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Inasmuch as the project was on an experimental basis, no funds were expended on textbooks. Daily reading assignments were made in the mimeographed material supplied by Prof. Stewart, but with that exception, this has been almost entirely a lecture course. The chief sources of material have been drawn from *Down to Earth* by Kroneis and Krumbein and from old college notes. Supplementary lecture material consisted of slides, photographs, maps, and fossil specimens.

The breakdown of the course is as follows: four lectures per week, with three reading assignments, one examination, and one period each week devoted to study of minerals and rocks.

SUMMARY

Our conclusions, based on this brief experiment, are: (1) that the sturdy of geology is definitely not too difficult for secondary school students; (2) that it fills a gap heretofore found in most, if not all, high school curricula; (3) that the tremendous enthusiasm shown by the students involved in this experiment indicates that it will become a permanent fixture in our own curriculum and, as such, we sincerely recommend its adoption, wherever possible, by other schools in the state.

TAMARACKS AND THEIR RELATION TO GLACIAL GEOLOGY — A STUDY OF THE ROCKVILLE-COLD SPRING AREA

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Introduction. Tamaracks are not haphazardly distributed in the Rockville-Cold Spring area; tamarack groves outline the banks of Lower Cold Spring Terrace, and seepage from the older and higher Upper Cold Spring Terrace creates hanging bogs. Terrace sediments favor retention of moisture in that they were originally derived from the shale, clay and limestone tills of the gray drift. The adjacent heights of the Saint Croix moraine provide protection from heat, dryness and high wind velocities. The granite outcrops of both Cold Spring and Rockville check the flow of the Sauk River and so tend to favor a swampy condition between these two localities. Eventually, however, the regional climate will prevail, the water supply will dwindle, the swamps will be filled or drained, and the local dominant deciduous forest replace the tamaracks—living relics of the geological recent retreat of the continental ice sheet.

The Tamarack. Larix laricina—the American larch, hackmatack or tamarack—is one of the four native larch species of North America. As the most widely distributed larch, it grows from Newfoundland and Labrador northwestward to Mackenzie, where it extends in dwarf forms to the Arctic Ocean. It occurs sparingly southward to West Virginia, northern Indiana, Minnesota, and the eastern base of the Rocky mountains in Alberta. In the south it is found only in deep, cold swamps, but in the north it often grows on well-drained uplands. The tamarack reaches its greatest size north of Lake Winnipeg and is the largest tree in Labrador. It attains a height of 50 to 60 feet and a trunk diameter of 1½ feet. (Harrar, 1947; Rosendahl & Butters, 1928.)

As a pioneer, the tamarack invades the tundra, a treeless plant community consisting largely of mosses and lichens, found in the arctic and above timberline on mountains. Also as a pioneer, the tamarack leads in the taiga, the coniferous evergreen forest, a plant community characteristic of cool regions bordering the tundra. Thus, the tamarack is a climax tree along the northern border of the Boreal Forest.

As a relic, the tamarack exists in cold, wet, low areas where its shallow root system allows it to dominate until winds arise and topple it easily. In short, the tamarack is both vanguard and rear guard of the coniferous evergreen forest. (Weaver & Clements, 1929.)

The Study Area. The study area is located in central Minnesota—in the center of the southeast quarter of Stearns County. (Allison, 1932.) No topographic maps are as yet available, but when they are the study area will be seen to be the northern half of Rockville Township (T. 123 N., R. 29 W.) and the eastern half of Wakefield Township (T. 123 N., R. 30 W.). Available air photographs were taken for the Production and Marketing Administration in 1951. The northwest corner of Photo Index 6, Stearns County, reveals that the study area is covered by twelve contact prints—BJN-5H-55 through BJN-5H-60, and BJN-5H-87 through BJN-5H-92. The Sauk River flows through the center of the study area. It comes from the lake complex in the Richmond Valley train (Wright, et al, 1954), cuts through the highlands of the St. Croix moraine from Cold Spring (N. 45° 27′, W. 94° 25′) to Rockville (N. 45° 28′, W. 94° 20′), then leaves northeastward on its way to join the Mississippi River just north of Saint Cloud.

As stated, the study area is dominated by the Saint Croix moraine. (Wilmarth, 1938.) In the study area, this complex can be divided into four parts: Collegeville moraine (north of Cold Spring), Barrier Ridge (north of Rockville), Rockville Ridge (northeast of Rockville) and Cold Spring Heights (south of Cold Spring).

To the west of the study area is the lowland lake complex of the Richmond Valley. To the east of the study area is the northward-sloping outwash apron of Kimball Prairie. Studding the area of this outwash are such possible remnants of the St. Croix moraine as Luxemburg Heights, Marty Ridge, Marine Prairie Heights, Fair Haven Ridge and Augusta Ridge.

Four terraces are found in the study area. From oldest and highest to youngest and lowest, they are: (1) Jacobs Prairie Terrace, (2) Upper Cold Spring Terrace, (3) Lower Cold Spring Terrace (Tamarack Terrace) and (4) the Sauk River Flood Plain.

Jacobs Prairie Terrace appears to slope southwestward toward Cold Spring. It separates Collegeville moraine from Barrier Ridge. On sheet 2, Stearns County General Highway Map, this highest terrace is marked by State Aid Road No. 2 coming south from St. Joseph. The Plan and Profile of State Aid Road No. 2 (1950) in the Stearns County Court House confirms Cooper's (1935) finding that this terrace slopes northward all the way to St. Joseph.

Upper Cold Spring Terrace is the highest terrace south of Barrier Ridge. It cuts deeply into Jacobs Prairie Terrace one mile north of Cold Spring, and the Highway Department has an excellent gravel source on the resulting south-facing slope of Goat's Prairie Quarry. Jacob's Prairie community is built atop the north bank of Upper Cold Spring Terrace just before the terrace is deflected east then south by the west and south spurs of southmost Barrier Ridge. Thus, at Jacobs Prairie there is a splendid southern view overlooking the three lower eastward-sloping terraces—all north of the east-west Minnesota State Highway No. 23 in this area. In short, Cold Spring Heights forms an untouched inner or concave side of a bend of all three of these lower terraces.

Aerial photographs allow the tracing of Upper Cold Spring Terrace as it turns southward (directly west of Rockville), then rounds southmost Rockville Ridge to join northbound Rousch Lake Channel and unitedly form northeast-bound Pleasant Lake Channel which separates Rockville Ridge and Luxemburg Heights. A series of lakes and swamps dots the Rousch Lake and Pleasant Lake Channel. A small tamarack grove is located at the southwest end of Pleasant Lake—the end at which vegetation is filling in the lake. The Plan and Profile of State Aid Road No. 6 (1928) in the Stearns County Court House shows these relative heights: Upper Cold Spring Terrace, 207.6 feet; Rockville Ridge, 247.0 feet; Lower Cold Spring Terrace, 199.0 feet. A similar plan and profile of this same east-west road (1952) uses elevations tied in with the U.S.G.S. markers and gives an elevation of 1,094.6 feet for the Pleasant Lake area. Volume of traffic did not merit the road survey to continue westward over Rockville Ridge and on to the Lower Cold Spring Terrace.

West of Rockville, Upper and Lower Cold Spring Terraces are practically at the same level. Large granite slabs on the west side of the short southmost spur of Barrier Ridge suggest a reason for the deflection of Upper Cold Spring Terrace. The granite-studded narrowed Lower Cold Spring Terrace in northern Rockville strengthens this suggestion. The Rockville Granite Quarry is located in this restricted portion of Lower Cold Spring Terrace. However, an acid-reacting gravel outwash pit an half mile north of Rockville, on the west side of County Aid Road No. 58, on the east side of Barrier Ridge spur, suggests the possibility of a gray till moraine. Red till is definitely exposed on an eroded farmland summit in the northeast part of Cold Spring Heights.

Lower Cold Spring Terrace is definitely Tamarack Terrace. Within its banks the Sauk River has a tendency to meander. Pinched together both at Cold Spring and at Rockville—sites of uncovered granite knobs—the section of Lower Cold Spring Terrace between these two localities has the appearance of a sausage. Within this "sausage" are the tamaracks.

The tamaracks are located along the banks of Lower Cold Spring Terrace, and justify the alternative name of Tamarack Terrace (in the study area). At Cold Spring, a small group of tamaracks is located at the northern limits of town; two other small groups are located within the eastern limits—one group between the two roads that cross the Sauk River, the other between Highway No. 23 and Cold Spring Heights. South of Jacobs Prairie and all the way to Rockville, an almost continuous band of tamaracks marks the northern bank of Tamarack Terrace. Along the south bank of Tamarack Terrace are two groups of tamaracks —the Heron Colony Woods and a small tamarack group directly west of Rockville: this latter group is in the center of the southbound Upper Cold Spring Terrace as it is bisected by the eastbound Tamarack Terrace.

Fortunately two farmers had cooperated fully enough with the Stearns County Soil Conservation Service to make available two soil maps of the lower terraces. Jerome Bechtold's Farm, Rockville Township, Section 7, shows that Barrier Ridge has a 20% gradient where it meets Upper Cold Spring Terrace; Tamarack Terrace has a 10% gradient bank. Both terraces are remarkably level—a 3% gradient at the most. Barrier Ridge has soil classified as Burnsville Sandy Loam; Upper Cold Spring Terrace has soils such as Wadena Loam, Biscay Loam, Estherville Sandy Loam, Estherville Loamy Fine Sand, Shallow Peat Over Sand, and Marshland. Evidently Upper Cold Spring Terrace once had soil classified as Peat—just as Tamarack Terrace has now.

Ray Froehle's Farm, Wakefield Township, Sections 12 and 13, spans all three lowest terraces. Once again, the soil types of Upper Cold Spring Terrace are Biscay Loam, Estherville Sandy Loam, Estherville Loamy Fine Sand, and Shallow Peat Over

Sand. Just west of the farm area, on the 26% gradient north bank of Tamarack Terrace, is a unique sight—tamaracks and bull rushes adjacent to scrub oaks and prairie grass. Seepage from Upper Cold Spring Terrace yields the explanation.

Tamarack Terrace has two soil types in Ray Froehle's land: level Deep Peat and 1% gradient Biscay Loam. On the Biscay Loam, which adjoins the north bank of Tamarack Terrace is the start of a line of tamaracks that reach almost continuously eastward to Rockville. Between the level Deep Peat and the actively aggrading Sauk River's Mixed Alluvial Bottomland Soils is a narrow strip of 3% gradient Shallow Peat Over Clay and Silt. Thus, it is easy to see how the spring-flooded Sauk River can help the nearby Deep Peat retain its moisture.

Directly east of the Froehle Farm and north of the Sauk River is the Cold Spring Heron Colony Woods. The herons prefer the tall stury deciduous trees that thrive on the ridges of shallower peat. In the center of the woods are the succumbing tamaracks—in an area of Deep Peat and water seepage. Perhaps the shallower peat ridges mark the bar of a lake whose ponded waters gradually filled in with peat and thus provided an excellent tamarack location.

The Geologic History of the Study Area. In conclusion, the writer presents a possible geologic interpretation of all the data and facts thus far assembled—even though these need further support and research to be fully adequate. Thereby the writer hopes to stimulate further research in the near future that will result in a better reconstruction of past events.

When the continental ice mass was depositing moraines near the town of Cary, McHenry County, Northeastern Illinois, a huge ice lobe covered northeastern Minnesota. In 1935, W. S. Cooper suggested this lobe be named the Minneapolis Lobe since the ice reached as far south as Minneapolis in transporting its red-colored sediments; other authors have suggested Superior Lobe (Cary Time) or Labradorian Ice because the lobe was traceable to these sources. The resulting dramatic terminal was named St. Croix moraine in 1897 by C. P. Berkley who studied it at Saint Croix Falls, Wisconsin (Wilmarth, 1925, 1938). When the red ice finally retreated from the high terminal moraine, the meltwaters were controlled by the moraine enough to determine the present course of the Mississippi River from Brainerd to Minneapolis. Meanwhile the gray ice of the Des Moines lobe may have found a local drainageway atop the massive Saint Croix moraine: these waters flowed from Cold Spring to St. Joseph to St. Cloud where they joined the meltwater Mississippi River—thus Jacobs Prairie Terrace was formed.

M. M. Leighton (1933), who named all the latest substages of the Wisconsin stage, suggested the name Mankato for the last minor advance of the continental ice mass. During the resurge of

gray ice towards Mankato from the general direction of the Red River Valley and northwestern Minnesota, a side- or sub-lobe of the Mankato (Des Moines) lobe butted against the granite bedrock and St. Croix Moraine barrier at Cold Spring, but overrode the St. Croix moraine and sedimentary bedrock from Kimball Prairie to Minneapolis, erasing red ice patterns as it pushed its way to Grantsburg, Wisconin. This tongue of ice diverted the floodwaters of the glacial Mississippi, and left the rivers of central eastern Minnesota with permanently offset river patterns. According to the excellent work done by W. S. Cooper (1935), the gray ice shallowly overrode the St. Croix Moraine so as to reach Luxemburg Heights, submerge Marty Ridge, and make nunataks of Maine Prairie Heights, Fair Haven Ridge, and perhaps Cold Spring Heights. A thunderous volume of water flowed northward towards the St. Cloud delta, became ponded eastward in the fluctuating levels of Lake Grantsburg and finally found southward release as the Grantsburg sublobe melted back and allowed the ponded waters to slice out Taylors Falls. Upper Cold Spring Terrace, Rousch Lake Channel, and Pleasant Lake Channel became a definite drainageway during this time. Buried ice blocks were destined to become a string of lakes.

Eventually the Grantsburg lobe retreated. The northern edge melted back from its long-held position—"Kimball Crest," the highest part of the Kimball Prairie outwash apron. A ditch appeared between Kimball Crest and the ice mass, and into this Clearwater fosse the meltwaters ran. The Kimball uplands became dry, perhaps warm enough then to have buried chunks of ice melt and form various lakes such as Pleasant, Grand, Rousch, Pearl, Goodners, Island, School Section and Laura. Other buried ice masses in the new Clearwater Channel would melt later to form lakes such as Louisa, Caroline, Augusta and Clearwater. During this time, lakes may have formed as stranded ice blocks melted between Cold Spring and Rockville.

Again conditions changed to allow a more rapid melting. Renewed meltwaters, clearer because farther from their ice source, cut into the alluvium of old streams. Tamarack Terrace cut down into Upper Cold Spring Terrace but met stiff opposition as it uncovered granite knobs at both Cold Spring and Rockville. However, the momentum and ingredients of the stream were sufficient to cut through the Rockville barrier and so separate Rockville Ridge from Barrier Ridge.

As the continental ice mass retreated northward, numerous divides blocked old meltwater routes, and streams became mere trickles. Into this barren waste of temperature extremes, moved the plant community called the Arctic Cold Barrens or Tundra. In turn these plant pioneers were replaced by heralds of a new plant community—the Boreal or Northern Forest, the tiaga or coniferous evergreen forest. Foremost was the stunted tamarack which eventually became a truly climatic tree. Upper Cold Spring Terrace

may have been a tamarack forest at this time.

Later, the climate became increasingly warmer and drier. The tamaracks of Upper Cold Spring Terrace succumbed and migrated to Lower Cold Spring Terrace—a last-ditch position. However, even this favorable position is being lost: the peat is being filled with alluvium, or drained by erosion; the climate favors the hardier deciduous treets and grasses; wind storms topple the shallow-rooted tamaracks—and soon there will be no living tamarack relics in the Rockville-Cold Spring area to dramatically bring to the observer's attention that here the coniferous forest once flourished in the successive plant communities that are following the ice masses northward.

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THE EFFECT OF LAND REDUCTION ON SEA LEVEL AND CONTINENTAL AREA

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INTRODUCTION

Because lands were raised to exceptional height in late geologic time, the earth today possesses a relatively high relief in comparison with the average relief of the past. Repeatedly during long intervals of the earth's history the continents existed as low partially inundated plains. Accordingly, it is at least not unrea-