PAPERS.

ON THE GEOLOGY OF THE NEW ZEALAND ALPS.

By Captain F. W. Hutton, Corr. M.R.S., of Tasmania.

[*Read April 13th*, 1886.]

The New Zealand Alps form a narrow range of mountains dividing the plains of Canterbury from those of Westland, and attain in Mount Cook an elevation of 12,349 feet. Both to the north and to the south they widen out into several subordinate ranges with peaks from 6,000 to nearly 10,000 feet in height. The principal snowfields and glaciers occur in the central portion between the sources of the River Rakaia and those of the Waitaki; but small glaciers are found as far north as the head of the Waimakariri, near the West Coast Road, and as far south as Lake Wakatipu and Milford Sound. The largest glacier is the Tasman, which lies on the eastern side of the range just north of Mount Cook and which, according to the survey of Dr. von Lendenfeld, is rather more than twenty miles in length by nearly two in breadth; its terminal face being 2,450 feet above the sea. On the western side of the range the glaciers are smaller, but descend much lower; the Francis Joseph glacier reaching to 705 feet above the sea. This is owing partly to the greater snowfall, and partly to the steeper slope on that side of the mountains.

Nearly the whole of the Alps are composed of much disturbed sedimentary rocks, principally sandstones, mudstones, and greywackes. The main anticlinal, or true tectonic axis, runs in a south-westerly direction from Tasman's Bay to Otago, where it curves round to the south-east, and reaches the sea near Dunedin. The central parts of this anticlinal are composed of Schists of different kinds. The tectonic axis, however, nowhere coincides with the orographic axis of the range, but lies along its western base in Westland, where the whole of the western portion of the elevated *massif* has been removed by denudation, so that the main ridge of the Alps is carved out of the south-easterly face of the anticlinal curve. To the north and to south of the Alps proper, both wings of the anticlinal remain. West of this main anticlinal a synclinal runs through the provinces of Nelson and through Southland, lying parallel with the anticlinal; but on the eastern side the rocks are more irregular, there being several synclinals and anticlinals

running more or less at right angles to the main anticlinal. The south-western portion of the mountains in Otago is separated geologically from the rest by a fault running through Lake Te Anau in a north and south direction, with its upthrow to the west.

Four different rock systems take part in building up these mountains. The first is the MANAPOURI SYSTEM * composed of Gneiss and Schists of Archæan age. It occupies the south-western portion of Otago, which has been thrown up by the fault and appears again in places along the main anticlinal axis through Westland and Nelson to Tasman's Bay. The second is the TAKAKA SYSTEM, which is largely developed on both sides of the main anticlinal in Otago, extends through Westland and Nelson at the western base of the Alps and is found on the eastern side along the secondary anticlinals in Nelson and South Canterbury. The age of this system is probably Ordovician and Silurian and partly perhaps Devonian. It is composed of Schistose rocks, which, in Nelson, get slaty, and contain Graptolites, while in Otago they are quite crystalline and foliated. Whether these Schists of Otago (Wanaka System) are truly the equivalents of the more slaty and calcareous rocks in Nelson (Takaka System) or whether they form an underlying system has not yet been proved. The third is the MAITAI SYSTEM, which forms the principal parts of the mountains in East Nelson, Marlborough, and Canterbury, and occupies the synclinal in West Nelson. Its age appears to be Carboniferous. The rocks are never Schistose, but often include basic eruptive rocks, such as Diabase and Serpentine, and more rarely, as at Croixelles Harbour, near Nelson, acidic Felsites. The fourth is the HOKANUI SYSTEM, a littoral formation 20,000 to 25,000 feet thick with plant remains all through it. In age it probably covers the Triassic and part of the Jurassic periods. It occurs along the synclinal in Southland, as well as in those of East Nelson and Canterbury, but it is not found in Westland nor in Western Nelson. †

Exposures of granite, belonging probably to the Maitai System, occur in Preservation Inlet on the south-west coast of Otago, and in Westland and Nelson, chiefly along the main anticlinal axis.

The next rock system is of cretaceous, probably upper cretaceous, age, and is known as the WAIPARA SYSTEM. Along

*Quar. Jour. Geol. Soc., Vol. 41, p. 194.

† In the Quar. Jour. Geol. Soc. of London, Vol. 32, p. 54, Dr. Hector gives a section from the Alps to Brighton, on the West Coast, in which this system (marked p.) is shown. But this section appears to be quite a hypothetical one, and intended to explain how the rocks would occur if they were present; for it shews other rocks (k) with "Saurian bones, Ammonites, &c.," although none have ever been found on the West Coast.

the eastern base of the main range it lies quite unconformably on the Hokanui and older rocks, and, according to Dr. Hector and Dr. von Haast, it is also found in a similar position on the West Coast; thus lying at a low level almost on the main anticlinal axis. The Waipara System has itself been much disturbed in Nelson and in Otago, and is everywhere denuded and overlain unconformably by beds of the Oamaru System (Oligocene) and Pareora System (Miocene). Outliers of these cretaceous and tertiary rocks are found far up the Alpine Valleys, reaching a height of 3,000—4,000 feet above the sea, but they do not take part in the folds of the older rocks. Volcanic rocks, chiefly acidic, belonging to the Waipara System, lie along the eastern flank of the mountains in Canterbury from Mount Somers to the Malvern Hills, and later volcanic outbursts took place in the Oligocene and Miocene periods. In the South Island volcanic action appears to have become extinct in the Miocene; the focus of energy changing to the North Island, where it has not yet quite died out.

The probable geological history of the New Zealand Alps is as follows:—The volcanic outbursts which took place during the deposition of the Maitai System, and which we now recognise in the row of granite hills along the centre of the main anticline in Westland and Nelson, as well as in the greenstone ash beds associated with the sandstones and mudstones of the system, may perhaps be taken as the first step towards the formation of the New Zealand Alps. This must have been followed, or accompanied, by elevation and sufficient denudation to lay bare the granitic roots of the volcanoes. A range of mountains must have been formed lying to the west of New Zealand. Their height must have been immense, rivalling probably the Himalaya; for, during the subsequent deposition of the Hokanui System, a subsidence of more than 20,000 feet took place, and yet land must always have been in the neighbourhood, for plant remains are found throughout the system. At the close of the Hokanui period lateral compression, accompanied by upheaval, took place along a line to the east of the earlier chain, and the main outlines of the New Zealand Alps were formed. It was then that New Zealand was separated from Tasmania, and the two have never been connected since. A long period of subaërial denudation succeeded, during which the greater part of the west wing of the main anticlinal was removed, and most of the present river valleys were formed. When this elevation was at its height, volcanic eruptions broke out along the eastern (and perhaps western) side. Depression followed, and the Waipara System was deposited round the coasts. Again, a third elevation took place, accompanied by

folding of the rocks in Otago, in Nelson, and in Malborough, but not in Canterbury. Since then three depressions and two elevations have taken place, during which the greater part of the cretaceous and tertiary rocks were removed by denudation. A third elevation is going on at present.

No one who, after visiting the Alps of Switzerland, should explore the Alps of New Zealand could, I think, fail to notice two remarkable points of difference between these mountain regions. The first is that mountains, with sharp serrated summits, which are the exception in Switzerland, are the rule in New Zealand. The second is that waterfalls are rare in New Zealand in comparison with Switzerland, although the mountains of New Zealand are quite as rough and as rugged as the Alps of Europe. Also, the passes in New Zealand are lower, the valleys are much more terraced, and the mountains are generally much more covered with loose *debris*, than any part of the Swiss Alps. The explanation of these differences lies in the fact that the New Zealand Alps are far older than those of Switzerland. They have been constantly exposed to the action of rain and wind ever since the Jurassic period, and most of the larger valleys had been cut down nearly to their present depth before the Oligocene; a time when the European Alps and the Himalaya were only just rising above the sea.

CONTRIBUTION TO THE PALÆONTOLOGY OF THE UPPER PALÆOZOIC ROCKS OF TASMANIA.

By Robt. M. Johnston, F.L.S.

[*Read April* 13, 1886.]

During many years of observation among the Upper Palæozoic rocks of Tasmania I have made large collections of fossils in different parts of the island. Among these I have identified many forms, already described by Morris, M'Coy, Dana, de Koninck, and other authors, as occurring in a similar formation in New South Wales. There is a considerable number of important fossils which I believe to be new to science, and, as it is very desirable for purposes of reference and classification that these fossils should be described, I have ventured to submit a list of the fossils known to me as occurring in Tasmanian rocks, together with provisional descriptions of the species deemed by me to be new to science. I have long studied the variability of the various fossil forms