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FOSSIL SAND WEDGES AT EDMONTON, ALBERTA, CANADA

Abstract

Fossil sand wedges beneath till are present in a sand pit at Edmonton, Alberta, Canada. Climatic implications derived from the wedges are: (1) permafrost was present for at least 400 years and possibly 2400 years prior to ice advance; (2) average annual temperature was at least —5°C or 7°C colder than present; (3) precipitation was less than half of the present precipitation of 40 cm/yr.

INTRODUCTION

Fossil soil wedges filled with sand or other materials have been reported from many places in North America, e.g. Denny, 1936; Horberg, 1949; Frye and Willman, 1958; Black, 1965; Borns, 1965; Dionne, 1966. These forms are thought to be casts of former ice-wedges, and therefore, indicative of a cold, wet climate (Black, 1965).

Recent work in Antarctica (Péwé, 1959; Black and Berg, 1963, 1964; Berg and Black, 1966) has shown the existence of actively growing wedges filled entirely with sand. Wedges containing a mixture of ice and sand, or "composite" wedges, are also present in Antarctica (Berg and Black, 1966). Sand wedges are indicative of a cold, arid climate with an abundant supply of free-running sand, whereas composite wedges indicate a slightly more humid environment or lack of free-running sand (Berg and Black, 1966). In contrast to these, ice wedges are characteristic of a cold, humid climate. All active wedges are found only in areas of continuous permafrost where the average annual temperature is —5° or lower (Péwé, 1965). Recently, fossil sand wedges have been found near the City of Edmonton, Alberta, Canada.

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PHYSICAL SETTING

The City of Edmonton, located at 53°30′N. latitude and 113° 30′W. longitude (Fig. 1), has an average annual temperature of 2°C and receives an average of 40 cm of precipitation per year, of which 12 cm falls as snow.

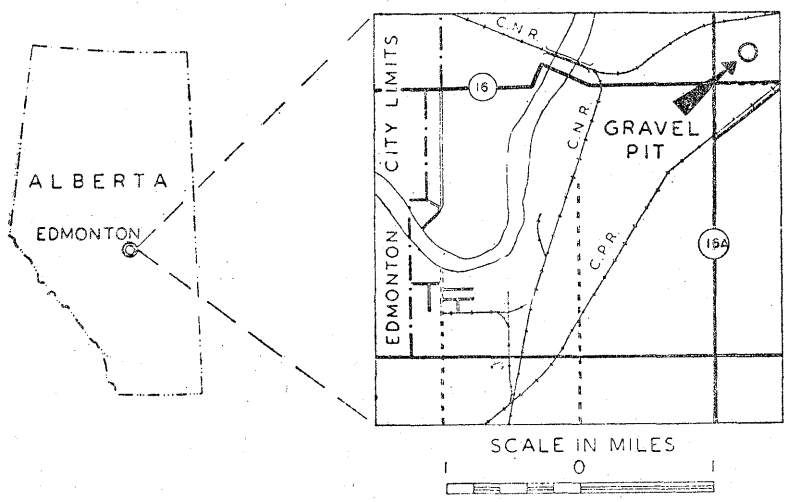

Fig. 1. Map showing location of sand pit with fossil sand wedges

The area is underlain by poorly consolidated Upper Cretaceous shales and sandstones dipping gently to the southwest.

Surficial geology of the area has been described by Bayrock and Hughes (1962). The area was glaciated only during Wisconsinan time by a continental glacier which advanced over the region from the Keewatin center (Bayrock, 1965). Retreat of the glacier was largely by stagnation. Blockage of the natural northeasterly drainage by the ice resulted in the formation of large, short-lived glacial lakes. One such lake, Glacial Lake Edmonton, covered the area under discussion for a very short time immediately following the disapearance of ice.

STRATIGRAPHY

The wedges are found in a borrow pit operated by Twin Bridges Sand and Gravel Co. on the east side of Edmonton in Lsd. 6, Sec. 16, Tp. 53, R. 23, W. 4th Mer. (Fig. 1). The stratigraphy of the

pit and the surrounding area is shown diagrammatically in Figure 2. The wedges occur at the top of a deposit of fluvial sands and gravels locally known as the Saskatchewan Sands and Gravels which overlie bedrock (Bayrock and Berg, 1966). The sands and gravels occur as fillings in and as terraces along the sides of

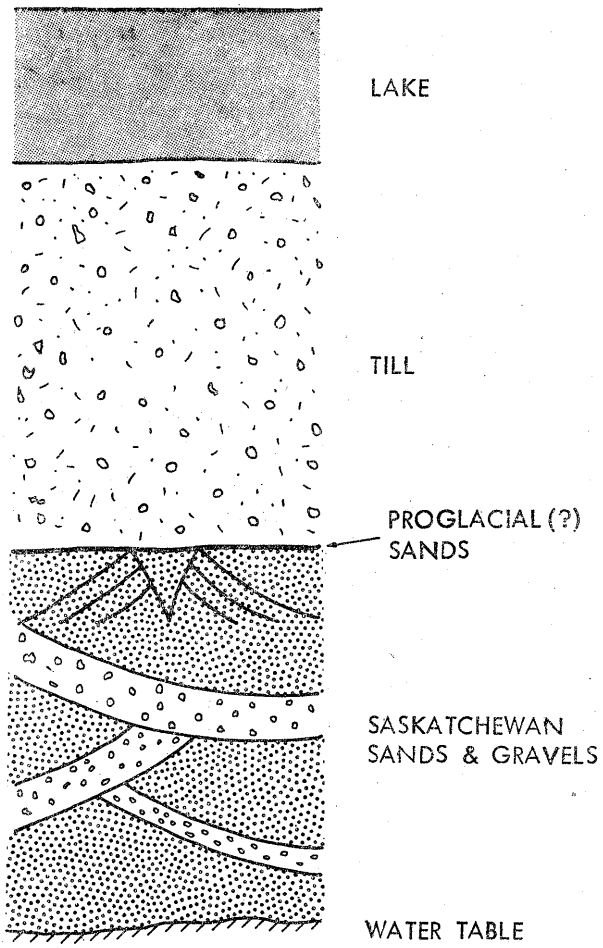

Fig. 2. Stratigraphic section showing position of fossil wedge in the section

preglacial river valleys. The gravel fraction is composed of rounded cobbles of quartzitic sandstone, chert, and arkosic sandstone, with minor amounts of volcanic rocks and limestone, all derived from the Rocky Mountain region to the west. No Canadian Shield material is present. The heavy mineral fraction of the sands is strikingly different from that of the overlying materials (Table I).

Table I

Comparison of heavy minerals from wedge material with analysis from till and the Saskatchewan Sands and Grevels

Heavy Mineral	Till [1]	Saskatchewan Sands and Gravels [2]	Wedge
	%	%	%
Hornblende	40	2	0
Epidote	3	53	52
Garnet	13	14	27
Magnetite	14	17	4
Limonite	11	Tr	7
Pyroxenes	4	4	2
Other	12	10	8
	100	100	100

[1] Data from Bayrock, 1962
[2] A. Allong, unpubl. ms.

The Saskatchewan Sands and Gravels are everywhere overlain by glacial deposits and are preglacial in the sense that they predate the invasion of Keewatin ice into the area. Radiocarbon dating of wood in the sands and gravels gives dates of older than 35,000 yrs. B. P. (Geochron Laboratories GX-0106 and GX-0210). A recent discovery of a vertebra of a *Bison* sp. (Bayrock and Reimchem, ms.) indicates that the deposit is not older than Wisconsin.

Overlying the wedges is a layer of well sorted, stratified sands 5—20 cm thick that may represent proglacial lake sediments deposited during advance of the glacier. The sands were derived primarily from the underlying Saskatchewan Sands and Gravels but contain some glacially derived material. Locally a one-pebble-thick layer of ventifacts is present at the base of the proglacial lake sands.

Unconformable on top of the sands is 3—4 meters of till, separable into two units, a lower dark grey clayey till and an upper brown till. Erratic lenses of the Saskatchewan sands up to 6 meters long and 1 meter thick are present in the lower till. No evidence suggests a time break between the two tills, and they are both regarded as late Wisconsin in age. The tills contain abundant cobbles and boulders derived from the Canadian Shield, and the heavy mineral fraction abounds in minerals from the Shield. Above the till is 1—2 meters of glacial-lacustrine material depo-

Plate 1. Vertical lineations in sand wedge. Lineations stand out in relief due to weathering of section. Notice the upturned beds surrounding the wedge

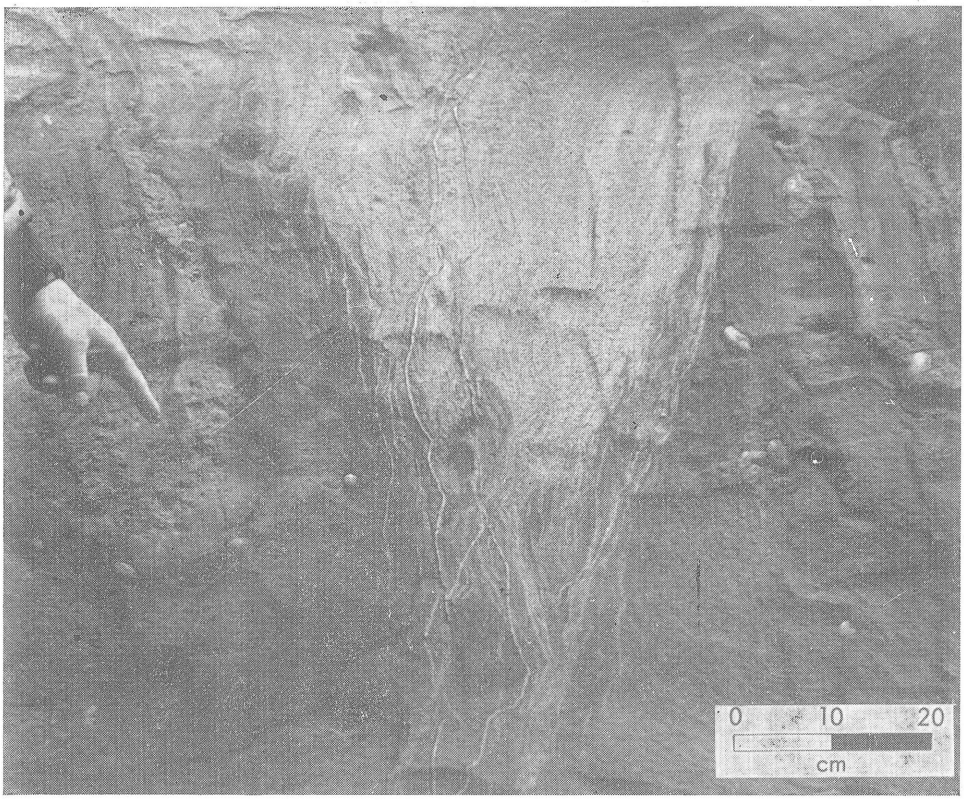

Plate 2. Sand filled veins at base of wedge. The veins may be traced upward into the wedge proper

sited in Glacial Lake Edmonton during the retreat of the Wisconsin glacier (Bayrock, 1964). The lake sediments are banded and contain pebbles indicative of ice-rafting.

DESCRIPTION OF THE WEDGES

Casts of former wedges are common in the Edmonton area. Westgate and Bayrock (1964) reported involutions and wedges in a pit approximately 2 miles southwest of the pit described herein. The wedges, unfortunately since destroyed by mining operations, were filled with structureless sand and are thought to have been fossil ice wedges.

Other wedges have been observed by the author in nearby gravel pits, but none is as well developed or permit positive identification of the mode of origin as well as those described below.

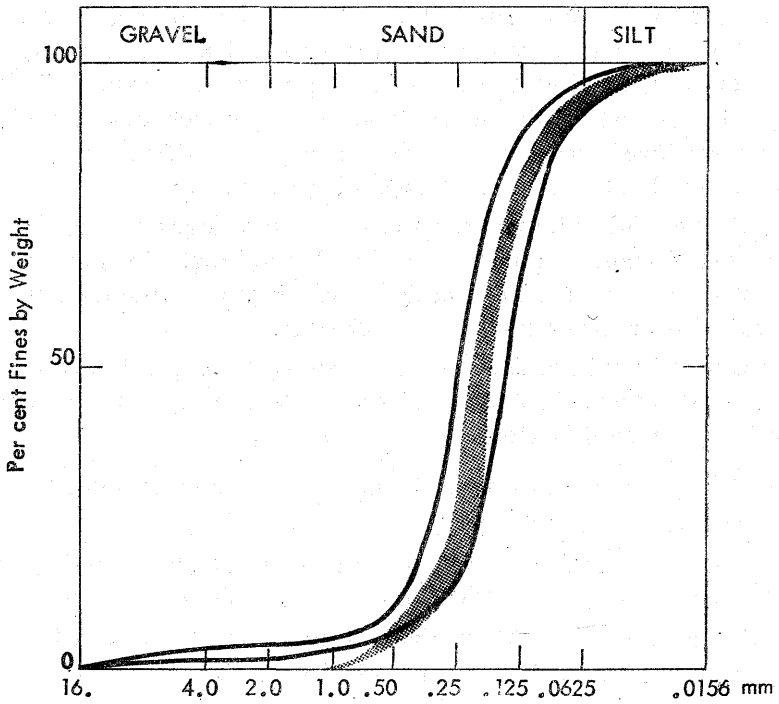

Fig. 3. Grain-size distribution of samples from wedges and surrounding materials. Stippled area covers range of wedge material, dark lines the range of the host material

At least six wedges have been exposed during excavations at the Twin Bridges Sand and Gravel Pit No. 1. The wedges are from 40—100 cm wide and 80—160 cm high. All are filled with clean, round, well-sorted, quartz sand, which was derived from the Saskatchewan Sands and Gravels as evidenced by the heavy mineral content (Table I). The wedge fillings lack the coarse fragments present in the surrounding material (Fig. 3), thus indicating resorting, either by wind or water. However, the presence of a ventifacted layer at the top of the surrounding Saskatchewan Sands and Gravels indicates that wind was the dominant means of sorting.

MODE OF ORIGIN

That these wedges are true periglacial features indicative of permafrost is evident from the following features:

(1) Upturning of the surrounding layers. Growth of ice or sand wedges results in a net addition of material to the ground, forcing the surrounding material upward (Péwé, 1965). This is one of the most diagnostic features that permit distinguishing fossil frost phenomena from wedges formed by desiccation, groundwater, slump or vegetal growth.

(2) Size. The width and height of the wedges are typical for fossil frost phenomena. The ratio of width to height in these wedges is from 1 : 1.6 to 1 : 2. Desiccation and slump phenomena usually have ratios on the order of 1 : 3 or greater.

(3) Continuity. Excavation of several wedges indicated that they extend laterally for at least one meter. In plan they form an irregular polygonal pattern.

That the wedges are true fossil sand wedges is evident from the following characteristics:

(1) Vertical lineations. Vertical lineations are common to all wedges; however, lineations in ice wedges disappear with the melting of the ice. All wedges at the Twin Bridges pit possess well-developed vertical lineations (Plate 1).

(2) Sand-filled veins at base of wedge. Annual contraction cracks do not occur at exactly the same spot or reach the same depth each year. Infilling of these cracks with sand re-

sults in their preservation in fossil form (Plate 2). When the cracks are filled with ice and subsequent melting occurs, the surrounding material expands into the voids. The presence of vertical lineations and sand-filled veins at the base of a wedge are the two most diagnostic criteria in the identification of fossil sand wedges.

(3) Absence of slump structures in wedge. Sand-filled ice-wedge casts are common. However, practically all such wedges possess slump structures in the wedge proper (Black, 1965). Melting of an ice wedge may cause the surrounding material to slump toward the wedge. This is not the case with the wedges under consideration.

(4) Wedge filling. The wedges are filled with aeolian sand (Fig. 3) derived from the surrounding Saskatchewan Sands and Gravels (Table I), which is normal for true sand wedges. On the other hand, if the wedges were ice-wedges formed just prior to the ice advance into the area, one would expect that some or all of the filling would be from glacially derived material.

CLIMATIC IMPLICATIONS

As the wedges under consideration are true fossil sand wedges, then the climate under which they formed should be similar to the climate existing where active sand wedges are growing today, i.e. Victoria Land, Antarctica. McMurdo, Ross Island, has an average annual temperature of —17°C, and precipitation is probably about 16 cm a year where sand wedges are actively growing (Stuart and Heinie, 1961). The amount of local moisture available is more important in determining the wedge filling than is temperature (Berg and Black, 1965). Therefore, the precipitation at Edmonton at the time of wedge growth should have been approximately half the present precipitation. The presence of the ventifacted layer at the top of the Saskatchewan Sands and Gravels also suggests an arid climate.

The average annual temperature must have been at least —5°C (Péwé, 1965), or 7°C colder than present, and possibly colder.

It is also possible to provide an estimate of the duration of the climatic conditions that permitted the growth of sand wedges. In Antarctica, measurements of the growth rate of sand wedges

range from 0.3 mm/yr to about 1 mm/yr (Berg and Black, 1965). If similar growth rates are assumed for the wedges at Edmonton, the wedges were active for at least 400 years and conceivably for 2400 years. A period of growth lasting 500—1000 years seems most likely.

Therefore, prior to the advance of the Wisconsin ice into the Edmonton area, permafrost was present for at least 400 years and possibly for 2400 years. The average annual temperature must have been at least 7°C colder than present. Precipitation was slight, probably half of the present precipitation. The area could thus be classified as a cold desert.

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