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The construction of Kangerlussuaq Airport - A case story from West Greenland

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Kangerlussuaq Airport (Latitude 67.01° N and Longitude 51.69° W) is the main international airport hub of Greenland. Most international travellers arrive at Kangerlussuaq and are transferred to their final destinations by a network of local fixed-wing and helicopter flights. The future fate of the Kangerlussuaq airport has been the target of much political and media debate in Greenland in recent years, due to plans by the Greenland Government to restructure the airport infrastructure. Permafrost conditions at the airport has often been brought up in the debate without much factual evidence – which has prompted us to study and summarize the constructional history of the airport and on that basis evaluate the likelihood and extent of future damages due to permafrost degradation.

Kangerlussuaq Airport was established by the U.S. Army Air Force in October 1941 under the code name Bluie West 8 (BW-8) in order to provide an alternative runway to the base at Narsarsuaq (Bluie West 1), and was used as hub and refueling station for transatlantic flights during World War II. A harbor (Camp Lloyd) was established approx. 10 km south west of the airport at the eastern end of the 175 km Sondre Stromfjord (Kangerlussuaq:'the great fjord'). From 1954, regular civilian flights to Kangerlussuaq were operated as part of the route from Copenhagen to Los Angeles, and Kangerlussuaq thus became also a civilian airport and the main gateway for air traffic to Greenland. The U.S. Air Force operated the base until 1992 except a short period under Danish authority (1951-1952), after which the base reverted to the U.S. Air Force under a new defense agreement in light of Cold War fears (Jensen et al., 2013). It served as a Distant Early Warning (DEW) line base and supply station for other such facilities in Greenland. In 1992, after the fall of the Soviet Union, the U.S. Air Force abandoned the airport as a military base and handed over all facilities to the Greenlandic Government for civilian use, but retain priority military access at short notice. In recent decades, Kangerlussuaq has developed a local tourism industry benefitting from easy access to the Greenland Ice Sheet and serving as a hub for cruise ships.

The airport and supporting settlement (see figure 1) is situated in the rather complex geological setting of a marine delta in the valley system east of the head of the Kangerlussuaq fjord. The delta deposits formed during ice marginal retreat from the area approx. 7-8 ka BP, in a period of rapid sea level fall, and range from fine grained marine silt and clay deposits to coarse grained (sand, gravel and stones) river deposits. The combination of a relatively narrow valley confinement and rapid sea level fall, resulted in successive periods of fast depositional infill and subsequent erosion, leaving a system of distinct river terraces [Storms et al., 2012]. The major part of the Kangerlussuaq village, airport structures and runway are located on one such river terrace at an elevation of approximately +50 m.a.s.l., however, the western part of the runway extends onto a slightly sloping plateau of fine grained sediments (clays and silts) of marine origin at an elevation of +30 to +20 m.a.s.l. and dated around 6000 yr BP. Younger eolian deposits in the silt and fine sand fraction are wide spread in the area.

Due to the inland location and proximity of the Ice sheet, the airport experiences a stable dry subarctic climate with a mean annual air temperature of -3.3 °C (2004-2014). Winter temperatures range down to approx. -45 °C and summer temperatures up to 25 °C [Menne et al., 2012]. The area has continuous permafrost, the thickness of which has been estimated at 130 m at the airport location [Van Tatenhove and Olesen, 1994] and measured to 335 m by the ice sheet margin, 25 km inland at 450 m surface elevation [Harper et al., 2011]. Permafrost temperature measurements show an Active Layer Thickness (ALT) of about 2 m under natural conditions, while Ground Penetrating Radar measurements indicate an ALT of approximately 4 m below paved surfaces (Jørgensen & Ingeman-Nielsen, 2007). Perenially frozen fine grained marine and eolian deposits in the area are typically ice rich, however, in certain areas the marine sediments

Figure 1: Aerial view of the Kangerlussuaq airport and surrounding settlement situated on a river terrace in a marine delta at the head of the Kangerlussuaq fjord.

contain considerable residual salinity which suppresses the freezing point and leave the sediments technically unfrozen (although still cryotic). Coarser deposits typically range from well bonded to friable, with limited excess ice (e.g. of Engineers [1957]). Massive ground ice features such as ice-wedge polygons and pingos have been reported although not from the vicinity of the airport and settlement locality.

Runway construction commenced in autumn 1941 and was operational in spring 1942. 1700 m long and 46 m wide, the runway was constructed with a sand base course and asphaltic macadam pavement placed directly on the old river plateau at elevation +45 to +48 m.a.s.l. During the period of 1957-1960 the runway was extended to 3000 m length and widened to 61 m and the southern parking area was expanded. Areas adjacent to the existing runway were excavated, and frost susceptible and ice rich soils were replaced down to 3 m.b.s. by non-frost-susceptible (NFS) materials obtained from sand and gravel pits along the adjacent Watson River. The area of the original runway was not reconstructed, although the construction was reinforced by an additional sand-gravel base course and new pavement surface on top of the original construction. The western-most part of the new runway extended on to a lower plateau of marine fine-grained and very ice rich sediments. A thick embankment of NFS materials was constructed to protect the thermal regime of the underlying thaw-sensitive permafrost.

There have always been load restrictions on the runway in the summer time. These restrictions are related to the fact that the oldest part of the runway was constructed without replacement of weak surficial deposits. There are no restrictions in the wintertime, when the active layer is frozen, ensuring a high bearing capacity. Recently, a notam was issued on the westernmost 250 m of the runway, due to development of settlements and cracking of the pavement. It is presently unknown whether these settlements are related to insufficient compaction of the thick embankment or to thermal degradation of the ice-rich permafrost below or beside the embankment.

Other parts of the runway seem to experience no permafrost related issues due to a low ice content in the underlying sediments, but suffer from a deteriorating pavement. Thermal cracking is a severe problem due to the more than 60 °C surface temperature variation experienced over the course of a year. Crack sealing is performed yearly, but with the different thermal properties of original asphalt and sealant, cracking redevelops and worsen over time. As the runway has not been repaved since 1987, the typically applied 20-year runway repavement cycle is long overdue.

Thaw settlements do occur locally on the southern apron and taxiway. A preconstruction ravine filled with fine grained ice rich material has caused differential settlements of up to 45 cm, and a few other areas are affected by local settlements as well. The northern apron was originally designed for DC8 aircrafts, and the current use of the much heavier Airbus 330 and intensive traffic with domestic Dash 8 flights cause fatigue cracks and viscous deformation of the asphalt in the summer. Some of these issues have been addressed by painting the asphalt in a light color to reduce surface temperature, and the construction of concrete slabs at certain parking locations.

Generally the runway and main aprons are not expected to experience significant damage related to future permafrost degradation, due to thaw stable subgrade materials or thick protective embankments. Local thaw-settlements may continue to develop in areas with remaining ice-rich eolian deposits. The duration of active settlements will be limited by the relatively small thickness of ice-rich deposits (typically up to 2 m), and settlements should thus be manageable. However, the surrounding infrastructure, especially the road system, will continue to suffer locally from thaw degradation, which is expected to accelerate due to future warming and severe drainage problems which are presently not properly addressed.

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