Verendrye valley and the Glidden esker, Saskatchewan: subglacial and ice-walled features in southwestern Saskatchewan, Canada

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Received April 4, 1986

Revision accepted June 26, 1986

Verendrye valley is more than 100 km long, about 1 km wide, and at least 225 m deep. Southward, the valley grades into the Glidden esker, the surface of which rises about 280 m above the lowest point in the valley. The sediments in the valley and esker are 205 and 75 m thick, respectively, and form a fining-upward sequence from sand and gravel at the base to silt with sand interbeds in the upper part of the sequence, which, in turn, is covered by a blanket of glacial lake clay.

The concave-upward longitudinal profile of Verendrye valley, the genetic relationship between Verendrye valley and the Glidden esker, and the age of the features indicate the valley and esker were formed by a subglacial stream during the last deglaciation 15 500 – 14 000 years ago. The fining-upward sequence of sediments in the valley and esker suggests the subglacial valley formed time transgressively by headward erosion while the glacier margin remained stationary at the Glidden esker.

La vallée Verendrye excède 100 km de longueur, sa largeur est environ 1 km, et sa profondeur est d'au moins 225 m. La vallée en direction sud passe graduellement à l'esker Glidden dont la surface s'élève à 280 m au-dessus du point le plus bas dans la vallée. Les sédiments dans la vallée et de l'esker ont une puissance de 205 et 75 m, respectivement, et ils forment une séquence de sédiments devenant plus fins vers le toit incluant sable et gravier à la base, surmontée de limons avec des interlits de sable, recouverts à leur tour par une couverture d'argile de lac glaciaire.

Le profil longitudinal de la vallée Verendrye de forme concave vers le haut, les relations entre les origines de la vallée Verendrye et de l'esker Glidden, et l'âge des particularités révèlent que la vallée et l'esker furent formés par un cours d'eau sous-glaciaire durant la dernière déglaciation, il y a 15 500 – 14 000 ans. La séquence en sédiments plus fins vers le toit dans la vallée et l'esker indiquent que la vallée sous-glaciaire s'est formée trangressivement dans le temps par une érosion en amont, tandis qu'à l'esker la marge du glacier demeurait stationnaire.

[Traduit par la revue]

Can. J. Earth Sci. **24**, 170–176 (1987)

Introduction

Verendrye valley (Fig. 1) is an anomalous drainage feature from both geomorphic and stratigraphic points of view. The valley disappears southward into an esker, and its thalweg is lower than the preglacial valleys in the region (Christiansen *et al.* 1980). The objectives of this note are to describe this anomalous drainage feature and to draw attention to the process of subglacial drainage, which was important in the development of the landscape of Saskatchewan.

Geomorphology

Verendrye valley, named by Christiansen (1965), is more than 100 km long, about 1 km wide, and at least 225 m deep. The longitudinal profile is irregular, with Cutbank Lake, Verendrye Marsh, Teo Lakes, Herrick Low Lake, and Street Lake lying in depressional areas (Fig. 2). The valley sides, for the most part, are gently sloping (commonly cultivated) and covered with a blanket of glacial lake clay. Verendrye valley is flanked discontinuously with ridges that grade into the Glidden esker (Fig. 3). Flaxcombe valley (Christiansen 1965) is similar in morphology to Verendrye valley and, presumably, is a tributary to it (Fig. 1).

The Glidden esker, formerly called the Glidden moraine (Christiansen 1965), forms a broad, hummocky upland between Glidden and the South Saskatchewan River (Figs. 1, 3). The upland is 25 km long, 2–10 km wide, and up to 60 m high. The stratified nature of the sediments in the upland and its geomorphic and stratigraphic relationships to Verendrye valley are the reasons for calling the upland an esker rather than a moraine.

Stratigraphy

Verendrye valley was eroded through Pleistocene glacial deposits and through Upper Cretaceous Bearpaw and Judith River formations into the Upper Cretaceous Lea Park Formation (Figs. 2–5). Verendrye valley fill is at least 205 m thick and is composed of lower and upper units of stratified sediments that form a fining-upward sequence (Fig. 6). The lower unit, which is up to 160 m thick, grades from gravel at the base to sand with silt interbeds in the upper part of the unit. The upper unit, which is up to 45 m thick, grades from silt with sand interbeds at the base to massive silt in the upper part of the unit. The upper unit is covered with a blanket of glacial lake clay that is too thin to be separated from the upper unit in Figs. 2–5.

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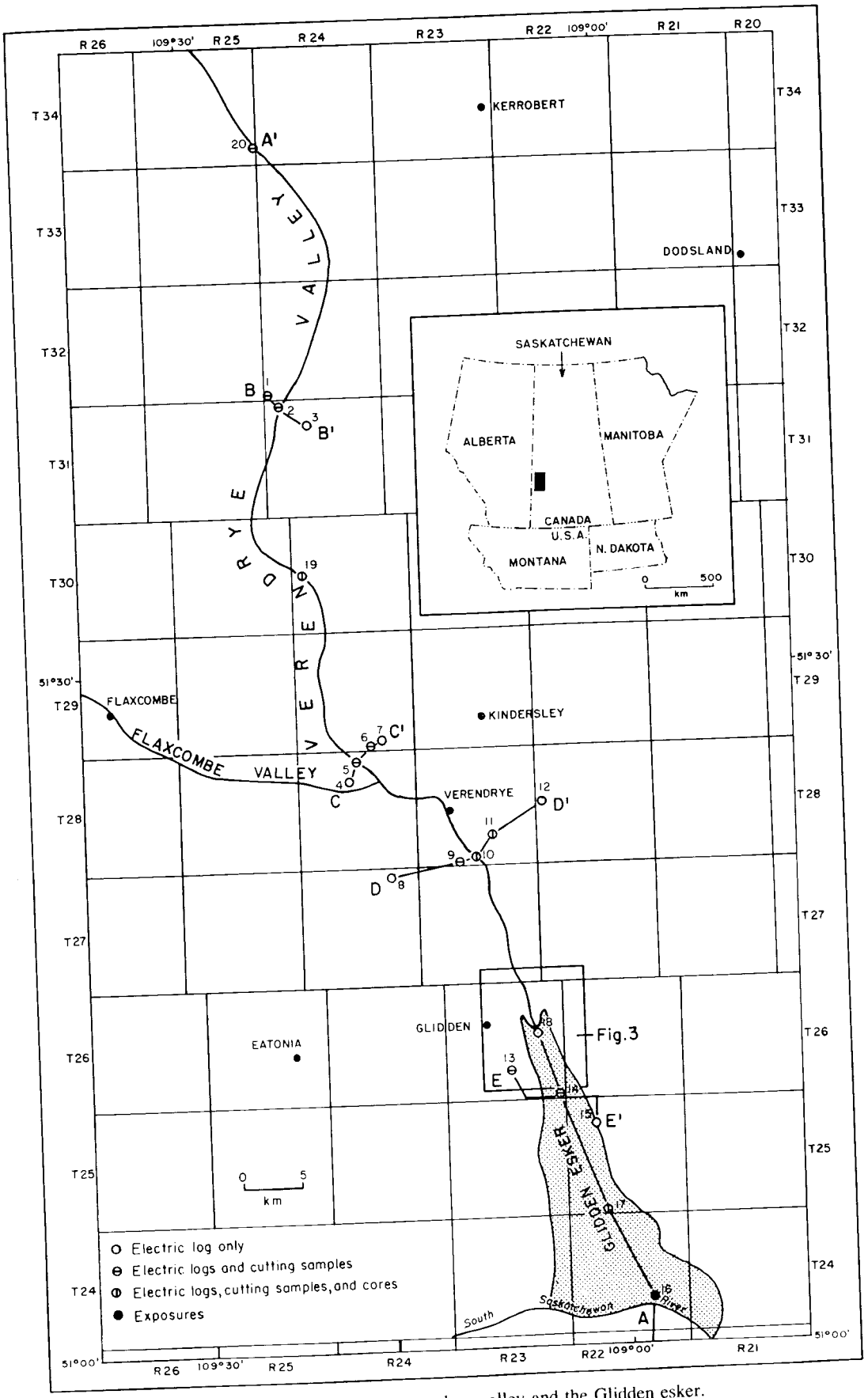

FIG. 1. Location map of Verendrye valley and the Glidden esker.

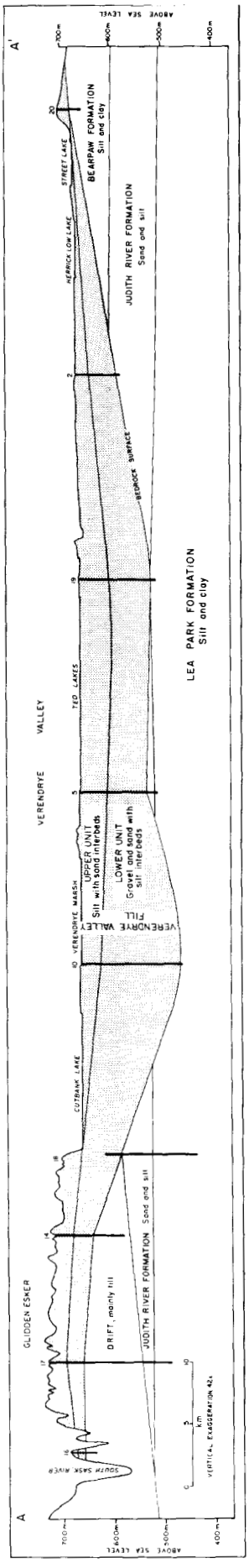

FIG. 2. Longitudinal section A–A' along Verendrye valley and through the Glidden esker.

The Glidden esker is also composed of a fining-upward sequence of stratified deposits. The lower unit is composed of about 40 m of sand and gravel, and the upper unit is composed of about 35 m of silt with sand interbeds (Fig. 2; Fig. 5, cross section E–E'). In cross section A–A' (Fig. 2), the lower and upper units in the Verendrye valley fill are correlated with the lower and upper units in the Glidden esker on the basis of stratigraphic sequence, lithology, and geomorphic relationship.

Age

Verendrye valley truncates the Battleford Formation, which is the youngest till in southwestern Saskatchewan, and is covered with a blanket of clay laid down in glacial Lake Stewart Valley (Christiansen 1965). It can be concluded, therefore, that Verendrye valley was formed during the last deglaciation after the youngest till (Battleford Formation) was deposited but before clay was laid down in Lake Stewart Valley between 15 500 and 14 000 years ago (Christiansen 1979).

Origin

The concave longitudinal profile, which Embleton and King (1975, pp. 344–349) considered diagnostic of subglacial valleys, the similarity between Verendrye valley and the tunnel valleys of Denmark (Schou 1949), the genetic relationship between Verendrye valley and the Glidden esker, as shown by the esker grading northward into ridges flanking the valley (Fig. 3), and the age of the valley between deposition of the Battleford Formation and surficial glacial lake clay indicate Verendrye valley was formed by a subglacial stream whose source of water was subglacial and (or) superglacial meltwater. According to the classification of Weertman (1972), Verendrye valley is a "Nye channel" type of valley formed subglacially and eroded wholly in the glacier's substratum.

Based on the surficial geology of Christiansen (1965) and the geomorphology and stratigraphy of Verendrye valley and Glidden esker, the following origin for these features is proposed. Initially, the glacier readvanced to the position shown in phase 1 (Fig. 7), which is similar to phase 3 of Christiansen (1965, Pl. 7). As meltwater discharged through Verendrye valley into Lake Stewart Valley during phase 2, the roof of the tunnel collapsed, forming the ice-walled channel into which the Glidden esker was deposited.

The fining-upward sequence of sediments in Verendrye valley and the Glidden esker suggests these features were developed time transgressively. Although it appears that the subglacial channel, which formed Verendrye valley, developed by headward erosion, there is no evidence to suggest a corresponding retreat of the ice margin. If the glacier margin had retreated during the formation of the valley, other eskers like the Glidden esker should be found. It is concluded, therefore, that the glacier margin was stationary throughout the life of the subglacial channel.

The Glidden esker is similar to the "delta-moraine" of Embleton and King (1975), who believed such features were formed between ice walls where a stationary ice front ended in a glacial lake. In Denmark (Schou 1949), valleys like Verendrye valley are referred to as *tunneldale* (tunnel valley). Gravenor and Kupsch (1959) prefer "ice-walled channels" for both open trenches, such as the Glidden esker, and closed tunnels, such as Verendrye valley.

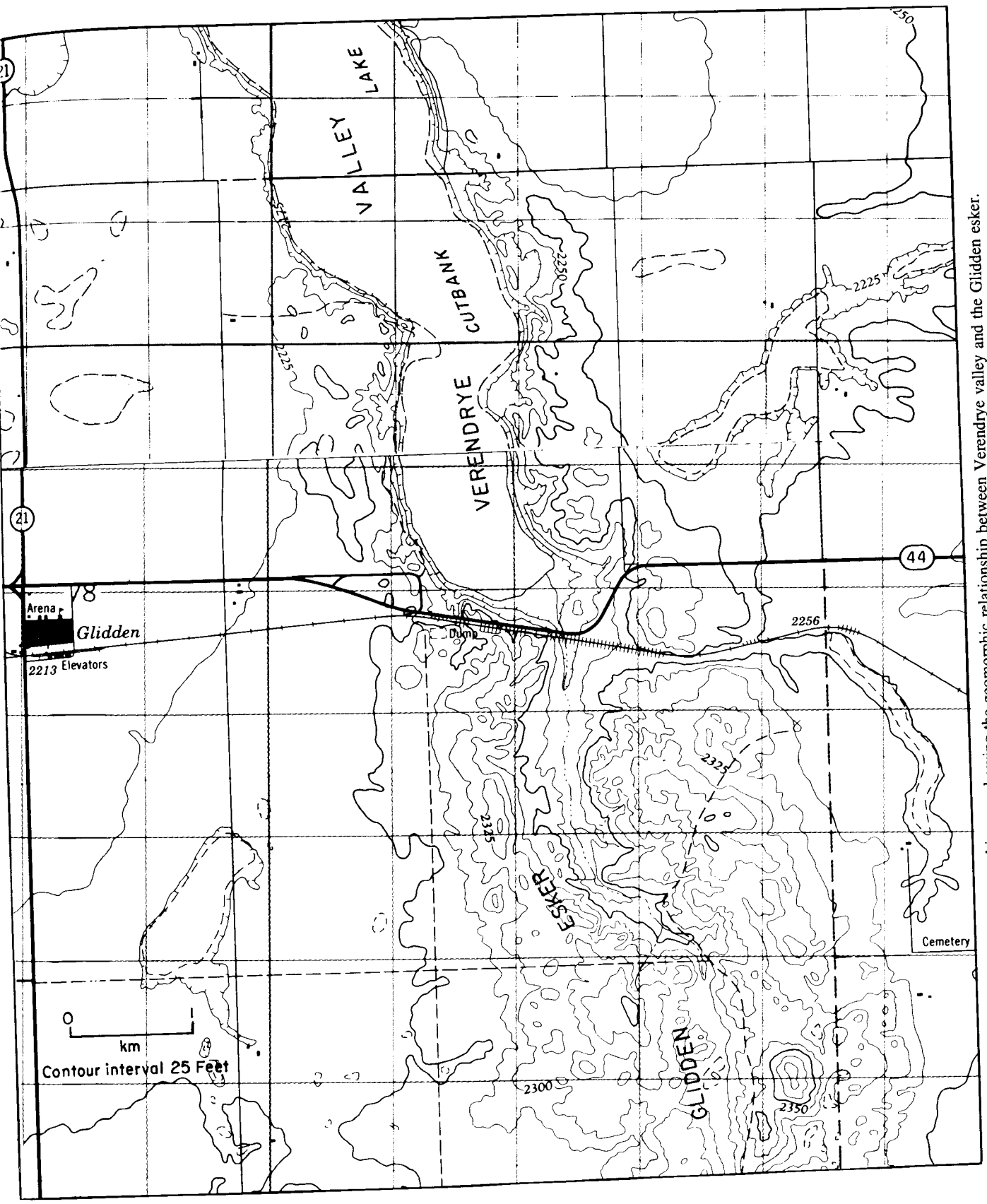

FIG. 3. Topographic map showing the geomorphic relationship between Verendrye valley and the Glidden esker.

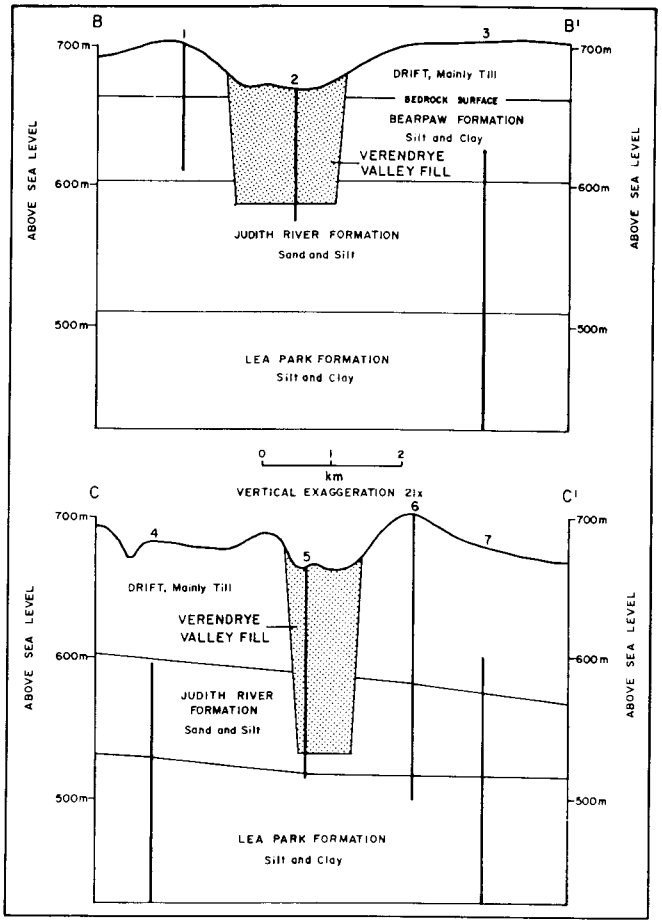

FIG. 4. Cross sections B–B′ and C–C′ across Verendrye valley showing Verendrye valley fill.

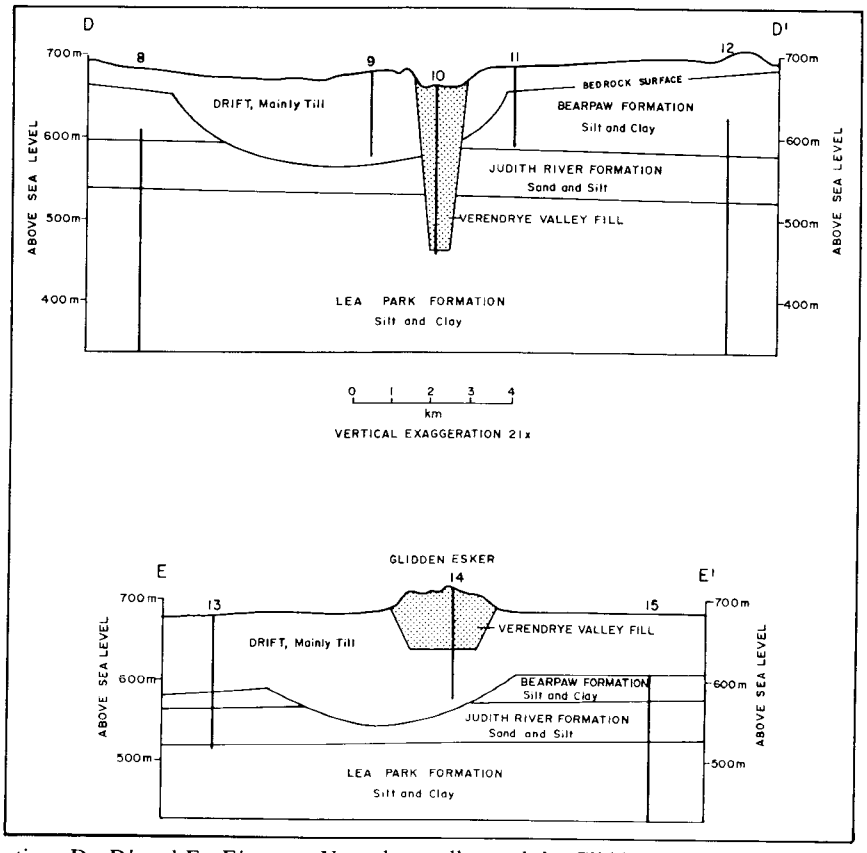

FIG. 5. Cross sections D–D′ and E–E′ across Verendrye valley and the Glidden esker, showing valley fill and esker.

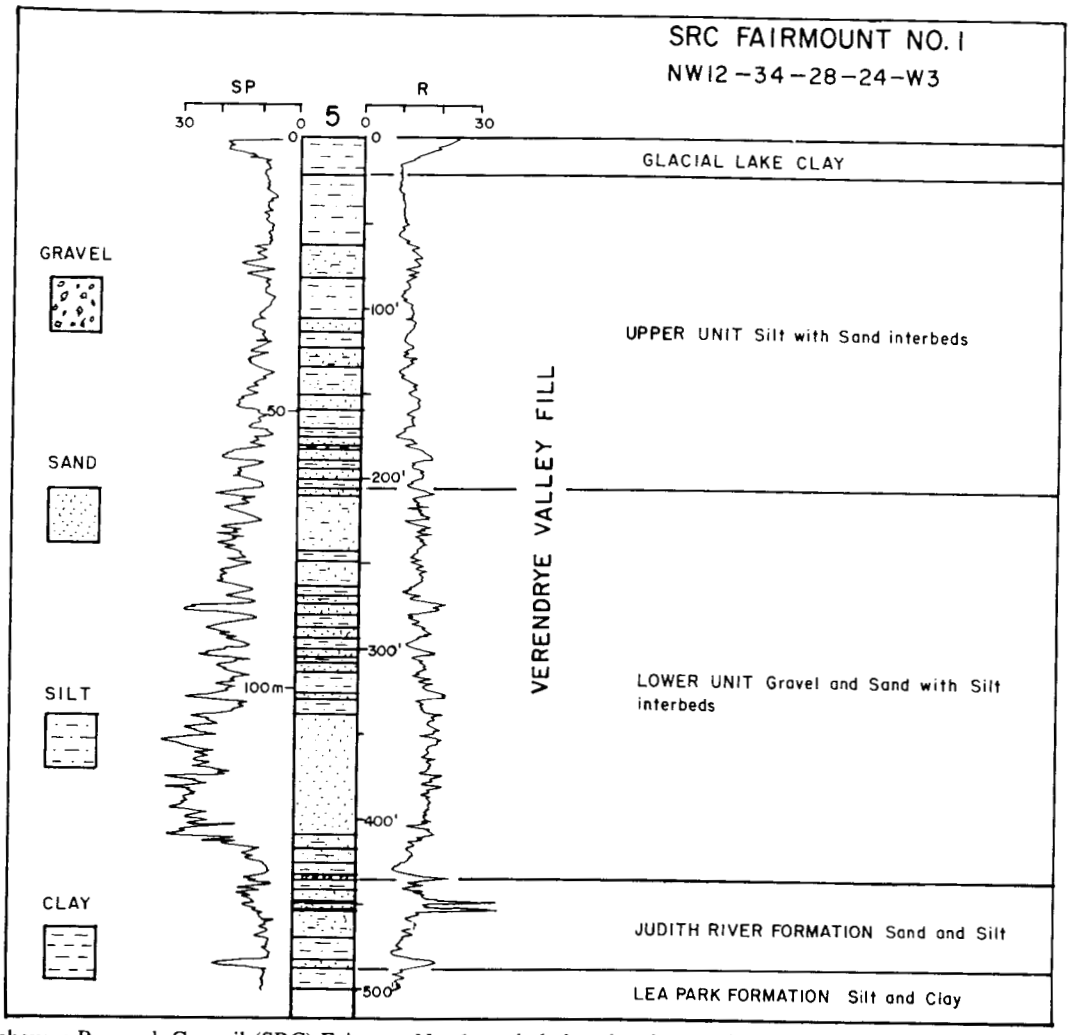

FIG. 6. Saskatchewan Research Council (SRC) Fairmont No. 1 test hole log showing stratigraphy of Verendrye valley fill. Notice the fining-upward sequence of sediments. The log is represented by number 5 in Figs. 1, 2, and 4.

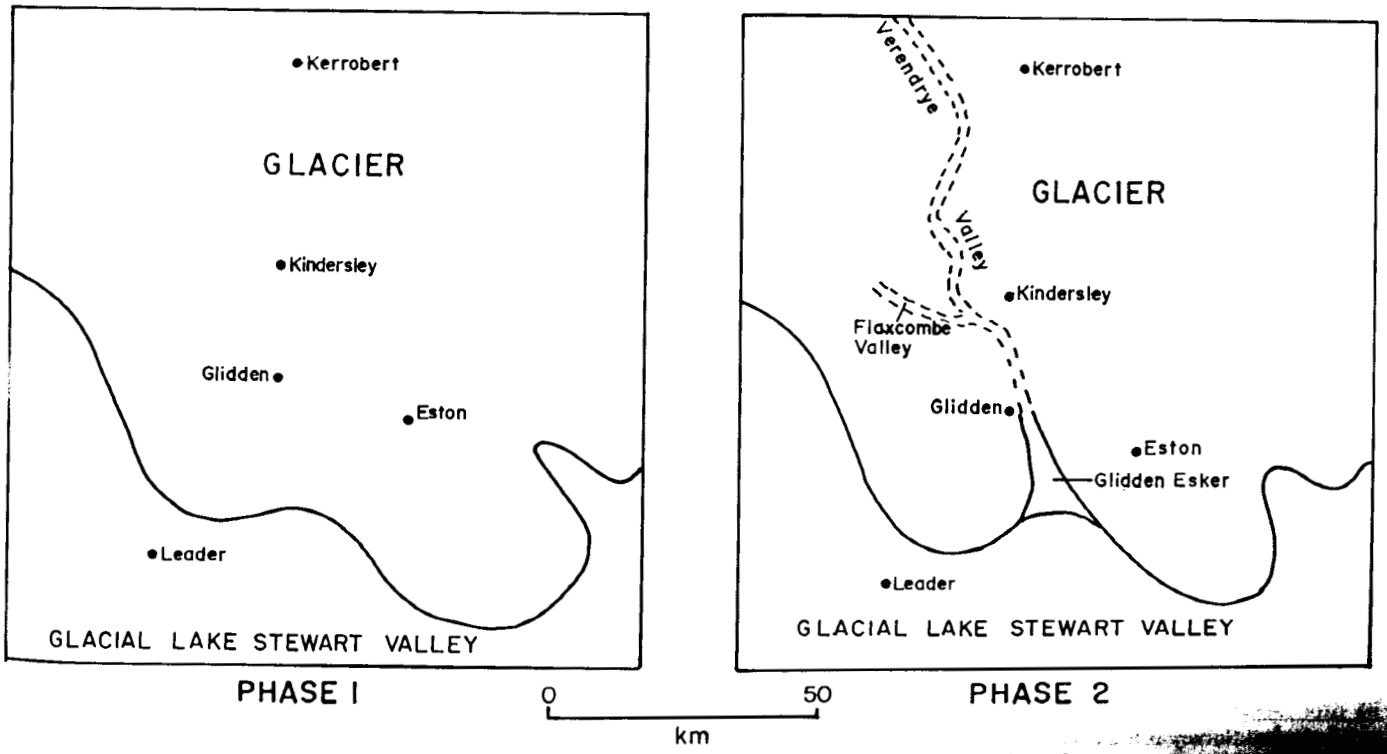

FIG. 7. Sketches postulating the origin of Verendrye valley and the Glidden esker.

Conclusions

The concave-upward longitudinal profile, with a closure of at least 200 m, the genetic relationship between Verendrye valley and the Glidden esker, as shown by the esker grading into ridges flanking the valley, and an age between the deposition of the youngest till (Battleford Formation) and that of clay deposited in glacial Lake Stewart Valley during the last deglaciation indicate Verendrye valley was formed by a subglacial stream. The fining-upward sequence of sediments in Verendrye valley and Glidden esker suggests these features were formed time transgressively by headward erosion of the subglacial valley. The presence of only one esker suggests the glacier stood at the Glidden esker throughout the development of Verendrye valley.

Acknowledgments

The manuscript was read by Drs. W. H. Mathews, W. A. Meneley, and E. K. Sauer, whose comments were most helpful. Test holes were drilled by Elk Point Drilling Ltd., North Battleford; Hall Drilling Ltd., Regina; and Hayter Drilling Ltd., Watrous, Saskatchewan. Test-hole information was provided by the Saskatchewan Research Council through Mr. B. T. Schreiner. Drafting was done by Mr. Carlos Sardinha.

CHRISTIANSEN, E. A. 1965. Geology and groundwater resources of the Kindersley area (72 N), Saskatchewan. Saskatchewan Research Council, Geology Division, Report 7.

——— 1979. The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas. Canadian Journal of Earth Sciences, **16**, pp. 913–938.

CHRISTIANSEN, E. A., KEWEN, T. J., and SCHNEIDER, A. T. 1980. Geology and groundwater resources of the Kindersley area (72 N) Saskatchewan. Saskatchewan Research Council, Geology Division, Map 23.

EMBLETON, C., and KING, C. A. M. 1975. Glacial geomorphology. Edward Arnold Ltd., London, England.

GRAVENOR, C. P., and KUPSCH, W. O. 1959. Ice-disintegration features in western Canada. Journal of Geology, **67**, pp. 48–64.

SCHOU, A. 1949. Atlas of Denmark. Hagerup, Copenhagen, Denmark.

WEERTMAN, J. 1972. General theory of water flow at the base of a glacier or ice sheet. Reviews of Geophysics and Space Physics, **10**, pp. 287–333.

A rock avalanche triggered by the October 1985 North Nahanni earthquake, District of Mackenzie, N.W.T.[1]

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Received June 19, 1986

Accepted July 21, 1986

A major rock avalanche (estimated volume, $5-7 \times 10^6$ m^3) was triggered by the October 1985 North Nahanni earthquake ($M_s = 6.6$). The landslide is located at 62.27°N, 124.18°W, 23 km southwest of Carlson Lake, in an uninhabited part of the District of Mackenzie, N.W.T. It occurred within 10 km of the epicentre. The rock avalanche detached from the northeast flank of a ridge located along the axis of the English Chief Anticline and involved massively bedded limestones of the Middle Devonian Nahanni Formation. Whilst most of the landslide mass was deposited at the foot of the original slope, a mobile tongue of debris turned at right angles to the direction of initial sliding and travelled down valley, coming to rest on a slope of about 5°. The distal margin of the mobile tongue is approximately 1.55 km from the top of the rupture surface. The fahrböschung of the landslide is estimated to be 14.5°, and the rock avalanche exhibits exceptional mobility in relation to its volume. The rupture surface is well exposed and is a combination of planar structural elements, viz. a bedding surface and a steeply dipping fault plane. The marked streaming behaviour in the mobile tongue raises the question of a possible link between this phenomenon and intense strong ground motion during the earthquake.

Le tremblement de terre du nord du Nahanni en octobre 1985 ($M_s = 6{,}6$) a engendré une importante chute brutale de roches (volume estimé, $5-7 \times 10^6$ m^3). L'éboulement est situé à 62,27°N, 124,18°O, à 23 km au sud-ouest du lac Carlson, dans une région inhabitée de district de Mackenzie, T.N.-O. L'événement s'est produit à moins de 10 km de l'épicentre. Les roches ont

Can. J. Earth Sci. **24**, 176–184 (1987)

[1]Geological Survey of Canada Contribution No. 21186.

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