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Workshop Report

The Kråkenes Late-glacial Palaeoenvironmental Project

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Abstract

Kråkenes is the site of a small lake on the west coast of Norway that contains a long sequence of late-glacial sediments. The Younger Dryas is well represented, as a cirque glacier developed in the catchment at this time. This site offers unique opportunities to reconstruct late-glacial environments from independent sources of evidence; physical evidence (glacial geomorphology, sedimentology, palaeomagnetism, radiocarbon dating), and biological evidence from the remains of animals and plants derived from both the terrestrial and aquatic ecosystems. This report describes the background to the site, and the international multidisciplinary project to reconstruct late-glacial and early Holocene environmental and climatic changes at Kråkenes.

This report describes the Kråkenes late-glacial palaeoenvironmental project, and the Project Workshop held at Kråkenes, Vågsøy, western Norway, 23–25 April, 1995. Seventeen of the twenty-four people working with the Project attended, from five countries. The Project team members are using palaeoenvironmental and sedimentological techniques to reconstruct late-glacial environmental and ecosystem changes from evidence preserved in the sediments and surroundings of Kråkenesvatnet (Kråkenes lake). Emphasis is placed on the rapid environmental changes associated with the Younger Dryas event.

Kråkenes is at the outermost coast of the Nordfjord area of western Norway (Fig. 1). The lake at Kråkenes (Lat. 62 °02′ N; Long. 5 ° 00′ E) is on the Kråkenes peninsula of Vågsøy island at 38 m a.s.l. The lake has three basins, and is approximately 530 m long, with a present maximum depth of 12 m, and originally 0.07 km^2 in area (Larsen & Longva, 1979). The shores are either stony or marshy, and the bays are presently occupied by floating-leaved aquatic and reedswamp communities (see Jonsgard & Birks (1995) for further information). To the south the cliffs of Mehuken mountain rise to 433 m a.s.l. At about 100 m a.s.l., on the north side of the mountain, is the base of a cirque that was occupied by a glacier during the Younger Dryas (Larsen *et al.*, 1984) (Fig. 2). The outflow from the cirque enters the southwest basin of the lake (Figs. 1, 2) where it deposited laminated glacio-lacustrine sediments during the Younger Dryas.

The Kråkenes area was originally studied by Larsen & Longva (1979) [see also Mangerud *et al.* (1979), Longva *et al.* (1983), Larsen & Mangerud (1981), Larsen *et al.* (1984), and Mangerud (1987)] to date the deglaciation at the end of the last ice age, and to determine the subsequent development of the cirque glacier during the Younger Dryas. Ice was absent in the Allerød period preceding the Younger Dryas, and organic sediments rich in plant and animal remains were deposited in the lake. These are overlain by the Younger Dryas laminated silts that originated from the glacial outwash and more coarse-grained sediments deposited by debris flows from the steep slopes to the south (Fig. 2). The early Holocene organic sediments are not laminated, and their silt content decreases rapidly. During this early work, a pollen diagram was produced (Larsen *et al.*, 1984) and palaeomagnetic studies were also performed (Løvlie & Larsen, 1981).

The late-glacial period (*c.* 13-10 000 ^{14}C-years BP) was a time of rapid climatic and vegetational changes. Western Norway was glaciated during the Weichselian. The glaciers withdrew inland, starting at around 12 300 yr BP in the Ålesund area (Mangerud *et al.*, 1979; Kristiansen *et al.*, 1988), and at about the same time at Kråkenes (Larsen & Longva, 1979; Larsen *et al.*, 1984). Birks (1994) showed that the vegetation in the coastal area of western Norway developed in response to the relatively warm interstadial temperatures (Allerød, *c.* 12–11 000 yr BP) and then to the renewed cold conditions of the Younger Dryas (*c.* 11–10 000 yr BP). The climate became substantially warmer at the start of the Holocene (*c.* 10 000 yr BP), exceeding the interstadial temperatures. Succession proceeded uninterrupted from the open pioneer vegetation of the Younger Dryas towards forest communities in the lowlands. The first fossiliferous sediments at Kråkenes were originally dated at 12 300 yr BP (Larsen *et al.*, 1984), and were deposited soon after local deglaciation. The pattern of local vegetation development follows that of the outer west Norwegian coast (Birks, 1994), with a cool, treeless Allerød, severely cold Younger Dryas, and a substantial temperature rise in the early Holocene, initiating a vegetational succession that culminated in open birch forest.

Kråkenes lake has several advantages for late-glacial palaeoecological research. The late-glacial lake sediments are thick in the basins, and the rate of sediment accumulation was especially high in the Younger Dryas, thereby permitting decadal sampling resolution. Inwash of organic material, including fossils, from a variety of terrestrial habitats occurred during the whole late-glacial and the early Holocene, and the lake itself contained a diverse and responsive community of organisms.

Because of the potential interest of the Kråkenes sequence demonstrated by the initial study (Larsen *et al.*, 1984), a multi-disciplinary study on new cores was initiated in 1993 by Hilary H. Birks to investigate the biological and physical aspects of the environmental changes associated with the climatic and glacial changes of the late-glacial at Kråkenes. An international group of 24 scientists are studying glacial geomorphology, sedimentology of the Younger Dryas laminations, palaeomagnetism, radiocarbon (AMS) dating, identification and dating of volcanic ash layers, stomatal density and CO_2 reconstruction, and biological indicators including pollen and spores, plant macrofossils, mosses, diatoms, chrysophytes, other algae, fungi, siliceous protozoa, Bryozoa, Oribatid mites, Cladocera, Chironomidae, Coleoptera, and Trichoptera.

Figure 3 shows the bathymetry of the lake before lacustrine sedimentation started. The Younger Dryas sediments are thickest in the delta area near core site 51 (2.0–2.5 m). They are thinnest at the thresholds between the basins. Near core sites 66 and 46 in the south basin, they are around 1.5–1.8 m thick. Detailed studies of the Younger Dryas laminations and the distribution of the sediment were supplemented

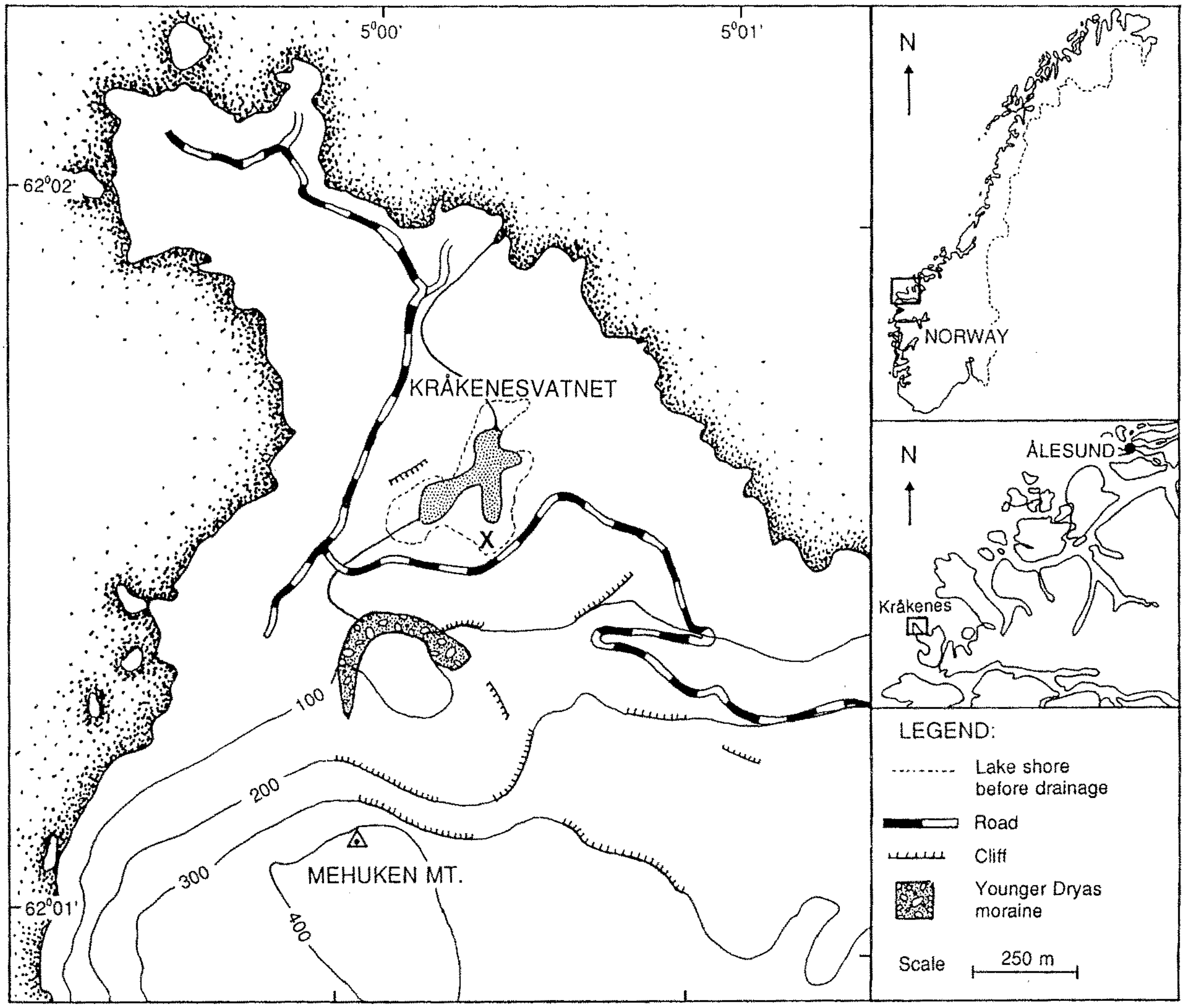

Fig. 1. The location of Kråkenes and the setting of Kråkenes lake. The position of the site of the master core sequence 46 is shown by X in the south basin of the lake.

by palaeomagnetic studies of several cores taken from different parts of the lake.

Most of the other investigations have been made on one master core series (46) (Fig. 3) taken from the south basin of the lake. Early in this century the water level of the lake was lowered by *c.* 1.5 m in an attempt to increase agricultural land (Fig. 3). The exposed sediments have subsequently developed into wet marsh communities. The master core sequence was taken on 15 November 1992 with a piston corer 11 cm in diameter from the marsh surface in the south basin (Figs. 1, 3).

Throughout the late-glacial and early-Holocene sediments, leaves of *Salix herbacea* (dwarf willow) are common. These have been used for 60 AMS radiocarbon dates throughout the sequence, thus providing the most detailed radiocarbon chronology for this period (Gulliksen, Possnert, H. H. Birks & Mangerud, in prep.). The stomatal density of the fossil *Salix herbacea* leaves has been used to reconstruct the late-glacial sequence of changes in atmospheric carbon dioxide concentrations (Beerling, H. H. Birks, & Woodward, 1995). To these results will be added stable carbon isotope ($\delta^{13}C$) measurements on the fossil leaves. The high resolution of the Kråkenes late-glacial CO_2 record is more detailed than those from Antarctic ice cores. The mid-Younger Dryas Vedde tephra and the early Holocene Saksunarvatn tephra have both been identified in the Kråkenes sediments and closely dated by AMS (H. H. Birks, Gulliksen, Haflida-

Fig. 2. Kråkenes lake from the north, with Mehuken mountain behind. The Younger Dryas moraine is clearly visible, looping around the mouth of the cirque. (Photo. J. Mangerud).

son, Mangerud & Possnert, 1995). These projects have wide-ranging or global significance in Younger Dryas research.

A major focus of the Kråkenes Project is to reconstruct the past changes in the ecosystem, both terrestrial and aquatic, and the magnitude and rates of past environmental and climatic changes. Because of the long sediment sequence covering the late-glacial and early Holocene, high-resolution (decadal or less) sampling has been used, especially for the periods of rapid climatic change, so that the biological and physical response times of the various indicators of environmental change can be estimated. In conjunction with detailed radiocarbon dating, the timing and rates of vegetation succession over the Younger Dryas/Holocene boundary and into the early Holocene have been reconstructed, the fine time-resolution providing a link between palaeoecological evidence and modern ecological successional studies (H. J. B. Birks, Peglar & H. H. Birks, in preparation).

Some of the main issues of the Kråkenes Project include:

1. Climate reconstruction, particularly temperature and precipitation, and their relationship to snow cover, and to ice cover on the lake.
2. Glacier formation and melting. Did the glacier have a local climatic influence?
3. Changes of soil stability in the past. What evidence do we have from organic and inorganic material washed into the lake?
4. Changing extent of vegetation cover and vegetation type, both on the land and in the lake, in response to climatic change.
5. How was the associated terrestrial and aquatic fauna affected by these changes?
6. How was aquatic productivity affected by these changes? Were benthic littoral communities affected in the same way as planktonic communities?
7. To what extent can limnological variables, such as temperature, turbidity, pH and other chemical variables, and nutrient status (N and P) be reconstructed from the palaeolimnological indicators?
8. What were the rates of change during the late-glacial? Were rapid biotic changes driven by rapid climatic changes, and were more gradual changes

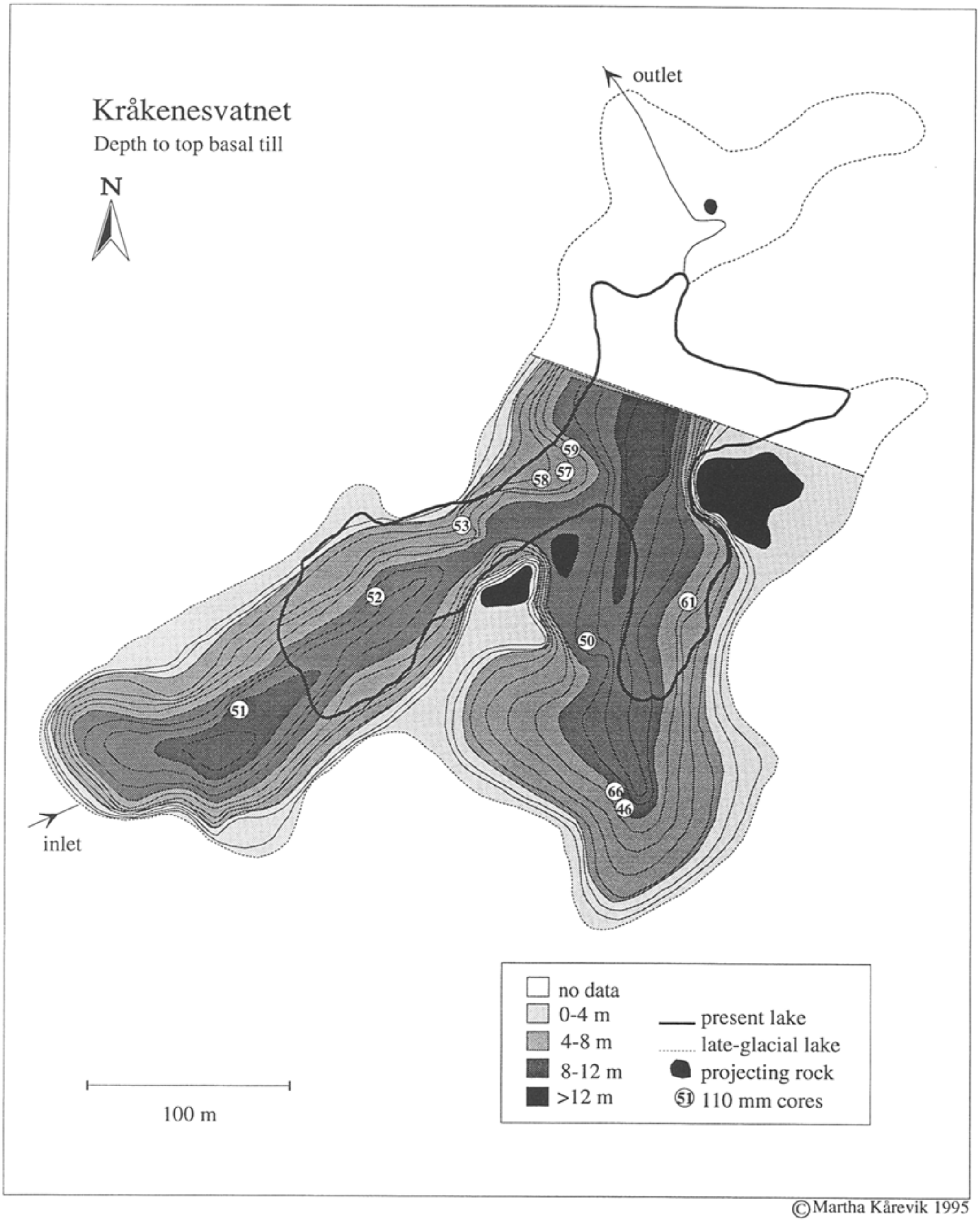

Fig. 3. Bathymetry of the Kråkenes basin before lacustrine sedimentation. The Younger Dryas sediments form a large delta in the southwest basin. The master core sequence was taken at site 46 in the south basin. The present shoreline is marked, showing the reduction in lake size after partial drainage.

controlled by succession processes or by gradual climatic changes?

9. Do the results from Kråkenes have a significance or application beyond western Norway?

During the April Workshop, considerable progress was made in addressing these issues. Places where more detailed analyses are needed were identified. Publications on the individual projects are being prepared, and several synthesis papers are planned.

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