NORGES GEOLOGISKE UNDERSØKELSE

The Bordvedåga Beryllium Deposit
Rana, Nordland County, Norway

Summary report

NGU-report 91.181

NORGES GEOLOGISKE UNDERSØKELSE

Postboks 3006 - Lade
7002 Trondheim
Tlf. (07) 90 40 11
Telefax (07) 92 16 20

RAPPORT

Rapport nr. 91.181	ISSN 0800-3416	Åpen/Fortrolig

Tittel:	
The Bordvedåga beryllium deposit, Rana, Nordland County, Norway. Summary Report.	
Forfatter: R. Wilberg and I. Lindahl	**Oppdragsgiver:** NGU
Fylke: Nordland	**Kommune:** Rana
Kartbladnavn (M. 1:250 000) Mo i Rana	**Kartbladnr. og -navn (M. 1:50 000)** 1927 I, Mo i Rana
Forekomstens navn og koordinater: Bordvedåga, UTM 4975 6575	**Sidetall:** 27 **Pris:** 47,- **Kartbilag:**

Feltarbeid utført:	Rapportdato:	Prosjektnr.:	Seksjonssjef:
1984-1988	17.5.91	67.2441.00	

Sammendrag:

Investigations in the Høgtuva and Sjona basement windows in Nordland County were carried out from 1980 to 1990. Detailed work including drilling on the Be-deposit at Bordvedåga was done from 1984 to 1988 by NGU in cooperation with Nordsulfid A/S. The Be-deposit is located in granitic basement rocks of supposed age 1700 - 1900 M.a. The emplacement of the ore was prior to the amphibolite grade metamorphism and foliation of the basement during the Caledonian Orogeny. The deposition of Be, Sn, U, Th, Y, REE, etc. involved magmatic differentiation and hydrothermal activity. A large number of mineral phases have been identified and are listed. So far drilling has proven 350 000 tonnes of ore with average grade 0.18 % Be, and there is a potential for further reserves in the area. A pre-feasibility study for the exploitation of the deposit was started but not carried through. Flotation tests give a high grade phenacite concentrate (23 % BeO) with good recovery. This report summarizes the results and lists the reports from the investigations. All data can be made available for companies interested in exploitation.

Emneord	zirkonium	yttrium
ore geology	uranium	
beryllium	REE	

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THE BORDVEDÅGA BERYLLIUM DEPOSIT, RANA, NORDLAND COUNTY, NORWAY

SUMMARY REPORT

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Introduction

The work that led to the discovery of the Bordvedåga deposit was started in 1974, this was essentially a study of the lithogeochemistry of granites throughout Nordland County. The analyses of trace elements in the samples showed anomalously high uranium content and high U/Th ratio at locations in the eastern part of the Høgtuva basement window.

Reconnaissance work based on these results was carried out in 1981 by the "Uranium project" at the Geological Survey of Norway (NGU). This follow-up of the anomaly led to the discovery of a granitic gneiss zone within the basement, with anomalously high values of Zr, Y, U, Th, Sn and REE. In 1984 Be-mineralizations were discovered to occur within this anomalous gneiss, and later several smaller Be-mineralizations were mapped outside the gneiss.

The Bordvedåga Be-deposit is situated 15 km NW of the town of Mo i Rana, and approximately 15 km S of the Arctic Circle. NGU planned and carried out the investigations of the area around the Bordvedåga Be-deposit during the years 1984-88, with economic contributions from Norsulfid A/S, Nordland Fylkeskommune, Distriktenes Utbygningsfond and Rana Utviklingsselskap. The total cost of the project is just over 9 mill. NOK, with most extensive work done in 1987-88 (Fig. 1).

This summary report is based on the project reports and selected literature given in the reference list.

Geological setting

The Precambrian windows in the Caledonian nappes from the Mo i Rana to the Ofoten region (Fig. 2) are dominated by granitic terrains. The term *window* is here used for Precambrian crystalline rocks, which may constitute basement (autochthonous), partly displaced basement (parautochthonous), or mega-boudins intercalated in the Caledonian nappe (allochthonous) sequence.

The age of the basement rocks is within the time span of 1700-1900 Ma. Locally, remnants of autochthonous late Precambrian (?) metasedimentary rocks of arkosic to pelitic composition, sometimes graphite-bearing, may be found unconformably overlying the granitic rocks. Remnants of Cambrian carbonaceous shale are found locally around the Høgtuva Window.

The granitic terrains have generally undergone amphibolite grade metamorphism. Both intrusive granites and granitic gneisses of sedimentary and volcanic origin occur. Metamorphosed remanents of supracrustal rocks (sediments of greywacke-type, carbonates, carbonaceous sediments, and volcanites of acidic to mafic composition) have been mapped.

The basement windows in the Rana - Glomfjord region are dominated by granitic rocks that are moderately to strongly foliated and sheared, with varying texture and grain size. In the Høgtuva and Sjona windows the gneisses are coarse-grained and medium-grained. The foliation is generally more intense toward the tectonic contact with the overlying Caledonian nappe sequence and mainly parallels the schistosity of the rocks within the nappes. It is not clear if the intensity and orientation of foliation and the variation in grain size within the Høgtuva, Sjona, Laksådal and Svartisen Windows indicate that these basement rocks are autochthonous, parautochthonous, or allochthonous. Detailed gravimetric surveys covering the Sjona and Høgtuva windows indicate that Caledonian cover sequence does not exist beneath the granitic basement.

The rocks in the Høgtuva window are dominantly composed of medium-grained granitic gneisses. Medium- to coarse-grained and less foliated gneisses occur locally interlayered with the more foliated and medium-grained gneisses. The differences in major-element composition between gneisses with varying texture and foliation are minor.

Amphibolite and biotitite rocks are found as 0.5 - 5.0 m thick and several kilometre long layers. They vary from a rock essentially composed of biotite, to garnetiferous and biotite-bearing amphibolites. In areas with strong deformation, as in the Bordvedåga area, the amphibolites are sheared, brecciated and altered to a biotitite. The mafic layers may readily be overlooked even with 90% outcrop because they weather easily and are found in depressions in the terrain below benches of the granitic gneiss.

Small lenses of felsic and mafic non-foliated pegmatites, conformable or cutting the foliation at a low angle, commonly occur within the gneisses. The felsic pegmatites (0.1 - 0.3 m thick and a few metres long) have a simple mineralogy and are composed of quartz, K-feldspar, plagioclase (albite), and opaques. They are not enriched in the rare elements. The mafic pegmatites are rare. They have a complex mineralogy which comprises K-feldspar, plagioclase, quartz, biotite, zircon, Ca- and Na-amphiboles (green and blue under the microscope), fluorite, clinopyroxene, garnet, opaques, and several REE-minerals. They are enriched in U, Zr, Be, REE, and Sn, and appear to be restricted to the Bordvedåga area. Both types of pegmatite are interpreted to be metamorphic mobilizates emplaced during and after the Caledonian shearing. Isotope studies of the two types of pegmatites indicate that they have different ages, the mafic one being youngest.

The gneisses within the window have apparently undergone episodes of isoclinal folding.

Near vertical joints and faults cut the gneisses in a more or less N-S direction. The most pronounced breccia zone, the Kjøthogget breccia zone, can be traced as a marked topographic depression across the entire window. It shows both ductile and later brittle deformation. Despite repeated movement within the zone, large lateral displacement is not apparent. None of these fracture zones appear to have elevated contents of rare elements. Open joints with the same orientation as the fracture zones are typical and most likely related to isostatic adjustment after the last deglaciation, 10,000 years ago.

Geology of the deposit area

The gneisses in the Bordvedåga area have been subdivided into the footwall gneiss (FG), the mineralized gneiss (MG), and the hanging-wall gneiss (HG). Megascopically these three sub-units look very much the same. However, the MG has a slightly higher content of biotite, and is generally slightly finer grained than the FG. The MG and the HG are more stronger foliated than the FG. The FG contains bodies of coarse-grained granitic gneiss with weak foliation.

The MG crops out in a NW-SE (dip 20-30°NE) belt up to 250 metres thick and 8 kilometres long, and parallels the foliation in the window. In the SE the MG is cut by a thrust and in the NW it wedges out. This sub-unit is most readily distinguished by its elevated radioactivity (Fig. 3). The presence of amazonite in the felsic pegmatites was also used as a criterion to delimit the MG, since the amazonite-bearing pegmatites only occur in the MG and in a narrow aureole around it.

The mineralogy of the three gneissic units differ only slightly with respect to major minerals though differ clearly in minor and accessory minerals. The major minerals are quartz, K-feldspar, albite and biotite. Decreasing amounts of biotite are found from MG to HG to FG. Zircon, fluorite and locally phenacite are strongly enriched in the MG. A large number of trace minerals are identified, especially in the MG. A Be-bearing silicate, høgtuvaite, has been accepted as a new mineral.

The average major and trace element geochemistry is given in Table 1, which shows that the MG is slightly depleted in SiO_2, K_2O and Al_2O_3 and enriched in Fe_2O_3 and Na_2O. The MG classifies as peraluminous in contrast to the metaluminous HG and FG. Most incompatible trace elements are abnormally enriched in the MG.

The MG is further subdivided in three units with the major and trace element compositions given in Table 2:

- The weakly mineralized zone (WMZ) defined by radiation between 70-180 μR/h and/or greater than 0,2 % Zr.

- The highly mineralized zone (HMZ) defined by radiation greater than 180 μR/h and/or greater than 0,8 % Zr.

- The beryllium mineralized zone (BMZ) defined by a Be-content greater than 0,1 %.

Be-mineralizations were found in the eastern part of the Høgtuva window in FG, MG and HG in nearly 100 different locations.

The Bordvedåga deposit

The Bordvedåga Be-deposit is located in the MG cutting the border of HMZ and WMZ. The deposit extends on both sides of the Bordvedåga stream, which has given the name to the deposit. The ore body forms two lenses lying parallel to the foliation of the host gneisses.

The outcrop of the deposit has less than 20 % till cover, and is located 400 m.a.s.l. The dip is 20-30° towards the NE. The two ore lenses are intersected by 45 drill holes distributed over 400 metres along strike and 170 metres down dip. With a cut off at 0.1 % Be the deposit is delimited in all directions. Proven tonnage (cut off at 0.1 % Be) is 350,000 tons with an average grade of 0.18 % Be. The drilling program is shown in Fig. 4. A vertical section through the two Be-ore lenses at the outcrop is shown in Fig. 5.

The Be-mineralization (> 200 ppm Be) can be followed 400 m along strike in drill rows II and III (Fig. 4). The thickness of mineralization containing more than 200 ppm Be increases towards depth, from 12-14 m in row I (outcrop) to 18-20 m in the mid part of rows II and III. The thickness of the ore lenses (> 0.1 % Be), however, drecreases towards depth from maximum 14 m in outcrop to maximum 3 m in row III. The upper of the two lenses decreases quickly towards depth. The lower high grade lens is more extensive and is followed in rows II and III over lengths of 300 m and 220 m respectively.

The two ore lenses could be either two separated lenses or the same layer repeated by isoclinal folding. Above, below and between the Be-ore lenses, zones enriched in other elements occur. These two mineralization types are named Be-ore and Y-zone. Elements that are enriched in the Be-lenses are Be, U, Th, Zr, Nb, Sn, W, Mo, Cu and Ba. The Y-zone is enriched in Y, Ce, La, Rb, Li, Zn, Pb and Co.

The elements in each group have a positive correlation in the same zone but either a negative or no correlation with the elements in the other zone. This zonation is important for determination of the ore boundaries because Y and some of the REE, which is economically important, are enriched outside the Be-ore. The Be-ore has a somewhat higher content of the HREE (Yb and Lu) and lower content of the LREE (Ce, La, Sm and Tb) compared to the Y-zone.

The mineralogy of the Bordvedåga deposit is complex. The beryllium content is mainly found in phenacite with minor quantities in gadolinite, genthelvite and høgtuvaite. Phenacite and other minerals are enriched in cm-scale bands, but in metre scale the content of elements is homogeneous. Average grain size is 0.3 - 0.5 mm in the ore. Phenacite is normally of size 0.2 - 0.3 mm, while the minor and accessory minerals highly enriched in incompatible lithophile elements Zr, Nb, Y, REE, U, Th, F, Rb, Bi, Ga, Hf, Ta, Sn are less than 100 μm. A list of the so far identified minerals are given in Table 3.

The major minerals in the Be-ore and host rocks are quartz, K-feldspar, albite, biotite, and small, varying amounts of hornblende. The biotite may contain several percent of ZnO.

Phenacite from the Bordvedåga Be-ore is chemically very pure and contains but small amounts of other elements, but the anhedral grains quite frequently contain inclusions of other minerals.

Høgtuvaite, recently accepted as a new mineral, belongs to the aenigmatite group and contains about 2.6 % BeO. The growth of høgtuvaite, as cm long needle shaped crystals, are preferably orientated in the foliation, but may also intersect the foliation. Høgtuvaite is restricted to Be-rich (greater than 100 ppm Be) portions of the gneiss. Macroscopically iron-depleted haloes surround the crystals, which have a poikiloblastic texture with inclusions of a number of different minerals. Zonation with highest number of inclusions in the central part of the crystals is normal.

Gadolinite appears as anhedral to subhedral individual grains in quartz and feldspar and sometimes in aggregates intergrown with other accessory minerals. The mineral is frequently zoned with a light coloured core rimmed by a hydrated darker phase, or with a complex mixture of oscilatory zoning. Gadolinite from Bordvedåga has a high Y and REE content.

1-2 mm euhedral crystals of genthelvite occur typically associated with sphalerite and other sulphides in cm-thick, often fluorite enriched bands.

Allanite occurs usually in biotite rich layers. It is characterized by a variable chemical composition and growth zonation. The allanite has a high content of LREE, and some grains are thorium rich and are classified as thoro-orthite.

Sphene occurs in relatively large, anhedral and homogeneous grains, generally with a high tin content.

Pyrochlore and thorite occur in characteristic spherical grains (10 - 200 μm) often with a rim of chlorite. Both pyrochlore and thorite normally have a secondary hydrated phase. The pyrochlore is uranium enriched (15 - 20 % UO_2).

Uraninite is found as a few small (10 - 30 μm) scattered anhedral grains.

Most of the zircon forms clouds of crystallites. It also occurs as euhedral up to 0.5 mm crystals with clouded metamict interiors and clear rims.

Fergusonite, euxenite, kainosite, thalenite and ytrialite are all present in the Y-zone while only fergusonite is found in the Be-ore. These minerals are rich in HREE and yttrium.

Fluocerite occurs both as small (< 10 μm) anhedral grains disseminated in the rock and mobilized along fractures and grain boundaries.

Small amounts of cassiterite and wolframite occur as small grains up to 10 μm.

The Be-ore contains sulphides (sphalerite, galena, molybdenite, chalcopyrite, pyrite and arsenopyrite) as individual grains and along fractures and grain boundaries.

Magnetite is abundant in the ore, in amounts up to 2 %. The euhedral to subhedral metablastic magnetite crystals can be up to 2-3 mm in size. They are frequently surrounded by dish shaped iron depleted haloes. The magnetite phase may contain several percent of zinc. Ilmenite occur as lamellae in magnetite and as individual grains.

Fluorite is a common minor mineral. Calcite, apatite and muscovite are less abundant. Chlorite is present as alteration product from biotite and also overgrows pyrochlore and thorite.

Some of the minerals show differences in chemical composition related to the chemistry of the ore lenses. Genthelvite from the Be-ore is enhanced in beryllium compared to that from the Y-zone. The high Y-content in the Y-zone, compared to the Be-ore, is reflected in gadolinite, fergusonite and sphene. The enhanced Zn-content in the Y-zone is reflected in genthelvite, sphene and biotite. Both biotite and whole-rock from the Y-zone are enhanced in Rb.

The Y-zone is enriched in LREE and intermediate REE, and depleat in HREE compared to the Be-ore. Gadolinite from the Y-zone is enriched in intermediate REE but depleat in LREE compared to gadolinite from the Be-ore. Sphene has a higher REE-content in the Y-zone. The enrichment of Sn and U in the Be-ore is reflected in sphene and gadolinite respectively.

The Be-bearing rocks at Bordvedåga have metamorphic textures and are of amphibolite facies grade. The ore-forming process occurred prior to the peak of metamorphism. The primary host rock to the ore could have been a granite, a high level intrusive, a rhyolitic extrusive or even rhyolitic tuffs. The original rock may have been highly differentiated.

It is not possible to explain the enrichment of elements in the mineralized gneiss and Be-deposit without employing hydrothermal activity. This activity introduced the different elements in fluor-complexing solutions. Varying LREE/HREE ratios may be explained by different pulses of solutions. Very little mobilization in syn- or post-peak of metamorphism has taken place. The latest local transport of elements is connected with the forming of mafic pegmatites and quartz veins.

Continued research will be directed toward elucidating the genesis of the deposit.

Additional Be-mineralizations

Within an area of 8 km^2 in the south-eastern part of the Høgtuva window a great number of beryllium and rare metal mineralizations have been found (Fig. 3). The mineralizations occur as dissemination in different lithologies such as:

- granitic gneiss (Bordvedåga deposit)
- fluorite-rich bands in the gneiss
- fluorite-rich bands with skarn mineralogy
- aplite dikes
- mafic pegmatites
- undeformed quartz veins.

The Bordvedåga type of deposit would appear to be the only one of economic interest. A number of mineralizations of this type are found within the MG between Bordvedåga and Tverrbekkfjellet (Fig. 3). Be-mineralizations also occur outside the MG, especially in the HG in an area called Lia, and in the FG at Tverrbekkfjellet.

The mineralizations in the area Bordvedåga - Tverrbekkfjellet - Lia are dominated by the paragenesis: phenacite, høgtuvaite, gadolinite and genthelvite (or danalite). It is the høgtuvaite that makes this mineralization type visible in the field, while it is beryl that makes the other paragenetic type (beryl, phenacite, gadolinite, genthelvite/danalite) visible. The colour of the beryl varies from yellowish to green and sometimes greenish blue. Beryl and høgtuvaite are never found in the same mineralization. Some mineralizations have phenacite as the only Be-mineral, and some have no associated enhanced radiation. In these cases they are very difficult to find. Some of the mineralizations are discordant to foliation.

Below the granite lens in the FG there are several extensive fluorite and calcite rich gneissic layers, locally massive ½ m thick fluorite, which runs from Sørfjellet to Trolldalsaksla (Fig. 3). At Trolldalsaksla occurs is a local enrichment of the Be-minerals danalite, helvite, høgtuvaite and gadolinite in a fluorite and calcite rich layer. This mineralization is characterized by skarn mineralogy and high concentrations of trace elements. At Sørfjellet beryl appears in thin concordant layers in fluorite rich gneiss. Also among the mineralizations in the Bordvedåga - Tverrbekkfjellet - Lia area there are Be-enriched fluorite rich layers with both parageneses (beryl-phenacite-gadolinite-helvite group and høgtuvaite - phenacite - gadolinite - helvite group).

At Snøfjellet (Fig. 3) a Be-mineralization is related to a swarm of aplite dykes in the granitic gneiss. Small irregular pegmatite segregations and undeformed quartz veins are also beryl-bearing with crystals from 1 mm to 1 cm in size.

All the Be-mineralizations in the Bordvedåga-Tverrbekkfjellet-Snøfjellet-Lia area have been surveyed with beryllometer and scintillometer. The most promising mineralizations have been sampled by diamond drilling (5-10 m holes). Mineralizations may have a strike length of 50 - 400 m and be of high grade but with a thickness of a few dm. None of these mineralizations, only the Bordvedåga deposit, has economic significance.

Prospecting work

Prospecting work has been focusing on the Bordvedåga deposit and the SE part of the Høgtuva window around the deposit. In total approximately 9 million NOK has been spent (Fig. 1). In this sum also the more regional prospecting covering the Sjona and Høgtuva windows has been included. Most of the work was done in the period 1986-88. All prospecting work has been carried out by the Geological Survey of Norway. Several reports have been compiled and they are, together with selected references from the region, listed in Table 4.

Geological mapping was carried out in scale 1:50 000 in the eastern part of the Høgtuva window. In the regional prospecting campaign mapping was done within the Sjona and Høgtuva windows and in great detail in the Bordvedåga area. This mapping was done in a grid covering all the major mineralized areas (Bordvedåga, Tverrbekkfjellet, Lia and Snøfjellet). All types of surveys on the ground in this area are related to the same grid.

A number of geochemical methods were used with the purpose to find new mineralizations within the two basement windows. Systematic lithogeochemical sampling was carried out in the two windows (600 samples, 1 sample pr. square km). Parts of the windows are covered with stream sediment sampling and heavy mineral sampling in streams by panning. Special studies were made on stream water and moss along streams.

Detailed lithogeochemistry was also carried out on samples systematically collected in the Bordvedåga area within the grid and on the drill cores. All lithogeochemical samples were analysed for major and trace elements including beryllium.

Geophysical helicopter-borne surveys cover the Sjona and Høgtuva windows. The surveys include radiometric, magnetic, VLF and electromagnetic methods. On the same scale susceptibility, gravimetric, and radiometric surveys were carried out on the ground (1 observation locality pr. square km). These are the same localities as used for lithogeochemistry.

Detailed geophysical surveys were made within the grid in the deposit area. This includes radiometric, magnetic, susceptibility, IP, and VLF. Beryllometer surveys were carried out on most of the outcropping Be-mineralizations.

Diamond drilling at the Bordvedåga deposit was done in 1986-88, 45 drill holes totaling 2215 metres. In addition 1028 metres were drilled on the other mineralizations in Lia, at Tverrbekkfjellet and Snøfjellet.

The outcrop of the Bordvedåga deposit provided material for ore dressing tests. The conclusion from the flotation of phenacite is that it is possible to obtain a concentrate with at least 23 % BeO at 80 % recovery.

Prefeasibility study

Separate work on a prefeasibility study was attempted in 1989. This was to be a cooperation between the SINTEF organization and NGU. The aim of the work was to give an answer of the possibility for exploitation of the Bordvedåga deposit and to study the processing of a phenacite concentrate. The possibility for processing at Mo i Rana and the market for beryllium was also included in the project. However, full financing of the study was not achieved and the work had to be curtailed. Some of the results are reported in a preliminary form.

The content of the prefeasibility study was:

- *Ore reserves and mineralogy:* The description of the mineralogy in this report is a summary of the investigations.

- *Dressing of the phenacite* ore was tested on lab. scale and gave good recovery (80-85 %) and an acceptable concentrate. Separation of the Y, Zr, U and REE minerals was not studied.

- *Further processing of phenacite* concentrate was studied, partly using consultants. Reporting, however, was not done.

- *Dressing and extraction* of by-product from the ore was not done.

- *Mining and transport* was also planned to be studied, but was not carried through.

- *Environmental problems* with beryllium processing was studied and a preliminary report was compiled.

- *Market situation* was also studied, but the final report was not written.

The results of this effort has led to some preliminary conclusions, but the material has to be compiled and the results summarized.

Evaluation

Regional geological geochemical and geophysical studies in the Høgtuva and Sjona windows showed the southeastern part of the Høgtuva window to be favourable for Be-enrichments. Comprehensive investigations in that area led to the discovery of the Bordvedåga deposit with a calculated 350,000 tonnes of proven ore averaging 0.18 % Be. A large number of additional Be-mineralizations have been located. These are either considerably smaller or of lower grade than the Bordvedåga deposit. The majority of the mineralizations are disseminations of Be-minerals and other economically interesting minerals in granitic gneiss. The evaluation of the area and the deposit has been made solely on the basis of beryllium.

To exploit a deposit several factors have to be answered positively. These includes: size and grade of the deposit, mining and dressing, transportation and infrastructure, processing and marketing.

The grade of the deposit at cutoff 0.1 % Be averages 0.18 % Be, mainly in phenacite. It is not possible to achieve a better grade on a smaller tonnage partly because of the small thickness of the deposit. The reserves at Bordvedåga may be increased by an extended drilling program which would have to be financed by a mining company or industry. If one should look for additional reserves in the region, the work should be concentrated in the SE corner of the Høgtuva window. This area has the best potential based on the prospecting carried out in the Sjona and Høgtuva windows.

The Bordvedåga deposit is well situated for mining and the operation could be either in open pit or underground. Dressing of the ore has been tested and it seems possible to achieve both good recovery and a high-grade concentrate. Further testing should obviously be done, but so far the preliminary results are promising. By-products may give a significant contribution to the economy of the deposit. So far little has been made to investigate for this possibility.

The location of the Bordvedåga deposit is approximately 12 km from the Rana fjord. An additional ca. 5 km road has to be built to have a direct connection with the fjord. The infrastructure is better than in most places in Norway. Support from local authorities and government can be given for establishing a mine and a plant. Qualified personel with experience in mining, dressing and metallurgy already exist at Mo i Rana.

How far the processing of the Be-concentrate at Mo i Rana should be taken has to be studied. Most likely processing would not be done further than to a beryllium-oxide. The market situation in the western world and the fact that the metal is strategic is a problem for exploitation. However, the deposit is so far the only one proven in western Europe and may be looked upon as a strategic reserve for this part of the world.

A company is needed to complete the evaluation of the exploitation of the deposit. Support from the authorities can be expected, who would want to see as much processing as possible located to the Rana district.

Summary

Investigations in the Høgtuva and Sjona basement windows in the Caledonian mountain belt in Nordland County NW of the town of Mo i Rana has been carried out during the period 1980-1990. Most of the work was focused on the Bordvedåga area and the Bordvedåga deposit in the SE part of the Høgtuva window, 15 km from the center of Mo i Rana. The prospecting methods used are detailed geology, several types of geophysics and bedrock geochemistry. Drilling of the Bordvedåga Be-deposit was done from 1984-1988, with 45 holes totaling of 2215 m. 1015 m of drilling was done on smaller mineralizations in the area. Approximately 9 mill. NOK has been invested, half of it from the Geolgoical Survey of Norway, 2.5 mill. NOK from Norsulfid A/S and the remainder funded by government and local authorities.

The Precambrian basement, which hosts the deposit, is greatly dominated by medium grained granitic rocks. Aplitic dykes and bodies of various shapes are common and show the largest degree of magmatic differentiation (high U, Th, REE, etc.). Mafic dykes occur more frequently in the SE part of the Høgtuva window than elsewhere. The foliation in the basement is parallel with the foliation in the overlying Caledonian nappes. The rocks have undergone amphibolite grade metamorphism.

In the Bordvedåga area a 200 m x 8 km lense of high radioactive granitic gneiss occurs. The lens is strongly enriched in incompatible elements and fluorine. Locally layers of massive fluorite and calcite are found. The Bordvedåga Be-deposit occur as a lens-shaped body within the high radioactive gneiss. Several additional Be-mineralizations are found within the high radioactive gneiss and in its hanging wall and footwall. Enrichment of most of the incompatible elements is considered to be a result of magmatic differentiation. The enrichment of Be took place in a later event which involved hydrothermal F-rich solutions. After deposition the rocks were subject to amphibolite grade metamorphism.

The Geological Survey of Norway has undertaken a limited study of the northern part of Nordland County, regarding it as a province for Be and high technology metals. New localities with Be-mineralization have been recognized. The Bordvedåga area has been investigated to a certain degree and limited drilling carried out. There is a geological potential for additional reserves of Be-ore in the northern part of Nordland County. The first step in proving additional reserves should be further investigations in the Bordvedåga area where a reserve has already been proven.

A prefeasibility study for the exploitation of the Bordvedåga deposit was initiated but not fulfilled. The study was to evaluate the reserves of ore, the mineralogy, the conditions for mining, ore dressing, further processing of a phenacite concentrate, and environmental

problems. The most important conclusion of the uncompleted study was that flotation of phenacite ore gives a concentrate with ca. 23 % BeO at ca. 80 % recovery, which then can be leached with sulphuric acid (80 %). The market for Be-products is very special, a near monoply exists in the western world, with the vertically integrated Brush Wellmann company as the supplier.

The continuation of the Bordvedåga Be-project is dependant on interest from a company that would consider the possibility of entering the Be-market. The main product from the ore would be Beryllium, but metals like Y, Zr, U and REE might give a significant economic contribution, which has so far not been evaluated. The location of the deposit is favorable concerning infrastructure, and establishment of new industry in the region would most likely be supported financially by national and local authorities.

List of Figures and Tables

FUNDING OF THE HØGTUVA PROJECT

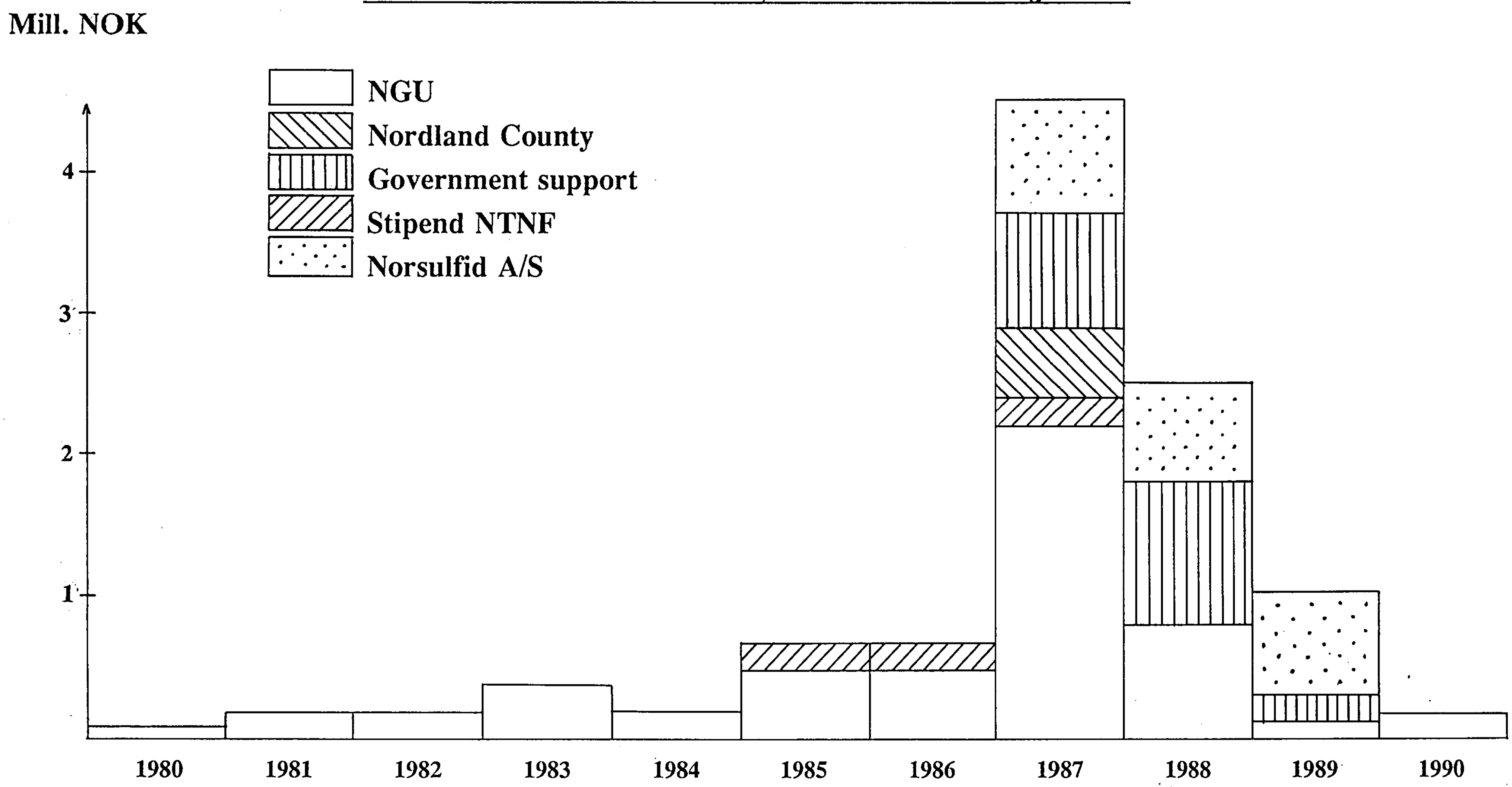

Fig. 1: Cost of the prospecting work in the Høgtuva area 1980 - 1990.

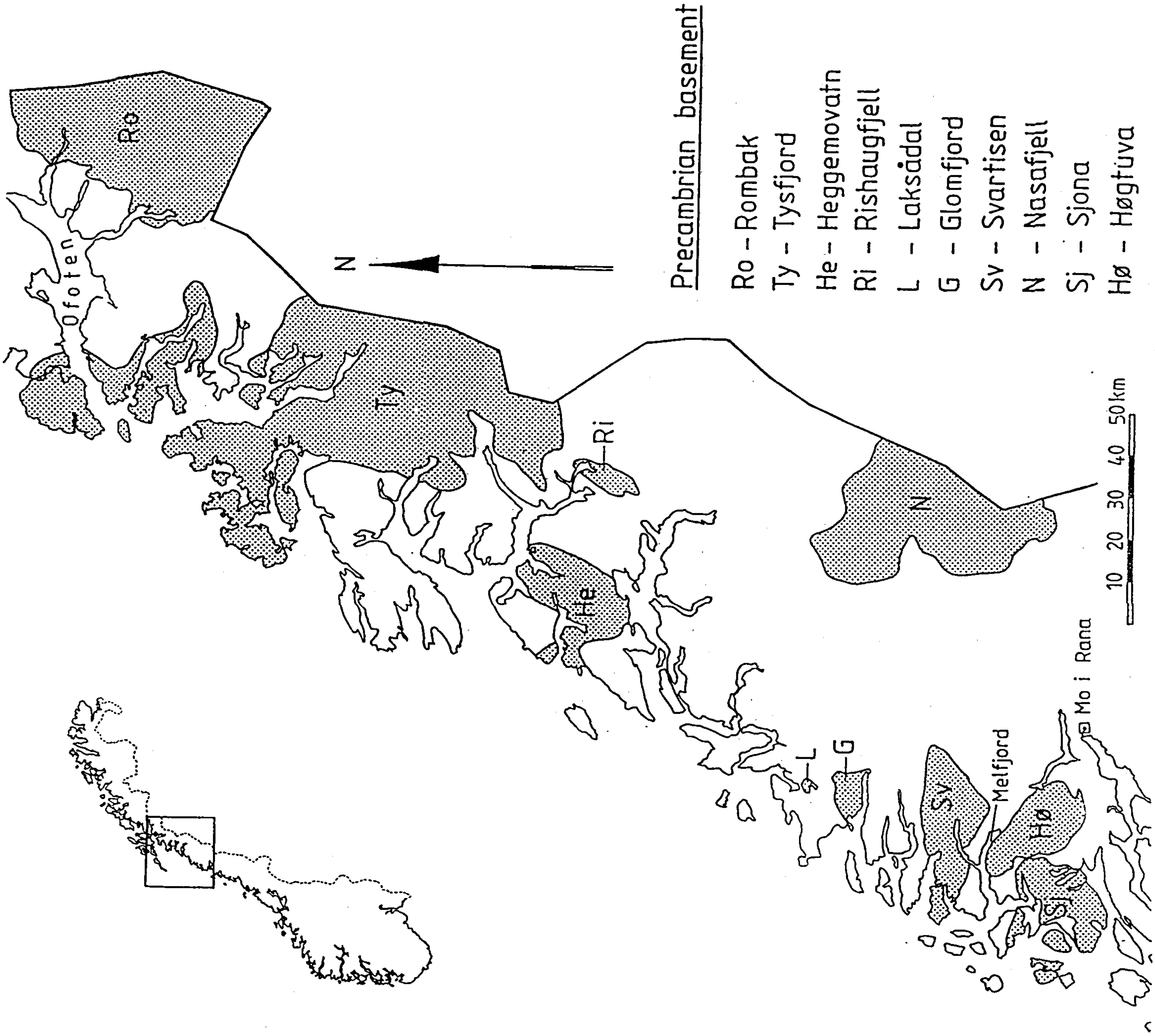

Fig. 2: Simplified geology for Nordland county.
Caledonian rocks with no signature.

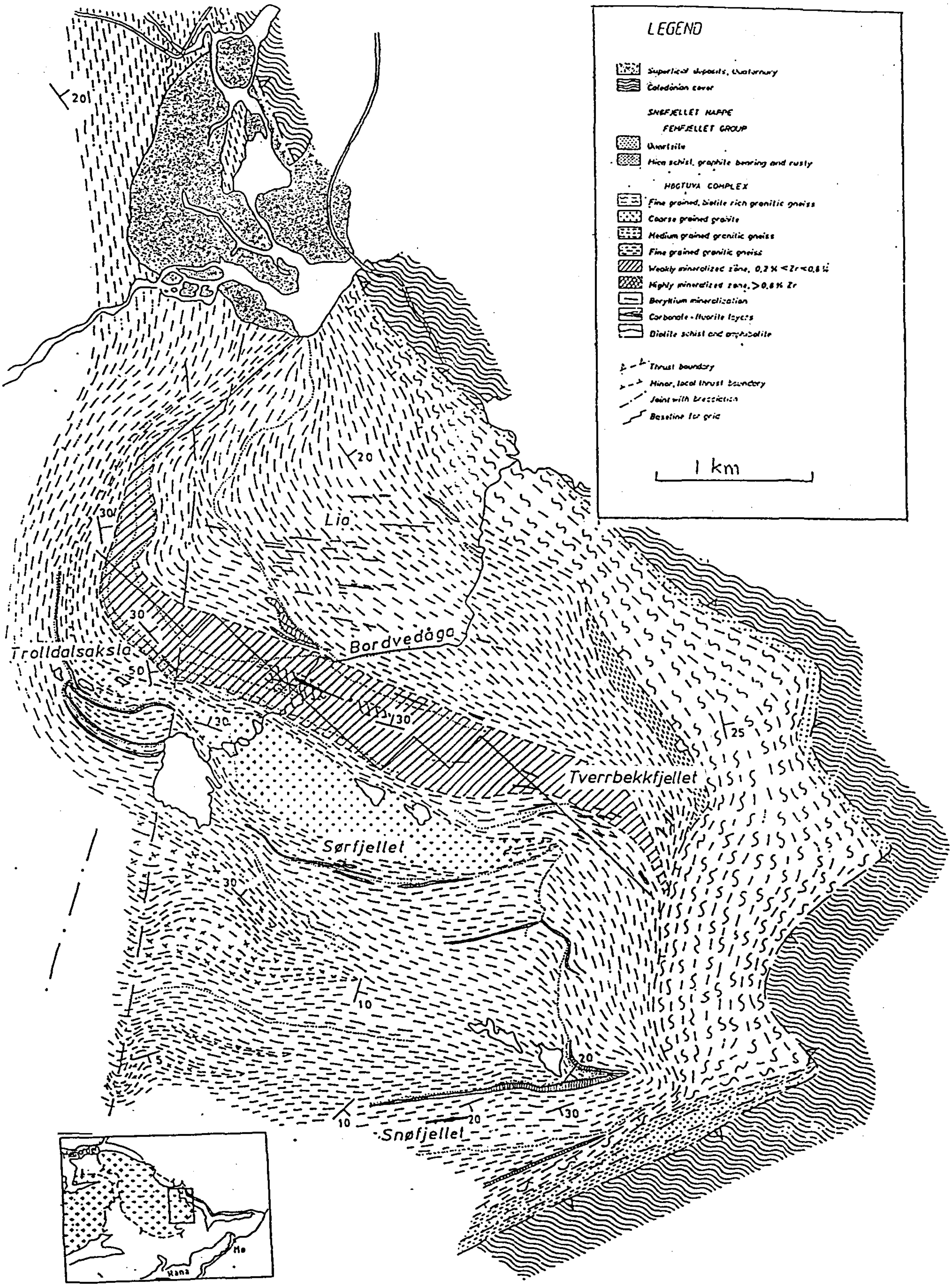

Fig. 3: Geological map of the Bordvedåga area; the eastern part of the Høgtuva Basement window.

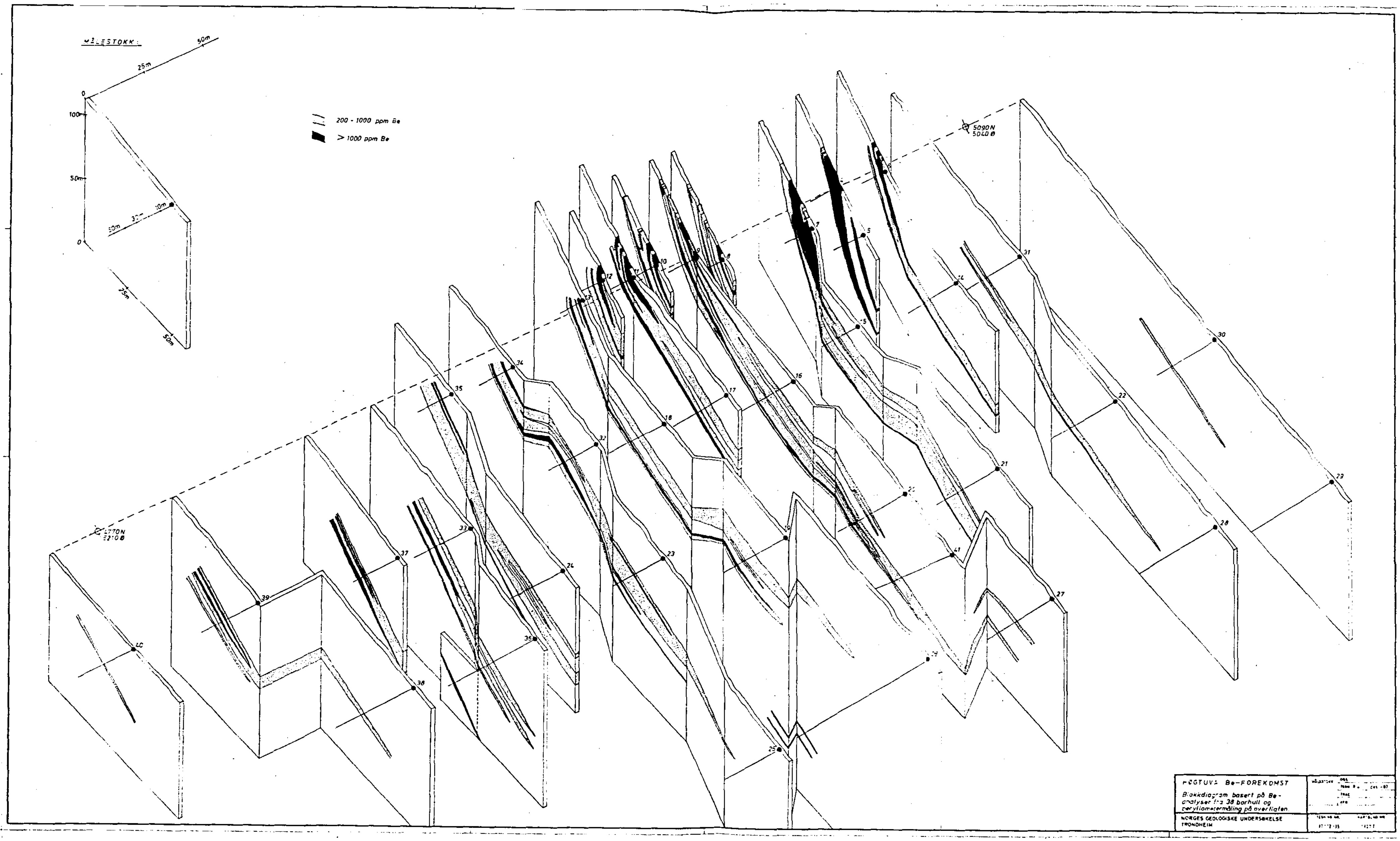

Fig. 4: Block diagram based on diamond drilling results. Scale and grades in the upper left corner.

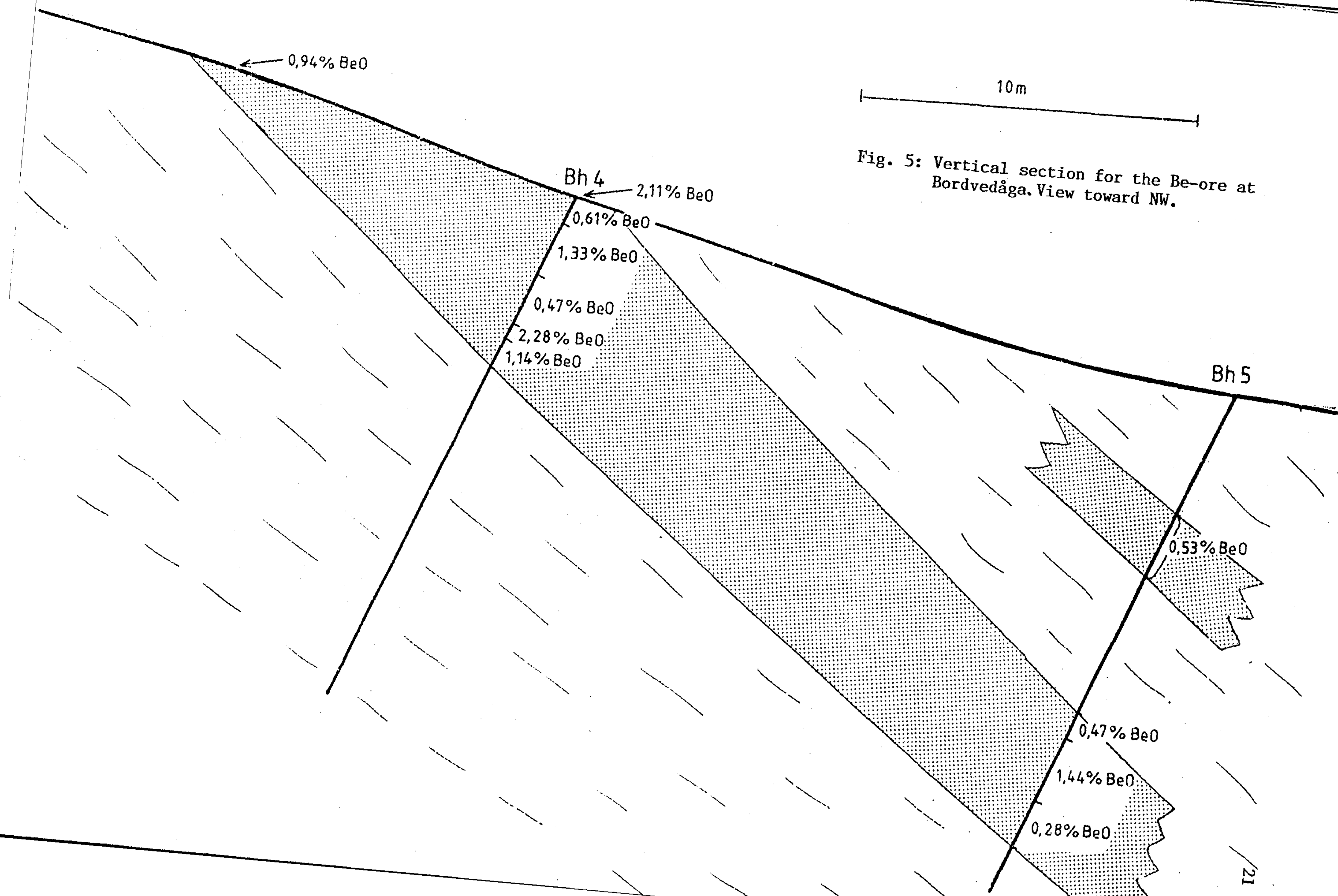

Fig. 5: Vertical section for the Be-ore at Bordvedåga. View toward NW.

Tab. 1. Major (in per cent) and trace elements (in ppm) in hanging wall gneiss (HG), mineralized gneis (MG) and footwall gneiss (FG). Analysed at NGU by XRF.

Number of samples	**FG**	**MG**	**HG**
	11	**35**	**4**
SiO_2	75.3	73.0	75.1
Al_2O_3	12.3	12.0	11.5
TiO_2	0.15	0.21	0.15
Fe_2O_3 (tot.)	1.8	3.6	2.3
MnO	0.04	0.02	0.03
MgO	0.09	0.41	0.26
CaO	0.38	0.26	0.42
Na_2O	3.7	4.2	3.6
K_2O	4.7	3.8	4.5
P_2O_5	<0.01	<0.01	<0.01
Loi	0.26	0.34	0.36
Number of samples	**15**	**108**	**14**
Nb	36	293	34
Zr	360	7733	647
Y	64	644	97
Rb	387	1026	323
Zn	60	210	78
Sn	14	94	11
U	18	149	15
Th	37	278	31
Pb	45	151	52
Co	<10	42	<10
Sr	42	16	108
Ba	146	21	277
Ce	142	346	228
La	54	107	109

Tab. 2. Major (in per cent) and trace elements (in ppm) in BMZ, HMZ and WMZ. Analysed at NGU by XRF. Be is analysed by the fluorimetric method.

	BMZ	HMZ	WMZ
Number of samples	11	58	12
SiO_2	69,93	72,60	72,85
Al_2O_3	12,62	11,92	12,16
Fe_2O_3	4,21	3,18	4,10
TiO_2	0,24	0,25	0,16
MgO	0,13	0,25	0,38
CaO	0,28	0,35	0,45
Na_2O	5,30	4,39	3,85
K_2O	2,93	3,60	4,41
MnO	0,02	0,04	0,03
P_2O_5	< 0,01	< 0,01	< 0,01
K_2O/Na_2O	0,55	0,82	1,15
Nb	606	457	101
Zr	12800	10000	2900
Y	1160	1100	383
Sr	17	26	20
Rb	1287	1200	670
Zn	255	373	154
Cu	11	11	8
V	< 5	< 5	< 5
Ba	25	28	28
Sn	192	125	45
Mo	23	9	13
U	321	232	56
Th	702	408	114
Pb	215	482	72
Co	81	70	19
Ce	448	457	420
La	152	144	157
Be	3700	30	16

Mineral	Be-zone	Y-zone	Identified by Debye Scheerer	Important as bearer of metals of economic interest
quartz	xxxx	xxxx	+	
albite	xxxx	xxxx	+	
microcline	xxxx	xxxx	+	
biotite	xxxx	xxxx	+	Zn
phenacite	xxxx	x	+	Be
høgtuvaite	xxxx	-	+	Be
gadolinite	x(x)	xxx	+	Be, Y, REE, Th
genthelvite	x	x	(+)	Be
allanite	xx(x)	xxx		REE
sphene	xx(x)	xxx	+	Sn
pyrochlore	xxx	x(x)	+	Nb, U
zirkon	xxxx	xxxx	+	Zr, Hf
thorite, orangite, calcio-thorite and uranothorite	xxx	xx	+	Th, U
uraninite	x	x		U
fergusonite	x	xxx		Nb,Y,REE,U,Th
euxenite	-	x		Nb,Y,REE,U,Th
kainosite	-	xx		Y, REE
thalenite	-	xx		Y, REE
yttrialite	-	x		Y, REE, Th, U
fluocerite	x	xx		REE
unidentified LREE-minerals	x(x)	xx		REE, Th, U
cassiterite	x	x(x)		Sn
wolframite	x	x		W
magnetite	xxx	xxx	+	
ilmenite	x(x)	x(x)		
sphalerite	x(x)	xx	+	Zn
galena	xx	xx	+	Pb
molybdenite	x	x		Mo
chalcopyrite	x	x	+	Cu
pyrite	x	x	+	
arsenopyrite	-	-	+	
hornblende	xx	xx		
riebeckite	x(x)	x(x)		
fluorite	xxx	xxx	+	
calcite	x	x		
kyanite	x (?)	x (?)	+	
løllingite	-	-	+	
gøthite	-	-	+	
apatite	x(x)	x(x)	+	
chlorite (rim on biotite)	xxx	xxx		
muscovite	x	x		

Table 3: Identified minerals in the Bordvedåga Be-deposit, with amount in Be-zone and Y-zone. Mineral identification by optical methods, microproble or Debye-Scheerer camera.

xxxx = rock forming mineral, > 1 %
xxx = minor mineral
xx = common accessory mineral
x = accessory mineral
\- = not observed

Table 4: Project reports and selected references for geology and ore geology of the Rana region.

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Krog, J.R. 1988b: Litogeokjemisk undersøkelse av Høgtuva og Sjona grunnfjellsvinduer. XRF-analyser av hovedelementer og to sporelementer. NGU-rapport nr. 88.161.

Lindahl, H. 1989: Innmåling av diamantborhull. Bordvedåga-forekomsten, Rana, Nordland. NGU-rapport nr. 89.065.

Lindahl, I. & Grauch, R.I. 1986a: A Be, U, Sn and REE mineralization in Precambrian granitic gneisses at Høgtuva, Northern Norway. Abstract. Terra Cognita, vol. 6, no. 3, p. 554.

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NGU
NORGES GEOLOGISKE UNDERSØKELSE
Leiv Eirikssons vei 39
Postboks 3006 - Lade
7002 Trondheim
Tel. (07) 90 40 11
Telefax (07) 92 16 20
Telex 55417 NGU N

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- is a neutral and independent organization
- has responsibility for the building-up and maintainence of the national geological databank. The databank will include all available information concerning the bedrock, surficial deposits and groundwater in Norway
- will arrange that this knowledge is available to the wider public in ordre to address national and international tasks.


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