

## Geology of Fossil Localities near Waipukurau, Hawke's Bay.

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As a fossil locality Waipukurau is known chiefly for the late Tertiary Bryozoa collected by A. Hamilton and described by A. W. Waters in 1887. The neighbouring township of Waipawa is known chiefly for the record by A. McKay (1879) of an ammonite in the "chalk marls" of the Waipawa Gorge, which was supposed to prove the Cretaceous age of the Amuri limestone. In 1919 Mr. E. K. Lomas read a paper (not published) to the Geological Section of the Wellington Philosophical Society, entitled "Some Geological Observations in the Hatuma District," and exhibited collections of fossils, mainly late Tertiary brachiopods, from numerous localities near Waipukurau. In 1921-22, during a residence of over a year at the Pukeora Sanatorium, I was able to make extensive collections of fossils from its immediate neighbourhood. During the same period Dr. G. Uttley and Dr. J. Marwick collected in the late Tertiary beds farther north, and together we made two excursions in the country around Waipukurau. Dr. Marwick (1924) has already published an account of the fossil molluscs collected by him, only one species, however, from the Waipukurau area being included, and I have to thank him for the identifications published in this paper, including those collected by Dr. Uttley and himself. In point of number the Bryozoa easily come first amongst the fossils I collected, being numbered in many hundreds of specimens, and Brachiopoda come next, with over a hundred. The Bryozoa have been handed to Dr. G. Uttley for examination in connection with the general revision, which he has in hand, of the Tertiary faunas of that group. In the meantime, until lists of species are prepared, it seems desirable to give an account of the fossil localities in order to facilitate subsequent reference, and that is the primary purpose of this paper. The area closely studied and explored on foot lies within a circle of a mile radius from Pukeora. Occasional motor and train journeys, however, enable a general outline of the broad structural and stratigraphical relationships of a much wider district to be attempted, and this may be of service in directing the attention of geologists to a part of New Zealand which will amply repay more detailed investigations.

The only geologists who have recorded their observations in the area are A. McKay (1877, 1879, and 1887) and H. Hill (1887, 1891, 1893, and 1909), and in neither case are the writers particularly concerned with the area under discussion, but make brief mentions of the more important beds and geological features in papers covering a much wider area, exception being made of Hill's paper (1893) on the structure of the gravels of the Ruataniwha Plains. McKay's papers were written early in his career, when writing did not as yet come easy to him, and before he had developed fully the ideas on structure which his explorations in the Clarence Valley crystallized; nevertheless, as in so many other districts in New Zealand, he laid a true foundation, and has proved to be correct in all but minor

points in stratigraphy and structure, while in regard to physiography it is of interest to record that in his paper of 1877 he gave a clear description of a stripped deposition plane or "fossil peneplain" on the greywacke rocks north-west of our area. Hill, in his numerous papers on the geology of Hawke's Bay, has given many valuable details in regard to the Tertiary rocks, but in our area he has not added much to McKay's account; his most valuable contributions relate to the artesian systems in the various alluvial plains of Hawke's Bay, a field in which he is the only authority, but with which we are here not concerned. His later paper (1909), on "The Great Wairarapa: A Lost River," is entirely discounted by recent physiographical studies on the origin of the surface features throughout New Zealand.

The rocks which, in my former papers on the Clarence Valley and the Waipara and Weka Pass districts, I have grouped together as broadly accordant series under the name of Notocene, in southern Hawke's Bay form two strongly discordant series, for which I propose the local names of the Waipukurau series for the Upper Tertiary members, and the Waipawa series for the Middle or Upper Cretaceous members. These correlate with the upper and lower parts of the Notocene of the South Island, the middle parts being missing. With this qualification it is possible, as in other areas, to divide the rocks into Prenotocene, Notocene, and Notopleistocene.

#### PRENOTOCENE ROCKS.

Prenotocene greywackes, argillites, and the usual associated rocks form the Ruahine Range and its northern continuations lying to the west of Hawke's Bay, and presumably form the floor of the Notocene rocks to the east. Within this area there is no intrinsic evidence as to their age; doubtless, as in other parts of New Zealand, they are mainly Triassic, but may include strata from Permian to Lower Cretaceous. McKay has divided them, in the area between Masterton and Napier, into an older Rimutaka series and a younger Wairoa series; but his main criterion appears to be the state of weathering of the included sandstones, which in turn is dependent on their porosity and their late physiographical history, and is not a valid criterion for stratigraphical separation without regard to these other factors. The greywacke series, according to McKay, project through the Notocene cover to the east in only one place between Woodville and Napier—viz., to the south of Takapau, as shown on his map (1877). I have, however, in 1914 recorded an outcrop a little to the north of Woodville, and there are probably others not yet discovered. In the case alike of the main ranges to the west and of these two inliers, contacts only with the younger Tertiary rocks are displayed, but no contacts with the older Waipawa series, and unless further inliers are found within the area occupied by the latter series its relationship to the greywacke series must remain a matter of inference. The evidence is clear enough that the Ruahine and northern greywacke ranges owe their present elevation to post-Notocene earth-movements (the Kaikoura orogeny). Not only are rocks of the Waipukurau series deeply involved with the greywackes to the north-west of the Ruataniwha Plains, but a little farther north the mountains are capped with beds of limestone, which thus connect the Upper Tertiary rocks of Hawke's Bay with those of the Taihape district to the west of the greywacke mountains. Between the Waipukurau series and the greywackes, however, there is a profound unconformity, with close folding and peneplanation of the greywackes before the Upper Tertiary sea transgressed

over them; judging from the history of other parts of New Zealand, the probabilities are that the close folding antedated the deposition of the rocks of the Waipawa series; but, as stated above, this must remain an inference until actual contacts are discovered between the two series.

#### WAIPAWA SERIES.

The attitude of the rocks of the Waipawa series proves that an orogenic movement of considerable magnitude took place within the Notocene. As mapped by McKay, under the name of "Inoceramus beds," these rocks extend south-east from about Otane in a broad band to the sea-coast from Black Head, north of Porangahau, to some miles south of Cape Turnagain. They form, according to him, an undulating country of low hills, exhibiting a remarkable uniformity in rock characters—viz., chalk-marls with black bituminous marls full of scales of mica at one or two points. For the most part they dip at high angles to the east, and are shown on his sections as fairly closely folded, in contrast to the gentle dips of the rocks of the Waipukurau series which overlie them on the west.

McKay's description of these rocks as chalk-marls is quite inaccurate, and was due partly to his inexperience at this time and partly to his expectation that they must correlate with the Amuri limestone. The rocks in the Waipawa Gorge, to which he first gave the name of chalk-marls, are light-coloured, fine-grained, almost flinty, siliceous mudstones exactly similar to flinty mudstones in the Clarentian series in the Ward, Woodside, and Keckerangu districts of Marlborough, and bearing rare elongate brownish calcareous concretions similar to concretions in the Clarentian; somewhat similar flinty mudstones are also locally developed in the Piripauan of the Weka Creek, Waipara district, but without concretions. I have tested these rocks in the Ward district with acid for lime, with entirely negative results. As described by McKay, these rocks contain rather poorly preserved Foraminifera and fish-scales, and dip steeply to the east or south-east. The supposed ammonite which he obtained from them was some years ago examined by Mr. H. Wood, of Cambridge, who reported that it was a crushed Nautiloid. Farther down the Waipawa River, on the north side of the road-bridge, there is a cutting exposing the rocks which he described as "black bituminous marls full of scales of mica." The rocks, however, are not black, but dark purple, and they are covered on joint-planes and outcrops with a yellow sulphur efflorescence; they agree exactly in appearance with the sulphur mudstones found in the Clarentian of Keckerangu and the Piripauan of the Waipara River, but, unlike them, contain recognizable Foraminifera. The peculiar lithology of these two types of rock, known in New Zealand only in the Piripauan and Clarentian, is evidently the result of special conditions which prevailed during those stages, and gives good grounds, in anticipation of examination of the fossils, for correlating these beds with the Cretaceous members of the Notocene—viz., with the Piripauan or the Clarentian.

In the Tukituki River below Waipukurau the rocks of the Waipawa series are dark mudstones of more ordinary nature, but harder than is usual amongst Tertiary mudstones in New Zealand. Similar dark mudstones outcrop at many points on the road to Porangahau, and there is a large district here awaiting exploration. Near Porangahau there is a road-metal quarry in thin-bedded, pale-green, moderately coarse glauconitic sandstone and finer-grained grey-green streaky and flinty rocks, some of which greatly resemble some bands of the Amuri limestone of Marlborough. All are

steeply inclined. Beyond these, the Mangamaire Valley to the south of Porangahau is a broadly open valley composed of soft mudstones and weak sandstones, more comparable in induration to Tertiary than to Cretaceous rocks. The ridges bounding the valley are hard glauconitic sandstones, alternating with white flinty and lilac-coloured mudstones of more usual Cretaceous aspect. It appears possible that the soft mudstones are of Tertiary age, lying above the limestone, and that the Waipawa series ranges up to the Lower Tertiary, but a critical examination of the Foraminifera collected from them will probably resolve the doubt. No doubt molluscan and other larger fossils will be obtained from the mudstones of the Waipawa series by a more extended search than I was able to make. Meanwhile small collections of Foraminifera are available in the Dominion Museum for any specialist who cares to undertake their examination.

#### WAIPUKURAU SERIES.

The rocks of the Waipukurau series, as developed near Pukeora, may be subdivided as follows:—

	Feet.
Maharakeke clays .. .. .	100+
Pukeora oyster-beds .. .. .	80-90
Makaretu clays . . . . .	60-100
Te Aute limestone .. .. .	200-300
Tukituki sands .. .. .	200

These names for the subdivisions of the Waipukurau series have been given for convenience of description and reference, but may prove to have a purely local value, and are not intended to replace earlier names for the same rocks in other parts of Hawke's Bay. As to correlations, the Te Aute limestone has usually been correlated with the Waitotaran. The beds overlying the limestone are apparently the equivalents of the Petane clays, which Marwick (1924) correlates with the Nukumaruian. The Tukituki sands are presumably older than Waitotaran, but the species of *Neothyris* which they contain forbid correlation with the Awamoan. A critical examination of the brachiopods may assist in defining the correlations more exactly.

The Te Aute limestone forms a bold escarpment 300-400 ft. above the low-lying ground occupied by the Waipawa series to the east, and dips at about 10° to the west. It is, according to McKay, a continuation of the limestone of the Puketoi Range north-east of Woodville, and from the Waipukurau area trends north and then north-east to Cape Kidnappers. With the associated rocks it forms a line of hills, rising over 1,000 ft. in height, which separate the extensive Ruataniwha Plains on the west from a low-lying strip on the east on which lie Hatuma and Waipukurau. The Ruataniwha Plains form a large intermont basin comparable to those in Canterbury and Otago. Like the Culverden basin, it possesses two distinct drainage outlets—viz., the gorges of the Waipawa and Tukituki Rivers—and has a third breach in the eastern wall not occupied by a stream but used by the railway between Takapau and Hatuma. The plain is composed of river alluvium, brought down from the greywacke ranges to the west by the tributaries of the Tukituki and the Waipawa Rivers, and spread out to form a continuous plain between these rivers; its height above sea-level at the Tukituki Gorge is approximately 400 ft. The courses of these rivers through the eastern limestone wall must thus be antecedent to the synclinal deformation which caused the basin. Its western margin,

which I have not had an opportunity of examining, and which McKay did not examine in detail, appears to be composed also of Upper Tertiary rocks, dipping to the east, together with older gravels. Probably the eastern depression on which Hatuma and Waipukurau lie is equally a structural basin, but it is probable that faulting has had more influence in its development than simple folding.

Of the rocks of the Waipukurau series McKay originally recognized in this neighbourhood only the Te Aute limestones and overlying clays. He described the Te Aute limestone as lying hard upon the Waipawa series south of the Waipawa River, recognizing beds conformably under the limestone only farther north, where they are described as blue sandy beds. I did not see the actual junction in the Waipawa Gorge, but the relative positions of the limestone escarpment, dipping gently to the west, above, and the flinty mudstones of the Waipawa series dipping steeply to the east in the road-cuttings below, leave no doubt of the strongly unconformable relationship of the two series, but at the same time admit the possibility of 100 ft. or more of weak beds below the limestone. These underlying beds are exposed near the Tukituki limestone gorge in road-cuttings on the Main South Road, and also on the Onga Road flanking the base of the hill towards the gorge. They are for the most part grey sands containing occasional brachiopods (*Neothyris*) and rare pelecypods—viz., *Anomia undata* Hutt., *Chlamys radiatus* (Hutt.), and *Ostrea angasi* Sow.; on the Onga Road the lowest rocks seen contain thin clay bands with fragmentary plant-remains and hard impure sandstone bands. Near the base of the limestone on the main road is an outcrop of blue clayey sandstone with oysters and numerous broken brachiopods, mostly *Tegulorhynchia nigricans*, but this may possibly be a down-slipped mass of the Makaretu clays which overlie the limestone. To the beds underlying the limestone I have given the name of the "Tukituki sands." I estimate their thickness at about 200 ft. For the most part they are obscured by extensive talus deposits of soft limestone coming from the escarpment above, deposits which should be of value for agricultural purposes, as they are considerable in extent, need little crushing, and are easily accessible to the road and railway. They would also be excellent material for fowl-grit.

McKay (1887) has described a considerably greater thickness of beds conformably underlying the Te Aute limestone in a section a few miles to the south-west from the Takapau Railway-station east to the inlier of greywacke rocks forming Woolshed Hill ("Johnston's woolshed"). The beds are brown and grey sands, the latter with bands of brown and greenish soft sandstone, yielding fossils which he identified as *Dentalium nanum*, *D. laeve*, and *Limopsis aurita*. These rest on a bed of white clay. It seems probable that a lower horizon than the Tukituki sands occurs here, pointing to an overlap.

In 1879 McKay found clays with fossils on the eastern slope of Mount Vernon, near Waipukurau, below the limestone escarpment, and correlated them with the clays overlying the limestone; in consequence he concluded that a marked unconformity must exist between the limestone and overlying clays. In 1887 he abandoned this view after examination of the Takapau section, and concluded that the clays on Mount Vernon underlay the limestone; doubtless they are a facies of the Tukituki sands.

The Te Aute limestone, as exposed along the Main South Road passing Pukeora, is composed of massive beds about 200 ft. thick, passing down into calcareous sands with an increasing amount of quartz downwards, with a second thin bed of limestone at the base. Followed down the dip

to the limestone gorge the massive beds appear to thicken, and there is probably 300 ft. of limestone at this point. Where exposed in cuttings the limestone is rather soft and friable, and is composed largely of worn *Balanus* valves, with Bryozoa next in importance. It is apparently a detrital rock, and shows good current-bedding on the Maharakeke-Hatuma Road; unfortunately, I neglected to observe the direction of the current-bedding, which may be of importance for the mid-Tertiary palaeogeography. There is a small percentage of quartz and glauconite, but the whole rock is very high in lime content. Through the softer parts run joint-planes lined for 6 in. to 2 ft. with very hard limestone of secondary calcification. The boulders outcropping on the hilltops are quite hard, and are partly of this nature and partly residuals of originally harder parts of the limestone left by weathering. Excluding Bryozoa, the limestone is not rich in fossils; whole cirripede valves and calyces are rare, and brachiopods are mostly represented by single valves of *Neothyris* sp., *Terebratella inconspicua*, and *Tegulorhynchia nigricans*; the Mollusca collected have been identified by Dr. Marwick as *Anomia trigonopsis* Hutt., *A. cf. undata* Hutt. (juv.), *Chlamys cf. convexus* (Q. & G.), *C. radiatus* Hutt. (juv.), *Ostrea angasi* Sow., *O. ingens* Zittel, *Pecten* n. sp., *Pecten* n. sp. aff. *triphooki* Zittel. From the cliff in the Tukituki Gorge opposite Waipukurau Dr. Marwick collected *Anomia undata*, *Chlamys cf. convexus* (Q. & G.), *Ostrea angasi*, and *Ostrea ingens*. Probably at other points the limestone will prove more fossiliferous. I have retained the name of "Te Aute limestone," as the escarpment continues unbroken, except for the Tukituki and Waipawa gorges, from Waipukurau to Te Aute.

The beds following the limestone are not exposed in continuous section near Pukeora. On the dip-slope of the limestone below the Sanatorium destructor is a small hillock of sandstone containing a few oysters and casts of other molluscs and fairly numerous finger-shaped and pustulate Bryozoa. This sandstone does not seem to form a persistent horizon. Elsewhere the beds following the limestone form smooth grassy slopes at the foot of the dip-slopes of the limestone, and are evidently weak rocks protected by the overlying harder oyster-bed. They are partially exposed in cuttings on the Onga Road near the bridge over the Makaretu River, and on cliffs on this river between the Onga Road and the Main South Road, as blue clays, to which the name of "Makaretu clays" may appropriately be given. They are at least 60 ft. thick, and may possibly be 100 ft. Besides Bryozoa, brachiopods, and cirripedes, they contain fairly plentiful molluscs, the following being identified by Dr. Marwick from the collections I made: *Anomia undata* Hutt., *Anachis pisanioopsis* (Hutt.), *Alcithoe lutea* Marwick, *Antigona zelandica* (Gray), *Calyptrea alta* (Hutt.), *Chione subsulcata* Suter, *Chlamys radiatus* (Hutt.), *Cominella hamiltoni* (Hutt.), *Crepidula monoxyla* Lesson, *Dentalium* n. sp. cf. *namum* Hutt., *Lucinida* n. sp., *Modiolus australis* (Gray), *Ostrea angasi* Sow., *Struthiolaria fossa* Marwick, *Turritella vittata* Hutt. var., *Turritella rosea* Q. & G. var., *Trophon ambiguus* Phil., *Venericardia lutea* Hutt., *V. purpurata* Desh.

The highest points on the hills near Pukeora are composed of oyster-beds with a calcareous cement, which follow the Makaretu clays, and to which the name of "Pukeora oyster-beds" may appropriately be given. They are partially exposed in cuttings on the Main South Road, where they are relatively rich in brachiopods, and in a cutting on the Onga Road at the bridge, and in the forementioned cliff on the Makaretu River. It is from these beds that the largest and best-preserved Bryozoa are obtained, especially from the dip-slopes near the hilltops and in the grass below the

outcrops. Molluscs other than oysters are not abundant, but the following have been identified by Dr. Marwick: *Anomia trigonopsis* Hutt., *Cantharidus* n. sp. cf. *sanguineus* (Gray), *Chione subsulcata* Suter, *Diplodonta zelandica* (Gray), *Gaimardia* n. sp., *Lima (Limatula) bullata* Born, *Myodora striata* (Q. & G.), *Umbonium anguliferum* (Phil.), *Venericardia purpurata* (Desh.).

The beds immediately following the oyster-beds are not well exposed, but appear to be blue sandy clays. They outcrop in a few cuttings on the Main South Road, where Dr. Marwick collected *Baryspira* cf. *australis* (Sow.), *Callanatis yatei* (Gray), *Dosinia* sp., *Lutraria solida* Hutt., *Ostrea angasi* Sow., *Philobrya trigonopsis* (Hutt.), *Turritella rosea* (Q. & G.), *T. vittata* Hutt., and *Venericardia lutea* Hutt. The higher beds are better exposed along the Maharakeke Road and Stream, from which they take their name. The beds are upwards of 100 ft. thick. To the west they are covered by the alluvial deposits of the Ruataniwha Plains, so that higher Tertiary beds, such as occur near Napier, are not found near Waipukurau.

From these blue clays on the Maharakeke Road (Geol. Surv. loc. 1092) Drs. Uttley and Marwick collected the following species: *Aethocola taitae* Marwick, *Alcithoe gracilis* (Swainson), *Anachis pisaniopsis* (Hutton), *Antigona zelandica* (Gray), *Baryspira waikopiroensis* (Suter), *Barbatia novae-zelandiae* (Smith), *Calyptraea novae-zelandiae* (Lesson), *Chione* cf. *subsulcata* Suter, *Chalmys radiatus* (Hutt.), *Cominella hamiltoni* (Hutton), *Cominella* n. sp., *Corbula zelandica* Q. & G., *Dentalium nanum* Hutton, *Evarne striata* (Hutton), *Hexaplex espinosus* (Hutton), *Lucinida concinna* (Hutton), *Melatoma buchanani* (Hutton), *Melatoma wanganuiensis* (Hutton), *Melatoma (Splendrilla) laevis* (Hutton), *Murex zelandicus* Q. & G., *Natica australis* Hutton, *Ostrea angasi* Sow., *Ostrea* sp., *Pratulium pulchellum* (Gray), *Seila terebelloides* (Hutton), *Struthiolaria fossa* Marwick, *Tugali* cf. *intermedia* (Reeve), *Turritella rosea* Q. & G., *Turritella* cf. *symmetrica* Hutton, *Turritella vittata* Hutton, *Venericardia lutea* Hutton, *Verconella thomsoni* Marwick, *Xymene* n. sp.

#### NOTOPLEISTOCENE BEDS.

No special study has been made of the Notopleistocene beds of the district. Besides the alluvial deposits of the Ruataniwha Plains, which have been described by Hill (1893), there is a series of lacustrine beds in the Tukituki Valley, near Patangata, described by McKay in 1879 and 1887, containing lignite-seams, plant-remains, and fresh-water molluscs.

#### NOTOCENE HISTORY.

Until the correlations of the Waipukurau series and the Waipawa series are more firmly established, and the beds of intervening age which are known to occur in east Wellington and southern Hawke's Bay have been more closely studied in their relations to the two former series, it is premature to attempt to reconstruct the Notocene history of this part of New Zealand. That intervening beds, of presumably Oamaruan age, are present to the north of the Waipawa series appears probable from McKay's and Hill's descriptions of the beds forming the Silver Peaks Range and exposed in the Tukituki River cliffs near Patangata, but no fossils have been found here. Far to the south, Oamaruan beds are known to the east of Masterton—the Taipo beds of early reports. The exact correlation of these, and an exposition of their relationship to the overlying Wanganui and underlying Cretaceous beds, are great desiderata.

Ongley (1924) has described an inter-Notocene unconformity in the Poverty Bay district between the Awanui series of Cretaceous age and the Ihungia series of late Awamoan age, and concludes that it is the same unconformity as is present at Waipawa: "Evidently, then, there is a regional unconformity above the fine-grained (Amuri) limestone extending the length of the east coast, and it is thought likely that it extends to the South Island." While agreeing with Ongley as to the probable identity of the unconformities in Poverty Bay, Hawke's Bay, and east Wellington, I cannot follow him in all the conclusions he draws. In the first place, neither the Awanui series nor the Waipawa series has been demonstrated to be exclusively Cretaceous—they may contain early Tertiary beds comparable to the Grey Marls of Canterbury and Marlborough. Secondly, the unconformably overlying beds are distinctly older in Poverty Bay than in Waipawa, pointing to considerable overlap; one would like to know the relationship of the Oamaruan beds in the southern part of the North Island before attempting to reconstruct the Notocene history.

The careful examination of the contact between the Amuri limestone and Weka Pass stone made by Marshall, Speight, and Cotton, by Morgan, by Speight and Wild, and by myself has conclusively proved that there is entire conformity of bedding and no extensive orogeny between these two beds, though doubtless an erosion-interval is present; to compare this contact with the violent unconformities present in the North Island between Cretaceous and Upper Tertiary is to compare small things with great. The reasonable interpretation of the facts as known is that the Notocene history of the North and South Island is dissimilar, and that the Notocene grouping of the various Cretaceous and Tertiary series, which is a practical necessity in the South Island, is hardly justified in the east coast of the North Island.

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