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scale at the public water-works of Antwerp in Belgium, whereby a badly contaminated river water is said to be made thoroughly wholesome. It is asserted that living germs as well as dead organic and inorganic matter are destroyed and removed from the water. Perhaps the people of Minneapolis, and other populations along the Mississippi, may in time avail themselves of such filtering processes. Scientific authority tells us that we run great risk in drinking water which has at any time been contaminated with animal excreta unless we apply to that water the most thorough methods of destroying organized microscopic impurities. The people of Winona, for example, and the people of Hastings, would run great risk of infection from impurities that enter the river at Minneapolis and St. Paul, although chemical tests as at present known and applied give the water at Winona and Hastings such comparatively good credit for purity. The best known methods of purification may not remove all this risk. But it would be the part of prudence to apply them when practicable.

JAMES A. DODGE.

[Paper E.]

CHANGES IN THE CURRENTS OF THE ICE OF THE LAST GLACIAL EPOCH
IN EASTERN MINNESOTA. —Warren Upham.

Read before the Minnesota Academy of Natural Sciences, May 8, 1888.

When the ice of the last glacial epoch attained its maximum extent, it appears that the ice-current moving southwestward from lake Superior across the northeast part of Minnesota, spreading a reddish till containing boulders and pebbles peculiar to the region from which it came, had its limit at a line reaching from lake St. Croix southwesterly across the Mississippi and through the north part of Dakota county, thence bending to a northwest direction and continuing by lake Minnetonka and through Wright and Stearns counties. At the same time another portion of the ice-sheet was pushed from the region of lake Winnipeg and the Red river valley toward the south and southeast, meeting and opposing the ice-current from lake Superior along a line from Stearns county southeast by lake Minnetonka to Crystal lake in Dakota county: beyond which its eastern limit farther south was

at the outer or eastern belt of the terminal moraine as traced in Rice, Steele and Freeborn counties, and onward to central Iowa. The angle formed by the margins of these portions of the ice-sheet, moving respectively from the northeast and the northwest, was at Crystal lake and Buck hill in Burnsville, Dakota county; from which point northwesterly, along an extent of a hundred miles or more, these ice-currents were pushed obliquely against each other.

At a late date in this last glacial epoch, after the ice-border had for the most part retreated considerably from its farthest limit, it is known to have halted in its recession (and it even probably re-advanced), forming a second belt of morainic accumulations, usually from five to fifteen miles back or inside from its former line of drift-hills. This second morainic belt is well exhibited from Rice county south to central Iowa, and at the west side of this lobe of the ice-sheet upon the Coteau des Prairies. At this time the ice-sheet that was pushed southwestward from lake Superior and northern Wisconsin probably terminated only a few miles back from its earlier limit east of lake St. Croix, and in Washington, Dakota and Ramsey counties, and in the east edge of Hennepin county at Minneapolis. But farther northward the presence of bluish till, weathered next to the surface to a yellowish color, containing boulders and pebbles of limestone and of Cretaceous shale and other material brought from the northwest overlying the red till with rock fragments from the region of lake Superior, proves that the ice-current from the northwest was stronger and extended farther, the ice on this side of the great western lobe of the ice-sheet being therefore even deeper, at least in comparison with the eastern ice flowing southwestward from lake Superior, than in the former part of this glacial epoch when these ice-fields covered their greatest area. In that earlier part of this epoch the ice-currents from the northwest and northeast had met along a line drawn from Crystal lake and lake Minnetonka northwestward, but now, when elsewhere the border of the ice-fields had somewhat retreated and formed the second and inner terminal moraine, the ice flowing from the west extended eastward across Wright and Hennepin, Sherburne and Anoka counties, to the St. Croix river at the east side of Chisago county, and into the adjoining edge of Wisconsin, pushing back the ice-current that came from lake Superior and covering the red till brought by that ice with the characteristic blue till brought by the ice from the northwest and west.

The cause of this changed course of the line at which the currents of the west and east portions of the ice-sheet met, is to be found in the changed meteorological conditions of this time. During the increased ice-melting attendant upon the recession of the ice-fields from the outer to the inner terminal moraine, the prevailing westerly winds sweeping over the western side of the ice-sheet upon the Coteau des Prairies and eastward became more laden with moisture than in the earlier part of this epoch, when there was comparatively little melting upon the surface of the ice; and the increased temperature enabled these winds to carry their moisture farther than when the ice had its greatest extent. Then the precipitation of rain and snow took place more upon the western side of the ice; but at this later time the precipitation, by reason of the causes here mentioned, probably became much greater than before upon the east part of the lobe of the ice-sheet that extended southeastward from the Red river valley to central Iowa. Before this, lake Minnetonka and central Wright county had been the limit where this ice-flow was stopped by the opposing ice-current from lake Superior; but now, because of the relatively, and perhaps absolutely, greater thickness of this part of the ice flowing from the northwest, due, as shown, to climatic changes, its current pushed back that opposed to it on the east, covering the red till brought by that ice with blue till containing plentiful limestone boulders and other material from the west and northwest. The limit where these ice-fields, moving from the west and from the northeast, now met, lies in the south edge of Mille Lacs, Kanabec, and Pine counties, and even beyond the St. Croix river at the east side of Chisago county, fully seventy-five miles east of the line where these ice-currents formerly met; but it scarcely reaches into Washington and Ramsey counties, which remained covered with ice that came from the northeast. This persistence of the ice-flow from the northeast near the margin of the ice-covered area, and also in Stearns and Morrison counties north of the changed portion of the line of confluence of these ice-fields, proved by the character of the drift upon these counties, seems yet quite consistent with this explanation, by meteorological causes, of the change in source of the ice covering the intervening district, from Wright and Hennepin counties eastward to the St. Croix river and the edge of Wisconsin.

Details of sections in the drift, showing the blue (or next to

the surface, yellow) till overlying the red till in this district, and more complete discussion of the glacial period, its ice-sheets, and their various drift deposits in this state, have been partially presented in the fifth, sixth, eighth and ninth annual reports of the Geological and Natural History Survey of Minnesota, and will be fully exhibited in the final reports of this survey.

In the later part of the last glacial epoch, the ice flowing from the northeast formed a terminal moraine of very roughly, knolly and hilly till, which is intersected twice by the Mississippi river on the northern border of Dakota county, once seven to ten miles below St. Paul, and again between St. Paul and Fort Snelling. This moraine is crossed by the river-road below St. Paul in sections 11, 14 and 22, Inver Grove. Thence it extends to the west a few miles, and soon (at the east side of Wescott station) curves to the north, forming the belt of irregularly broken highland, composed at the surface of till with many boulders, which occupies the northwest part of Inver Grove and the west half of West St. Paul, varying from two to three miles in width, and elevated about 300 feet above the Mississippi, or approximately 1,000 feet above the sea. The heights of the separate hills or ridges of this belt are from 40 to 75 feet above the hollows. In Mendota another belt of morainic drift-hills, also accumulated by the ice-current from the northeast, probably at nearly the same date with the preceding, lies one to three miles farther west, forming prominent hills and ridges in sections 35, 34, 26, and the southeast part of 23, about 250 feet above the Mississippi, and 50 to 75 feet above the belt of smooth prairie a mile wide between this and the parallel line of hills in West St. Paul. The most conspicuous hill of this moraine in Mendota is Pilot knob, in the northwest quarter of section 34, only about a mile southeast from Fort Snelling. Its height is 260 feet, approximately, above the Minnesota and Mississippi rivers. The continuation of this moraine to the north lies east of the Mississippi, reaching from the high hills in Reserve township two or three miles northeast of Fort Snelling, to the belt of hills, composed at the surface of very knolly drift, chiefly till, but partly gravel and sand, that lies about one mile east and northeast of the borders of Minneapolis, having a height 75 to 150 feet, and a few miles farther north fully 200 feet, above the plain of modified drift on which this city is built.

At this time the ice-current from the west appears to have

pushed against that from the northeast along this line of morainic deposits in Inver Grove, Mendota and Reserve, and at the east border of Minneapolis. The junction of the margins of the ice-fields moving from the northeast and from the west was in Inver Grove, close east of Westcott station; and the waters produced by the melting of the ice were now conveyed to this point by the converging slopes of its surface, just as they had before been principally discharged at the angle formed in the ice-margin at Crystal lake in Burnsville, when the ice of this epoch had its maximum extent. From these two points of its terminal moraine, namely, Crystal lake and Inver Grove, very remarkable channels are found extending southeastward, which evidently once carried an immense volume of water but which are now dry.

The first of these channels is crossed by the road that leads southwest from Rosemount, in sections 2 and 3, Lakeville. The bed of this channel is a level plain of sand and fine gravel at least 25 to 30 feet deep, as shown by wells, and extending here a mile and a half in width, this expanse being commonly known as the "low prairie." On its northeast side it is bounded by a steep terrace-like escarpment of gravel and sand, 30 or 40 feet high, from the top of which a similarly flat plain, called in this vicinity the "high prairie," composed of the same modified drift, stretches eastward through Lebanon, Rosemount, and the north part of Empire and Vermillion, to the Vermillion river, and beyond that stream through Marshan and Ravenna to the Mississippi. This belt of modified drift, three to five miles wide and more than twenty miles in length from west to east, forming a flat plain with a slope descending about 100 feet toward the east in this distance, is the sediment deposited by the floods from the glacial melting, chiefly discharged from the ice-covered area in Inver Grove, at Crystal lake and at Lakeville lake.

After the floods that spread this extensive plain of gravel and sand had been so diminished that they could no longer cover all its surface and add to its thickness by further deposition, the volume of water still poured from the dissolving ice-sheet was sufficient to cut in this plain the broad channel called the "low prairie." This has a width of about one mile at the east end of Crystal lake, and it widens to one and a half miles, as stated, in the northeast part of Lakeville. It continues with nearly the same features southeastward to the Vermillion river close east of

Farmington, being bounded on its northeast side along this extent of eight miles by the plain of modified drift, 30 to 50 feet higher, on which the village of Rosemount is built.

Southwest of this channel, the road to Fairfield in its next three miles crosses massive swells or hills of till, 75 to 100 feet higher, and nearly as much above another plain of modified drift, which lies in the south part of Lakeville and northeastern Eureka, extending east to Farmington, and merging with the great expanse of this formation before described as reaching from west to east through the center of Dakota county. Farmington and Fairfield are situated on this belt of modified drift. It narrows in its west extremity from an average width of two miles to only about a quarter of a mile at the southeast end of Lakeville lake, which like Crystal lake, seems to mark the point in the terminal moraine where the waters of glacial melting had a principal outlet.

The channel which seems to have been formed by the waters discharged from the margin of the ice-sheet at the junction of its opposing currents, when the second or inner terminal moraine of the last glacial epoch was being accumulated, is well known under the name "Rich Valley." This is from one quarter to three quarters of a mile wide, with a bottom consisting, like the "low prairie," of stratified gravel and sand. It is bounded on each side, for the most part, by moderate slopes of the same materials or of till, rising 25 to 50 feet higher. Beginning within the hilly belt of the terminal moraine in the southwest quarter of section 20, Inver Grove, this valley extends with a course a little to the east of south four miles, to Rich Valley postoffice in the northeast corner of section 26, Rosemount. At the north side of this and the adjoining section 25, Rich Valley is turned east by a swell of till, a mile and a half long from west to east and about a third of a mile wide, which rises some 75 feet above this valley and 40 feet above the adjacent Rosemount plain. Thence the course of the valley is east-southeastward, passing through sections 30, 29 and 28, in the east part of Rosemount.

A great glacial river appears to have flowed to the head of Rich Valley in Inver Grove, passing through the terminal moraine in the northeast part of Eagan, where the railroad now runs on a belt of undulating modified drift, from a quarter of a mile to one and a half miles wide, in some portions enclosing numerous hollows and lakelets 25 to 75 feet below the general level, to which depth, at least, this deposit of gravel and sand extends.

[Paper F.]

THE TOPOGRAPHY AND ALTITUDE OF MINNESOTA. — *Warren Upham.*

[ABSTRACT.]

The topographic features of Minnesota may be briefly summed up for its western three-quarters, being a moderately undulating, sometimes nearly flat, but occasionally hilly expanse, gradually descending from the Coteau des Prairies and the leaf hills, respectively about 2,000 and 1,700 feet above the sea to half that height, or from 1,000 to 800 feet, in the long flat basin of the Red river valley, and to the same height along the valley of the Mississippi from St. Cloud to Minneapolis.

The only exceptions to this moderately undulating or rolling and rarely hilly contour, are the southeast part of the state where the Mississippi river and its tributaries are enclosed by bluffs from 200 to 600 feet high; and the northwest shore of Lake Superior, and the part of the state lying north of this lake and east of Vermillion lake. A very bold rocky highland rises 400 to 800 feet above lake Superior, within from one to five miles back from its shore-line, all along the distance of 150 miles from Duluth to Pigeon point, the most eastern extremity of Minnesota; while farther north are many hill-ranges, 200 to 500 feet higher, mostly trending from northeast to southwest or from east to west. The most jagged of these lines of rugged peaks and ridges of rock, near the shore of lake Superior from Temperance river to Grand Marais, is called the Sawteeth mountains; and a second range of hills, rising from the more elevated region half-way between the lake and the north boundary, is called the Mesabi range. The height of lake Superior is 602 feet above the sea; and of the higher of the Sawteeth mountains 1,300 to 1,600, Carlton's peak being 1,520 feet above the sea, or 927 above lake Superior, about one and a half miles distant. The Mesabi range, south of Vermillion lake and eastward, is found by Prof. Winchell to be from 1,800 to 2,200 feet above the sea, being the highest land in Minnesota.

A few more altitudes in various parts of the state are as follows: Low water of the Mississippi river at the southeast corner of Minnesota, 620 feet above the sea-level; same of Lake Pepin, 662; same at St. Paul, 683; top of the falls of St. Anthony, 800; Mississippi river at St. Cloud railroad bridge, 906; at Brainerd, 1,152; head of Pokegama falls, 1,266; lake Winnibigoshish, 1,290; Leech lake, 1,292; Cass lake, 1,300; Itasca lake, about 1,500; high-