212/1
3/3/58

COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS.

RECORDS.

1957/106

BUREAU OF MINERAL RESOURCES LIBRARY Copy 3 CANBERRA, A.C.T.

VISIT TO NEW ZEALAND

A.N.Z.A.A.S. 1957

by

L. C. Noakes and E. K. Carter

VISIT TO NEW ZEALAND

A.N.Z.A.A.S. 1957

by

L. C. Noakes - E. K. Carter

CONTENTS

VISIT TO NEW ZEALAND

by

L. C. Noakes and E. K. Carter

Records 1957/106

INTRODUCTION

The geological section of the Bureau of Mineral Resources was represented by L. C. Noakes and E. K. Carter at the 32nd Meeting of A.N.Z.A.A.S. at Dunedin in January, 1957.

The itineraries of the two members in New Zealand were as follows:-

L. C. Noakes:

10-15th January pre-sessional excursion in the southern portion of the South Island (Christchurch, Mt. Cook, Queenstown, Mossburn, Gore, Dunedin).

The excursion dealt with the glaciation, and the stratigraphy and structure of portion of the New Zealand Geosyncline.

16-23rd Conference at Dunedin.

24-25th Visit to Geological Survey, Wellington.

26-27th Wellington to Auckland by road.

28th Return to Canberra.

E. K. Carter:

10-15th Pre-sessional excursion through portion of the North Island from Auckland and including Hamilton-Rotorua District, Waimangu, Wairakei, Taupo, Tongariro National Park, Rangitidei River Valley and Wellington.

16-23rd Conference at Dunedin.

23-29th Post-sessional excursion - Christchurch, Weka Pass, Lewis Pass, Reefton, Garvey Creek Coalfield, Buller Gorge (including the original uranium discovery), Lake Rotoiti, Wairau River Valley, Murchison, Blenheim, Picton and Nelson.

Both members attended a mid-sessional one-day excursion on the 19th January to Brighton and Taeri Mouth and a half-day excursion along the Otago Peninsula on the 23rd January.

In this record the writers have tried to summarise those features of both field trips and conference papers which are most likely to be of interest to the geological section; the account is necessarily brief and disconnected but further information may be sought from the writer concerned. Abstracts of the papers presented to Section C were issued in book form and a copy has been filed in the library. These papers are referred to in the following summary by quoting author and the serial number of the abstract in the collection, e.g. (Coombs, C64). Readers are referred also to the geological map of New Zealand in two sheets which accompanies the book of abstracts in the library.

PART I - L. C. NOAKES

GENERAL GEOLOGY.

The most significant events in New Zealand geological history are:- major orogeny and erosion in the interval between Upper Jurassic and Upper Cretaceous, and folding and major uplift at the end of Tertiary time when the New Zealand we now know emerged as a land mass. These important events, particularly the Mesozoic orogeny, are used to subdivide the New Zealand geological record in that pre-Cretaceous rocks are commonly called the "Undermass" and post-Cretaceous rocks the "Covering strata". Using this convenient division, one sees three broad elements in New Zealand geology - an old geanticlinal belt (Precambrian to Devonian) followed by the New Zealand Geosyncline (Permian to Jurassic), which together make up the 'undermass'; and the strata of the Cretaceous and Tertiary troughs including Tertiary and Quarternary vulcanism which form the covering strata.

The geanticlinal belt, cropping out in the southern and western portions of the South Island, has a core of Precambrian rocks and includes granites of more than one age. This belt apparently provided most of the sediments for the great New Zealand Geosyncline between Permian and Jurassic time; the sediments and low-grade metamorphics of the geosyncline now underlie most of the South Island, but are largely covered by younger deposits in the North Island. Major features of the New Zealand Geosyncline are a prominent marginal syncline of shelf or transitional-type beds on the southern and western sides and a typical greywacke facies (the Alpine facies) in the geosyncline proper where thicknesses are very great (supposedly 70,000' and more); measurements are, as yet, rather uncertain because of the severity of folding. The strata were folded and eroded in late Mesozoic time but there is little, if any, evidence that granites were involved in the orogeny.

In late Mesozoic and Tertiary time younger troughs developed, particularly in the eastern portion of the North Island and in the western portion of the South Island. Quarternary volcanic activity is restricted to a narrow meridional belt in the middle of the North Island which roughly parallels the trend of the present Kermadec trough.

Geologists interested in the Tasman Geosyncline in eastern Australia cannot but be struck by the fact that the geology of New Zealand, particularly that of the South Island, is in many ways complimentary to that of eastern Australia. The southern portion of the Tasman geosyncline consists of a geanticline in the east and a shallow trough (mio- or idioe-geosyncline) between the geanticline and the craton to the west, with no evidence of the existence of a trough east of the geanticline in the Tasman Sea. The South Island of New Zealand consists of a geanticline in its western portion bordered to the east by a major trough - the New Zealand Geanticline - in which were dumped a very great thickness of sediments to be eventually folded and uplifted into a non-volcanic, non-granitic mountain chain which is typical of the ranges called Outer Arcs by Umbrove, Van Bemmelen and T. J. Wilson.

This complimentary relationship between eastern Australia and New Zealand has of course been seized on by some "Continental Drifters" as evidence of the erstwhile close association of the two terrains. One New Zealander suggests that a conglomerate toward the northern end of the South Island can be matched with Mesozoic conglomerates on the north coast of New South Wales.

It is obvious that the New Zealand geanticline with its proved Precambrian core cannot be matched along the Australian coast so that at least part of the floor of the Tasman Sea should hold the remnants of land which, at one stage, shed west to the Tasman Geosyncline and east to New Zealand. 'Drift' is neither proved or disproved.

SEDIMENTATION IN THE NEW ZEALAND GEOSYNCLINE.

A note on stratigraphic nomenclature in New Zealand is pertinent at this stage. In description of the sediments of the New Zealand Geosyncline the New Zealanders are using nomenclature which in general follows the general principle of our code, but with little of the precision we use. ... local time-rock terms (systems) with local names are currently used as well as rock-terms for which the term "group" is usually employed, but the practice is not disciplined, and in places "series" are more rock-terms than time-rock terms and a 'group' in places includes two other groups. The difficulty found by New Zealanders in applying rock terms to some of the Tertiary claystone sequences is well known; in these sequences they work mainly with stages but none of these sequences was seen in the field.

In regard to sedimentary nomenclature, New Zealanders certainly need to compile a glossary to set out the exact meaning of the terms in current use; they showed great interest in our glossary and a sub-committee of A.N.Z.A.A.S. is now tackling the problem of sedimentary nomenclature in New Zealand. There are at present contradictory views on the meaning of terms in New Zealand as in Australia; in general, the "greywackes" that I saw in the field we would term greywacke or quartz greywacke, but to some, at least, the reason for calling these rocks 'greywacke' was largely because the rock was a partially indurated sandstone - i.e. argillite is taken to mean an indurated mudstone and greywacke an indurated sandstone. Others agreed that mineralogical constitution, sorting etc. should be the main criteria. In some company, I found little use of the term "siltstone" (of which there was much in the field), or of quartz-greywacke or equivalent terms, and a disinclination to distinguish between clastic and non-clastic limestones.

Three broad "facies" have been recognized in the rocks of the New Zealand Geosyncline in the South Island - the facies of the marginal syncline which borders the trough of the New Zealand Geosyncline - the 'alpine facies' of greywackes and argillites of the trough and the schist facies (mainly the Otago Schists) which outcrop in a belt north-east of the marginal syncline, bordered on both sides by rocks of the alpine facies. The schists apparently represent low-grade metamorphism of the alpine facies by deep burial.

Across the marginal syncline transition-type sediments which have been folded into a synclinal structure are reported to show facies changes from the south-west to north-east, contrasting "fine" shelf deposits with those of the geosyncline proper (Mutch 1957). The sediments and volcanics range in age from pre-Permian (mainly Carboniferous?) to Jurassic as do the rocks of the alpine facies. A belt of ultrabasic rock occurs along the north-eastern limb of the syncline. The greater part of the sequence is pre-Permian; to the south the rocks consist mainly of coarse pyroclastics with andesite flows and sills changing gradually to the north-east to fine grained feldspathic and tuffaceous greywackes, transitional to the alpine facies of greywacke and argillite. These pre-Permian rocks of the marginal syncline are apparently up to 30,000' - 35,000' thick in places and the application of the term "shelf" to their environment seems a misnomer, particularly since at least some of the 'sandstones' seen in this sequence are greywackes and quartz sandstones.

The pre-Permian sequence is overlain by Permian and Mesozoic rocks which are comparatively thin and do constitute a more normal shelf facies - sandstone, shales, limestone etc.

The alpine facies crop out along the north-eastern margin of the marginal syncline and, farther north, outcrop over a considerable area of the South Island in the vicinity of Mt. Cook and the Southern Alps. Although the pre-sessional excursion covered a considerable area underlain by rocks of the alpine and schist facies, the route lay mainly along the glaciated valleys and in the time allowed few well-exposed sections could be visited.

The alpine facies is characterised by alternations of fine to medium greywacke and argillite (indurated claystone) although in places thick sequences of thinly bedded siltstones occur. The greywackes are, in many places, graded and can be used for determining the facing of beds. Dips are commonly very steep and folding isoclinal, and since outcrops are not continuous in most places, the measurement of thickness requires much detailed mapping which in most places has not been done. Thicknesses quoted at A.N.Z.A.A.S. of 70,000' - 90,000' in the alpine facies were received with caution when it was realized that these were based on map distances across the regional strike with apparently no adequate correction for isoclinal repetitions.

The graded greywackes which are recognised as density current or re-distributed deposits show micro-current bedding in places but evidence of slumping or of sole markings were disappointingly missing from the sections seen. Some slump-like structures now showing sinuous quartz veins are referred to locally as 'ptygmatic folds', but some of these appear to the writer to be original slumps.

The schist facies underlies the alpine facies, apparently with no unconformity, and is regarded as the most deeply buried portion of the geosynclinal sediments which have been raised to chlorite and biotite grades of metamorphism by burial. The Otago Schists which have been studied in considerable detail have been subdivided into four chlorite sub-zones and the highest grade of metamorphism is referred to the biotite zone. Higher zones of metamorphism including the garnet zone have been mapped in the western part of the South Island, immediately east of the Alpine Fault, but none of these areas was visited. In the Otago Schists, complete reconstruction of mineral constituents does not occur below the chlorite sub-zones 3 and 4, and in the fields many of these low-grade metamorphics we would not ourselves term 'schist'.

The best section of the schists seen was between Dunedin and Taeri Mouth where a sequence some 5000' - 8000' in thickness shows increasing metamorphism from chlorite sub-zone 1 to the biotite zone. A feature of these schists is the particularly well developed "rodding" or lineation. The rocks consisted mainly of greywacke and argillite with some basic submarine flows, pyroclastic material, cherts and small calcareous lenses. Graded bedding is common in the greywackes but little slumping was observed.

Investigation of the New Zealand Geosyncline is now in a most interesting stage; thorough detailed work is obviously required to throw more light on the history and sedimentation of the geosyncline. One of the most interesting problems is the source of the exceptionally thick piles of sediment involved; the problem largely hinges on estimates of thickness which one feels are not yet really substantiated.

The theory that the main sedimentation came from the geanticline to the south-west and partly from volcanic activity at the south-western border of the marginal syncline poses the problem of how such a thickness of sediment in the alpine facies (18 miles - not including the schist facies (Mutch 1957)) was passed across the marginal "shelf" area to the trough when this so called shelf area, in pre-Permian times, collected some 35,000' of lavas and sediments itself. Obviously this marginal zone was at best a very unstable shelf in pre-Permian times and when it is realised that some at least of the 'sandstones' in the marginal geosyncline are greywackes rather than sandstones, it is difficult to visualise the process by which so much material could be passed on to the trough. Furthermore, the predominance of quartz-greywacke in much of the alpine and schist facies is not easy to reconcile with sedimentation in the marginal syncline; the small amount of tuffaceous material in the alpine facies farther north has been remarked on (Coombs 64). Mutch (1957) suggests that the alpine facies north-east of the main belt of schist may have been shed from a land mass to the north-east so that the belt of the Otago Schist represents the central axis of a geosyncline to which sediments were contributed from either side. This idea is to some extent supported by a verbal report that, in detailed work carried out by Lilley and assistants in the Mt. Cook area, evidence was found of current directions which suggested that the alpine facies in that area came from an easterly direction. This again raised the question whether some of the sedimentation in the geosyncline might not be contributed by tectonic land within the trough.

We might summarise the position by saying that great thicknesses of mainly pre-Permian sediments are known from the New Zealand Geosyncline in the South Island and these have been divided into three main 'facies' but problems of providence and history of sedimentation will remain largely the subject of conjecture until a great deal of detailed mapping has been carried out. The evidence of sedimentary structures particularly dealing with current directions will doubtless play an important role in tracing the history of sedimentation.

TECTONICS AND STRUCTURE.

A Symposium on "Tectonics of the South West Pacific" was given a prominent place in the agenda of the conference. In a sense it was a disappointing session because Professor Carey, who was to deliver the review lecture was absent due to sickness; no review lecture covering the whole subject was given. Except for one paper on crustal structure of Australia by Bolt (C49). The session dealt entirely with New Zealand and no synthesis of ideas on the tectonics of the South West Pacific emerged.

The most striking structural feature in New Zealand is undoubtedly the Alpine Fault which shows prominently on the geological map of the South Island. The fault runs from Milford Sound, on the west coast of the Island, to Cloudy Bay on the southern shores of Cook Strait; its continuation in the North Island is not clearly defined and is the subject of controversy. In the South Island the fault separates two components of the undermass, the pre-Carboniferous rocks of the geanticline on the west from the sediments of the New Zealand Geosyncline.

Most New Zealand geologists appear to follow Wellman (1956) who postulates a 300 mile transcurrent shift on the fault; the main evidence stated by Wellman in support of the shift is:

1. The marginal syncline in the south of the Island with its belt of ultrabasic rocks fits reasonably well the similar structure on the opposite side of the fault 300 miles north, at the north-eastern extremity of the Island.

2. The trace of the fault suggests it is near-vertical and evidence of faulted terraces toward the northern end of the Island indicates that transcurrent movements in the same sense (west block to north-east) is still active.

Some evidence of recent movement is noted by E. K. Carter in a later section. The mechanism of the faulting can be simply explained by transcurrent movement, extending perhaps from Cretaceous time in response to periodic east-west compressions.

In Tertiary time, an important vertical component is attributed to the Alpine Fault, at least in the central portion of the South Island, where the east block moved upwards, in the sense of a high-angled reverse fault, to contribute to the present relief. This concept is in keeping with the current ideas of widespread Tertiary deformation in the South Island, by movement of fault blocks in the undermass, as noted later in this section.

A paper by Brodie (C43) dealing with structural features of the sea floor around New Zealand presented some convincing support for Wellman's idea. Hydrographic work has indicated 'highs' on the ocean floor trending north-west from Cook Strait (north-western structural province) and ridges of the same general magnitude trending east-west off the east coast of the South Island, some 300 miles farther south (the Chatham Province). These 'highs' are on opposite sides of the

Alpine Fault but become one province or belt if the postulated shift of 300 miles along the fault is taken into account.

The main opponent of the transcurrent theory of Wellman appears to be Dr. Kingma (C53) who interprets the Alpine Fault as a nappe structure dipping east. An outsider is not competent to judge some of his evidence and interpretation but some ideas seemed forced and unattractive. The only direct field evidence cited for an easterly-dipping overthrust is the local overriding (apparently at a high angle) of Pliocene-Pleistocene gravels, which is explained by most geologists as high angle reverse movement in Tertiary time. The Alpine Fault, following a remarkable linear trace over country with high relief certainly appears near-vertical to the observer; one is left with the impression that a European geologist is forcibly interpreting New Zealand geology in terms of his beloved Alps!

Structures referred to above lie in the undermass; structural problems in the 'cover strata' were not covered in the same detail at the conference (some papers listed were not given) but a paper by Wellman (C57) presented interesting ideas on Tertiary deformation in the South Island. In the South Island, where Tertiary beds rest on highly compacted greywackes, deformation apparently affected both basement and Tertiary strata, and in the folding there was apparently no décollement (unglueing) of strata. Wellman considers that the undermass was broken into blocks that were tilted as rigid units (hinge faults) and these movements controlled deformation of the Tertiary beds. Folds in Tertiary strata are strongly asymmetrical, particularly where deformation is low; the steep limbs are controlled by high angle faults and, do in fact, pass into high angled reverse faults in places (e.g. Moonlight Fault, seen at Lake Wakatipu). The dip of the gentle limbs of the folds are considered to indicate the amount of tilting the underlying block has undergone.

Although I did not see these structures in any detail, the evidence of post-depositional fault movements in the basement was clear in places examined; the possibility that dips might be depositional rather than tectonic had been overlooked by field workers. not

Wellman showed a model in which blocks were deformed and tilted by high angle faults to produce the structures he described. Deformation by tilting and faulting is produced by either tensional or compressional forces; in the case of compressional forces significant fore-shortening of strata by block tilting was demonstrated.

Another paper of structural interest was one by Bradley (C58) who postulated that major faults should pass into flectures at depths at which rocks have some degree of plasticity. Major transcurrent faults, he postulates, would at depth pass into a vast number of minute faults with transcurrent movement. These may exhibit drag in the horizontal plane, and produce intense plication of beds inclined at an angle to them. Such plications have been attributed to compression and to movement normal to fold axes but on this hypothesis they might well be the results of horizontal movements on steeply-inclined shear planes. Bradley gave examples from New Zealand and from Tasmanian west coast mines where plicated structures may indicate transcurrent faulting rather than folding.

GLACIATION.

An Australian notices the obvious morphological differences which existed between the eastern Australia cordillera and the Alps in the South Island of New Zealand in Pleistocene time. Pleistocene glaciation in Australia occurred on an uplifted and partly dissected plateau, whereas in New Zealand it occurred on a very narrow high range in places only 15-20 miles across, but reaching to some 12,000' above sea level. In this terrain, valley glaciation has carved wide U-shaped valleys, mainly from pre-existing stream valleys, and remnant glaciers still exist at the head of most of these. The glaciers of the Mount Cook region are the longest in the Southern Hemisphere outside Antarctica; they lie at latitude $43\frac{1}{2}^{o}$S and are thus south of the latitude of Tasmania. Another contrast to glaciation in Australia is the comparatively low level at which evidence of glaciation and, indeed, glacier ice is found. The Hermitage, counter-part of our Hotel Kosciusko, is situated a few miles from the snout of glaciers but at at an elevation of only 2500', approximately the elevation of the snout of the Tasman Glacier.

The route to the Mt. Cook glacier region followed the Canterbury Plains south from Christchurch and climbed the foothills to Burke's Pass (2,700') which forms the gateway to the McKenzie Basin and the glacial country. This basin was named after a notorious sheep stealer who used the basin as an illegal ranch in the last century; it is a fine example of an inter-montane depression of tectonic origin. This wide, glaciated depression runs for some 50-60 miles in a meridional direction with smaller glaciated valleys joining from the north and west. The general level of the depression ranges from about 2,500' above sea level in the north to less than 1,500' in the south and large lakes, Tekapo, Pukaki and Ohau, have been formed by the damming back of glacier-fed rivers by large accumulations of fluvo-glacial gravels, veneered by moraine of the last glacier retreat. Similar glacial valleys with lakes are found farther south but the McKenzie Basin offers the widest extent and most complete history of glacial movements. Glacial deposits, outwash and morainal material, of at least three separate glacial advances and retreats have been mapped in some detail in this area by lithology, by super-position and by elevation. The sequence is as follows:-

Glacial Deposits - McKenzie Basin

Outwash	1 Tekapo	Late Wisconsin Glaciation (1–5)
Moraine	2 Advance (@ 20,000 years)	
Outwash	3 Balmoral	
Moraine	4 Advance	
	5 Undifferentiated Balmoral-Tekapo	
Outwash	6 Quail Burn Advance	
Moraine	7 Early Wisconsin Glaciation?	
Gravels	8 Upper Tertiary	
Sand and clay	9 ? Lower Pleistocene	

In an interesting paper at Dunedin, McKellar using radiocarbon determinations and physiographic evidence (C25) places the end of the last (Tekapo) advance at about 20,000 years.

The distinction between moraine and outwash was of particular interest. The material of both moraine and outwash is poorly sorted and has a varying proportion of rounded boulders, but, in New Zealand practice, the presence of rock flour is an <u>essential</u> feature of moraine or till. Photos of both types of deposits are available in the photo library. The rarity of striated boulders, even in terminal and lateral moraines on active glaciers is noteworthy. One is impressed with the fact that the conditions under which true tills are preserved as such in the geological record must be rare and that much of the material popularly called tillite in Australia would probably be better described as fluvo-glacial outwash.

One doubts whether there can be any such thing as a marine tillite - dumping of material from icebergs into marine beds might produce a "tillitic" conglomerate, outwash or sandstone etc., but the term "tillite" in such an environment would seem inappropriate.

The Tasman Glacier, which was seen in some detail, is by far the largest of the four main ice streams in the Mt. Cook area and a set of coloured photographs are available showing many of its features. The total length of the glacier, including névé, is 18 miles and the ice extends 14 miles down the valley from the summer snowline. The glacier varies in width from $\frac{3}{4}$ - 2 miles and its area is estimated to be 14,000 acres with a catchment supplying snow of some 25,000 acres.

There are no ancient terminal moraines in the centre of the Tasman valley, downstream from the terminal face of the glacier, and the margin of the bare, hummocky ablation moraine is still close to the position of the terminal face of the glacier as known in 1889. Melt-water wells up at the foot of an ice-cliff to form a giant spring at the terminal face of the glacier and from this source flows the Tasman river.

It was surprising that the position of the snout of the glacier was not accurately marked to allow retreat to be measured but recourse is made to old photographs to prove that there has been no significant retreat in the last 60-70 years. However, five miles farther up the glacier, photographs prove a vertical shrinkage of about 300' in the same time, and the edges of the glacier ice for $\frac{1}{4}$-$\frac{1}{2}$ mile in from the lateral moraine is dirty and black in colour due to the load of fine to coarse greywacke material concentrated by this ablation. The central portion of the glacier is white and relatively clean because of the constant accession of clean ice from farther up the glacier. However this too becomes dirty as the snout is approached.

On the glacier, ice tunnels and crevices are common; about five miles up from the snout the glacier is moving at a rate of 9-18" per day, dependant on the position of the point of measurement, but the Hochstetter Ice-fall, a tributary ice-stream falling abruptly to the Tasman, moves at the rate of about 2' per day.

Stresses within the ice produce a number of structures and of particular interest were a number of low angle thrust "faults", striking approximately normal to the flow of the ice and dipping upstream at angles of about 30° - agreeing very well with Anderson's (1942) calculation. Other features of particular interest were the immense quantity of rock material in the lateral and terminal moraines associated with the Tasman Glacier. Lateral moraines, traversed on the southern edge of the glacier for five miles upstream from the snout, form ridges some 200' high and 100 yards or so across. The considerable proportion of rounded boulders in the terminal face of the glacier is surprising. These occur particularly below water level at the base. There was some controversy as to the process by which these become rounded, but the explanation seems to be that they are part of the ground moraine and have been rounded by movement in water and ice.

The glacial carving of the landscape, mamillation, is seen on all sides and gives rise to what local geologists like to call 'voluptuous topography'. The depth of ice in the main valleys during the maximum advance can readily be measured in the vicinity of some glacial lakes as the sum of the amount of super-scooping of the lake plus the height to which mamillation extends up the valley slopes. In places, i.e. Lake Wakatipu, a depth of ice of 4,000' can be proved.

The immense quantity of fragmentary material left in valleys by the glaciers obviously provides a ready source of rudacious material for subsequent cycles of either terrestrial or marine sedimentation. The building up of the Canterbury Plains near Christchurch is a fine example of transported and deposited glacial material. These famous plains are underlain by 2,000' and more of gravel, fairly well sorted, bedded in places, ranging from silts to boulders and showing some current bedding; rare striated cobbles are found. The plains are alluvial piedmonts, formed in Pleistocene to Recent times by coalescence of the fans of rivers flowing down from the Alps and dumping immense quantities of outwash on a slowly subsiding shelf area. The better sorted beds of gravel provide excellent aquifers; the deposits provide ready sources of aggregate for all purposes, particularly for roads. Indeed the high quality of gravel roads traversed in the alpine country is largely due to the ready supplies of fluvio-glacial material.

MISCELLANY.

Economic Aspects:

Increasing use is being made of glacial lakes in the generation of hydro-electric power. The head of water involved is relatively small but this is, to some extent, compensated by the large volume of water available. At Lake Tekapo the lake level has been raised by damming the outlet over the moraine; a mile long tunnel leads the water to a power station with a head of some 150 feet.

Works at Lake Pukaki, including an earth dam, sluice gates and spillway, are used only for lake control at present although hydro-electric installation is intended. Water is stored in the lakes during spring and summer, when the supply from the north-west rains and melting snow and ice is more than sufficient for electricity generation, and is released during the winter to supply the hydro-electric stations farther down the Waitaki river.

New Zealand's dependence on supplies of superphosphate becomes ovcious to the traveller interested in soils and agriculture. The Canterbury Plains, famous for fat lamb production, overlies thick gravel deposits with poor soils;

large areas used for sheep and mixed farming in the South Island have similar soils on glacial deposits or greywacke. In the North Island there are considerable areas of poor siliceous soils on acid volcanics which also are dependent on super-phosphate for fertility.

Aerial spreading of super is popular and well organized in New Zealand and one gains the impression that the New Zealand rural economy is much more dependent on fertilisers than is our own. The Dominion has no significant source of superphosphate as yet, hence their interest in the present search for phosphate rock in the south west Pacific.

Rates of Erosion:

Some figures on rates of recent erosion in the South Island are of interest. In general, quoted rates need to be qualified by the type of material eroded and the characteristics of the stream system. Very high rates have been quoted from New Zealand where recently uplifted soft sediments have provided an easy target for streams.

Based on the age of 20,000 years for the end of the last major ice advance in the South Island, an average rate of down-cutting in glacial draft of about one foot in 400 years is apparent along some of the rivers in the glacial country; these are glacier-fed and are, at most times, fairly large rivers. However this rate may have been controlled by temporary base levels in harder rock downstream because in another locality there was evidence that a narrow gorge 40' - 50' deep had been cut in greywacke and schist in the same period (20,000 years). This average rate of one foot in 400 years in greywacke has been achieved by a large river - a veritable torrent in the gorge - headed in country with a rainfall of snow and ice ranging from 150 - 200 inches per year.

New Zealand Geological Survey:

A brief visit was paid to the headquarters of this Survey at Wellington. The Survey is an integral part of the Department of Scientific and Industrial Research and works in close contact with other branches of the Department. The Survey has a number of regional offices such as those at Invercargill, Auckland, Rotorua, etc. The present strength of the Survey is a little over thirty professional officers. The palaeontological section seemed very well organised, although the housing of the section was poor; specimens of their card and sheet system for recording fossils have been passed to the palaeontologists. They are doing considerable work on spores and pollens and are enthusiastic about their use in correlation in the Mesozoic system and series. The Director, Mr. Willett, could arrange for one of our officers to train in this work in the palaeontological laboratory.

In the production of maps, the Survey is fortunate in that it has excellent co-operation from the Government Printer and little trouble in obtaining materials from dollar sources. They have been using "Contak" lithological symbols on shading (transparent) film for some time, and find that they save considerable drafting time. These are like Zipatone, but include a larger range of symbols and have more reliable glue. Furthermore, the Government Printer in Wellington prints down on this shading film, thus providing the Survey with transparent stick-up lettering for fair drawing. We have ordered Contak material but are still awaiting delivery; equivalents from the sterling area are inferior to the American material.

I noticed a pegboard in the tea room of the Geological Survey at Wellington on which is noted the progress of all publications in preparation. This seems to be a very good idea in that dilatory authors are faced with a constant reminder of their procrastination each time they drink a cup of tea!

PART 2 - E. K. CARTER

As stated in the introduction this report is not intended to be comprehensive but to record points of interest or significance made by speakers during the session or observed on excursions. The treatment is therefore somewhat disjointed but Part 2 falls into 4 general headings - vulcanicity; igneous rocks; transcurrent faulting and economic geology.

A photographic record (Kodaslides) of the excursions has been filed in the photographic library. Those covering excursions attended by E. K. Carter are numbered NZ1 to NZ65 .

Specimens were also collected and may be seen in the museum; they are listed in the Appendix.

Literature collected during the visit to New Zealand, including programme, tour notes, abstracts of papers and a handbook titled "Science in New Zealand" by F. R. Gallagher, may be seen in the library.

VULCANICITY.

Volcanic activity has been prevalent in the North Island throughout the whole of the Tertiary. Isolated centres developed in the South Island during Pliocene to Early Pleistocene to form the Otago and Banks Peninsulas, on the East coast. Basic and ultrabasic volcanics of ?Permian age also occur in the Lake Rotoiti - Nelson area of the South Island. In addition to this much of the Tertiary, Mesozoic and older greywackes in both islands contain high proportions of detritus of volcanic origin. B. L. Wood (paper no. C62) concludes that a volcanic island arc lay to the west and south-west of the New Zealand Geosyncline during early Permian and Carboniferous time.

Present day vulcanicity is restricted to a north-east trending belt passing through White Island, the Rotorua-Taupo graben and the Tongariro National Park volcanoes. This belt parallels the Wellington-Napier-Gisborne seismic line and lies along the Tonga-Kermadec volcanic line. Mount Egmont, which erupted last about 350 years ago, also is on this line, well to the south-west. Points of eruption are invariably associated with fault lines - most of them north-easterly, some of them north-westerly. Locally this is well illustrated by Kodaslide which shows Tarawera, Inferno Crater, Frying Pan Flat Crater and Southern Crater in alignment.

Prehistoric volcanoes on the North Island, extending back into the Tertiary, show a gently-curved, generally north-trending alignment, which is convex to the east. This reflects an earlier important structural trend.

In the North Island all present-day volcanic material is basaltic (the Tarawera eruption of 1886 is believed to have been hydrothermal in origin and not associated with magmatic activity). The earlier lavas of the Auckland district and farther south are also basaltic. The Recent ash and pumice showers of the Rotorua-Taupo regions are all rhyolitic. Extending back into Pleistocene and Tertiary time the compositions of lavas range from basalt to rhyolite.

The Otago Peninsular volcanics, in the South Island, are unusual in that they are generally sodic-phonolite and trachyte - and appear (according to W. N. Benson) to constitute too large a volume to be differentiates from the postulated standard basaltic magma. The Banks Peninsular flows are basalts. The Brooks Street and Croixelles Volcanics (?Permian) and those in the Te Anau Beds (Carboniferous) in the Nelson area include basalt, tuff and serpentinites (see spec. R6844). They are probably related to the Dun Mountain Intrusions, which include dunite and serpentinite.

PRODUCTS OF VULCANICITY.

Ignimbrite: Sheets of ignimbrite cover wide areas of the central part of North Island. There was little opportunity for detailed examination. At Arapuni Dam on the Waikato River strongly columnar-jointed ignimbrite is well exposed (see Kodaslide N24). The ignimbrite here is light grey in colour, easily scratched and somewhat friable. It has the appearance of a fine agglomerate, fragments being apparently rhyolitic, commonly pumiceous and in some cases glassy. It could not be mistaken for a flow. R. A. Bailey presented a paper on ignimbrites (paper no. C6). In occurrences greater than 200 feet thick he recognised 5 zones, from top to bottom:

1. Incoherent ash and pumice.
2. Coherent ash and pumice with hydrothermally deposited minerals.
3. Dense lithic zone of devitrified welded ash and pumice.
4. Dense perlitic glass zone of welded ash and pumice.
5. Basal zone of incoherent ash and pumice.

Ignimbrites are generally considered to be the product of nuées ardentes.

Ash & lapilli: These, of rhyolitic composition, have covered many thousands of square miles in the central district of the North Island. In a quarry on the Taupo-Napier road, 3 miles from Taupo a series of ash and lapilli deposits have been dated by radiocarbon methods as from 9000 to 1800 years old. The total thickness is of the order of 30 feet and represents more than 26 showers. The "Taupo pumice", erupted about 120 A.D., is at least 6 inches thick over 8,800 square miles even today. Photographs of the ash and lapilli in the quarry are numbered NZ32-34. Kodaslide no.NZ34 shows ash from the 1886 eruption of Tarawera; this deposit shows an initial dip of about 30 °.

Lahars: Lahars - volcanic mud flows - serve as an important distributory process for sub-aerial volcanic ejectamenta. They may accompany volcanic activity or postdate it by some time, in which case they may be triggered by seismic activity or merely by the build up of ponded water in, for example, a crater until the strength of the containing ash barrier is exceeded. This is what happened in the Tangiwai railway disaster in 1953.

Lahars are essentially sub-aerial density current phenomena and may carry boulders weighing many tons. They can be seen well around the volcanoes of the Tongariro National Park. Their lower termination is characteristically irregular and have been confused with glacial moraines (see Kodaslide nos. NZ 11 & 12).

Basalt avalanche: A large mass of fragmental basalt has been strewn down the western flank of Ngauruhoe by the shattering and pushing over the crater rim of a cold basalt mass by a later flow. If preserved in the geological column, this feature could give rise to a considerable mass of volcanic breccia without the associated ash of an agglomerate (unless the latter were supplied from later ash showers).

Water-borne volcanic detritus: Along the valley of the Waikato River, from about 12 miles north of Hamilton to 30 miles to the south-east of Hamilton, a vast accumulation of volcanic (rhyolitic and pumiceous) sands and gravels form a surface, known as the Hinuera Surface, which rises gently towards the south-east. It represents redistributed volcanic detritus, totalling several cubic miles. The mechanism of distribution and the source of the material have not yet been adequately determined. Fragments are slightly rounded and poorly sorted. Cross-bedding has been observed. The age of the Hinuera sands and gravels is uppermost Pleistocene.

The thermal manifestations of recent vulcanicity are mentioned under the section on geothermal power, under "Economic Geology".

The following papers on vulcanicity were presented during the Dunedin meeting:

Paper No. C4 - "The structural evolution of the central volcanic region, North Island, N.Z., from physiographic evidence" by J. Healy.

Paper No. C5 - "Relationship of volcanoes to structure" by D. Kear.

Paper No. C6 - "Internal structures and lateral variations of ash flows" by R. A. Bailey.

Paper No. C7 - "Lavas of the Tongariro volcanoes" by R. H. Clark.

IGNEOUS ROCKS.

Volcanic rocks have been referred to in the previous section. Intrusive igneous rocks, other than dykes associated with lavas, are not extensively exposed in New Zealand. Those exposed, however, cover a wide range of chemical composition. With the exception of two small exposures of diorite on the Coramandel Peninsula, the geological map of the North Island shows no plutonic rocks. In the South Island granite (using the term in its broadest sense) crops out extensively west of the Alpine Fault, particularly in the northern half of the island, and on Stewart Island. Ultrabasic and basic rocks crop out discontinuously in a narrow belt more than 80 miles long which runs north-easterly from the Wairau Fault, north-east of Lake Rotoiti, along the east side of Tasman Bay. A larger, discontinuous arcuate belt east of the Alpine Fault occurs in the south of the South Island. This belt is paralleled by another in, and along the north shore of, Foveaux Strait. Specimens of dunite and other ultrabasic rocks were examined 10 miles north-east of Lake Rotoiti where the ultrabasic belt (Dun Mountain Intrusives) is terminated against the Wairau Fault (see spec. R6843). Mineralogically, the ultrabasic components of the Brooks Creek and Croixelles Volcanics and the Te Anau Beds appear to be similar to the Dun Mountain Intrusives (see spec. R6844 from the Te Anau Beds). The Croixelles Volcanics (which were not examined) bear a close spatial relationship to the Dun Mountain Intrusives. The Brooks Creek Volcanics form a belt farther west. The ultrabasic intrusive-extrusive complex appears to form an ophiolitic suite similar to that described in the literature from other parts of the world. Probable pillow lavas have been recognized in the basics of the Te Anau Beds.

The postulated 300 mile lateral displacement on the Alpine Fault is based partly on the relative positions, on either side of the fault, of the ultrabasic belt in the north-western and southern parts of the South Island.

The granites of the South Island, which were seen only east of Reefton, in the Victoria Range, are typically biotite granites, but hornblende granite, grano-diorite and diorite occur. The granite, where seen, is a medium-fine grained, massive, rather femic-poor, biotite granite. At Reefton "floaters" in the bed of the Inangahua River show a splendid variety of granite and gneiss types. It is evident from these specimens that quite extensive metasomatic replacement of the country rock by granite (i.e. granitization) has taken place. Porphyritic granite, augen and other gneisses, lit-par-lit injection phenomena and selective replacement of metasediments can all be seen.

A body of rock, mapped as quartz porphyry, was examined in a road cutting in the Buller Gorge, upstream from the original discovery of uranium in the area. Where examined the rock was found to be a breccia, with huge boulders of porphyry so little weathered that the biotite is still fresh. It seems that the breccia was derived from an igneous terrain during an active phase of the Hokonui orogeny. Its stratigraphic relationship to the Hawk's Crag Breccia has not been satisfactorily determined, but the age difference, if any, is probably fairly small.

TRANSCURRENT FAULTING.

Transcurrent faults - faults with dominantly lateral movement - are active in the South Island and the southern part of the North Island at the present time. The record of their movement throughout the last 100,000 years or so can be readily read from the topographic evidence and from measured movements in historic time. Evidence for the Alpine Fault and several of its branch faults, notably the Wairau Fault, were seen during the post-sessional excursion S26. The E-W Hope Fault, along the valleys of the Hope and Waiau Rivers, on which transcurrent movement took place in 1888; the White Creek Fault, movement on which caused the 1929 Murchison earthquake; and the Whangamoa Fault were also seen. A Kodaslide (no. NZ47) of the Whangamoa Fault (which is related to the Alpine Fault system) shows how narrow is the fault zone. The lack of major deformation zones associated with these faults, some of them with very large displacements, is a feature of the New Zealand transcurrent faults.

The history of the movement on the Wairau Fault since the height of the last glacial epoch is recorded by the displacement of a series of terraces, formed during glacial retreat in the valley of the Wairau River, north of its junction with Branch Creek. These have been detailed by H. W. Wellman, "New Zealand Quaternary Tectonics" in Geologischen Rundschau 43 (1), 1955. There are six terraces. On the youngest the horizontal movement is 33 feet, vertical displacement 3 feet; on the oldest the figure for horizontal displacement is 195 feet, but that for vertical movement has not been determined (but is to the order of 10 feet). Kodaslides nos. NZ43 to NZ46 show the Wairau Fault.

Wellman has calculated, from geodetic surveys and from measurable post-glacial movement, that the lateral displacement in the Alpine Fault System in Recent times has been at the rate of upwards of one inch per year. Horizontal movement of 300 miles since Jurassic time only requires an average rate of movement of 0.15 inches per year.

ECONOMIC GEOLOGY.

Only those aspects of economic geology which the author saw at first hand, or on which papers were presented, will be dealt with.

METALS.

Iron: Paper No. C13(B5) "New Zealand iron sands" was presented by W. R. B. Martin. Black sands, containing titanomagnetite and ilmenite, form dune and beach sands along the west coast of the North Island. In North Island there are an estimated 800,000,000 long tons of recoverable titanomagnetite, containing 50-58% Fe and 7-9% TiO_2, together with 8,600,000 tons of recoverable ilmenite. The grade of the sands varies from 5-90% titanomagnetite. South Island deposits contain over 40,000,000 tons of ilmenite but testing has been inadequate. There are also a four small limonite deposits with total reserves of 9,000,000 tons.

NON-METALS.

Chemical salts: Salts from seawater are recovered by solar evaporation at Lake Grassmere. T. Hagyard and S. R. Siemon expressed the view in their paper "Chemicals from seawater" (No. C14 (B6)) that weather conditions and available space for pans inhibit large expansion, but by improved methods output would be increased and useful by-products obtained.

Ceramics: In "Ceramic resources of New Zealand" (Paper C12 (B4)) I.C.McDowall discussed the sources of clays for bricks, tiles, earthenware, pipes etc. and refractories. The clays are all Tertiary or younger in age and derive from argillites and greywackes or from volcanic rocks.

Perlite is obtained from certain zones of ignimbrite sheets and is used for light weight aggregate and refractories. Pumice can also be used for the same purpose.

FUELS.

Uranium: The first uranium deposit found in New Zealand was located in a road cutting of the Inangahua-Westport road through the Buller Gorge. The mineralization is in a narrow silicified zone in a coarse breccia (Hawk's Crag Breccia) - see Kodaslide no. NZ63 . The uranium appears to be introduced.

Subsequently widespread radioactivity was discovered in fresh-water sediments of the Ohika Beds in the region. The relationship of the Hawk's Crag Breccia and the Ohika Beds has not been established beyond doubt. They may be contemporaneous or the Hawk's Crag Breccia may be younger. The Ohika Beds are Upper Jurassic to Lower Cretaceous in age and consist of well-bedded arkose and carbonaceous beds. Near the base (see Kodaslide no.   ) conglomerate and subeconomic coal bands form an important part of the succession.

R. Willett, director of the New Zealand Geological Survey, gave a brief account at Dunedin of the geology of the area. He was followed by F. Joubin, of Blind River fame, who remarked on the similarity between the Buller Gorge deposits and those of the Colorado Plateau. The finds to date in the Ohika Beds are associated with carbonaceous matter and are poor in sulphides. Deposits have been located over a strike length of several thousand feet. The uraniferous exposures have thicknesses ranging from 6 inches to 5 feet (average 2 feet) and are of sufficient size and abundance to warrant extensive exploration.

Coal: Coal of Eocene age has been found in several localities west of the Alpine Fault, in the South Island. (Deposits of other ages also occur in New Zealand). From the west coast eastwards the rank of the coal increases from lignite, through sub-bituminous to bituminous. Mapping has shown that, despite the fact that the degree of structural deformation varies greatly throughout the coal-bearing area, the rank of the coal is directly related to the maximum depth of burial and has apparently been unaffected by tectonic deformation.

The open-cut at the Garvey Creek Coalfield, east of Reefton, was examined. Here the coal seam dips at from 60° to vertical (see Kodaslide nos.NZ57-60). The coal is bituminous and is of Eocene age.

GEOTHERMAL POWER.

Several zones which display thermal activity occur within the Rotorua-Taupo volcanic belt of the North Island and provide potential sources of power. The zone at Wairakei is being actively developed.

The following papers on the subject were read at Dunedin: Paper No. C35 (A34, B17) "Recent work on geologically important acid gases in high temperature pressure water", by A. J. Ellis. Paper No. C38 (A40, H9) "Geological aspects: Geothermal steam in the central North Island volcanic zone" by G. W. Grindley. Paper No. C39 (A41, H10) "Temperature distribution, heat storage and heat balance in the thermal areas" by C. J. Banwell. Paper No. C40 (A42, H11) "Long term physical measurements in the thermal area" by G.E.K. Thompson.

Paper No. C45 (A46, H15) "The estimation of dryness fraction and mass discharge of geothermal bores" by A. E. Bainbridge.
Paper No. C55 (B26) "Analytical and chemical problems of the Wairakei geothermal investigations" by S. H. Wilson.
Paper No. C56 (B27) "Hydrothermal rock alteration in an active thermal area" by A. Steiner.

The Wairakei project was visited on 12th January and the scheme explained by project engineer Mr. Fuchs. Bores have been discharging freely from the area, which covers an area of about one mile x ¼ mile, for three years. There are now over 40 bores with diameters up to 10 inches and maximum depth 3,500 feet. Most producing bores are between 1500 and 2000 feet deep. They pass through unconsolidated superficial valley fill, ash and pumice, lacustrine sediments, pyroclastics and acid lavas, and finally ignimbrite. The base of the ignimbrite has not been penetrated, but the ignimbrite is believed, on geophysical evidence, to be about 1200 feet thick.

At a depth of 500 feet steam can be obtained almost anywhere in the area but at greater depths the yield is variable from point to point; the availability of steam is controlled by the existence of faults and drilling is now designed to intersect known faults. A good yield of high pressure steam is obtained from the upper part of the ignimbrite, which is fractured and extensively hydrothermally altered, but at greater depths the ignimbrite is less fractured and yield falls off. Seismic work shows that below the ignimbrite the rate of travel of shock waves is less than that in water-saturated unconsolidated sediments. It has been suggested that high-pressure dry steam may be available at that depth.

The discharge from the bores consists of from 25-33⅓% steam and the remainder water. Corrosive volatiles and solutes are not expected to be a serious engineering problem. The main gases are CO_2 and H_2S, which form 0.2 to 0.1% of the recovered steam. The pressure in the bores varies, with depth, from 70 to 200 lbs. per inch. The water and steam are separated at the bore head by means of a 180° bend in the discharge pipe, followed by a cyclone separator; the final steam product is 99.95% dry.

In an attempt to determine the capacity of the region for sustained power generation bores have been allowed to discharge freely over a period of upwards of three years. Some bores have declined in output but this is believed to be due to clogging of the bore. The overall yield has fluctuated slightly in a direct relationship to rainfall so that it is believed that the field is not being overdrawn.

At present the bores sunk have a total capacity of about 150,000 kw. The foundations of the first power station, of 70,000 kw capacity, are at present being built, about a mile from the producing area, on the bank of the upper Waikato River. Plans have recently been announced for the production of 250,000 kw from the field. Other fields, for example that at Waiotapu, are also being investigated. Kodaslides nos.NZ35-37 show aspects of the Wairakei project, including the silencers on the bore outlets and the steam-water separators.

REFERENCES

ANDERSON, E.M., 1942 - The Dynamics of Faulting. Oliver and Boyd. Edinburgh.

MUTCH, A.R., 1957 - Facies and Thickness of the Upper Palaeozoic and Triassic Sediments of Southland. Trans.Roy.Soc.N. Zeal., 84 pt 3, 499-511.

WELLMAN, H.W., 1956 - Structural Outline of New Zealand. Bull. 121 Geol. Surv. N. Zeal.

APPENDIX

List of Rock Specimens

R7762	Fine to medium quartz-greywacke and argillite (hardened claystone) from "schist facies" 6 miles west of Cromwell, near Greenstown, South Island, New Zealand.
R7763	Fine quartz-greywacke and thin-bedded greywacke silt and claystone - "schist facies" - low-grade chlorite zone (Sub-zone 2), Lindis Pass, 30 miles north of Cromwell, South Island, New Zealand.
R7764	Dark, impure limestone (calcarenite?) from Arthurton Group, Maitai series, Permian $\frac{1}{4}$ mile south east of Arthurton on Waipahi River, South Island, New Zealand.
R7765	Calcarenite from Balfour, South Island, New Zealand, Duntroonian Stage, London Series (Oligocene).
R7766	Greywacke and quartz-greywacke ("Alpine facies") from boulders - Tasman Glacier moraines - Mt. Cook area, South Island, New Zealand.
R7767	Schist (chlorite Sub-zone 3) and metamorphosed tuff or flow material. "Schist facies" - Lindis Pass, South Island, New Zealand, five miles north of Specimen R7763.
R6836	Mesozoic greywacke, from quarry on Auckland-Rotorua road, 10.5 miles south-east of Cambridge, New Zealand.
R6837	Scoriaceous basalt from 18th August, 1954 flow, Ngauruhoe, New Zealand.
R6838	Fragment of boulder of basalt thrown out of Ngauruhoe, September, 1954 (see Kodaslide NZ18).
R6839	Pre-history (but Recent) porphyritic basalt from Ngauruhoe, New Zealand.
R6840	Schistose greywacke of Otago Schists, Brighton-Taeri Mouth area, New Zealand.
R6841	Tertiary-Carboniferous greywackes, west of Alpine Fault, north-western part of South Island, New Zealand.
R6842	Specimen from breccia, of igneous rocks, Buller Gorge.
R6843	Dunite (?) from Red Hill, about 10 miles N.E. of Lake Rotoiti, South Island.
R6844	Serpentinite from Upper Te Anau Beds, from cutting between Rai Falls and Whangamoa.