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The potential for ore, industrial minerals and commercial stones in the Simpevarp area

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October 2004

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Summary

On behalf of Svensk Kärnbränslehantering AB, SKB (the Swedish Nuclear Fuel and Waste Management Company), a survey has been made of existing information concerning the potential for ore, industrial minerals and commercial stones in and around the two candidate areas for a deep repository in Oskarshamn. A deep repository for spent nuclear fuel should not be located in a rock type or in an area where mineral extraction might be considered in the future, since this would make it difficult or impossible to exploit this natural resource. Avoiding such areas reduces the risk that people in the future will come into contact with the deep repository through mineral prospecting or mining activities.

The survey has made use of the geoscientific information compiled in the more regional investigations in Oskarshamn Municipality in 1998–99. The new information after the municipal study includes extensive geophysical measurements from both the air and the ground. The results of the recently completed geophysical helicopter survey of the Simpevarp area are presented in a special chapter. The judgement of an area's ore potential is in part based on the evaluation of these geophysical measurements. In order to be better able to judge the ore potential, a geochemical investigation of soil samples, including reanalysing of older samples collected by the Geological Survey of Sweden (SGU), has been carried out. The report also discusses prospecting efforts in the area as well as relevant Swedish mining legislation.

In cooperation with SGU a mineral resource map of the Simpevarp area has been prepared. The map shows two areas with a potential for commercial stones, namely the granites at Götemar and Uthammar, situated in the northernmost respectively the southernmost part of the study area. Furthermore, the Götemar granite has probably a small potential for ores containing tin (Sn) and/or wolfram (W). Although no mineralisations of this type have so far been found, the Götemar granite area may be unsuitable or for siting a deep repository.

The Simpevarp regional model area is covered mainly by intrusive rocks that vary in composition from granite to quartz monzodiorite. Except for Götemar granite the Simpevarp area has no ore potential, and the two sub-areas Laxemar respective Simpevarp situated inside the study area, can be described as sterile from an ore viewpoint.

There is no interest for prospecting in the area. Stone quarrying has however from time to time been extensive in this part of Sweden, but it has gradually declined to being of limited extent today. A possible rock quarry, with quarrying in a shallow open pit, would only marginally limit the siting of a deep repository. It is highly unlikely that prospecting will take place in the coastal and marine parts of the Simpevarp area in the near future. Circumstances counter-indicative of this are environmental aspects and the fact that large areas are protected by law.

The concluding judgement is that there is no ore or mineral potential in the SKB candidate (sub-)areas Laxemar and Simpevarp within the Simpevarp area. There is no interest in prospecting in the area, at present or in the future.

Sammanfattning

På uppdrag av Svensk Kärnbränslehantering AB (SKB) har en sammanställning och utvärdering gjorts av befintlig information av potential för malm, industrimineral och nyttosten i och omkring två kandidatområden för lokalisering av ett djupförvar i Oskarshamns kommun. Ett djupförvar för utbränt kärnbränsle bör inte

lokaliseras till ett område med berggrund med potential för malm eftersom nyttjandet av denna naturresurs då blockeras. Undvikande av sådana områden innebär vidare en minskad risk för att människor i framtiden skulle kunna komma i kontakt med förvaret genom prospekteringsverksamhet eller gruvdrift.

Utredningen har nyttjat den information som framtogs 1998–99 i den mera regionala kommunundersökningen i Oskarshamn. Utredningens målområde sammanfaller med SKB:s regionala modellområde benämnt Simpevarp, och täcker en yta på omkring 270 km^2. Den nya information som därefter tillkommit utgörs av omfattande geofysiska mätningar från marken och från luften, en ny geokemisk provtagning av morän med fokus på malmpotential, geologisk kartläggning av berggrund och jordarter, samt information från pågående djupborrningar. Dessa mera detaljerade undersökningar har utgjort en viktig bas för sammanställningen av en mineralresurskarta över Simpevarpsområdet.

Utredningen visar att det finns två områden med potential för nyttosten inom undersökningsområdet, nämligen ett i områdets norra del, och ett i områdets södra del. Det förra utgörs av Götemargranit, det senare av Uthammargranit. Brytningen av dessa graniter är idag dock av liten omfattning med endast ett aktivt stenbrott inom Simpevarpsområdet.

Den cirkelformade Götemargraniten bedöms även ha en potential för malm innehållande metallerna tenn, wolfram och/eller molybden. Det finns dock inga kända malmförekomster av denna typ i Götemarsområdet, varför potentialen måste bedömas som liten.

Stora delar av Simpevarpområdet täcks av en berggrund som helt saknar malmpotential. Detta gäller även för de två kandidatområdena Laxemar respektive Simpevarp. Det finns därför inget intresse för prospektering i dessa områden, och den bedömningen torde även gälla i ett längre tidsperspektiv.

Utredningen ger även korta sammanfattningar av svensk gruvlagstiftning, en historik av stenbrytningen i Kalmar län, en beskrivning av utförda prospekteringsinsatser och en sammanställning av de stenbrott där brytning förekommit i närtid.

Utredningen har skett i nära samarbete med SGU och särskilt med personer som varit eller är involverade i platsundersökningarna i Oskarshamn. Två kapitel har sålunda skrivits av experter inom egna fackområden, kapitel 5: geofysiska undersökningar av Carl-Axel Triumf, Geovista AB, och kapitel 6: geokemiska undersökningar av Bengt Nilsson, Mirab Mineral Resurser AB. Carl-Henric Wahlgren, SGU, har rådgivit i frågor som berör berggrundsgeologi och ansvarat för den geologiska kartan i utredningen.

Litteraturförteckningen i slutet av rapporten upptar officiella rapporter eller kartor som på ett eller annat sätt berör Simpevarpområdet och som använts som referenser i undersökningen. En stor del av SKB-rapporterna finns numera även tillgängliga elektroniskt på SKB:s hemsida (www.skb.se).

Ordlistan i appendix omfattar i huvudsak termer som förekommer i rapporten.

Contents

1 Introduction

1.1 Background and problem formulation

A deep repository for spent nuclear fuel should not be located in a rock type or in an area where mineral extraction might be concidered in the future, since exploitation of this natural resource would then be blocked. Avoiding such areas furthermore reduces the risk that people in the future will come into direct contact with the deep repository through mineral prospecting or mining activities. According to the Environmental Code, areas that contain valuable substances or materials shall be protected against measures that may be prejudical to their extraction /Environmental Code, 1998/. In addition, a deep mine greatly affects groundwater conditions as well due to drainage.

An important part of SKB's feasibility studies has been to identify and analyse, based on generally available information, geoscientific conditions that could be unsuitable or unfavorable for the siting of a deep repository /SKB, 2000/. A condition that should be avoided is the occurrence of rocks with ore potential or rocks of interest for mineral extraction. The feasibility study in Oskarshamn included a special survey of the potential of ores, minerals and commercial stones in the municipality /Bergman et al. 1998/. The survey showed that only a small area in the northernmost part of the municipality can be regarded as having ore potential, and that the rest of the municipality was mainly covered by a granite bedrock without potential for ore or industrial minerals. Commercial stone quarrying has for a long period been focused on certain granite types in this region, like the Götemar and Uthammar granites. This is still generally true, but stone quarrying has gradually declined.

As a part of the ongoing site investigation in Simpevarp, SKB initiated the present study which covers the "regional model area" including the two candidate sub-areas Simpevarp respectively Laxemar. This area, here described as the Simpevarp area, covers about 270 km^2, of which about one third is marine area (Figure 1-1). An important part has been to present a new up-dated version of the bedrock map of the Simpevarp regional model area including inserted a more detailed bedrock map of the Simpevarp sub-area /Wahlgren et al. 2004; SKB, 2004/. The main aim of the present study has been to make a site-specific assessment of the ore potential. The geoscientific programme of the Simpevarp site investigation /SKB, 2001/ and the site descriptive model (SDM version 0) describes methods and techniques for investigation and evaluation of the bedrock /SKB, 2002/.

In modern time there has been almost no, or very limited, exploration for ore and minerals in this area. This is partly because of the character of the dominating rock types, i.e. dioritoids-syenitoids and granites that belong to the Transscandinavian Igneous Belt (TIB), which by experience is more or less devoid of mineralisations. However, granites may host vein-type mineralisations of such metals as wolfram (W), molybdenum (Mo) and occassionally gold (Au). Questions have been raised concerning which methods and criteria should be used to judge an area's ore potential. In this case, and regarding metals which could be associated with granitic rocks, geochemical methods have proven to be the most effective. Therefore, a special study of soil samples including older samples and samples from the ongoing site investigation (2004) has been analysed or reanalysed with regard to principal and trace elements, including gold. The purpose has been to obtain a better basis for an ore geology assessment.

Figure 1-1. *Location of the Simpevarp area in south-eastern Sweden.*

A major part of the study area has recently been surveyed with modern airborne geophysics /Rönning et al. 2003/, and thereafter interpreted by several experts with focus on different scientific aspects /Triumf et al. 2003b/. Though there is nothing in the geophysical surveys so far identified that can be related to an ore or to a bedrock with an ore potential, a check-up of certain geophysical anomalies have been done and included in this report. Focus in this study has been on magnetic anomlies related to mafic-ultramafic rocks with a possible ore potential for elements like copper and nickel. Furthermore, some of the known or interpreted deformation zones in the area /Triumf, 2003a, 2004b/ has been examined as possible structures of vein-type gold mineralisations.

The present survey has been carried out in close cooperation with geologists and geophysists in the Simpevarp site project. The geochemical investigation (Chapter 6) has been compiled and reported by Bengt Nilsson, MIRAB Mineral Resurser AB, advised by Gustav Sohlenius, SGU, and Lars Rudmark, SGU. Carl-Axel Triumf, GeoVista AB, has critically restudied the airborne and ground geophysical surveys with special emphasis on ore potential (Chapter 5). The geological map as well as most of the descriptive geology in the text is taken from /Wahlgren et al. 2004; SKB, 2004/. Carl-Henric Wahlgren and Torbjörn Bergman , SGU, have advised in the geological part of the study. Finally, Fredrik Hartz, SKB, has compiled GIS-data and designed most of the figures in this report.

1.2 Structure of present report

The report begins with a description of the study's objective and methodology, and general comments about information and map scales. This is followed by a brief ore geology overview where the Simpevarp area is put in its regional geological context. The ore geology overview clearly demonstrates the relation between the existing bedrock geology and the occurrences of certain ores. This is further stressed in the description of the geology of the Simpevarp area being covered mainly with granitic rocks of a type without any mineralisations or orebodies.The stone quarrying in the region is described in a brief historical retrospective. Then the quaternary geology of the Simpevarp area is outlined. Known ore mineralisations and stone quarries are listed and described. The end product of the survey is a mineral resource map. It shows areas where potential for ores and/or commercial stones exist and thereby which areas are unfavorable for a deep repository from this point of view.

The new information after the municipal survey 1998–99 includes extensive geophysical surveys both from the air and on the ground. This part is presented in a special chapter with focus on geophysical anomalies which could be related to structures or bedrock bearing on ore potential.

The results of geochemical till sampling and geological bedrock and borehole sampling carried out to date are reported in a special chapter.

The results of the geophysical and geochemical surveys are important contributions when constructing a reliable and conclusive mineral resource map of the study area. The mineral resource map is the final product based on a succession of geoscientific proofs and on conventional experiences in ore and mineral exploration in Sweden.

The report also summaries recent exploration activities and sheds light on modern prospecting methods and the Swedish mining legislation.

The list of references at the end of the report includes public maps or reports which have some kind of bearing on Simpevarp. Information on mining legislation has been taken from SGU's website (Mining Inspectorate of Sweden). A glossary explaining some of the most common geoscientific and mining related terms used in this text is included in an appendix.

1.3 Information sources

The study is based on existing data from previous general siting studies, mainly geological and ore geological surveys /Bergman et al. 1998, 1999, 2000; Stanfors and Larsson, 1998/ as well as on new information from the ongoing site investigation in the Simpevarp area /Wahlgren et al. 2004/. Figure 4-1 displays the detailed bedrock map of the Simpevarp sub-area, inserted in the version 0 bedrock map of the regional model area. The existing information within the Simpevarp subarea is very extensive and the observations have good coverage (outcrops, exposed rock). Detailed bedrock mapping of the Laxemar subarea and its immediate surroundings has been carried out during the summer 2004. The results of this mapping will be incorporated in the Laxemar SDM 1.2.

Information on stone quarrying is based on surveys by SGU /Bruun et al. 1991; SGU, 2004/ or from a special study in the 1998 municipal survey /Bergman et al. 1998/.

Geophysical information in this study is mainly based on data from the helicopter borne survey /Rönning et al. 2003/ and on interpretation reports based on this survey /Triumf, 2004 a,b,c/.

The analytical results from older till surveys by SGU has been used in this investigation. A few new samples from the ongoing geological – quaternary geological site investigation in Simpevarp are added. These new samples have been analysed at ACME Analytical Laboratories Ltd, a Canadian laboratory that holds an international certificate (no 378/96 and ISO 9002) for analysis of geological materials with regard to principal and trace elements, including precious metals (gold, silver and platinum group of elements). A few selected till samples from the old till survey by SGU, 1992, has been reanalysed at the same ACME laboratory. The bedrock samples commented are taken from the SICADA database. They have been sampled and compiled by SGU.

Oral information /Peter Hultgren, SKB, September 2004/ and site investigations reports from SKB's deep drillings /Ekman, 1998, 2001; Ehrenborg and Steiskal, 2004; Mattsson et al. 2004; Drake et al. 2004/ have been included in the assessment of the ore potential in this study.

2 Definitions

An ore is by definition a metalliferous mineral deposit that can be mined with economic gain. The word ore is also used for a major concentration of one or more metals, known as a mineralisation, regardless of the economic value of the deposit. Rockbound natural resources that are uneconomical today may become economical, i.e. “ore”, in the future. This is determined by factors such as metal prices and the cost of mining, dressing and environmental protection. The known metalliferous mineral ocurrences of the Simpevarp area are small and have probably never been mined. They are described as mineralisations. Within the municipality of Oskarshamn there a few occurrences of sulphide minerals containing the metals copper, lead, zinc and molybdenum, and in a few cases small-scale mining has been carried out.

Areas with known ore deposits or other conditions of ore-related interest are termed “bedrock with ore potential”. There is only one area covered by the Götemar granite within the Simpevarp area which has a small potential for tin- and/or wolfram ore. In comparison, the well-known Bergslagen Ore Province in middle Sweden, hosts more than 2000 ore deposits, and consequently, much of ground there has an ore potential.

There is no occurrence of industrial minerals in the Simpevarp area. By “industrial minerals” is meant rocks and minerals that can be used directly or indirectly in an industrial process. Fore example, limestone is an industrial mineral with many technical applications.

By “commercial stones” is meant a rock that can be used in the construction or manufacturing industries either as such or as a fabricated product. For example, granite can be quarried and solds as blocks or sawn and ground to slabs and tiles. It can also be chrushed and used as aggregate. The county of Småland has a long tradition of stone quarrying, and a short historical retrospective is included in the report. Quarrying of commercial stones has gradually declined in importance in this region. Today there is only one stone quarry in production in the Simpevarp area, and currently no deposits are used for production of aggregate material.

3 Overview of ore geology

3.1 Prospecting methods

Searching for economically valuable mineral deposits has been, and still is, an important activity in Sweden if the country is able to maintain the country's position as a mineral producer. The goal of prospecting is to discover new deposits to replace those already exhausted. Mining can be said to begin with prospecting.

The most common prospecting methods include geological, geophysical and geochemical surveys. Prospecting for ore and minerals follows a logical procedure that starts with regional and ends with detailed characterisation.

When prospecting is begun in an area, it must at first be determined by means of a geological survey whether the bedrock is of potentially ore-bearing character. Mineral deposits are often associated with certain rock types or structures in the bedrock. Geologists also look for alteration zones that were created where hot aqueous fluids (called a hydrothermal fluid) were circulated in the Earth's crust. These zones usually surround certain ores, for example many sulphide ores in Bergslagen found in the middle of Sweden (see section 4.5).

Another important geological method is drilling, usually in the form of coring or percussion drilling. This enables a direct picture to be obtained of the bedrock and the mineralisation or minerals of interest. Samples are taken from drill cores for mineralogical investigations and chemical analysis.

In most cases the bedrock is covered by till or other Quaternary deposits. Ores covered by soil layers can rarely be indicated by geological methods. Because ores and alteration zones often deviate in their physical properties from surrounding rocks, they can be detected by geophysical methods. The most common geophysical methods are magnetic, gravimetric, electrical, seismic and radiometric. Measurements can be performed on the ground, in boreholes and from airplanes and helicopters.

Geochemical prospecting includes sampling, analyses of the samples and evaluation of the analysis result. The geochemical mapping done by SGU is aimed at determining the distribution of principal and trace elements in soil and water. Large parts of Sweden are today covered with modern geochemical maps. Samples taken of till reflect the natural chemical composition of the soil, and the maps can also be used for ore prospecting.

A Quaternary geology sampling by SGU is ongoing in the Simpevarp area (September 2004). Some of the collected samples have been analysed for several elements, including gold. Furthermore, six samples from SGU's till sampling in 1992 were reanalysed using the same analytical methods. The intention was to produce a geochemical map of the Simpevarp area and investigate if there were any elevations in metal concentrations (geochemical anomalies) that could be of further exploration interest.The results are presented in Chapter 6.

In recent years, Swedish authorities have tried to encourage exploration by amendments to the mining legislation (cf section 3.2). In addition, government agency databases have been made accessible to the private sector. Free access to SGU's geodatabases have made it much easier and faster for mining companies to choose the right target area for their operations.

In summary, the Simpevarp area is covered by realtively modern geological, geophysical and geochemical maps.These maps can be used both for scientific and prospecting purposes.

3.2 Swedish mining legislation

Foreign mining companies are today showing greater interest in prospecting in Sweden. One reason for this is the update of the Minerals Act from 1992. According to this law there are no restrictions on foreign ownership of mining and mineral rights in Sweden. The Minerals Act provides that exploration may be carried out only by the holder of an exploration permit and exploitation only by the holder of an exploitation concession. It is the Mining Inspector who issues exploration permits.

The Minerals Act was amanded since 1992, and was appended as of 1 January 1999 to the new Environmetal Code, which was put in force on the same date. An exploitation concession is reviewed by the Mining Inspector and the County Administrative Board with an Environmental Impact Assessment (EIA) under chapter 3–4 of the Environmental Code. An agreement with the landowner and a land acquisition permit are also required. Questions regarding e.g. water supply and groundwater are reviewed by the Environmental Court. A municipal building permit shall also be obtained for buildings and plants built in connection to the planned mine. Thus, an extensive regulatory review is required before a mine can start operating.

Special rules apply within areas protected under Chapter 7 of the Environmental code (national parks, nature reserves, cultural reserves). Permits and exemptions from the regulations are obtained from the Country Administrative Board.

It should also be pointed out that when an exploitation concession has been granted for an area, the public interest for mineral extraction has considerable strength. It is in the public interest that extraction of ores and minerals is secured within the country.

The Minerals Act does not apply within a public water area in the sea.The Continetal Shelf Act from 1966 governs mineral extractions in Sweden. By the continental shelf is meant a seabed within public water areas and the offshore area outside Sweden's territorial border. According to this law, the right to explore and extract natural resources of the continetal shelf belongs to the state. The Government can issue a permit to someone other than the state to explore the continetal shelf by means of geophyscial surveys, drilling or other means and to extract natural resources from it. An exploitation must also be examined under the Environmnetal Code, and an EIA shall be included in the permit application. A permit for sand, gravel and stone quarrying situated within a public water area in the sea is issued by the Geological Survey of Sweden (SGU).The survey area herein, known as the Simpevarp area, is thus subject to two different laws as regards investigation and exploitation of ore and mineral resources.

3.3 The Simpevarp area in a regional geological context

The majority of the rocks in southeastern Sweden were formed during a period of intense igneous activity c 1,810–1,760 Ma ago /Kornfält and Wikman, 1987; Kornfält et al. 1997/, during the waning stages of the Svecokarelian orogeny. The dominating rocks comprise granites, syenitoids, dioritoids and gabbroids, as well as spatially and compositionally related volcanic rocks. The granites and syenitoids, as well as some of the dioritoids are by tradition collectively referred to as Småland "granites". Both equigranular, unequigranular and porphyritic varieties occur. Hence, the Småland "granites" comprise a variety of rock types regarding texture, mineralogical and chemical composition.

This generation of igneous rocks belong to the so-called Transscandinavian Igneous Belt (TIB), which has a north-northwest extension from southeastern Sweden through Värmland and Dalarna into Norway where it finally disappears beyond the Scandinavian Caledonides (Figure 3-1). It is characterized by repeated alkalicalcic-dominant magmatism during the time period c 1,860–1,650 Ma ago. Magma-mingling and -mixing processes are typical for TIB rocks and indicate a close time-wise and genetic relationship between the different rock types. In mesoscopic scale, these processes often result in a more or less inhomogeneous bedrock regarding texture, mineralogical and chemical composition. Associated with the TIB rocks are dykes of fine- to medium-grained granite and pegmatite.

After the formation of the TIB-related rocks, the next rock-forming period in the Oskarshamn region, including southeastern Sweden, did not take place until c 1,450 Ma ago. It is characterized by the local emplacement of granitic magmas in a more or less cratonized crust. In the Oskarshamn region, the c 1,450 Ma magmatism is examplified by the occurrence of the Götemar, Uthammar and Jungfrun granites (Figure 3-1) /Kresten and Chyssler, 1976; Åhäll, 2001/. Fine- to medium-grained granitic dykes and pegmatites that are related to the c 1,450 Ma granites occur as well, e.g. in the Götemar granite.

For a more comprehensive description of the geological evolution of southeastern Sweden, see /SKB, 2004/.

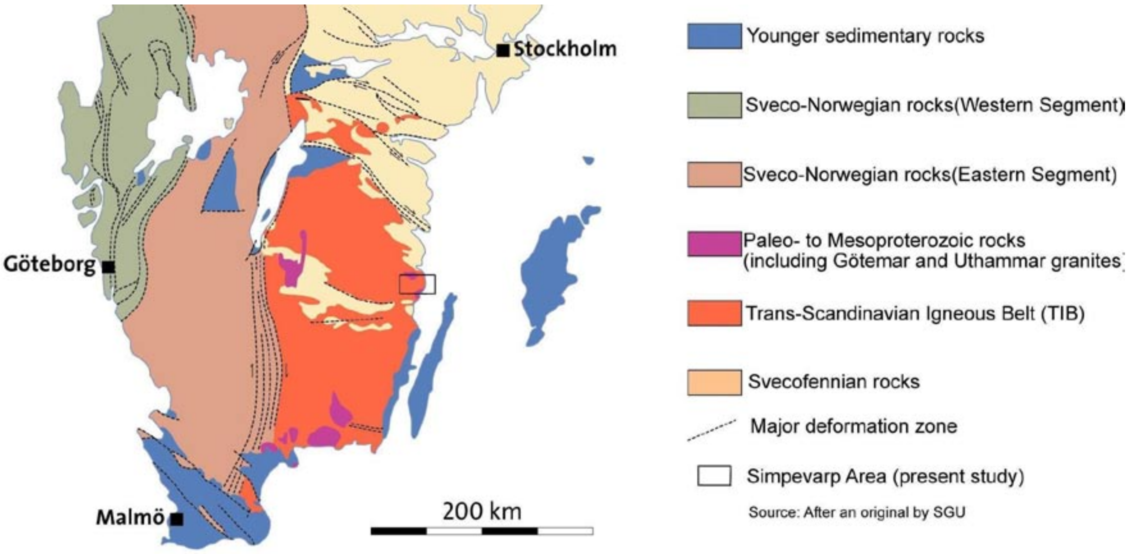


Figure 3-1. *Schematic geological map of southern Sweden. The Simpevarp area is indicated. After an original by SGU.*

3.4 Stone quarrying in the region – a historical retrospective

Quarrying of commercial stones has from time to time been extensive in the Oskarshamn Municipality. It is mainly granites that have been excavated and used as building- and ornamental stones. Already in the 1860ies there was a widespread quarrying of "the red stone" especially along the coastal land of the northern part of the Kalmar County /Länsstyrelsen i Kalmar län, 1993/. In connection to the quarries stonemasonries were established, and in the 1920ies use of framesaws were common. Stone masonry was a pure handicraft till about 1930. After the second world war the trend was towards mechanisation and to date modern machines and tools are highly used.

The products from the quarries have varied from time to time. At the end of the 1900 century quarrying of stone blocks for monuments were extensive and most of that stone was exported to countries in Europe. Production of paving-stones started leter but this manufacture came to an end at the beginning of the second world war.

As late as in 1989 about 17,000 tonnes of stone was mined in the County of Kalmar /Bruun et al. 1991/. In 1997 there were 11 quarries in production in Oskarsham Municipality /Bergman et al. 1998/. These quarries were located at the Götemar and Uthammar granites and to Påskallavik situated south of Oskarshamn. Gradually the stone quarrying declined in importance in the region, and to date there is only one pit in the study area which produces commercial stone. This pit at Kråkemåla is situated in the central part of the Götemar granite.

The Flivik, Götebo and Hökhult granite occurrences have been classified as deposits of national importance according to the Environmental Act /SGU, 2004/. The Götebo quarry is situated inside the study area.

Reliable information on geological parameters and physical properties is the basis for the quarrying and processing of a commercial stone deposit. SGU is the central authority for mineral supply under the Ministry of Industry and the expert consultant to the state regarding analysis and statistics in the minerals sector.

Svenska Bergmaterialindustrin, SBMI (the Swedish Aggregates Producers Association) is the aggregate industries national trade association.

4 Compilation of geological information bearing on ore potential

4.1 Bedrock geology of the Simpevarp area

The SDM version 0 bedrock map of the Simpevarp regional model area is shown in Figure 4-1. Inserted is the detailed bedrock map of the Simpevarp sub-area /Wahlgren et al. 2004/. Dominant and subordinate rock types as well as tectonic structures are described in /Wahlgren et al. 2004; SKB, 2004/.

Detailed bedrock mapping of the Laxemar subarea and its immediate surroundings has been carried out during the summer 2004 and the results will be incorporated in the Laxemar SDM 1.2. Despite the lack of detailed bedrock information in the regional model area outside the Simpevarp sub-area, the bedrock map in Figure 4-1 gives an overview and includes symbols for stone quarries that were in production year 2001.

The bedrock of the Simpevarp area is dominated by c 1,800 Ma old granites to dioritoids that belong to the Transscandinavian Igneous Belt (TIB), Figure 3-1. The dominant rock type in the Simpevarp regional model area is the so-called Ävrö granite, which is a collective name for a reddish grey to greyish red, medium-grained, generally porphyritic rock that varies in composition from granite to quartz monzodiorite (Figure 4-1). It belongs to the suite of igneous rocks that traditionally is called "Småland granite". Furthermore, grey to reddish grey, medium-grained and equigranular quartz monzodiorite constitute a dominant rock type. The southern part of the Simpevarp peninsula is dominated by a grey, fine-grained dioritoid. The latter also occurs as a narrow, winding northeast trending belt through Ävrö, and as minor bodies west of the Simpevarp peninsula. Furthermore, red to greyish red, medium- to coarse-grained granite and fine- to medium-grained diorite to gabbro are also characteristic rock types in the Simpevarp regional model area (Figure 4-1).

A characteristic feature in the Simpevarp regional model area is the occurrence of fine- to medium-grained granite, usually as dykes but also as veins and minor bodies /Mattsson et al. 2002/. Furthermore, pegmatite frequently occurs and pegmatite cross-cutting granitic dykes and vice versa is observed. Consequently, at least two generations of fine- to medium-grained granite as well as pegmatite occur. However, they are all interpreted to belong to the waning stages of the igneous activity that formed the majority of the rocks in the region.

Locally, a fine-grained mafic rock occurs as sheets, dykes or minor bodies. Generally, it is mixed (net-veined) with fine- to medium-grained granite, and, thus, they constitute composite intrusions.

A conspicuous rock type in the regional model area is the occurrence of two large bodies of approximately 1,450 Ma old granite /Åhäll, 2001/, the so-called Götemar granite in the northern part and the so-called Uthammar granite in the southern part. The granites are red to greyish red and commonly coarse-grained, but fine- to medium-grained varieties occur in the Götemar granite. The Götemar and Uthammar granites are characterised by a relatively high content of fluorine /Alm and Sundblad, 2002/. The Götemar granite has a relatively high content of radium, generally more than 100 Bq/kg /Bergman et al. 1998, p 78/. Analysis of scattered bedrock samples around the Kråkemåla stone quarry /Wikman and Kornfält, 1995/ indicate a relatively high content of uranium and thorium, and the Götemar granite is one of the most uranium-rich (and radium-rich) granites in Sweden /Wilson and Åkerblom, 1980/.

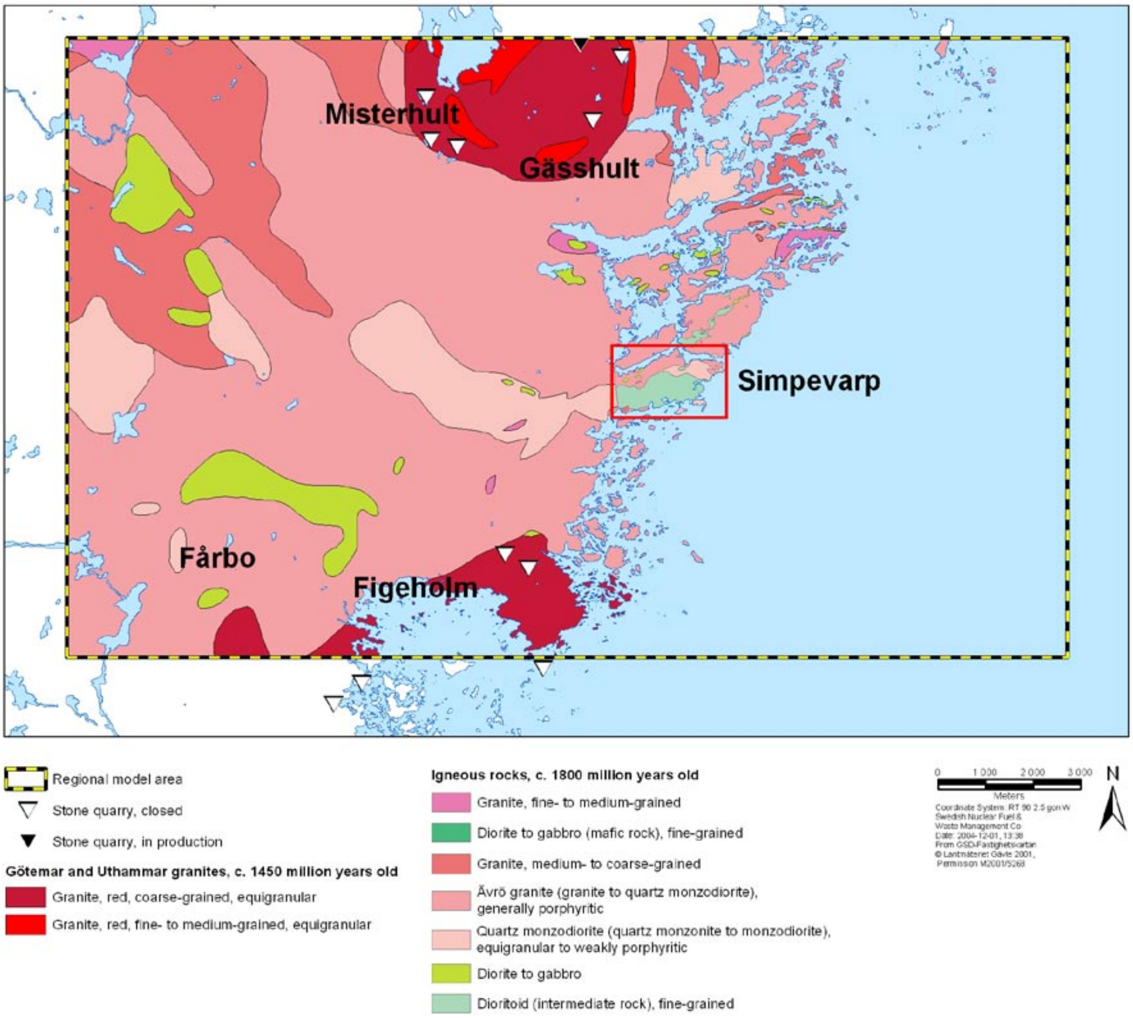


Figure 4-1. *Geological map of the Simpevarp area. Combination of the bedrock map from the model version 0 and the bedrock map of the Simpevarp sub-area.Compiled by SGU.*

The extension of the Götemar and Uthammar granites, as shown in Figure 4-1, have been used in construction of the mineral resource map of the Simpevarp area (Figure 4-3, section 4.4).

Pegmatites occur in the Götemar granite, some of which contain beryl and topaz /Kresten and Chyssler, 1976/, minerals that could be associated with tin- and wolfram-mineralised granites. However, so far no occurrence of these metals have been found /Bergman et al. 1998/. Occassionally, thin veins filled with fluorite, calcite and/or galena are found both in the Götemar and Uthammar granites /Alm and Sundblad, 2002/. The ore potential of these relatively small vein-mineralisations is discussed in section 4.3.1. In the Kråkemåla 1 quarry (section 4.4.2 and Figure 4-3), narrow dykes filled with sandstone have been found in the Götemar granite /Kresten and Chyssler, 1976; Alm and Sundblad, 2002/. These sandstone fillings are probably related to the Cambrian sandstone that covers the Precambrian basement along the coast in the southern part of the Oskarshamn community.

A lot of lineaments have been identified in the regional model area, some of which have been upgraded to deformation zones /SKB, 2004/. Some of these are treated in connection with the geophysical study in Chapter 5, since they are originally identified by interpretation of geophysical and topographic data. Interpretations of their possible ore potential are given in Chapter 5, and the ductile Äspö shear zone is discussed to be of possible gold-exploration interest.

For a more comprehensive description of the bedrock geology of the Simpevarp area, see /SKB, 2004/ and /Wahlgren et al. 2004/.

4.2 Quaternary deposits – an overview

The SKB 1998 municipal survey included a chapter dedicated to the quaternary geology /Bergman et al. 1998/. The survey included a Quaternary geological map which partly was compiled from data interpreted from airphotos.The area of exposed bedrock or bedrock with a thin overburden is relatively high in the entire Oskarshamn Municipality.The dominating Quaternary deposit is glacial till. Other glacial sediments are mainly clay. Some postglacial sediments which can be desribed as resedimented glacial soils, are also encountered. In certain areas the till surface has been reshaped by wave-washing during land uplift /Rudmark, 2004/. The most common organic sediment is the peat.

Till has been extensively used in Scandinavia as a sample medium for geochemical mapping and geohemical ore exploration. Fore example, regional geochemical maps based on till samples have been compiled by SGU for a long time all over Sweden.The County of Kalmar was included in 1992 /Andersson and Nilsson, 1992/.The geochemical survey in this study (Chapter 6) concerns mainly top-till samples, and minerogenic samples taken from streams.

4.3 Known mineral- and dimensional stone occurrences

4.3.1 Sulphide mineralisations and minor vein mineralisations

Occurrences of sulphide minerals are not common within the Simpevarp area. However, in a few cases sulphide minerals containing lead (Pb), zinc (Zn) and copper (Cu) as well as molybdenum (Mo) occur outside the study area, and mainly in rocks belonging to the Småland Granite suite. Such minor mineralisations have partly been mined. Within the municipality of Oskarshamn, three shallow quarries at Ramnebo are examples of a local, small-scale mining, in this case for copper /Bergman et al. 1998/. Most probably the copper ore was transported to the near Mörtfors where a copper-leaching plant was situated. This type of mining, mainly between the world wars, was probably of importance for the region, but small in a national perspective.

Scattered occurences of molybdenum are encountered within a few places in the municipality of Oskarshamn /Bergman et al. 1998/. All occurrences are associated with the Småland granite. Molybdenum is an alloy metal used for production of special steel. It is commonly associated with granitic rocks. During word war II the demand for molybdenum was higher than it is today. Consequently, mining for molybdenum was then more common and a major Scandinavian producer was the Knaben Mine i Southern Norway /SOU, 1979/. There is little information about molybdenum mining in Sweden, most known occurrences are situated in the County of Norrbotten.Two small Mo-occurrences named Bankhult and Östrahult, both situated east of the Simpevarp area, have no economic potential /Bergman et al. 1988/.

Occurrences of fluorite-calcite-galena-bearing veins are found in several places in the counties of Kalmar and Blekinge /Alm and Sundblad, 2002/. Fluorite (CaF_2) is a fluorine-bearing mineral which commercially is used in the steel industry as an fluxing agent and for production of fluoric acid (HF). There has never been any mining of fluorite in Sweden.

Calcite is the most common carbonate mineral ($CaCO_3$). Galena is the most common lead-bearing mineral (PbS). These types of vein occurrences are encountered at Götemar, Uthammar-Figeholm and on the island of Blå Jungfrun /Alm and Sundblad, 2002/.

Fluorite veins are relatively frequent in the Götemar granite /Kresten and Chyssler, 1976; Kornfält et al. 1997/. However, their scattered appearences and the fact that the flour-content is, from an ore-geological point of view, relatively low grade, 0.43% F in average as reported by /Kresten and Chyssler, 1976/, judge them as being of no economical value.

The thin calcite-galena-bearing veins are neither of economical value. Galena has only been noticed in two places in the Kråkemåla 2 quarry and in one place at Uthammar /Alm and Sundblad, 2002/. It is obvius that the younger granites at Götemar and Uthammar-Figeholm (Figure 4-1) contain a lot of small vein mineralisations associated with a fracture-forming process of no ore economical value. The enhanced lead-content in the geochemical samples taken by SGU from an area south and south-east of Lake Götemaren may be related to the galena-bearing veins here described (Figure 6-4 in Chapter 6).

Dykes and veins of coarse-grained pegmatite are also found in the Götemar granite /Bergman et al. 1988/. Some pegmatites contain the minerals beryl and topaz. In a few cases they also contain quartz-veins surrounded by thin mica-rich alteration zones resembling “greisen veins” being typical for tin (Sn) and wolfram (Wo) mineralisations /Kresten and Chyssler, 1976; Bergman et al. 1998/. So far no tin or wolfram minerals has been reported in outcrops at Götemar. However, south of the Götemar granite massif elevated concentrations of tin and wolfram has been noticed in till samples and minerogenic stream sediment samples collected by SGU and SGAB, respectively (see Chapter 6).

In summary, the small sulphide mineralisations in the Småland granites and the different types of vein-mineralisations in the Götemar and Uthammar granites have probably no or very small economical value. They suggest that fracture-forming processes have occurred in this part of the Swedish bedrock with subsequent introduction of metal-bearing solutions in relatively low concentration and distribution.

4.3.2 Commercial stone occurrences

By commercial stone is meant a rock that can be used in construction or manufacturing industries either as such or as a fabricated product.For example, granite can be quarried and solds as blocks or sawn into slabs. It can also be chrushed and used as aggregate.

Stone quarrying in the region has a long tradition. Most of the quarries in Småland are situated near the coast where possibilites for loading blocks of stone on ships for transport to the different parts of Europe existed. The most important commercial stone is granite or “the red stone” as it was named by the people of county. Geologically, both the older Småland granite and the younger Götemar and Uthammar granites have been mined. However, the stone quarrying in this area has recently decreased. In 1998 there were 11 quarries in operation within the Municipality of Oskarshamn /Bergman et al. 1998/. Today there are only two quarries in production, at Askaremåla and at Kråkemåla /SGU, 2004/. The Kråkemåla occurrence includes at least three separate quarries and the largest pit is the Kråkemåla 2 pit with a dimension c 600 m in length and c 100 m wide (Figure 4-2).

Figure 4-2. *The Kråkemåla stone quary situated in the northernost part of the Simpevarp area. Photo B Alm, University of Stockholm, 2004.*

In order to visualize the extent of stone quarrying within the Simpevarp area the most important ones were plotted onto the geological map, Figure 4-1. They are listed in Table 4-1. The information is taken from reports by SGU /SGU, 2004/ or from the regional community investigation /Lindroos in Bergman et al. 1988/. Unfortunately there is no avilable information on the present quantities of stone mined at Kråkemåla. It is common that stone quarrying at this scale is not a continous process. Many times abandoned quarries can be put into production when demand and/or the price of the stone becomes financially tractable.

There is a lof of scrap produced from this type of stone quarrying. From time to time the scrapstone (Swedish "skrotsten") has been used as paving stone.

In modern time chrused rocks, mainly from shallow pits or road cuts, are widely used for production of aggregates. However, there is no production of chrushed rocksat present within the Simpevarp area /C Ålinder, SGU, oral information, September 2004/.

Table 4-1. Commercial stone pits within the Simpevarp Area.

No in Figure 4-3	Name	Coordinates	Type of rock	Status	Relative size *
1	Kråkemåla 1	6372860 N 1549790 E	Götemar granite	In production 2004	2–3
2	Kråkemåla 2	6372600 N 1550650 E	Götemar granite	Closed	3
3	Götebo	6371750 N 1546550 E	Götemar granite	Closed	3
4	Bussvik	6371250 N 1550050 E	Götemar granite	Closed	2
5	Gästernäs 1	6370850 N 1546650 E	Götemar granite	Closed	2
6	Gästernäs 2	6370700 N 1547200 E	Götemar granite	Closed	2
7	Uthammar 1	6362150 N 1548200 E	Uthammar granite	Closed	2
8	Uthammar 2	6361850 N 1548700 E	Uthammar granite	Closed	2
9	Oxelholmen	6359750 N 1549000 E	Uthammar granite	Closed	2
10	Stora Skaftvik	6359450 N 1545200 E	Uthammar granite	Closed	1
11	Lilla Skaftvik	6359000 N 1544600 E	Uthammar granite	Closed	1

Relative size of pit:

1 = pit with a mining front < 20 m in width.

2 = pit with a mining front 20–100 m in width.

3 = pit with a mining front > 100 m in width.

4.4 The mineral resource map of the Simpevarp area

The mineral resource map, Figure 4-3, shows the extent of bedrock with ore and commercial stone potential in the Simpevarp area. The map is based on the geological map (Figure 4-1), the geophysical survey (Chapter 5), the geochemical surveys (Chapter 6) and commercial stone occurrences in SGU's mineral deposit database /SGU, 2004/. The mineral resource map is the final product of the present study being based on a succession of geoscientific proofs, and on conventional experiences in ore and mineral exploration in Sweden.

Within the study area there are two areas composed of the younger granites, the Götemar respectively the Uthammar granite, with a potential for commercial stones. The reddish Götemar granite has been quarried for about one hundred years and it is likely that this activity will continue with variable intensity also in the future. The geophysical survey has outlined areas outside the major massif of the Götemar granite as possible smaller sub-intrusions of the same type of granite. As there is today no geological proofs for this, the limit of the stone potential area at Götemar coincides with the extent of the Götemar granite on the geological map in Figure 4-1.

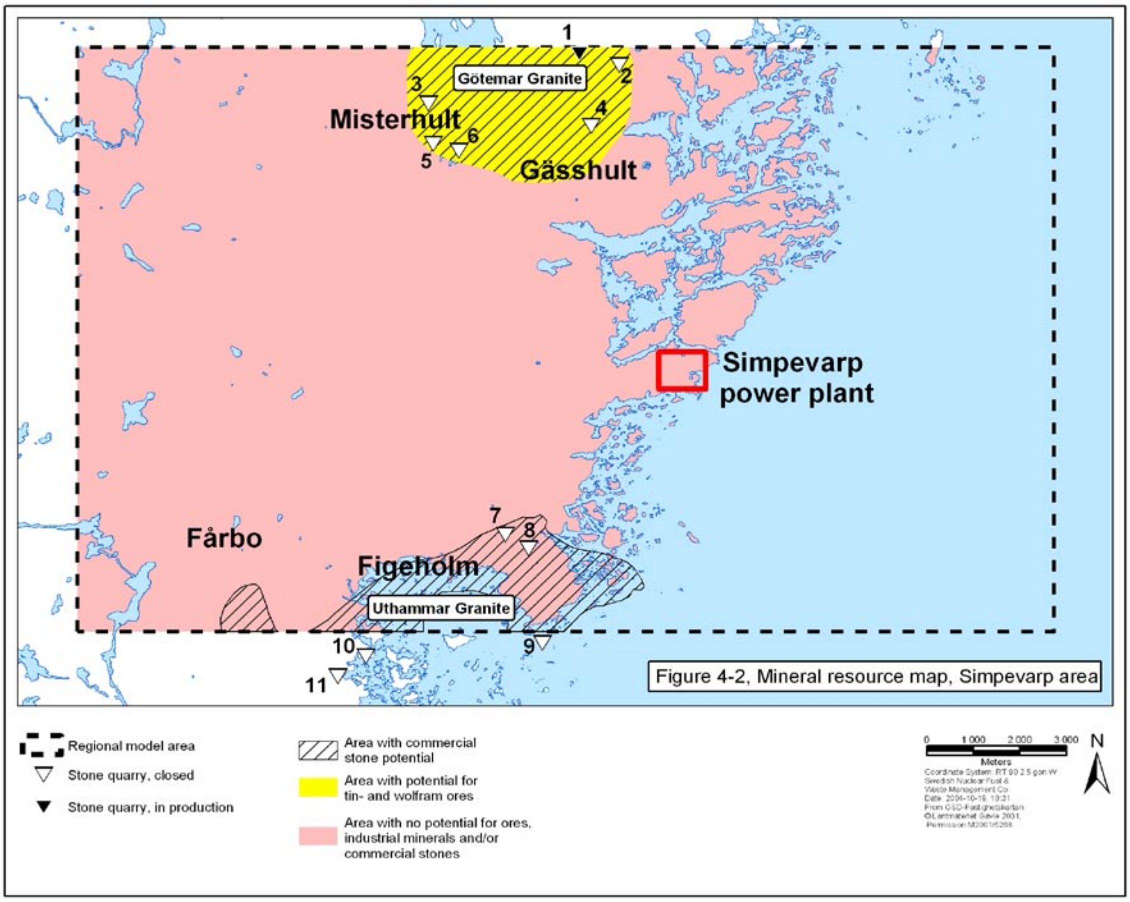


Figure 4-3. *Mineral resource map of the Simpevarp area. Areas with ore and dimensional stone potential are shown on the map. The numbering of the stone quarries refers to Table 4-1, section 4.3.2.*

The Götemar granite may also have a potential for tin- and/or wolfram-mineralisations. The reasons for this is the occurrence of beryl- and topaz-bearing pegmatites and minor greisen-veins, both normally associated with tin- and/or wolfram-mineralisations. Furthermore, the results of the geochemical survey using heavy mineral samples (Chapter 6 and Figure 6-6) indicate the occurrence of wolfram-bearing mineral (scheelite) in an anomaly situated to the southeast i.e. the dominant ice-direction of the Götemar granite. These and other geochemical samples from the Götemar area show enhanced values of the elements lead (Pb), wolfram (W), zinc (Zn) and copper (Cu).

There is no global shortage of the metals tin and wolfram, and no domestic interest in mining these types of ores. Therefore, the ore potential described here should be judged as very small.

Stone quarrying along the coast at Uthammar has been of less importance compared to that in the Götemar area. Because of environmental aspects, it is unlikely that extensive stone quarrying will take place in the coastal and off-shore area at Uthammar-Figeholm.

The geophysical EM-anomalies described (Chapter 5) may have many various explanations. There are however no anomalies that can be related to any sulphide mineralisation of economic dimensions.

The scattered, thin veins occassionaly containing galena in the Kråkemåla area (section 4.3.1) are of no economical interest. A weak geochemical anomaly with enhanced values of i.a. lead occurs to the south of Lake Götemaren (Figure 6-5) probably reflecting the occurrence of galena-filled veinlets in the granite.

The geochemical survey (Chapter 6) shows no samples that can be interpretad as geochemical anomalies related to an economically interesting mineralisation containing e.g. base metals or gold. In fact, the gold content of the analysed till samples is very low. An earlier evaluation of the gold potential in the region using geochemistry and ore boulder prospecting methods resulted in a similar judgement /SGAB, 1987/.

A major part of the Simpevarp area has no potential for ore, industrial minerals or commercial stones. The two candidate areas of the SKB site investigation in Oskarshamn, the Simpevarp and the Laxemar sub-areas (see Figure 1-1 and Figure 4-3), are completely avoid of ore or mineral potential. There is no interest for prospecting in the entire area.

4.5 Comparisons with southern Sweden

The dominating rocks of the Simpevarp area are different types of granitoids (Figure 4-1). A majority of the known iron- and sulphide ores in middle and southern Sweden are associated with supracrustal rocks. In the Bergslagen Ore Province (Figure 4-4) nearly all ore deposits occur in supracrustal rocks of volcanic or sedimentary origin. There is thus a connection between these rocktypes and the occurrences of ore. The bedrock of the study area consists primarily of plutonic rocks, and there is nothing to indicate the occurrence of mineralisations containing economical concentrations of the metals iron, lead, zinc, copper and gold, or rocks or minerals of interest of an ore geology viewpoint.

The Götemar and Uthammar granites may contain minor greisen-type of tin- and wolfram mineralisations. These types of mineralisations are found elsewhere in Sweden, mainly in the Storuman-Arjeplog area in northern Sweden.

Small mineralisations with copper and/or molybdenum are occasionally found in the Småland granites and a few within the Oskarshamn area /Bergman et al. 1998/.

There are no known gold occurrences in this part of Sweden. Outside the study area small gold deposits occur around Ädelfors to the west of Oskarshamn Municipality (Figure 4-4). These deposits are gold-bearing quartz veins mainly located in shear zones. The Äspö shear zone (Chapter 5) could be of some exploration interest in this aspect, but as compared to the Ädelfors area, there are – according to the till sampling survey (Chapter 6) – no gold geochemical anomalies and no field observations favouring the occurrence of gold. In contrast, the Ädelfors area is highly anomalous to gold as seen on SGU's geochemical maps /Andersson and Nilsson, 1992/.

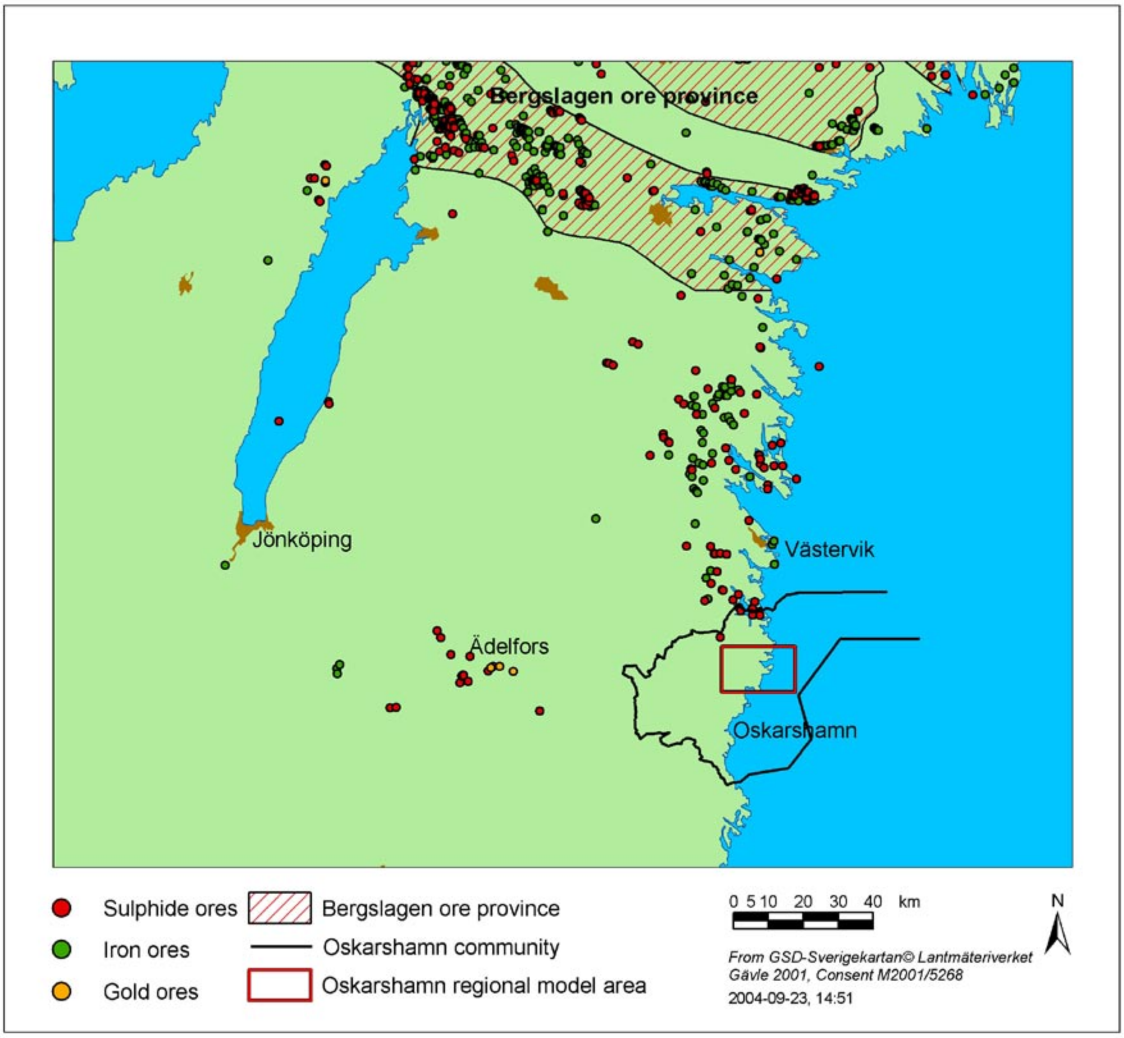


Figure 4-4. *Known deposits of iron ores, sulphide ores and gold ores in south-eastern Sweden. The Simpevarp area is marked. Deposit data compiled by SGU, 2004.*

5 Geophysical investigations

5.1 Recent geophysical surveys and their ability to reflect the ore potential of the Simpevarp area

In 2002, the Geological Survey of Norway (NGU) carried out a detailed helicopter-borne geophysical survey over the Simpevarp area /Rönning et al. 2003/ (Figure 5-1). The survey was conducted along north-south lines with tietly-lines flown east-west and it included gamma ray spectrometry, VLF, magnetics and multi-frequency electromagnetics. The line separation was 50 m with sensors at an altitude of about 30–60 m.

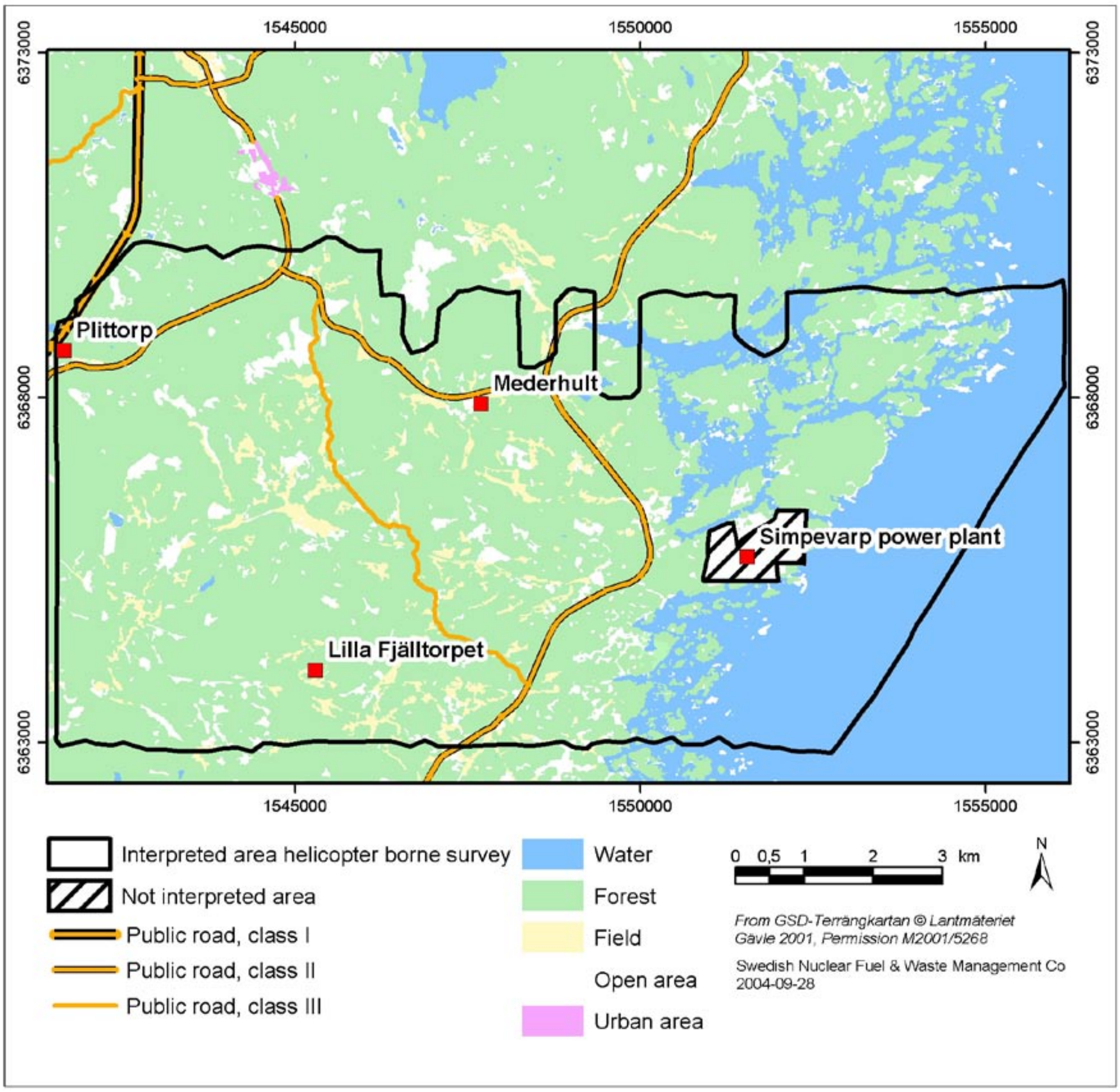


Figure 5-1. *Map showing coverage of the helicopter-borne geophysical survey carried out over the Simpevarp area /Rönning et al. 2003/.*

The helicopter-borne survey was interpreted and described in the form of lineaments and of surfaces or volumes of bedrock with homogeneous petrophysical characteristics /Triumf et al. 2003b/.The report included some geometrical information about the sources of the geophysical anomalies. The lineaments identified from different data sets, such as the helicopter-borne survey, the digital elevation model based on an air photo survey /Wiklund, 2002/ and the data from a detailed marine geological investigation /Elhammer and Sandqvist, 2005/ were analyzed jointly /Triumf, 2004a,b/. Some of the lineaments were investigated further with ground geophysical measurements /Thunehed et al. 2004/.

In 2004 a gravity survey was carried out in the Simpevarp area /Triumf, 2004c/. The survey was focused on the Laxemar area and its surroundings. The principal aim was to determine the geometry (dips) of the major rock units within the area. The gravity survey of 2004 should be regarded as an "in-fill survey" of a regional gravity survey of 1987 /Nylund, 1987/ which covers the Simpevarp and Oskarshamn areas.

Through the geophysical surveys mentioned above a comprehensive petrophysical characterisation of the different rock types was established. An additional petrophysical survey included compilation of data from rock samples and in-situ measurements /Mattson et al. 2003/. It is also possible to use the geophysical surveys in order to predict the occurrence of possible ore mineralisations.

One example of a mineral occurrence, which often is related to tectonical processes, is gold in quartz veins. These tectonical processes, which have acted on the bedrock , are well reflected in the digital elevation model and in electrical and/or magnetic properties of the bedrock. The magnetic susceptibility of shear zones, for example the Äspö shear zone, appears to be affected by tectonic processes in a different manner as compared to zones characterised by a more brittle fracturing. Shearing in a dominantly ductile mode appears to have lowered the magnetic susceptibility of the host rock. This phenomenom occurs in a wider zone as compared to the same phenomenom of a purely brittle deformation. Several wide low-magnetic zones interpreted have also been identified on outcrops (Figure 5-2).

The Götemar granite occurs in the northernmost part of the study area (Figure 4-1). The air-borne survey carried out by SGU shows a fairly low-magnetic circular anomaly with an increased level of the radiation of uranium and thorium (Figure 5-3). The granitic body is also visible in the form of a minimum on the gravimetric map.

The Götemar granite may have a potential for the greisen-type of tin- and wolfram-mineralisations /Bergman et al. 1998/. These normally thin vein-mineralisations can not be detected by the helicopter-borne surveys here described. If field conditions are favourable a detailed ground geophysical surveys with the IP-method (induced polarisation) may detect this type of mineralisation.

Minor sub-intrusions could also be associated with the larger dome-like Götemar granite and thereby have a potential for the same type of mineralisations as the major intrusion. The ability for geophysical methods to detect minor granitoid bodies depends on their size, shape and depth of burial and, on the character of the surrounding rocks. Though the Simpevarp area has been thoroughly surveyed with different geophysical methods, it can not be ruled out that still unknown sub-intrusions of the Götemar-type of granite could occur in peripheral areas.

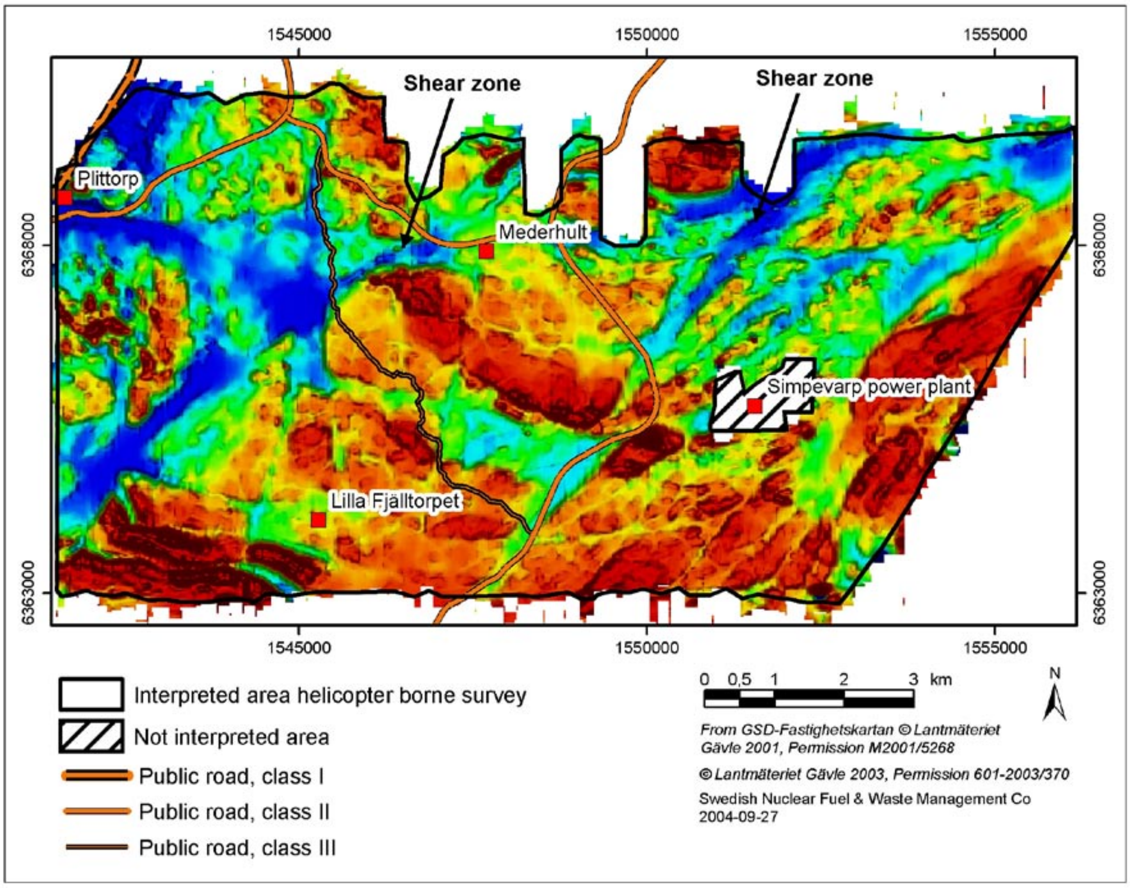


Figure 5-2. *Map showing the magnetic total anomaly field as recorded in the helicopter-borne geophysical survey carried out over the Simpevarp area.Two of the more easily visible shear zones in the magnetic data show prominent reduction in magnetic susceptibility.*

In the Simpevarp area several bodies of dioritic to gabbroic rocks oocur (Figure 4-1). Theoretically these type of rocks could host nickel- and copper-bearing mineralisations, and also the platina group of elements. Normally these metals are associated with sulphide minerals and therefore an increase in the electrical conductivity could be expected over zones containing substantial amounts of sulphide minerals. If so, the increased conductivity would probably be detected with the electromagnetic systems used in the helicopter-borne survey. However, the size, shape and contrast of a sulphide mineralisation are factors of importance for a possible air-borne detection.There are no EM-anomalies in the study area which can be related to a sulphide mineralisation of economical dimensions.

Deposits containing the platina group of elements are often hosted in mafic layered intrusions. Generally the content of sulphide minerals of these types of mineralisations is so low that a detectable increase in the electrical conductivity is not to be expected.

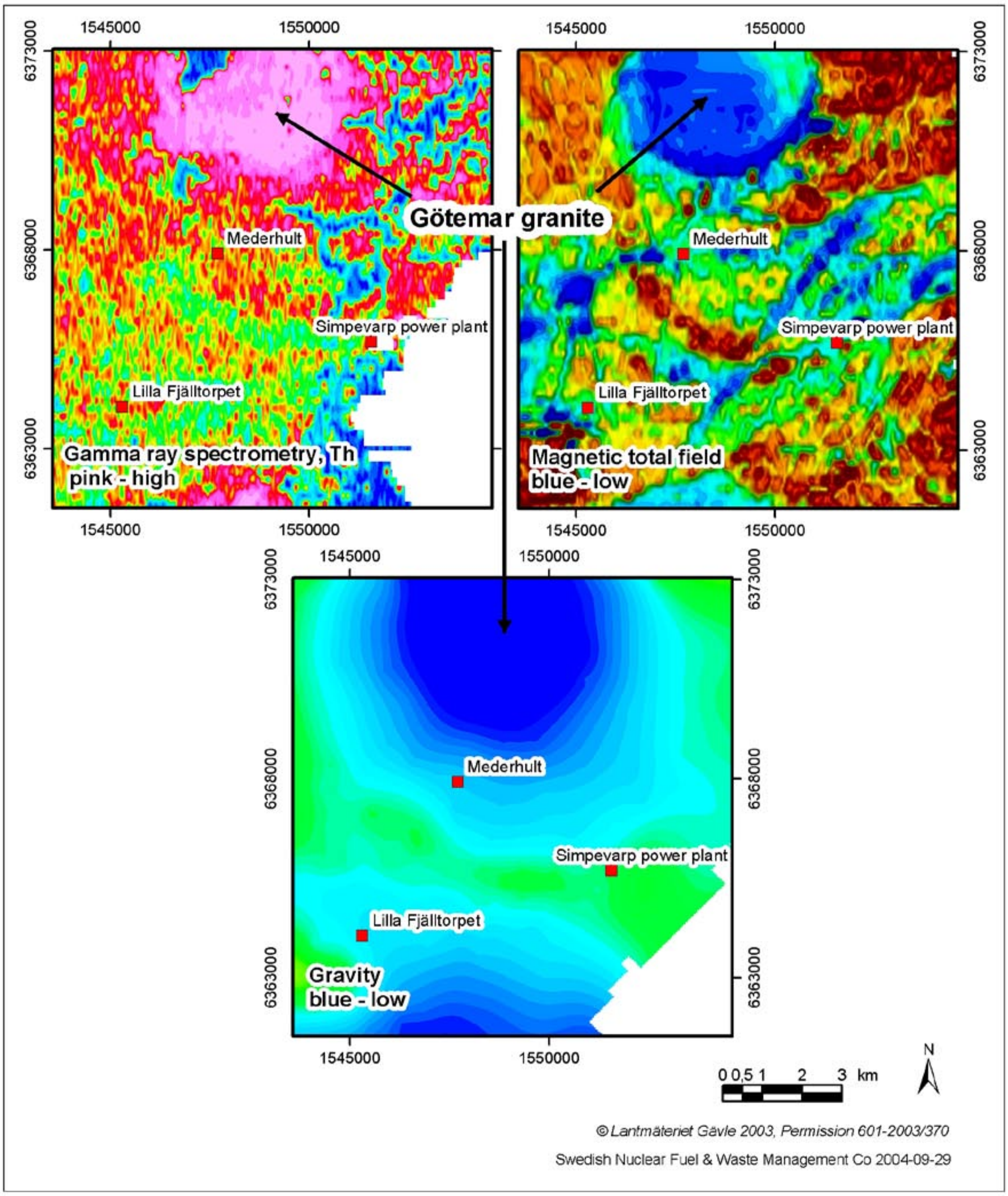


Figure 5-3. *Maps showing geophysical responses of the Götemar granite as recorded in the air-borne fixed wing survey carried out by SGU in 1986 and the gravity surveys of 1987 and 2004. Upper left: radiometrics, Th component (pinkish = high Th content). Upper right: magnetic total field (bluish = low-magnetic field). Lower centre: gravitry (bluish = low).*

In the Simpevarp area (Figure 5-3) larger dioritic to gabbroic rocks may contain volumes with both low and high magnetic susceptibilities, though the latter appears to be dominant. It is thus possible to delineate some of the dioritic-gabbroic massifs by the use of magnetic data. One dioritic-gabbroic complex illustrating this situation is situated a few kilometres north-east of Fårbo (Figure 5-4). Field follow-up measurements indicate that low magnetic bands resembling a layered structure occur within the complex.

Due to a decreased content of the elements K, U and Th, the gamma radiation from most dioritic-gabbroic rocks is low as compared to granitic rocks.The relatively high density of these mafic rocks results in distinct anomalies in the gravity field, provided they have larger dimensions. It is thus believed that it should be fairly easy to detect all the major dioritic-gabbroic complexes in the area covered both by the helicopter-borne geophysics and the ground gravity surveys.

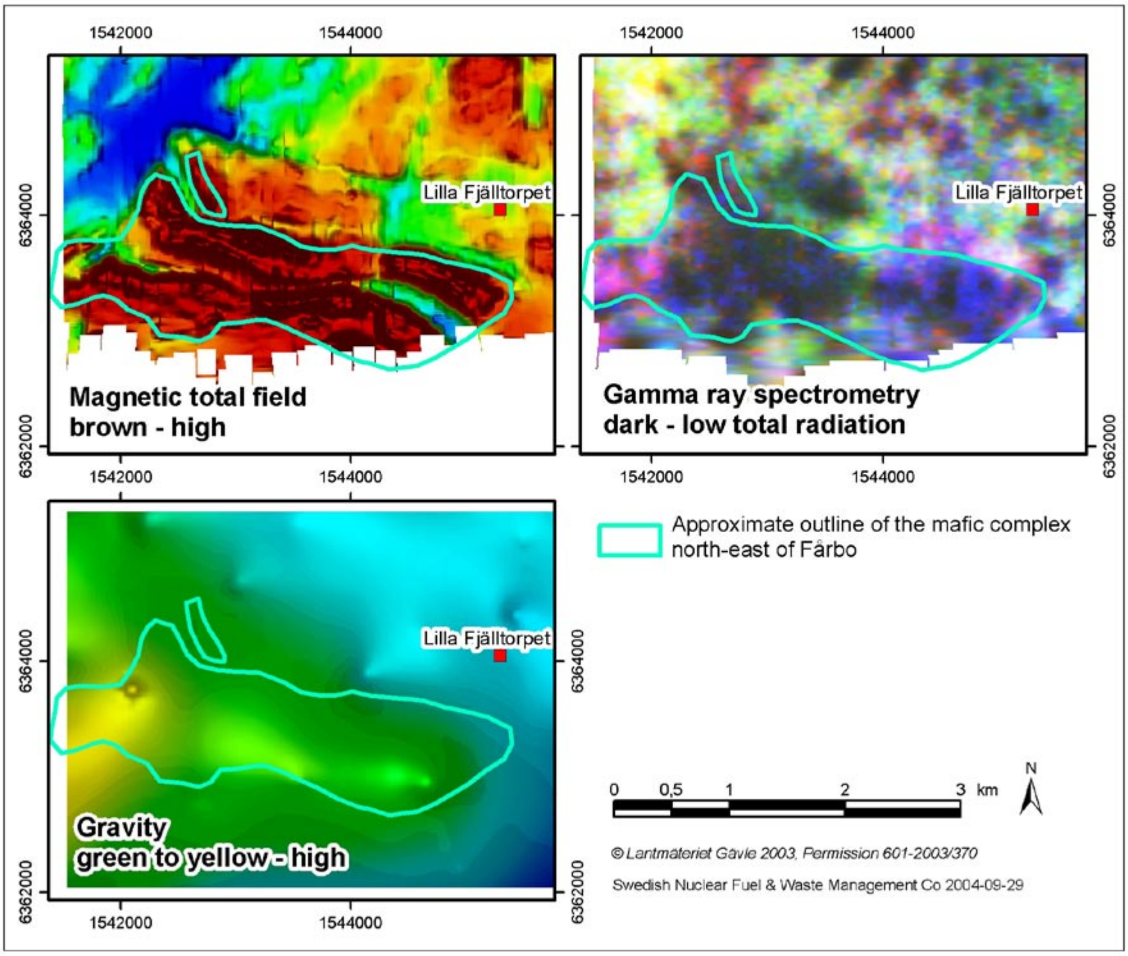


Figure 5-4. *Maps showing the geophysical responses in magnetics (brownish = high magnetic field), radiometrics (dark colours = low radiation) and gravity (greenish to yellowish = high) over a dioritic-gabbroic complex situated to the north-east of Fårbo. Within the magnetic total field several low magnetic bands are visible within the complex.*

5.2 Features of possible exploration interest detected by geophysics

Lineaments

The result of a joint interpretation of lineaments carried out during 2004 has been reported /Triumf, 2003a, 2004b/. Most of the lineaments detected outside the helicopter-surveyed area have been identified from digital elevation models based on air photo or marine geological surveys. A majority of these have probably sometime during the tectonical history suffered from brittle deformation.

Among the lineaments identified within the helicopter-surveyed area some are coinciding with prominent minima in the magnetic field. It is possible that among these a component of ductile deformation may be more common than in the lineaments not coinciding with such loss of magnetic susceptibility.

As gold could occur in ductile shear zones, probably the highest potential forgeophysical identification of such a type of mineralisation is within linear features with pronounced loss of magnetic susceptibility. Figure 5-5 shows the result of the interpretation of magnetic data where i.a. broad zones of low magnetisation occur. The Äspö shear zone is indicated.

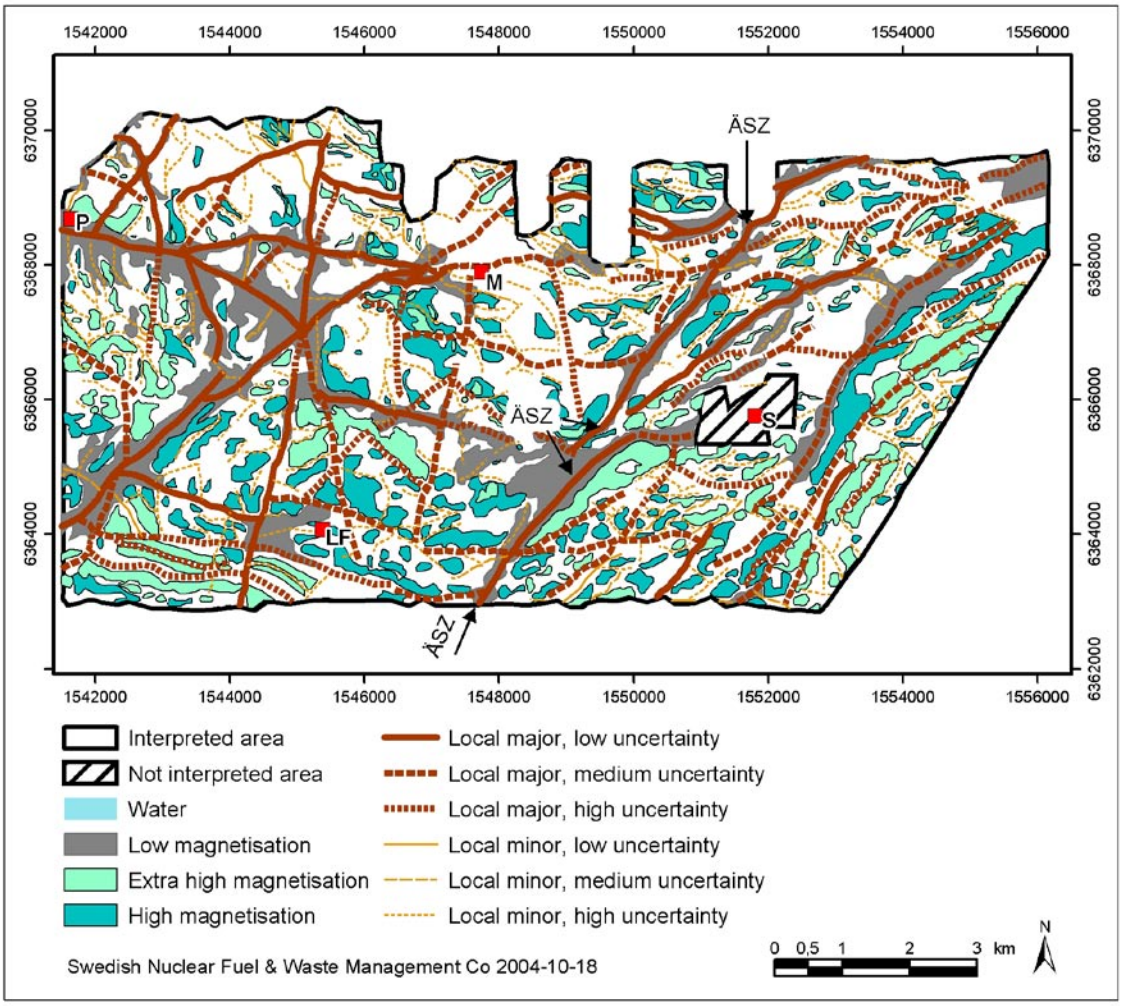


Figure 5-5. *Results of an interpretation of the magnetic total field from the helicopter-borne survey 2002. The area near the Simpevarp power plant is not interpreted. The Äspö shear zone is indicated. S=Simpevarp power plant, M=Mederhult, LF=Lilla Fjälltorpet and P=Plittorp /Triumf et al. 2003b/.*

Dioritic-gabbroic massifs

Within the study area some units of diorite to gabbroic rocks occur (Figure 4-1). Some of them are situated inside the area that has been surveyed with both gravity and helicopter-borne geophysics. Outcropping mafic units, together with unexposed "probable diorite to gabbro complexes" indicated geophysically, have been checked in field regarding their electrical conductivity, as revealed from the multi-frequency EM data (Figure 5-6). In a few cases a slightly increased conductivity can be found to be, at least partly, associated with these mafic complexes. However, by comparing these conductive areas with the digital elevation model it is obvious that most of the anomalies, if not all, are associated with topographic depressions in the terrain. In depressions and low-land areas the conductivity is normally higher because of the increased soil cover and/or increased fracturing in the underlying bedrock, although an increased weathering due to the occurenc of sulphide minerals in the bedrock can not be excluded.The general conclusion is that the anomalies studied here are not related to any near surface sulphide mineralisation associated with dioritic to gabbroic rocks.

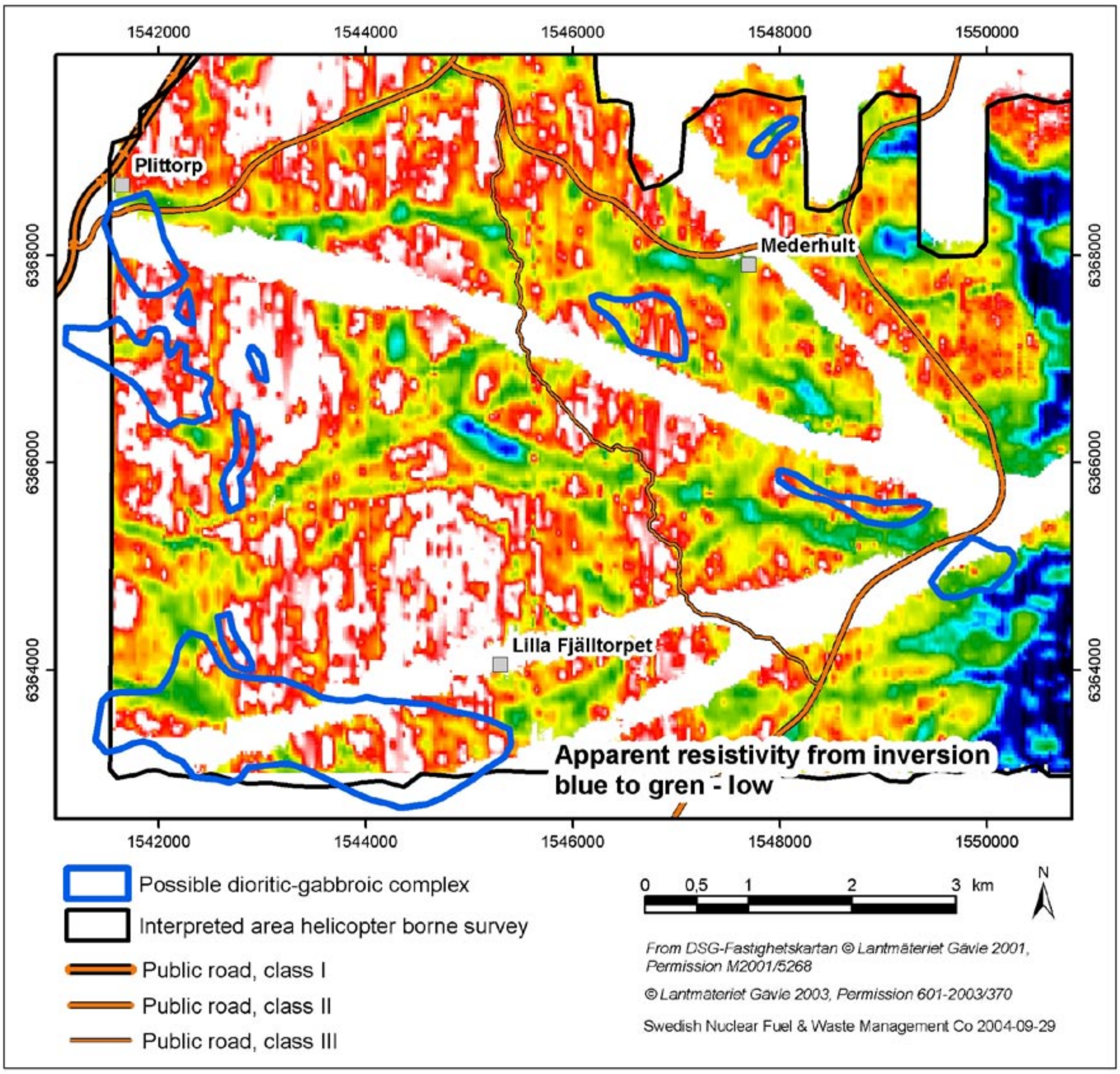


Figure 5-6. *Map showing the electrical conductivity of possible dioritic-gabbroic complexes in the Simpevarp area. In the background the out-of-phase component of the coaxial 7001 Hz EM-system is shown where yellowish to greenish colours indicate increased conductivity. Conductors are found at the borders of the possible mafic complexes and where the digital elevation model oftenly shows topographic depressions.*

Possible sub-intrusions of the Götemar granite type

The petrophysical characteristics of the Götemar granite have been described (cf section 5-1). The geometry of the dome-like intrusion is quite well known at surface. It is possible that minor "satellite" intrusions of Götemar granite could occur outside the dome structure. If they are 300–400 m in surface diameter they would probably yield an anomaly complex with the following characteristics:

- low magnetic total field,
- high content of Th and U in gamma ray spectrometry,
- locally low gravity.

An attempt to deliniate such possible sub-intrusions has been made (Figure 5-7). The identified anomaly complexes may thus indicate sub-intrusions associated with the major Götemar granite massif, but there are also granitic rocks in the area with a similar type of petrophysical characteristics. These are fine- to medium-grained Småland granites. In Figure 5-7 many of the gamma radiation anomalies having a similar appearance as that of the Götemar granite have not been included due to an irregular and partly high magnetisation, or because they can be related to depressions in the terrain.

In the Simpevarp area outcrops are fairly common. Many of the identified complexes presented in Figure 5-7 are probably exposed, which should make future follow-up work diagnostic.

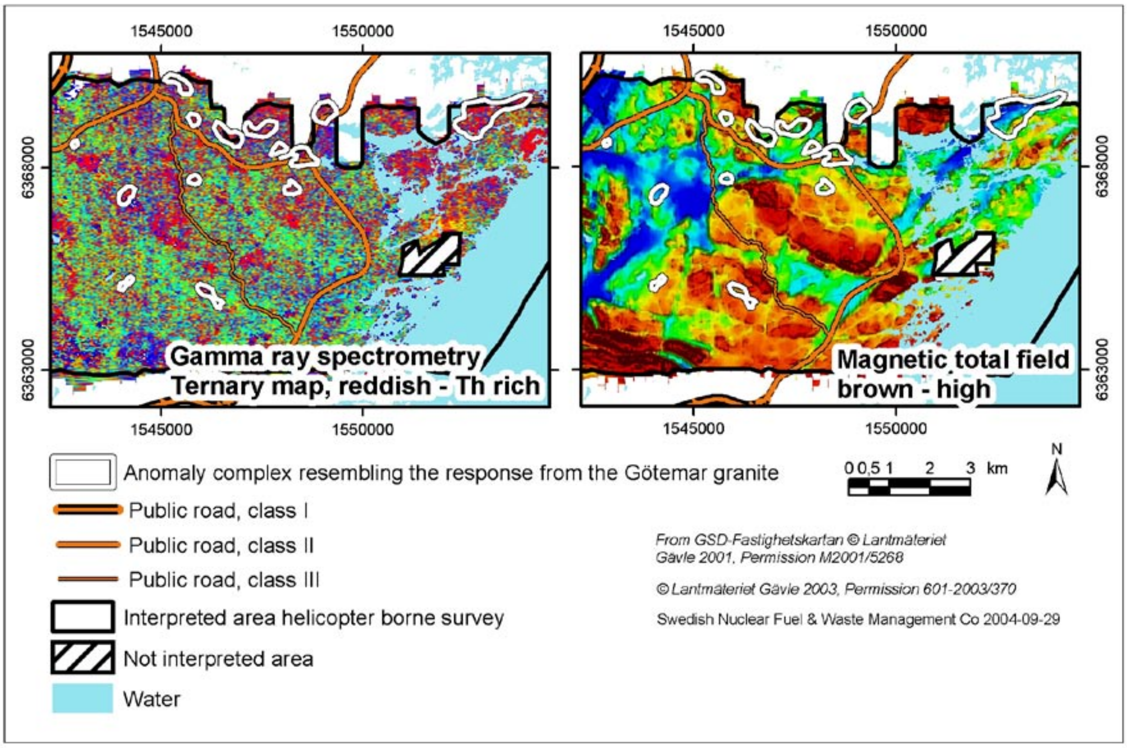


Figure 5-7. *Maps showing some of the areas with a petrophysical character resembling the Götemar granite within the helicopter-surveyed area. To the left the areas are shown on a ternary map presenting the normalised three components K, U and Th where reddish areas resemble the Götemar granite response. To the right the areas are presented on the total magnetic field.*

6 Geochemical investigations

6.1 Geochemical sampling of the bedrock

In conjunction with with the bedrock mapping of the Simpevarp area chemical analyses of 24 samples (Idcode: PSM002138–158, PSM005942,952; PSM003474) of the area's typical rocks were carried out /Wahlgren et al. 2004/. Furthermore, 9 samples from borehole KSH01 and 3 samples from borehole KSH02, respectively, were also analysed (SKB's SICADA data base). In the current survey, the content of certain base metals in the samples has been studied. In brief, there are no anomalous concentrations of metals in the rocks typical of the Simpevarp area.The content of trace elements is also normal for these rock types.

In a few cases very small amounts of sulphide minerals, mainly pyrite and/or chalcopyrite, has been reported in some of the drill cores from the deep boreholes in the Simpevarp subarea /Ehrenborg, oral communication, 2004/. However, the amount of sulphide minerals observed is insignificant and probably of normal appearence for these types of Småland Granites. There is nothing of interest from an ore viewpoint.

6.2 Geochemical sampling of the till

The current geochemical investigation compiles results from older till sampling performed by SGU together with results from new till sampling performed during the years 2003–2004 within the SKB site investigation study at Oskarshamn.

The Quaternary deposits (mainly till) covers about 40% of the investigated area. The thickness of the till is generally between 0.2–3 m. The till normally reflects the morphology of the underlying bedrock surface.The composition of the till matrix is generally sandy.The dominating ice movement is from N40–50°W.

6.2.1 Older till sampling by SGU and NSG-SGAB

A geochemical sampling of till for heavy minerals was performed in the the Simpevarp in 1972 by SGU. In this survey the till fraction < 0.5 mm, having a density > 2.97 g/cm^3, was treated with weak magnetic separation and thereafter analysed by X-ray analysis (XRF) and tape feeded optical emission spectrography (OES-Jumbo).

From this till survey only "dot maps" in paper form could be found in the archieves for the elements wolfram (W), tin (Sn), lead (Pb), zinc (Zn), molybdenum (Mo) and nickel (Ni). Unfortunatelly no report and no analytical data either in paper or digital form was documented.

In 1984 a geochemical exploration project was carried out by the Swedish Geological Company (SGAB) on behalf of the State Mining Property Comission (NSG) in the northern parts of the County of Kalmar including the northern part of the Oskarshamn Municipality as well as the Simpevarp area. Minerogenic sediments were collected in streams and brooks and the samples were panned, resulting in heavy mineral concentrates. These concentrates were investigated minerologically under a binocular microscope, and by a UV-light lamp study for fluorescence. Samples with interesting minerals in the panned concentrate were further analysed with the ICP-AES- and XRF-methods. No analytical data has been digitally stored, but the results have been reported /Hallgren et al. 1985/.

In the summer of 1990 a regional till topsoil-survey was performed by SGU in and around the Simpevarp area with a sample grid of 1 sample/km^2. The fine fraction of the till (< 0.06 mm) was digested in Aqua Regia and analysed using the ICP-AES-method. This fraction was also analysed with the XRF-method for total element analyses. This till survey produced geochemical maps in the scale 1:1 million /Andersson and Nilsson, 1992/.

6.2.2 Till sampling from the ongoing site investigation

Drilling and sampling of soil for groundwater monitoring wells were performed in the Simpevarp area during the period December 2003 – January 2004. However, none of these till samples could be used for this study.

Quarternary field works including till sampling within the investigated area were carried out by SGU in the summer of 2004. From this survey 7 till samples from the topsoil have been be analysed in this study.

The new till samples were however too few in number and spatially they were clustered in two small areas within the eastern part of the study area. Consequently, the criteria to provide interpolated values on a regular grid in order to visualize patterns of geochemical trends within the investigated area, was not fullfilled. With this fact in hand, it was decided to use the analytical results from the more evenly distributed samples from the till survey by SGU, 1990, cf section 6.2.1, jointy with the seven new samples.

The till sampling depth in the C-horizon of the topsoil and the preparation and analytical methods were exactly the same for the two populations of samples. Six prepared till samples from the older till survey by SGU were picked out for reanalysis together with the seven new ones from the till sampling 2004. By doing this it should be possible, if necessary, to make a level correction of the elements from the two populations of samples from the investigated area.

6.3 Preparation of till samples and analytical methods

The randomized till samples were sent to ACME Analytical Laboratories Ltd in Vancouver, Canada. ACME is an accredited laboratory (ISO 9002). At ACME, the original, unprepared seven till samples were dried and sieved to obtain the fraction < 0.063 mm (63 µm). This fraction was digested in Aqua Regia (NO_3:HCl:H_2O 2:2:2) for 1.5 hours and then analysed with the ICP-MS-method for 35 elements including gold.

6.4 Statistical methods and quality control of the values of the analysed elements

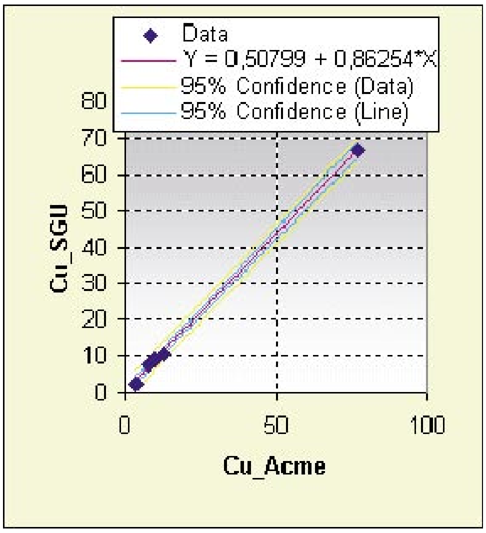
The reanalysed samples were compared with the same samples analysed 1990 by SGU. By use of a simple regression analysis-method the results were visualized in XY-plots. It was astonishing how well the fit and correlation of the regression lines from the XY-plots were for the base and alloy metals of the two analytical runs, seperated in time of more than ten years (Figure 6-1).This also means that no analytical error was introduced in any of the two runs and no level correction was needed.

Simple Regression

X-Variable: Cu_Acme
Y-Variable: Cu_SGU

Y = A + B*X

N	A	B	R
6	0,5079918	0,86255	0,99951

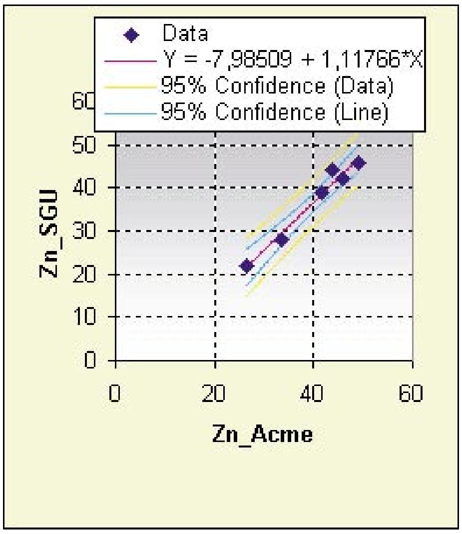


Simple Regression

X-Variable: Zn_Acme
Y-Variable: Zn_SGU

Y = A + B*X

N	A	B	R
6	-7,985098	1,1176666	0,984984227



Simple Regression

X-Variable: Pb_Acme
Y-Variable: Pb_SGU

Y = A + B*X

N	A	B	R
6	-0,993492	1,10119	0,992893

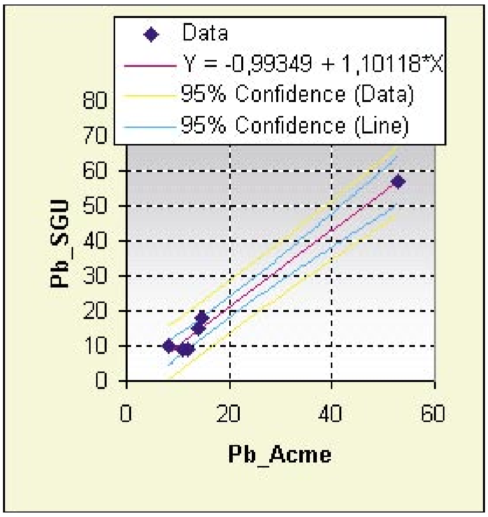


Figure 6-1. *Diagrams with regression analysis and XY-plots of the elements Cu, Pb and Zn.*

6.5 Visualization of the geochemical distribution pattern

The element distribution has been visualized by using the data processing and analysis program /Oasis Montaj/. By this program values are first gridded with the Kriging Method using a spherical variogram model. From the variogram of each element a scale of correlation in terms of a so called range (in metres) can be estimated (Figure 6-2). The search criterion is spherical without any correction for trends in the geochemical distribution pattern. Contoured and colour shaded maps were produced from the gridded values. For each sample point, a circle is shown overlain and combined with this contoured, colour shaded map. The circle size is proportional to the element value.

6.6 Evaluation and interpretation of the geochemical pattern

Knowing the ice movement directions within the area and the thickness of the overburden, it is possible to evaluate the likely distribution pattern of each element, estimate their concentrations and interprete the potential of mineralisations at, or close to, the bedrock surface.

6.7 Geochemical maps

Kriging-contoured coloured shaded geochemical maps were produced for the elements Cu, Pb and Zn, and shown in Figure 6-3 – 6-5.

The values of the element gold (Au) were all below the detection limit of 1 ppb for the SGU-analysis 1992.

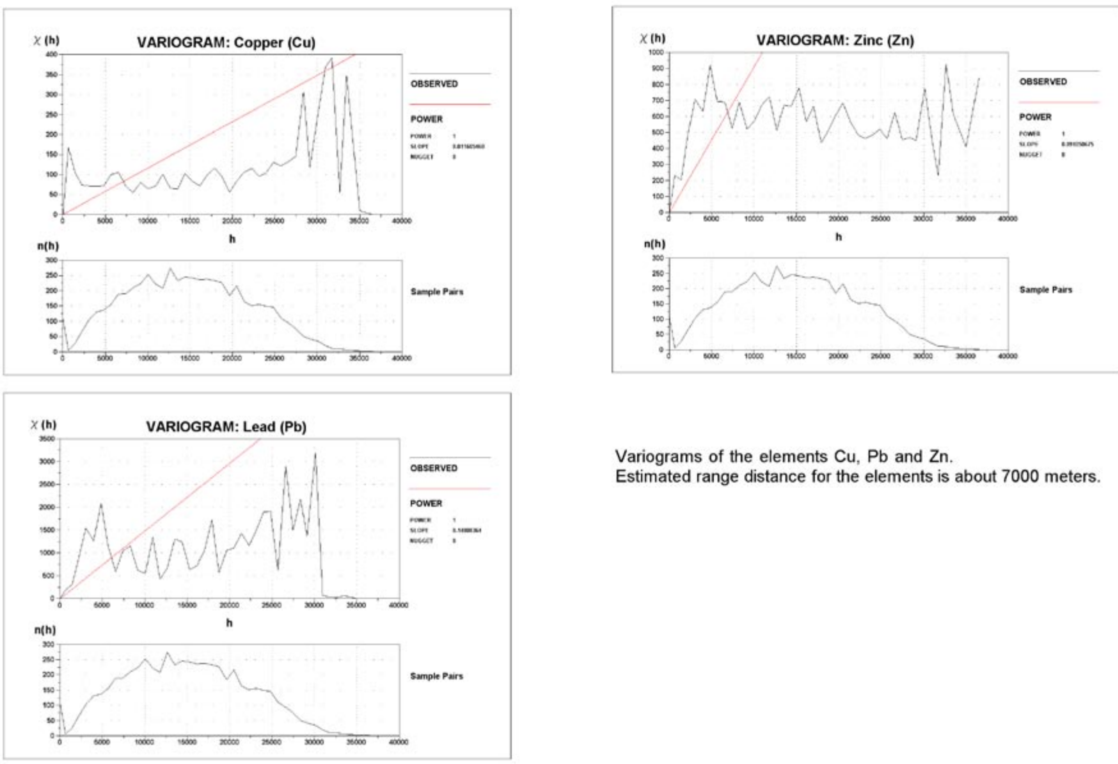


Figure 6-2. Variograms of the element Copper (Cu), Lead (Pb) and Zinc (Zn).

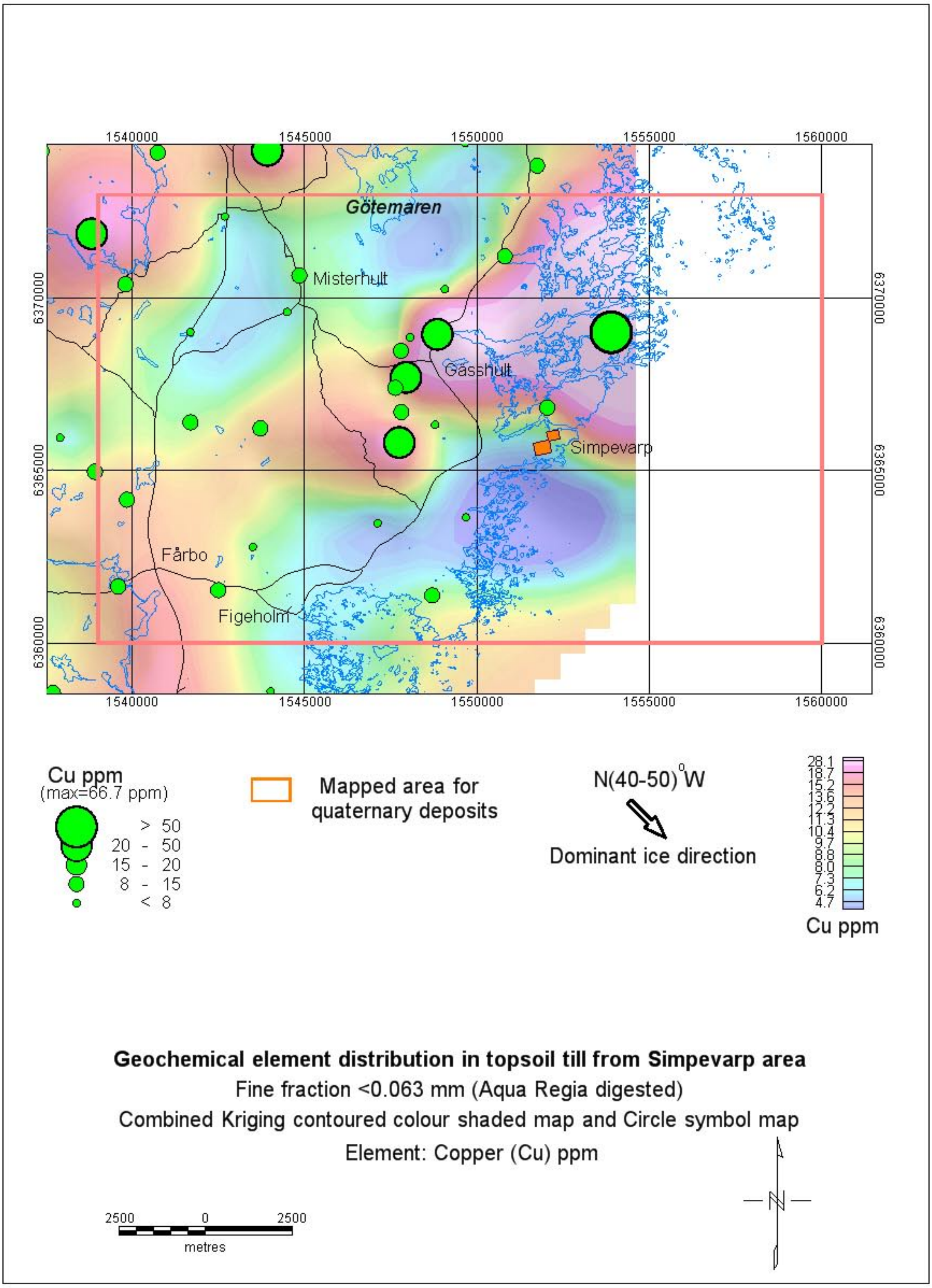

Götemaren
Misterhult
Gåsshult
Simpevarp
Fårbo
Figeholm
1540000
1545000
1550000
1555000
1560000
6370000
6365000
6360000
Cu ppm
(max=66.7 ppm)
> 50
20 - 50
15 - 20
8 - 15
< 8
Mapped area for quaternary deposits
N(40-50)°W
Dominant ice direction
28.1
18.7
15.2
13.6
12.2
11.3
10.4
9.7
8.8
8.0
7.3
6.2
4.7
Cu ppm
Geochemical element distribution in topsoil till from Simpevarp area
Fine fraction <0.063 mm (Aqua Regia digested)
Combined Kriging contoured colour shaded map and Circle symbol map
Element: Copper (Cu) ppm
2500
0
2500
metres
N

Figure 6-3.

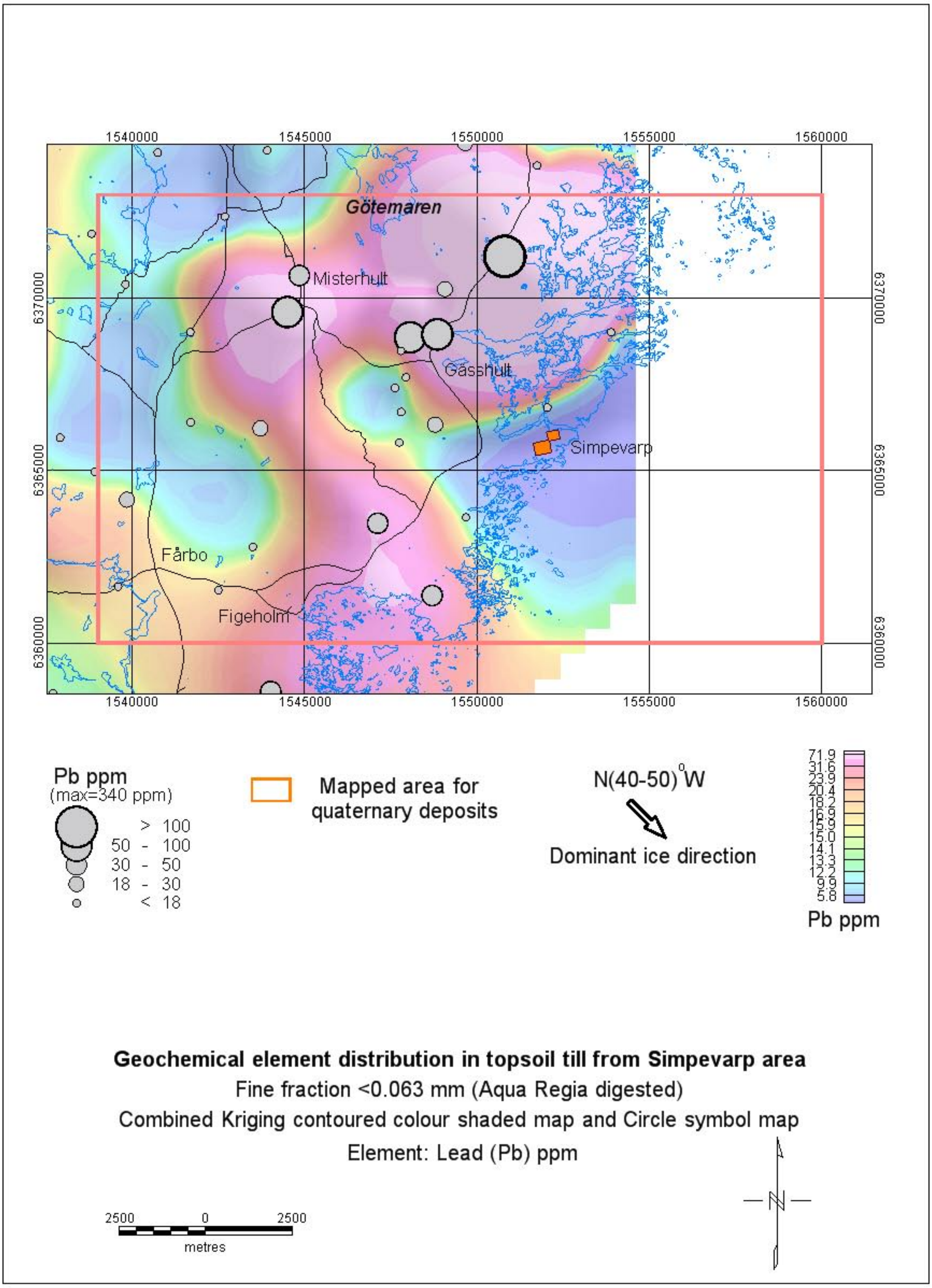

Götemaren
Misterhult
Gässhult
Simpevarp
Fårbo
Figeholm
1540000
1545000
1550000
1555000
1560000
6370000
6365000
6360000
Pb ppm
(max=340 ppm)
> 100
50 - 100
30 - 50
18 - 30
< 18
Mapped area for quaternary deposits
N(40-50)°W
Dominant ice direction
71.9
31.6
23.9
20.4
18.2
16.9
15.9
15.0
14.1
13.3
12.2
9.9
5.8
Pb ppm
Geochemical element distribution in topsoil till from Simpevarp area
Fine fraction <0.063 mm (Aqua Regia digested)
Combined Kriging contoured colour shaded map and Circle symbol map
Element: Lead (Pb) ppm
2500
0
2500
metres

Figure 6-4.

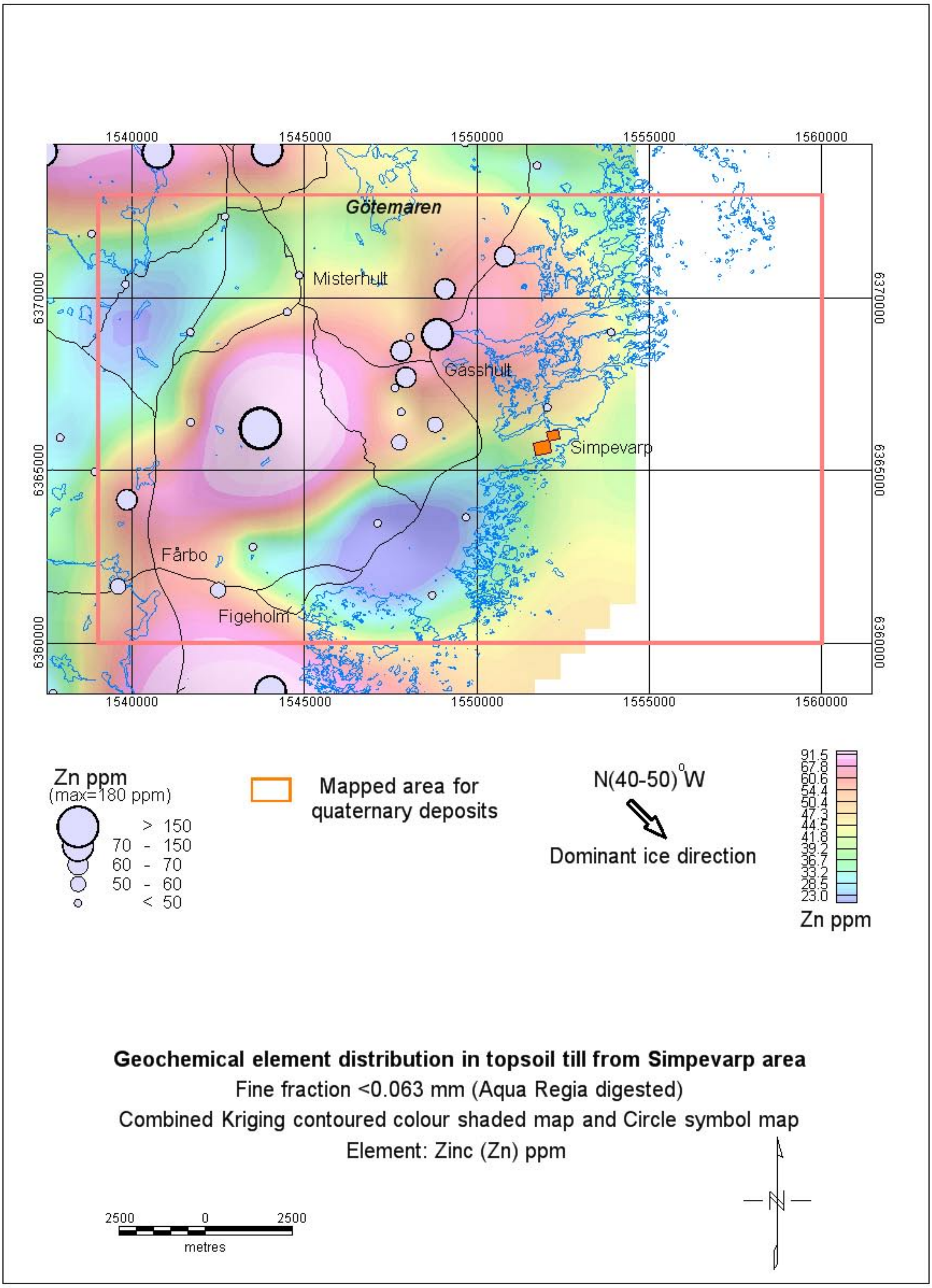

Götemaren
Misterhult
Gässhult
Simpevarp
Fårbo
Figeholm
Zn ppm
(max=180 ppm)
> 150
70 - 150
60 - 70
50 - 60
< 50
Mapped area for quaternary deposits
N(40-50)°W
Dominant ice direction
Zn ppm
Geochemical element distribution in topsoil till from Simpevarp area
Fine fraction <0.063 mm (Aqua Regia digested)
Combined Kriging contoured colour shaded map and Circle symbol map
Element: Zinc (Zn) ppm
metres

Figure 6-5.

6.8 Conclusions regarding the geochemical investigation

Table 6-1 shows descriptive statistics of median, 95th percentile (= geochemical anomalous limit) and maximum values of the base metals Cu, Pb and Zn from the present analytical results (SICADA database) of topsoil till samples from the Simpevarp area (Cu, Pb, Zn – SGU) in comparison to the analytical result from a topsoil till survey, performed by SGAB 1987–1991 (Cu, Pb, Zn – SGAB), in an area in northern Bergslagen, including the ore districts of Falun and Garpenberg. The base metals Cu and Zn from the Simpevarp area indicate moderate to low values as compared to the Falun-Garpenberg area. It is further evident that the base metal Pb has a high background values in the Simpevarp area, one single sample containing extremely 340 ppm Pb.

Some geochemical patterns of the element distribution may be noticed from the investigated area. The element Pb shows a wide anomaly pattern in an area between Götemar and Simpevarp (Figure 6-4). The element Cu shows an anomalous pattern to the south of, and partly overlapping, the Pb-anomaly (Figure 6-3). The Pb-anomaly has a rounded, to the north-west concave curvature being in conformity with the border zone of the Götemar granite massif situated in the north-west, which also is parallell with the dominant ice movement direction in the area. The shape of the Cu-anomaly is more convex in relation to the Pb-anomaly and may, to some extent, be related to an east-west striking “swarm” of dioritic-gabbroic outcrops extending from the coastline north of Simpevarp westwards to Gässhult.

In the NSG-SGAB survey using panned minerogenic stream sediments, an anomaly denoted “Gässhult” overlaps the Pb- and Cu-anomalies described above (Figure 6-6). Several heavy mineral concentrates from the “Gässhult-anomaly” showed elevated contents of the minerals scheelite, fluorite, pyrite and monazite. Analyses of the panned concentrates also showed elevated values for the elements Pb, Cu, Zn, W, La and Sn.

Till sampling for heavy mineral by SGU from 1972 also shows elevated values of Pb and W from the same area (Figure 6-6).

In 1985, a boulder hunting campaign, within the “Gässhult-anomaly” and in the neigbourhood of the Götemar granite massif, resulted in the discovery of outcrops and local boulders of granitoids with minor greisen-type veins and with fissure surfaces containing violet fluorite and blue-white fluorescensing scheelite. Impregnation of scheelite was also noticed in some dolerite boulders /Hallgren et al. 1984/.

The conclusion of the present geochemical analysis of the Simpevarp area is that there is probably not a high potential for base metals or gold. The periphery of the Götemar granite massif, in the northernmost part of the study area, is geochemically characterised by elevated values of elements that could be related to i.a. tin- and wolfram-mineralisations, and partly to lead-mineralisations. This result is in agreement with the geological observations and inferences described in Chapter 4.

Table 6-1. Descriptive statistics from geochemical results of till samples from Simpevarp (SGU, 1992) and Northern Bergslagen Ore districts (SGAB, 1987–1991).

Element	Cu_SGU ppm	Pb_SGU ppm	Zn _SGU ppm	Cu_SGAB ppm	Pb_SGAB ppm	Zn_SGAB ppm
Median	9.3	15.0	42.0	11.9	6.6	35.4
95th percentil	27.8	46.4	90.2	80.7	79.8	208.8
Max	66.7	340.0	180.0	1,190.0	345.0	283.0
Cases	107	107	107	104	104	104

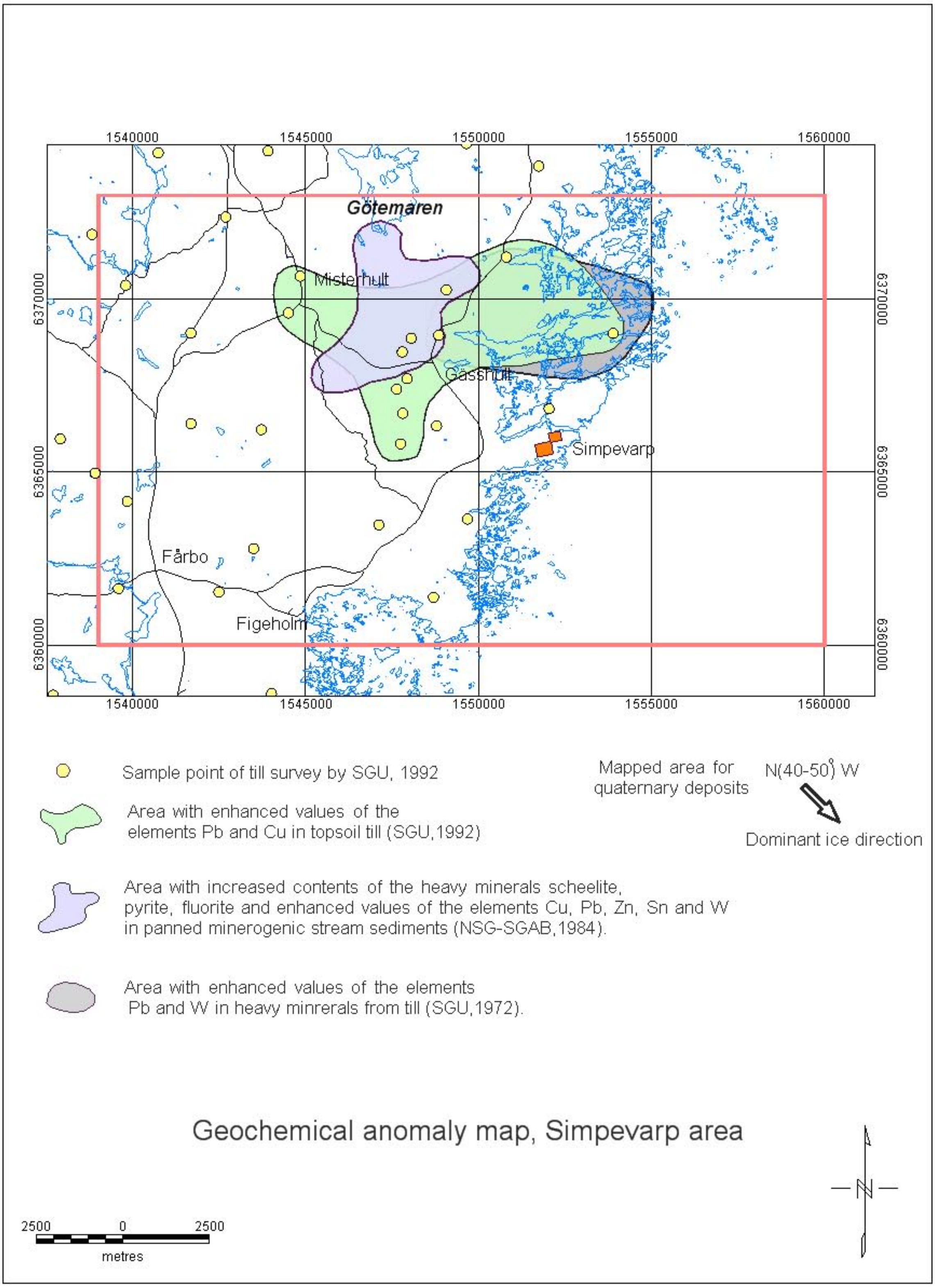

1540000
1545000
1550000
1555000
1560000
6370000
6365000
6360000
Götemaren
Misterhult
Gässhult
Simpevarp
Fårbo
Figeholm
Sample point of till survey by SGU, 1992
Area with enhanced values of the elements Pb and Cu in topsoil till (SGU,1992)
Area with increased contents of the heavy minerals scheelite, pyrite, fluorite and enhanced values of the elements Cu, Pb, Zn, Sn and W in panned minerogenic stream sediments (NSG-SGAB,1984).
Area with enhanced values of the elements Pb and W in heavy minrerals from till (SGU,1972).
Mapped area for quaternary deposits
N(40-50°) W
Dominant ice direction
Geochemical anomaly map, Simpevarp area
2500
0
2500
metres
N

Figure 6-6.

7 Exploration potential in the Simpevarp area

The study area described in the report, the Simpevarp area, covers about 270 km^2, of which about one third is covered by the see. Available information from the land area has been compiled in a mineral resource map (Figure 4-4), and new geological, geophysical and geochemical survey results have subsequently been evaluated with regard to potential for ores, industrial minerals and commercial stones. Reanalysis of till samples carried out by SGU has been included in the assessment. The geological survey, mainly bedrock mapping and information from ongoing deep drilling, all emphasise the reason for the lack of ore mineralisations in the study area: granites of this type are virtually sterile from an ore viewpoint.

The geochemical sampling of the till shows only low to moderate metal concentrations, and very low for gold. The geophysical study has outlined some features of possible exploration interest. These are broad low-magnetic lineaments interpreted as ductile shear zones, zones with increased electrical conductivity in dioritic-gabbroic complexes possibly containing sulphide minerals. In addition, low-magnetic anomalies with a relatively high radiation levels of thorium and uranium situated outside the Götemar granite, were deliniated as possible sub-intrusions from the major dome-like massif.

The Götemar and Uthammar granites have been exploited for commercial stones since the beginning of the 19th century. In recent years stone quarrying has decreased significantly, and today (2004) there is only one quarry in production in the Simpevarp area, at Kråkemåla within the Götemar granite. The Götemar and Uthammar granites have a potential for commercial stones, and the potential areas for stone are outlined on the mineral resource map.

The Götemar granite has a lithogeochemical character resembling tin- and/or wolfram-mineralized granites /Bergman et al. 1998/. Small outcropping "greisen-veins" /Kresten and Chyssler, 1976/ and elevated levels of the geochemical analyses of till samples with regards to the content of wolfram (Figure 6-6) are other indicative features. The Götemar granite also contains calcite-fluorite-galena veins but of a size with no economical value.

The final judgement is (see Figure 4-4) that the Götemar granite has a moderate potential for commercial stones, and a small potential for the metals tin (Sn) and wolfram (W). The Uthammar granite has a small to moderate potential for commercial stones. As stone quarrying might be continuing in the Götemar area in the future, siting of a deep repository should consider this. However, quarrying in shallow open pits would only marginally limit the siting of a deep repository.

Today there is no interest in ore or mineral exploration in the Simpevarp area. Even viewed in a long-time perspective, it is highly unlikely that there will be any new exploration for ores in this area. It is also unlikely that in the future exploration will take place in the coastal and offshore area of Simpevarp becuse of environmental aspects and the fact that large areas are protected by law. It is probably also expensive to explore and exploit an offshore ore.

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Glossary of terms

Aggregate	Gravel, stones and chrushed rocks used in concrete and i road and railway constructions.
Aplite	A fine-grained siliceous igneous rock consisting mainly of quartz and feldspar.
Area of ore potential	An area or volume in the bedrock that has the geological potential for hosting ores of a certain kind. Prospecing can yield new finds in this area.
Base metal	Copper (Cu), lead (Pb) and zinc (Zn).
Beryl	A beryllium-bearing silicate mineral mainly found i some pegmatites.
Calcite	A common rock-forming mineral (CaCO3). Calcite is the chief constituent of limestone.
Cassiterite	A tin-bearing mineral (SnO_2).
Chalcopyrite	A copper sulphide mineral ($CuFeS_2$). The most important mineral for extraction of copper.
Clay	An earthy, extremely fine-grained sediment or soft rock composed primarily of caly minerals (hydrous silicate minerals).
Commercial stone	A type of rock that can be utilized technically and commercially.
EIA	Environmental Impact Assessment.
EM	Electro-magnetic geophysical method for detection of the electrical conductivity of an ore, mineralisation, rock or overburden.
Feldspar	A group of minerals, all silicates of aluminum, with potash, sodium and/or calcium.
Fluorescence	Emission of visible light by a sunstance exposed to ultraviolet light.
Fluorite	A fluor-bearing mineral (CaF_2).
Galena	An ore-forming lead mineral (PbS).
Gamma Ray Spectrometry	A geophysical technique which provides information about the distribution of K, U and Th that is directly interpretable in terms of surface geology.
Geochemical methods	Use of the geochemical methods in ore prospecting is based on the facts thar rocks, Quaternary deposits, vegetation, groundwater and surface water near an ore occasionally exihibit elevated concentrations of the elements that comprise the ore. This elevation is termed a geochemical anomaly.

Granite	A holocrystalline quartz-bearing, plutonic rock. Quartz makes up 10 to 50 percentage of the minerals in a granite.
Gabbro	A basic, generally dark-colored igneous rock mainly composed of pyroxene and/or amphibole and feldspars like labradorite or bytownite.
Gravimetry	The measurement of gravity or gravitational acceleration, especially as used in geophysics.
Heavy minerals	Minerals with a density more than 2.95 g/cm_3. Heavy minerals are used in certain geochemical surveys and as a geochemical exploration method.
Hydrothemal fluid	Hot (> 375°C) aqueous fluid of metamorphic, magmatic or geothermal origin. Certain ores are formed by hydrothermal processes.
Igneous	Said of a rock or mineral that solified from molten material, i.e. from a magma.
Industrial mineral	A rock or mineral that is economically mineble. It can be used directly or in an insdustrial process.
Magma	Molten rock-matter together with dissolved gas and vapour. Magmatic rock is a rock originating from a magma.
Magnetic prospecting	A technique of applied geophysics: a survey is made with a magnetometer, on the ground or in the air, which yields local variations, or anomalies, in magnetic-field intensity.
Magnetic lineament	A linear structure which can be seen on a magnetic map, either high magnetic or low magnetic in relation to the surrounding.
Magnetite	A common iron-oxide mineral (Fe_3O_4). Important mineral for extraction of iron.
Metalliferous	Metal-bearing.
Mica	A group of silicate minerals which split into thin elastic laminae and range from colorless to black. Mica is commonly found in granites.
Mineral deposit	A mass of naturally occurring mineral material, e.g. metals ores or nonmetallic minerals, ususlly of economic value without regard to mode of origin.
Mining	The process of extracting metallic or nonmetallic mineral deposits from the earth.
Molybdenite	The most common molybdenum-bearing mineral (MoS_2).
Monazite	A mineral containing rare earth metals.
Moraine	A Quaternary deposit, chiefly till, deposited by direct action of glacier ice.

Paleozoic	An era of geologic time from about 570 to 255 million years ago.
Panning	A technique for prospecting for heavy minerals, e.g. gold, by washing placer or till material in a pan.
Pegmatite	A coarse-garined igneous rock usually found as dykes, lenses or veins. The composition of pegmatites is generally that of granite.
Pentlandite	A nickel iron sulphide mineral. Pentlandite is the principal ore of nickel.
Phanerozoic	That part of geologic time represented by rocks in which the evidence of life is abundant.
Plutonic rock	A rock formed by considerable depth in the Earth by crystallisation of magma and/or by chemical alteration. Granite is a typical holocrystalline, quartz-bearing plutonic rock.
Postglacial	Formed after a glacial period.
ppm	parts per million. Unit of concentration, for example the metal content in a rock or soil.
Precambrian	All geologic time, and its corresponding rocks, before the beginning of the Paleozoic (cf Paleozoic).
Precious metals	Silver, gold and the platinum group of elements.
Prospecting	Searching for economically valuable deposits of ore. Synonymous term: exploration.
Pyrite	A common iron sulphide mineral (FeS_2).
Quarry	Open workings, usually for the extraction of stone.
Quartz	Crystalline silica, a common rock-forming mineral (SiO_2).
Quaternary	A geological period that began three million years ago and that extends to the present.
Rare earths	Oxides of a series of fifteen metallic elements, from lanthanum (La) to luthenium (Lu).
Scheelite	A wolfram-bearing mineral ($CaWO_4$). Important mineral for extraction of wolfram. Scheelite is an ore of wolfram.
SDM	Site Descriptive Model. Term used by SKB in site investigation studies.
Seismic prospecting	The use of artifically seismic waves in the search for economic deposits (salt, oil, water, ores), or in engineering studies.
Silica	Silicon dioxide (SiO_2). A common mineralogical form: quartz.
Spectrometry	See gamma ray spectrometry.

Sphalerite	A zinc-bearing sulphide mineral (ZnS). The most important mineral for extraction of zinc.
Sulphide ore	Ore that contains sulphide mineral(s).
Topaz	An aluminum-silicate mineral sometimes found in tin-bearing veins.
Till	A glacial sediment consisting of a mixture of clay, sand, gravel and bouldes ranging widely in size and shape.
Trace element	An element that is found in very small quantities.
Ultrabasite	A plutonic rock having an extremely low silica content (< 45 percent SiO_2). Synonymous term: ultramafite.