Late Quaternary glacial and environmental history of Kongsøya, Svalbard

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On western Kongsøya, Svalbard, three coarsening-upwards sequences of marine to littoral sediments, separated by tills, are recognised in sections at ca 50–92 m above present sea level. These sequences show major glaciations in the northern Barents Sea, resulting in substantial glacioisostatic downpressing of Kongsøya. Till fabrics indicate ice movements controlled by the local topography, while glaciotectonic deformations suggest that ice moved from an ice divide northeast of Kongsøya, independent of the local topography. The stratigraphical evidences show two pre-Holocene ice-free periods, when the climate was similar to or slightly warmer than at present. The age of these periods is not clear. It is suggested that the elder ice free interval is older than isotope stage 5e. The younger ice free interval could be of Eemian or Early Weichselian age. The uppermost succession of sublittoral–littoral sediments is of early Holocene age. It relates to the high (≈100 m) postglacial marine limit, dated to approximately 10,000 BP.

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Introduction

Kongsøya (191 km²) is the largest of a number of islands comprising Kong Karls Land in the easternmost part of the Svalbard archipelago (Fig. 1A). The island is mainly made up of Jurassic and Early Cretaceous strata, and the low (≤300 m) mountains on eastern and western Kongsøya (Fig. 1B) are erosional remnants of a Cretaceous plateau, capped by basaltic lavas (Smith et al. 1976). Quaternary sediments mainly occur below 100 m a.s.l. (Salvigsen 1981). The purpose of the present investigation has been to locate and study pre-Holocene glacial and marine sediments on the western part of the island. Preliminary results were reported by Ingólfsson et al. (1992), Rögnvaldsson (1992) and Ingólfsson & Lirio (1993).

Previous studies

Geological observations were begun when Pike (1898) and Nathorst (1901) described raised marine beaches on the island and reported finds of driftwood at levels up to ca 40 m a.s.l. The idea of a glacier occupying the Barents Sea basin was first suggested by De Geer (1900). Nathorst (1901), who observed striated boulders on the plateau between Retziusfjellet and Tordenskjoldberget (Fig. 1C), suggested that a Nordaustlandet glacier could have covered the Barents Shelf as far east as Franz Josef Land. Strömberg (1972) found glacial sculptures almost totally lacking on western Kongsøya. He discovered glacial striae at two localities, at high levels above cirques on Sjögrenfjellet and Tordenskjoldberget (Fig. 1C). Strömberg mapped the directions of glacial striae as indicating ice movements from SSW–SSE and concluded that most probably the striae were formed by former local glaciers of modest extent. Schytt et al. (1968) and Hoppe (1972) used the Kongsøya striae when reconstructing an extensive Weichselian Barents Ice Sheet, with an ice divide somewhere to the south-southeast of Kongsøya.

Knape (1971) reported driftwood from raised beaches up to 36 m a.s.l. and pre-Holocene marine shells from altitudes up to 89 m. The driftwood samples were ^{14}C dated and used for constructing an uplift curve (Schytt et al. 1968; Hoppe

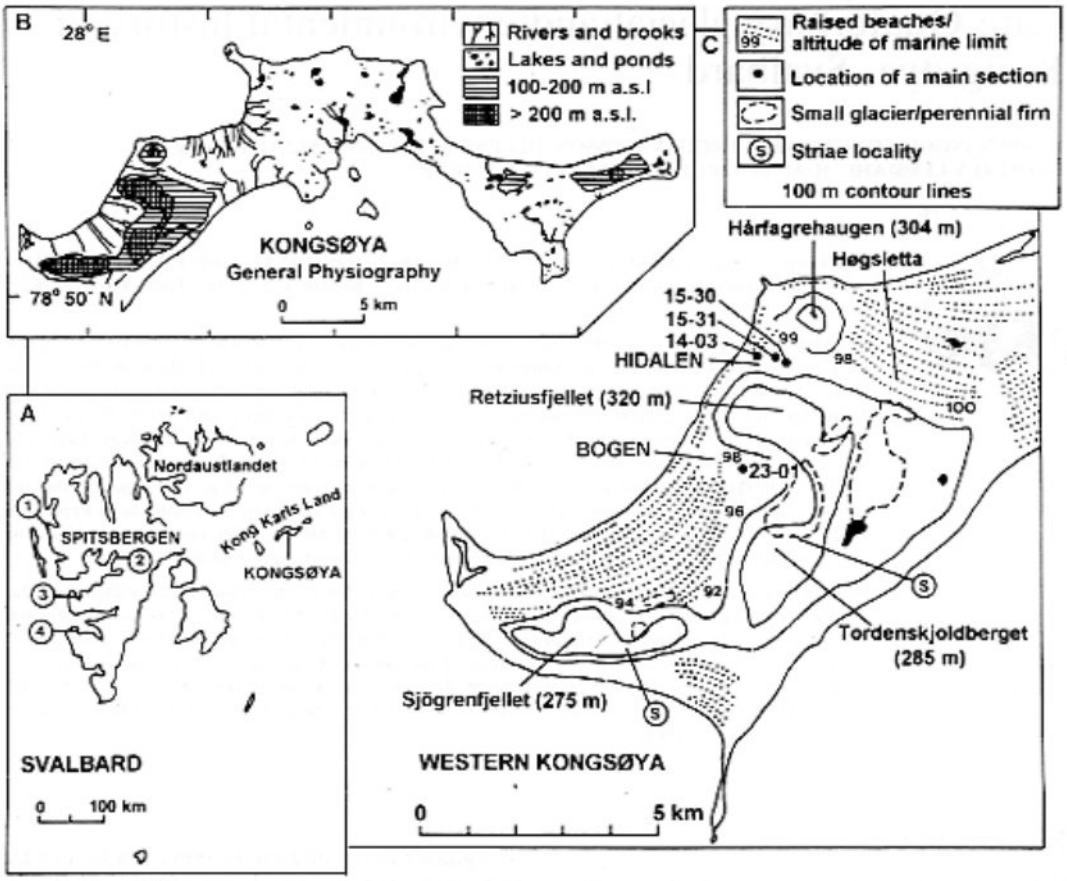

Fig. 1. A: Svalbard location map. Localities mentioned in the text: (1) Brøggerhalvøya; (2) Kapp Ekholm; (3) Linnédalen; (4) Skilvika/Bellsund. B: The general physiography of Kongsøya. C: Western Kongsøya. The location of raised beaches is shown as an approximation of areas where beach ridges occur rather than location of individual ridges.

1972), indicating that beaches below 36 m were younger than 7000 BP Boulton (1979) suggested that there were two sets of beaches on Kongsøya, a lower Holocene set, and a higher >40,000 BP set extending to the marine limit at 100 m. He suggested that Kong Karls Land had not been glaciated except by small glaciers during the Late Weichselian. Salvigsen (1981) published new radiocarbon dates from Kong Karls Land and presented an emergence curve for eastern Kongsøya. He showed that a shoreline displacement of more than 100 m had taken place during the Holocene, and his emergence curve is the strongest evidence presented for a Late Weichselian Barents Ice Sheet over Kongsøya. Marine geological data from the Barents Shelf (Elverhøi & Solheim 1983; Vorren et al. 1988; Elverhøi et al. 1990; Solheim et al. 1990; Polyak & Solheim 1994) show glaciations several times during the Pleistocene. Geomorphic features on the sea floor in the northern Barents Sea, some 150 km south of Kongsøya, are interpreted as fluted surfaces and *De Geer* moraines, thought to show that the Barents Shelf had been covered by a sliding temperate glacier, at least in the observation area (Solheim et al. 1990; Elverhøi et al. 1990).

Although the existence of a large Late Weichselian ice sheet covering the northern and central Barents Sea area is now generally accepted, its extension, thickness and duration are still discussed and debated (e.g. Mangerud et al. 1992; Elverhøi et al. 1993; Forman et al. 1995; Lambeck 1995; Siegert & Dowdeswell 1995). Forman (1990) described the spatial variation in emer-

gence records from Svalbard, and concluded that the uplift pattern in Nordaustlandet, the islands in the Barents Sea and on central and western Spitsbergen, reflect glacial loading of the Barents Ice Sheet during the Late Weichselian. This conclusion strongly indicates that the same ice dome or separated ice domes in dynamic equilibrium have caused the isostatic depression observed. Thus, almost synchronous interglacial/interstadial events in the whole Svalbard area could be expected, provided that this pattern of emergence is valid for earlier deglaciations. Mangerud et al. (1992) concluded that prior to the Late Weichselian glacial build-up, the Barents Ice Sheet was small or non-existent, and that glaciers on and around Svalbard were not much larger than today when the advance to the last glacial maximum started sometime after 25,000 BP.

Methods

The stratigraphic investigations were concentrated at two main localities, the col of *Hidalen* and in the *Bogen* cirque (Fig. 1C). The sites were spotted by shell fragments in scree, and then cleared by digging. Elevations of sections and of raised beaches were surveyed by repeated measurements by AIR-HB-1A electronic altimeter and some were levelled by theodolite. Samples were collected for analysing grain-size, plant and insect macrofossil content, foraminifera and mollusc species, Thermoluminiscence (TL) and ^{14}C determinations and amino acid diagenesis. The ^{14}C age determinations were performed at Lund University's Radiocarbon Laboratory, and the TL-dating was carried out at the Nordic Laboratory for Luminiscence Dating in Risø, Denmark, using sand-sized potassium feldspars. Amino acid diagenesis was measured in the protein matrix of fossil molluscs at the Bergen Amino Acid Laboratory, following the procedure described by Miller et al. (1983).

Glacial morphology

Glacial sculpturing and erratics

The landscape of Kongsøya (Fig. 1B) indicates that basal sliding and glacial erosion occurred when the island was completely covered with ice. On western Kongsøya the glacial erosion is concentrated in shallow cols, valleys and cirques, leaving the plateaux relatively unmodified. The plateaux of Hårfagrehaugen, Retziusfjellet, Tordenskjoldberget and Sjögrenfjellet, as well as basaltic bedrock outcrops at lower altitudes, have been searched for glacial sculpturing, striae and erratics. The basalt plateaux are deeply weathered, and no clear glacial sculpturing is evident. Usually the surface is covered with regolith and crude soils. In a few localities bedrock outcrops show stoss-and-lee topography, but none were found to carry glacial striae. The only erratics found on the plateaux were remains of petrified Cretaceous tree trunks, probably eroded by the glacier from the local sedimentary bedrock and only transported a short distance.

Raised beaches and the marine limit

The marine limit on western Kongsøya is at 94–98 m a.s.l. (Fig. 1C), which is in good agreement with Knape's (1971) results. The highest beach ridges on Høgsletta were levelled to ca 100 m a.s.l., which is about 10 m lower than Salvigsen's (1981) marine limit on eastern Kongsøya. Salvigsen & Nydal (1981) found that isostatic uplift has been greater in the eastern than in the western part of Kongsøya during the last 7000 ^{14}C years, and they took this as an indication of a Late Weichselian ice centre east of Kongsøya. The material in raised beach ridges on western Kongsøya is primarily of local basaltic provenance, but crystalline rocks, granites and gneisses, are also found. These have probably been carried to the island by sea ice. The beach ridges at altitudes between ca 40 m and 60–70 m a.s.l. on Høgsletta, formed between ca 9000 BP and 7000 BP (Salvigsen 1981), are composed of well-rounded cobbles and boulders, with little gravel or sand, while the finer grain sizes are more characteristic for beach ridges above and below. This could indicate a higher energy in the coastal environment and less annual sea-ice cover during the formation of intermediate altitude beach ridges. This is supported by the lack of driftwood on beaches above 35–40 m.

Glacial stratigraphy of Hidalen

Fluvial erosion in Hidalen (Fig. 1C) has exposed Late Quaternary sediments resting on Triassic and Lower Jurassic bedrock. Knape (1971)