Atlantic Geology

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Volume 7, numéro 3, december 1971

URI : https://id.erudit.org/iderudit/ageo07_3rep02

Aller au sommaire du numéro

Éditeur(s)

Maritime Sediments Editorial Board

ISSN

0843-5561 (imprimé)
1718-7885 (numérique)

Découvrir la revue

Citer cet article

Brookes, I. A. (1971). Fossil Ice Wedge Casts in Western Newfoundland. *Atlantic Geology*, *7*(3), 118–121.

Maritime Sediments, Vol. 7, No. 3, December 1971, pp. 118-122. 

# Fossil Ice Wedge Casts in Western Newfoundland*

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## Introduction

The purpose of this note is to record the location and form of what are tentatively identified as fossil ice wedge casts in Western Newfoundland, and to comment on their origin, age, and palaeoclimatic implications. During geomorphological investigations in the area between Port aux Basques and Bonne Bay, continuing since 1963, these features have been identified in only two localities (Fig. 1). At St. David's, one cast was located in 1963 but has since been destroyed by coastal cliff recession. At York Harbour, a new borrow gravel pit has exposed five casts.

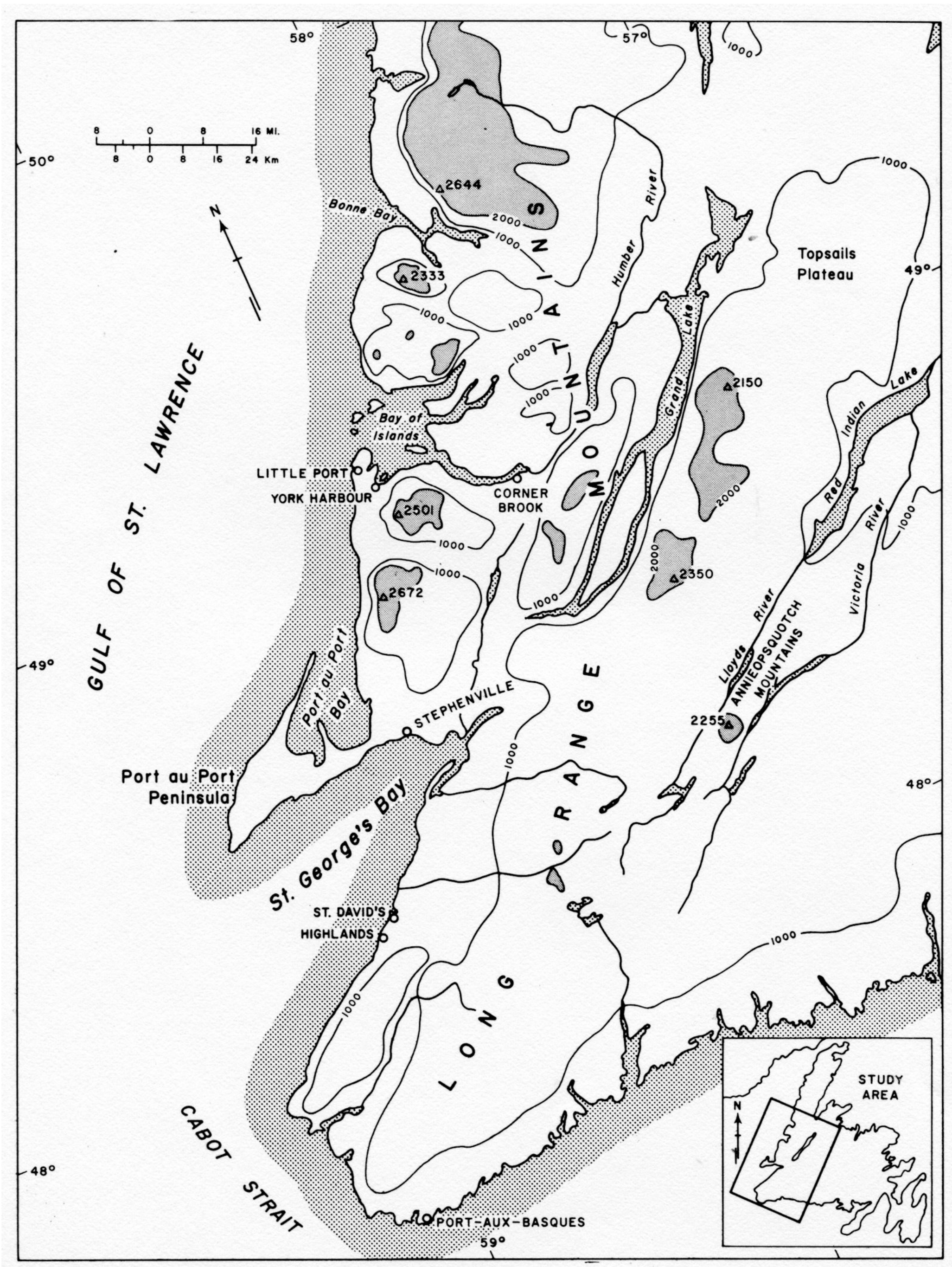


Figure 1 - Location map.

* Manuscript received March 23, 1972.

<u>Location and Description of the Features</u>

At the St. David's site, the ice wedge cast occurred in horizontally bedded, sandy gravels which underlie a terrace surface at 26 m above HHWL (Fig. 2). These were laid down during a regressional stillstand of sea level, when the terrace was set into a pre-existing marine limit delta that rose to about 40 m. The stillstand is seen as contemporaneous with the construction of an end moraine marking the seaward limit of an ice readvance across the delta, some time after the onset of marine overlap (Brookes 1969, p. 1401-1402). Beneath the terrace gravels, seaward-dipping, sandy foreset beds are related to the original delta, and the ice wedge cast continued downwards into them.

The cast was 2.5 m deep and 0.5 m wide at the top, beneath an 0.8 m thickness of "cryoturbate" (material churned by freezing and thawing). The churned layer, still visible in other cliff sections on this coast, is overlain disconformably by 0.8 m of wind-blown fine to medium sand which exhibits some bedding. This has probably accumulated since the forest clearance by European settlers 150 years ago, and attains 2.5 m thickness nearby.

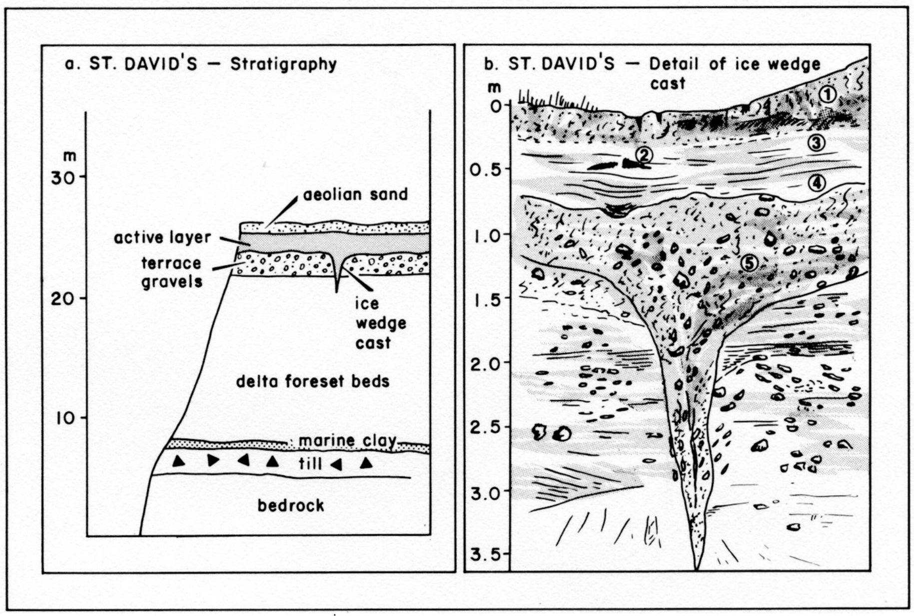


**Figure 2 - Sketch of stratigraphy and ice wedge cast at St. David's. Legend for Figs. 2 and 3: 1. modern soil; 2. partyly decayed tree roots; 3. stratified aeolian fine and very fine sand; 4. structureless aeolian fine sand; 5. cryoturbate layer.**

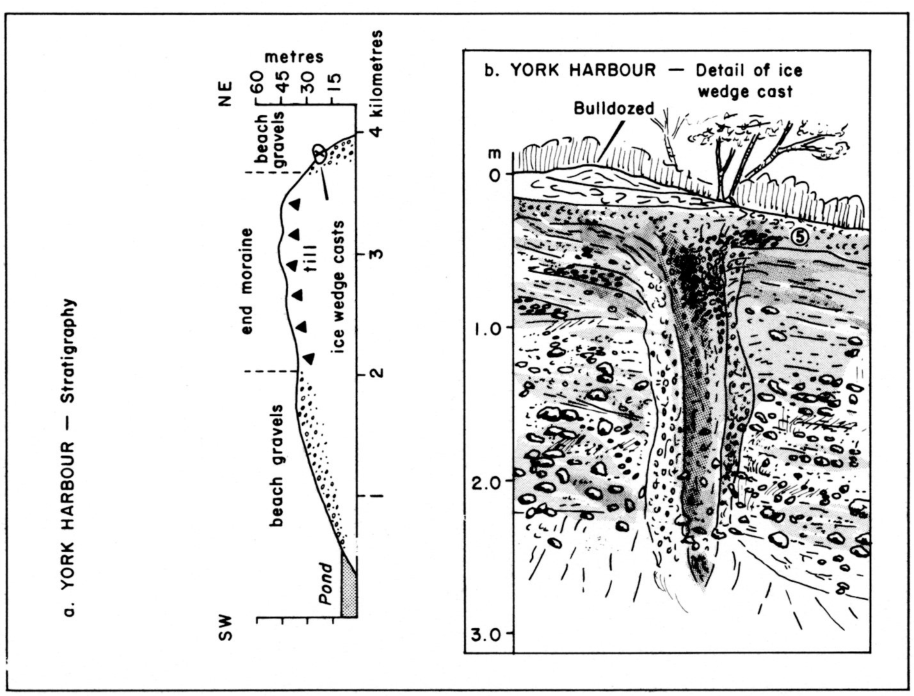


**Figure 3 - Sketch of stratigraphy and ice wedge cast at York Harbour.**

At the York Harbour site, the ice wedge casts are developed in well-sorted, pebbly to cobbly beach gravels which dip gently towards the present shoreline. These underlie a beach-ridged slope which rises from a low abandoned cliff near the shoreline to 30 m above HHWL at the southern edge of the pit. This slope continues to rise gently inland to its junction with a proximal side of an end moraine at about 35 m (Fig. 3a). The moraine was built during a halt in the northeastward recession of a glacier tongue out of the pass confining it, into Bay of Islands.

The casts are seen at four places in the walls of the pit, but at one place there are two adjacent casts, so five are present. It was not feasible to excavate the casts to see how far they extend into the gravels but, assuming that they are linear in plan, a rough rectangular pattern emerges when they are extended out for a short distance perpendicular to the pit wall.

The casts here range from 1.8 to 2.5 m in depth and 0.6 to 0.4 m in width at the top. The cryoturbate horizon has been partly destroyed by bulldozing, but seems to have been about 0.4 m thick. The bedded structure of this material has not been obliterated as much as at St. David's, possibly because of the freer drainage within these gravels. The deepest cast is shown in Figure 3b.

## Comments on the Origin of the Features

Ground-ice wedges were attributed by Leffingwell (1915) to contraction-cracking induced by ground freezing. He noted a widening of 5 to 10 mm per year developed in this way. Thaw-season melt-water freezing in the contraction-crack was seen as responsible for the maintenance of the weakness which would be exploited each winter, so progressively widening and deepening the crack.

This theory was objected to by Taber (1943), who explained ice wedges by their downward growth from the base of generally horizontal ice lenses. More recently, however, Leffingwell's theory has regained favour, particularly since the theoretical justification for it has been provided by Lachenbruch (1960a, 1960b). Lachenbruch noted the importance of rapid cooling across the freezing point, in addition to its amount, in the contraction process. He also disposed of an objection to Leffingwell's original thesis - that of the propagation of a crack to the great depths observed in Alaska - by noting that the release of strain energy upon cracking is sufficient to propagate the crack to depths below the zone of freeze-induced tensile stress.

Notwithstanding the refined explanation arising out of Lachenbruch's expansion upon Leffingwell's theory, the features they referred to occur in fine-grained sediments in which melt-water retention is great. Thermal contraction and ice-segregation are both understandable in the sediments. But it is not at all clear how the coarser gravels and sands in which the Newfoundland features are found could have retained sufficient water to freeze in the cracks during the winter. It may be speculated that the water table was close to the surface when these features were formed. Indeed, at both localities the casts are developed in sediments formed close to a higher sea level. If they were formed before sea level had fallen much below the present elevation of the casts, the water table could well have been higher. However, ice wedges are undeniably associated with permafrost, so that the depth of annual thaw penetration is more important than water-table depth. Above the permafrost table, water will be available to migrate towards the crack before the frost-line descends to the top of the perennially frozen layer. It is well established that freezing of a coarse material expels free water from the pores.

It is worthwhile noting that, if the York Harbour casts belong to a rectangular, rather than a polygonal, system, the explanation of the pattern might lie in the following observation by Lachenbruch, 1960b: "Most orthogonal (i.e. rectangular) systems in permafrost are probably caused by horizontal stress differences which are generated by horizontal thermal gradients near the edges of gradually receding bodies of water.... Under such conditions the induced polygonal system forms with one set of cracks parallel to the water's edge, and the other set perpendicular to it." (p. B408). The York Harbour features are, indeed, developed in gravels deposited in a gradually receding body of water.

Some indication of the rate of growth of contraction cracks and ice wedges can be gained from earlier works, but those observations can only be applied to fossil features with caution, especially when, as in the present cases, the sediments are so different. Black (1954) reported a rate of growth of ice wedges in the continuous permafrost zone of Alaska of 0.5 to 1.5 mm per year. Washburn *et al.* (1963) observed frost cracks at Hanover, New Hampshire, 5.0 mm wide at ground surface and 2.0 to 10.0 mm wide at frost table, 260 to 320 mm below, with a 2.0 to 4.0 mm film of clear ice lining the opening. Black and Berg (1963) noted a growth rate of 0.3 to 5.0 mm per year for ice wedges in Victoria Land, Antarctica. Leffingwell's (1915) figure of 5.0 to 10.0 mm for the annual growth of ice wedges in the Alaskan continuous permafrost zone lies within the range of values given by these authors - 0.5 to 10.0 mm per year. The difficulty of extrapolating these rates into the past arises from the fact that, even in continuous permafrost zones, the amount and rate of winter freezing may be sufficient to cause cracking and ice wedge growth only in certain years.

Evidence Bearing on the Age of the Features

At both localities the ice wedge casts occur in marine sediments deposited in close temporal association with an active ice front: at St. David's a readvance, and at York Harbour a still-stand in retreat, is established. The age of the casts can only be approximated. The St. David's site lies between two localities on the St. George's Bay coast where the start of late-glacial marine overlap has been C-14 dated. At Robinsons Head, this event occurred 13,500 ± 210 years B.P. (GSC-1200), and at Highlands at 13,420 ± 190 years B.P. (GSC-598). At the former site marine overlap occurred to at least 35 m and possibly to 44 m. At Highlands a somewhat lower elevation is suspected because of the general northeastward rise in elevations of the marine limit between St. George's Bay and Bonne Bay. The ice wedge casts occur red in sediments related to a sea level 18 m lower than the marine limit. In the immediate postglacial interval sea level is estimated to have fallen at a rate of approximately 2.0 m per century. The sediments therefore are likely to be roughly 12,500 years old, and the same age applies to the ice readvance with which they are contemporary.

The York Harbour locality is 6.0 kms southeast of Little Port, on the Gulf of St. Lawrence, where a delta terrace with a maximum elevation of 46 m marks the local upper limit of postglacial submergence. Shells from the foreset beds of this delta have been C-14 dated at 12,000 ± 320 years B.P. (GSC-1462). The beach gravels at York Harbour are approximately 36 m above sea level at the junction with an end moraine. The ice wedge casts occur in the gravels where the surface is at 30 m, some 16 m lower than the marine limit delta at Little Port. With a rate of sea level fall of 2 m per century, the gravels would be about 800 years younger than that feature, or 11,200 years. The difference between the estimated ages of the sediments in which the casts occur at the two sites can be seen as a natural result of the uncertainty in the estimate of the rate of sea level fall, or as due to the uncertainty inherent in the C-14 dates. Alternatively, the interval of ice wedge growth can be seen as extending over a long period.

The duration of ice wedge growth can be determined only within wide limits and then only with uncertainty. At a widening rate of 0.5 mm per year (from Black, 1954) the 500 mm width of the Newfoundland examples would be attained in 1,000 years. Yet, at a rate of 10 mm per year (from Leffingwell, 1915 and Washburn, *et al*, 1963), 50 years would be sufficient. If the larger figure is adopted to give a maximum duration of ice wedge growth, the process would have operated from 12,500 to 11,500 years B.P. at St. David's and from 11,200 to 10,200 years B.P. at York Harbour.

Palaeoclimatic Significance of the Features

Some consideration should be given to the palaeoclimatic significance of the fossil ice wedge casts. Péwé (1966) argued that ice wedges only form when the mean annual air temperature is -6° C or less. Brown (1970) placed the boundary between continuous and discontinuous permafrost in northeastern Canada approximately coincident with the 17.5° F (-8.5° C) mean annual air-temperature line, and the boundary of the discontinuous permafrost zone coincident with the 30° F (-1.1° C) isotherm. If Péwé's figure of -6° C, as a maximum for the development of ice wedges, is postulated to have prevailed in these west Newfoundland localities when the ice wedges were forming, mean annual air temperatures have increased about 12° C since then.

At Robinsons Head plant detritus from a thin gravel layer below a thick, raised peat bog at 27 m above sea level, has been dated at 10,600 ± 150 years B.P. (GSC-1350). The plant fragments, believed to have been transported some distance to the bog, belong to a tundra assemblage. While tundra plants are not restricted to places where mean annual air temperatures are low enough to produce ice wedges, this assemblage indicates that the climate was markedly cooler than that present 10,600 years ago, close to the estimated minimum age of the ice-wedge casts.

Previous Records of Fossil Ice Wedge Casts in Southeastern Canada

Borns (1965) recorded more than fifty ice wedge casts in outwash delta sediments along the north coast of Minas Basin and Cobequid Bay, in northern Nova Scotia. They are of comparable form and dimensions as those reported here and occur in similar sediments. Borns felt that the sediments accumulated during the interval recorded in pollen zone L-1 of Livingstone and Livingstone (1958), which was interpreted by them as reflecting a low Arctic or sub-Arctic sedge-meadow vegetation with scattered clusters of trees. Borns also correlated the outwash sediments with the end moraine complex of southern New Brunswick, formed at approximately 13,325 ± 500 years B.P. (I-GSC-7). He thought that the cold climate required to form the ice wedges could have prevailed during the accumulation of the pollen zone L-3 of Livingstone and Livingstone, which is older than 10,340 ± 220 years B.P., and which was correlated with the Valders substage of the mid-continent glacial sequence. The age of the ice-wedge casts in Nova Scotia is, therefore, bracketed by dates of 13,325 ± 500 years and 10,340 ± 220 years B.P. Borns (1965) found further evidence of a return to colder climate after the initial deglaciation in the conclusion of Hickox (1962) that a plateau ice mass on South Mountain, Nova Scotia, moved north to emplace Palaeozoic granite erratics on the Triassic basalt surface of North Mountain. This occurred after the formation of a calving bay along the Bay of Fundy, a minimum age for which is provided by the 13,325 ± 500-year date on marine sediments contemporary with an end moraine at St. John, New Brunswick.

Summary

Fossil ice wedge casts, ranging from 1.8 to 2.5 m deep and 0.4 to 0.6 m wide at the top, are reported from two localities in western Newfoundland. They are developed in coarse-grained marine sediments 25 to 30 m above sea level in close proximity to end moraines. It is felt that ice wedges could have formed in such coarse material only if meltwater was prevented from moving out of the sediments by a layer of permafrost into which they were set. In addition, the sediments were probably not as free-draining as today because the sea was closer to the level of the casts.

The sediments in which the casts are found are suggested to be 12,500 years old in one locality and 11,200 years old in the other. The casts probably developed in a period lasting not more than 1,000 years after the sediments were first elevated above the sea. If Péwé's figure of -6° C for the mean annual air temperature necessary to develop ground ice wedges is accepted, there has been a 12° C (21.6° F) rise since their formation. This seems somewhat high from what is known of late-Pleistocene and Recent temperatures in North Atlantic areas. Similar casts reported by Borns (1965) from northern Nova Scotia are assigned to a time interval comparable to that suggested here.

Postscript

This author would be grateful for reports of similar features at other places in south-eastern Canada.

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