equal after lesions in any lobe (*1*) or that it should be maximal after injury to the frontal regions (*2*). There is, however, evidence that the present results are limited to the kind of test employed. Using the same population, we found that injury to any lobe of the brain, in either hemisphere, can interfere with performance on certain nonlanguage tasks such as the discovery of hidden figures (*7*).

Performance on a standardized test of "general intelligence," such as the AGCT, thus shows little or no change 10 years after penetrating brain wounds unless the entrance wound included the left parietotemporal region.

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4 March 1957

Radiocarbon Dates of Mankato Drift in Minnesota

The Mankato drift in Minnesota has recently been shown by Wright and Rubin (*1*), on the basis of radiocarbon dates, to be older than the Two Creeks forest bed in northeastern Wisconsin. In a paper (*2*) that was prepared and submitted for publication in June 1956 but which has just been issued, I reached the same conclusion for the Mankato drift of northern Lower Michigan. But Wright and Rubin *1*, p. 626 express the view that the Mankato drift "should be correlated with the Cary (pre-Two Creeks) rather than with the Valders (post-Two Creeks)." And they further state, "We therefore favor the use of the term *Valders* over the term *Mankato* for the last major substage of the Wisconsin." The question was not discussed that, even though the Mankato is older than Two Creeks, it might still be younger than the Cary, which I show in my article to be the case.

In northern Lower Michigan, as pointed out by Leverett long ago (*3*), the terminal moraine of the Mankato, the Port Huron, transects the last known interlobate deposits of the Lake Border system of late Cary age. Before it was built, the desiccation of the Cary ice had taken place. After a short intraglacial interval, the Cary-Mankato, the Mankato glacier formed from the renourished Patrician center and moved southward across the Straits of Mackinac to its terminal position (see *2*, Fig. 1). Leverett, the revered apostle of glacial-lobe deployment, pointed out that morainic systems which were built following marked readvances like the Port Huron system should be recognized as substages (*3*, p. 31). It is not a "recessional" of the Cary. Likewise, the red drift of the Valders is not a "recessional" of the Mankato.

In Minnesota a similar situation exists. Leverett's map (*4*, Plate 2) shows that immediately south of the Bigstone moraine in northwestern Minnesota, southeast of Ortonville, elongate ridges, resembling crevasse fillings, occur which are transected by the Bigstone moraine (Fig. 1), in the same way that the Port Huron moraine crosses the interlobate pattern of the Lake Border system, except that in Minnesota the transecting moraine is Valders and the deposits out in front are Mankato.

Upon searching for what Leverett might have said about this significant relationship, I find this (*4*, p. 105): "The morainic strips just mentioned [those out in front of the Bigstone moraine] seem to pertain to a very narrow ice tongue that was gradually reduced until it completely melted before the ice sheet readvanced with a broader front to a strong moraine that traverses southern Big Stone County and northwestern Swift County. . . . They complete the series which deployed in the basin drained by the Minnesota River and were followed by a series of moraines formed by an ice lobe that was confined mostly to the Red River Basin." Leverett recognized this as a younger and separate substage of the Wisconsin (*5*, Fig. 5).

Thus, it would appear that the retreat of the Mankato ice gave rise to Lake Agassiz I, that the Valders ice transgressed most if not all of the lake bed, and that the outlet waters of Lake Agassiz II, upon the retreat of the Valders ice from the Bigstone moraine, cut River Warren Valley II. This narrow gorgelike valley is clearly related to the marked change in topography brought about by the deposition of the Bigstone morainal system. As Leverett observed, it is in contrast to the much wider valley of River Warren Valley I, below the terminus of the moraine. Thus, the present beaches are younger than the Valders terminal moraine, although some of the recent topographic maps seem to show short stretches of slightly glacially modified beaches of Lake Agassiz I.

It is also interesting to note that the two valley-train terraces along the Mississippi River in western Illinois, which have been assigned to the early and late Mankato by Leighton and Willman, are but mere remnants of former fills, caused by two successive glacial torrents, the first greater than the second. The new facts throw interesting light on these interpretations. Leighton and Willman have consistently referred the destructive torrents which not only swept away most of the valley trains but sliced the bluffs and headland points in the Mississippi Valley, to the outlet waters of Lake Agassiz I and II and Lake Duluth. More recently Leighton has traced the upper and older terrace that is composed of coarser materials to the Mankato outwash to Dakota County, Minnesota, where it has been mapped as such by Ruhe and Gould (*6*). Now it appears that the lower terrace of finer materials may be Valders and may have come from the ice when it stood at the Bigstone moraine. The terrace at Bonfils, Missouri, across from St. Charles, which was formerly referred to the Mankato, is now known to be Tazewell, from two radiocarbon dates determined by the Washington laboratory. The Tazewell date is consistent with the fact that this terrace remnant has loess on its surface which is essentially lacking on Mankato or Valders terraces.

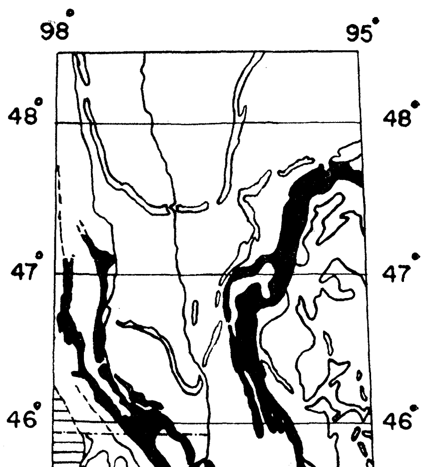

Fig. 1. Bigstone morainal system in the Red River basin, suggested as Valders. The outer portion of Valders is shown in black, Mankato open, Cary dotted, Tazewell diagonally lined, and glacial Lake Dakota horizontally lined [After Leverett (*4*, plate 3) and Flint (*8*)].

The radiocarbon dates that are cited by Wright and Rubin for the Grantsburg lobe of the Mankato (*1*, p. 625) are, it will be noted, rather young for the Cary and are what one might expect for the Mankato. A Washington date for Glenwood II beach of Lake Chicago which Bretz (*7*) refers to Lake Whittlesey and the culmination of the Port Huron ice is 12,200 ± 350 years (sample W-161).

The classification that I proposed in my recent paper (*2*, p. 109) after I had analyzed the Wisconsin-Michigan area seems perfectly applicable to the entire Mid-west. This classification divided the Wisconsin into the following substages: (i) Farmdale; (ii) Iowan; (iii) Tazewell; (iv) Cary; (v) Mankato; (vi) Valders.

The name of the intraglacial substage immediately preceding the Valders—Two Creeks—is well known and will be used as a matter of second nature, but for the others the compounding of the names will be adequate and appropriate until new information dictates otherwise (*9*).

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8 February 1957

M. M. Leighton has had the benefit of four decades of close attention to the problems of glacial stratigraphy of the Great Lakes region, and he is responsible for naming most of the subdivisions of the Wisconsin glacial stage in current use. His comments are therefore appreciated (*1*).

The history of the terminology is summarized in Fig. 1 (*2–12*). In brief, Leighton points out that Leverett's correlation (*2, 3, 4*) of the Port Huron moraine with the Mankato (Bemis moraine) of Minnesota has been vindicated by a combination of stratigraphic revisions in Michigan (*8*) and radiocarbon-based revisions in Minnesota (*9, 10*), and that the term *Mankato* should be retained as a post-Cary, pre-Two Creeks substage of the Wisconsin. He thus implies that the Two Creeks interstadial had been inserted into the Wisconsin classification at the wrong position—that is, below Mankato rather than above—because the Mankato equivalent had not at that time been identified in northeastern Wisconsin.

The problem of whether to consider the Port Huron moraine and the Mankato of the Des Moines lobe of Minnesota as representatives of a separate substage or as a late phase of the Cary depends on the magnitude of the warm interval and the accompanying ice recession that followed the Cary maximum and preceded the Mankato-Port Huron phase in question. Leighton (*12*) considers that the Cary ice withdrew north of the Straits of Mackinac during this interval before it readvanced to the Port Huron moraine in the Mankato with a somewhat different alignment. Bretz (*8*), however, mentions no evidence in the strand-line record of glacial Lake Chicago for a pre-Port Huron retreat and low-water level of this magnitude. Inasmuch as no buried soils or forest beds record the suggested interstadial in this region, the evidence for appreciable retreat of the Lake Michigan lobe prior to readvance is limited to the truncation of the Lake Border moraine by the massive Port Huron moraine. It might be admitted that such truncation is the basis for distinguishing Cary from Tazewell moraines in Illinois, but truncation of equal magnitude may be found for moraines within a single substage (as Bloomington versus Shelbyville moraines of the Tazewell).

Actually, the evidence for separating Mankato from Cary is stronger in Minnesota than it is in Michigan. The Superior lobe retreated at least 120 miles from its Cary terminus at the St. Croix moraine, so that its melt-water drainage channels were completely abandoned before the Mankato ice of the Des Moines lobe advanced from the west for 75 miles over the bared area (*13*). Although two ice lobes of diverse source are involved here, a significant climatic amelioration is suggested for the interval between the Cary and Mankato by these relations in Minnesota. This interval had been assumed to be the Two Creeks interstadial until it was found (*9*) that the retreatal deposits of the upper drift (Mankato) had a carbon-14 age of 11,000 to 13,000 years.

To date, no weathering horizon or buried forest bed has been identified from this stratigraphic position. The closest candidate is the wood found in outwash between two tills in the Lizard Creek section near Fort Dodge on the Des Moines River in central Iowa; the tills were interpreted as Cary and Mankato by Ruhe and Scholtes, and two samples of the wood (hemlock) were dated by radiocarbon analysis as 13,300 and 12,120 years old (*10, 14*).

I have previously agreed (*10*) with

Leverett 1915, 1929 1932 *(2, 3, 4)*	Leighton 1933 *(5)*	Thwaites 1943, 1946 *(6, 7)*	Bretz 1951 *(8)*	Wright & Rubin 1956; Zumberge & Wright 1956 *(9, 10)*	Leighton 1956, 1957 *(11, 12)*	Wright 1957
LATE: 5th-Big Stone moraine 4th-Pt. Huron; Bemis; red till NE Wis.	MANKATO	5th-MANKATO (or = Valders) 4th-VALDERS (red till NE Wis.)	VALDERS	VALDERS	VALDERS (Big Stone mor.)	VALDERS (Lake Agassiz)
					TWO CREEKS (L. Agassiz I)	TWO CREEKS (L. Agassiz)
INTERSTADIAL	INTERST.	TWO CREEKS	TWO CREEKS	TWO CREEKS	MANKATO (Pt. Huron; Altamont mor.)	MANKATO (Big Stone, Altamont; Mille Lacs, Highland; Port Huron moraines)
MIDDLE: 3rd-Kalamazoo mor.	CARY	3rd-CARY	CARY { Pt. Huron; L. Border & older mor.	CARY { Late (=Mankato); Maximum	INTERSTADIAL	INTERSTADIAL
					CARY (Lake Border & older moraines)	CARY (Bemis; St. Croix; Lake Border & older mor.)
INTERST.	INTERST.				INTERSTADIAL	
EARLY: 2nd-Bloomington mor. 1st-Shelbyville	TAZEWELL	2nd-TAZEWELL			TAZEWELL	
PEORIAN INTERGL.	INTERST.				INTERSTADIAL	
	IOWAN	1st-IOWAN			IOWAN	
					INTERSTADIAL	
					FARMDALE	
IOWAN	SANGAMON INTERGL.	SANGAMON INTERGLACIAL			SANGAMON INTERGLACIAL	
SANGAMON INTERGL.						

Fig. 1. History of classification of Wisconsin glacial stage in the Great Lakes region.

Leighton that the Mankato drift of southern Minnesota is probably correlative with the Port Huron moraine of Michigan, and, pending further field studies and radiocarbon dates of pertinent deposits, will yield to Leighton's proposal that the term *Mankato* be retained as a substage of the Wisconsin, in its new pre-Two Creeks position.

Leighton's suggestion that the Valders border of the Des Moines lobe lies at the Big Stone moraine represents a modification of a much earlier suggestion of Leverett (Fig. 1), who at one time designated this moraine as marking the fifth substage of the Wisconsin (*3*, Fig. 5). The suggestion has renewed appeal as one casts about for a Valders terminus north of the Mankato region.

The Big Stone moraine across the Minnesota River valley sharply truncates elongate ridges that Leverett implied were lateral moraines of the shrunken Des Moines lobe of the fourth substage. Leighton interprets these ridges instead as crevasse fillings; he likens the relations to the transection of the Lake Border interlobate moraine (Cary) in Michigan by the Port Huron moraine (Mankato), and considers that in both areas the intervening retreat should be of interstadial rank. Retreat of Mankato ice into the Red River valley during the Two Creeks interstadial, in this view, would allow the formation of Lake Agassiz I, with a broad southern outlet via River Warren I (Minnesota Valley). Valders readvance to the Big Stone moraine would be followed in turn by final retreat and the formation of Lake Agassiz II.

The elongate ridges in question are composed of clay till (*4*, p. 105). Aerial photographs suggest that they are neither lateral moraines nor crevasse fillings, but are erosional remnants of the Mankato till plain separated from one another by multiple drainageways funneling broadly from the Big Stone moraine into the center of the Minnesota Valley. The moraine was later cut by the River Warren drainage of Lake Agassiz.

With this interpretation, the necessity for inferring a distant withdrawal of the Des Moines lobe before readvance to the Big Stone moraine is reduced. The only reports of overridden lake beds in the Agassiz area refer to a much earlier lake (C^{14} dated as > 36,000 years old, Bronson, samples W-102 and W-468). At any rate, correlation of the Big Stone moraine with the Valders does not help with the problem in question because the C^{14} dates for undisturbed Lake Agassiz beds in Minnesota and southern Manitoba are mostly of Two Creeks age or older (*9*), and the Valders drift border must therefore be north of the radiocarbon sites.

Elson (*15*) postulated a Valders ice front extending from the Lake Winnipeg region eastward to Lake Superior and thence south to the Michigan Upper Peninsula and the Valders type area. This line circumvents Minnesota completely and denies the identification of Valders drift of the Superior lobe in northeastern Minnesota, which I (*16*) had made on the basis of lithologic and stratigraphic similarity to the Valders of northeastern Wisconsin. My Superior-lobe Valders in Minnesota had met with some radiocarbon difficulties, however: on the basis of interbedding it was considered to have formed contemporaneously with drift of the St. Louis sublobe (of the Des Moines lobe), which had its origin in the Red River valley in the very area where undisturbed Lake Agassiz sediments gave pre-Valders C^{14} dates. A new date (*17*) pertinent to this specific problem comes from glacial Lake Aitkin, a feature formed during the retreat of this St. Louis lobe and the presumed Valders Superior lobe. This date of $11,710 \pm 325$ years before the present (sample W-502) seems to be too old for late Valders, and fits the pattern of Two Creeks or "late Mankato" dates for the Anoka sand plain (Grantsburg sublobe of Des Moines lobe) and Lake Agassiz. If Elson's or some other northern Valders line is confirmed by additional work, the red clay till of northeastern Minnesota must reflect some pre-Two Creeks readvance of the Superior lobe. Two earlier Superior-lobe advances have been described (*13*), one as far as the St. Croix moraine (Cary maximum), a later one to the Mille Lacs and Highland moraines (Mankato?).

Despite the uncertainties of the correlations from lobe to lobe, the evidence from Lake Huron to the Dakotas, however, seems today to support the view that an important readvance of several ice lobes occurred just prior to the Two Creeks interstadial. Although I have previously suggested that this readvance be included as a late phase of the Cary, following Bretz, I am willing to apply to it the term *Mankato*, following Leighton, with the hope that correlation of the Mankato drift of the Des Moines lobe with the Port Huron of the Lake Michigan and Huron lobes will be more strongly confirmed.

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References and Notes

1. I am obliged to my coauthors of earlier discussions of this problem, Meyer Rubin of the U.S. Geological Survey and J. H. Zumberge of the University of Michigan, for reading this further discussion. I also appreciate the many keen comments offered by Leighton and many other participants in the 1956 Glacial Field Trip of the Geological Society of America, during which much of the field evidence bearing on the Cary-Mankato-Valders problem in eastern Minnesota was reviewed.
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4 April 1957

Dependence of Acute Radiosensitivity on Age in Adult Female Mouse

The literature on radiation sensitivity of animals at advanced ages is not extensive. Zirkle *et al.* (*1*) determined the LD_{50} for x-rays in the mouse as a function of age for ages ranging from 1.5 to 12 months. Hursh and Casarett (*2*) reported LD_{50}'s for rats at ages of 6 and 16 months. Kohn and Kallman (*3*) made a careful determination of the LD_{50} for single doses of x-rays for ages ranging from 40 to 640 days. Several studies have been made of age changes in sensitivity during the period of postnatal growth (*4*).

The paucity of information about acute lethality at advanced ages may be the result, in part, of the cost of such measurements when the conventional method of plotting a dosage-survival curve is employed. An effort was therefore made to develop a more efficient and less costly method of measuring the acute lethal action of ionizing radiation (*5*).

It was found, previously, that the mean accumulated dose that is required to determine a mean survival time of about 30 days (MAD/30 days) under a regime of daily exposure is correlated with the LD_{50}/30 days (*6*). This observation was based on interspecies comparison, but a high correlation has since been observed between these two measures for several mouse genotypes (*7*). A pilot study of age-dependence in acute radiosensitivity was therefore carried on, by use of the mean accumulated dose procedure.

Carworth female mice received at this laboratory at from 5 to 6 weeks of age were caged in groups of ten (11 in one