15 November 1957, Volume 126, Number 3281 SCIENCE

Lake Agassiz and the Mankato-Valders Problem

John A. Elson

Recent papers by Wright (1), Wright and Rubin (2), and Leighton and Wright (3) have dealt with the problem of correlation of Port Huron, Valders, and Mankato drift. Leighton suggested that the term *Mankato* be applied to a substage between Cary and Valders drift and suggested the Bigstone moraine as the western equivalent, in Minnesota and the Dakotas, to Valders.

Work of the Geological Survey of Canada (4), now being prepared for publication, yielded carbon-14 material dated at Yale early in 1953 that established the Two Creeks age of the Lake Agassiz I–II interval. The dates imply (i) that the Valders ice advanced little farther southwest than The Pas moraine in Manitoba and not as far southwest as Fort Frances in western Ontario, and (ii) that the Lake Agassiz basin drained eastward into the Lake Superior basin in Two Creeks time. In a search for eastern outlets of Lake Agassiz, air photographs of the area north and west of Lake Superior were examined, with satisfying results, although correlations of the moraines and outlets discovered await field studies. This article is a brief review of data on Lake Agassiz in the light of radiocarbon dates; it shows that the Valders ice border probably lay well inside the margin of the Canadian Shield in western Ontario and northern Manitoba and that the Cary-Mankato retreat and readvance were minor compared with the Mankato-Valders marginal fluctuation.

Early Lake Deposits

The oldest carbon-14 date obtained on deposits underlying Lake Agassiz is from Bronson, Minnesota (samples W-102 and W-468, > 36,000 years). This pre-Wisconsin deposit may correlate with 12 or 14 other interglacial occurrences, some containing organic matter and some not, that apparently underlie the same till sheet in and near the Lake Agassiz basin (5). No breaks in the overlying till sheets that can be attributed to subaerial erosion are known, although a striated boulder pavement is widespread in southern Manitoba (6); it may be the subglacial expression of a marginal retreat and advance of substage magnitude. Most, if not all, of the Lake Agassiz basin and probably all of western Ontario and Manitoba were covered by ice throughout Wisconsin time prior to the retreat from the Mankato-Port Huron moraine system.

Lake Agassiz I

Mankato till is overlain by the clays of Lake Agassiz I except where thin, lenticular deposits of sand and gravel, presumably deposited at the base of the ice margin standing in Lake Agassiz rather than subaerially, occur between them. Minor glacial readvances represented by till in and overlying sediments of Agassiz I are not known south of Lake of the Woods and Fort Frances (7).

Lake Agassiz II

Overlying the clays of Lake Agassiz I, unconformably, are the silty deposits of Lake Agassiz II. The disconformity, which may be recognized by the character of Agassiz II sediments—which are locally sandy and commonly contain gastropod shells and organic matter near the base (5, 8, 9)—by valleys eroded in the older sediments (5, 6, 8), and by drying surfaces recognized by soil mechanics tests (10), has been reported from about 25 localities. Till has been reported overlying clays of Lake Agassiz near Sioux Lookout (11), at Steep Rock Lake (12) in Ontario, and near Steinbach and Rosa in southeastern Manitoba (13), but correlation of the stratigraphy is not established, and the sediments may be Agassiz I. At the north end of Lake Winnipeg (5, pp. 145–146), 12 miles north of The Pas moraine, till overlies sediments characteristic of Lake Agassiz II.

Extensive areas of the lake floor have no lacustrine clay or silt, partly because of removal by wave action during subsidence of the lake and partly because no major river contributed sediments to those parts of the basin. Rivers seem to have contributed most of the sediments to Agassiz II, whereas glacial contributions were confined to a belt near the ice margin. The ice margin retreated across Agassiz I, so both glacier and rivers contributed to its deposits.

When the Lake Traverse outlet of Lake Agassiz I eroded down to bedrock, the water stood at a constant level and formed the Campbell strandline, generally a distinctive scarp with a massive beach at its toe that can be traced for hundreds of miles; it extends north of latitude 53° on the west side of the lake basin. A second, slightly lower Campbell strandline formed after the Agassiz I–II subaerial interval, when advancing Valders ice and possibly crustal uplift north of Lake Superior blocked the eastern drainage of the basin and formed Lake Agassiz II, which discharged southward through the Lake Traverse outlet for part of its history.

The Agassiz I–II interval has been dated by a radiocarbon sample from the base of Agassiz II sediments at Moorhead, Minnesota, at 9930 ± 280 years (W-388). Five dates on samples obtained in the Assiniboine Valley span part of the Agassiz I–II interval and the rising phase of Agassiz II: Y-165, sandy peat (12,400 ± 420 years); Y-166, shell (11,230 ± 480 years); and three recently published dates, Y-411, wood (10,550 ± 200 years); Y-415, wood (9110 ± 110 years); and Y-416, peat (8020 ± 100 years) (14), from successively higher

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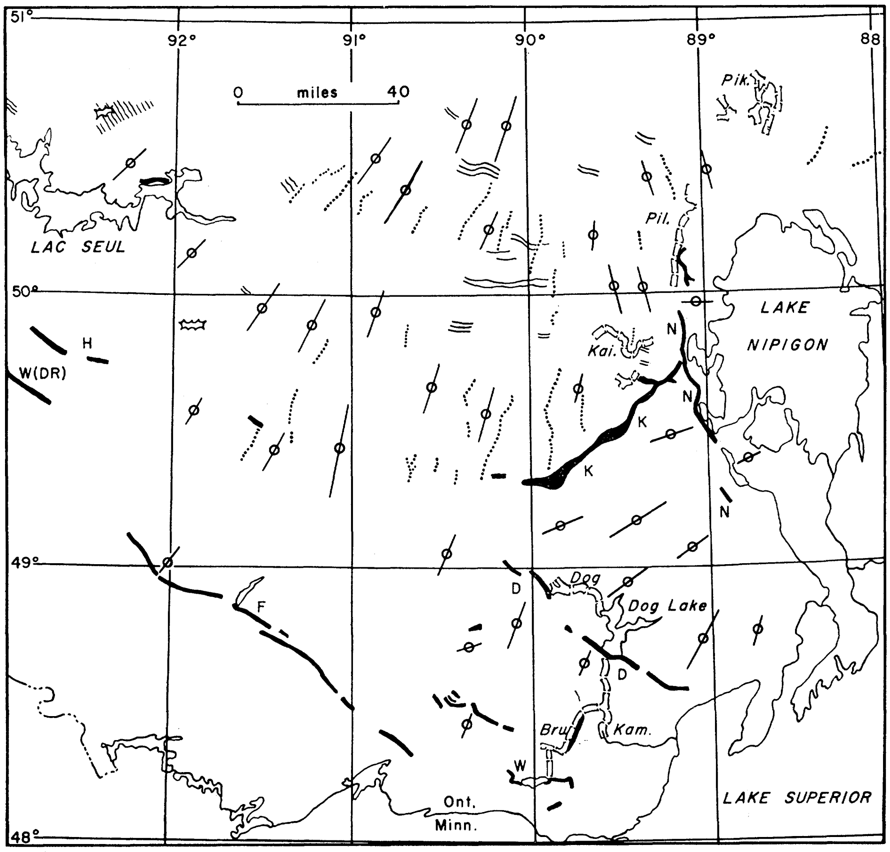

Fig. 1. Sketch map of area containing the eastern outlets of Lake Agassiz, showing glacial features interpreted from air photographs. End and interlobate moraines are black, with vertical letters: *D,* Dog Lake moraine; *F,* Finlayson; *H,* Hartman; *K,* Kaiashk (interlobate); *N,* Nipigon; *W,* Whitewater; *W(DR),* Wabigoon (Dryden). Spillways are bracketed, with slanted letters: *Bru.,* Brule Creek; *Dog,* Dog River; *Kai.,* Kaiashk River; *Kam.,* Kaministikwia River; *Pik.,* Pikitigushi River; *Pil.,* Pillar Lake. The trends of washboard moraines are shown as thin parallel lines. The principal eskers are dotted. The trend of glacially streamlined features is shown by straight lines and circles. Areas of wave-cut terraces have cuspate outlines.

positions in an alluvial fill. The six dates span the Two Creeks interval. Because the Campbell strandline extends north of latitude 53° and apparently has not been overriden by ice, the Valders glacier obviously could not have extended south of that latitude on the west side of Lake Agassiz. Its margin probably stood at The Pas moraine.

Boundaries to the East

Locating the ice border in the eastern part of the lake basin is much more difficult, because both ice advance and crustal uplift may have participated in closing the eastern outlets and because features associated with ice advances and lake outlets are not necessarily obvious in the air photographs of the wild, rugged, forested country of western Northern Ontario. Figure 1 shows moraines and outlets discovered in a reconnaissance study of 1-inch-to-1-mile photographs at the National Air Photo Library in Ottawa.

Portions of the Dryden-Wabigoon-Finlayson (Steep Rock Lake)-Whitewater moraine system have been described in the literature (*12, 15*); east of Whitewater Lake this moraine curves south as if to join the Highland or the Fond du Lac moraine in Minnesota. This moraine seems to represent a glacial advance east of Lake Agassiz during intermittent retreat in the western part of the basin.

The Dog Lake moraine, apparently not reported hitherto, is a splendid example of an end moraine with outwash fans, and it obstructs, in two places, the spillway formed by Dog River and Kaministikwia River. Including gaps, the moraine can be traced for at least 58 miles, from latitude 49°N, longitude 90°W southeast to the wave-washed, bare rock area 5 miles north of Thunder Bay on Lake Superior. It may correlate with the Kaiashk interlobate moraine, another well-defined feature that extends 50 miles southwest from the west side of Lake Nipigon, or it may represent the landward end of a slowly retreating ice margin that stood in Lake Agassiz and extended west and north to the Sachigo moraine. It is a possible candidate for designation as a Valders end moraine.

A third end moraine trends south along the west side of Lake Nipigon (*16*); the ice that formed it may have blocked the Kaiashk River outlet of Lake Agassiz. North of its intersection with the Kaiashk interlobate moraine the Nipigon moraine forms a sharp boundary between features indicating south-flowing ice to the west and west-flowing ice to the east. An eastward shift of a center of outflow is suggested. Almost as good a case can be made for correlation of the Nipigon moraine with Valders as for the Dog Lake moraine. Further comment on the correlation of these moraines would be mere speculation.

Broad, flat-floored spillways, either dry or containing underfit streams, form parts of the drainage systems of Kaministikwia, Dog, Kaiashk, and Pikitigushi rivers (Fig. 1). All of these may have functioned as eastern outlets of Lake Agassiz at different times.

Previously unreported terraces, interpreted as having been wave-cut during submergence in Lake Agassiz, occur on drift hills south of Minnitaki Lake and north of Lac Seul. Similar wave-cut benches occur on the Sachigo interlobate moraine south of Sachigo Lake (latitude 53°35′N, longitude 92°25′W). Altitude determinations of these features will be of assistance in the search for the eastern and northern boundaries and outlets of Lake Agassiz II. Late in its history the lake may have discharged northward, east of the Sachigo moraine, by way of Echoing River spillway into Hudson Bay, prior to marine submergence of that area.

Valders Ice Border

Probably the Valders ice border extended from the type area in Wisconsin northward, past the west side of Lake Nipigon, north-northwest to Sachigo Lake, west to The Pas moraine, which is almost certainly of Valders age, and northwest to the Cree Lake moraine in northern Saskatchewan. This border (Fig. 2) is compatible with the minimum retreat of the ice in Two Creeks time shown by R. C. Murray (*17*). A lesser retreat and readvance, between Cary and Port Huron-Mankato time, would account for the red drift of the Superior Lobe (*18*), the Dryden-Finlayson Whitewater moraine, and the till over varved clay near Sioux Lookout (*11*) and at Steep Rock Lake (*12*).

If the Coteau de Missouri represents the outer limit of the Mankato ice on the prairies, the minimum average width of ice removed in Manitoba and Saskatchewan in Mankato-Valders time is about 400 miles. Mankato drift may extend west of the Coteau (Fig. 2). The ice margin withdrew northwestward and later northward, breaking up into sublobes as it moved (*6, 19*); hence, the marginal retreat from the Mankato end moraine of the Des Moines lobe was at least 750 miles west of longitude 96°, and about 250 miles nearer Lake Superior.

The amount of advance of the Valders ice sheet in the west is not known, but it was probably much less in northern Saskatchewan than in Michigan and Wisconsin, because of slower metabolism of the ice sheet, due to low temperatures and precipitation. The retreat alone suggests a more significant climatic fluctuation than that so far demonstrated for the Cary-Mankato interval. I feel that the term *Mankato* is useful to denote drift referable to the Mankato-Port Huron moraine system but that it is more closely related to Cary than to Valders. Whether or not a drift sheet whose known margin lies mainly within the United States deserves substage rank is not for a Canadian to decide.

History of Glacial Lake Agassiz

A working hypothesis of the sequence of events in the history of Lake Agassiz follows; a summary of all the evidence would be too lengthy for presentation here.

1) Prior to lake formation there occurred a pre-Wisconsin interglacial interval.

2) An early proglacial lake was overridden by the advancing Wisconsin glacier.

3) An interval of glacial nondeposition or subglacial erosion formed a striated boulder pavement, probably during a late-Wisconsin interstadial.

4) A minor re-expansion of the ice sheet was followed by deposition of the Mankato (Altamont)-Port Huron moraine.

5) Intermittent northward retreat of Mankato ice resulted in the formation of Lake Agassiz I, which discharged southward through the Lake Traverse outlet (River Warren). The Sheyenne, Elk Valley, Pembina, and Assiniboine deltas, with corresponding moraines, were deposited in Lake Agassiz against the ice margin. There was contemporaneous retreat in the Lake Superior basin (Lake Keweenaw?).

6) The southern Agassiz outlet was eroded down to the Tintah or Norcross level, when retreat of the glacier in the Lake Superior basin opened an eastern outlet (Brule Creek?). The ice margin in the west retreated slightly north of Duck Mountain (latitude 53°N).

7) A minor readvance in the west deposited the Cowan moraine on Duck Mountain; a major advance in the east filled Superior basin and deposited red drift in northeastern Minnesota; the ice margin stood at the Dryden-Finlayson-Whitewater moraine.

8) Lake Agassiz I eroded its southern outlet down to a bedrock sill; the higher Campbell strandline was formed; the ice margin began to retreat; the Campbell strandline was abandoned when retreat again opened eastern outlet(s) (Dog River and others farther north).

9) The Lake Agassiz I–II interval (Two Creeks) followed. Withdrawal of ice into northern Ontario prior to major crustal upwarping opened lower outlets, and the Agassiz basin was drained. Erosion of lake floor and delta sediments occurred, and a molluscan fauna invaded the region. Prairie floras spread eastward across the dry lake basin. The Little Minnesota River deposited an alluvial fan at Browns Valley in the abandoned southern outlet.

10) Advancing ice (Valders) formed Lake Agassiz II. The eastern outlets were blocked by the advancing ice sheet and possibly also by crustal uplift. The ice margin extended from west of Lake Nipigon north to Sachigo moraine, west to The Pas moraine, and northwest to Cree Lake moraine. Lake Agassiz II discharged eastward until its highest available outlet (Dog River?) was blocked (Dog Lake moraine?), then rose and overflowed the alluvial fan damming the southern outlet at Browns Valley; the lake level temporarily rose to the former Norcross or Tintah stand, and alluvial fills were deposited in the Pembina and Assiniboine valleys. Then the Browns Valley alluvial dam was swept away, and the lake rapidly subsided to the second Campbell strandline, which is slightly lower than the first because of erosion of the outlet and crustal upwarping. Plainview and Agate Basin (lanceolate) projectile points were distributed around Lake Agassiz II.

11) The retreat of Valders ice opened eastern outlets north of the moraine-dammed and uplifted Dog River spillway; the Kaiashk and Pillar Lake outlets successively discharged southward into Lake Superior through Black Sturgeon spillway. Subsequently Pikitigushi and other northern spillways conducted Lake Agassiz discharge to Lake Superior by way of Lake Nipigon. The Campbell strandline was abandoned, and others formed at successively lower levels.

12) A northern outlet opened east of the Sachigo interlobate moraine when residual ice in Keewatin District (*20*) was severed from retreating Laurentide ice by melting into incipient Hudson Bay. Discharge through this outlet occurred prior to marine submergence and subsequent crustal uplift.

13) Residual ice in the Nelson River basin melted, and Lake Agassiz drained northward into Hudson Bay, prior to 3600 years ago, at which time Lake Shore projectile points (Signal Butte IA) were distributed throughout the basin. Forest flora invaded the eastern part of the basin, surrounding small prairie refuges that had formerly been on islands and on the eastern shore of Lake Agassiz II (*21, 22*).

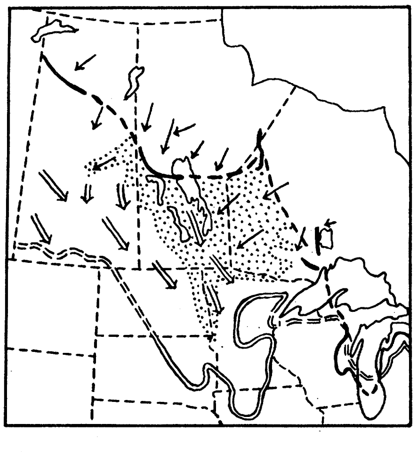

Fig. 2. South-central Canada and adjacent United States, showing known and postulated positions of Mankato-Port Huron (double line) and Valders (single heavy line) drift borders. Lines are solid where drift borders are known, or along end moraines, and are broken where drift borders are interpolated or postulated. Arrows indicate directions of ice flow; double arrows are Mankato, single arrows are very late Mankato and Valders. Lake Agassiz II is stippled. Directions are based in part on studies of air photographs taken in Saskatchewan, Manitoba, and northern Ontario and on field studies made in southern Manitoba and Saskatchewan.

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22. *Erratum ad referendum.* This is a suitable place to correct an error that has recurred in a generation of reference books [the most recent examples are J. K. Charlesworth, *The Quaternary Era* (Arnold, London, 1957), p. 476, and W. D. Thornbury, *Principles of Geomorphology* (Wiley, New York, 1954), p. 408]. Although a glacial lake in the lower Saskatchewan Valley may have merged with Lake Agassiz, glacial lakes Regina and Souris were entirely separate lakes. Neither merged with the other, and neither merged with Lake Agassiz.

Endocrine Control of Amino Acid Transfer

Distribution of an Unmetabolizable Amino Acid

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We can greatly oversimplify a description of amino acid metabolism by writing

$$\begin{tikzcd} & \text{proteins} \arrow[dl, shift left] \\ \text{Amino acids} \arrow[ur, shift left, "1"] \arrow[dr, "2"'] & \\ & \text{urea} + CO_2 + H_2O \end{tikzcd}$$

The remarkable features which dominate amino acid metabolism in the higher animal are (i) the large shift from fate 1 (anabolic) to fate 2 (catabolic) which takes place when the animal passes from fetal life and infancy to adulthood and (ii) the large shifts which can be induced experimentally, either by administering a hormone or by producing conditions which stimulate secretion of hormones.

The hypophyseal growth hormone and certain androgenic steroids are recognized to have strong anabolic effects, and some of the adrenal cortical steroids, strong catabolic effects. In addition, other hormones, notably the estrogens, produce growth of particular tissues. Before trying to explain these effects, we must complicate the above scheme by remembering that anabolism and catabolism do not take place from a single homogeneous pool. We can write instead, as a second approximation

$$\begin{tikzcd} \text{Amino acids in various nonhepatic cells} \arrow[r, shift left, "1"] \arrow[d, shift left] & \text{proteins} \arrow[l, shift left] \\ \text{extracellular amino acids} \arrow[u, shift left, "3"] \arrow[d, shift left] & \\ \text{amino acids in liver cells} \arrow[u, shift left, "4"] \arrow[r, shift left, "1"] \arrow[dr, "2"'] & \text{proteins} \arrow[l, shift left] \\ & \text{urea} + CO_2 + H_2O \end{tikzcd}$$

This scheme reflects the conclusion that most of the *net* degradation of amino acids occurs in the liver, whereas only hepatic proteins and some of the circulatory proteins are formed in the liver.

Steps 3 and 4 are *concentrative transfers* of the amino acids into the cells—that is, transport against concentration gradients, discovered in 1913 by Van Slyke and Meyer (*1*). The process has been extensively studied (*2, 3*), and may well be a restrained form of similar activities found in lower forms of life, which, however, have not yet been shown to be definitely concentrative.

Accordingly, concentrative transfer undoubtedly was developed before hormonal control; hormonal *restraint* appears, instead, to have been superimposed upon a primitive activity. In some microorganisms concentrative transfer may be substrate-induced (*4*). Concentrative transfer occurs across many cell barriers, such as the placental barrier (*5*), the renal tubular cells, and the intestinal mucosa, but also occurs across the cell barrier of most other cells so far studied (see Gale, *6*). It is a common step through which every amino acid must pass before it can be utilized. We have delayed calling the activity a "transportase" or "concentrase" (or, as one colleague has suggested, a "here-to-there-ase") until the enzymatic portions of the process have been more clearly demonstrated. A more objectionable term, *permease,* suggests incorrectly that we are dealing with the breakdown of barriers to diffusion, and should be rejected.

Paradoxically, we have observed many times that the free amino acid levels are higher in the more rapidly growing tissues, where they ought instead, if anything, to be depleted. This result has been observed in fetal life (*5*), in hepatic regeneration (*7*) and in neoplasia (*8*). Might an estrogen, for example, stimulate growth of the uterus, by increasing the extent to which that tissue concentrates amino acids? Might growth hormone increase the extent to which various tissues capture amino acids? Might the catabolic steroids increase particularly the hepatic capture of amino acids, thereby exposing them to accelerated destruction?

Such questions were asked (*9*), and the latter one tentatively answered in the affirmative, in 1948 (*7*), when hepatic amino acid levels were found to be increased in the rat after laparotomy. In

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