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ENGLACIAL AND SUPERGLACIAL DRIFT IN MINNESOTA, THE DAKOTAS, AND MANITOBA.

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Modified drift, consisting of stratified gravel and sand, with local deposits of clay, overlies the bed-rocks and the till, and generally forms the surface, on an extensive area stretching from St. Paul and Minneapolis northwestward to the lakes at the sources of the Mississippi, and onward to the Rainy river, the southwest side of the Lake of the Woods, and to the vicinity of the city of Winnipeg. The contour of the greater part of these deposits, through their extent of 400 miles, is flat or moderately undulating, and their surface varies in height from a few feet to 50 feet or rarely more above the adjoining lakes and streams. In central Minnesota these tracts of gravel and sand have an elevation that increases from south to north, being 825 to 950 feet above sea level near the Twin Cities, rising gradually to 1,200 feet in the distance of about 100 miles northwest to Brainerd, and ranging from 1,350 to 1,500 feet between the Leaf hills and Itasca lake. Thence their surface sinks to 1,150 to 1,075 feet in the vicinity of Rainy river and the Lake of the Woods, and is between 750 and 875 feet in the district close northeast of Winnipeg, where a part of these deposits forms a remarkable esker, named Bird's Hill.

On each side this broad belt is bordered by areas of nearly the same general elevation, which have mostly a surface of till; and it is to be remarked that the heights of the tracts of modified drift and till are alike determined by that of the underlying rocks, on which these superficial deposits are spread in a sheet of slight depth in comparison with the gradual change in their elevation. The drift sheet on this belt, including both the sand and gravel and the till, probably varies in its average thickness from 50 to 150 feet, while its central portion rises 400 to 600 feet above its south and north ends.

The distribution of the modified drift thus found upon large tracts along a wide belt from St. Paul to Winnipeg, while it is more scantily developed on a still wider region of Minnesota, South and North Dakota, and Manitoba, southwest of this belt, and likewise is scanty or wanting on its northeast side in northern Minnesota and about Rainy lake and the northeast and north portions of the Lake of the Woods, seems to be attributable to converging slopes of the surface of the ice-sheet and the consequent convergence of its currents, which brought an unusual amount of englacial drift into the ice along this belt, and by which also the streams produced in its melting were caused to flow thither from extensive tracts of the ice on the east and west. The glacial striae of these adjoining areas show that on the east the course of the motion and the descent of the surface of the ice-sheet were from northeast to southwest, but that on the west the

glacial currents moved and the ice surface sloped toward the southeast.

My studies of the prominent kame called the Devil's Heart hill,* on the south side of Devil's lake in North Dakota, and of Bird's Hill,† near Winnipeg, convince me that much drift was carried upward into the ice-sheet of this region, to heights of 1,000 to 1,500 feet or more above the ground. The distance from Bird's Hill to the boundary of the glacial drift is about 700 miles to the south and 300 miles to the southwest. It may be estimated, from altitudes of the drift on the White mountains, the Catskills, and the Adirondacks, that the ice-sheet similarly rising over Manitoba attained a maximum thickness of at least one mile, or more probably one and a half miles, about 8,000 feet. The gradients of its surface were similar to the slowly ascending slopes by which the ice-sheets of Greenland and the Antarctic continent rise to altitudes of about two miles above the sea. In the lower quarter or sixth part of the ice covering Manitoba, that is, to a height of probably 1,500 feet, much drift had been carried by its variable and partly rising currents.

Near the border of the ice-sheet during its time of accumulation, little drift could thus be carried into it, and therefore in the melting and recession of that outer part the englacial and finally superglacial drift was generally inconspicuous; but at any considerable distance inside the glaciated area as a score of miles or more, the final melting set free much formerly englacial till and modified drift. The processes of drift transportation and deposition here emphasized were well stated by Prof. N. H. Winchell in 1873,* by Prof. C. H. Hitchcock in 1878,† and by me in 1876 and 1878 and in numerous later papers and reports.‡ At the present day these processes are exemplified by the Malaspina glacier or piedmont ice-sheet in Alaska, which during the last century has been much reduced in area and thickness; but the Greenland and Antarctic ice-sheets, which are now constant or increasing by snowfall, have no superglacial drift.

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* The Glacial Lake Agassiz, U. S. Geol. Survey, Monograph XXV, 1895, pp. 156, 157.

† Ibid., pp. 183-188; also a paper presented to the Geological Society of America, December, 1909, vol. XXI, pp. 407-432.

* The Drift Deposits of the Northwest, Popular Science Monthly, vol. III, pp. 202-210, 286-297 (especially page 294, relating to superglacial drift).

† Geology of New Hampshire, vol. III, pp. 282, 283, 309, 326, 333-8.

‡ Proc. A. A. A. S., vol. XXV, for 1876, p. 218; vol. XXVII, for 1878, pp. 299-310. Geol. of N. H., vol III, 1878, pp. 9, 10, 175-6, 285-309. Geol. of Minnesota, Final Report, vol. I, 1884, pp. 440, 603-4; vol. II, 1888, pp. 252, 254-6, 409-417. Am. Geologist, vol. X, 1892, pp. 339-362; vol. XII, 1893, pp. 36-43; vol. XIV, 1894, pp. 69-83; vol. XVI, 1895, pp. 100-113; vol. XIX, 1897, pp. 411-417; vol. XX, 1897, pp. 383-7; vol. XXIII, 1899, pp. 369-374; vol. XXV, 1900, pp. 273-299.