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Evidences of Pleistocene Glaciation at Abbotsford, near Dunedin.

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In an excellent thesis* on "The General and Economic Geology of Green Island Coalfield," Mr. L. I. Grange, M.Sc., A.O.S.M., briefly discusses the origin of certain clayey boulder-beds at Abbotsford, a few miles south of Dunedin. Referring to the published views of different observers, including my own,† he says, "The presence at Abbotsford of well-rounded boulders consisting of dolerite, basalt, trachydolerite, and rarely phonolite rocks at the base, all of local origin, is very damaging to the idea of classing the deposit as a boulder-clay. Had the beds a glacial origin boulders of schist would naturally occur, since that rock outcrops at no great distance from the clay."

The aforesaid boulder-clay formation occupies the floor and slopes of the Abbotsford basin. From about 100 ft. above the sea it rises gently northward to a height of 475 ft. Generally it ranges from a few feet to 40 ft. thick, and rests unconformably on the denuded surface of the Tertiary greensands, Burnside marl, and drab-coloured sandstone underlying the marl. The character of the deposit changes with astonishing rapidity from blue clay with boulders to a yellowish-brown clay and rock-rubble.

The base of the deposit is generally a stiff blue clay that contains widely scattered boulders. In places the clay is streaked or intercalated with

* *Trans. N.Z. Inst.*, vol. 53, pp. 157-74.

† The Great Ice Age of New Zealand, *Trans. N.Z. Inst.*, vol. 42, pp. 580-612.

black peaty layers in which, notably at the new Silverstream dam, occur a few prostrate tree-trunks of the genus *Nothofagus*. In the peaty clay near Abbotsford Railway-station and at the new dam occur decomposed moa-bones.

In reference to Mr. Grange's remarks, I wish to say that few or none of the boulders I have seen in this deposit occur in the condition usually described as "well-rounded." The majority are rounded, a considerable proportion semi-rounded, and many slabby and angular. All the rocks are volcanic, and the rounded forms are, to my mind, the result of decomposition and exfoliation, a common occurrence with all igneous rocks. Even with residual clay still in place the undecomposed cores of rock are usually rounded or spheroidal as a result of slow underground decomposition.

The blue clay passing upward becomes yellowish-brown by oxidation, and resembles an ordinary, residual brick-clay. It contains scattered boulders, some of which are 4 ft. or more in diameter. Many varieties of volcanic rock are, however, represented among the boulders; and this, together with the peaty matter and tree-trunks, precludes the possibility of the boulder-clay being a residual clay, of which, be it said, there are many fine examples *in situ* on the Maori Hill ridge above Dunedin.

As viewed under the microscope the silt that occurs as pockets in the blue clay is seen to consist of fresh rock-flour. The blue clay itself occurs in sporadic pockets at different altitudes, and I can only conclude that it accumulated in hollows where the glacial waters were ponded by ice-dams.

The reference by Mr. Grange to the local origin of the boulders was evidently made under a misapprehension. I have examined boulder-clays on the northern foothills of the European Alps and Vosges Mountains, in Aberdeenshire and Morayshire, in the lake country of England, in north Wales, on the foothills of the Canadian Rockies, and on the shores of Puget Sound. In common with many other observers, I found that where the regional glaciation had been free of the influence of the northern ice-sheet the constituent boulders were of purely local origin; and, of course, in New Zealand it could hardly have been otherwise.

Mr. Grange further remarks that, had the beds in question a glacial origin, boulders of schist would naturally occur in them. This also would appear to be the result of a misunderstanding. The Abbotsford basin is ringed on three sides by high hills crowned by volcanic rocks, while the schist occupies only the lower ridges near Ferntown, to the south.

If the flow of the ice had been from south to north one would certainly expect to find boulders of mica-schist in the boulder-clay formation; but there is nothing whatever to show that this was the case. On the contrary, it seems more reasonable to believe that the ice flowed southward from the relatively higher Flagstaff gathering ground towards the Ferntown schist, than to conceive that the flow was northward and up-grade against the superior weight of the ice descending from the Flagstaff volcanic area. In my paper on "The Great Ice Age of New Zealand" I stated my belief that the flow was towards the south—that is, towards the schist area. I may here add that I know of no agency other than ice capable of forming such a heterogeneous deposit as the Abbotsford boulder-clay. Mr. Grange does not help us with any constructive suggestion as to its origin.

A recent re-examination of the deposit in question more fully than ever confirms me in my view of 1910.