagrammatic section was plotted and the recognisable beds indicated. Strictly localised fossil collections were then made from each bed, and from subdivisions of those beds in which faunal changes made this course desirable.

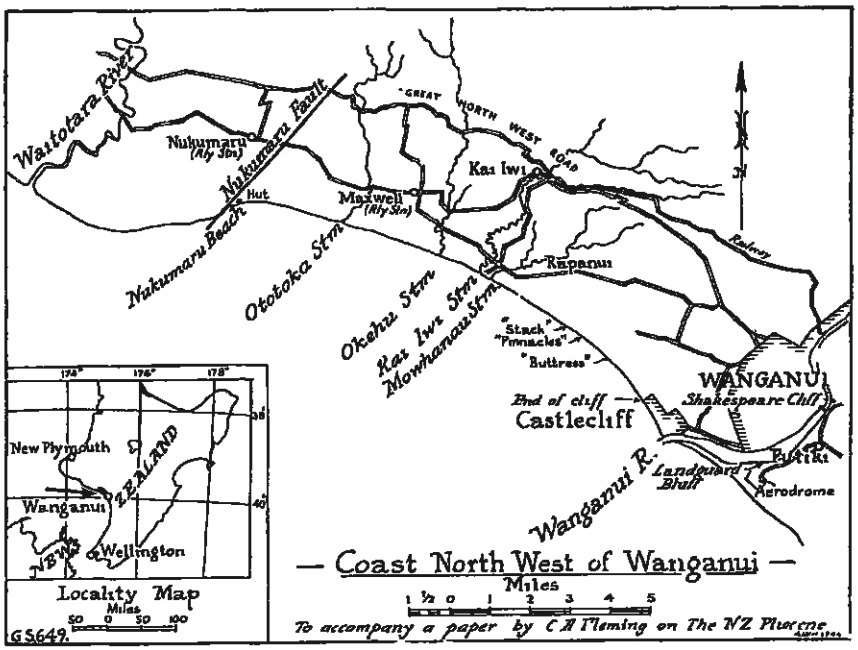
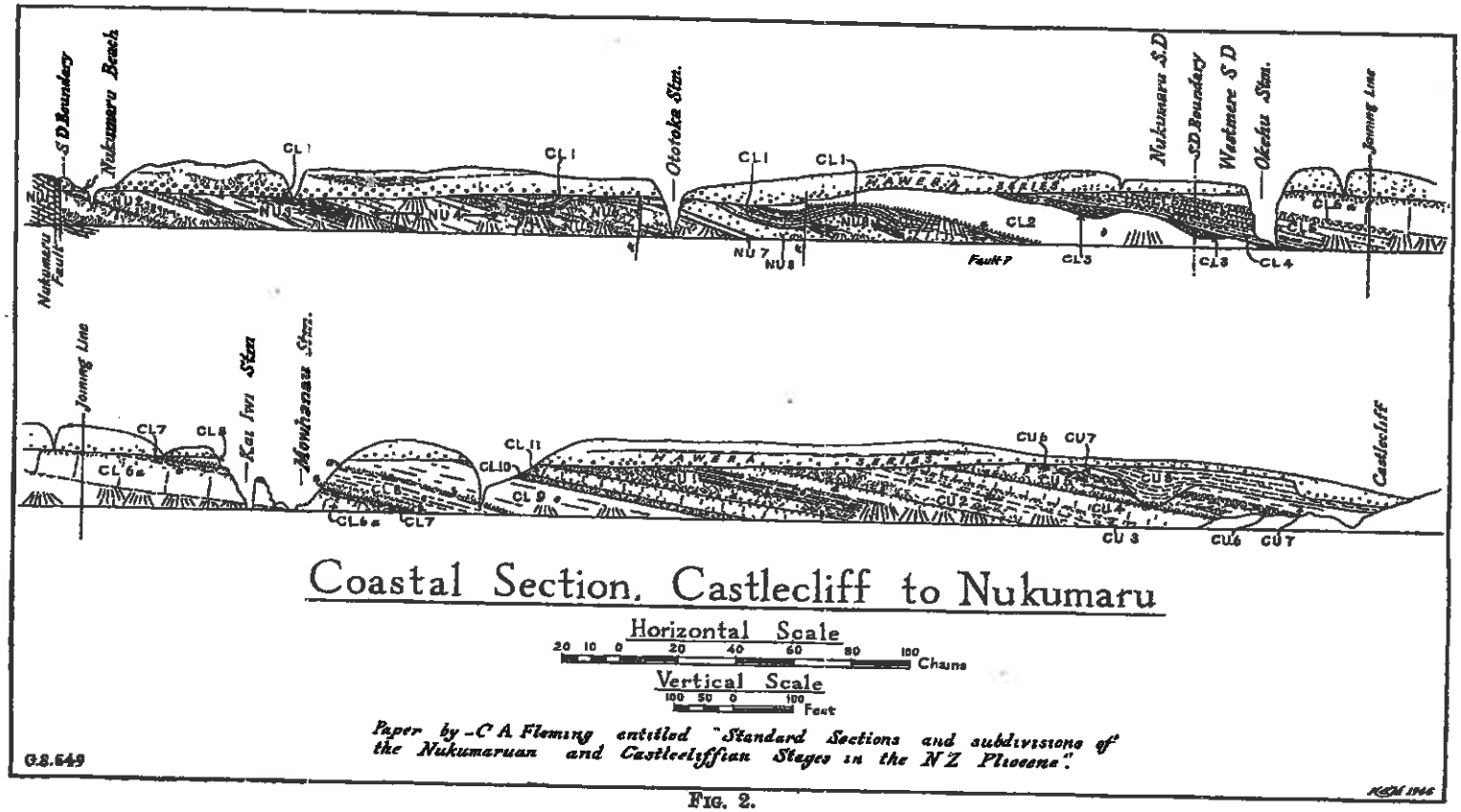


FIG. 1.

Early in the summer a system of notation for the various members and beds was devised and soon became stabilized, owing to the necessity of consistent labelling of fossil collections. A letter-number system has been used, similar to that employed by Gage and Wellman (1944) at Koiterangi, Westland, and by Gage at Ross (1945). Where possible, terms based on lithology (such as "Lower Kai Iwi Blue Silts") or zonal fossils (such as "Tainui Shellbed") have been used to supplement the code notation. Separate notations are given to the small sections at Putiki and Landguard Bluff.

It is hoped that a number of students on various stratigraphic and palaeontologic topics will be able to utilise this classification, which is presented in advance of detailed faunal treatment to allow



Coastal Section, Castlecliff to Nukumaru

Horizontal Scale

20 10 0 20 40 60 80 100 Chains

Vertical Scale

100 50 0 100 Feet

Paper by C. A. Fleming entitled "Standard Sections and subdivisions of the Nukumaruan and Castlecliffian Stages in the N.Z. Pliocene".

G.S. 649

FIG. 2.

citation in papers in preparation. These include ecological studies by Mr. A. W. B. Powell, Auckland War Museum, who has worked intermittently on the subject since his field trip in 1931 (in which the writer was privileged to participate) and who revisited the area in the course of the 1945 work.

STRATIGRAPHIC TERMINOLOGY.

The lateral equivalents of the beds at Nukumaru have been mapped as a formation, Upper Nukumaru (Petane) formation, by Superior Oil Company, and the lateral equivalents of the higher beds as the Castlecliff formation. The lithologic unit mapped as a formation is regarded as roughly equivalent in rank to the time-stratigraphic "stage" unit (Sutton, 1940, p. 1400). In the present instance, the Castlecliff and Nukumaru formations are the beds on which the Castlecliffian and Nukumaruan Stages are based, the boundaries being considered coincident, in the present state of our knowledge of the palaeontology of the two formations, i.e., there seems no reason to doubt that the best break between the subjective biostratigraphic concepts, Nukumaruan and Castlecliffian, corresponds with the lithologic break between the formations. There would appear to be no objection and much precedence in New Zealand and elsewhere for the use of the same geographic name for the lithologic and the time-stratigraphic units (see Tomlinson *et al.*, 1940).

In the accompanying columns (Figs. 4, 5, and 8) the headings, Nukumaruan beds, Lower Castlecliffian beds, etc., are informal abbreviations for "beds of Nukumaruan age," "lower beds of Castlecliffian age," and are not to be interpreted as use of the "-ian" stage suffix for a lithologic unit.

The finer subdivisions of the sequence which have been given code designations and, in most cases, informal vernacular names, have the rank of members (or perhaps of lentils or tongues). It has been recommended (Ashley *et al.*, 1939) that such units be named geographically in the same way as formations, but I have preferred to leave the names informal and have not hesitated to use names of characteristic fossils when geographic terms were not readily available. Such fossils in some cases are of purely ecological significance (e.g., *Chione-Potamopyrgus* silts) and in others are restricted to the bed (e.g., *Tainui* shellbed). Preliminary palaeontological study suggests that some of the beds (members) and groups of beds are characterized by restricted mollusca, and thus of zonal rank (Sutton, *et. al.* op. cit., p. 1406).

GENERAL DESCRIPTION.

From Castlecliff, at a point 124 chains north-west of North Mole at the mouth of the Wanganui River, to Nukumaru, 11 miles to the north-west, the coastline consists of youthful cliffs cut in gently-dipping marine Pliocene sediments, unconformably overlain by almost horizontal Late Pleistocene gravels and sands of the Rapanui formation of the Hawera Series (Fleming, 1946; see appendix to this paper). The cut surface at the base of the Pleistocene truncates the monocline of Pliocene beds at a height of 60-100ft above high-water level, which is the base on which the section (Fig. 1) is drawn. The section is interrupted by the mouths of the Mowhanau, Kai-Iwi,

Okehu, Ototoka, and several minor streams, but this interruption nowhere seriously affects the continuity of the beds.

The beds at Castlecliff strike about 80° east of north and dip to the south at 2° to 4°. Near Nukumaru the strike is more to the north-east and the dip locally approaches 8°. At the west end of Nukumaru Beach an important north-east-trending fault zone (the Nukumaru Fault of Superior Oil Company) upthrows resistant shelly conglomerates to the north-west some 80-100ft. against overlying Nukumaruan sands to the south-east. On either side of Ototoka Stream, faults with insignificant down-throw to the north-west are none the less important as indicating successive movements in at least three periods—pre-Castlecliffian, post-Castlecliffian, and post-Rapanui Pleistocene.

Nukumaruan: The oldest rocks in the section are the pebbly and sandy shell-limestones on the upthrow side of the Nukumaru Fault where they form a broad promontory between Nukumaru Beach and the mouth of the Waitotara River. These are included in the Nukumaruan as NU 1, but on the coast their base is difficult to define and their subdivision into minor units is not possible at present. Inland exposures of this Nukumaru Limestone show it to consist of discrete lenses of " shell-rock " in loose, barren sands, with a basal pebbly sand overlying the more consolidated muddy-sandstones of the Upper Waitotaran. There is a suggestion of disconformity which is supported by the occurrence of Upper Waitotaran derived fossils in the lower shell reefs of the Nukumaru formation. On the coast, west of the plotted section, an extensive area of shell reefs represents these horizons and is quarried for agricultural lime.

FIG. 3. Nukumaru Beach. View looking west towards promontory showing the planes of two splinters of the Nukumaru fault. Resistant Nukumaru shell-limestone (NU 1) forming the promontory is faulted against the Nukumaru brown sands (NU 2) on right of sketch. Drawn from a photograph.

South-east of the fault, two splinters of which are beautifully exposed at the west end of Nukumaru Beach (Fig. 3), what appears to be the top of the shell-limestone is present a foot or so above beach level, and is overlain by the sands of the type section of the Nuku-

maruan (here designated NU 2). Estuarine and locally terrestrial sediments with intercalated marine phases, overlying to the south-east, comprise beds NU 3 to NU 8, and extend to a point 3¼ miles beyond Ototoka Stream, where they are overlain by the lowest Castlecliffian bed (CL 1).

The Nukumaruan part of the section is the least satisfactory to map and subdivide. Featureless mudstones, siltstones and sandstones of paralic facies with no persistent or conspicuous marker-bands contain lignitic and marine (fossiliferous) horizons which are generally discontinuous. Also, the cliffs are not being actively eroded and are now more completely mantled with talus and vegetation than they were 20 years ago (Dr. J. Marwick, personal communication) and than those further south-east are now. The Nukumaru beds have been subdivided broadly into zones in which marine, estuarine, and terrestrial conditions appear to have been dominant. More detailed work, such as might be undertaken in the future for pollen-analysis studies of the lignitic bands, would result in finer subdivision.

Castlecliffian: The Castlecliffian beds have been divided into two series, an upper and a lower, with separate notation, CL 1 to 11 for the lower and CU 1 to 8 for the upper. The separation is made at the well-known stratigraphic break between Castlecliff and Kai Iwi described by Marwick (1931, p. 7). There is a number of faunal distinctions between the two subdivisions of the Castlecliffian (of which the upper includes the designated type locality) and a change in sedimentation. The Lower Castlecliffian contains rhyolitic pumice conglomerates and pumiceous sediment at a number of horizons (CL 1, CL 5, CL 9a, CL 10), whereas fresh pumice is conspicuous only at the base of the upper beds. Andesitic pebbles were noted in the basal conglomerate of the upper beds, but not in the lower. Inland, the Lower Castlecliffian beds are dominated by pumiceous sediments and the upper by heavy greywacke and igneous conglomerates.

Though the stratigraphic break between the Upper and Lower Castlecliff beds is conspicuous, it is far from being the only (though it may be the most important) break in the section, which consists of a rapidly varying sequence of littoral and sublittoral silts and sands, shellbeds containing both biocoenotic and thanatocoenotic elements (Hesse, Allee, and Schmidt, 1937), beach deposits, and estuarine silts and sands. In general, a wave-cut or scoured surface is immediately followed by coarse and then fine sediment, and shellbeds may occur at the bottom, at the top, or within such a sequence. Strong local scouring has carved deep irregular channels in the beds underlying CL 1, CL 3, and CU 8; wave-planed surfaces, locally bored by the intertidal mollusc *Anchomasa* and overlain by coarse beach or shallow-water conglomerates or shellbeds, occur below CL 2, CL 4, CL 8, CL 9, CL 10, CU 1, CU 5, CU 8. Such littoral and sublittoral horizons are separated by sandstones, mudstones, and siltstones of fine or medium texture, massive at CL 6, CL 11, CU 3, CU 4, and CU 7, and laminated or flaggy, with alternating fine and coarse bedding, at CL 2, CL 4, CL 8, CL 9, and CU 8. As a rule, massive (unbedded) beds are fossiliferous, and laminated, alternating beds almost barren. The shellbeds (CL 7, CL 10, CU 2a, CU 3, CU 6) composed of concentrated biocoenotic faunal elements of off-shore

benthic facies present an unsolved ecological problem. Faunally they are more closely related to the generally finer textured massive and sparsely fossiliferous beds (CL 6, etc.) than to coarser textured littoral shellbeds composed of thanatocoenotic elements.

The highest bed on the coast, CU 8, disappears under a mantle of blown sands at Castlecliff and is believed to reappear as unfossiliferous siltstone on the north bank of the Wanganui River near Castlecliff wharf. Still higher Castlecliffian beds occur at Putiki and Landguard Bluff on the south bank of the Wanganui, and as these are classic fossil localities, brief descriptions are given of the beds there exposed and their probable stratigraphic relation to the coast section.

Conditions of Deposition.

The general environmental picture is of relatively frequent repetitions, wholly or in part, of a succession of biotopes. Each succession commences with a shoreline phase of wave cutting, scouring and accumulation of beach deposits, and culminates in quieter, off-shore sedimentation below the local effective wave-base. Occasional gradual reversals of the sequence occurred prior to interruption and repetition of the succession. The controlling force has been the discontinuous diastrophic tilting of a geosynclinal margin, relative to successive base levels which determined the extent of erosion and deposition.

Several of the stratigraphic breaks marked by bored or scoured surfaces are at least locally unconformable on the next underlying bedding plane. The angle of unconformity can seldom be seen or measured, but is calculable from the thinning of the underlying bed. Thus CL 11 appears to thin from 25 feet to 18 feet in less than a mile; CU 4 and CU 7 also thin in the same direction*.

In a few instances (CL 1, CU 6) coarsening and faunal changes within a bed up the dip suggest that the present attitude of the beds is merely an exaggeration of the original depositional slope. The increase in dip with age of beds and the observed thinning up the dip of individual beds, with other evidence, point to intermittent cumulative tilting during their depostion. Fossils characteristic of and in some cases confined (in a biocoenotic condition) to a particular zone are not infrequently found derived above the succeeding erosion surface in a bed 50–100 feet stratigraphically higher. Thus, erosion of a deposit along its landward edge occurred shortly after its deposition, while later sediments were accumulating seaward. Tilting occurred about axes close to the Castlecliffian shorelines, which fluctuated back and forth across the Wanganui section. When the axis of tilting lay seaward, negative movement of strand-line allowed wave attack on the landward margin of earlier sediments; when it lay inland, positive movement allowed accumulation of sediment at depths below the profile of equilibrium.

The beds at Castlecliff lie on the margins of the Palmerston-Wanganui Basin (see Ongley, 1945, for map), a Pliocene geosynclinal area which subsided and allowed the deposition of over 3,000 feet of Castlecliffian sediment in its deepest parts (Superior Oil Co.,

* Since vertical measurements in the present work were all made by aneroid barometer, it is difficult to be certain of the small differences in thickness involved.

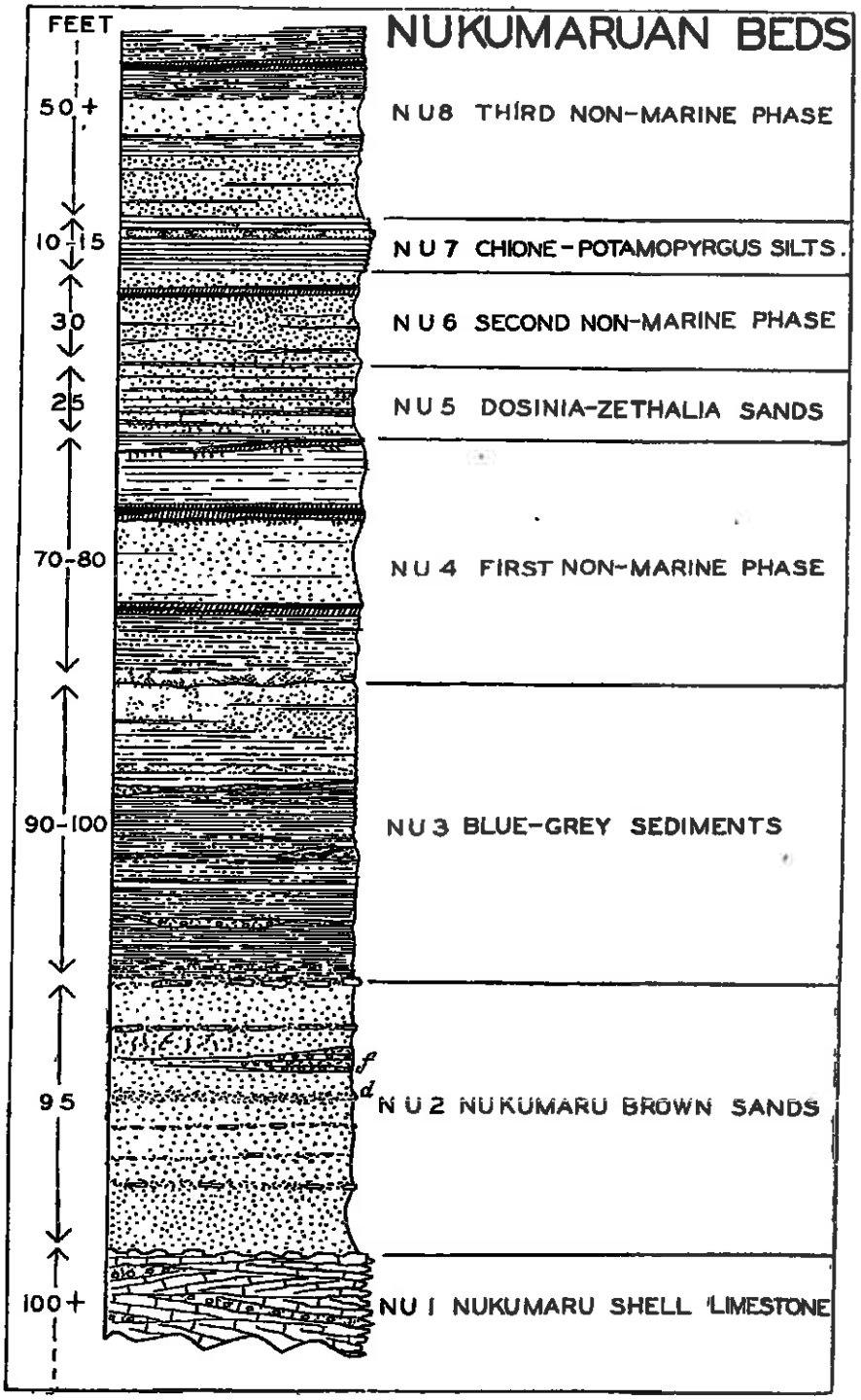


Fig. 4. Nukumaruan beds. Stratigraphic column of Nukumaruan beds on coast for four miles south-west of Nukumaru Beach, including the type beds of the Nukumaruan stage (NU 2).

1943). At Castlecliff, near the boundary between that basin and the emerging monocline of South Taranaki, elevation was subordinate to sinking and sedimentation; but less than 1,000 feet of Castlecliffian sediment was deposited.

Nukumaruan Beds (Fig. 4).

Classification.

NU 8. Third Non-marine Member.
NU 7. *Chione-Potamopyrgus* Siltstone.
NU 6. Second Non-marine Member.
NU 5. Marine Sands with Mollusca.
NU 4. First Non-marine Member.
NU 3. Marine and Estuarine Blue-grey Silts and Clays with Discontinuous Fossiliferous Lenses.
NU 2. Nukumaru Brown Sands: Loose marine sands with richly fossiliferous shellbeds, concretionary shellbeds and conglomerate.
NU 1. Nukumaru Shell-limestone.

Description.

NU 1. Nukumaru Shell Limestone.

Exposure: At the foot of the cliff for some four chains south-east of the plane of the Nukumaru Fault, and extensively on and around the low promontory on the upthrown side of the fault.

Lithology: Coquina limestone, coarse fossiliferous sands, and shelly quartzite-greywacke conglomerates, coarsely current bedded, with local concretionary cemented bands.

Fauna: Abundant, mainly thanatocoenotic, mollusca, brachipods and echinoids from several distinct biotopes; some biocoenotic elements; preservation variable; derived (allocthonous) molluscan shells not uncommon.

Contacts: Base not seen; top an irregular concretionary surface, the hollows filled with fossiliferous loose sands grading into basal sand of NU 2.

Thickness: Some hundreds of feet; cannot be measured on coast.

Remarks: Detailed work might enable subdivision, but this was not attempted. The Nukumaru Fault upthrows the top of the bed 65 feet at the first splinter and a further 15–20 feet at the second.

NU 2. Nukumaru Brown Sands.

Exposure: Between the Nukumaru Fault and a point some 50 chains south-east from the Nukumaru Beach hut site*.

Lithology: Loose, fine to coarse brown sands with shellbeds, concretionary bands and a lens of quartzite-argillite shelly conglomerate.

Fauna: Abundant mollusca, and echinoid (*Arachnoides*), mainly autocthonous; preservation variable.

Contacts: Base grading into fossiliferous sand at top of NU 1; top conformable under NU 3.

Thickness: About 95 feet.

* The site of the hut, dismantled in 1944, is shown on the Waverley sheet (N. 137) of the Provisional 1 Mile Series maps (Department of Lands and Survey) some 5 chains from the beach up a dry gully (grid reference 331957).

Subdivision: NU 2a, barren brown sand, 20 feet. NU 2b, muddy coarse sand, abundant *Tawera subsulcata* (Suter) with *Acominia, Eumarcia, Spisula, Lutraria,* etc. NU 2c, loose sands alternating with lensing shellbeds with dominant *Zethalia.* NU 2d, rich shellbed (3 feet) in muddy, brown, medium-grained sandstone, fairly loose; *Zethalia* dominant, *Lutraria* and gasteropods. Concretionary cemented bands are frequent in NU 2b to NU 2d, which together are about 35 feet thick. NU 2e, barren loose sand and muddy sand (25 feet) with tubular concretions of sand cemented by limonite, perhaps filling worm bores, becoming muddier above. NU 2f, lensing conglomeratic shellbed within NU 2e. Rich molluscan fossils densely packed, with small quartzite and argillite pebbles, in fine muddy-sandstone matrix, interbedded with pebbly silty sands, laminated and cemented in places; interfingering into sands (e) at the cliff top three chains west of gully from hut site. NU 2g, barren loose sands between concretionary sandy mudstone bands with poorly preserved shells (12 feet).

Remarks: NU 2 contains the well collected shellsands on which the Nukumaruan Stage is based—the *Rotella*-beds of Park, 1887. One of the shellbeds (possibly NU 2d) is the Waipuru Shell Sand of Superior Oil Co. (1943), which was mapped by that company as a persistent marker in the middle of their Petane (Upper Nukumaru) formation from the Kai Iwi Valley, 7 miles north-east of Nukumaru, to the Rangitikei River.

NU 3. Blue-grey Sediments with Lensing Shellbeds.

Exposure: Above NU 2 for some 55 chains to the south-east.

Lithology: Alternating blue-grey sands, silts and clays, laminated silts with sandy partings, massive coarse sands, lensing shelly conglomerates. Considerable lateral variation and some cross bedding. Tree-trunk in one conglomeratic lens.

Fauna: Predominantly barren of fossils. Shelly lenses were noted at about five horizons in the lower half of the bed, but most of such fossils are thanatocoenotic. Talus and vegetation have obscured much of the cliff since Powell (1931, p. 106) collected *Coluzea espinosa* Fin. from a blue clay band in this zone; at one time there were also exposed beds with clean *Tawera subsulcata* (Hutt.), *Chione crassitesta* Fin., *Amphidesma crassiformis* Fin., *Struthiolaria frazeri* (Hutt.) with blue sandy matrix, and other species from Nukumaru in the older Geological Survey collections.

Thickness: About 90 feet.

Contacts: Base an ill-defined concretionary shellbed; top coarse, barren sand.

Subdivision: Owing to the discontinuous outcrops, no subdivision is proposed, and different faunas can best be located by their height above the brown sands (NU 2). From one of the shelly lenses came the moa bone described by Marshall (1919A).

NU 4. First Non-marine Member.

Exposure: At foot of cliff, from 115 chains to 165 chains south-east of Nukumaru Beach hut site.

Lithology: Coarse grey sands, silts and clays, massive finely laminated or alternating, with some fine scale cross bedding; interspersed with several lignite bands and fossil soils (with root penetra-

tion of underlying beds), or fine purple-grey carbonaceous lagoonal or fresh-water clays.

Fauna: No marine fossils.

Contacts: Ill-defined blue-grey cross-bedded sands or finely alternating sands and silts overlie coarse sand of NU 3 at base. Highest lignite arbitrarily taken as top.

Thickness: 70–88 feet.

Subdivision: No subdivision is made. Lignitic soil horizons occur at 26 feet and 60 feet above the base and near the top.

Remarks: The beds are probably all non-marine and the lignite horizons show temporary land-surfaces on a prograding and subsiding coastline. Dune sands have not been definitely recognised.

NU 5. Marine Sands with Mollusca.

Exposure: Base of cliff for about 30 chains north-west from mouth of Ototoka Stream.

Lithology: Loose, brown, bedded, micaceous sands; muddy sands; micaceous dark silt-stones with shelly lenses.

Fauna: Lenses and bands of *Dosinia, Zethalia, Amphidesma,* etc., poorly preserved.

Contacts: Base not seen; top (highest shellbed) underlies massive barren sulphury (? dune) sand at base of NU 6.

Thickness: About 25 feet.

Remarks: This is a marine phase suggesting sublittoral conditions on a prograding sandy coast or perhaps in a harbour.

NU 6. Second Non-marine Member.

Exposure: Middle of section for 30 chains north-west of Ototoka Stream; lower part of cliff for 20 chains south-east of stream.

Lithology: Chiefly sulphury-looking, medium-grained, massive quartz sands (? dune sands), with rarer silty and carbonaceous partings, lignitic bands; purplish-brown, yellow-stained, carbonaceous, fresh-water clays and thin soil horizons with root imprints.

Contacts: Base conformable over marine sands (NU 5). Overlain conformably by NU 7 east of Ototoka Stream, but unconformably by CL 1 north-west of the stream (Fig. 6).

Thickness: 30–32 feet.

Remarks: Though no dune bedding was seen in any of the Pliocene rocks, some sands such as these, alternating with soil and fresh-water phases and with no marine fossils, were probably deposited subaerially. This remark applies to sands in NU 4, NU 6, and NU 8.

NU 7. Chione-Potamopyrgus Silts. (Plate 30, fig. 10.)

Exposure: About 50 feet above beach level in the cliff at mouth of Ototoka Stream, falling to sea-level 30 chains to the south-east.

Lithology: Fine pumiceous fossiliferous silts, well-bedded, locally cemented into flaggy concretions, containing rare half-inch pebbles of rhyolitic pumice and argillite. Matrix dominated by fine, fresh, angular rhyolitic glass.

Fauna: Abundant stunted *Chione* and *Potamopyrgus;* other mollusca few.

Contacts: Conformably interbedded between sands of NU 6 and NU 8; truncated by CL 1 at Ototoka Stream (Fig. 6).

Thickness 10–15 feet.

Remarks: An interesting bed ecologically, clearly indicating low salinity, intertidal, estuarine conditions. This is the earliest occurrence of rhyolitic pumice noted on the coast section.

NU 8. Third Non-marine Member.

Exposure: Beneath CL 1, south-east from mouth of Ototoka Stream for 120 chains.

Lithology: 25–30 feet of quartz sands enclosing small quarter-inch pumice pebbles, rare lensing carbonaceous and muddy bands, followed by muddy sands and finely current-bedded sands and silts, medium-grained loose sands; laminated silty sands and clays (65–70 feet) followed by carbonaceous, freshwater clays and lignite (3 feet), alternating sands and silts, finely cross-bedded (20 feet). A concealed pre-Castlecliffian fault, 105 chains south-east from Ototoka Stream, separates the latter from massive (? aeolian) yellow-stained sand with irregular root imprints, which grades up into clays and lignites beneath a well-preserved land surface penetrated by roots and trunks of trees (up to about 12 inches across).

Contacts: Conformable on NU 7; unconformably overlain by CL 1.

Thickness: About 90 feet, but faulting prevents measurement.

Remarks: The basal Castlecliffian bed (CL 1) angularly transgresses NU 8, and of the three faults noted none displaces the Castlecliffian as much as it does the Nukumaruan beds. It is not always possible to match the Nukumaruan beds on either side of the faults with confidence, especially where talus masks the cliff.

NU 8 contains no obvious marine beds, and those which show subaqueous bedding may be fluviatile or deltaic. Of the many soil horizons in the Upper Nukumaruan, that at the top of NU 8 is the only one giving evidence of arboreal vegetation.

LOWER CASTLECLIFFIAN BEDS.

Subdivision of the Castlecliffian beds proved easier than that of the Nukumaruan, the sediments are all marine, faunas are rich, and the cliff, on the whole, is not badly obscured by talus.

It has been found desirable to note restricted or otherwise significant fossils to facilitate description and identification of the beds: such palaeontological notes are tentative, as the work of listing faunas is not completed.

Classification. (*Fig. 5.*)

CL 11. Upper Kai Iwi Blue Silts.
CL 10. Kupe Shellbed.
CL 9. Upper Westmere Silts.
CL 8. Lower Westmere Silts.
CL 7. *Buccinulum caudatum* Shellbed.
CL 6. Lower Kai Iwi Blue Silts.
CL 5. Mowhanau Pumice Sands.
CL 4. Upper Okehu Silts.
CL 3. Okehu Shell Grit.
CL 2. Lower Okehu Silts.
CL 1. Ototoka Shell Conglomerate.

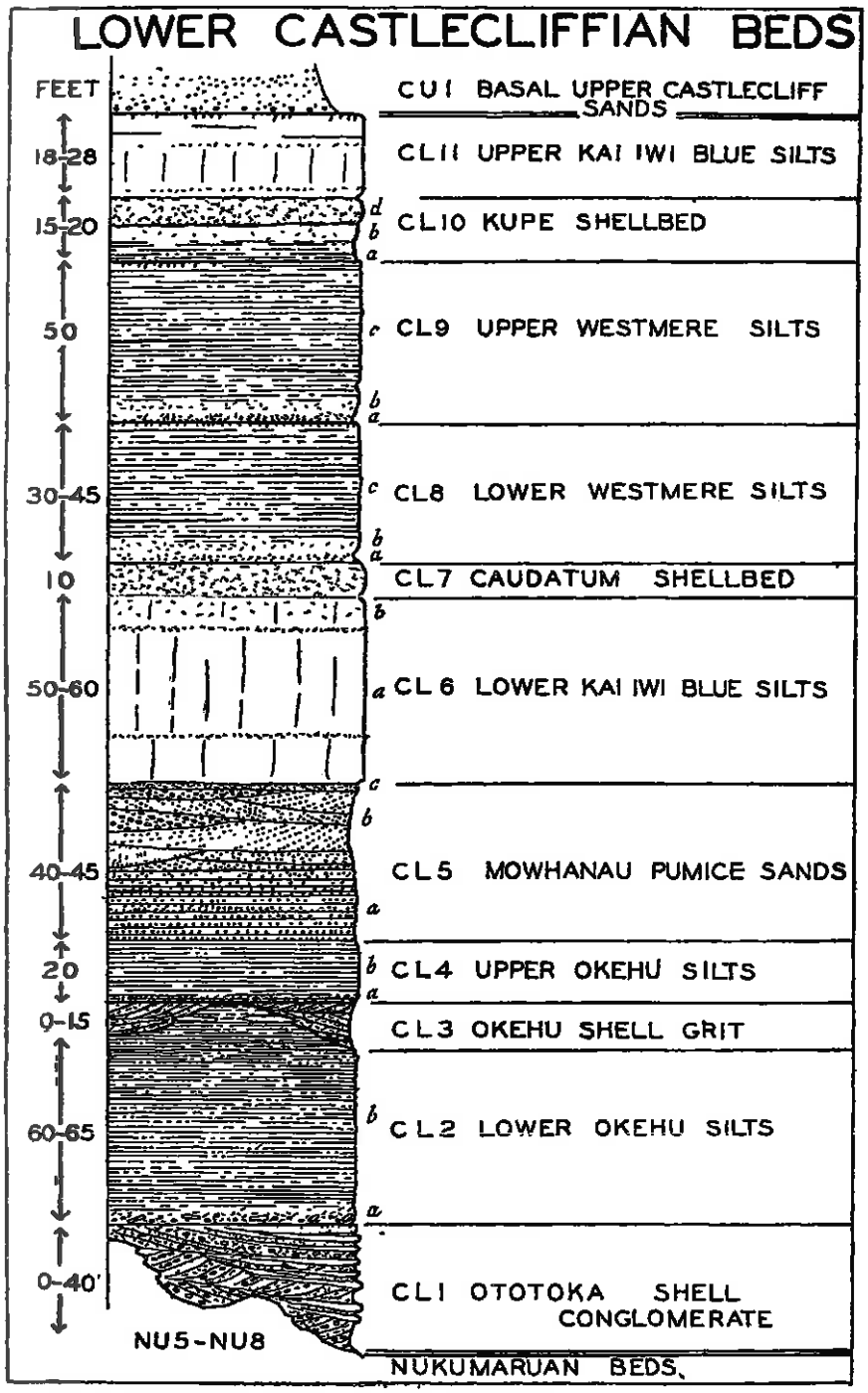


FIG. 5. Stratigraphic column of Lower Castlecliffian beds exposed on coast from mouth of Ototoka Stream to 190 chains north-west of Castlecliff.

CL 1. Ototoka Shell-conglomerate (Basal Castlecliff Ash) (R. S. A. 20).

Exposure: Upper part of section for 75 chains north-west from Ototoka Stream, at the mouth of the stream, and descending to sea-level from 12 chains to 130 chains south-east of Ototoka. At a point 65 chains south-east of Nukumaru Beach hut site a pocket of shell conglomerate at the top of the section is provisionally correlated with CL 1.

Lithology: Rapidly varying. Abundant worn shells in matrix of coarse sand, with pebbles of quartzite and of rhyolitic pumice (up to 9 inches). Interbedded tuff-silts, sands, and conglomerate; concretionary silts with large grit-filled worm tubes (?); fossiliferous gritty tuffs. Irregularly laminated silts and sands (CL 1′) in the most south-easterly exposures.

Fauna: Abundant thanatocoenotic molluscan shells, some derived from Nukumaruan and Waitotaran rocks, mostly worn; CL 1′ contains biocoenotic mollusca. *Austrovenus* is the dominant pelecypod in the shell conglomerates.

Contacts: Unconformable, undulating, scoured contact with Nukumaruan below, angularly transgressing beds NU 5 to NU 8 —possibly also NU 4 and NU 3, if the isolated outcrop is rightly correlated with CL 1 (Fig. 6). The irregular base of the bed is due to the development of deep scour channels in the underlying Nukumaruan sediments.

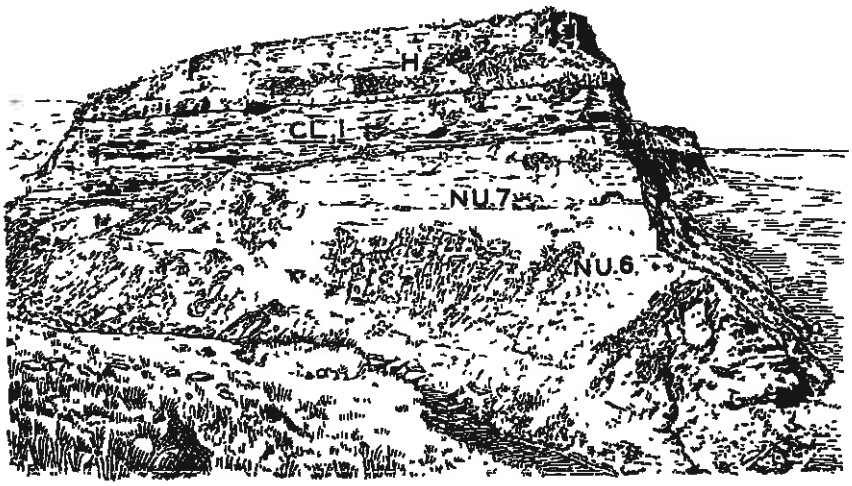


FIG. 6. Bluff at mouth of Ototoka Stream, drawn from a photograph, to show the unconformable relation of the Ototoka shell conglomerate (CL 1) to underlying Nukumaruan beds NU 6 to NU 8. H=Hawera beds. NU 8 (unlabelled) appears on right above NU 7.

Thickness: 10 feet to 40 feet.

Remarks: In Superior Oil Company's report (1943) the Castlecliff formation is stated to "grade up perfectly conformably from the estuarine beds of the upper Petane" (= Nukumaruan) "and is separated from the latter for purposes of mapping at a prominent ash bed which has been designated the basal Castlecliffian ash", so

that the unconformity on the coast may be local. Mollusca include so many derived from older rocks that it is difficult to be sure of the true fauna of the bed.

The bed is to such an extent dominated by pumice and pumice derivatives that there can be little doubt that an important eruption in the central volcanic region preceded its deposition.

CL 2. Lower Okehu Silts (R. S. A. 19).

Exposure: Descending from cliff top from 25 chains to 130 chains south-east of Ototoka Stream and at beach level between the latter point and Okehu Stream.

Lithology: Basal conglomerate (CL 2a) rapidly passing up into finely laminated and massive, blue-grey silts and sands (CL 2b). A concretionary band within 3 feet of the top is fairly persistent.

Fauna: Rich fauna in basal conglomerate, including derived elements. Upper beds almost barren; a few *Neilo* and *Baryspira*.

Contacts: Diastemic contact with CL 1 below; disconformably overlain by CL 3.

Thickness: 60–65 feet.

Subdivision: The basal "rolled concretion conglomerate" (CU 2a) is 1–3 feet thick and contains greywacke, argillite, quartzite, and rare igneous pebbles and distinctive rolled green calcareous concretions (up to 1 foot) apparently derived from CL 1. The lower Okehu silts proper (CL 2b) grade up from the conglomerate.

CL 3. Okehu Shell Grit (R. S. A. 18).

Exposure: From 3 feet to 8 feet above beach level at mouth of Okehu Stream (Fig. 7) and in lenses, ascending the cliff, for 90 chains to the north-west.

Lithology: Whole and broken shells and occasional quartzite pebbles (1 inch) in matrix of shell grit and muddy sandstone strongly current-bedded. No pumice pebbles are present.

Fauna: Abundant mollusca (dominant *Maorimactra*), mostly worn; a regular echinoid* is apparently biocoenotic.

Contacts: Disconformably overlies an undulating scoured surface of CL 2b which is locally bored by *Anchomasa*. CL 3 is restricted to lenticular depressions in this surface and is missing between them. The basal conglomerate of CL 4 overlies conformably.

Thickness: 0 to 25 feet.

Remarks: Absence of pumice and dominance of *Maorimactra* rather than *Austrovenus* or *Amphidesma* among the Pelecypoda distinguish this bed from CL 1 and CL 5.

CL 4. Upper Okehu Silts (R. S. A. 17).

Exposure: From 90 chains north-west to 20 chains south-east of the mouth of Okehu Stream.

Lithology: Basal fossiliferous conglomerate, leading up to barren, massive or finely bedded, blue-grey muddy silts.

Fauna: The conglomerate contains a similar fauna to CL 3, but the mollusca are in part biocoenotic.

Contacts: Conformable (diastemic) above CL 3 and below CL 5.

* Kindly identified by Dr. H. B. Fell as *Pseudechinus huttoni* Benham.

Thickness: 20 feet.

Subdivision: CL 4a, basal conglomerate (2–3 feet); CL 4b, barren silts (17 feet).

CL 5. Mowhanau Pumice Sands (R. S. A. 16) (Fig. 7).

Exposure: From 70 chains north-west of Okehu Stream to sea-level at mouth of Mowhanau Stream.

Lithology: Coarse, current-bedded pumice and tuff sands and grits; lensing pumice conglomerates; alternating pumice silts and sands.

Fauna: Rich lensing shellbeds in upper parts, consisting mainly of thanatocoenotic elements.

Contacts: Apparently conformable contacts above and below, perhaps some basal scouring.

Thickness: About 45 feet.

Subdivision: Character varies laterally, but a convenient subdivision between Kai Iwi and Okehu Streams is: CL 5a, barren alternating sands and silts (c. 20 feet); CL 5b, coarse current-bedded sands and pumice conglomerates with scattered mollusca (c. 20 feet); CL 5c, shell grit with abundant mollusca (*Amphidesma* dominant) (1–5 feet).

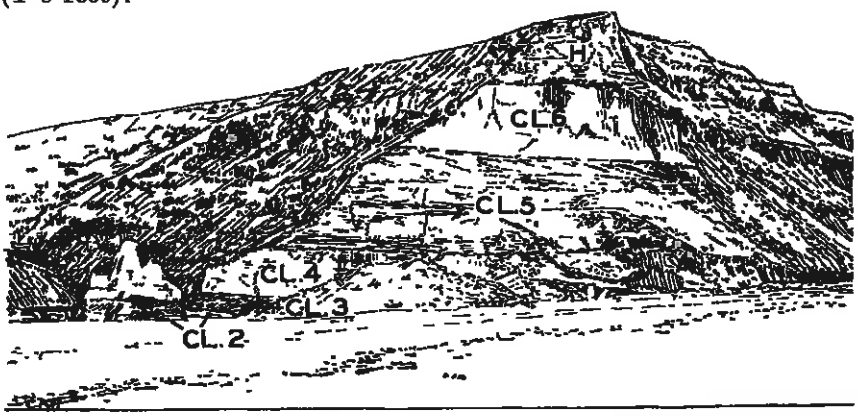


FIG. 7. Bluff at mouth of Okehu Stream. Hawera beds (H) at top of cliff truncate Lower Castlecliffian beds. CL 2: Lower Okehu silts; CL 3: Okehu shell grit; CL 4: Upper Okehu silts; CL 5 Mowhanau pumice sands; CL 6: Lower Kai Iwi silts. Drawn from a photograph.

CL 6. Lower Kai Iwi Blue Silts (R. S. A. 15).

Exposure: From mouth of Okehu Stream to 40 chains south-east of Mowhanau Stream.

Lithology: Light, blue-grey, fine-grained, micaceous massive muddy siltstone and fine muddy sandstone.

Fauna: Scattered, fairly abundant mollusca, cirripedes, rare fish bones. Fairly continuous bands of abundant *Nemocardium* or *Chlamys*.

Contacts: Rapid passage at base into shallow-water pumice sands of CL 5. Conformably overlain by CL 7.

Thickness: 50–60 feet.

Subdivision: A lower, sparsely fossiliferous part, CL 6a, grades into an upper, coarser-grained part, CL 6b (10 feet), in which lenses of *Chlamys* and other mollusca are more densely packed.

Remarks: These are the best known of the "Kai Iwi Blue Clays" of Park (1887) and later writers. Occasional pumice pebbles were seen at the base, but no bed corresponding to that in which Park (*op. cit.*, p. 52) described a "large quantity of pumice", "usually in blocks from 6 inches to 1 foot in diameter".

CL 7. Buccinulum caudatum Shellbed.

Exposure: High in the cliff for 20 chains north-west of Kai Iwi Stream; at the cliff top between that stream mouth and the Mowhanau, and from there for 45 chains to the south-west where the bed goes to earth.

Lithology: Grey medium-grained muddy sandstone.

Fauna: Abundant scattered mollusca, biocoenotic, with *B. caudatum* Powell as a characteristic (though not strictly limited nor dominant) gasteropod.

Contacts: A bedding plane, usually well defined, separates CL 7 from CL 6.

Thickness: 10 feet.

CL 8. Lower Westmere Silts (R. S. A. 14) (Name given from Westmere Survey District).

Exposure: From about 20 chains north-west of Kai Iwi to sea-level about 70 chains south-east of Mowhanau Stream.

Lithology: Basal fossiliferous free sand, fossiliferous silt and finely laminated silts and sands with carbonaceous streaks.

Fauna: Biocoenotic mollusca, in basal parts only.

Contacts: Disconformable above CL 7; truncated by CL 9a, perhaps unconformably.

Thickness: 30–45 feet.

Subdivision: CL 8a, free sand with concentrated *Scalpomactra* and *Divaricella* (9–18 inches) grading rapidly into CL 8b; blue muddy siltstone with scattered fossils (c. 3 feet) passing into CL 8c; barren laminated silts with carbonaceous bands.

CL 9. Upper Westmere Silts (R. S. A. 13).

Exposure: For about 140 chains south-east of the mouth of Mowhanau Stream.

Lithology: Basal shell grit, fossiliferous siltstone and barren laminated silts with carbonaceous bands.

Fauna: Thanatocoenotic shell grit at base; autocthonous mollusca in base of silts.

Contacts: Erosion plane bored by *Anchomasa* truncates CL 8, perhaps with slight unconformity. Similar erosion surface truncates the barren beds CL 9c and initiates CL 10.

Thickness: 50 feet.

Subdivision: CL 9a, *Amphidesma* grit-band over bored surface (6–18 inches); CL 9b, fossiliferous lower silts; CL 9c, barren laminated silts.

CL 10. Kupe Shellbed (R. S. A. 12).

Kupe is traditionally the earliest human visitor to New Zealand. The CL 10 shellbed contains the earliest trace of the immigrant pecten genus *Notovola*, hence the name given. The subdivisions of the bed differ so much from each other that they are described separately.

The bed descends from cliff top to beach level between 60 and 160 chains south-east of the mouth of Mowhanau Stream.

CL 10e. 3 in. layer containing abundant *Notovola.*
CL 10d. Muddy Sandstone packed with pelecypoda.
CL 10c. Layer of rolled *Mactra rudis.*
CL 10b. Muddy Sand with gasteropods.
CL 10a. Estuarine Sands.

CL 10a. Estuarine Sands.

Lithology: Loose sands, laminated and finely current-bedded, with small pebbles at base.

Fauna: Anchomasa boring in CL 9; *Amphidesma, Solletellina,* etc., in rare shelly partings.

Contacts: Disconformity at base; apparently passage into CL 10b.

Thickness: 7 feet.

CL 10b. Gasteropod Shellbed.

Lithology: Muddy sands, in places showing contemporary slump deformation.

Fauna: Plentiful scattered mollusca, chiefly gasteropods (*Phenotoma, Glaphyrina, Zeatrophon, Eucominia*).

Contacts: Conformable.

Thickness: 3–5 feet.

CL 10c. Mactra rudis Layer.

Lithology: Close packed rolled shells with sand matrix.

Fauna: Thanatocoenotic mollusca, especially valves of *Mactra* rolled and stained, apparently derived from CL 10b.

Contacts: Conformable; represents a strong diastem between b and d.

Thickness: 3–6 inches.

Remarks: This seems merely the scoured and sorted top of CL 10b in which most of the shells of CL 10c occur scattered and in a biocoenotic condition.

CL 10d. Pelecypod Shellbed.

Lithology: Muddy sandstone.

Fauna: Concentrated biocoenotic mollusca, mainly pelecypoda, among which *Zemysia, Dosinia maoriana, Aulacomya, Mantellum, Venericardia, Dosinula, Tawera* are conspicuous.

Contacts: Conformable.

Thickness: 3 feet.

CL 10e. Notovola Layer.

Lithology: Mudstone.

Fauna: Notovola, fairly abundant.

Contacts: Conformable.

Thickness: 3 inches.

Remarks: The pectens, which are rare in lower subdivisions of CL 10 and which have not been seen from CL 11, appear to lie partly on and partly in the top of CL 10d and to be covered by the lower part of CL 11. The layer would not be recognisable apart from the concentration of *Notovola* and is merely the thin passage bed between CL 10 and CL 11 given special significance through the occurrence of the shells.

CL 11. Upper Kai Iwi Blue Silts (R. S. A. 10).

Exposure: From 85 chains south-east of Mowhanau Stream mouth to 180 chains north-west of end of cliff at Castlecliff.* At a point 173 chains south-east from the Mowhanau Stream, CL 11 forms a conspicuous stack (Plate 30, Fig. 9).

Lithology: Massive fine blue muddy siltstone and mudstone, locally sufficiently unctuous to have been termed "clay", with rare carbonaceous bands which show contemporary deformation.

Fauna: Scattered mollusca, rarer near the top, with two layers of abundant *Ostrea.*

Contacts: Conformable passage from CL 10; separated by strong disconformity (and probably slight angular unconformity) from overlying CU 1.

Thickness: 28 feet thinning north-west to 18 feet.

Remarks: These are the beds immediately below the well-known Kai Iwi disconformity which separates the true or upper Castlecliffian beds from the lower beds containing the Kai Iwi fauna (Marwick, 1931) [see Fig. 9]. Park (1887) apparently included the bed in his "Kai Iwi Clays" (bed 5) and few later collectors have appreciated the separation of this bed from the Lower Kai Iwi Blue Silts (CL 6) which have a similar molluscan assemblage.

UPPER CASTLECLIFFIAN BEDS.

Classification. (*Fig. 8.*)

CU 8. Estuarine Sands.
CU 7. *Tawera* Silts.
CU 6. Upper Castlecliff Shellbed.
CU 5. *Zethalia-Amphidesma* Sands.
CU 4. *Stirocolpus* Silts.
CU 3. *Tainui* Shellbed.
CU 2. *Antisolarium* Sands.
CU 1. Basal Upper Castlecliff Sands.

CU 1. Basal Upper Castlecliff Sands (R. S. A. 8 and 9).

Exposure: Between 280 and 125 chains north-west from Castlecliff.

Lithology: Conglomerate, current-bedded sands, alternating sands and silts. Basal conglomerate contains andesite and rhyolite pebbles.

Fauna: Rolled mollusca in basal conglomerate; biocoenotic mollusca in uppermost sand (*Notovola, Myadora, Amphidesma*).

Contacts: Strongly disconformable on bored surface of CL 11 below; conformably overlain by CU 2a above.

Thickness: 60–65 feet.

Subdivision: Basal conglomerate (CU 1a); 3–5 feet of pebbly sands, coarsely current-bedded, with rare rolled shells (CU 1b); alternating loose sands and bedded muddy sands or silts, in beds 1–3 feet thick, barren (CU 1c); coarse loose sand with fossils (2 feet, CU 1d).

* In the descriptions of beds that follow, "Castlecliff" is to be interpreted as an abbreviation for the expression "end of the cliff at Castlecliff," this point having a grid reference 502871 on the Waverley sheet, Provisional 1 Mile Series.

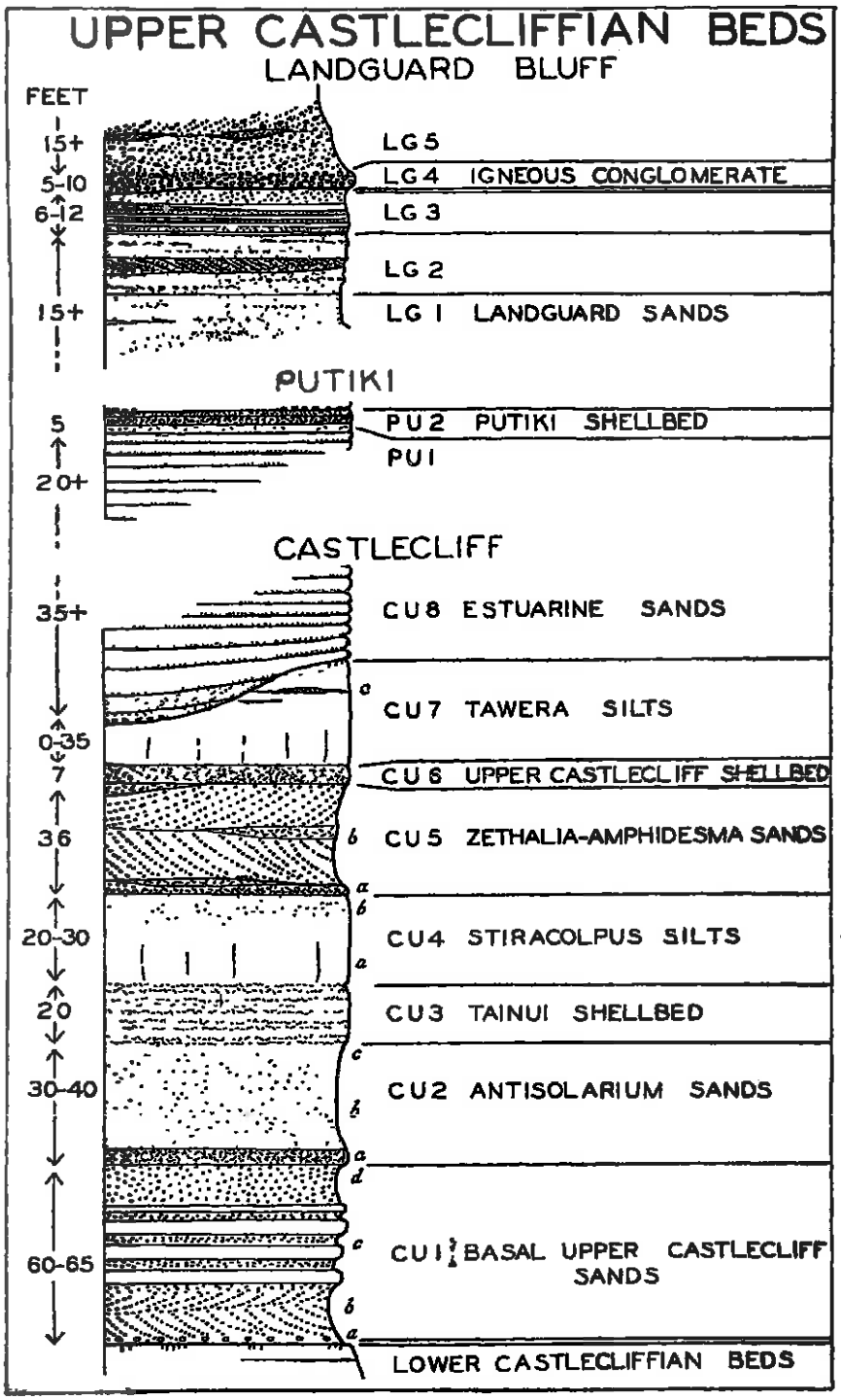


FIG. 8. Stratigraphic columns of Upper Castlecliffian beds showing subdivision of the type section of the Castlecliffian and of the beds at Putiki and Landguard Bluff.

CU 2. Antisolarium Sands (R. S. A. 6 and 7).

Exposure: From 205 to 95 chains north-west of Castlecliff. The sequence CU 1 to CU 3 is well shown at the "Pinnacles", a gulch in the cliff flanked on either side by a pinnacle of fossiliferous siltstone, 162 chains north of Castlecliff.

Lithology: Muddy medium micaceous sandstone; rare mudstone.

Fauna: Abundant mollusca, scattered throughout the bed and aggregated into a basal shellbed (CU 2a). *Antisolarium egenum* (Gld.) is strikingly dominant.

Contacts: An undulating parting separates the fine muddy sand of CL 2a from the uncoherent coarse loose fossiliferous sand at the top of CL 1. The subdivisions of CL 2 are perfectly conformable with each other. At the top the CU 2 sands become rapidly finer and pass into silts at the base of CU 3, where fossils become more abundant.

Thickness: 30–40 feet.

Subdivision: The basal 3 ft. shellbed (CU 2a = R. S.A. 7) packed with fossils (*Venericardia* locally dominant) passes abruptly into CU 2b, muddy sands with abundant scattered *Antisolarium* and other mollusca, which in places grade laterally into bedded silty mudstone with lenses of sand packed with *Antisolarium.* CU 2c and CU 2d form the uppermost five feet of the bed in which *Antisolarium* is virtually absent and lines of *Tawera, Notocallista* and *Glycymeris* are developed parallel to the bedding. CU 2d is the uppermost 9 inches immediately below the base of CU 3 (defined by the lowest occurring *Notovola tainui* and by rapid replacement of sand by silty mud) and is separated from CU 2c for purely faunal reasons.

CU 3. Tainui Shellbed (R. S. A. 5).

Exposure: Forming a "buttress" projecting on to the beach at high tide mark, 90 chains north-west of Castlecliff (Plate 30, Fig. 10) and rising to the top of the cliff 185 chains farther north-west.

Lithology: Fine, massive, smooth mudstone, unctuous (but not plastic) when wet.

Fauna: Abundant mollusca, bryozoa and brachiopods. Mollusca concentrated along bedding planes; bryozoa in lens-like colonies ("bioherms").

Contacts: Conformable, above and below.

Thickness: 18–20 feet.

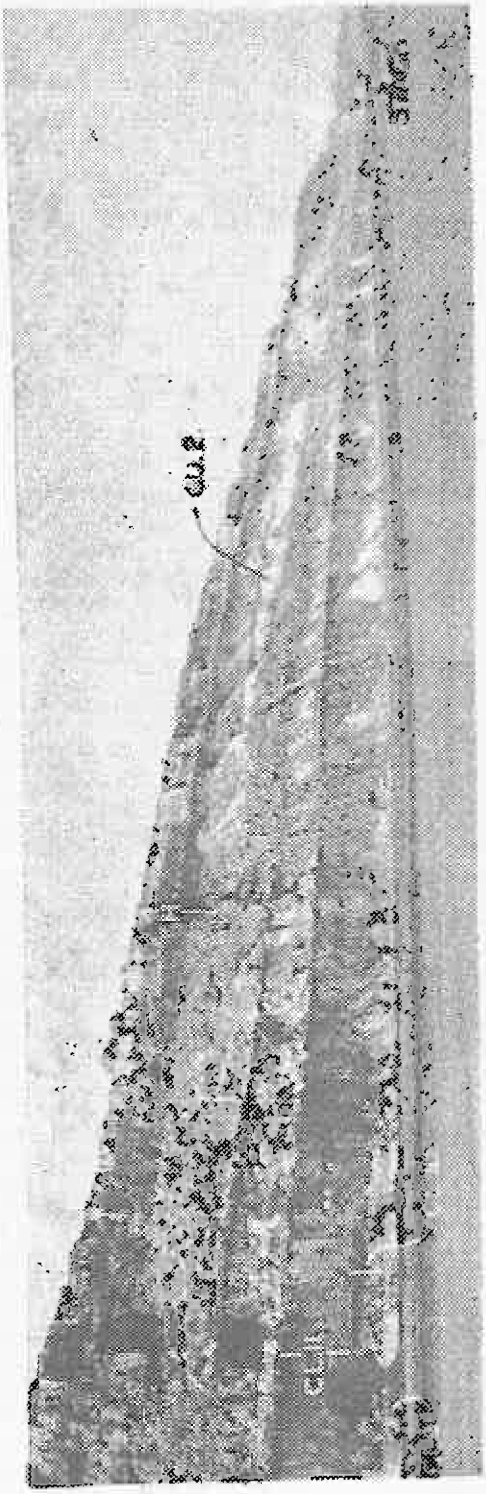
Remarks: This is one of the best-known Castlecliffian horizons, being the most important part of the blue clays with shells (bed 4) of Park, rightly correlated with the lower beds at Shakespeare Cliff, the Castlecliff "blue clays" and "papa" of most of Finlay's molluscan descriptions, and the "basal papa" of Powell (1931). The mollusca are beautifully preserved. *Notovola tainui* Fin. and *Pterochelus zelandicus* (Hutton) are conspicuous and apparently restricted fossils.

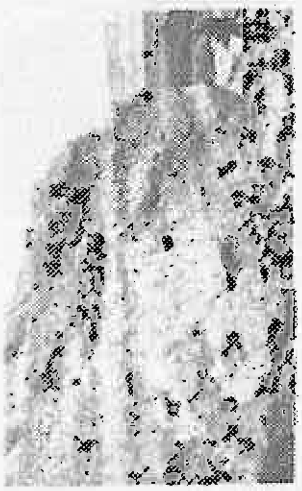
CU 4. Stiracolpus Silts (R. S. A. 4).

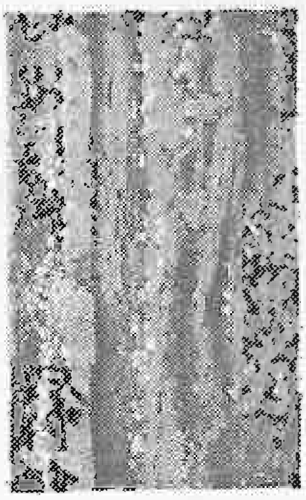
Exposure: From 50 to 160 chains north-west from the end of the cliff at Castlecliff.

Lithology: Fine, massive, micaceous siltstone, coarser above.

Fauna: Scattered mollusca, with *Stiracolpus* dominant.







Contacts: Conformable rapid passage from CU 3. A possible disconformity separates from CU 5.

Thickness: 30 feet, thinning to 20 feet north-west.

Subdivision: The upper 6 feet of the bed (CU 4b) contains more abundant fossils and is coarser than the lower part (CU 4a).

CU 5. Zethalia-Amphidesma Sands (R. S. A. 3).

Exposure: From 20 to 140 chains north-west of end of cliff at Castlecliff.

Lithology: Loose, coarse, current-bedded, micaceous sand, with lenses of shell-sand, and basal shellbed.

Fauna: Abundant fossils in basal shellbed (*Dosinula* and *Ostrea* dominant), and in lenses (*Zethalia, Amphidesma,* etc., and the echinoderm *Arachnoides,* Plate 30, Fig. 12).

Contacts: The base appears to truncate the underlying bed, causing it to thin to the north-west; there is no clear erosion surface, so that submarine scouring is possibly indicated at the time of rapidly changing sedimentation. The muddy sand of CU 6 overlies the underlying loose sands conformably.

Thickness: 36 feet, locally reduced to nothing by a scour channel filled with CU 8.

Subdivision: The 2 ft. basal shellbed of large pelecypods in coarse matrix is a conspicuous aquifer (CU 5a). The shellbeds in the overlying sands (CU 5b) are lenticular and developed at a number of horizons in the sand. They have not been mapped individually.

CU 6. Upper Castlecliff Shellbed (R. S. A. 2).

Exposure: 30 to 140 chains north-west of the end of the cliff at Castlecliff, cut out for some 20 chains by scouring of CU 8.

Lithology: Medium to fine muddy sandstone.

Fauna: Abundant mollusca and brachiopods.

Contacts: Conformable above and below.

Thickness: 7 feet.

Remarks: Although the fauna is rich, the bed has been somewhat leached and preservation is variable.

CU 7. Tawera Silts (R. S. A. 1).

Exposure: For 120 chains north-west of Castlecliff, interrupted by the scour channel of CU 8.

Lithology: Massive or poorly bedded fine micaceous grey siltstone with rare carbonaceous bands.

Fauna: Scattered mollusca; discontinuous lensing bands of shell dominated by *Tawera* 15–25 feet above base.

Contacts: Conformable over CU 6; overlain by CU 8 with strong disconformity.

Thickness: Up to about 35 feet, but cut out locally by CU 8.

Subdivision: CU 7a silts below *Tawera* band (CU 7b); CU 7c barren silts above *Tawera* band.

CU 8. Estuarine Sands.

Exposure: For 145 chains north-west of Castlecliff.

Lithology: Bedded alternating sands, silts, and muds with scattered pebbles at base and carbonaceous partings; locally with fine current bedding.

Fauna: Rare shelly partings near base, and rolled estuarine shells at base, which is locally a surface bored by *Anchomasa.*

Contacts: Strongly disconformable on CU 8, with a deep channel, about 20 chains wide in the section, scouring down to the base of CU 5. Top not visible.

Thickness: 35 feet +; thickens to 50 feet +, in scour channel.

Putiki and Landguard Bluff Sections.

Beds higher in the Castlecliffian than those exposed in the coastal section outcrop on the south-east bank of Wanganui River. At Shakespeare Cliff the lower shellbed in mudstone is readily correlated with CU 3 and is followed by CU 4, CU 5, and CU 6. The latter is faulted against beds lithologically similar to CU 8 at Durie Hill, and near Braemar Hotel, CU 6 is faulted against Pleistocene Terrace beds at road-level.

At the low cliff at Putiki, east of No. 1 Line, for some 20 chains south-east of Airport Road Corner, a section is exposed showing:—

PU 3 Conglomerate with andesite pebbles and rolled shells.
PU 2 {Sandstone 1 foot to 1 foot 6 inches.
{Putiki Shellbed (muddy sandstone 4 feet 6 inches, with abundant shells).
PU 1 Barren bedded silted sandstone alternating with sandstone up to about 60 feet above sea level.

PU 1 is provisionally correlated with CU 8. It is uncertain whether PU 3 is a further Castlecliffian horizon or represents the base of the Pleistocene.

A broad, alluvium-floored valley separates the Putiki section from the still younger beds forming Landguard Bluff. The following sequence is shown where the Airport Road climbs the bluff to the west along the river bank towards Landguard Trig.:—

LG 6 Yellow cross-bedded sands with local pumiceous layer, 45 feet +.
LG 5 {c. Pebbly coarse sand. About 6 feet.
{b. 0–3 feet lensing pebbly grit with marine mollusca.
{a. 10–15 feet coarse gritty current-bedded dark sands, grits and fine conglomerate.
LG 4 Coarse conglomerate, 5–10 feet, locally current bedded, unconformable on LG 3, with abundant andesite and rhyolite pebbles (2–6 inches).
LG 3 Loose micaceous sands over bedded sands, ashy siltstone in beds a few inches thick, and pebble bands, with rare shells. 6–12 feet.
LG 2 {Sands, broken-shell layers, pebble bands, grits, with a current-bedded (thanatocoenotic) gritty shellbed. Possibly including transgressive erosion planes. 20–25 feet.
LG 1 Loose yellow quartz mica sands with biocoenotic mollusca (*Notovola*, etc.), rare silt layers. 15+ feet.

The beds lens and it is difficult to be sure of minor details of correlation from one part of the section to another. LG 1 is the richest horizon for molluscan fossils, and most species hitherto described from Landguard Bluff probably came from here. According to the late Mr. G. Shepherd, Wanganui Museum, there was once a bed rich in small gasteropods exposed at river level, but now covered by talus, river deposits, and spoil from the construction of Airport Road. The beds grouped as LG 2 and LG 3 are still Castlecliffian, judging by their poor molluscan faunas and by the scarcity of volcanic pebbles. The heavy conglomerate (LG 4) is interpreted as the base of the Pleistocene, and beds LG 4 to LG 6 are deltaic deposits with a littoral interfingering bed (LG 5) which contains a scant Late Pleistocene fauna.

The relations of the Landguard Bluff and Putiki beds to those of the coast section are as follows:—

Landguard Bluff: LG 4 to LG 6 Late Pleistocene.
. . . . . Unconformity.
LG 3, LG 2, LG 1 } 50–60 feet.
Some 50–100 feet of beds not exposed.

Putiki:	PU 2 6 feet	*Coast Section:*
	PU 1 ?60 feet	CU 8 50+ feet.
		CU 7, etc.

APPENDIX: NOTE ON PLEISTOCENE BEDS.

In Fig. 2 the Pliocene beds are shown truncated by a sequence of Pleistocene beds up to 50 feet in thickness. These are the "Drift formation" of Park and the "Notopleistocene" Hawera Series of Thomson. They form the cover of the lower of two broad coastal benches recognised west of the Wanganui River. The molluscan fauna of the deposits of the upper (Brunswick) bench includes the genus *Leucotina,* previously considered restricted to the Castlecliffian; the fauna of the covering deposits of the lower (Rapanui) bench is scarcely to be distinguished from the Recent fauna. Owing, therefore, to its composite nature, the Hawera Series has been divided into two formations. The Brunswick formation includes the beds overlying the upper bench at heights of about 300 feet to 500 feet above sea-level, and the Rapanui formation, the beds overlying the lower bench, from 50 feet to 100 feet above sea-level in the coastal cliff to about 300 feet at the foot of the scarp between the two benches. In the Brunswick formation, fossils are known only from basal beds, but in the Rapanui formation, fossils occur both at the base (though not commonly in the section covered by Fig. 1) and above deltaic conglomerates (at Landguard Bluff). The cover was apparently deposited chiefly during the withdrawal of a prograding coast from the cut bench, so that faunas at different heights on the bench may not be strictly contemporary. After emergence of the bench, plant remains and lacustrine sediments were laid down, preserving the deposits of contemporary andesitic ash showers. These were later buried under advancing dune sands. The following table briefly summarises the succession of post-Castlecliffian beds near Wanganui.

Hawera Series	Rapanui Formation (Late Pleistocene)	c. Dune sands.
		b. Terrestrial and lacustrine beds, lignite, ash showers.
		a. Basal marine or delta deposits (unconformable on Pliocene).
	Brunswick Formation (?Mid Pleistocene)	(Not exposed on the coast, unconformable on Pliocene.)

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