SCANDINAVIA STUDIES OF RECENT CRUSTAL MOVEMENTS AND THE SPACE GEODETIC BASELINE NETWORK

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ABSTRACT

A brief review of crustal movements within the Fenno-scandia shield is given. Results from post-glacial studies, projects for measuring active fault regions, and dynamic ocean loading experiments are presented.

The 1979 Scandinavian Doppler Campaign (SCANDOC I) Network is discussed. This network includes Doppler translocation baseline determination of future VLBI baselines to be measured in Scandinavia. Intercomparison of earlier Doppler translocation measurements with a high precision terrestrial geodetic baseline in Scandinavia has yielded internal agreement of 6 cm over 887 km. This is a precision of better than 1 part in 10^7.

INTRODUCTION

Scandinavia is an ideal place for testing theories of recent crustal movements. Historically, there is a detailed record of the Fenno-scandia uplift provided for by local water level observations carefully recorded for periods of over one thousand years. Furthermore, apart from this well studied phenomenon, the Fenno-scandia shield is known to be one of the most stable plates on the earth, with a seismic background far below that of most other parts of the crust.

For these reasons, Heiskanen (1958), Cathles (1975), and others have used the Fenno-scandia uplift data to provide the best overall measurements of the viscosity and behavior of the earth's mantle to surface loads. The relaxation time, or 1/e value, has been shown to be about 10^4 years. Detailed models using various hypotheses have been generated for the region. Predictions on the uplift phenomenon can be very accurate over the entire shield area.

Detailed records of earthquake activity have also been kept. The largest earthquake in recent time occurred in the Oslo fjord in the year 1904. Its estimated Richter magnitude was 6.5. Since that year, a seismograph has been in continual operation at Uppsala. This earthquake and the seismicity of Scandinavia have been the subject of papers by Husebye, Ringdal, and Lande (1976), Båth (1977), and others.

Two large aperture seismic array stations are operated in Scandinavia; one in Norway, one in Sweden. The station at Hagfors in Sweden has been used for the basis of a recent book on the detection of underground nuclear explosions (Dahlman and Israelsson, 1978).

It is clear then that the Scandinavian area provides a good control ground for testing theory against measurement for recent crustal movements.

RECENT STUDIES OF DYNAMIC CRUSTAL MOVEMENT

Figure 1 shows the extent of post-glacial uplift measured in Sweden using shore line data by Mörner (1979). These values agree well with precise levelling data obtained over the past 50 years by the Swedish Survey Office. The vertical rate approaches 1 cm/yr at the upper part of the gulf of Bothnia. Vertical uplift gradients are sometimes very steep, leading to some local seismicity.

Figure 2 has plotted all earthquakes which have occurred in Sweden above magnitude 2.5 during the 1951-1976 period, with data from Båth (1977). It can be seen that the level of seismic activity is small and is related to two main areas, that along the coast of the gulf of Bothnia and that around Lake Vattern, an ancient fault in south central Sweden.

Crustal loading by the ocean tides has been the topic of a recent investigation (Anderson (1976). Figure 3 shows a time series obtained with a geodynamics recording gravity meter in central Finland. The spectral analysis of this record indicates a peculiar signal believed to be caused by the resonance

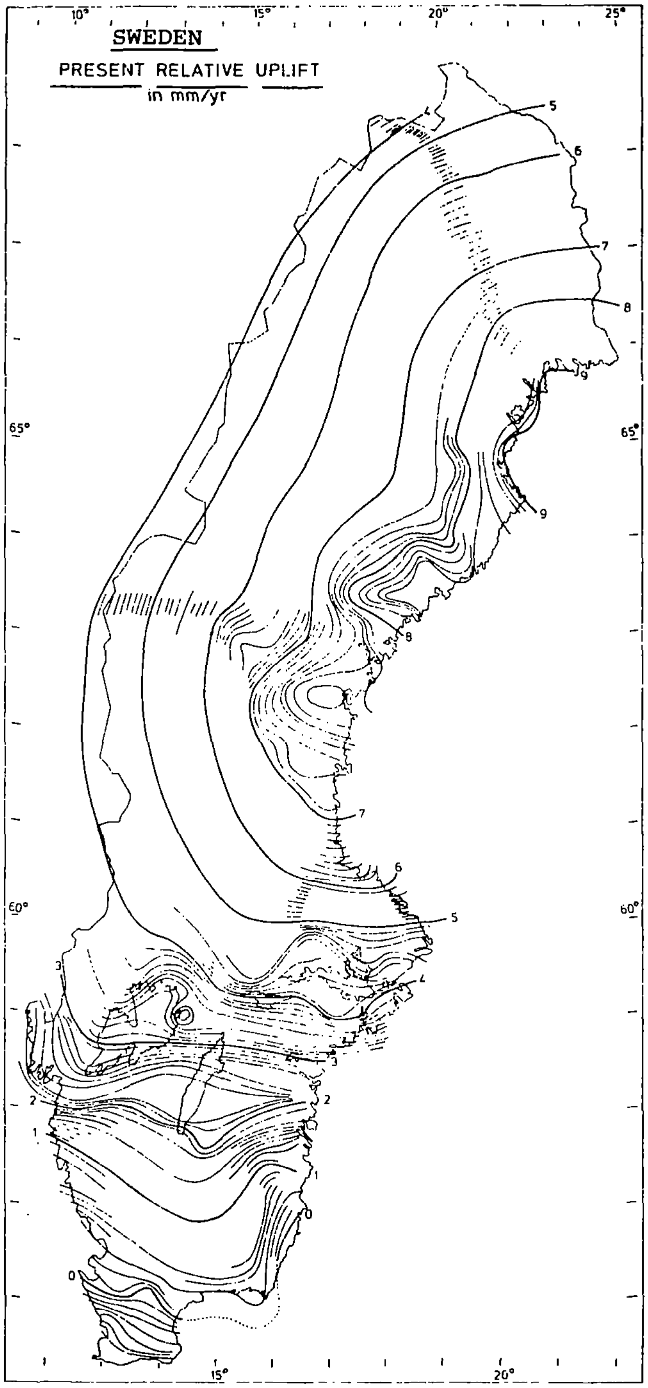

Figure 1. Present uplift in Scandinavia caused by post-glacial rebound (Mörner, 1979).

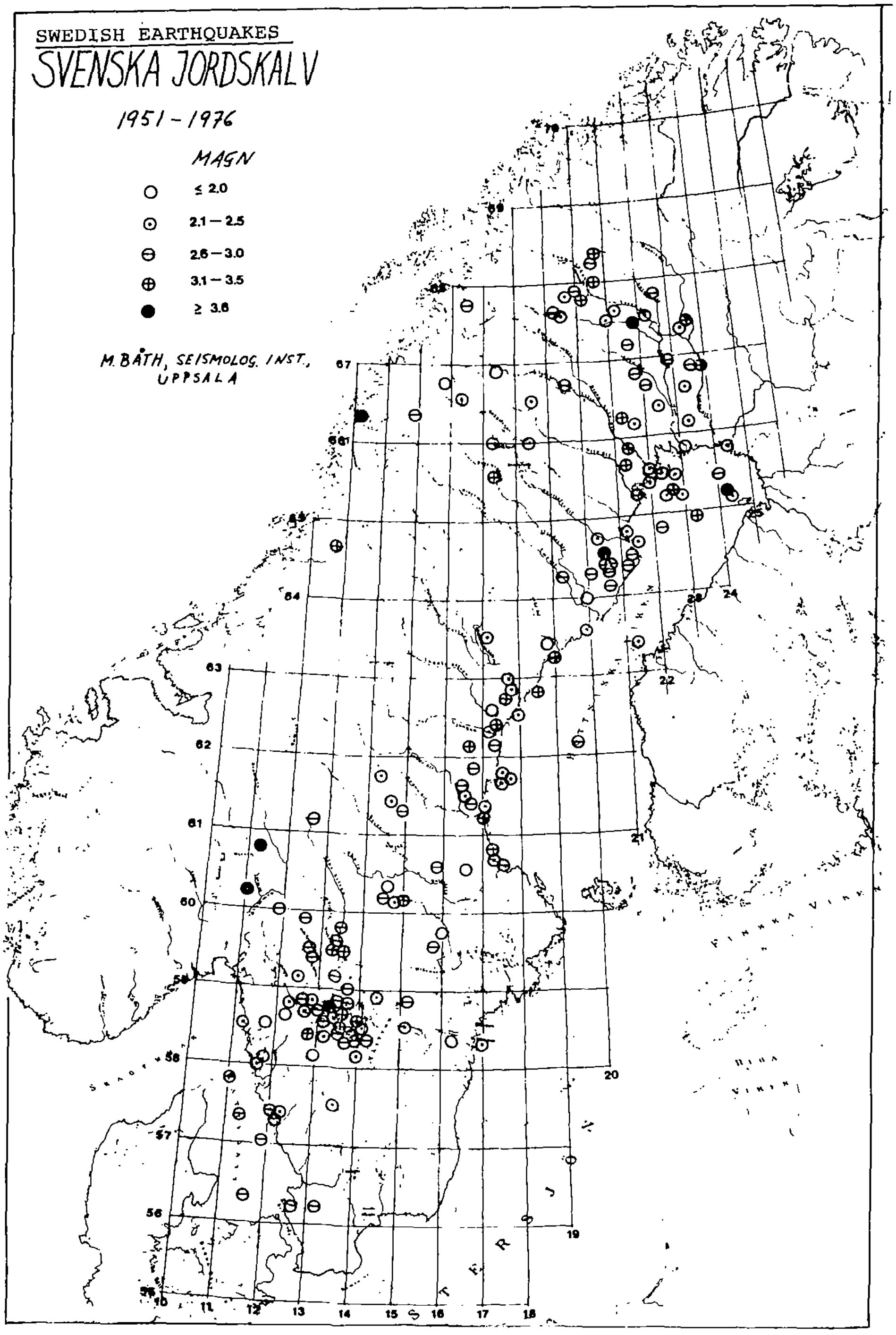

Figure 2. Recent earthquakes in Sweden (Bath, 1977).

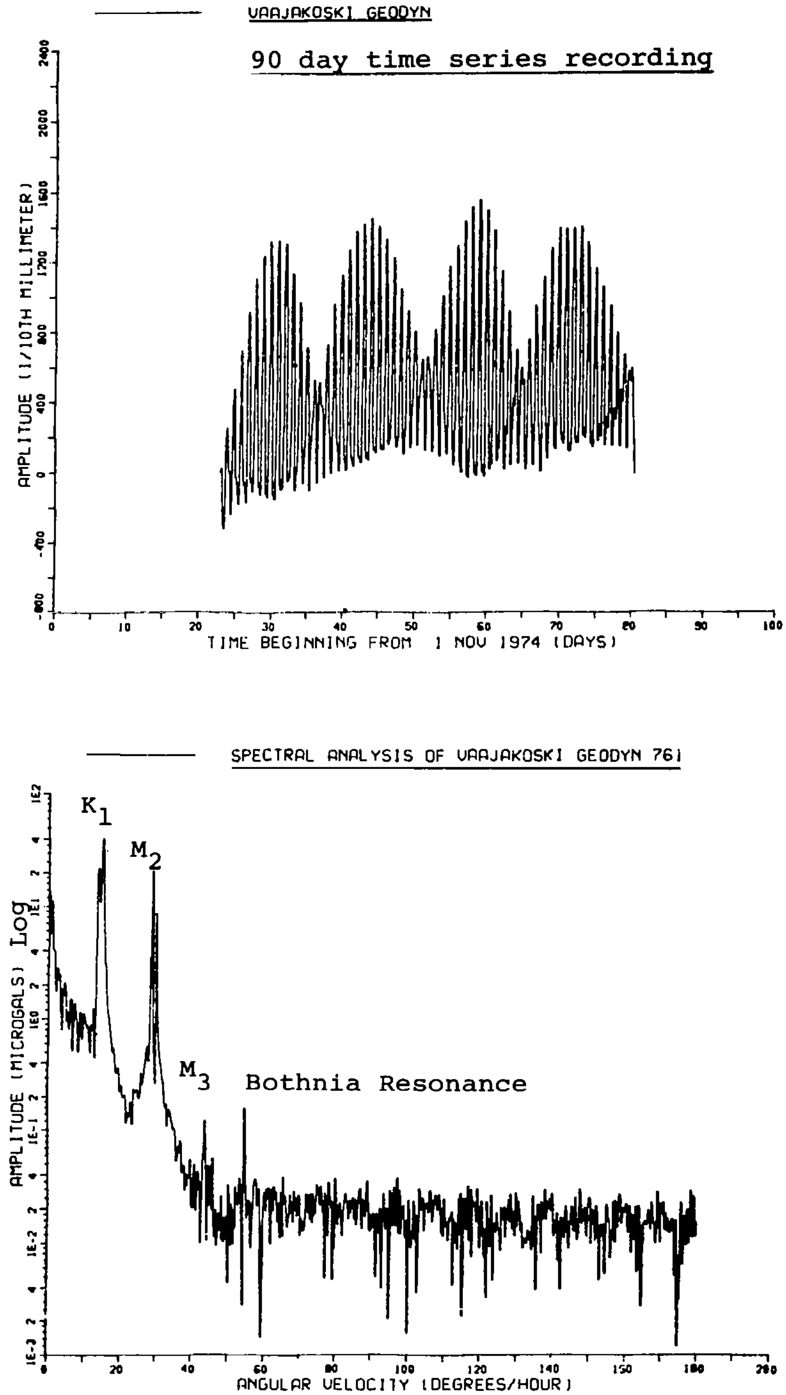

Figure 3. Solid-earth tidal gravity recording showing spectra and Bothnia Gulf resonance effect (Anderson, 1976).

of the Gulf of Bothnia. This resonance causes areas perpendicular to the gulf to move up and down by several tenths of a centimeter with a period of 6.59 hours. A further study of horizontal tilt was made along the Scandinavian peninsula and models for the global ocean loading terms were considered (Anderson (1977)).

A study of the secular change of gravity in the area of uplift is being carried out by the Finnish Geodetic Institute and the Swedish Survey Office.

The Swedish Geological Survey is studying what are believed to be ancient active faults activated by post-glacial rebound.

THE SPACE GEODETIC NETWORK

To coordinate these activities on the study of recent crustal movements, Anderson (1978) presented a paper at the Nordic Geodetic Commission meeting in the hope that modern Doppler and VLBI methods would be able to provide the first confirmation of plate motion to the Scandinavian Shield area and provide a means of mapping local crustal displacements.

In coordination with the National Survey Offices of each Scandinavian country and in cooperation with the Finnish Geodetic Institute and the Institute of Geophysics at Uppsala, the Scandinavian Doppler Campaign for 1979 (SCANDOC I) was carried out in May 1979. Ten individual receivers were used in the translocation mode (relative Doppler). It is expected that such measurements shall be repeated and improved regularly throughout the 1980's.

Figure 4 shows the SCANDOC I network and indicates the future VLBI baselines expected to be measured in the 1980's. An earlier joint VLBI-Doppler experiment was carried out between Onsala and Bonn in 1975 (Campbell and Beyer (1978)), and a further one was repeated in 1978.

Comparison with the Finnish precision baseline and relative Doppler has been made during 1977-78. On the basis of 3 months of data, an agreement of 6 cm was obtained between the measured baseline results (Kakkuri, 1979) and the relative Doppler value (Mårtensson, 1978).

Figure 5 shows a polar projection of the VLBI baselines considered for study in this paper. An estimate of the expected horizontal displacement rate due to known geophysical phenomenon is given in table 1. Correction terms for land uplift are calculated, and it is shown that these terms are dominant for Scandinavian Plate baselines. As much as 26 percent in addition to the mid-Atlantic term needs to be taken into account for the Haystack-Sodankylä baseline.

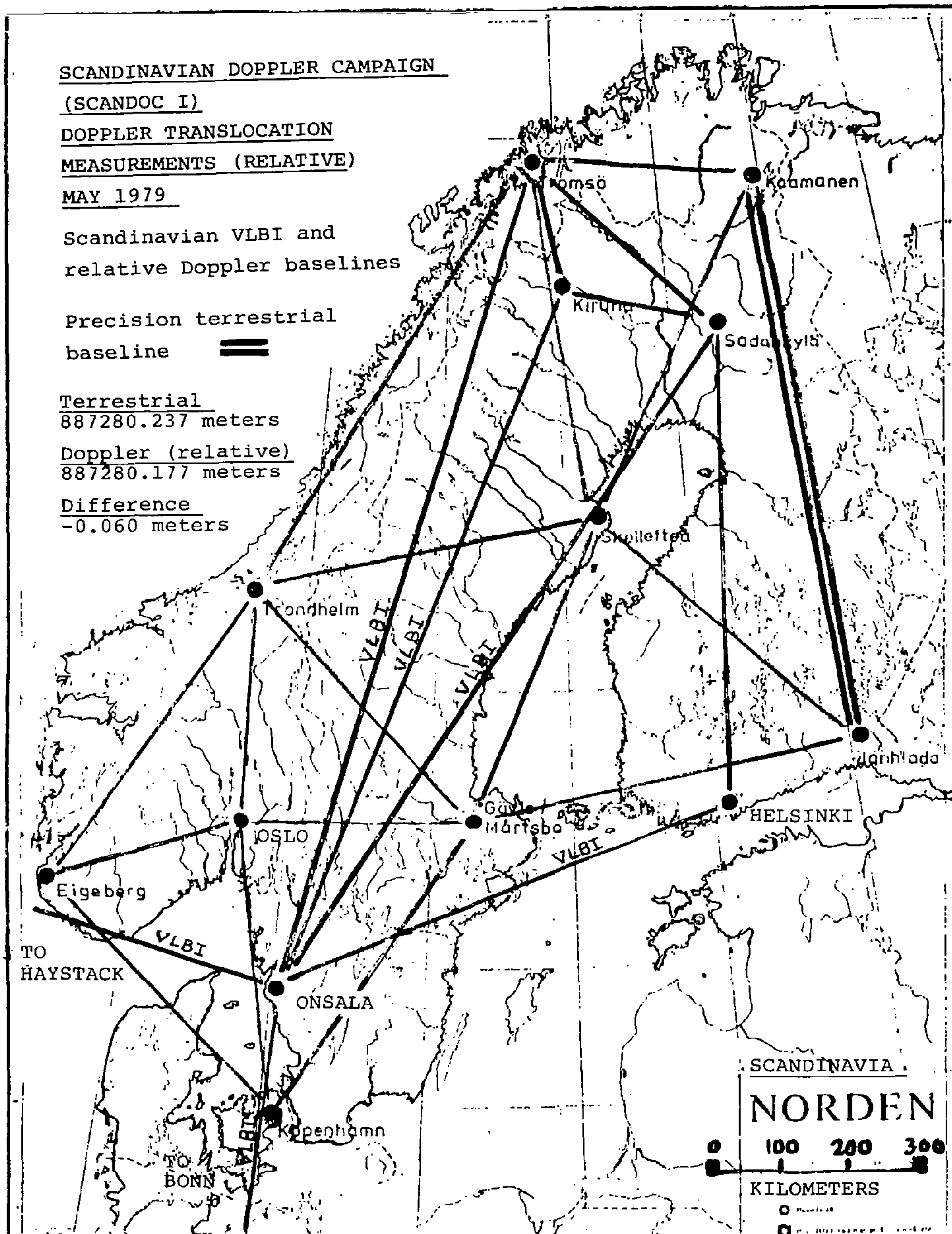

Figure 4. Scandinavian Space Geodetic Network showing SCANDOCI and future VLBI baselines. Comparison of precise terrestrial and relative Doppler made (Kakkuri, 1979).

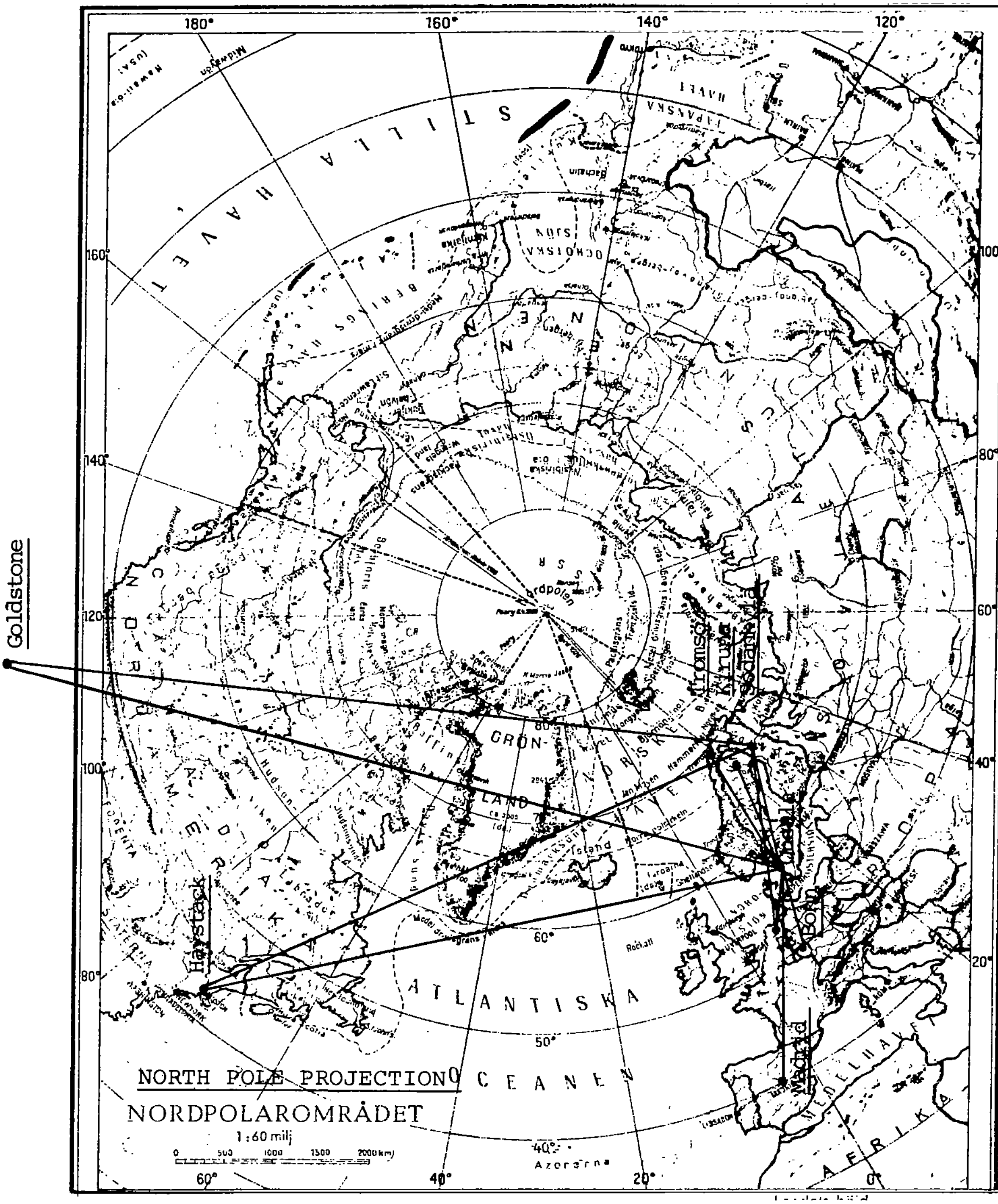

Figure 5. Polar projection of VLBI baselines planned for use with Scandinavian stations. Expected horizontal strain rates and uplift corrections are given in table 1.

Table 1
Rates of Uplift, Baseline Rates, Estimated Horizontal Strain Release vs. Uplift Baseline Rates for Scandinavian VLBI Baselines

	VLBI BASELINE	ΔZ DIFFERENCE (CM/YR) VERTICAL UPLIFT RATE	ΔZ·SIN(Θ/2) BASELINE RATE	HORIZONTAL STRAIN RELEASE (CM/YR)		VRS UPLIFT BASELINE RATE (%)
1.	Onsala-Kiruna	+0.6 (cm/yr)	+0.05 (cm/yr)	+0.1 (cm/yr)		+50%
2.	Onsala-Sodankylä	0.7	0.07	0.1	Fennoscandia plate	+70%
3.	Onsala-Tromsö	0.0	0.00	0.1		00%
4.	Dwingeloo- Onsala	0.2	0.01	0.2	Uplift bulge	+05%
5.	Dwingeloo- Sodankylä	0.9	0.13	0.2		+65%
6.	Bonn-Onsala	0.1	0.01	0.5	Oslo-Rhein graben	+02%
7.	Bonn-Sodankyla	0.8	0.13	0.5		+26%
8.	Haystack-Onsala	0.2	0.09	1.8	Mid-Atlantic ridge	+05%
9.	Haystack-Sodankylä	0.9	0.43	1.8		+24%
10.	Goldstone-Onsala	0.1	0.06	1.8		+03%
11.	Goldstone-Sodankylä	0.8	0.47	1.8		+26%

CONCLUSIONS

It has been demonstrated that the Scandinavia area provides an excellent area for testing theories of crustal motion. It provides the addition of a stable, well-studied crust complimented with long sets of geodynamic data and well-refined solutions. It also provides for sets of unique VLBI baselines with many of the world's observatories due to its proximity to the pole.

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