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GEOLOGY OF THE HAMILTON REGION

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INTRODUCTION

This account takes the form of a synopsis which closely follows that prepared for a bulletin entitled "Geology of the Ngaruawahia Subdivision" (Kear and Schofield, in press). Normally such repetition should be avoided but an exception is made in view of delays in publishing the bulletin and of the parochial nature of this first number of the Earth Science Journal.

The area described is limited to three "one inch to one mile" sheets of the "Geological Map of New Zealand—1:63,360" being produced by the New Zealand Geological Survey. One of these, N.65—Hamilton, is already available (Kear and Schofield, 1965) and of the other two, N.56—Ngaruawahia and N.52—Te Kauwhata, N.56 may be out by the time this paper is published. The area they cover stretches from Mt. Pirongia in the west to Cambridge in the east at its southern end, and from Mercer in the west to Ngatea in the east, at its northern end. This region is separated from the Coromandel Range to the east by a rift valley known as the Hauraki Lowlands. Within the Hamilton region itself, Mesozoic rocks crop at the surface in ranges along both its western and eastern margins. A central physiographic depression is divided by the Taupiri Range (Mesozoic rocks) into the Hamilton Lowlands in the south and the Lower Waikato Lowlands in the north. These depressions are filled with Cainozoic sediments of which only those of Quaternary age are exposed at the surface in the Hamilton Lowlands. Tertiary rocks are known at depth in the latter area and crop out in the western ranges but not in those to the east.

Because of the three "one inch to one mile" maps mentioned above and the availability of the "one inch to four miles" maps—Sheet 4, Hamilton (Kear, 1960); Sheet 5, Rotorua (Healy et al., 1964) and Sheet 3, Auckland (Schofield, 1967), no geological figure is enclosed.

Permission from the Director of the New Zealand Geological Survey and Dr D. Kear to publish this information is gratefully acknowledged.

MESOZOIC ERA

The most ancient rocks of the region belong to the Hokonui System; date back to about 200 million years ago; and are of contrasting facies in the west and east.

Western facies. In the western Hakarimata and Kapamahunga ranges some 18,000 ft. of marine tuffaceous sediments and volcanic greywackes are mapped within the Newcastle, Rengarenga and Kirikiri groups. They range in age from Oretian-Otamitan to Heterian; are tolerably fossiliferous; belong to the zeolite mineral facies of Coombs (1960) and the "Hokonui Facies" of Wellman (1952); show a marked upward decrease in induration, and their stratigraphy and structure are reasonably simple.

The Newcastle Group contains four formations—the Hakarimata Formation, Marakopa Formation, Te Pake Sandstone and Pongawhakatiki Siltstone.

The Hakarimata Formation is the oldest and comprises unfossiliferous indurated siltstones and tuffaceous sandstones at its base. These are overlain by tuffaceous sandstones, siltstones and conglomerates, which become increasingly fossiliferous upwards. **Halobia** appears first, and a shell-bed of **Manticula problematica** is present near the top. Well-bedded indurated siltstones and sandstones of the Marakopa Formation overlie. They show intraformational slump structures, and include a shell-bed of **Monotis richmondiana** (Warepan) near their base. Recent work by Mr M. G. Laird has located **Otapiria dissimilis** (Otapirian) in the upper Marakopa Formation, and **O. marshalli** (Aratauran) in the overlying Te Pake Sandstone, which contains plant fragments at its top. The thick, indurated Pongawhakatiki Siltstone, with relatively common **Pseudaucella marshalli** (Ururoan), is the next youngest formation and is exposed in the west of the region. The overlying Rengarenga sandstones and conglomerates (Temaikan), and the Kirikiri siltstones (Heterian) are restricted to small areas in the extreme south-west of Sheet N.65—Hamilton (Kear and Schofield, 1965).

These Hokonui rocks of the west are essentially normal shelf sediments deposited on the margins of a geosyncline, although the lowest Hakarimata beds are unfossiliferous and have that factor at least in common with beds from nearer the geosynclinal axis. These shelf sediments were deposited rapidly, and the presence of both local unconformities and of slumping imply perhaps that the area was one from which sediments were transported in turbidity currents towards the axial regions.

Eastern facies. In the eastern Hapuakohe, Hangawera and Morrinsville ranges, rocks of the Manaia Hill Group (Hokonui System) are more indurated than those of the same age (Kirikiri Group) in the west. This fact is consistent with their increased stratigraphic thickness. The most common Manaia Hill lithologies are massive medium greywacke sandstones, "chipwackes" (greywackes with dark siltstone chips), and dark or black argillites. Bedding cannot easily be seen in many outcrops, and face can commonly be determined only with difficulty. The rocks were deposited nearer to the geosynclinal axis than those of the west, but they lack certain typically axial features (e.g. of Wellman's "Alpine Facies"). Redeposited graded beds for example are no more common than in the typically marginal-geosynclinal sequence at Kawhia Harbour (Fleming & Kear, 1960), although some additional evidence of redeposition is given by the presence of chipwacke. The typical "red beds" association of pillow lavas, manganese deposits and cherts, is almost entirely absent, although a few cherts are known. To the north there may be a lateral gradation into the more typical "Alpine Facies" of the Hunua Hills where cherts, "red beds" and manganese beds are more common.

The Manaia Hill sequence is hard to establish in the absence of good marker beds, and the apparent stratigraphic thickness total of 42,500 ft. could be an erroneous estimate. Fossils are rare in the north, where they may be as young as Puaroan, but are more common in the south (e.g. near Morrinsville), where they could be as old as Temaikan. In spite of these age extremes, all fossils could be from within the range of Heterian to Ohauan.

Discussion. The broad sedimentational pattern in the Triassic is uncertain, for no such beds are known in the east. The local sequence is considerably thinner here than in the coastal areas of Kawhia and Marakopa to the south-west, but, in spite of this, the geosynclinal axis is thought to have been to the east, as is generally supposed (e.g. Grindley, 1961, Fig. 1).

In Kawhia Series time, when information is available from both eastern and western areas, the sedimentational picture is more clear. The geo-synclinal axis was undoubtedly in the east and appears likely to have trended north-north-west.

The Hokonui stratigraphy is too poorly known in both western and eastern areas for much useful comment to be made on contemporaneous tectonic activity. In the west there may be a major unconformity closely above the Newcastle Group (i.e. post-Ururoan), and, as at Kawhia, the coarse Rengarenga Group with its carbonaceous beds is the sole representative of all time from the Toarcian to the Kimeridgian. Tectonic movement at such a time is likely, for it would explain the coarseness of sediments, the non-marine facies, the probably unconformities, and the subsequent erosion of Warepan and Oretian-Otamitan beds that caused boulders with **Monotis** and **Halobia** to be present in the Manaia Hill conglomerates (Heterian-Ohauan) of Morrinsville (Kear and Tolley, 1957).

POST-HOKONUI OROGENY

The "Post-Hokonui Orogeny" was responsible for most of the present structures observable in Hokonui rocks. Its onset was certainly heralded by movements that resulted in the deposition of the Ohauan and younger conglomerates of Kawhia Harbour, and the eventual non-marine conditions at Port Waikato (Huriwai Formation of Purser, 1961). Perhaps the movements around the time of Rengarenga Group deposition can also be considered as an early "Post-Hokonui" phase. The rocks were folded into the major features, the Kawhia Syncline and Hakarimata Anticline, both of which strike broadly north and have subsidiary folds on their limbs. Waipa, Wilton, and other major faults were developed either during folding, or soon afterwards, and strike broadly parallel to the beds. The Manaia Hill rocks of the east are poorly known structurally, beyond the fact that their strike is broadly parallel to the local trend of MacPherson's structural arc (1946, map 2) in the north at least. The dissimilar eastern and western areas meet at Waipa Fault (Sheet 4, Hamilton; Kear, 1960) which is thus shown to be a major discontinuity, although the precise tectonic movements involved in its formation are uncertain.

Mesozoic sedimentation may have continued well on into the Cretaceous, any rocks produced being subsequently eroded.

CAINOZOIC ERA

The next period of undoubted sedimentation did not commence until upper Eocene times when the Waikato Coal Measures of Arnold age were deposited. Locally the Tertiary and Quaternary periods are represented by rocks of the shelf facies, totalling probably no more than 5,000 ft. in thickness. They are divided into three major groups, consisting of a few sub-groups, many formations and some members (Kear and Schofield, 1964). Each group differs in its lithology and lithological trends, and is separated from the others by periods of non-deposition, uplift and erosion.

Te Kuiti Group

The Te Kuiti Group is the oldest, is of Bortonian to Duntroonian age (upper Eocene to upper Oligocene) and exhibits a classical sequence from coal measures at the base (Waikato Coal Measures) passing up into estuarine mudstones and sandstones (Glen Afton Claystone, Pukemiro Sandstone, Mangakotuku Siltstone), then open-water marine sandstone, mudstones and limestones (Glen Massey Formation; Whaingaroa Siltstone) which become more calcareous towards the topmost beds of the

Group (Te Akatea Siltstone). Deposition commenced in a structurally-formed long, narrow depression inherited from the Post-Hokonui Orogency, which was similar to the present Firth of Thames and its southward continuation, the Hauraki Lowland. Like the latter it was open to the north and its main trends were slightly west of north. During the early stages of Te Kuiti deposition, up to and including the Mangakotuku Siltstone, overlap on to the Hokonui rocks occurred to the east as well as to the west and south. This is reflected by isopach trends as well as by a change of facies from predominant mudstones in the central and northern parts of the region to predominant sandstones along the margins, particularly towards the south. Although the isopach trends are due mainly to overlap and compaction of underlying beds, there may have been some differential subsidence. Penecontemporaneous faulting of basement almost certainly occurred during deposition of the oldest coal measures and may have continued for some time afterwards. The continuity of an eastern shoreline seems to have been broken when deposition of the youngest estuarine formation (Mangakotuku Siltstone) ceased. However, some eastern overlap of the immediately younger Glen Massey Formation on to the Hokonui rocks is known in the south-west of the region near Karamu. Subsequent to the Mangakotuku Siltstone the environment was consistenly an open-water aerobic one. Although the eastern shore line had lost its continuity, it is probable that a chain of islands existed near the eastern boundary of the region. Shorelines continued to migrate further westwards and southwards (Kear and Schofield, 1959) and this is reflected locally by predominant mudstones in the north (Whaingaroa Siltstone) and by contemporaneously formed sandstones and shallow-water limestones in the south (Glen Massey Formation). The youngest Te Kuiti formation locally is the very calcareous Te Akatea Siltstones of which only the basal beds of probable Duntroonian age are present. This formation is known to extend up into the Waitakian, west of the region (Kear and Schofield, 1959).

A period of block faulting brought Te Kuiti Group deposition to a close, and the rocks of the Group were eroded down to the Mangakotuku Siltstone within the Hamilton region and probably completely destroyed in some areas nearby. Waikato coal pebbles (Kear, 1961), together with Glen Massey Sandstone and greywacke boulders appear in the basal beds of the subsequently deposited Waitemata Group, which comprises sandy Otaian sediments that become less calcareous upwards.

Waitemata Group

The paleogeography during deposition of the Waitemata Group and relationships of the different formations, one to another, are not well known. However, broad outlines are partly established even though they are somewhat complicated by local conditions. South of the region the deep water, off-shore Mahoenui Formation is of Otaian to possibly Hutchinsonian age. Glennie (1959) believed that the Mahoenui graded sandstones were "deposited in part, by turbidity currents initiated by the flooding of a major river flowing from the north." North of the region, particularly north of the Waitemata Harbour, there are thick widespread conglomerates within the Waitemata Group which are only weakly and locally developed here. This suggests that the main landmass was to the north, but there may have been local, smaller landmasses nearer to hand (see below). Within the Hamilton region, the basal formation of the group, the partially calcareous Waikawau Sandstone, passes up into the calcareous Koheroa Siltstone of Otaian age. This formation is very similar in lithology to the Mahoenui massive mudstone facies; the latter is of the same age, it lies on the periphery of Glennie's (1959) Taranaki Basin, and it probably passes laterally into the graded sandstone and siltstone facies. The Mercer Sandstone, of Otaian age, lies conformably above the Koheroa Siltstone, and is possibly the main source of the sandstones within Mahoenui graded sandstones and siltstone facies. In the north-western parts of the Hamilton region its deposition was followed in upper Otaian times, by that of the Amokura Formation—interbedded, mainly non-calcareous, carbonaceous siltstones, and graded, carbonaceous sandstones —a non-shallow-water re-deposited facies quite distinct from the Mahoenui graded sandstone and siltstones sequence. Contemporaneous deposition of the Mercer Sandstone with the Amokura Formation probably occurred in the east, as is shown in the Maramarua area by a probable thickening of the sandstone, by the absence of the Amokura Formation, and by the similarity of floras in the upper beds of both formations. Further evidence of an eastern provenance lies in the lateral change from lower Koheroa Siltstone to Waikawau Sandstone in that direction (Hornibrook and Schofield, 1963). The Amokura Formation is also absent in the south-west of the region where, just north of Mt. Pirongia, there are noncalcareous or slightly calcareous sandstones equivalent to the Waikawau and/or Mercer sandstone. Thus there may have been a western provenance also, further evidence being the north-eastward directed turbidity currents as shown by current bedding of the graded sandstones at the type locality (Kear and Schofield, 1964) of the Amokura Formation.

Tauranga Group

The Tauranga Group overlies the Waitemata Group unconformably. It is dominated by terrestrial sediments derived from rhyolitic provenances —from the Coromandel Range during the Waitotaran and mainly from the Rotorua-Taupo region in subsequent times. Pakaumanu Ignimbrites appear in the extreme south-east and the weakly consolidated distal portions of other ignimbrite sheets are recognised as far north as Ngaruawahia. Marine sediments of the Tauranga Group are rare, and with the exception of the Post-glacial Hauraki Clay, are solely Waitotaran or Opoitian-Waitotaran in age. The latter are found only in drillholes at Huntly and possibly at Horotiu. Terrestrial beds of the same age are also present and extend more than 600 ft. below present sea level (Couper and Harris, 1960).

The similarity of sediments and paucity of outcrops has made it difficult to unravel the complex Quaternary history, but still-stands at high base levels are well represented at 200 to 215 ft., 110 and 140 ft. and probably at 550, 325 and 60-70 ft. The latest and thus clearest episodes in a long history of fluctuating base-levels and fluctuating sedimentary supply (due to climatic changes and intensity of volcanism) consist of a cold-climate aggradation during the Last Glaciation—the Hinuera Formation (Schofield, 1965)—and deposition of the Taupo Pumice Alluvium caused by pumice eruptions at Taupo about 120 A.D. During deposition of both these formations, sorting action has resulted in the deposition of current-bedded sands and gravels within the river channels and finer pumice sands and silts away from the main channels and in interdistributary troughs.

After the retreat from the 110-140 ft. base level the Franklin Basalts were erupted in the north, and include the Kellyville Tuff Ring near Mercer and lava flows from the Pukekawa cones immediately to the west.

Finally, large areas of peat bog covering about 50% of the region are more than 30 ft. thick in places, and are thus locally important sediments. These bogs developed on the surface of the Hinuera Formation but their great thicknesses are not necessarily due to a rising base level although this may be important in some instances.

VOLCANISM

Local volcanic activity which made its first appearance as minor acidic tuffs in the lowest part of the Waitemata Group, became progressively more and more prominent, finally culminating in the widespread rhyolitic sediments which make up the bulk of the Tauranga Group. During the Miocene the dominant form of activity was widespread eruptions of andesite which are represented in the Hamilton region by andesitic tuffs—common in the upper parts of the Waitemata Group—and by roots of ancient volcanoes (Kiwitahi Volcanics) along the eastern margin of the Hapuakohe Range. From Pliocene times this chemically intermediate type of activity was replaced by dominantly basic volcanics in the west (Alexandra Volcanics of Pirongia and Franklin Basalts at Mercer) and acidic rocks along the Coromandel Range to the east; some local andesitic activity continuing along a medial zone from Kiwitahi to Maungatautari. Although younger than the andesites of the Hapuakohe Range the similarity of these later andesites to the earlier ones has led to the extension of the name Kiwitahi Volcanics.

Although local volcanic activity ceased by mid-Quaternary times eruptions in the central North Island districts continue to be important in supplying sediment via the Waikato River.

Relation to Structure

Schofield (in press) considers that following the period of crustal stress that led to the formation and concomitant folding of the Mesozoic sediments within the New Zealand Geosyncline, widespread crustal melting led to the development of a magmatic chamber which dipped westwards below the northern arcuate structure of the North Island. By the end of the Oligocene, at the time when deposition of the Te Kuiti Group ceased, this magmatic body had grown to such an extent that collapse of the overlying crust by block faulting initiated not only the deposition of the Waitemata Group but also the widespread outpourings of andesite, a lithology which is chemically closer to the local crust than any other type of volcanic material. With time, differentiation in the chamber by settling of heavier, more basic minerals down dip to the west, and penecontemporaneous remelting of some or all of this material, produced the western basic volcanics. The lighter differentiate in the upper parts of the chamber became the source of both the eastern acidic rocks that make up the bulk of the youngest volcanic rocks along the Coromandel Range, and the mineralisation that affected all rocks deposited earlier than these.

Steep geothermal gradients, hot springs, and localised shallow earthquakes within the Hauraki lowlands are all signs that the magmatic body is still cooling below the Hamilton Region, but there is unlikely to be further volcanic activity as the region is now essentially tectonically stable. In contrast, the tectonic activity of the Central Volcanic Region is still causing the eruption of material from this widespread and long-lived magmatic chamber.

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