BERICHTE UND MITTEILUNGEN

CLIMATE-PERMAFROST INTERACTION BETWEEN 18 ka AND 8 ka BP IN NORTHWESTERN NORTH AMERICA

With 1 figure

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Zusammenfassung: Wechselwirkungen von Klima und Permafrost im nordwestlichen Nordamerika zwischen 18 ka und 8 ka BP

Das Inlandeis der Spät-Wisconsin-Zeit erreichte seine Maximalausdehnung an verschiedenen Stellen zu verschiedenen Zeiten. Die früheste Maximallage fand sich im östlich-zentralen Yukon (35–16 ka BP), während sie in Waterton Park (Südwest-Alberta) erst um 12 ka BP erreicht wurde. Nachdem sich zwischen 15–12 ka ein Eisdom über dem zentralen British Columbia entwickelt hatte, zog sich der Ostteil des Cordillierischen Inlandeises ins Gebirge zurück. Die Schneegrenzen verliefen 300–700 m tiefer als heute und die mittlere Jahrestemperatur der unvergletscherten Gebiete lag bis zu 10 °C niedriger. An den Rändern des Gletschers bildeten sich Eiskeile und Sandkeile.

Das Cordillierische Inlandeis wurde durch auflandige Niederschläge vom Pazifischen Ozean her ernährt, während die zum Aufbau der Laurentidischen Eisbedeckung erforderlichen gewaltigen Niederschlagsmengen wohl auf tropisch-maritime Karibikluft als Ursprung hindeuten. Der Großteil der Laurentidischen Vergletscherung hatte Basistemperaturen unter dem Gefrierpunkt.

Der Abbau des Cordillierischen Inlandeises erfolgte rasch zwischen 13,5–10 ka. Stagnierendes Eis war verbreitet, insbesondere im Präriegebiet. Das Laurentidische Eis wies ein sehr geringes Gefälle auf und hinterließ Toteisblöcke bis zu 100 × 200 km Größe. Solche Eisblöcke überdauerten in Nord-Dakota den allgemeinen Eisrückzug um bis zu 2,5 ka. Reste von stagnierendem Laurentidischen Inlandeis mögen noch heute um den Arktischen Ozean herum existieren. Im Gebiet waren große proglaziale Seen weitverbreitet. Ein erneuter Vorstoß einiger Eismassen bei Calgary ließ zwischen 10,6–8 ka Eisstauseen in der Fußhügelregion von Alberta entstehen. Dabei herrschte wahrscheinlich eine aufwärts gerichtete Zirkulation im Uhrzeigersinn um das zurückgehende Laurentidische Eis herum, was auch für die trocken-warmen Verhältnisse im südlichen British Columbia verantwortlich gewesen sein mag. Eine trocken-kalte Phase trat ebenfalls im Früh-Holozän auf.

Die proglazialen Seen führten zum Abschmelzen nahezu des ganzen Spät-Wisconsin-Permafrostes, so daß der heutige Permafrost in West-Kanada sich ganz überwiegend erst im Holozän gebildet hat. Die ehemaligen Eiskeile schmolzen ab und hinterließen Eiskeil-Pseudomorphosen. Lediglich kleine Reste des Spät-Wisconsin-Permafrostes erhielten sich an ehemaligen Nunatakkern (z. B. am Plateau Mountain).

Introduction

One of the largest areas of ice sheets developed in North America during the Late Wisconsinan glaciation. Together, the Cordilleran and Laurentide ice sheets covered most of Canada as well as appreciable areas of Alaska and the northern States of the contiguous U.S.A. Today, the glaciers have largely disappeared, but almost 50% of Canada is underlain by permafrost. This paper will summarize the development of this permafrost in relation to the Late Wisconsin glacial history.

Extent of Glaciation between 18 ka and 13.5 ka BP

One of the characteristics of the growth and decay of the Late Wisconsinan ice sheets in North America is that the maximum ice advances occurred at different times in different places (Fig. 1). Thus the ice maximum position in the Bonnet Plume Basin of east central Yukon for the Laurentide ice sheet occurred at about 36 ka–16 ka BP (HUGHES et al., 1981), whereas the ice sheet only reached the Calgary-Waterton Park area after the mountain ice was in retreat (ALLEY, 1973, ALLEY a. HARRIS, 1974), which is now believed to have occurred about 12.0 ka BP.

The Cordilleran ice sheet expanded from an alpine phase, which may have started as early as 29 ka BP (CLAGUE, 1976, 1977, 1980; ALLEY, 1979) to a piedmont phase which only finally covered the area near Kamloops, British Columbia about 15 ka BP (CLAGUE et al., 1988). Thereafter it formed the major dome that cut off the supply of moisture to the eastern slopes of the Cordilleran ice cap, resulting in the retreat of the eastern margin into the mountains at 12 ka BP. In contrast, the ice maximum position on the west side of the Queen Charlotte Islands was achieved about 15 ka BP (BLAISE et al., 1990), and the maximum southern extent was reached at between 14.0 and 14.5 ka BP (MULLINEAUX et al., 1965; HICOCK a. ARMSTRONG, 1985).

Climatic Conditions between 18 ka and 13.5 ka BP

To develop the ice sheets, tremendous amounts of snow had to accumulate and become metamorphosed

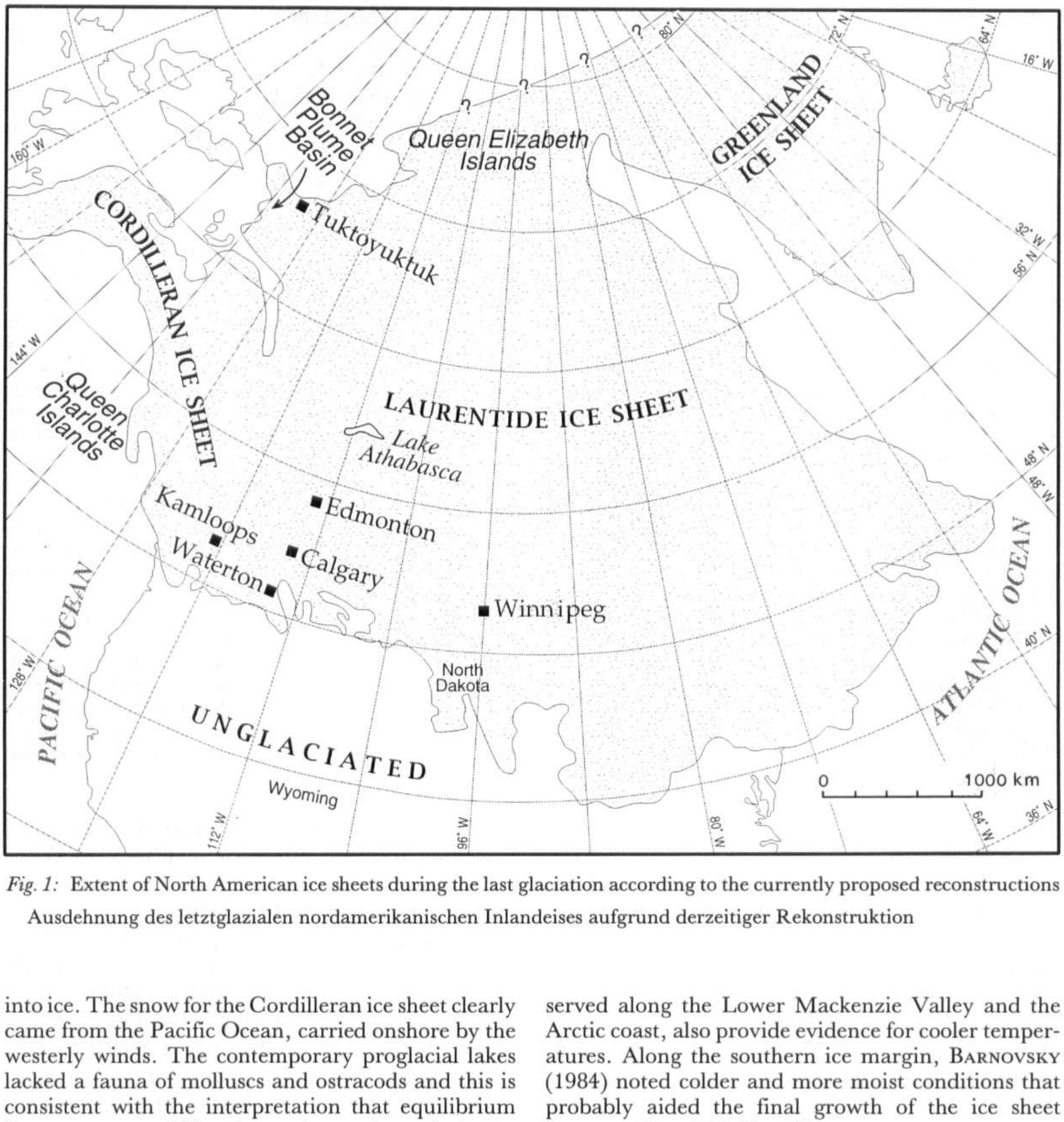

Fig. 1: Extent of North American ice sheets during the last glaciation according to the currently proposed reconstructions
Ausdehnung des letztglazialen nordamerikanischen Inlandeises aufgrund derzeitiger Rekonstruktion

into ice. The snow for the Cordilleran ice sheet clearly came from the Pacific Ocean, carried onshore by the westerly winds. The contemporary proglacial lakes lacked a fauna of molluscs and ostracods and this is consistent with the interpretation that equilibrium lines were up to 500 m lower than today at latitudes 40°–48° N (Richmond, 1965) and 300–700 m lower in central Alaska (Péwé, 1975, p. 109). Although the snow deposited by the onshore westerly winds has a relatively high density (approximately 0.1 g/cm^3, i.e., 9 m of snow would yield 1 m of glacial ice), the snowfall may have been higher in order to build the ice sheets across the central plateau. Evidence from the fauna and flora and from the contemporary permafrost landforms preserved in nonglaciated areas suggests a mean annual air temperature up to 10 °C colder than today in Alaska (Péwé, 1975). Ground temperature profiles along the Arctic Coast, together with stable isotope analyses of contemporary ground ice preserved along the Lower Mackenzie Valley and the Arctic coast, also provide evidence for cooler temperatures. Along the southern ice margin, Barnovsky (1984) noted colder and more moist conditions that probably aided the final growth of the ice sheet between 15 and 12.5 ka BP.

South of the ice sheets, there are well-preserved ice-wedge casts along the outer margin of the ice sheets (e. g. Péwé, 1983) and southwards along the higher plateaus and basins of the Rocky Mountains (e. g. Mears, 1981, 1987). This evidence has recently been summarized in Harris (1994, Fig. 4). Marker (1990) summarized the evidence for lower periglacial landforms southwards along the nonglaciated parts of the Rocky Mountains, while Heine (1994 a) has described the evidence for continuation of this climatic change into Mexico.

In the case of the Laurentide ice sheet, a mere change in temperature would not account for its size.

There must have been a substantial increase in precipitation in the form of snow. The present-day mean winter snow density is only about 0.03 g/cm^3 over much of the Canadian Prairies, so it would take 25 m of snow to produce 1 m of glacial ice, assuming no ablation or sublimation. Typical present-day mean annual precipitation is only 300–500 mm, yet somehow enough snow fell on the Prairies to cause the Laurentide ice to advance 3000 km from Hudson Bay to Waterton National Park in about 13 ka. This is a mean rate of ice advance of about 230 m per year – a rate that today would be considered by many to be that of a surging glacier. The only suitable source for such enormous quantities of precipitation would be maritime tropical air from the Caribbean Sea, perhaps advancing further north and west than at present due to the ice cap in the north preventing the cold Arctic air from moving as far south as at present. This would cause heavy snowfalls along the front where it met the cold Arctic air on the southern slopes of the ice sheet.

Whatever the cause of the higher precipitation, the colder air temperatures permitted much of the Laurentide ice sheet to be a cold-based glacier. Evidence for this includes the preservation of erosion surfaces in the Arctic Islands (BIRD, 1967) and the karst features in the limestones beneath the glacial till near Winnipeg. Undoubtedly permafrost was widespread around the margins and beneath parts of both the Laurentide and Cordilleran glaciers.

Deglaciation

RYDER et al. (1991) conclude that the retreat of the Cordilleran ice sheet began along the west coast about 13.5 ka BP and was completed within two millennia (CLAGUE, 1981). The southern margin was retreating northwards by 14 ka BP, but the rapid coastal deglaciation is quite different from the melting down and ice stagnation that occurred in the interior valleys (FULTON, 1967). In the latter, the mountain peaks appeared first, but stagnant ice choked the interior valleys and large lakes formed around the ice margins. On the eastern side of the ice sheet, the ice had retreated into the mountain valleys by about 11 ka BP west of Calgary. In the southern Fraser valley, a minor ice readvance occurred at 11.5 ka BP (SUMAS advance of ARMSTRONG, 1981; SAUNDERS et al., 1987), but the Cordilleran ice sheet ceased to be a continuous mass shortly after 11 ka BP and melted relatively rapidly, responding to a warm, dry climate that began about 12.5 ka BP (BARNOVSKY, 1984). These warmer conditions persisted until after 8 ka BP.

The Laurentide ice sheet was much larger and probably had a low average slope to its surface. If it were 3000 m high over Hudson Bay, the slope to Waterton Park (elevation 1200 m) would have had a drop of only 1800 m in about 3000 km. The thinner the ice sheet, the lower the slope.

As noted previously, the southwestern margin only reached its maximum extent about 12 ka BP, although the southern margin was in retreat by 12.5 ka (CLAYTON, 1966). In most areas of the western and southern Prairies south of Edmonton, ice stagnation was widespread (PREST et al., 1968). The largest stranded blocks were at least 100 × 200 km in size and their downwasting took up to 2.65 ka in one case in North Dakota (TUTHILL et al., 1964) and 2 ka in Saskatchewan (PARIZEK, 1964). Ice stagnation also occurred in the Lower Mackenzie Valley and on the Arctic Islands, but there it seems that some of the stagnant ice may still remain today as buried massive icy beds (MACKAY et al., 1979; LORRAIN a. DEMEUR, 1985). The abundance of these ice masses is still being debated, but the cold continental climate of north-central Canada is suitable for the preservation of buried glacial ice, in contrast to the climate in the western Cordillera.

The persistence of buried glacial ice in the Arctic Basin is surprising since low-lying coastal areas were inundated by the sea as the ice retreated, only to reappear as isostatic rebound occurred. The latter has resulted in postglacial marine deposits occurring as raised beaches at elevations exceeding 300 m above present-day sea level along the western margin of Hudson Bay.

Large proglacial lakes developed around the western and southern margins of the Laurentide ice cap during both advance and retreat (ALLEY a. HARRIS, 1974; PREST et al., 1969; TELLER, 1987). The largest of these was Glacial Lake Agassiz, but most lowland areas of the Prairies were inundated at least once during deglaciation.

The inferred positions of the active Laurentide ice front based on radiocarbon dates are provided by PREST (1968) and DYKE and PREST (1987). By 10 ka, the front of the active ice was north of Lake Winnipeg and crossed the western end of Lake Athabasca. The Laurentide ice still formed a formidable ice cap that only split into three parts when the ice lying in Hudson Bay melted shortly before 8 ka. It provided a high pressure cell in the atmosphere that caused upslope winds bringing heavy precipitation to the high plains of southwestern Alberta. This resulted in reactivation of some stagnant ice masses, e. g., the Innisfail advance of STALKER (1973), causing blocking of river valleys and the formation of new proglacial lakes starting about 10 ka and lasting until 8 ka, e. g. the last Glacial Lake Calgary (HARRIS, 1985). This air may also have crossed the continental divide to provide dry, warm conditions in southern British Columbia. There is also evidence of drier, warm conditions in the mountains and foothills of southwest Alberta at this time. When the main ice sheet diminished, so did the precipitation, and the ice masses on the Plains melted.

There were intermittent, short-lived readvances or surges of lobes of the Laurentide ice sheet during its retreat, but these tended to affect only one sector at any one time (Prest, 1968; Dyke a. Prest, 1987). In the mountains, up to five small moraines predating the Mazama Ash (6.83 ka) and postdating the main Cordilleran ice retreat can be found in individual valleys. Glacier Peak ash, dated at 11.3 ka, has not been found on their surface. These advances are quite minor and their age and correlation from valley to valley are problematic. However, there is also evidence from Jasper National park south to Plateau Mountain, southwest Alberta, for a post-glacial advance of rock glaciers to 500 m below the present lower limit of permafrost. The exact age of this event is unknown, but an advance of rock glaciers without a substantial complementary change in the glaciers can only be achieved by a reduction in precipitation without a temperature change (Harris et al., 1994). Evidence for this type of climatic change in the early Holocene has not been recognized by palynological studies, but the geomorphic evidence for a climatic change of this type is overwhelming. Such a change would have required perhaps a millennium to produce the rock glaciers, but whether this occurred before or after 8 ka is unclear. The small moraines and these rock glaciers could be ascribed to the Younger Dryas event, but Heine (1994b) correlates similar well-dated moraines on Mexican volcanoes to the discharge of cold glacial meltwater into the surrounding oceans (e.g., Kennett a. Shackleton, 1975; Teller, 1990a, 1990b). Those same discharge events also produced changes in the vegetation in the adjacent Mexican Highlands (Straka a. Ohngemach, 1989).

Effects of Deglaciation on Permafrost

In the north, the marine incursions would have tended to interfere with any permafrost left from the Late Wisconsinan glaciation. Thus relict permafrost is only found in the unglaciated zones east of Tuktoyaktuk, and is characterized by colder ground temperatures and greater thicknesses of permafrost (360 m compared with 90 m - Judge, 1973). Permafrost has reformed on all the suitable land areas after retreat of the glaciers, sea, and meltwater. The proglacial lakes undoubtedly caused the thawing of any permafrost in the underlying sediments (Judge, 1973), so the present-day permafrost is postglacial.

Proof of the postglacial age of the permafrost is seen in its shallower thickness (usually 100-200 m, ranging up to 600 m on Ellesmere Island at -20 °C mean annual temperature) compared with permafrost in Siberia (up to 1500 m thick). Ice wedges in Siberia may be 30 m deep and up to 20 m wide, compared with 5 m deep and 1 m wide in Canada. The ground temperature profiles in most Canadian permafrost only show the effects of Holocene climatic changes (Judge, 1973), while the isotopic composition of the ice reflects the changing ground temperatures of the Holocene (Michel a. Fritz, 1978; Michel, 1983, 1995; Burn a. Smith, 1985a, 1985b; Harris, 1988, 1989). This is in marked contrast to unglaciated areas (Gold a. Lachenbruch, 1993; Lachenbruch a. Marshall, 1969), and the isotopic composition of buried glacial ice (Lorrain a. Demeur, 1985).

Southwards, it is similar story, except that conditions suitable for the formation of permafrost under the present-day climate are only found along the higher mountains (Harris, 1986) and beneath postglacial peaty deposits (Zoltai a. Vitt, 1990). Occasional relict permafrost may be found on former Late Wisconsin nunataks such as Plateau Mountain (Harris a. Brown, 1978). In Wyoming, the former ice-wedges have melted, leaving ice-wedge casts and sand wedges as evidence of the much colder climate during the Late Wisconsin glaciation. Thus the former ice sheets have had very little effect on where permafrost occurs today in western North America.

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DAS FINNISCHE „MÖKKIWESEN“ – EIN LANDESTYPISCHER LEBENSSTIL IM UMBRUCH?

Mit 4 Abbildungen und 3 Photos

KRISTIINA JÄDERHOLM-VOGEL und WILHELM STEINGRUBE

Summary: The Finnish "Mökkis" – a change in a typically Finnish life-style?

To have a free-time residence of one's own has been a long tradition in Finland. At the beginning (in the early 19th century) there were impressive summer villas belonging to a small and wealthy group of the population. After a period of slow but steady growth the demand for private leisure homes in Finland has risen exponentially since the Second World War. Nowadays it is no longer a privilege of a certain social or income class to own such a home. Meanwhile nearly every third family has its own "Mökki", as the Finns call their summer cabin. The period of use is getting longer and longer, and the simple summer cabin has often become a free-time residence fit to live in all year round.

Fundamental changes in political, economic and social conditions (economic crises, new planning regulations, ecological problems and so on) will, however, bring to a sudden halt a further increase in the number of free-time residences, possibly within a few years. Nevertheless, initial findings show clearly that many Finns are striving for their own "Mökki" or are maintaining emotional bonds with their family leisure home, which is of central importance to their lives, i. e. the "Mökki" has become an important component of their life-style. As this life-style component is spread across all social classes all over Finland we can speak of a national life-style.

Most Finns do not consider their leisure houses as normal economic goods – they have strong emotional bonds with them. The Finnish "Mökkis" will therefore probably prove to be relatively resistant to negative external influences. For prognosticating the further development of the "Mökki" network it is therefore not sufficient to analyze the economic and "objective" general conditions. In order to draw up realistic scenarios we will have to pay special attention to the life-style conception or similar approaches which take the individual level of evaluation and decision into consideration.

1 Einführung

Die Sommerhütte am See ist in Finnland mehr als nur ein landschaftsprägendes Element. In diesen Häusern verbrachten und verbringen immer noch viele Finnen nahezu den gesamten Sommer, darin investieren sie einen großen Teil des Familieneinkommens, das Mökki (fin.: mökki = Haus, Hütte) ist für viele Finnen Teil ihres Lebens.

Die Anfänge des Mökkiwesens gehen zwar auf die Sommerresidenzen Adliger und anderer Privilegier-