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Economic Geological Report on Marble Deposits in the Salsbruket Area, Central Norway

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REPORT

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Economic Geological Report on Marble Deposits in the Salsbruket Area, Central Norway.

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Summary:

The report contains an economic geological evaluation of the marble deposits in the Salsbruket area. The key market for the Salsbruket marble is considered to be as a filling and coating pigment in the paper industry, and emphasis is given to this application in considering the viability of each deposit.

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Marmor		
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Economic Geological Report on Marble Deposits in the Salsbruket Area, Central Norway

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1. Terms of Reference

This report has been prepared by the author in accordance with the Codes of Conduct (1990) of the Geological Society (UK) and the Code of Professional Conduct of the European Federation of Geologists. Every effort has been made to ensure that the information is factually correct and of the highest possible professional standard.

However, it must be appreciated that the information is derived from a wide variety of sources. Therefore, the author cannot take responsibility for any omissions or inaccuracies for which he is not aware at the time of writing the report, nor for the result of any consequential action that the client may make based on this information.

Summary and Recommendations

a) This report has been commissioned by the Norges geologiske undersøkelse (NGU) with the objective of producing an economic geological evaluation of the marble deposits in the Salsbruket area which could be developed by Norkalsitt AS.

b) The key market for the Salsbruket marble is considered to be as a filling and coating pigment in the paper industry, and emphasis is given to this application in considering the viability of each deposit.

c) Four areas have been defined which could have some technical and/or commercial potential to expand Norkalsitt's reserve base:

Deposit	Access	Distance from Coast (km)	Proved Reserves (tonnes)	Potential Resources (tonnes)	Quality Potential	Overall Potential	Priority for further Exploration
Existing Reserve Base							
Hestvika Surface to -10m	Excellent	0.2 - 0.8	2,500,000		Excellent	Excellent	
Possible Extensions to Reserve Base							
Hestvika -10 to -70m	Excellent	0.2 - 0.8		4,500,000	Good	Excellent	1st
Hestvika Svartdalen	Very good	0.8 - 1.5		4,000,000	Good	Good	2nd
Krokvatnet	Poor	6.0		?	Moderate	Limited	4th
Kvernvatnet	Poor	3.0		?	?	?	3rd

d) A petrological investigation of the Hestvika, Svartdalen and Krokvatnet material would suggest that most of the samples are pure, coarsely crystalline calcitic marbles with minor silicate (mica) and quartz impurities. There is occasional some visible iron pyrite but, within the limited scope of an optical microscopic investigation, there does not appear to be any noticeable graphite. The crystal contacts are typically straight, lacking any major interlocking features, and are likely to separate readily with crushing. This could result in excessive fines production.

e) It is recommended that the Hestvika reserve extension at depth, and the Svartdalen deposit should be evaluated by a more detailed exploration borehole programme to confirm the field observations. Further field mapping should be undertaken on the Kvernvatnet to assess the continuity and quality of the marble believed to be present in this area.

3. Objectives

This report has been commissioned by the Norges geologiske undersøkelse (NGU) as part of a wider exploration programme being undertaken on the carbonate potential of Norway. The principal objective of the report is to produce an economic geological evaluation of the marble deposits in the Salsbruket area which could be developed by Norkalsitt AS as a natural extension of the current Hestvika mineral reserves.

Particular attention is made in the report to the issues which the author believes to be fundamentally important when considering whether a deposit could be commercially viable and of sufficient interest to merit further more detailed investigation. These include:

- what is the key market for the material?
- who is supplying this market at the moment?
- what are the current and future (?) technical requirements for these markets?
- what are the technical advantages and limitations for using the material?
- what are the commercial advantages and limitations for using the material?

Ground calcium carbonate (GCC) can be used in a wide range of applications from low cost/high volume usage in agriculture and construction to high cost/low volume usage in specialised chemically-treated usage in performance plastics. However, the key market which has provided the momentum for the extensive exploration in Norway, undertaken by several international mining companies, during the past 5-10 years is as a filling and coating pigment in the paper industry.

The technical and commercial requirements for this market are extremely demanding as quality and costs are subjected to continual improvement through rigorous competitive pressure. Processing plants are becoming larger and more complex in order to achieve lower operating costs and companies are intent on securing adequate reserves of high quality raw material to support these investments for at least the next 20-30 years.

In several instances, this 'in-house' exploration has satisfied the immediate objectives of the mining companies. However, the market is substantial, it exhibits continual growth and there are, therefore, always new mining companies who are interested in becoming involved in the business.

4. Ground Calcium Carbonates in the Paper Industry

4.1 Markets

In the early 1970's kaolin was the dominant filler as well as the dominant coating pigment used by the paper industry. The installation of new paper production capacity led to an unexpectedly large demand for this pigment but the European customers were discouraged by the high prices and tough pricing policy of the suppliers and thus began to look for alternatives. Many woodfree mills switched to neutral sizing with the aim of profiting economically from the use of natural ground calcium carbonate as a filler. The main factors for this change to neutral sizing was the higher brightness and lower cost of GCC, together with a range of technical advantages.

In the early 1980's calcium carbonate had a market share of merely 20% among the coating pigments in Europe. Currently (1992) the figure is 42-43% and by now has replaced kaolin as the dominant coating pigment.

4.2. Current European Production

It is not the intention of this report to review the current European production of GCC. However, there are three main companies involved in the development of GCC for the European paper coating market as follows:

a) Pluess-Staufer AG (Omya)
CH-4665 Oftringen, Switzerland

Private family owned and managed company established in 1884 and specialising in the world-wide production and marketing of ground calcium carbonates for use in a wide range of applications principally paper, plastics, paint and agriculture.

b) ECC International Ltd
John Keay House, St.Austell, Cornwall, UK

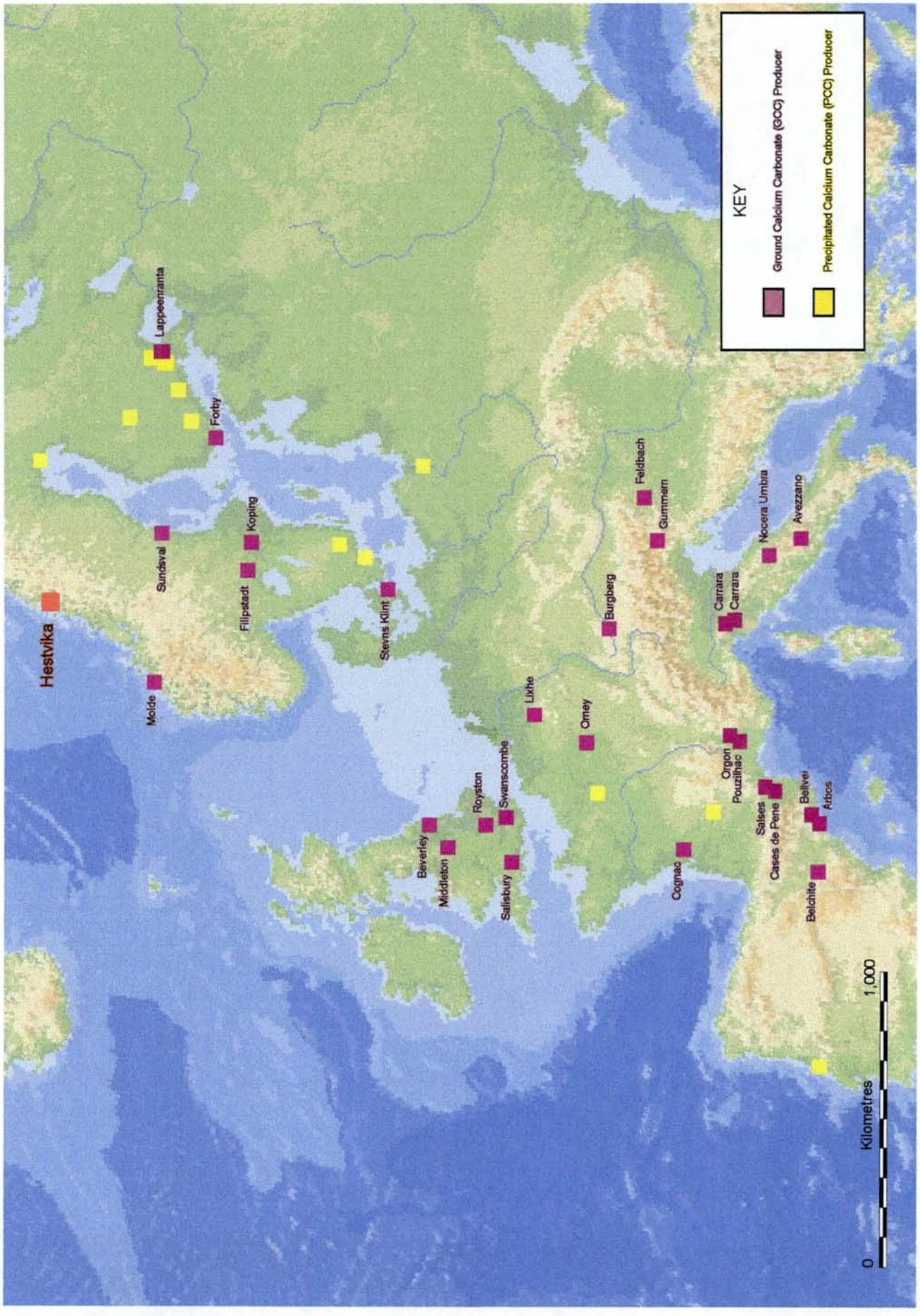
A major public limited company with the largest kaolin production in the world. The company specialises in the world-wide production and marketing of kaolin and ground calcium carbonates for use in a wide range of industrial applications including paper, ceramics, plastics and paint .

c) Faxe Kalk
Frederiksholms Kanal 16, 1220 Copenhagen, Denmark

Faxe Kalk is a public limited company owned by Group Lhoist, the Belgium lime producer. The company specialises in the production of high quality, chalk-based products from deposits at Stevns Klint, south of Copenhagen together with the production of precipitated calcium carbonate at several satellite plants adjacent to paper mills in Europe and N.America.

For locations of European calcium carbonate producers, see Figures 1

Map Showing General Locations of Major European GCC Producers Figure 1



4.3 Product Specifications

There are a wide range of specifications which are important in defining the suitability of a calcium carbonate sample for the paper industry. Typically, these specifications will include chemical and mineralogical purity, particle size and colour. The standards required for pigments with different applications are set by the quality of the currently available products and are continually changing as producers seek to find competitive advantages for their own products.

The following information relates to the Carbital/Carbilux products produced by ECC International and the Hydrocarb products produced by Pluess-Staufer.

Typical pre-coating pigments (Carbital 60) are relatively coarse with a particle size content of 60 wt.% less than 2 microns. Carbital 75 is finer at 75 wt.% less than 2 microns and can be used for pre-coating or matt and semi-matt coatings.

Typical top-coating or gloss-coating pigments (Carbital 90 and Hydrocarb 90) are relatively fine at 90% less than 2 microns with a new generation of high glossing pigments (Carbilux) with 90 wt.% less than 1 micron.

General development trends towards finer products and steeper and more precise particle size distribution curves.

Typical properties of a Carbital 90 type paper coating pigment are as follows:

Chemical properties	$CaCO_3$	98.1 wt.%
	$MgCO_3$	1.4
	SiO_2	0.4
	Fe_2O_3	0.04
	pH at 10% solids	9.6
Physical properties	Particle size distribution	
	+53μ maximum	0.01 wt.%
	+20μ maximum	0.1
	+10μ maximum	1.0
	+5μ	4
	-2μ	90
	-1μ	70
	Specific gravity	2.70
	Viscosity @ 70%	2.0 poise
Optical properties	I.S.O. Brightness	95.0±1.0
	Yellowness	1.0
	Mean refractive index	1.58

5. Salsbruket Marble Deposits

5.1 Location and Estates

Salsbruket is situated in the Nord-Trondelag Fylke, 170 km north-north-east of Trondheim.

The town is 63 km from the main Steinkjer to Mosjøen highway (E6) and is accessed with a recently improved metalled road via the town of Høylandet. This road crosses the Grønnings fjellet mountains and can become impassable during the winter.

Salsbruket can also be reached from the north by ferry via Hofles and Geisnes. The closest airport is 30 km to the north at Rørvik.

Salsbruket is located directly on the coast at the head of the Foldfjorden and has excellent access by sea. The town has a small harbour which is currently disused following a fire which destroyed the local paper mill.

Hestvika is situated 7 km west of Salsbruket adjacent to the Salsbruket/Geisnes road. Access to the current underground mine is within 500 metres of the coast although currently all crushed marble is transported 7 km by road to a small harbour at Geisnes for shiploading. The current maximum vessel size capable of using this facility is 2,500-3,000 tonnes. However, new development is in progress which involves construction of an underground access drive from the deposit to an on-site harbour facility capable of handling up 10,000 tonne vessels.

The area is generally sparsely populated and consists of open moorland and forest with a maximum elevation of 360 metres above sea-level. The region is not developed for tourism but is a recognised destination for hunting and fishing. There is no history in the region for mining although until recently there was a substantial paper plant at Salsbruket which attracted a wide range of skill people to the area. This plant was destroyed by fire in the 1980's and no alternative employment has been developed.

Norkalsitt AS have access to mineral exploration rights for in excess of 500 hectares of land in the Salsbruket area together with all of the necessary exploitation rights, permissions and agreements to undertake commercial development of marble on the Hestvika property.

All major services are available in the region including hydro-electricity which is generated locally.

For general location map of the Salsbruket area, see Figure 2

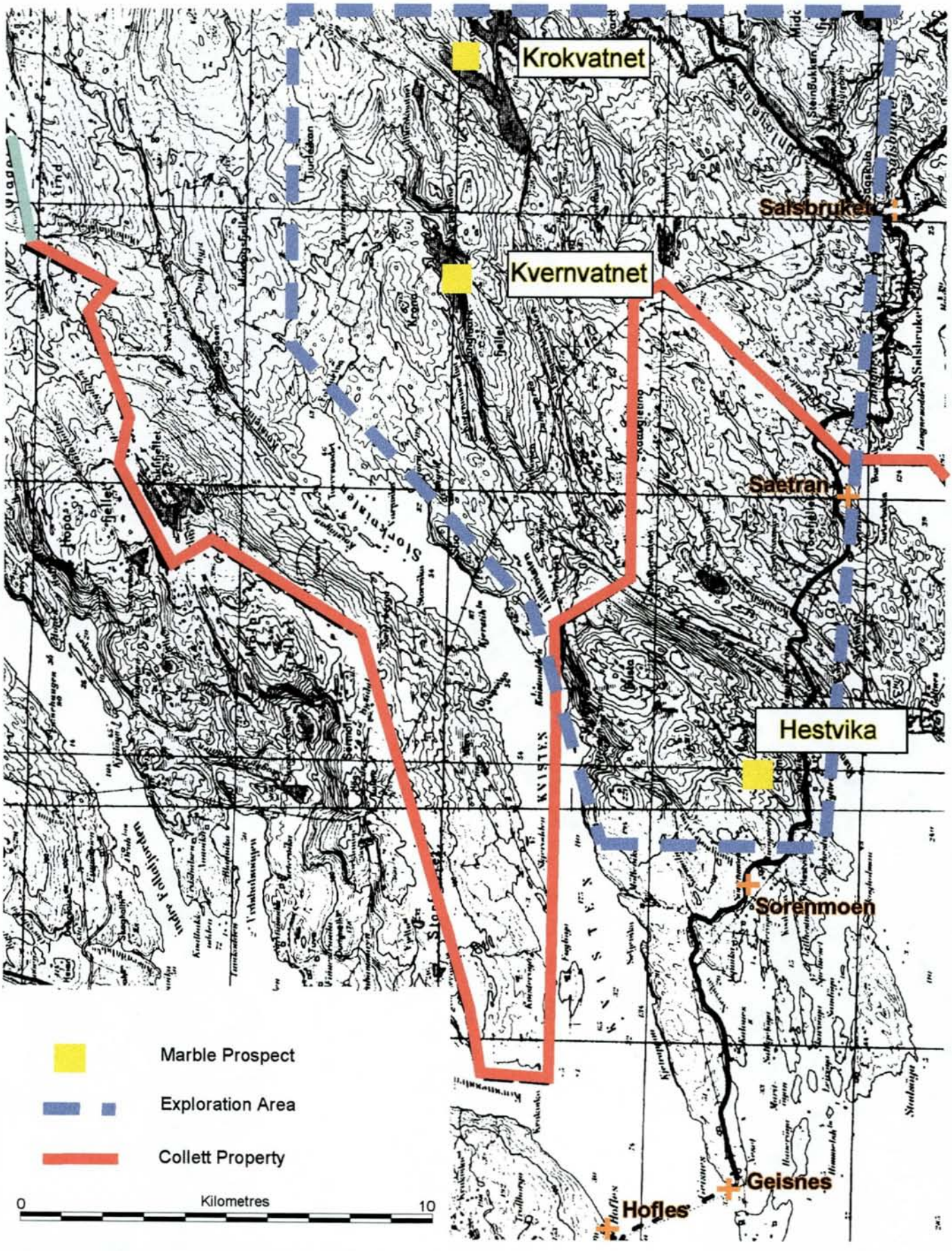
For a general location map of exploration area, see Figure 3

General Location Map of Salsbruket Area

Figure 2

General Location Map of Salsbruket Exploration Area

Figure 3



5.2 Geology

5.2.1 General geology

The rocks in the Salsbruket area consist of a cover of metapsammites, gneisses, calc-silicate schists, amphibolites and calcitic marbles overlying a basement sequence of porphyroclastic augen gneisses and granites.

The marble horizons exposed in the area occur within an undifferentiated sequence of biotite gneiss and amphibolite and appear as three synclinal structures 'nested' within each other. These synclines trend north-east/south-west and have very steeply dipping limbs which are frequently vertical or over-turned. The structures plunge to the south-west and possibly represent the same horizon repeated by folding and faulting.

For the purposes of this report these structures are referred to as the Hestvika, Kvernvatnet and Krokvatnet structures.

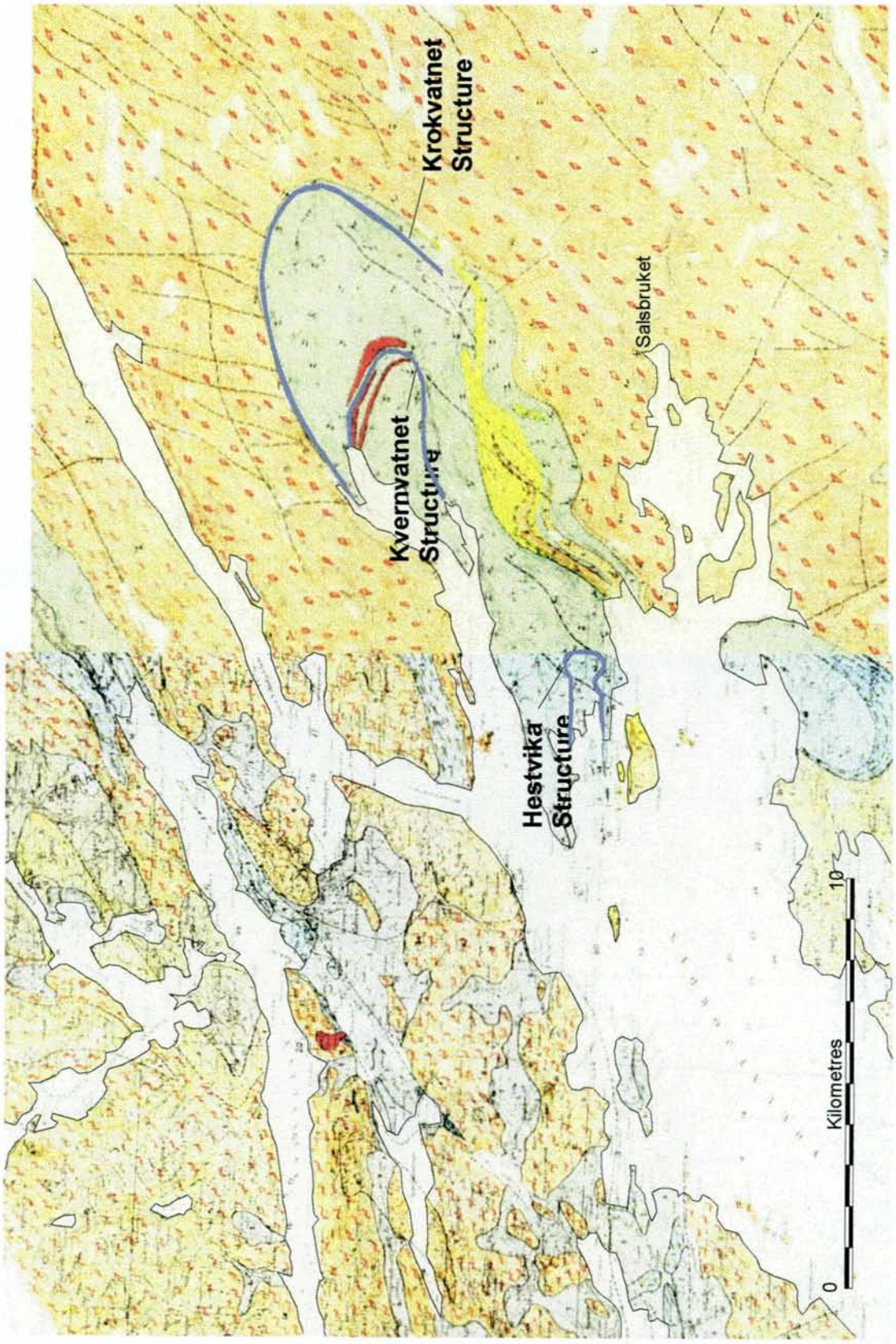
The marble horizon is typically 25-35 metres wide and shows a very distinct contact with the adjacent amphibolites and schists. The structure of the horizon is extremely continuous despite minor, shallow-angle, transverse faulting which seldom displaces the marble for more than 1-2 metres. These fractures are occasionally infilled with a dark green clay ('fault gouge') and may produce minor localised folding within the marble.

Water movement within the marble is very dependant on fissure-flow along the fracture zones, particularly in the areas effected by the shallow-angle faulting. The majority of the current reserve at Hestvika will be available for exploitation without the need for substantial pumping. This will involve utilisation of a new access level from the harbour as the main drainage system. However, if the reserve below sea level is to be exploited in the longer term, pumping will be required and this could result in some salt-water incursion which will need to be carefully monitored.

The marble typically consists of coarsely crystalline calcite (<5mm) with very small amounts (<0.5%) of acid insoluble residue (mainly mica, quartz and minor iron pyrite). Recent ironstaining, related to water percolation through the deposit, is frequently evident on near surface fracture surfaces and this can have a detrimental effect on the colour of the adjacent 10-20mm of marble. Unusually for a Norwegian marble, the material lacks any appreciable amount of graphite. This aspect is of particular benefit in the production of high brightness ultra-fine ground products for the paper industry.

For a general geological map of the area, see Figure 4

General Geological Map of the Salsbruket Area Figure 4



5.2.2 Samples

Thirteen samples were collected for petrographic study from the marble deposits in the Salsbruket area, including four samples from the Krokvatnet structure. These samples were designated as follows:

Salsbruket Project Area

1/97	Hestvika	White, coarsely crystalline marble
2/97	Krokvatnet	White/pale pink marble with silicates
3/97	Krokvatnet	Pale grey, medium crystalline marble with visible mica
4/97	Krokvatnet	White, pale grey, medium crystalline marble
5/97	Krokvatnet	Pink, finely crystalline marble
6/97	Hestvika	White, coarsely crystalline marble
7/97	Hestvika	Grey, medium crystalline marble with abundant silicates
8/97	Hestvika	Cream, medium crystalline marble
9/97	Hestvika	White, finely crystalline marble with pale green silicates
10/97	Hestvika	White, finely crystalline marble
11/97	Hestvika	Grey, coarsely crystalline marble
12/97	Hestvika	Dark grey, medium crystalline marble
13/97	Hestvika	Cream, finely crystalline marble

The samples were stored at the mine office at Hestvika prior to being returned to the NGU laboratories at Trondheim for evaluation. Small (50gm) representative samples were collected from each of the larger samples and were returned to the UK for petrological investigation.

For details of sample locations, see Figures 8 and 10

5.2.3 Petrography

The Hestvika deposit is an extremely pure, white, calcitic marble with minor silicate and quartz impurities. It is unusual in that the rock contains virtually no included graphite particles which normally have a detrimental effect on the brightness of finely-ground products. In different parts of the deposit the rock has both a coarse and finely crystalline texture.

A standard 3"x1" thin section was prepared from each sample by Camborne School of Mines.

The thin sections were examined by a conventional Vickers transmitted light, polarising microscope, with photomicrographs taken on standard Agfacolour HDC 200 ISO colour negative film using a camera body mounted on a trinocular head. These photographs were taken using a x4 lens and a x10 eyepiece resulting in 3mm x 2mm field of view.

The rocks are generally coarse-grained, and as only one thin-section was prepared from each sample it was impossible to make quantitative estimates of mineral abundance. Minerals are therefore recorded as major (>10%), minor (1-10%) and trace (<1%).

Sample number 1/97 - Hestvika

Mineralogy

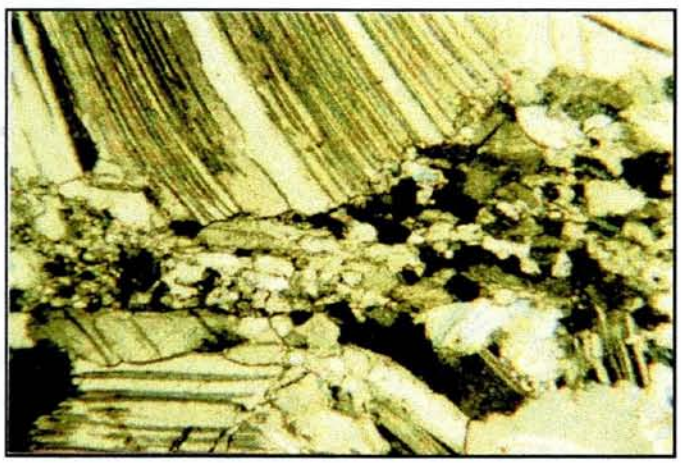
Calcite	major

Description

The rock is a pure, very coarsely crystalline calcitic marble with a granoblastic texture in which the calcite shows no apparent mineral elongation but has distinct curved strain lamellae. It consists of approximately equigranular crystals of calcite which range in size from 500μ to 3 mm. with a cement of fine calcite crystals (100-200μ). The crystal boundaries are typically partly tessellated to straight with some open cavities.

Photomicrographs

Sample 1/97 Plane polarised light



Sample 1/97 Crossed polarised light

Sample number 2/97 - Krokvatnet

Mineralogy

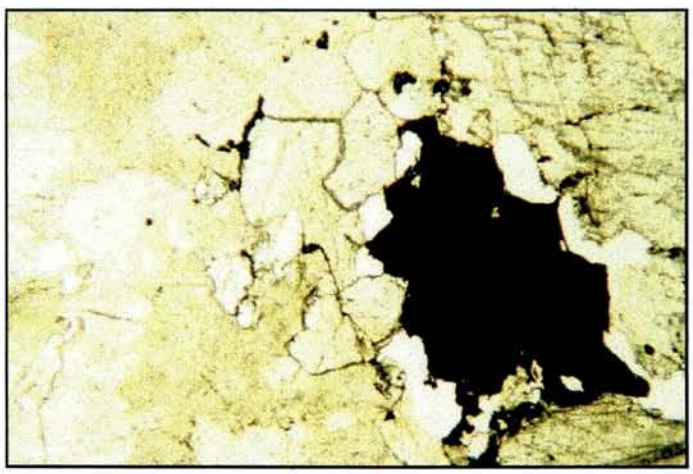
Calcite	major
Mica	trace
Quartz	trace

Description

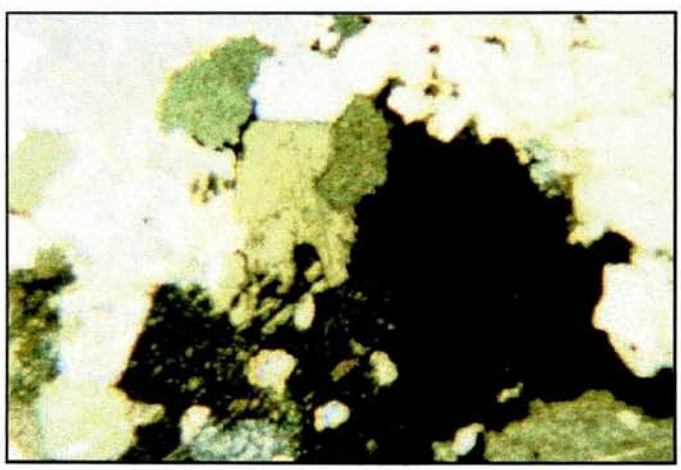
The rock is a medium crystalline calcitic marble with observable lathes of silicate minerals (mica), quartz and a frequent infilling of iron pyrites between the crystals boundaries . It consists of approximately equigranular crystals of calcite which range in size from 500μ to 5 mm. The crystal boundaries are typically extremely straight and lack any interlocking, sutured features.

Very effective liberation of the silicates and quartz could be achieved by grinding to approximately 50μm. However, release of the pyrites would not be complete at this particle size with some fine material (<25μ) still remaining on the crystal boundaries.

Photomicrographs



Sample 2/97 Plane polarised light



Sample 2/97 Crossed polarised light

Sample number 3/97 - Krokvatnet

Mineralogy

Calcite	major
Mica	minor

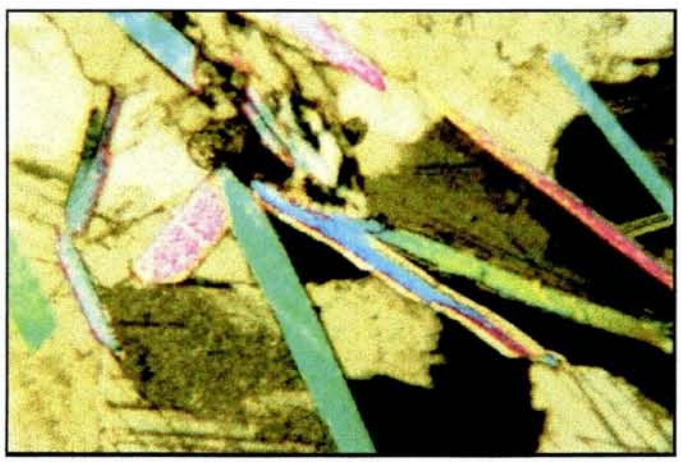
Description

The rock is a medium to coarsely crystalline calcitic marble with no apparent mineral elongation or obvious textural fabric. It consists of approximately equigranular crystals of calcite (500μ to 1000μ) interspersed with elongated lathes of mica (1500-2000μ). The crystal boundaries are typically extremely straight and lack any interlocking, sutured features. However, the contacts are extremely tight and generally lack the presence of any recrystalline material.

The silicates could probably effectively be removed by grinding to 200 μm.

Photomicrographs

Sample 3/97 Plane polarised light



Sample 3/97 Crossed polarised light

Sample number 4/97 - Krokvatnet

Mineralogy

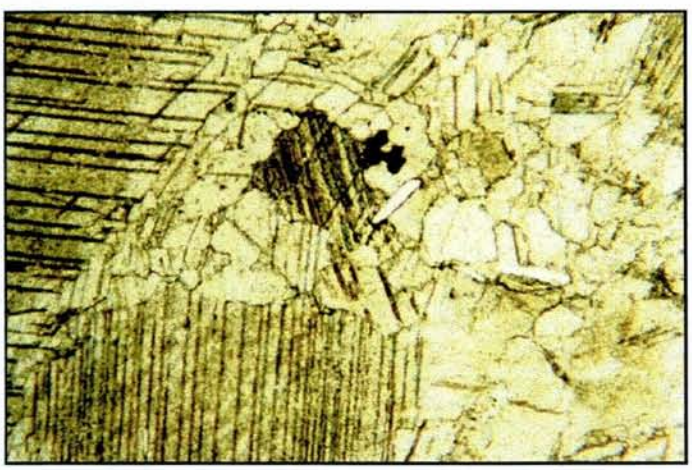
Calcite	major
Quartz	trace
Mica	trace

Description

The rock is a very coarsely crystalline calcitic marble with large crystals of calcite (2-3mm) cemented by a ground-mass of finely crystalline calcite (100-300μ). Although there is no apparent mineral elongation, the calcite crystals do show a very distinctive lamellar structure. The crystal boundaries show some minor interlocking, sutured features and the whole rock has a coherent structure.

Minor amounts of fine (<300μ) mica and quartz are visible but have a very clean contact with the calcite and could be readily liberated by grinding to 250μm.

Photomicrographs



Sample 4/97 Plane polarised light

Sample 4/97 Crossed polarised light

Sample number 5/97 - Krokvatnet

Mineralogy

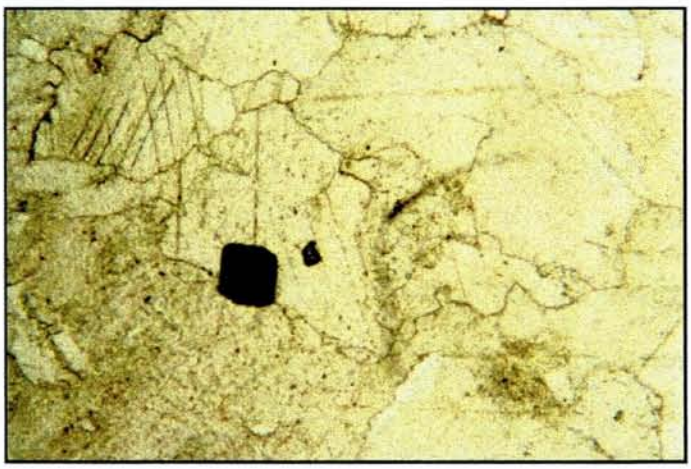
Calcite	major
Quartz	trace

Description

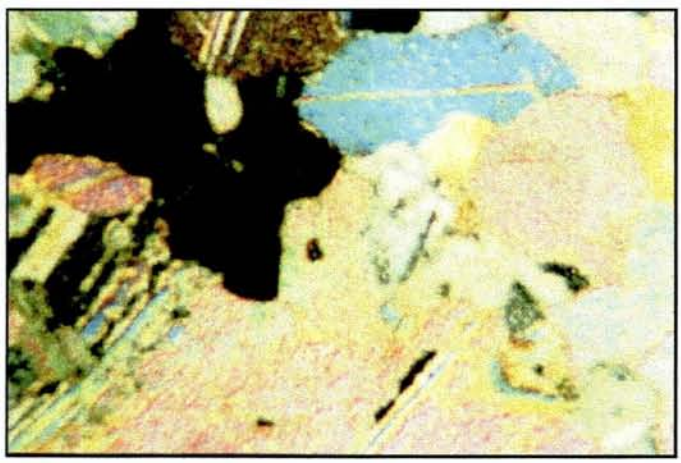
The rock is a pure, medium crystalline calcitic marble with a granoblastic texture in which the calcite shows no apparent mineral elongation. The equigranular crystals of calcite range in size from 500μm to 2000μm and have crystal boundaries with interlocking, sutured features.

Occasional pyrite cubes are visible and would be released by grinding to 250μm.

Photomicrographs



Sample 5/97 Plane polarised light



Sample 5/97 Crossed polarised light

Sample number 6/97 - Hestvika

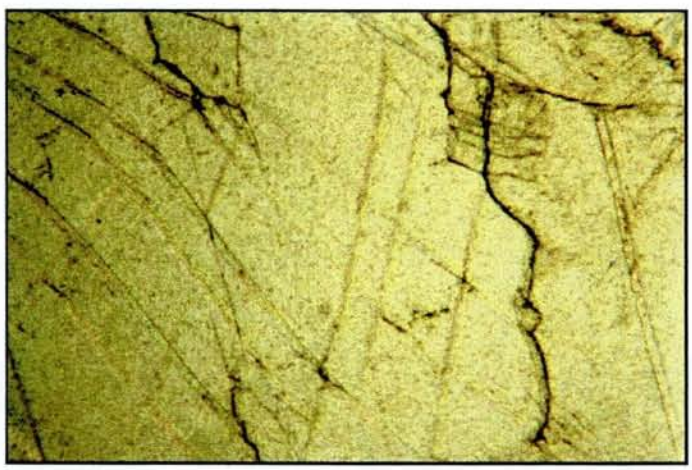
Mineralogy

Calcite	major

Description

The rock is a pure, extremely coarsely crystalline calcitic marble with a granoblastic texture in which the calcite shows pronounced curved strain lamellae. The crystals of calcite range in size from 500μ to 5 mm. and have typically straight crystal boundaries with minor sutured features. However, the contacts show frequent fracturing, both parallel and perpendicular to the crystal interfaces and this would suggest that the material would produce excessive fines during coarse grinding.

Photomicrographs



Sample 6/97 Plane polarised light

Sample number 7/97 - Hestvika

Mineralogy

Calcite	major
Mica	minor
Quartz	trace

Description

The rock is a medium crystalline calcitic marble with some texture visible in the slight elongation of the calcite crystals(?). It typically consists of equigranular crystals of calcite which range in size from 500μ to 2 mm. with extremely straight crystal boundaries lacking any interlocking, sutured features. The calcite shows very pronounced internal lamellae.
There is frequent silicate mineralisation (mica and diopside) ranging from 200-1500μm, and occasional quartz visible in the specimen with very clean contacts with the calcite.

Photomicrographs

Sample 7/97 Plane polarised light

Sample 7/97 Crossed polarised light

Sample number 8/97 - Hestvika

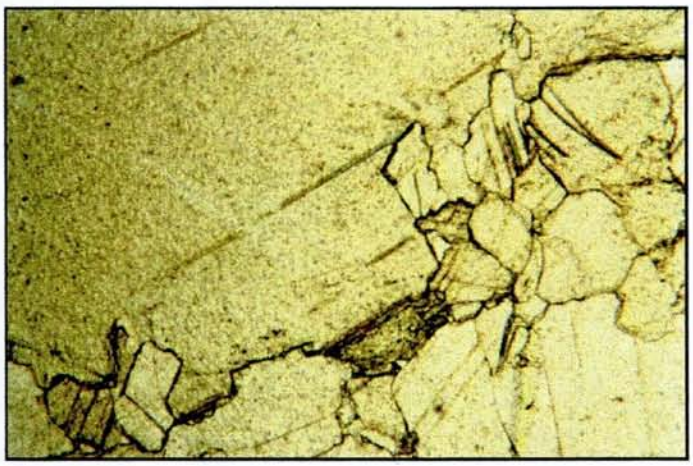
Mineralogy

Calcite	major

Description

The rock is a pure, coarsely crystalline calcitic marble with a distinctive granoblastic texture. in which the. It consists of large, irregular calcite crystals, ranging in size from 1 to 4mm, cemented by medium crystallised (250-750μm), strongly fractured calcite with straight, slightly interlocking crystal boundaries. The calcite shows very distinctive internal lamellae.

Photomicrographs



Sample 8/97 Plane polarised light

Sample 8/97 Crossed polarised light

Sample number 9/97 - Hestvika

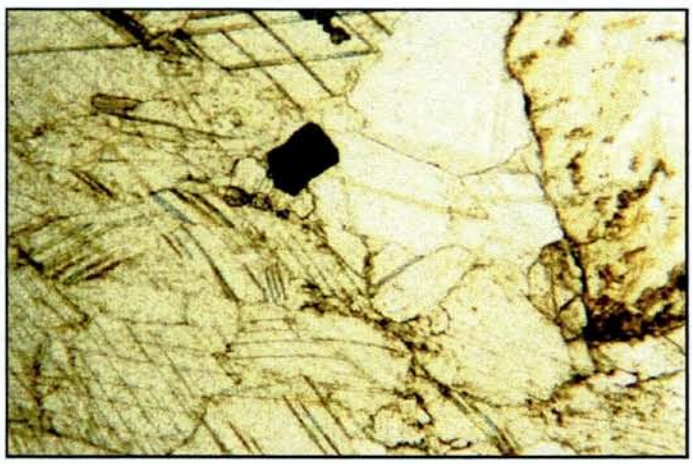
Mineralogy

Calcite	major
Quartz	trace

Description

The rock is a medium crystalline (750-1500μm) calcitic marble with a granoblastic texture in which the calcite shows a distinctive rhomboidal cleavage pattern. The crystals of calcite have tight interlocking boundaries and are frequently cemented by a ground-mass of finely crystalline calcite. Minor cubes of iron pyrites (300μm) occur within the calcite together with occasional corroded crystals of pyroxene. These impurities could be released by grinding the marble to 250μm.

Photomicrographs



Sample 9/97 Plane polarised light

Sample 9/97 Crossed polarised light

Sample number 10/97 - Hestvika

Mineralogy

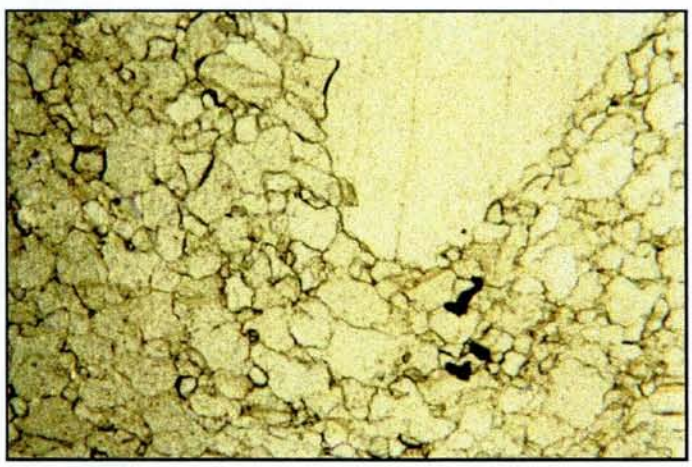
Calcite	major
Quartz	trace

Description

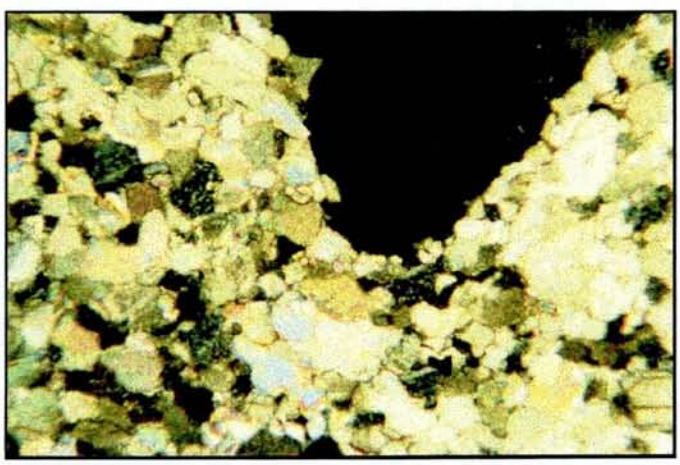
The rock is a pure, finely crystalline(<250μm) calcitic marble with occasional larger (1500-2000μm) included phenocrysts of quartz. The calcite has a typical granoblastic texture in which the crystals show no apparent mineral fabric. It consists of approximately equigranular crystals of calcite with straight and curved crystal boundaries lacking any regular interlocking, sutured features.

Occasional small (<250μm) inclusions of iron pryite are found within the calcite and would readily be released by grinding the marble to <200μm.

Photomicrographs



Sample 10/97 Plane polarised light



Sample 10/97 Crossed polarised light

Sample number 11/97 - Hestvika

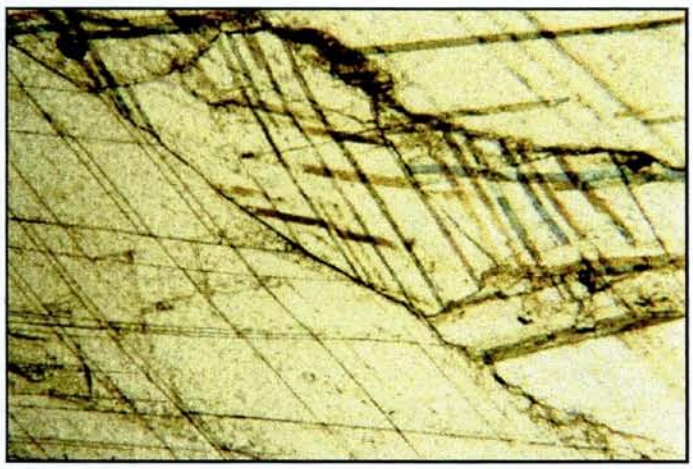
Mineralogy

Calcite	major
Quartz	trace

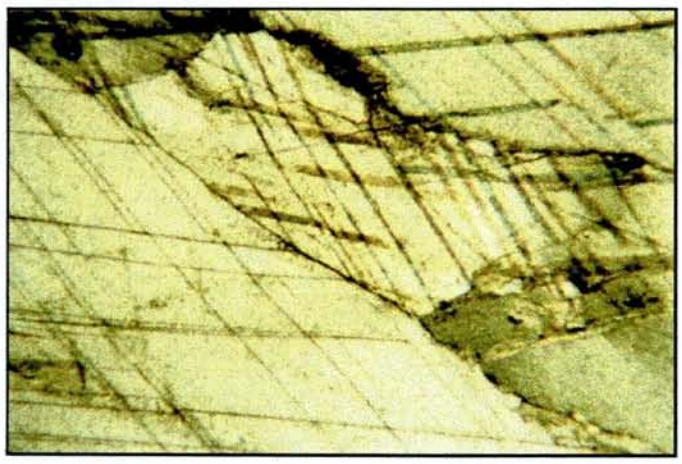
Description

The rock is a pure, very coarsely crystalline calcitic marble in which the crystal to crystal contacts are typically extremely straight and lack any interlocking, sutured features. The typical granoblastic texture of the marble shows no apparent fabric and consists of approximately equigranular crystals of calcite which range in size from 1000μm to 15 mm. The surface of the calcite crystals shows a very pronounced cleavage and it is likely that grinding would readily breakdown the calcite along these cleavage plane producing abundant fines.

Photomicrographs



Sample 11/97 Plane polarised light



Sample 11/97 Crossed polarised light

Sample number 12/97 - Hestvika

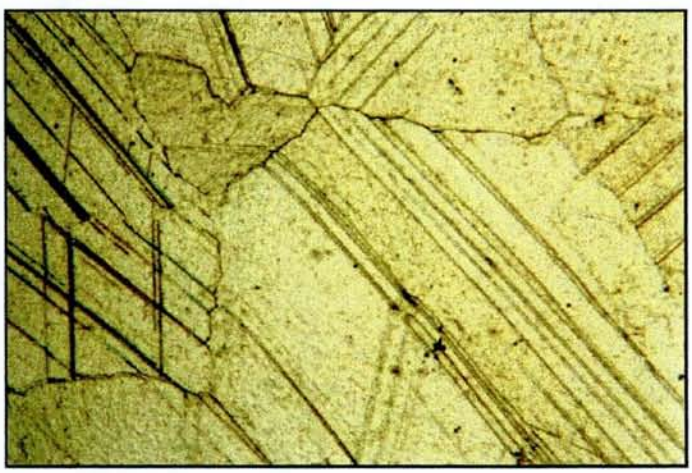
Mineralogy

Calcite	major
Quartz	trace

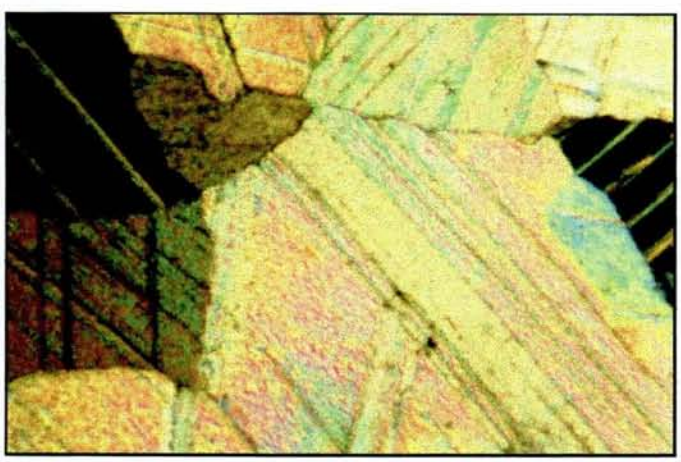
Description

The rock is a pure, very coarsely crystalline calcitic marble in which the crystal boundaries are straight to slightly tessellated and lack any major interlocking, sutured features. The typical granoblastic texture of the marble shows no apparent fabric and consists of approximately equigranular crystals of calcite which range in size from 1000μm to 5mm. As with sample 11/97 the surface of the calcite crystals shows a very pronounced cleavage and it is likely that grinding would readily breakdown the calcite along these cleavage plane producing abundant fines.

Photomicrographs



Sample 12/97 Plane polarised light



Sample 12/97 Crossed polarised light

Sample number 13/97 - Hestvika

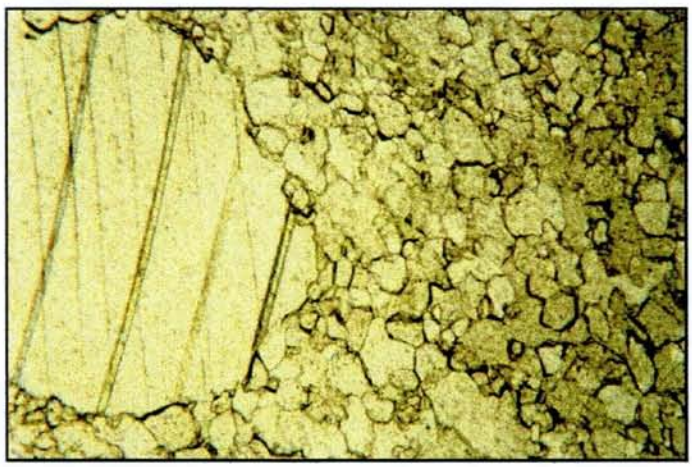
Mineralogy

Calcite	major
Quartz	trace

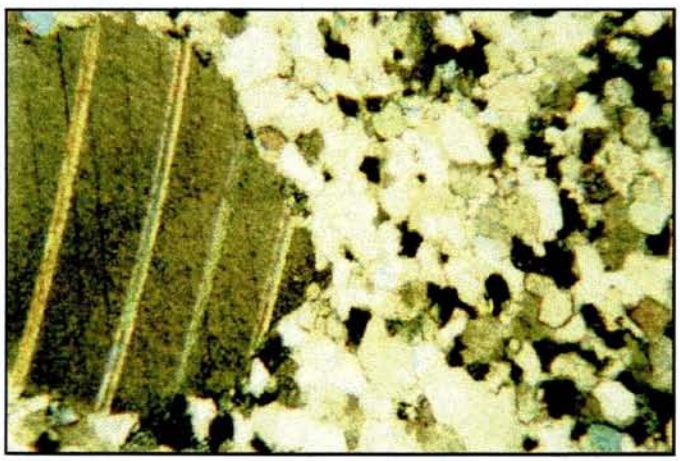
Description

The rock is a pure, coarsely crystalline calcitic marble with large crystals of calcite in a mosaic-like groundmass of finely crystalline (100-200μm) calcite. The large equigranular crystals of calcite range in size from 500μ to 3 mm. The crystal boundaries are typically slightly interlocking with minor sutured features.

Photomicrographs



Sample 13/97 Plane polarised light



Sample 13/97 Crossed polarised light

5.3 History of Exploration

Although the marble occurrences in the Salsbruket area have been known for many years, they have only been explored in detail during the past 20 years.

The primary exploration target has been the marble deposit at Hestvika because of its good exposure, excellent access and obvious high quality.

This marble deposit was first evaluated in detailed by AS Sydvaranger and Nocolay Buch AS during 1980. Nine boreholes were drilled (total depth 1,073 metres) along the eastern flank of the deposit and 130 samples were tested. This exploration programme concluded that there was a central high brightness marble zone with a potential resource of 5.5 million tonnes.

The exploration data was re-assessed in 1984 by Aspro Prospektering (Report No. 1227 - Øyvind Gvein) and the reserves available within a 620 metre mining block, from surface to 10 metres below sea level were established to be 2.2 - 2.5 million tonnes.

During 1988, the deposit was re-evaluated by the NGU on behalf of Norcem AS (NGU Report 88.194 - Odd Overeng). Eleven additional boreholes were drilled (total depth 825 metres) concentrating on the southern flank of the deposit and considerable laboratory and process studies were undertaken. This information was comprehensively reported by Norcem during 1989 ('Hestvika Kalsittforekomst' - Norcem AS).

In the Summer 1990, the tectonic and metamorphic history of the Salsbruket-Kvisten area was investigated in detail by Reidun Rovde and Anne Ullern (University of Bergen) and during their field mapping, several other areas of calcitic marble were identified.

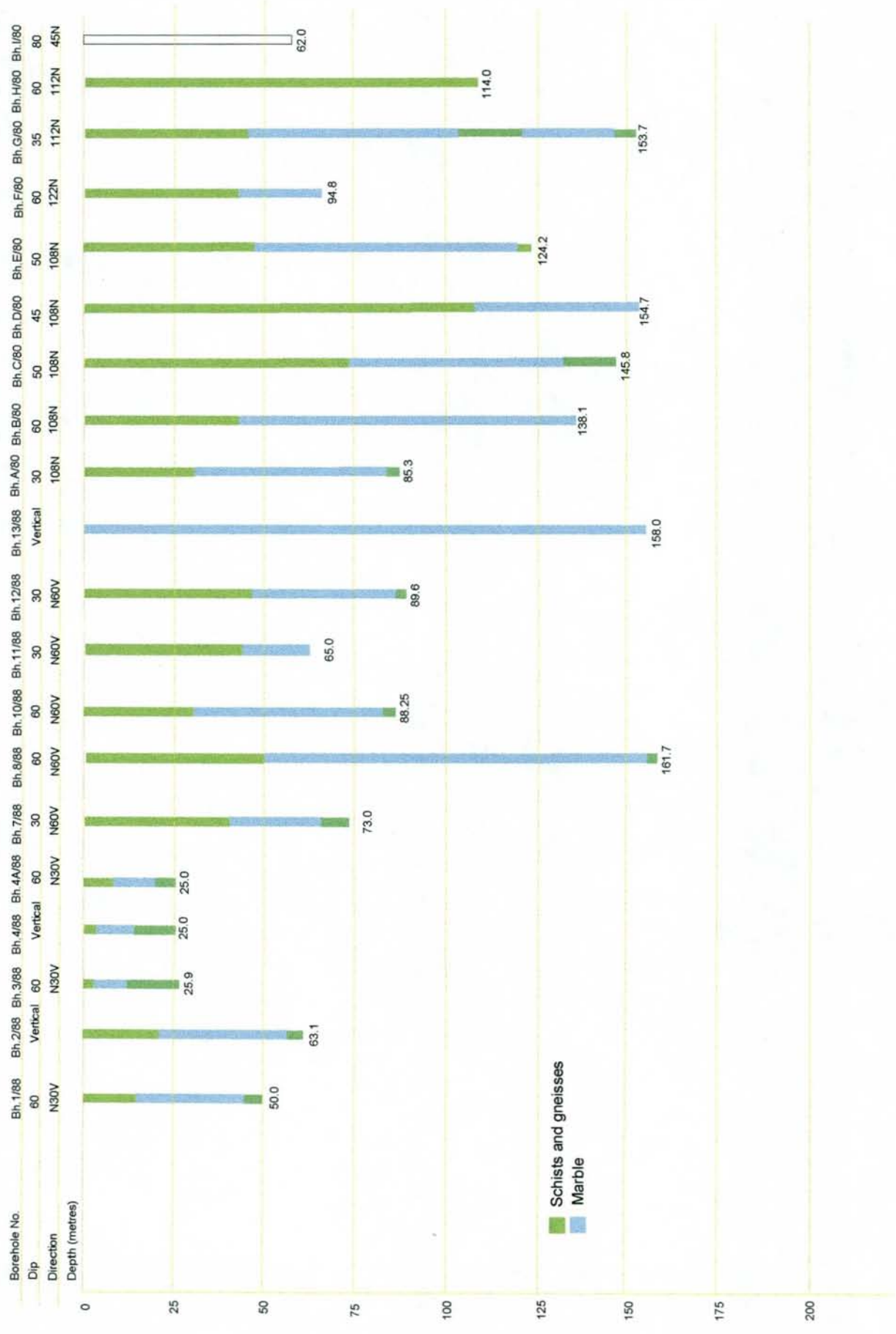
Since 1990, the exclusive exploration and exploitation rights for an extensive area of land in excess of 500 hectares west of Salsbruket, including the Hestvika deposit, have been held by Norkalsitt AS. Norkalsitt AS is a mining company established specifically to develop the deposits of marble in the Salsbruket area, with the principal aim of becoming a recognised producer of high quality calcium carbonate products for supply to a wide range of western European markets

Norkalsitt undertook re-evaluation of the deposit for specific market applications, particularly as a high brightness pigment for the paper industry, together with detailed assessments of mine planning, processing, ship loading and distribution economics. In 1995, underground mining began within reserve block A/B and extended into blocks C and D.

For summary of borehole information, see Figure 5.
For locations of boreholes, see Figure 6.

Hestvika Marble Deposit - Summary of Borehole Information

Figure 5



5.4 Marble Resources available to Norkalsitt AS

5.4.1 Hestvika

The Hestvika marble deposit occurs within a metamorphic cover sequence on the limbs of an extremely steeply dipping (70-90°) synclinal structure which plunges at a shallow angle towards the west. The marble horizon is 30-40 metres wide, extends to a depth of at least 160 metres below the surface, and can be traced by surface field mapping as a continuous horizon for in excess of 3 kilometres.

The sequence is effect by a series of north-east to south-west trending faults which appear to be dipping to the south-east at 45-55°. Although there is some evidence of movement on these fault planes (slickensides and infilling of fault gouge), the marble does not seem to show any appreciable displacement. The only exception to this, is in reserve block G/H where the marble has been displaced approximately 50 metres to the north-west.

There is evidence of minor internal folding within the marble horizon, frequently associated with the faults, but again this does not appear to have any appreciable effect on the overall structure of the sequence.

The marble is strongly jointed with frequent iron-staining occurring on or within 5 cm of the joint surface.

The marble is typically consists of coarsely crystalline (<15-20mm) calcite with minor inclusions of silicate minerals, particularly biotite mica, and quartz. There is no evidence of finely particulate graphite which is typically present in the majority of Norwegian marble deposits. There are horizons of finer marble within the sequence and in general the purest material occurs within the central 20 metre wide zone. In the centre of the sequence is a thin (<10 cm) band of silicate-rich marble which appears to extend continuously within the current working area.

Norkalsitt AS currently holds 2.5 million tonnes of high quality marble reserves at Hestvika within a series of mining blocks extending 650 metres northwards from the road exposure (block F) to a depth of 10 metres below sea level. It is considered that the comprehensive exploration, laboratory evaluations and mine designs undertaken on this section of the deposit are sufficient to categorise the reserve as proved.

However, there is clear evidence from earlier borehole results (e.g. Bh.13/88 drilled by the NGU) that in some (e.g. block A/B), if not all, of the reserve blocks the marble horizon continues to a depth of at least 70 metres below sea level.

If this vertical extension to the deposit could be confirmed for each of the other reserve blocks, and including marble south of the road, it is considered that the reserve base could be substantially increased as follows:

Elevation (metres above sea level)	Cross sectional area (m^2)	Total block length (metres)	Density (t/m^3)	Mining losses	Potential Resources (tonnes)
-10 to -70m	2,100	950	2.7	15%	4,500,000

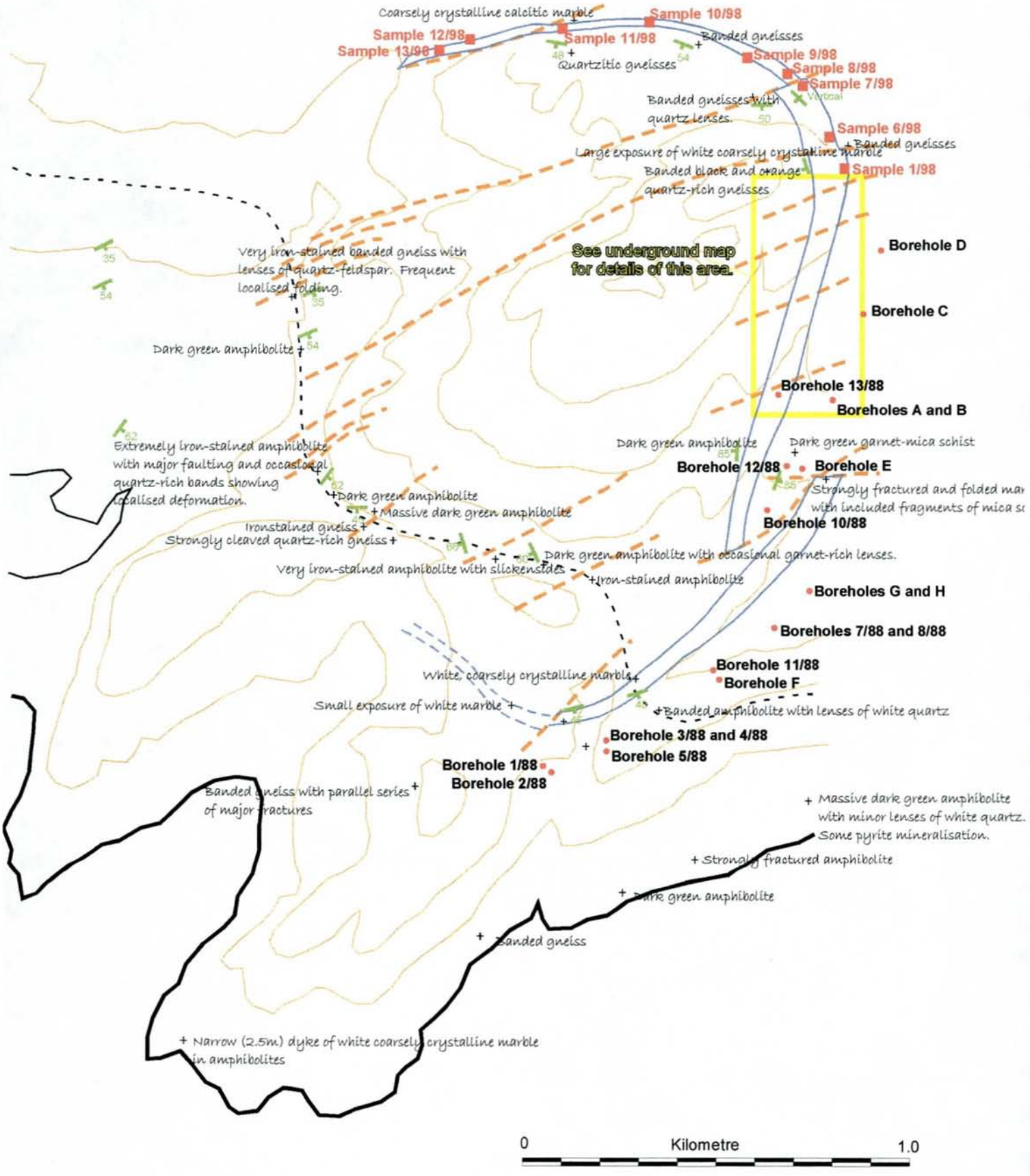
There is very little information available to confirm the quality of this possible marble resource. The limited laboratory results obtained by the NGU for Bh.13/88 would suggest that the coarse-ground brightness of the material may be deteriorating with depth (see below). However, without an associated particle size analysis, it is not possible to realistically correlate these results . It is also quite possible that, at depth, the marble horizon deviates from the vertical structural dip observed at the surface and that the borehole penetrated the more marginal quality marble known to be present close to the amphibolite contact.

This marble resource could easily be exploited as a natural development of the current mine design and would obviously form an extremely important extension to the reserve base currently held by Norkalsitt AS. It is therefore important to clarified the availability and quality of this material by additional exploration drilling.

For geological map of the Hestvika area, see Figure 6
For geological map of the Hestvika underground mine, see Figure 7

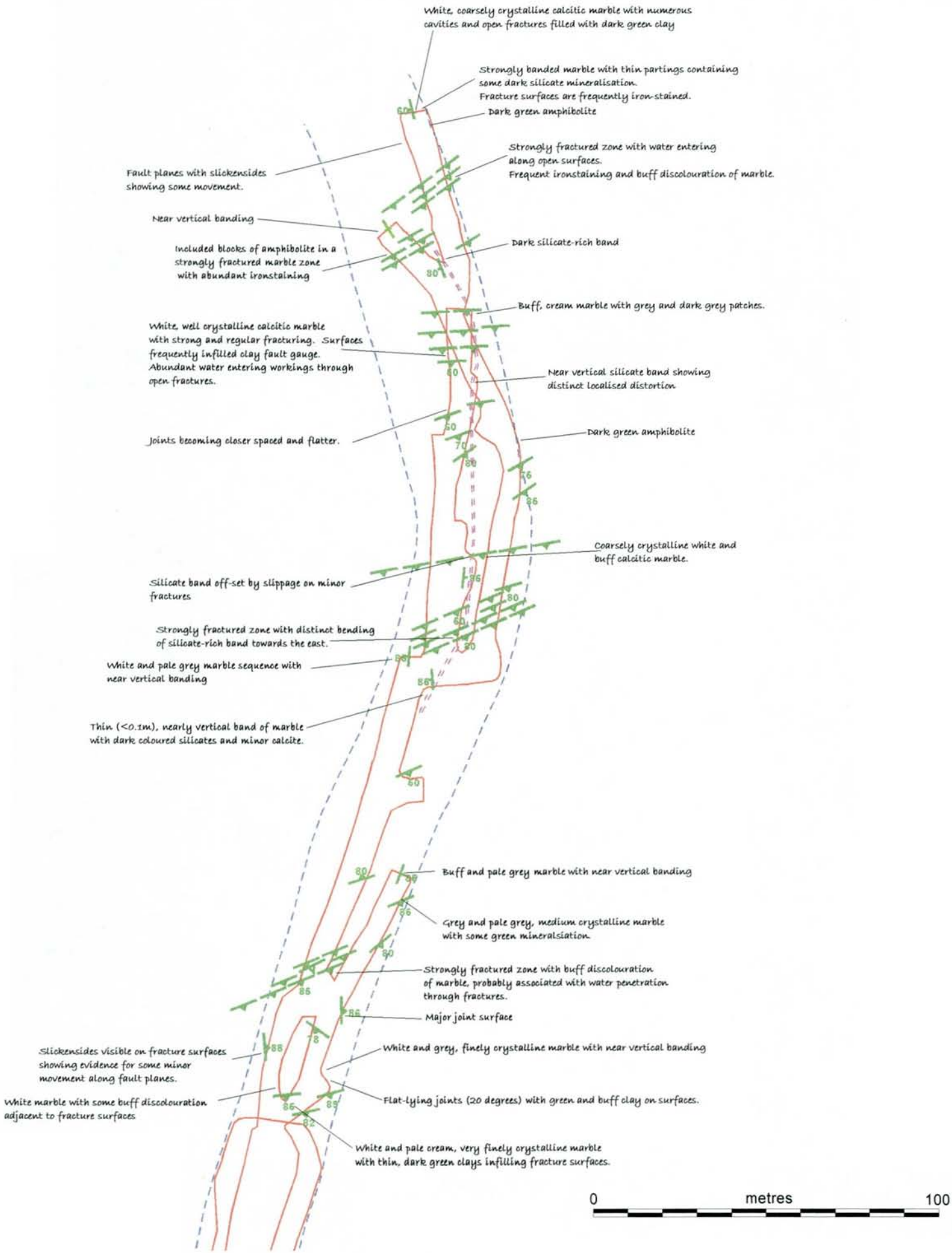
Sketch Geological Map - Hestvika and Surrounding Area

Figure 6



Sketch Geological Map - Hestvika Underground Mine

Figure 7



5.4.2 Svartdalen

The Hestvika marble horizon extends north of the current Norkalsitt reserve blocks, outcropping in the bottom of the valley and in the ridge on the eastern side of Hestvikkammen, at an elevation of 140 metres above sea level. The sequence then curves around to the west at an elevation of 100 - 120 metres above sea level on the top of the plateau before descending rapidly along the line of the Svartdalen stream. It is difficult to trace the sequence beyond the point where the Svartdalen valley joins the Seterelva stream and may have been faulted out at this point.

The marble horizon at Svartdalen represents the axis and northern limb of the Hestvika syncline and can be traced around the axis of the structure for approximately 1,500 metres. Exposures in this area are generally reasonably good, although they are obscured on the flat-lying plateau by a superficial cover of peat and glacial alluvium. The hanging and footwall of the deposit continues to be banded, dark green gneisses with occasional quartz lenses, and show a very distinctive contact with the marble. The marble appears to have thinned slightly when traced into this area, with a typical width of 20 - 30 metres. The structure of the synclinal sequence remains typically steep with south and south-west facing dips of 60 - 85°.

Although there is evident lateral continuation of the marble horizon, there is also a noticeable increase in major faulting associated with the axis of the structure. These faults have a typical trend of north-east/south-west and appear to be parallel with the axis of the structure. They are generally shallow-angle features, dipping to the south at 45 - 55°. Although they do not show any substantial displacement of the marble, they are responsible for localised folding and inclusion of lenses of the surrounding gneisses. These structural discontinuities are also observed at the northern end of the underground workings and are typically associated with abundant ingress of water through the open fractures. However, it would seem likely that this structural complexity will reduce when mine is developed north of the axis.

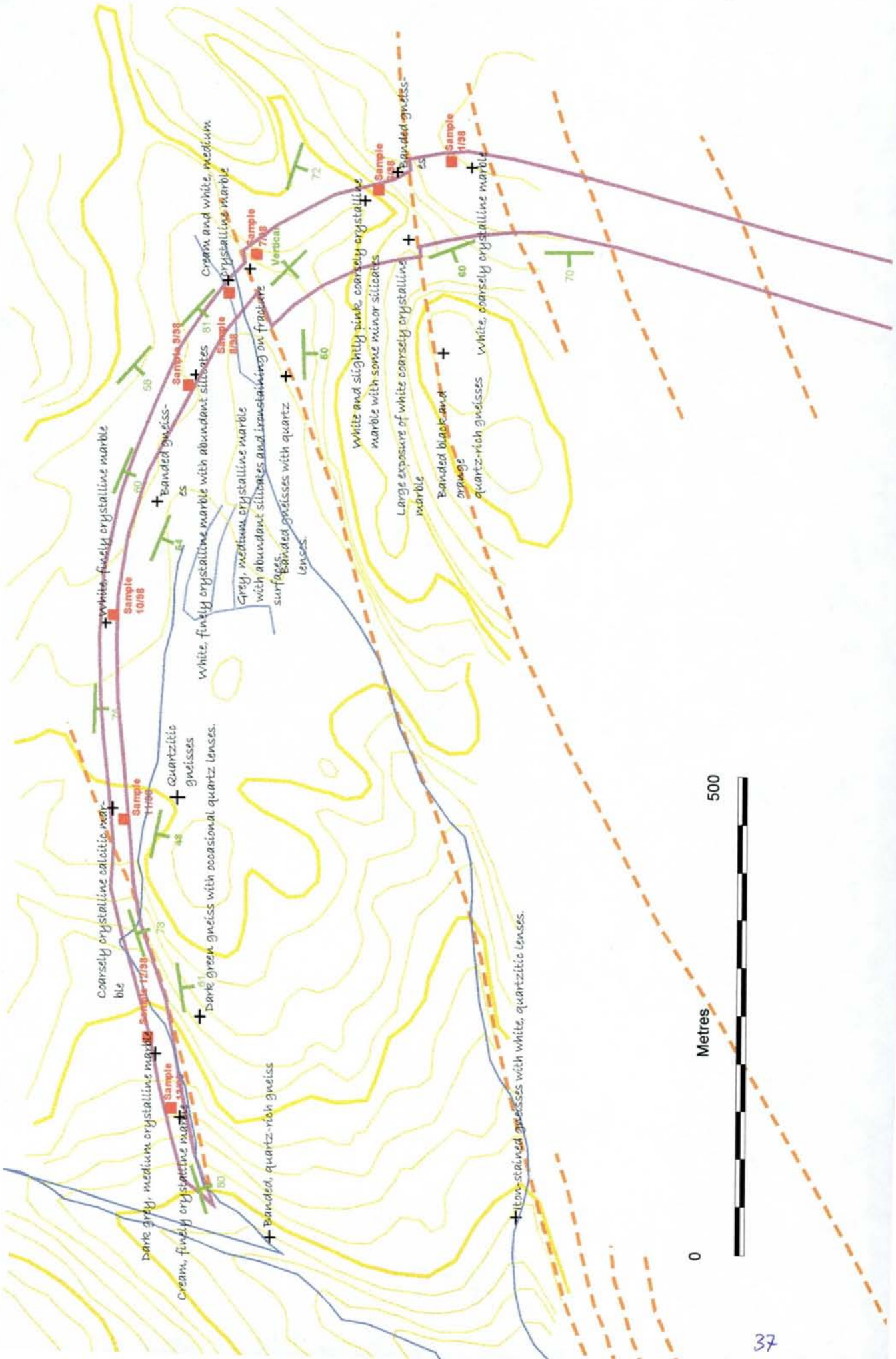
The quality of the marble appears similar to the material currently being produced from the Hestvika mine, although the samples collected appear to have a finer crystalline texture with possibly a slight increase in the A.I.R content. Samples have been collected to assess this in more detail.

If the continuation of the marble sequence and associated quality was confirm to be in line with the brief field mapping undertaken in the Svartdalen area, the availability of additional marble resource could be as follows:

Elevation (metres above sea level)	Cross sectional Area (m^2)	Total block length (metres)	Density (t/m^3)	Mining losses	Potential Resources (tonnes)
Surface (less 25 m) to -10m	85x20 = 1,700	700	2.7	25%	2,400,000
-10 to -70m	60x20 = 1,200	700	2.7	25%	1,700,000
				Total	4,100,000

For sketch geological map of the area, see Figure 8.

Sketch Geological Map - Svartdalen, North-west of Hestvika Figure 8



5.4.3 Krokvatnet

The Krokvatnet structure is located 6 km north of Salsbruket on the northern and eastern slopes of the Grönlituva mountain range. Access to the area is via 6 km of dirt road along the Opplöyelva valley from Salsbruket to Liavasselva, and then 3 km of footpath along the northern edge of Blakkmyrfjelle. The area is at an average elevation of 100-150 metres above sea level.

The area consists of open moorland and peat marshes with patchy forests particularly on the slopes of the mountains.

The marble sequence occurs on the northern flanks of a north-east/south-west trending syncline and can be traced from aerial photographs for a distance of 11 kilometres from Krokvatnet to Storkvisten.

Exposures are generally very limited due to the dense woodland on the valley slopes. However, some of the most accessible outcrops are 1.5 kilometres north-east of the lake in a small stream which runs down to the western side of Masterdalen (GR 06385/71955).

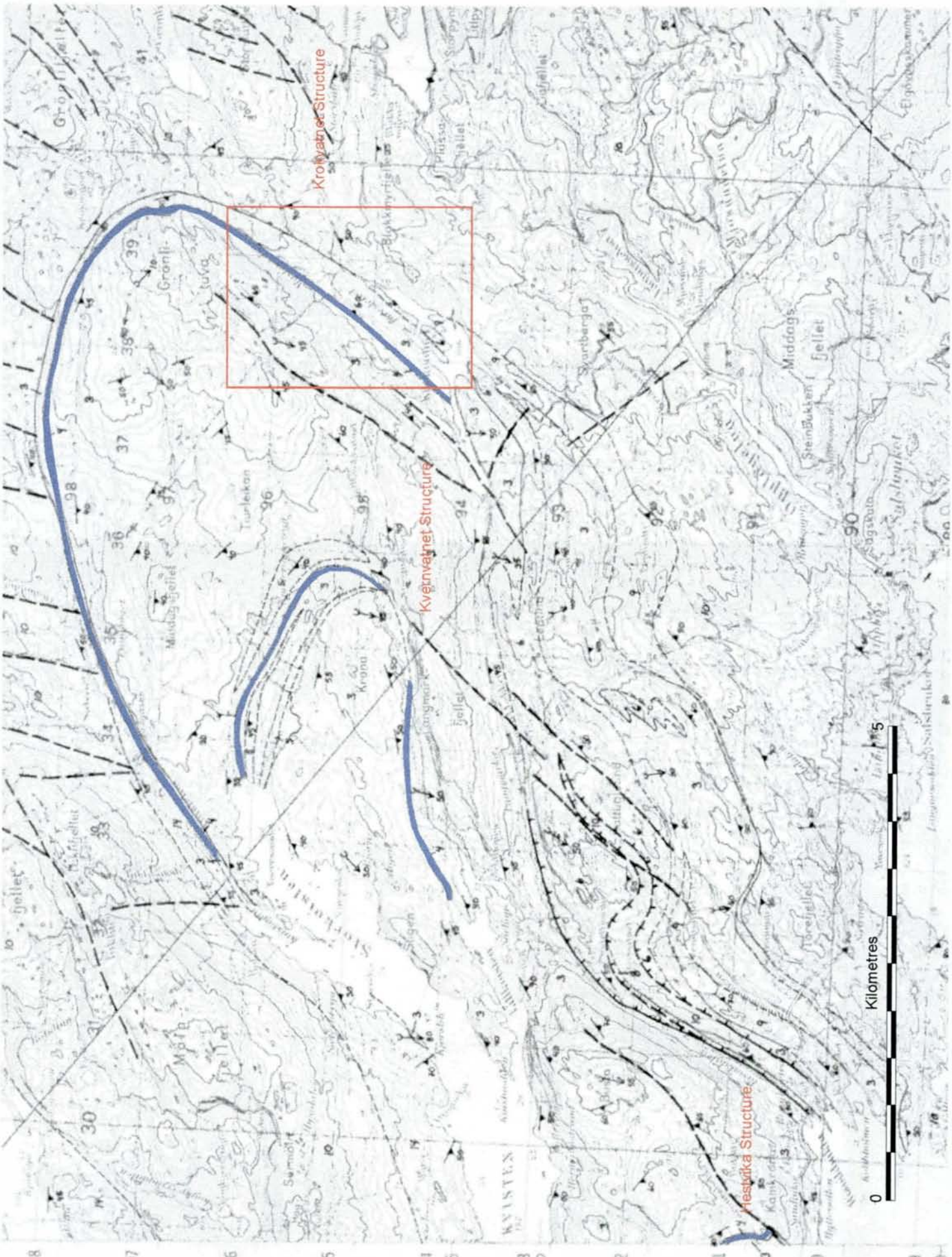
The sequence consists of 20-25 metres of white and pink, finely crystalline marble in dark green calc-silicate schists. The marble appears to be quite massive with only minor jointing and dips at approximately 70-80° to the north-west. There is evidence that the synclinal structure may be locally overturned. The marble outcrop can be traced for approximately 300 metres to the north-east but almost certainly extends considerably further. To the south-west the horizon continues towards Krokvatnet, but from the brief field observations, it cannot be traced beyond the shores of the lake.

Four samples were collected from the Masterdalen outcrops (samples 2/97 - 5/97) and these have been submitted to the NGU laboratories for evaluation, together with a petrological examination in the UK (see section 5.4.4 Petrography).

It is impossible to make any useful prediction on the availability of marble resources in the Krokvatnet area due to the limited exposure of the deposit. However, due to the environmental value of the land together with the inaccessibility of the area, it is considered extremely unlikely that the marble deposit could be commercially exploited.

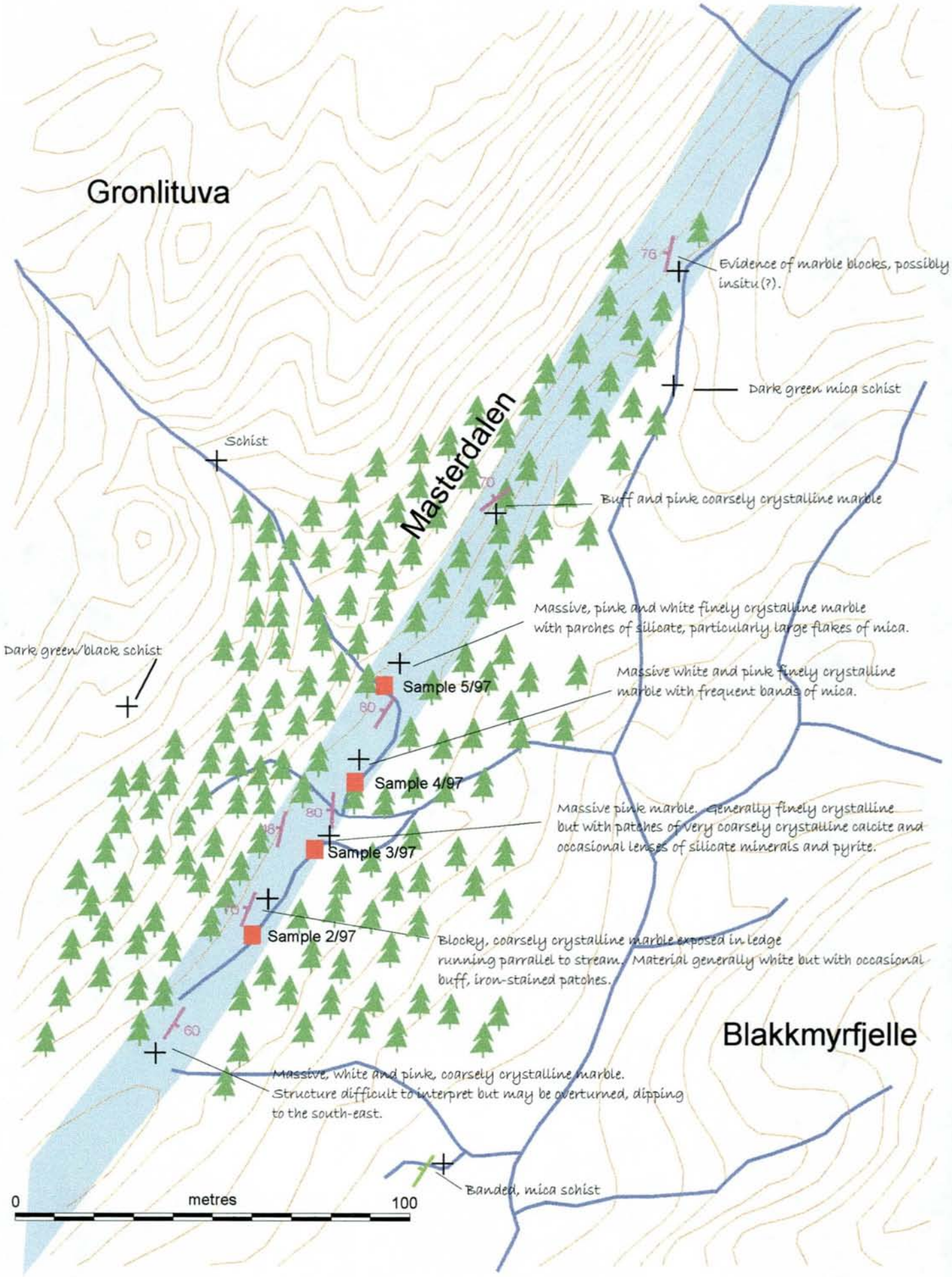
For a general location and geological map, see Figure 9.
For a detailed sketch geological map, see Figure 10.

General Location and Geological Map (1:50,000) - Krokvatnet Area Figure 9



Sketch Geological Map - Krokvatnet Area

Figure 10



Photographs - Krokvatnet Marble Deposit

Figure 11

Marble exposure near Sample 3/97

White and pink marble with some silicates exposed in stream near Sample 4/97

Coarsely crystalline white marble with included lens of fine calcite with ironstained contact.

5.4.4 Kvernvatnet

The Kvernvatnet structure is located 4 kilometres west of Krokvatnet and outcrops on the shores of Litlkvisten and Storkvisten.

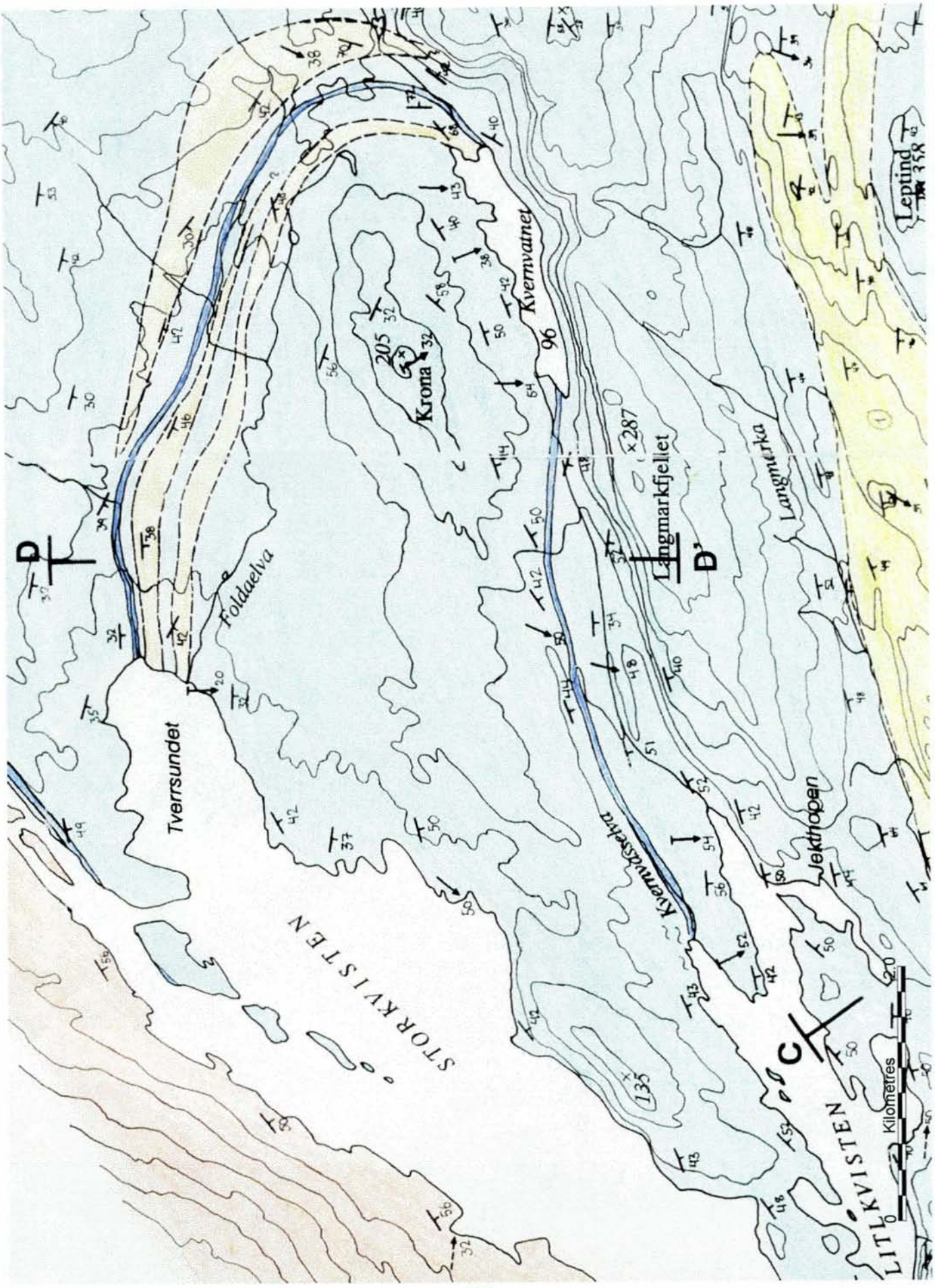
Access to the area is extremely difficult by land and is probably best approached by sea. The area was not visited during the fieldwork of this investigation because of these access problems.

However, the work by Ullern and Rovde (1990) would suggest that the marble horizon can be traced over a distance of 4-5 kilometres, and although having a similar synclinal structure to the Hestvika and Kvernvatnet structures, the southern limb appears to be strongly overturned.

For details of the geology of the Kvernvatnet structure, see Figure 12.

Geological Map of the Kvernvatnet Structure

Figure 12



5.4 Quality

5.5.1 Laboratory evaluation procedures

When evaluating the suitability of samples of industrial minerals for commercial applications, it is extremely important that the laboratory evaluation procedures are designed, as far as possible, to replicate the processes and products currently available to that industry. This is important both technically and commercially when determining the economic potential of a particular deposit.

The tests that are common to all evaluations are colour (brightness) and chemical analysis (particularly calcium and magnesium contents, the amount of acid soluble iron and the content of acid insoluble residue) at relatively coarse particle sizes. There are many procedures used in measuring brightness but when interpreting and comparing data, it is important to know the relationship between brightness and particle size. Without particle size measurements, an individual brightness result is virtually useless.

A typical evaluation procedure for a sample of calcium carbonate is as follows:

a) the material is ground to a powder by jaw crushing and disc milling and a sample of this 'as received' material is tested for chemical and mineralogical properties.

b) the powder is 'rough ground' to approximately 30-40 wt.% <2μ and a sample measured for particle size, ISO brightness and chemical analysis. These results are used to decide the subsequent processing requirements.

c) the powder is ground in a wet media mill continually measuring work input using a load cell. Each sample is ground to 90 wt.% <2μ or finer depending on the application being considered.

d) the grinding characteristics of each material are observed by measuring brightness and wt.% <2μ on samples of slurry at pre-set work inputs.

e) on completion of grinding, the slurry is screened to remove any unground material and the product tested for chemical and physical properties.

f) depending on the product qualities achieved by straightforward grinding, it may be necessary to re-test the sample including a beneficiation step(s) into the procedure. This could involve bleaching (reductive and/or oxidative), flotation and/or magnetic separation. The precise point at which these processes will be undertaken will depend on the nature and particle size of the impurities being removed and also on the pre-existing process used in the plant for which the material is required.

Depending on the potential observed in the above tests, it may be considered necessary to undertake additional pilot scale trials to scale up the evaluation closer to an industrial process and also to obtain representative samples for specific application testing (e.g. paper coating performance and printing trials).

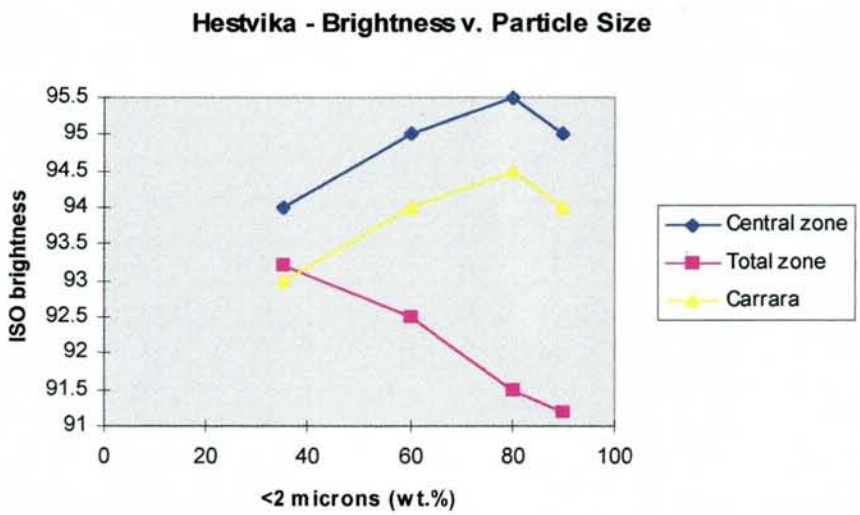
These tests are particularly designed for evaluating the material as a pigment for the paper industry. Other, more specific testing may be required for evaluating potential in other applications (e.g. as fillers in polymers).

Obviously, the comprehensive nature of this testing is beyond the scope or ability of many laboratories. However, it is extremely important to recognise the key parameters required by the industry and not to use resources purely because they are available.

5.5.2 Results

This report is being written without the benefit of any results from the samples collected during the field investigation. However, the following data is included so that, when available, these results can be compared with the material currently available from the Hestvika deposit.

	Hestvika (central zone)	Hestvika (total zone)	Carrara
Rough ground			
+10μ	45	45	45
-2μ	35	35	35
ISO brightness	94.0/1.3	93.2/1.2	93.0/1.0
Fine ground			
-2μ	60	60	60
ISO brightness	95.0/1.2	92.5/0.8	94.0/0.8
-2μ	80	80	80
ISO brightness	95.5/1.1	91.5/0.6	94.5/0.5
-2μ	90	90	90
ISO brightness	95.0/1.0	91.2/0.4	94.0/0.4
Chemical analysis (wt.%)			
CaO	55.3	54.9	55.0
MgO	0.2	0.3	0.60
Fe_2O_3	0.03	0.07	0.01
Acid Insoluble Residue	0.3	1.0	0.2



5.6 Current production and logistics

An investigation of possible alternative exploitation techniques for the development of the Hestvika deposit confirmed that underground mining would maximise the available reserve and would be the most efficient and environmentally acceptable method. Several underground mining schemes have been considered based on the geotechnical properties of the marble and a full-face, stoping-type approach is currently being adopted.

Phase 1

The first phase of site preparation and underground mining began in 1995. A large diameter access tunnel was developed for a distance of several hundred metres in the upper section of the deposit. Additional tunnels are being extended from this main drive to higher and lower levels within the marble horizon. The face is carefully being drilled and blasted to ensure a safe working environment.

A primary crushing and screening system with a capacity of approximately 100,000 tpa, was installed near the tunnel entrance. Marble is currently transported from the underground working face to the plant by front loader or mine payloader. Crushed marble is then taken 10 kilometres by lorry to a 20-25,000 tonnes stockpile facility adjacent to the temporary wharf at Geisnes. This wharf can handle vessels of up to 2,500 tonnes capacity which can be loaded by mobile conveyors at a rate of approximately 1,500 tonnes/day.

Although this is currently working well, it is only planned to be a temporary production system until Phase 2 of the development can be completed.

Phase 2

Construction of the second phase of the development consisting of a new wharf and stockpile facility adjacent to the deposit, began in Spring 1998, This facility, together with a new 200 metre long access tunnel from the wharf to the deposit, will allow marble to be mined and crushed underground and for the products to be transported direct to the harbour by conveyor.

New Port Facility

Development of New Access Tunnel

6. Maps

Geological Maps

'Kolvereid' Sheet No.1724-4 1:50,000
Foldereid' Sheet No.1724-1 1:50,000
'Geologisk Kart over Salsbruket-Kvisten-Området' 1990 1:20,000

Topographic Maps

1:5,000

'Sørenmoen' Sheet No. CV 159-5-3
Sheet CV 159-5-1
Sheet CV 159-5-2
Sheet CV 159-5-3
Sheet CV 159-5-4
Sheet CW 159-5-3
Sheet CW 159-5-4

1:20,000

'Oppløyelva' Sheet No. CWX 159-160-20
'Kolvereid' Sheet No. CUV 159-160-20

Aerial Photographs

6-7-81 2800m AK 07 6875
6-7-81 2800m AK 08
6-7-81 2800m AK 09
6-7-81 2800m AK 010
6-7-81 2800m AK 011
6-7-81 2800m Z08
6-7-81 2800m Z09
6-7-81 2800m Z10

7. Definitions

Aragonite. A mineral having the same composition as calcite, sometimes with 1-2% of strontium carbonate or other impurity, but belonging to the orthorhombic crystal system. A prismatic crystal form is common. Cleavage is poor.

Calcite. A mineral having the composition $CaCO_3$ which corresponds to a composition of 56.0% CaO and 44.0% CO_2. Calcite belongs to the hexagonal (rhombohedral) crystal system and good crystals are common with three main habits ('nail-head', 'dog-tooth' and 'prismatic'). Cleavage is perfect parallel to the unit rhombohedron. Calcite is the essential constituent of limestone, chalk and marble and a minor constituent of many other rocks.

Chalk. Chalk is a soft limestone composed predominantly of the shells of microscopic algae (coccoliths).

Limestone. Limestone is a sedimentary rock containing calcite, dolomite or any combination of these two carbonates, at least to the extent of 50% of the rock. Limestones are formed by the consolidation of calcareous ooze, which may be chemically precipitated from solution, derived from some pre-existing limestone by the normal processes of erosion, or formed by organic agencies (e.g. coral reefs and shell banks).

Marble. Marble is a metamorphic rock composed essentially of a combination of calcite and dolomite. A true marble may be considered to be a limestone which has been recrystalized by heat and/or pressure and is capable of being cut and polished as dimension stone. However, for the purposes of this report, marble is used to describe any carbonate rock which has been sufficiently metamorphosed so that the original texture and fabric of the rock has been completely obscured by the recrystalization process. The differentiation between limestone and marble is important in the evaluation of calcium carbonate deposits because, when ground to very fine particle sizes, each rock type produces very distinctive final products.

8. References

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VEDLEGG

XRF-hoved og sporelementer, hvithet og syreløselig CaO & MgO

- Prøvene er samlet inn og beskrevet petrografisk av D. Wigley i rapporten, mens de kjemiske analyser blir behandlet i dette vedlegget.

Hovedelementer

PR.NAVN	SiO2 %	Al2O3 %	Fe2O3 %	TiO2 %	MgO %	CaO %	Na2O %	K2O %	MnO %	P2O5 %	SUM
DW 1/97	<0.01	<0.01	0.05	<0.004	0.30	55.27	<0.10	<0.003	0.009	0.18	55.81
DW 4/97	1.15	0.17	0.05	0.006	2.02	53.11	<0.10	0.109	0.008	0.16	56.78
DW 6/97	<0.01	<0.01	0.02	0.006	0.31	55.28	<0.10	0.006	0.008	0.17	55.80
DW 7/97	3.31	2.29	0.62	0.129	0.46	50.73	0.19	0.289	0.010	0.19	58.22
DW 8/97	<0.01	<0.01	0.02	<0.004	0.19	55.15	<0.10	<0.003	0.011	0.18	55.55
DW 9/97	1.55	0.35	0.22	0.035	0.38	53.26	<0.10	0.073	0.010	0.17	56.05
DW 10/97	1.96	0.30	0.01	0.006	0.18	55.02	<0.10	0.198	0.009	0.18	57.86
DW 11/97	0.13	0.11	0.08	0.012	0.37	54.29	<0.10	0.018	0.017	0.18	55.21

Sporelementer I

PR.NAVN	Ba %	Sb %	Sn %	Cd %	Ag %	Ga %	Zn %	Cu %	Ni %	Yb %	Co %	Ce %	La %	Nd %	W %
DW 1/97	0.0012	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	<0.0005	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 4/97	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	0.0005	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 6/97	0.0027	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	0.0006	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 7/97	0.0029	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	0.0006	0.0025	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 8/97	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	<0.0005	0.0017	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 9/97	0.0051	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	0.0006	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 10/97	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	<0.0005	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030
DW 11/97	0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0005	<0.0005	<0.0005	0.0017	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030

Sporelementer II

PR.NAVN	Mo %	Nb %	Zr %	Y %	Sr %	Rb %	U %	Th %	Pb %	Cr %	V %	As %	Sc %	S %	Cl %	F %
DW 1/97	<0.0005	<0.0005	<0.0005	<0.0005	0.0167	<0.0005	0.0022	<0.0010	<0.0010	<0.0005	0.0010	<0.0010	<0.0010	<0.10	<0.10	0.69
DW 4/97	<0.0005	<0.0005	0.0006	0.0007	0.0214	<0.0005	0.0048	<0.0010	<0.0010	<0.0005	0.0010	<0.0010	<0.0010	<0.10	<0.10	0.67
DW 6/97	<0.0005	<0.0005	<0.0005	<0.0005	0.0279	<0.0005	0.0026	<0.0010	<0.0010	<0.0005	0.0008	<0.0010	<0.0010	<0.10	<0.10	0.66
DW 7/97	0.0022	<0.0005	0.0024	0.0006	0.0144	0.0008	0.0059	<0.0010	<0.0010	0.0017	0.0021	<0.0010	<0.0010	<0.10	<0.10	0.63
DW 8/97	<0.0005	<0.0005	0.0007	<0.0005	0.0089	<0.0005	0.0033	<0.0010	<0.0010	<0.0005	0.0011	<0.0010	<0.0010	<0.10	<0.10	0.65
DW 9/97	<0.0005	<0.0005	0.0007	<0.0005	0.0160	<0.0005	0.0014	<0.0010	<0.0010	<0.0005	0.0026	<0.0010	<0.0010	<0.10	<0.10	0.65
DW 10/97	<0.0005	<0.0005	<0.0005	0.0005	0.0104	<0.0005	0.0017	<0.0010	<0.0010	<0.0005	0.0009	<0.0010	<0.0010	<0.10	<0.10	0.63
DW 11/97	<0.0005	<0.0005	<0.0005	<0.0005	0.0195	<0.0005	0.0040	<0.0010	<0.0010	<0.0005	0.0012	<0.0010	<0.0010	<0.10	<0.10	0.62

Syreløselig

PR.NAVN	CaO %	MgO %
DW 1/97	54.97	0.30
DW 4/97	53.08	1.95
DW 6/97	55.08	0.32
DW 7/97	50.71	0.42
DW 8/97	55.00	0.24
DW 9/97	53.32	0.36
DW 10/97	55.10	0.20
DW 11/97	54.35	0.40

Hvithet

PR.NAVN	FMX %	FMY %	FMZ %	R457 %
DW 1/97	93.6	93.3	92.1	92.1
DW 4/97	89.3	89.0	87.6	87.6
DW 6/97	95.4	95.2	94.1	94.1
DW 7/97	81.3	81.2	80.1	80.2
DW 8/97	94.8	94.5	92.7	92.7
DW 9/97	87.8	87.6	86.1	86.2
DW 10/97	89.2	89.0	88.5	88.5
DW 11/97	93.8	93.4	91.6	91.7

Kommentar til laboratorieanalyser.

8 av de innsendte prøvene var egnet for analyse. Disse er analyserte på XRF hoved- og sporelementer, syreløselig CaO og MgO, samt hvithet. En kortfattet oppsummering av de viktigste trekk er gitt nedenfor.

Tabell 1: Viktige parametre for kvalitetsvurdering.

	SiO_2	Fe_2O_3	CaO	MgO	Syre-løselig CaO	Syre-løselig MgO	FMY %	R457 %
DW1	< 0.01	0.05	55.27	0.30	54.97	0.30	93.3	92.1
DW4	1.15	0.05	53.11	2.02	53.08	1.95	89.0	87.6
DW6	<0.01	0.02	55.28	0.31	55.08	0.32	95.2	94.1
DW7	3.31	0.62	50.73	0.46	50.71	0.42	81.2	80.2
DW8	<0.01	0.02	55.15	0.19	55.00	0.24	94.5	92.7
DW9	1.55	0.22	53.26	0.38	53.32	0.36	87.6	86.2
DW10	1.96	0.01	55.02	0.18	55.10	0.20	89.0	88.5
DW11	0.13	0.08	54.29	0.37	54.35	0.40	93.4	91.7

Analysene viser at 4 av prøvene, DW4, DW7, DW9 og DW10, er SiO_2-holdige og inneholder silikater. En korrelasjon mellom SiO_2 og innhold av Al_2O_3 og K_2O antyder at feltspat og/eller glimmertypen muskovitt utgjør en vesentlig andel av silikatene. Det høye MgO-innholdet i prøve DW4, som er løselig i syre, tyder på innhold av dolomitt. De SiO_2-fattige prøvene er ellers av god kvalitet når det gjelder kjemisk innhold og gir brukbar hvithet.

De oppnådde hvithetene avspeiler i dette tilfellet et noe varierende innhold av grovkornet grafitt, magnetitt og ulike silikater.

Problemet med grafitten vil i dette tilfellet komme fram ved nedmaling til < 10 µm hvor grafitten frimales, noe som igjen fører til en drastisk nedgang i hvitheten (FMY). Det samme gjelder for opptreden av finfordelt magnetitt. Ved bruk som råstoff til produksjon av PCC vil imidlertid det lave grafittinnholdet ha mindre betydning.

De hvithetsmålingene som er utført på NGU er ikke ledsaget av siktekurver som viser kornfordelingen på det analyserte materialet. Den rutinemessige prepareringen av prøvematerialet som gjøres vil således ikke avdekke forholdet med finfordelt grafitt slik det er beskrevet ovenfor.

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