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EARTH SCIENCES

TWO-ICE-LOBE MODEL FOR KANSAN GLACIATION

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The Kansan glaciation should be representative of Early Pleistocene glaciations in the Kansas-Nebraska-Iowa-Missouri region. It is often assumed the Kansan ice-sheet advanced as a single, broad lobe coming from somewhere in Canada. This simple view contrasts with the known complexities of the younger Wisconsin glaciation, and indeed there is much evidence that the Kansan glaciation was equally complex. A two-ice-lobe model for the Kansan glaciation includes two confluent ice-streams, "Dakota Ice" and "Minnesota Ice," both moving generally southward either side of the Coteau des Prairies in eastern South Dakota. Iowa and Missouri were covered mainly by Minnesota Ice, while Dakota Ice advanced into Nebraska and Kansas. The general boundary zone between the two ice-lobes is marked by the Kansas City re-entrant and by the Missouri River north of Kansas City, which may have developed as an interlobate drainage during deglaciation.

† † †

INTRODUCTION

It is now well known to geologists that the region including northeastern Kansas along with adjacent Nebraska, Iowa, and Missouri was glaciated by continental ice-sheets several times during the Early Pleistocene Epoch (Boellstorff, 1978). Over the years, interpretations of these glaciations have become more and more complex (Reed and Dreeszen, 1965), and within the last few years deep test-drilling and fission-track dating of volcanic ash beds included in the glacial sequence (Boellstorff, 1976) have greatly improved stratigraphic understanding of the region. Still, there are certain basic aspects of the Kansan glaciation as defined by Frye and Leonard (1952:34) that have escaped critical analysis.

It has often been assumed that ice advanced simply as a broad front without distinct lobes coming from a northerly source somewhere in Canada (Dort, 1965:601). Other geologists have suggested specific Canadian source areas and lobate patterns for the Kansan glaciation. One possibility is for a western source area, the so-called Keewatin Center, in the region west of Hudson Bay. Frye and Leonard (1952:11) supported this concept on the basis of distribution of the Sioux Quartzite, a common erratic derived mainly from eastern South Dakota and southwestern Minnesota. The idea of a two-ice-lobe Kansan glaciation was suggested much earlier by Todd (1914:270), who stated, ". . . in this Kansan stage the Dakota ice lobe reached perhaps as far south and west as West Point, Neb., and became confluent with the west edge of the Minnesota-Des Moines lobe for hundreds of miles." However, Todd (1908:107) believed the Dakota lobe had reached only northeastern Nebraska, and Kansan glaciation of the region to the south was the result solely of the Minnesota lobe coming from the northeast. This viewpoint has also been accepted by others including Lammerson and Dellwig (1957:548). More recently, Willard (1980:79) concluded on the basis of distribution of Sioux Quartzite erratics that the Kansan glaciation was the result entirely of the Dakota lobe.

Opinion is, thus, divided concerning the "directional aspects" and lobate pattern of the Kansan glaciation. This subject has an important bearing on the continuing revision of Early Pleistocene glacial stratigraphy in this region, since the lobate patterns developed during glaciation would have markedly influenced the resulting glacial deposits.

WISCONSIN GLACIATION ANALOGY

It is often said in geology that, "the present is the key to the past." This statement could be modified to read, "the Wisconsin glaciation is the key to the Kansan glaciation." The relatively recent Wisconsin glaciation of the northern Plains region can be used as a model for the earlier Kansan glaciation (Fig. 1). The most conspicuous elements of the Wisconsin glaciation are two major ice-lobes marked by

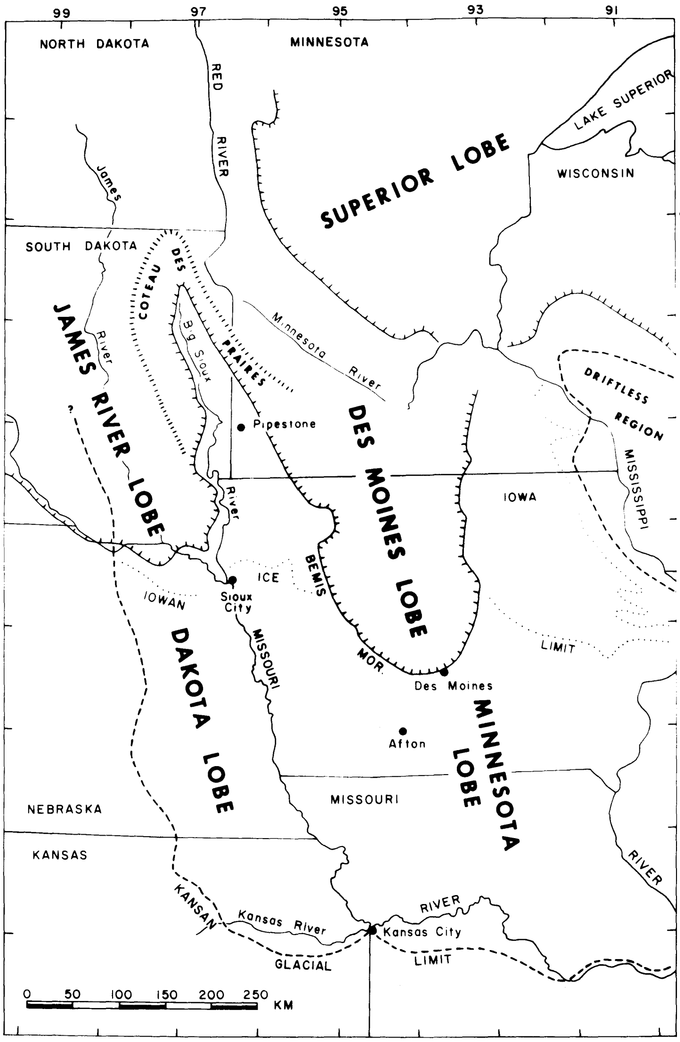

FIGURE 1. Map of northern Plains area, U.S.A., showing Wisconsin and Kansan glacial features. The James River, Des Moines, and Superior lobes were major Late Wisconsin lobes, whose patterns are shown by conspicuous end moraines, such as the Bemis moraine. The Coteau des Prairies, underlain in part by resistant Sioux Quartzite in the Pipestone vicinity, separated the James River and Des Moines lobes. Early Wisconsin (Iowan) glaciation shows less pronounced lobation. The Dakota and Minnesota lobes were the respective Kansan equivalents to the James River and Des Moines lobes. The general boundary between the two confluent Kansan lobes is marked by the re-entrant in the glacial limit at Kansas City and by the Missouri River between Kansas City and Sioux City. Glacial features are from Schoewe (1930), Flint (1955 and 1959), and Wright, Matsch, and Cushing (1973).

prominent moraines. The Des Moines lobe extended *via* lowlands from Minnesota southward into central Iowa, and is marked by the Bemis moraine. The James River lobe extended southward through lowlands in the eastern Dakotas and is likewise shown by conspicuous moraines. Both of these lobes were fed by ice coming from Manitoba, Canada, directly to the north. The two Wisconsin ice-lobes were separated by a prominent highland called the Coteau des Prairies. The Coteau is underlain by a core of Cretaceous sedimentary bedrock as well as the resistant Sioux Quartzite of Precambrian age. The Coteau obviously formed a topographic barrier to southward ice movement, and ice flow was diverted into adjacent lowlands (Wright, Matsch, and Cushing, 1973:160). This situation illustrates the strong control bedrock topography exerted on glaciation throughout the north-central United States (Horberg and Anderson, 1956).

Drainage features of the area are also closely related to glaciation. The upper tributaries of the Des Moines River and the Missouri River above Sioux City both developed as Wisconsin ice-marginal drainages. On the other hand, the Big Sioux River in eastern South Dakota represents an interlobate drainage.

A similar set-up may have developed during the much earlier Kansan glaciation. Although the Kansan glaciation was more widespread, and undoubtedly the ice-sheet thicker, the same basic topographic elements of uplands and lowlands were probably present to influence ice flow.

MODEL FOR KANSAN GLACIATION

Lobate Pattern

At its maximum, the Kansan ice-sheet spread south of the Kansas River valley in Kansas and south of the Missouri River valley in Missouri (Fig. 1). The model proposed here assumes the Kansan ice-sheet was actually supported by two confluent ice-streams coming southward either side of the Coteau des Prairies (Aber, 1981). To the west, the so-called "Dakota Ice" advanced through the eastern Dakotas, across Nebraska, and into Kansas, while to the east, "Minnesota Ice" pushed southward from central Minnesota through Iowa, and into Missouri. The Coteau was likely covered during glacial maxima; nonetheless, it presented a resistant topographic obstacle, which split the main lines of Kansan ice flow into Minnesota and Dakota lobes (Fig. 1).

It could be argued that the Coteau des Prairies had only a local influence on ice flow patterns, and surely this had little or nothing to do with glaciation several hundred kilometers to the south in Kansas and Missouri. There is enough evidence to suggest, however, that influence of the Coteau on the ice flow pattern extended all the way south to the glacial border.

The configuration of the Kansan glacial margin provides one line of evidence for a two-ice-lobe glaciation. In Kansas, ice advanced to a maximum position several kilometers south of the Kansas River valley to latitude 38° 50′ N. Likewise in Missouri, the maximum advance reached southward to latitude 38° 35′ N. Between these two maximal positions, a marked re-entrant in the glacial border is found at Kansas City, where apparently ice did not even reach latitude 39° N. This Kansas City re-entrant coincides with a sharp bend in the course of the Missouri River valley, as well as the junction of the Missouri and Kansas rivers. In this two-ice-lobe model, the Kansas City re-entrant marks the approximate boundary between the Minnesota and Dakota ice-streams.

The probable long-distance separation of Dakota and Minnesota ice-streams is also confirmed by observations on modern glaciers. Typical alpine glaciers are often composed of several tributary glaciers which join forming a trunk glacier. Although the tributary ice-streams flow together, they do not mix. Individual ice-streams remain physically separate, each moving with a characteristic velocity (Embleton and King, 1968:85), and can be readily traced to the glacial margin by medial moraines on the ice surface. A similar phenomenon could have occurred when the Dakota and Minnesota ice-streams flowed together south of the Coteau des Prairies; the two streams did not mix, but remained distinct all the way to the glacial border.

Directional Evidence

Striations provide first-hand evidence concerning the directions of ice movement. Striation data from several sites in northeastern Kansas and adjacent Missouri show two distinct maxima when plotted on a rose diagram (Fig. 2). One maximum trends northwesterly, while the other trends nearly due north. Striations in themselves can be variously interpreted, and Schoewe (1931) suggested several possibilities. In this proposed model, the northwesterly striations presumably represent Dakota advances, while northerly striations resulted from Minnesota advances. Elsewhere, striation data from Nebraska, South Dakota, and Minnesota (Chamberlin, 1886: Pl. VIII) seem to conform to a two-ice-lobe pattern, but striation observations are too scattered to draw firm conclusions throughout the area.

More convincing directional evidence for glaciation is provided by ice-induced deformations of bedrock and drift. Ice-pushing often creates overturned folds and thrust faults, and the orientations of fold axes and thrust planes are good indicators for ice-movement directions. These structures are considered more reliable indicators for major ice advances than are striations, since a large volume of material is involved in the deformations (Berthelsen, 1978). Dellwig and Baldwin (1965) reported on six examples of ice-push deformation in northeastern Kansas. At three localities, ice advance came from the northwest to southeast. At three other sites, ice movement was from the northeast to southwest. Although

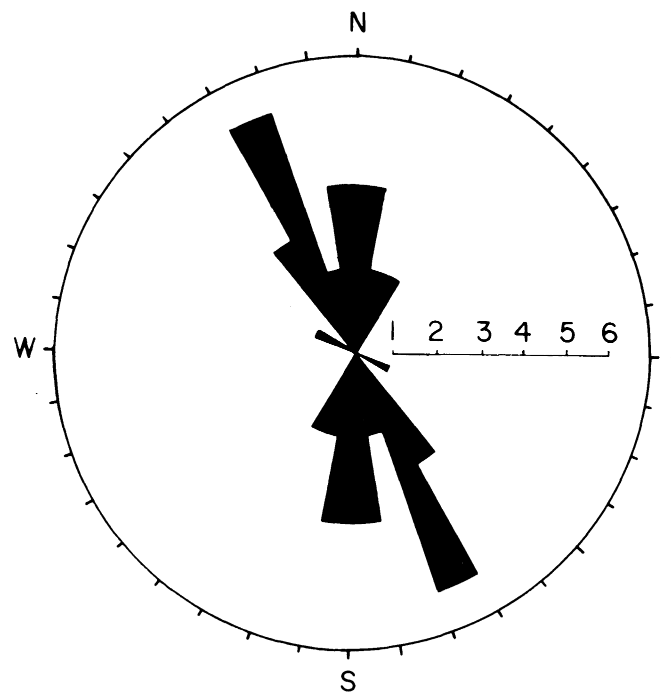

FIGURE 2. Rose diagram showing striation data from sites in northeastern Kansas (Schoewe, 1931, 1937, and 1941) and adjacent Missouri (Jewett, 1934). Diameter scale indicates number of localities with striations in each 10° interval. Two distinct maxima are apparent; northwesterly striations are presumably related to Dakota advances, while northerly striations may be associated with Minnesota advances.

this information appeared to conflict with the glacial stratigraphy accepted at the time, the implication of ice advances from two directions is quite clear. The northwesterly advances would supposedly correspond to Dakota Ice, whereas pushing from the northeast relates to Minnesota Ice.

Certainly, much more field study of directional features in the Kansan drift is needed to test this two-ice-lobe glaciation model. The directional data from striations, ice-push structures, and the like must be placed in proper stratigraphic context. Recent field studies in Atchison and Doniphan counties of northeastern Kansas demonstrate that an Early Kansan (Nickerson) ice advance came from the northeast, whereas a Late Kansan (Cedar Bluffs) glaciation advanced from the northwest (Aber, 1982).

In addition, lithological differences would be expected between Minnesota and Dakota drifts. Several geologists have maintained there is no lithological way to distinguish between various Kansan tills [Type A tills of Boellstorff (1978)]. Yet, other geologists have used lithological differences to separate different Kansan tills (Reed, Dreeszen, Drew, Souders, Elder, and Boellstorff, 1966; Bayne, 1968).

In northeastern Kansas, clay mineralogy seems most useful in distinguishing an illite-rich Lower Kansan till from a kaolinite-rich Upper Kansan till (Tien, 1968). With additional investigation, it may become possible to relate particular till lithologies to certain ice lobes.

Kansan Stream Drainage

Segments of three streams, the Big Blue River on the west, the Kansas River to the southwest, and the Missouri River east of Kansas City, represent the principal system of ice-marginal drainage that developed during the Kansan glacial maximum. Through this system, drainage from the upper Missouri, White, Niobrara, Platte, and Kansas rivers together with glacial meltwater flowed southward and eastward around the ice-sheet (Todd, 1914).

There are various opinions concerning the origin of the Missouri River between Kansas City and Sioux City. This generally north–south segment of the Missouri River is not obviously related to a major ice-marginal position. Frye and Leonard (1952:192) wrote simply that the Missouri River took its present course across the Kansan till-plain as the Kansan ice-sheet retreated. Somewhat more to the point, Reed, Dreeszen, Bayne, and Schultz (1965:194) stated: "The Missouri River between Sioux City and Kansas City trends down the ground-moraine depression of the Kansan glaciation." They suggested, in effect, that the Missouri River valley marks the central axis of the Kansan advance, and that the Missouri River developed along this axis as the Kansan glacier retreated. However, this interpretation does not account for the re-entrant in the glacial border. If the Missouri River valley really was the axis for ice advance, a salient, not a re-entrant, should be found in the glacial border at Kansas City. According to Todd (1914:271), the Missouri River above Kansas City does represent an ice-marginal drainage, which developed along the western margin of the Minnesota lobe as this lobe retreated to the northeast. This interpretation would seem likely, assuming the Dakota lobe had not advanced into southeastern Nebraska or northeastern Kansas. Finally, O'Connor and Fowler (1963) thought the Missouri River above Kansas City represents a post-Kansan stream, unrelated to the Kansan glaciation.

In light of a two-ice-lobe glaciation model, an alternate interpretation for development of the Missouri River between Kansas City and Sioux City is seen. It could have developed as an interlobate drainage between the Dakota and Minnesota lobes during Kansan deglaciation. During deglaciation, the re-entrant along the ice margin retreated northward, and meltwater funneled off the ice into the re-entrant led to the development of the Missouri River north of Kansas City. Thus, the positions of the Kansas City re-entrant and the Missouri River valley above Kansas City mark the approximate boundary between the Dakota and Minnesota ice-lobes during the Kansan glaciation (Aber, 1981).

IMPLICATIONS OF MODEL

There is no reason to assume the Minnesota and Dakota ice-streams advanced simultaneously. Undoubtedly, the boundary between the two lobes shifted back and forth somewhat as the lobes expanded and shrank. Their histories may have been noticeably different, and the interplay between these two lobes would have led to a complex sequence of erosional and depositional events in the boundary zone near the Kansas City re-entrant and along the Missouri River valley between Kansas City and Sioux City.

With this probable complexity in mind, consider the situation at Afton, Iowa, the original type locality for the Kansan and Nebraskan tills. Deep drilling at Afton has now revealed at least six tills, the oldest of which is overlain by a volcanic ash dated 2.2 m.y.B.P. (Hallberg and Boellstorff, 1978). This important site lies in the region influenced mainly by the Minnesota Ice. Most geologists have assumed that drift stratigraphy to the west could be correlated either directly or indirectly to this site. This assumption now appears unreliable in light of a two-ice-lobe model for glaciation of the region. Stratigraphy of glacial deposits west of the Missouri River valley may turn out to be different in many details.

The two-ice-lobe model for Kansan glaciation is presented here as a working hypothesis. Available evidence, especially in northeastern Kansas, seems to support the validity of the model but is insufficient to prove the two-ice-lobe hypothesis on a regional basis. It is hoped that continuing field studies emphasizing directional aspects of the Kansan glaciation will contribute to the model and to a fuller understanding of Early Pleistocene glaciation in the region.

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