Pleistocene Glaciation of Central Otago.

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[*Read at the Wellington Philosophical Society on 11th July, 1928; received by Editor, 5th September, 1928; issued separately, 23rd November, 1928.*]

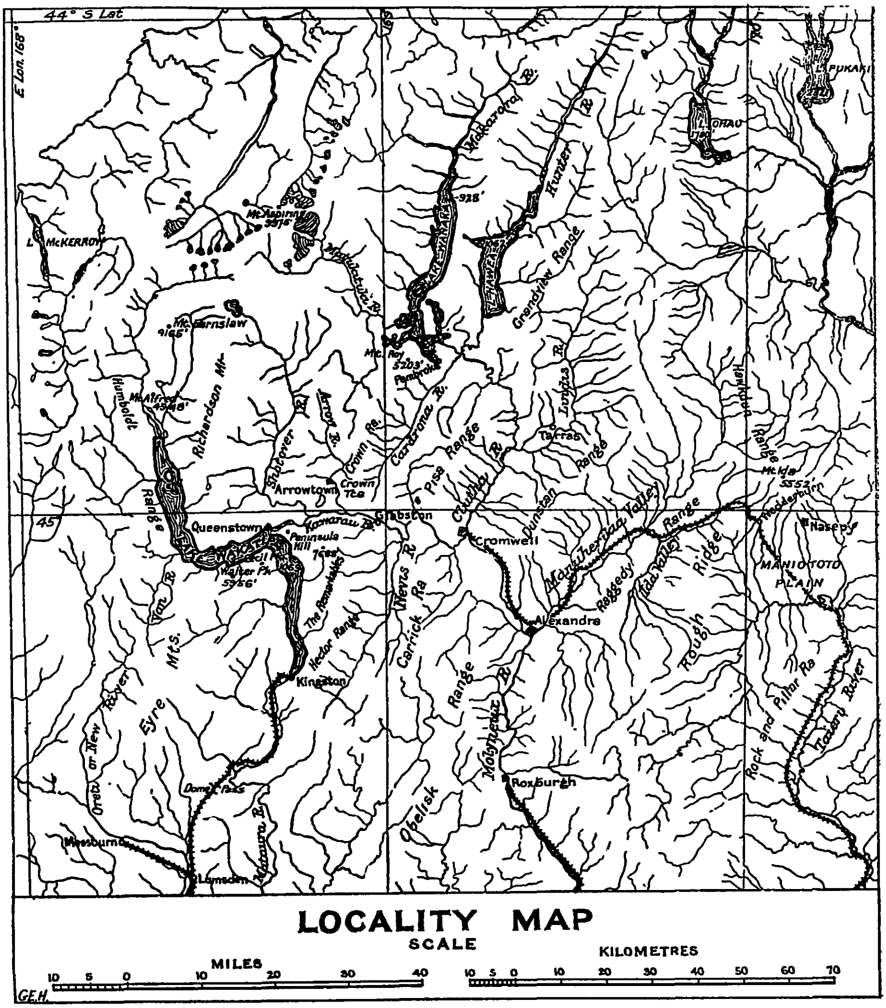
Plate 71.

Signs of a former and greater glaciation than obtains at present in the interior portions of the South Island of New Zealand were observed by the first geologists to explore these regions. Haast (1861*) noticed terraces and transported blocks near Lake Rotoiti in Nelson Province and later when he first reached lakes Pukaki and Tekapo in Canterbury (Haast 1862), he was struck by the fact that the lakes were bordered by lateral and terminal moraines of enormous glaciers that had once extended out from the Southern Alps. Similarly Hector (1863), on his first expedition to the West Coast of Otago recorded the presence of striated rock-surfaces and erratic blocks far removed from present glaciers. Locke-Travers (see Travers 1866) and other geologists who subsequently visited these regions confirm and amplify the observations of Haast and Hector, but differences of opinion have existed and still exist as to the former extent of the ice when it was at its maximum flood-level. The purpose of this paper is to present some new data bearing on the subject, gathered while the writer was making a soil-survey in Central Otago during the past three summer seasons.

The earliest map showing the distribution of ancient moraines was prepared by Haast (1865). It shows morainic accumulations on the flanks of the Southern Alps and includes those on the shores of lakes Hawea and Wanaka, but it does not extend farther south into Central Otago. The next map was that of Hector (1870) which symbolizes ancient moraines on the shores of Lake Wakatipu. At intervals during later years small-scale maps of the South Island were drawn by Hutton (1894), Marshall (1908 and 1912), Park (1910A.), and Morgan (in Mss.), which show their ideas of the former extent of the ice rather than distribution of ancient moraines and of other signs of former glacial action. Park's contention (1909, 1910A, and 1910B) that an ice-sheet of continental dimensions formerly covered Central Otago is at variance with the views of most New Zealand geologists and was opposed by Marshall (1910) on theoretical grounds, by G. M. Thomson (1910) on botanical grounds, and by Benham (1909) on biological grounds. The evidence gathered recently supports Morgan's statement (1926, p. 278) that Central Otago, doubtless owing to light precipitation, was little affected by the ice of Pleistocene times. This evidence will now be catalogued in order from the east side of the district westward to Lake Wakatipu.

*Figures in brackets refer to the appended list of literature.

Maniototo Plain.—On Maniototo Plain no striated rock surfaces, nor isolated mounds of unsorted rock-material that could be called moraines, were seen. Near the portals of the larger gorges of creeks such as the Pigburn, the Sowburn, the Linnburn, the Waitoitoi, etc., flowing off the Rock-and-Pillar Range and Rough Ridge, there are occasional large angular blocks of rock and accumulations of angular



LOCALITY MAP

rock-material. Although these form part of the outwash delta-fans of the creeks, they look like ice-transported debris, for many rock-fragments are standing on edge instead of lying flat as they would do had they been washed out of the gorges.

There are no erratic blocks far out on the plain, but within 20 chains of the hill-edges, especially near the Pigburn and the Stotburn, there are areas littered with erratic blocks of schist five to ten feet in diameter, and of silicified quartz-grit up to five feet in diameter. Likewise on the north side of the plain there are a few perched blocks on Quartzreef Hill near Naseby, and on Seagull Hill near Wedderburn apparently moved by ice only a few chains from their sources.

The inference from this evidence is that glaciers occupied valleys on the surrounding ranges and that they extended only short distances out on to the plain which was in existence in pre-Pleistocene time.

Ida Valley.—At the south end of Ida Valley there is a low-level lateral moraine of a glacier that once moved out north-eastwards from Low Saddle; and to the south of German Hill Diggings a clutter of wetherstones, consisting of silicified quartz-grit, shows that a short glacier once flowed westwards off Rough Ridge. Farther north near Oturehua undisturbed wetherstones indicate absence of ice-action in this quarter. It would thus seem that during the epoch of former maximum glaciation there were only small valley-glaciers on the surrounding hills and a narrow piedmont-glacier along the south-east and south sides of the valley.

Manuherikia Valley.—Near the north end of Manuherikia Valley the flat top of Tunnel Hill, an isolated hill composed of Tertiary sediments, is strewn with angular greywacke material; evidently this hill was once overridden by ice. Large boulders of greywacke two miles south of Hawkdun Home Station indicate that the front of a glacier from the north once reached this point.

Along the west side of Manuherikia Valley occasional mounds of rock-debris indicate that valley-glaciers from the Dunstan Range once protruded short distances into the valley (see Fig. 1). Along the east side of the valley the only sure indication of former ice-action was seen to the east of Galloway Flat where dislodged wetherstones of Tertiary quartz-grit are strung out westwards on a schist spur.

Erratic blocks on the terraces above Clyde prove, as already stated by Park, that a glacier once flowed out of the Dunstan Gorge. A number of large erratic blocks on the terraces between Springvale Creek and Alexandra show that this glacier extended across the south end of the valley, but there is no evidence that it invaded the gorge of the Molyneux River below Alexandra.

At the ice-maximum then, there were in Manuherikia Valley a fairly large piedmont-glacier at its northern end, a number of short valley-glaciers on its sides and an expanded foot or cats-paw glacier occupying its southern end.

Molyneux Valley.—At Bald Hill Flat to the south of Alexandra there are small terminal moraines of glaciers that once descended from the east side of Obelisk Range, and farther south scattered wetherstones show that somewhat larger glaciers moved out of valleys such as those now occupied by Gorge Creek, Chasm Creek, and Shingle Creek. These glaciers probably ended fairly close to the hills without coalescing and without forming a trunk-glacier in the main valley.

Upper Clutha Valley and Cromwell Basin.—The morainic accumulations at the southern ends of lakes Wanaka and Hawea and at the lower (eastern) end of the Kawarau Gorge near Cromwell have long been known. More striking than these are the rounded and smoothed schist surfaces of the rocky barrier over which ice has flowed and through which the Matukituki Stream now finds its way into Lake Wanaka. A row of hillocks at the foot of Mount Roy shows similar rounded outlines.

On the north end of Pisa Range an ancient lateral moraine is visible at Mount Barker and there are erratic blocks 1,000 ft. above the valley floor at Luggate and at Queensberry. Farther east at Tarras, on Malvern Downs, and on Bend Terrace, there are stranded moraines at lower levels athwart the Lindis Valley. Morainic debris was found on the eastern flanks of Pisa Range and on the terraces at Lowburn. Morainic debris also occurs, at the same height as the Lowburn terraces, on the flanks of Dunstan Range at Northburn and at other points nearer Cromwell.

This distribution of ancient moraines shows that a stagnant glacier probably occupied the area north of Tarras where Timburn Flat now is, and that large glaciers from the Wanaka and Hawea depressions formerly invaded the Cromwell Basin. These large glaciers, augmented by ice descending the Matukituki and Cardrona valleys, coalesced and spread out over the Cromwell Basin, there to be further augmented by ice shed from the Pisa Range and from the Kawarau Gorge. The thickness of this ice was perhaps 1,000 ft. at Queensberry and 500 ft. at Cromwell. The discharge from it was probably thaw-water, but a small quantity of ice found its way down the Dunstan Gorge as a narrow glacier, which after receiving additional ice from the Dunstan and Obelisk ranges, spread itself out towards the place where Alexandra now stands, as the cats-paw glacier mentioned above in Manuherikia Valley.

Lower Shotover Depression and Wakatipu Basin.—Many geologists have noted the abundant evidence of former ice-action in the Lower Shotover depression and in the Wakatipu Basin and some of them, notably Hector (1863, 1865, 1870, 1873), Haast (1865), Hutton (1873), Andrews (1905), and Park (1909, 1910), have used this evidence in attempts to prove that such depressions were excavated by glaciers. Although Hector insisted (1874, p. 375) that the Wakatipu trough was glacially excavated, he had shown rightly some time previously (1870, p. 372) that the basins of Central Otago were due to dislocations and were in existence before the Pleistocene glacial advance. Enormous excavation implies enormous glaciers, hence various estimates have been made of the thickness the ice attained. That the district was not buried beneath an ice-sheet seems certain, hence signs of maximum ice-flood level should be sought on the mountains forming the sides of the pre-glacial intermontane basins.

Signs of glacier action in the Lower Shotover-Wakatipu district are abundanat at low levels but at high levels they are hard to find. Striated rock-surfaces are rare, the best seen in this district being exposed in an abandoned gold-sluicing claim on the outer edge of Crown Terrace at a height of about 2,000 ft. above sea-level, or 1,000 ft. above the floor of the Lower Shotover depression. At this height also erratic blocks of granite and other rocks foreign to the district were seen at three points on the outer (western) edge of Crown Terrace, but no morainic material was noted along the inner or east side of the terrace where it abuts against the Crown Range. A great quantity of morainic debris was, however, found 1,000 ft. higher, tucked away in Bracken Gully, a tributary of the Arrow River. From this evidence one pictures the upper Arrow valley filled with ice to about the present 3,000 ft. contour. A tongue of this ice crept up Bracken Gully there to stagnate and melt away, the thaw-water escaping on to Crown Terrace by way of the pre-glacially beheaded First Burn valley. The main discharge of this Arrow Glacier was south-westwards into the eastern end of the Lower Shotover depression which was occupied by a mer-de-glace 1,000 ft. thick. Morven Hill (2,443 ft.) appeared as a nunatak projecting 200 ft. above this mer-de-glace (see Fig. 2), Slope Hill (2,031 ft.) was buried at maximum ice-flood.

Farther west at the north-west corner of Lower Shotover depression, unsorted boulder-clay covers a hill nearly 2,000 ft. above sea-level, but no signs of ice-action were seen on Skippers Saddle (3,200 ft.) The mammilated surface on Skippers Saddle, described by Park (1909) and figured by Cotton in his Geomorphology of New Zealand and by both ascribed to ice-action, is merely a collection, a maze, of conical hummocks of dislodged and slumped schist. No rock-fragments foreign to the district were seen here and the ice-shorn crag figured by Park is unshorn! The glacier that occupied the Shotover valley and deposited foreign rock-material on the terraces at Skippers, therefore did not spill over Skippers Saddle but flowed past Arthur Point and merged into the Lower Shotover mer-de-glace which at this end may have reached up to the present 2,500 ft. contour.

Away to the west signs of former glaciation at high levels are perceptible at the upper end of the Wakatipu trough. The rounded outline of Mount Alfred (4,548 ft.) is evidence that this hill was overridden by ice; and to the south of this point the appearance of the eastern face of the Humboldt Range suggests that maximum ice-flood level reached to about two-thirds of the way up, say 5,000 ft. above Lake Wakatipu. To the south of Humboldt Range the slopes of Mount Nicholas and in the Von Valley give the impression that here glacier tongues had protruded south-westward into Oreti Valley. Farther east, in the middle reach of Wakatipu trough, the flowing contours half-way up Walter Peak and Cecil Peak indicate that ice attained to a height of about 3,000 ft. Opposite these peaks on the north side of the trough, Park (1910A) records boulder-clay 2,000 ft. above the lake on Queenstown Hill. Farther east again, Peninsula Hill (2,768 ft.), the "Crag-and-Tail Hill" of Park (1909), at the east end of the reach, shows remarkably fine glacier-shorn surfaces and was probably overridden by ice.

Along the western face of The Remarkables, no horizontal features or "ridgings" are noticeable, such as should be developed by a glacier nearly filling the Wakatipu depression. There are, however, a great number of erratic blocks in Strath Gyle, a longitudinal valley at the foot of the range. To the south of The Remarkables the lower slopes of the Hector Range have smooth outlines from the shore of Lake Wakatipu up to a height of about 2,000 ft. This smooth zone becomes narrower as Kingston is approached and almost

Fig. 1.—Morainic debris overlying Tertiary sediments at Tinker's on west side of Manuherikia Valley. The water in the foreground fills the abandoned Sugar Pot sluicing claim.

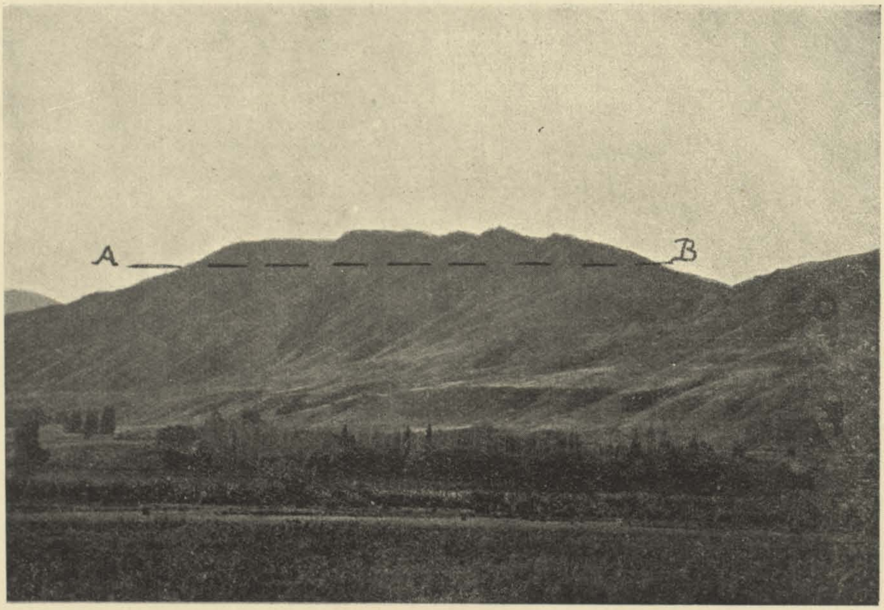


Fig. 2.—Morven Hill, Lower Shotover Depression. No foreign rock-material was found above the line A—B.

Face p. 618.

merges into the Kingston moraine. The moraine in its turn merges into river-terraces on which are scattered numerous erratic boulders.

The ice of the great glacier that once occupied the Wakatipu trough was thus apparently 5,000 ft. thick at its upper end, and thinned to 3,000 ft. at the eastern angle of the basin where some of it was discharged into the Lower Shotover depression. This ice, together with the overflow from the Lower Shotover mer-de-glace, invaded the Gibbston basin and made its way down the Kawarau gorge as a narrow sinuous glacier. A glacier in the Nevis Valley probably did not reach the Kawarau gorge. Another portion of the Wakatipu glacier flowed down the Kingston reach of the trough and may have extended 20 miles down Mataura valley to near Dome Pass where the Mataura River enters a gorge. There was probably a lens of stationary ice in the bottom of the Wakatipu trough (now 226 ft. below sea-level) over which the moving portions of the Wakatipu glacier slid.

The Pleistocene glaciation of Central Otago was followed by a period of river erosion when moraines were destroyed and river-terraces were formed (cf. Speight 1911). The collection of great erratic blocks on the valley-floor of the Clutha at Queensberry, the erratics on Victoria Flat near Gibbston, and the line of erratics stringing out from the portal of the Kawarau Gorge at Ripponvale indicate that there was a second but smaller advance of ice subsequent to the formation of the river-terraces. This is in agreement with the observations of Hutton (1875), McKay (1893, 1894), Bell and Fraser (1906), Cox (1926), and Speight (1926, 1928) in other parts of the South Island.

Cause of the Pleistocene Glaciation.—The cause of this Pleistocene glaciation is not known. Possibly it was a general lowering of temperature. Hutton (1876) thought a reduction of more than 10° F. would be necessary, but on palaeontological grounds could not admit that such had taken place. Benham (1909) likewise holds that there was no general reduction of temperature at or about this period. A general lowering of temperature of 4° C. to 6° C., as postulated by Morgan (1926), would have affected regions at a distance from New Zealand. One of the many difficulties this postulate entails is that it conflicts with conditions in Ross Dependency where the former high flood-level of ice was probably due to higher temperatures and the present dessication to extreme cold (Ferrar 1905, 1925). On the other hand lower temperatures in these high latitudes would intensify the indraught of air from high levels (katabatic winds) and might cause ice to accumulate instead of decrease as at present. Murray (1894) was the first to draw attention to the observations of Ross and others as indicating that anticyclonic conditions and out-flowing winds predominate in high southern latitudes, and lately Hobbs (1911, 1926) has advanced a theoretical explanation of such conditions to account for the present glaciation of Greenland and Antarctica. If an intensified down-draught of air from high levels is competent to increase the quantity of ice in the Antarctic then a general lowering of temperature becomes a reasonable explanation of the former glaciation of Central Otago. As, however, the rarified upper air contains hardly sufficient water-substance to account for the present 7 in. to 8 in. of precipitation on South Victoria Land, intensified katabatic winds would not cause an ice-flood there. Hence general reduction of temperature does not satisfy.

Another possible cause is elevation of the land. The following are estimates, by writers on this subject, of the uplift required to produce the former greater glaciation;—4,000 ft. to 5,000 ft. (Travers 1874), 3,000 to 4,000 ft. (Hutton 1876), 2,000 ft. (Hector 1863), 1,000 ft. to 1,500 ft. (Morgan 1926), 600 ft. (Speight 1908). Morgan's estimate is suported by Henderson (1924) who considers that in the early Pleistocene New Zealand was 1,000 ft. higher than it is now. Since the terminal faces of glaciers near The Hermitage on the east side of the Southern Alps are at about 2,300 ft. above sea-level and the once ice-covered terraces at Alexandra are at about 700 ft., the difference, or an elevation of 1,500 ft. to 1,600 ft. seems sufficient to account for the Pleistocene extension of the glaciers of Central Otago.

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