Geological Survey of Norway

ANNUAL REPORT 2012

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

USEFUL FOR NORWAY

Director General Morten Smelror

Our Annual Report for 2012 folds out like a map. We have chosen this layout to illustrate that NGU's benefit to society is derived from basic mapping.

NGU manages knowledge on Norwegian geology - about bedrock, unconsolidated deposits, mineral resources and groundwater.

« In fact, we map the whole country to reveal both hazards and resources – for the benefit of industry, local authorities and the people. »

One example: on New Year's Day 2012, a big landslide occurred on Byneset, south of Trondheim. A state of emergency was proclaimed and people were evacuated. Mapping had already shown that the area consisted of marine clay and several parts contained quick clay. Would further landslides occur, and when would it be safe to return home? Under difficult conditions our geophysicists undertook resistance measurements, resulting in a detailed cross-section of the subsoil. This was of great help for the continual assessments made by the city of Trondheim and the Norwegian Water Resources and Energy Directorate.

Some figures: we map the bedrock of Norway on scales of 1:250 000 and 1:50 000, and we have digita¬lised all our map sheets. So far, about 55% of Norway is covered on a scale of 1:50 000. Some 23% of the land area has been completed in the nationwide mapping of unconsolidated deposits, and by the end of 2012, 40% of northern Norway was covered by high-resolution geophysical maps. In addition, we continually perform geochemical mapping. So we have achieved a great deal, but much remains to be done.

Geophysical measurements and basic bedrock mapping provide us with knowledge on mineral deposits, on the potential for developing geothermal energy from the underground, on the hazard from radon exposure, and on the risk for landslides and rock falls. The basic mapping of surficial deposits helps us, for example, to find good-quality construction materials such as sand and gravel, sources of drinking water, and areas with a risk for landslides and quick-clay slides.

In this annual report, we write, among other things, about new maps which can help to reveal zones of weakness in the bedrock of south-eastern Norway. This information can save large sums of money during the construction of tunnels, and build underground constructions safer and faster. We also report on new maps of the seabed, providing knowledge to help Norway manage her deep-sea and coastal resources as well as possible. These are examples of products that result from basic mapping and first-rate research carried out by our experts.

In addition, watch out for a new environmental focus in geology: urban mining is all about recycling minerals from used PCs and smart phones. A mobile phone, for instance, contains 40-50 minerals. Taking the environmental aspect seriously is important for the sustainable extraction of geological resources.

Useful means "that which is of assistance". To fulfil our mandate to work for society, NGU continues to be of assistance. For 155 years, we have taken good care of the legacy after our first director, Theodor Kjerulf, who promised the Norwegian Parliament that he would set up an institution that will be *«practically useful, scientifically essential and honourable for the country»*.

PURE QUARTZ

Quartz is very common and is found in the majority of rocks. It is hard and can scratch glass.

It is an important industrial mineral used in everything from memory chips, solar panels and smart phones, via glass and cosmetics, to silicon metal.

NGU maps quartz deposits in Norway and is a world leader in precise chemical analyses of trace elements in quartz. The content of trace elements is extremely low, but it determines the quality, and hence the price. High-purity quartz is a concentrate that has extreme chemical purity and is used when manufacturing electronic items and solar panels. It is rare to find high-purity quartz that is suitable for extraction.

In Norway, 148 people are now employed in quarrying quartz and quartzite at seven localities, giving a total turnover of NOK 400 million. NGU scientists have contributed to investigations at Drag in Nordland and at Svanvik in Finnmark. In recent years, thorough analyses of deposits in Evje-Iveland and Froland in Aust-Agder have been carried out. The preliminary results show that the quartz in some of the Froland deposits is of economic interest, but the Evje-Iveland quartz cannot compete.

A quartz deposit at Nesodden in Kvinnherad, Hordaland, may soon come into operation. It was originally mapped and recognised as a high-purity deposit by NGU scientists. The vein is large and massive, some 600 metres long, and located between 210 and 320 metres above sea level. It is esti-mated to contain 2.7 million tonnes of quartz.

Geologist Axel Müller

WORTH THEIR WEIGHT IN GOLD

Calculations performed by NGU in 2012 valued the mineral deposits in Norway's bedrock at a minimum of NOK 2500 billion. Metals account for more than half of this.

Geologist Ron Boyd

In well-documented deposits «in-situ», that is, as they occur in the ground, the metals are valued at as much as NOK 1388 billion.

In addition, geologists believe that so-far unidentified ore reserves can be found at depth beneath ore fields that were abandoned decades ago, like Røros and Løkken in central Norway, and in large, so far little-investigated deposits such as Raitevarre and Gallujav'ri in Finnmark. Public authorities have wanted a more precise evaluation of the resources in Norway's bedrock for a long time. However, the values that can be achieved by future mining depend upon the conditions for working the deposits, the dressing technology and future price fluctuations.

A review of the metals shows that iron, iron-titanium and titanium ores alone have a value of NOK 1224 billion, with the Sydvaranger and Rana mines as the main metal producers. Added to these are deposits of copper, copper-gold, zinc, lead and nickel, as well as a group of special metals.

Similar evaluations of the large Norwegian resources of industrial minerals, such as marble, olivine and quartz, show an in-situ value of NOK 400 billion. Norway meets some 40 per cent of the world demand for olivine, and is the largest European producer of milled calcite marble. Norway has building raw materials, such as sand, gravel and crushed rock, worth nearly NOK 500 billion. The total reserves and resources are estimated at 8300 million tonnes and are expected to last well over 100 years. Natural rock products, like larvikite and flagstone, are valued at NOK 250 billion and the coal reserves on Svalbard at NOK 23 billion.

PRODUCING MAPS FASTER

For the first time, NGU has produced a map sheet using a digital workflow all the way from fieldwork to user product.

This is a map of the Quaternary geology of Kristiansand and a nearby part of Vest-Agder on a scale of 1:50 000. Working on this map started in 2010 in a county where we had unsatisfactory coverage of the Quaternary geology in NGU's database. Previously published data from Vest-Agder have been sorely in need of revision.

To map this area around Kristiansand, the geologists have used new technologies and methods for mapping unconsolidated deposits. The workhorse was a rugged digital tablet PC, which withstands rough treatment in bad weather. It contains a simplified version of the corporate database and existing knowledge from the area.

The data capture is based on field observations and digital 3D aerial photographs, and everything is plotted directly and digitally.

After the fieldwork, errors are corrected, and the data are published in NGU's public database. The first map sheet, Kristiansand-Høvaag, has been completed and is accessible from the database through NGU's web services on *www.ngu.no* .

The shift to digital mapping has been successful. The geologists praise the system because it gives them better control in the field and they experience greater precision when collecting data. More fully-digital map sheets from Vest-Agder and other counties are just around the corner.

In 2012, NGU's 1:50 000 bedrock maps have also been made available in digital format. These maps have for many years been published on paper, but have now been digitalised and are available on the web. Some 55% of the country is now covered by the dataset.

AN ATTRACTIVE APP

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If you have a smart phone or tablet PC handy, you can now find geological attractions in your vicinity, whether you are at home or on holiday in another Nordic country. The attractions are described in English and in the language spoken in the country you are in. Students have been asked to prepare the content.

Geology plays a central role in many of the biggest tourist attractions in Norway.

Mountains and fjords with their geological history draw large numbers of tourists to Norway every year. In addition, there are many isolated geological phenomena spread around the countryside that have become magnets for adventure tourists from Norway and other countries.

We have described and illustrated many of these attractions in the «GeoTreat» app which you can download free from your app shop. It currently contains descriptions of around a hundred places in Norway, and this figure will increase. To make it easy to see where the various attractions are, you can begin with a map or your GPS location. It is hoped that GeoTreat data will eventually be included in other apps.

GeoTreat will hopefully become more than just information for tourists. NGU wants to give everyone easier access to knowledge about geology. The app is therefore also a tool in a wider effort to make politicians, environmental managers and the general public more aware of our geological treasures, our geological history and the geological resources we use.

The geological treasures are an important part of the diversity of nature, and must be both used and protected for the future.

Student Åse Hestnes

URBAN VALUES

Natural resources do not last forever. When the ore has been extracted from a mine, it has gone for good, unless the resources are recycled. Tons of metals are present in electronic equipment, building waste and rubbish dumps.
The demand for resources is huge over large parts of the world. It is vital to move mining into the urban setting and use rubbish dumps as modern mine sites.

Rare Earth Elements (REE) must be recycled to a greater extent. Many people are aware that mobile phones, televisions and computers may contain precious metals, like gold and silver. But for such devices to work they must also contain metals that are more difficult to obtain, like indium, gallium, tantalum, europium, terbium and other rare earth elements. Urban mining is all about reclaiming these resources from waste and used materials.

Moving mining into urban settings and using old electronic equipment as ore is profitable.

For instance, there may be up to 25-30 times more gold to extract from used mobile phones than from a traditional gold ore.

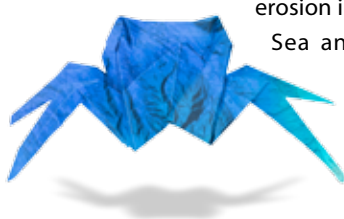
NGU is keen to see the rare earth metals being recycled, and is involved in this effort through its Urban Mining project, which received NOK 250 000 from the Elretur environmental fund in 2012. More recycling of rare earth metals from used electronic products is very beneficial to the environment compared with extracting the same metals from the earth.

NGU has been mapping Norway for 155 years. Recently, more focus has been put on exploration for mineral resources, and we are in the middle of a programme to map the mineral resources in northern Norway. At the same time, we are enhancing our knowledge of modern mining in urban settings.

Geochemist Belinda Flem

BUBBLING SEABED

Gas is leaking from the seafloor in the Barents Sea. Investigations carried out with instruments that study both the water body and the uppermost kilometre of the seafloor have recorded columns of gas bubbles that are up to 200 metres tall at several places in the Barents Sea.



The gas is mostly methane.

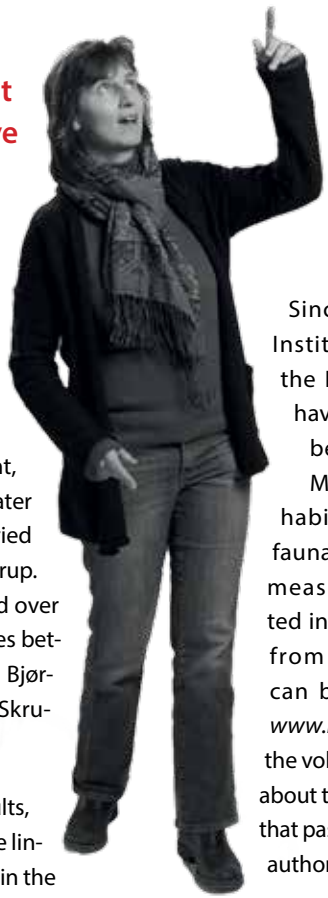
Crusts of carbonate that resemble sediment have formed on the seabed and are clear evidence of the gas leaks.

The gas leaks in the Barents Sea were discovered through collaboration between NGU, Lundin Petroleum and the Norwegian Defence Research Establishment, and the measurements of the water body and the seafloor were carried out by the naval vessel HU Sverdrup. Sixteen gas columns were found over an area of 2700 square kilometres between the coast of Finnmark and Bjørnøya (Bear Island), close to the Skrugard and Havis oilfields.

The gas vents lie along major faults, and NGU scientists think they are linked with gas seeping from deep in the seafloor. The combination of former glacial erosion in the entire Barents Sea and the opening of existing faults have been instrumental in the gas now leaking up to the seabed, and continuing into the sea and the atmosphere.

NGU thinks greater effort should be made to learn more about the venting of natural gas. Too little is known about its scale, and still less about what may happen in the future if the water in the Barents Sea gets warmer.

Since 2005, NGU, the Norwegian Institute for Marine Research and the Norwegian Mapping Authority have been involved in a major seabed mapping programme called MAREANO. Since 2005, data on habitat types, seabed conditions, fauna, pollution and detailed depth measurements have been collected in Norwegian waters. All the data from the MAREANO programme can be accessed from the website *www.mareano.no*. At the same time as the volume of data increases, knowledge about the seabed is growing for each year that passes, to the delight of management authorities and the business community.



Geologist Margaret Dolan

THE LØKKEN STORE

At Løkken in Meldal, south of Trondheim, NGU has a national archive of geological samples, mainly cores drilled from the bedrock during more than 100 years. You can find here more than 600 000 metres of cores from the whole country, the distance from Alta to Rome and back. It has cost more than a billion Norwegian crowns to obtain these cores.

New mineral resources are in strong demand by global markets. The world population is growing, and global urbanisation means that the consumption of such resources is about 15-18 tons per person each year.

Senior Engineer Rolf Lynum

Thanks to steadily improving analytical techniques and new geological knowledge, valuable new information can be obtained from old cores. New technology also provides knowledge about new mineral raw materials with different properties compared with previously known materials. Since it costs a great deal to get drill cores from the bedrock, taking good care of them is very worthwhile.

The store was set up in 1991. In 2012, a new building was opened expanding the storage capability with more than 500 000 metres of new drill cores. The Minerals Act of 2010 requires NGU to keep the cores from mineral exploration, and geological surveys in many countries have similar legislation.

Storage space and rooms to study cores can be rented. The Løkken store also has samples available for inspection of dimension- and building stone, environmental geology, marine geology, Quaternary geology and bedrock. It also houses special collections, mining history and reference materials from NGU's laboratory.

The web portal *www.prospecting.no*, run jointly by NGU and the Directorate of Mining with the Commissioner of Mines at Svalbard, provides information on mineral resources for prospecting companies, consultants and the mining industry.

DANGER. STOP

New maps can help to reveal zones of weakness in the bedrock in south-eastern Norway. This information can save large sums of money during the construction of tunnels, and build underground constructions safer and faster.

During 2012, better methodology was used to extend and complete a six-year-old version of the geohazard map for an area in south-eastern Norway where dozens of tunnels are under construction or being planned. The map, compiled by interpreting terrain features and magnetic data obtained from planes and helicopters, shows probable weakness zones in the bedrock.

The weakness zones are mostly formed by chemical weathering of rocks in a warm, humid climate about 200 million years ago, when dinosaurs still roamed south-eastern Norway.

The weathering took place over millions of years on the surface, but it penetrated deep into the bedrock in numerous, old joint zones.

The clay minerals formed by the weathering were scraped away by the glaciers during the major ice ages, but this erosion did not reach into the deep joint zones where weathering products may still be preserved down to a depth of several hundred metres.

The problems often do not appear before tunnels are driven beneath depressions in the terrain, such as valleys or fjords. In several tunnelling projects that experienced such problems, the geohazard map has since revealed weakness zones containing weathered material at depth.

However, the geohazard map must be used sensibly. It is a guide to predict possible areas with weakness zones which must be mapped in detail before a tunnel is excavated. The work is performed in

Geophysicist Vikas Baranwal

GETTING A GRIP ON GRAPHITE

Helicopter-borne geophysical measurements are absolutely essential to reveal the underground bodies of graphite that wind their way through schists. It is difficult, but most important, to find and extract this mineral.

The EU and the USA characterise graphite as a critical mineral which can become in short supply. Western nations fear that secure sources will dry up.

In 2012, NGU used geophysical equipment mounted on a helicopter to map the Skaland graphite deposit on Senja.

Norway produces here a large part of western Europe's demand for flake graphite, the natural graphite used, for instance, in electric car batteries.

Skaland Graphite, a company in the Leonhard Nilsen og Sønner AS group, produces around 8000 tonnes of graphite a year on the ouermost coast of Senja. Alltogether, more than thirty graph-ite deposits are known in Norway. Most of them are located in the Lofoten and Vesterålen archipelago in northern Norway, and along the E18 highway in the Bamble district of southern Norway. New opportunities for extraction may be found there. Geophysical measurements are absolutely essential if we are to understand the extent of new graphite deposits, and find out more about mineralisations that are already known.

NGU estimates that Norway has graphite reserves worth NOK 14.7 billion, based on present-day conditions. The mineral is common, but is rarely economically workable because the deposits are comparatively small and generally have a low content of graphite. The soft schists concealing the Norwegian deposits may be rich in graphite.

Graphite is used where high heat-resistance is important, in smelting plants and metal industries, to make such items as refractory crucibles and casting moulds. It is also used in car brake linings, as a lubricant, and in pencils, batteries and anodes.

Geologist Håvard Gautneb

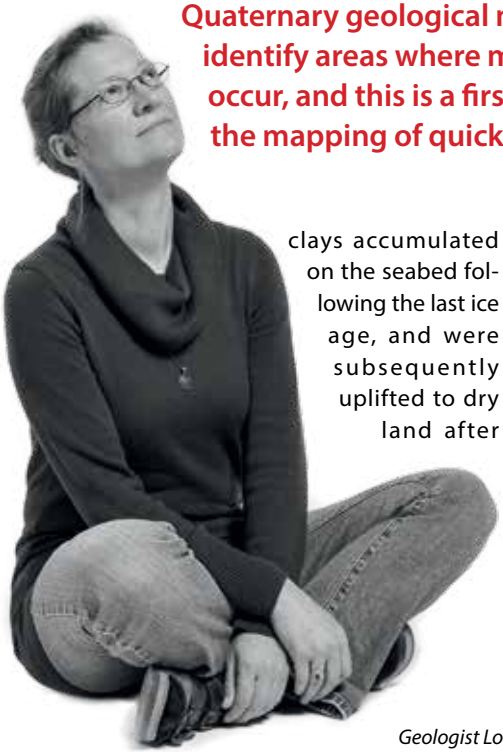
SCARY CLAY

An alarm sounded in Trondheim on New Year's Day 2012. A quick-clay landslide had wreaked havoc on Byneset. No one was hurt, but several houses and farms were evacuated. Mapping had previously established hazard and risk zones for large quick-clay landslides in this part of the Byneset peninsula in Trondheim.

Areas containing quick clay are known in many parts of the country, especially in central and south-eastern Norway. Quick clay is rather solid if it remains undisturbed. However, if disturbed the clay liquifies and the ground collapses. This happened outside Trondheim on New Year's Day 2012, and has happened many times earlier around the country, with greater consequences.

Marine clays accumulated on the seabed following the last ice age, and were subsequently uplifted to dry land after the ice was gone. When groundwater then leaches away the salt from the clay, thereby reducing the binding forces between the clay particles, this may lead to the formation of quick clay. Mapping of Quaternary geology is used as a basis for hazard and risk mapping in areas potentially subjected to large quick-clay landslides.

Quaternary geological mapping can identify areas where marine clay deposits occur, and this is a first important step in the mapping of quick clay.



Geologist Louise Hansen

The Norwegian Water Resources and Energy Directorate (NVE) has the national responsibility for assisting municipalities with the prevention of landslide disasters. NGU collaborates with NVE on knowledge about landslides, and much of NGU's mapping is used in NVE's services aimed at landslide prevention such as *www.skrednett.no.* All municipalities in Norway are responsible for considering the potential for landslides in their areal planning. We contribute with our knowledge and data.

NGU also help developing methods, knowledge and databases beneficial for quick-clay mapping. The measurement of 2D-resistivity in the underground has proved to be a useful complementary tool for the mapping of quick clay. This method, for instance, was helpful immediately following the Byneset landslide to identify bedrock limiting further landslide development. A new database on the marine limit, the uppermost possible occurrence of uplifted marine clays, has also been developed and is now available on the internet. A new national database for ground investigations (NADAG) is at its infancy and is under development in cooperation with a number of different governmental institutions.

ACCOUNTS

Accounts **2009-2012 (NOK million)**

INCOME	2009	2010	2011	2012
Ministrry of Trade and Industry	137,4	140,5	179,2	194,1
Other income	84,0	80,9	74,8	80,1
Total income	**221,4**	**221,4**	**254,0**	**274,2**

EXPENSES				
Salary/ nat. ins.expenses	126,4	135,9	141,3	150,7
Other expenses	81,5	79,6	103,5	113,4
Investments	10,4	8,2	8,1	9,5
Total expenses	**218,3**	**223,7**	**252,9**	**273,6**

Accounts 2012 by main goals (NOK million)

Main goal	Total	External finance
Sustainable added value from geological resources	89,5	26,2
Effective use of geoscience knowledge land-use planning and develoment	109,1	40,4
Better knowledge of geological development and processes in Norway	49,9	8,4
Management and dissemination of geological data and knowledge	24,5	1,9

NGU's total production of reports, publications, presentations and maps for 2009-2012

Product type	2009	2010	2011	2012
NGU-reports	67	66	67	80
Articles, refereed journals	166	138	126	173
Other published articles	41	32	42	37
Presentations, teaching and posters	484	542	449	447
forskning.no	19	16	17	15
Bedrock and surficial deposits maps	9	12	13	14

NGU's employees

	2009	2010	2011	2012
Total number of employees	216	221	222	211
With MSc Degree	142	150	153	143
With PhD Degree	77	81	82	72
Non-Norwegian citizens	67	72	74	66

DIRECTOR GENERAL
Morten Smelror

COMMUNICATION & PUBLIC RELATIONS
Berte Figenschou Amundsen

Communication,
Gudmund Løvø

GEORESOURCES
Tom Heldal

Mineral resources,
Henrik Schiellerup

Natural construction materials,
Rolv Dahl

Applied geophysics,
Jan Steinar Rønning

Geochemistry, Belinda Flem

GEOENVIRONMENT
Jan Cramer

Marine geology,
Reidulv Bøe

Groundwater and urban geology,
Hans deBeer

NGU-Laboratory,
Ana Banica

GEOMAPPING
Øystein Nordgulen

Bedrock geology, *Ane Engvik*

Quaternary geology, *Astrid Lysså*

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Geohazards, *Reginald Hermanns*

Continental shelf geophysics, *Odleiv Olesen*

Network and cooperation, *Jan Høst*

GEOMATICS & IT
Frank Haugan

Geomatics,
Jacob Solvoll

IT,
Jacob Solvoll

HR & RESOURCE MANAGEMENT
Bente Halvorsen

HR,
Ingunn Kringstad

Resource management,
Per Gunnar Ørndahl

NGU

Geological Survey of Norway is the country's central institute for the collection, processing and distribution of information on the bedrock geology, superficial deposits, mineral resources and groundwater of mainland Norway.

Goals:

- **Long-term added value from geological resources**
- **Increased use of geoscience knowledge in land-use planning and development**
- **Better knowledge of geological development and processes in Norway**
- **Good management and customization of geological knowledge**
- **Good communication and dissemination of geological knowledge**
- **Improving effectiveness through cooperation**

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Geological Survey of Norway (NGU)
P.O. box 6315 Sluppen
NO-7491 Trondheim
Norway

Visiting address:: Leiv Eirikssons veg 39
Phone: +47 73 90 40 00
E-mail: ngu@ngu.no
www.ngu.no

Text: Gudmund Løvø, Erik Prytz Reitan and Berte Figenschou Amundsen, NGU. Art director: Lisa Løseth, NGU. Photo: Geir Otto Johansen