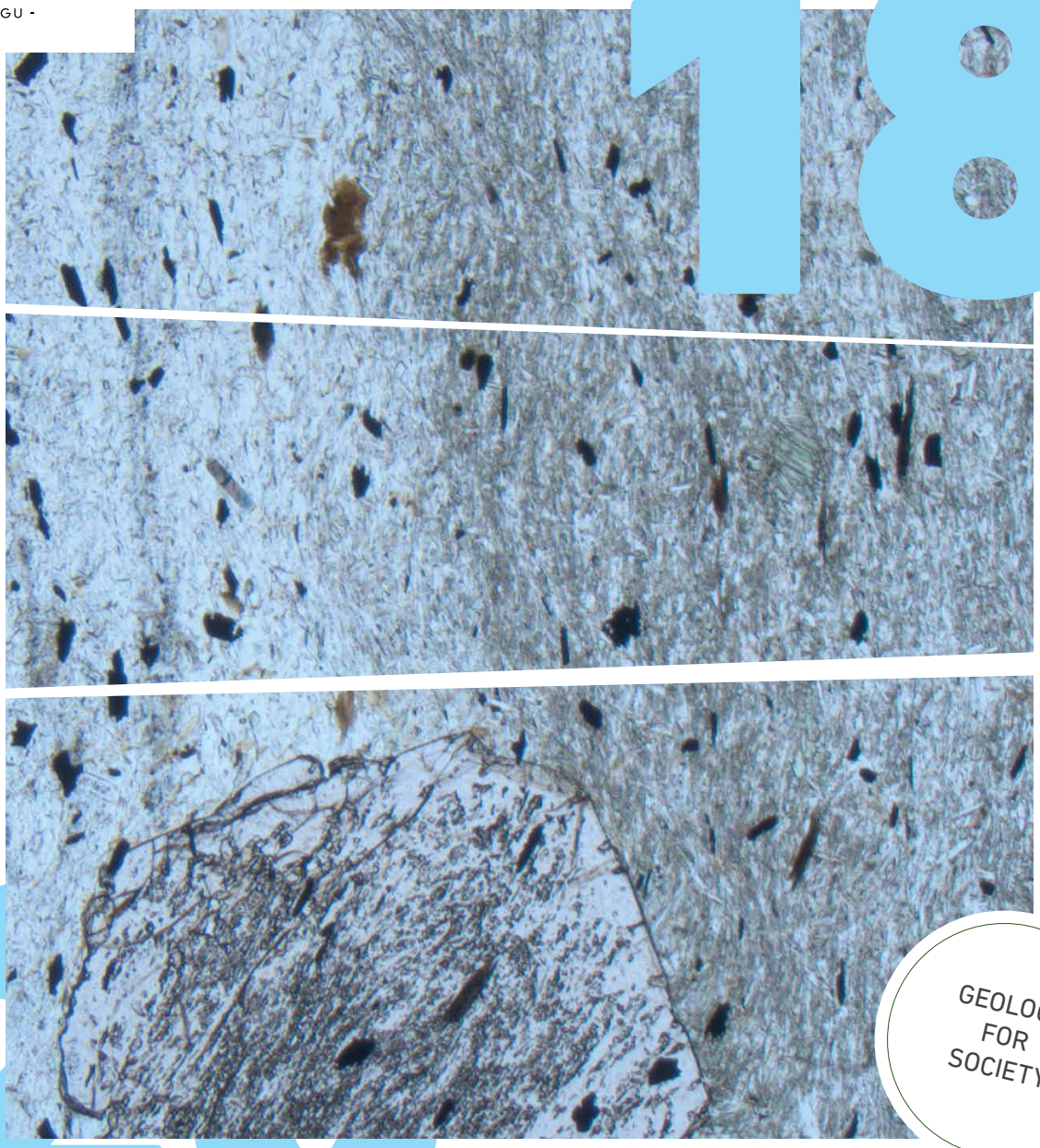
GEOLOGICAL SURVEY OF NORWAY
- NGU -

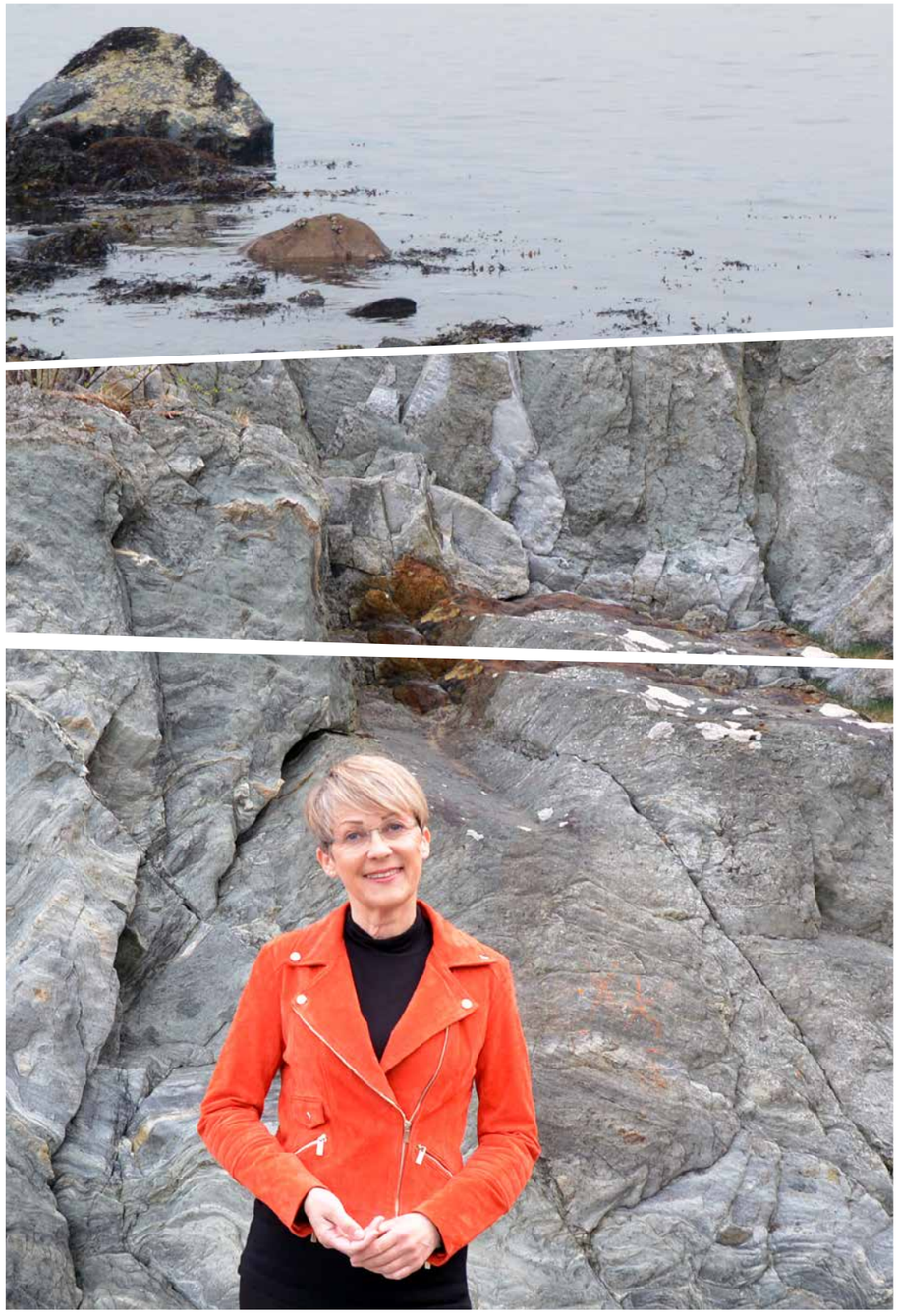


GEOLOGY FOR SOCIETY

A JIGSAW

ANNUAL REPORT 2018

Like a complex geological jigsaw puzzle, pieces both big and small fit together to form the Norway we all know. NGU's geological knowledge - developed in close collaboration with many others - will serve as a sound foundation for holistic decision-making needed for the betterment of society. The jigsaw pieces presented in this annual report will give you a partial glimpse of the total picture of our work in 2018.



NGU provides open access to information of high quality, which is a prerequisite for effective, sustainable management of Norway's natural resources and environment.

May Britt Myhr, Director, Geological Survey of Norway

A JIGSAW

The Geological Survey of Norway operates along three axes. From tradition to innovation, from fieldwork to people and from the past into the future. We, together with many others, fit the pieces together, forming a large jigsaw, which, collectively, forms the geology of Norway as we know it.

NGU's task for society is to map the bedrock, mineral resources, surficial deposits and groundwater of Norway. NGU also maps the geology of the seafloor, both along the coast and on the ocean floor. NGU's work is characterized by its high level of professionalism, in which applied research and development of new methods support our mapping activities.

NGU's results contribute to the ability of numerous organizations, in the public and private sector, to manage hazards and resources. Geological mapping provides, for example, data which is essential in work on landslide hazards: mineral resources cannot be extracted without basic mapping. NGU adapts to the changing needs of society and this broad interaction enables us to continually improve our solutions to the tasks which we are expected to fulfil. We have, in this year's report, assembled small and large "pieces" as examples of our priorities in the past year, with the goals in our strategic plan as a guiding line. We have increased mapping of geological resources, improved access to geological information for use in land planning and development: we have acquired more knowledge of the structural development of Norway and of the geological processes which this involved.

Data and information are processed and in national databases, freely available for all. Users have, via our digital maps and services, access to appropriately adapted and quality-assured information about geological properties and processes that has been gathered from various localities throughout Norway. Accessibility to reliable data and information is a prerequisite for efficient and sustainable management of Norway's natural resources and environment.

We will show, using the pieces of the puzzle which we share with you in this Annual Report for 2018, the long, proud traditions that NGU plans to carry into the future. Our knowledge - in close collaboration with many others - serves as a sound foundation for holistic decision-making in the best interests of society. We put geology on the agenda and will work to keep it there.

The Geological Survey of Norway - Geology for Society!

Trondheim, 01.03.2019
May Britt Myhr
Director

GEOLOGICAL SURVEY OF NORWAY
- NGU -

Annual Report 2018

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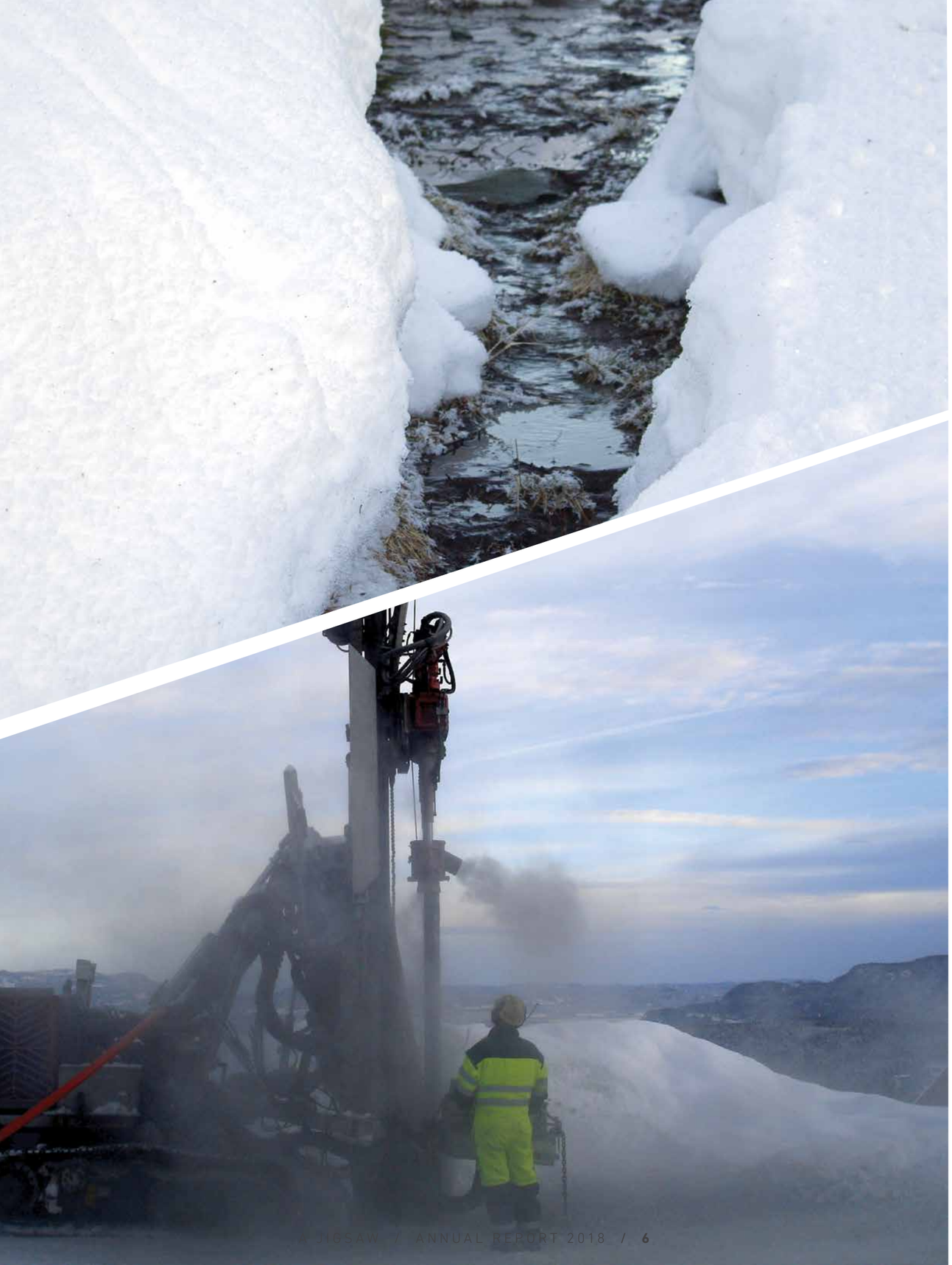


> ***Without NGU, we would not be able build safely. The knowledge NGU produces is fundamental to the safe development of Norway.***
>
> *Julie Brodtkorb, Director, Norwegian Association of Heavy Equipment Contractors (MEF)*

CROWD-SOURCING

Have you ever had a water-well drilled at the cabin? Or maybe, a geothermal system heats your home? The drilled wells found in Norwegian gardens and near cabins are an essential source of geological information.

Valuable geological and groundwater observations are collected when wells are drilled deep into the subsurface. The drillers can observe and document if the drilling mud consists of sand, gravel or clay. Perhaps the colour of the mud changes with depth? Shudders will pass through the whole drilling rig when the drill bit hits hard bedrock. The key question is: how much can the water well produce when drilling has been completed?

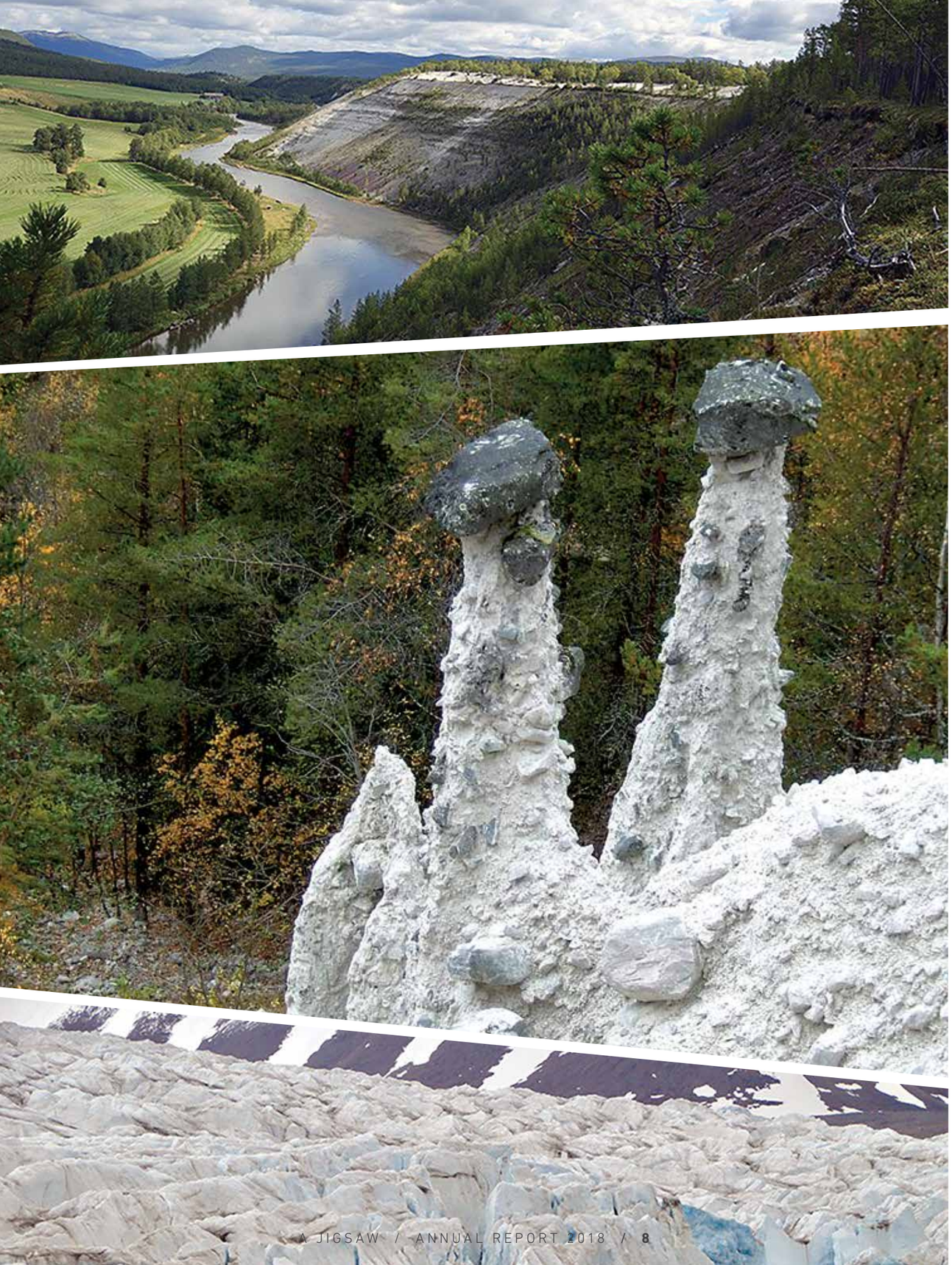
NGU's geologists and others can learn more about the subsurface from the information recorded by the drillers. Their observations can be used for making new maps, for research or in preliminary construction-site investigations. Society must, in addition, have an overview of the location of wells, before starting building projects or excavations. Drilling contractors are in Norway, are therefor, required by law to deliver a short report to NGU each time they drill a well. NGU assembles this information in the National Groundwater Database, which contains national coverage regarding the location of wells, and of the observations made by the drillers during the drilling operation.

NGU launched, in 2018, a new well-registration platform, Brønnreg, which well-drillers can use to report their observations. Drillers can use a mobile phone app which uses GPS to define the location of the well and other data fields in which they can enter information. Brønnreg is also available on the internet via NGU's national groundwater net portal, www.grunnvann.no.

Drillers had previously to fill out a paper form which they sent by post to NGU. NGU later entered the information manually into its database. Brønnreg saves time for both NGU and the drilling contractors, and the information entered is more reliable. NGU can, by streamlining geological data collection, prioritize delivery of better services to planners, building developers and others who need information about the subsurface geology.

Subsurface studies are expensive. NGU, in the future, collect, re-use and re-distribute more of the geological information acquired from various development sources. Other geological-data services at NGU are now reusing digital solutions created for Brønnreg. One of these is a customized registration service for ground surveys, which allows municipalities, government agencies, consultants and other companies to share their reports from basic surveys via NGU's registration system. We publish this information in the NADAG database (The Norwegian National Database for Ground Investigations). We are aiming, in addition, to develop a similar solution for geophysical surveys, which would allow us to assemble and share more data in the National Geophysics database (DRAGON) (DiRect Access to Geophysics On the Net).

Brønnreg has been developed within NGU's "Underground Programme". This programme aims to make more and better geological information available to both NGU and Society.



> ***As the nation's databank for biodiversity, the NBIC depends on good collaboration with the Norwegian academic community. NGU has collaborated with us on Norway's Red List for Ecosystems and Habitat and Norway's Species Map Service and has become a valuable partner and professional resource.***
>
> *Einar Hjorthol, Director, The Norwegian Biodiversity Information Centre (NIBC)*

RED-LISTED LAND-FORMS

The Norwegian Red List for Ecosystems and Habitat Types was revised for the second time in 2018 - and now geology is a criterion. Twenty-eight (28) types of landform have been added to the Red List: these include: caves, glaciers, flood plains and earth pyramids (hoodoos).

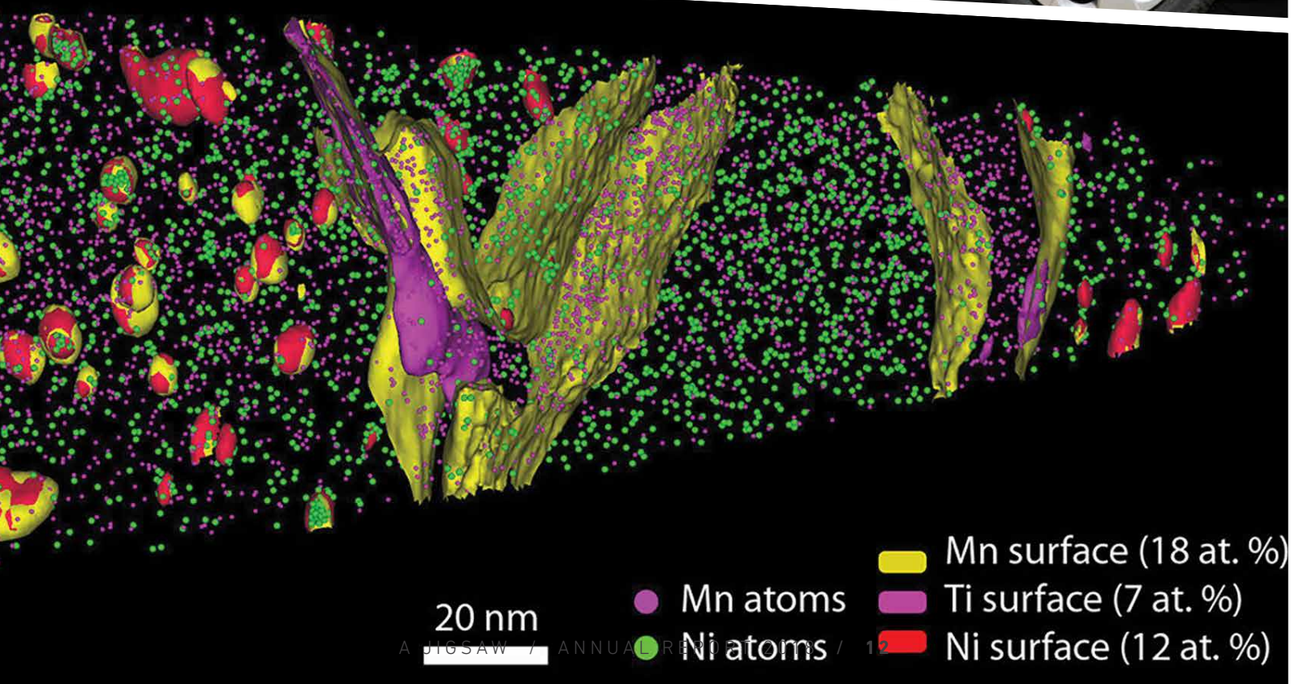
The framework used for red listing in Norway was developed by the International Union for Conservation of Nature (IUCN), the only environmental protection organization with permanent official observer status at the United Nations. Nine expert committees have been established under the Norwegian Biodiversity Information Centre which leads the work in Norway. NGU has been a member of one of the committees and has also contributed information to the committee which has worked with marine habitats.

Probably the best-known IUCN product is the "Red List of Threatened Species" or simply, the "Red List". IUCN also maintains the "Global Invasive Species Database." Recently, IUCN introduced the "Red List for Ecosystems and Habitat Types" and, it is in this context that geology is introduced, with "landforms". The list describes the types of nature; deposits, whether the sites are threatened or vulnerable, and the probability of their being lost. What is known as "Nature Types in Norway" is designed to provide decision-makers with a better knowledge base for managing ecosystems and habitats. Land planners working throughout Norway have, in this way, a better knowledge base when planning new highways, changing the planning status of new sites or establishing nature reserves.

There are, in the list, 14 sub-groups within the nature-type "landforms," with a total of 85 evaluation criteria. All the landforms are assessed to determine if they are vulnerable, threatened or rare. Twenty-eight (28) landforms have been added to the red list. Most of these are related to limestone caves, landforms such as river deltas and floodplains, and various types of glaciers. The vulnerability of the sites is commonly linked to tourism, regulation of waterways, climate changes and infrastructure development.

Our landscape tells a long story about the planet on which we live. Future generations deserve access to this landscape, not only knowledge and interpretation of it. The Red List for Habitats and Ecosystems is based on a holistic approach in which both geology and landforms are recognized as independently valuable entities, both of which can be subject to alteration and some of which may be lost in the same way as more biologically based features in nature. That recognition makes us happy at NGU.

The “super-laboratory” will receive state-of-the-art equipment to enable scientists to characterize materials and minerals, among them those types that are vital for developing future green technologies.



> ***This type of equipment takes the laboratory to the level of "world leaders" and is well worth the investment. The ability to see every single atom in a sample is extremely dramatic!***
>
> *Jostein Mårdalen, Head of Department, Materials Science and Engineering, NTNU.*

IN PURSUIT OF THE FUTURE

NTNU and SINTEF, together with NGU initiated, in 2018, a "super-laboratory" in Trondheim called the "Norwegian Laboratory for Mineral and Materials Characterization" or, in abbreviated form, MiMaC.
The laboratory will receive state-of-the-art equipment to enable scientists to characterize materials and minerals, among them those types that are vital for developing future green technologies.

Solar panels, super-magnets, batteries and new construction materials are developed from resources and materials with exceptional properties and qualities. Scientists and engineers must commonly, in order to develop new technology, examine materials and minerals right down to the atomic level: this is what the scientists call characterization.

The MiMaC laboratory was established with the aim of uniting the disciplines of mineralogy and materials science. Assembling the scientists from both disciplines in a joint laboratory, gives them a unique opportunity to investigate the entire value chain from minerals to material. Industry, in order to develop innovative materials, must have access to minerals and metals with specific properties. The mineral industry must also acquire information on which minerals and raw materials will be in demand in the future.

The project received NOK 71 million from the Research Council of Norway, most of which was used to acquire laboratory equipment. The instrument which had the highest cost is the so-called atom probe, costing ca. NOK 40 million. An atom probe permits examination of parts of a sample at a level which allows detection of individual atoms. This type of equipment makes the laboratory world leading.

NGU and SINTEF, in conjunction with the opening of the MiMaC laboratory, arranged the conference "Minerals and materials for a sustainable future" in Trondheim in September 2018, in collaboration with the world-leading journal of science, Nature.

The conference gathered leading scientists from around the world for three days, to discuss future demand for minerals and materials, with special attention on how to succeed in meeting the unique requirements of the "green shift".

The conference was broad in scope and addressed large-scale topics. These included identifying the resources needed to meet the challenges being faced by society, via the contribution of material technology to "green" solutions, and how a circular economy could really function. The scientists participating agreed that the global community must work hard to achieve the UN goals for Sustainable Development. Success will necessitate a much greater level of cooperation and mutual understanding between different professional fields and research disciplines.

We hope that we have, with the establishment of MiMaC, taken a major step in this direction.

MAREANO's knowledge base is vital for the comprehensive management of the oceans. Access to good quality-controlled data is fundamental for both exploitation and protection.

Signe Nåmdal, Division Director, Norwegian Environment Agency

SEABED MAPPING

The mapping program MAREANO assembles data from the seabed. A team of evaluators from Oxford Research, working on behalf of the Ministry of Trade, Industry and Fisheries, concluded that this state programme succeeds in providing users with products that are relevant, user-friendly and accessible.

Seven trawling companies with sea-going vessels, as well as several coastal fishermen participated, in 2018, in a trial project to use new bottom-type maps and bathymetric data from MAREANO and other sources. The digital subsea maps were loaded on Olex chart-plotter systems, and the results were positive. The fishermen report positive experience with the new detailed seabed maps: fuel consumption has decreased, and there has been less damage to equipment. Good bottom-type maps can hopefully contribute to reduction in damage to nature and sensitive nature-types on the seafloor.

The results from the seabed mapping are also useful for marine spatial planning for other research objectives. Central users, according to the Oxford Group's user-evaluation, viewed the MAREANO products as relevant, accurate and, in general, adapted to their needs. The MAREANO mapping programme model can be adopted, in whole or in part, by other coastal nations with an interest in "blue" growth.

The MAREANO program's primary user-groups are public administration; governmental ministries and, in part, their sub-agencies. Other research agencies, including those responsible for data collection; namely, the National Institute of Marine Research, NGU and the Norwegian Mapping Authority, are important users of the results of the programme. MAREANO's map products, reports and, in part, analytical data, receive the most extensive use.

The MAREANO maps encompass data on bathymetry, bottom conditions, biodiversity, nature types and pollution in the sediments in Norwegian oceanic waters. The Institute of Marine Research, the Geological Survey of Norway (NGU) and the Norwegian Mapping Authority are jointly responsible for the day-to-day operations, while the Norwegian Environment Agency leads the programme.

The MAREANO Steering Group consists of five governmental departments. The programme is funded by the Ministry of Trade, Industry and Fisheries and by the Ministry of Climate and Environment.

“NGU demonstrates, by facilitating access to knowledge, analyses and physical material, and especially drill cores, that it is a service-minded, professional agency. NGU has been invaluable to us. We perceive NGU as highly conscious of their mandate – at times almost self-critical – and genuinely concerned about how they can best contribute to the establishment of a new Norwegian mineral resource industry.

Tore Viana-Rønningen, General manager for Arctic Mineral Resources AS

AT THE CORE

Here lies Norway’s unique rock archive. This ca. 1600 square-metre storage facility, located in Løkken Verk in Meldal, holds the geological heritage for an entire nation.

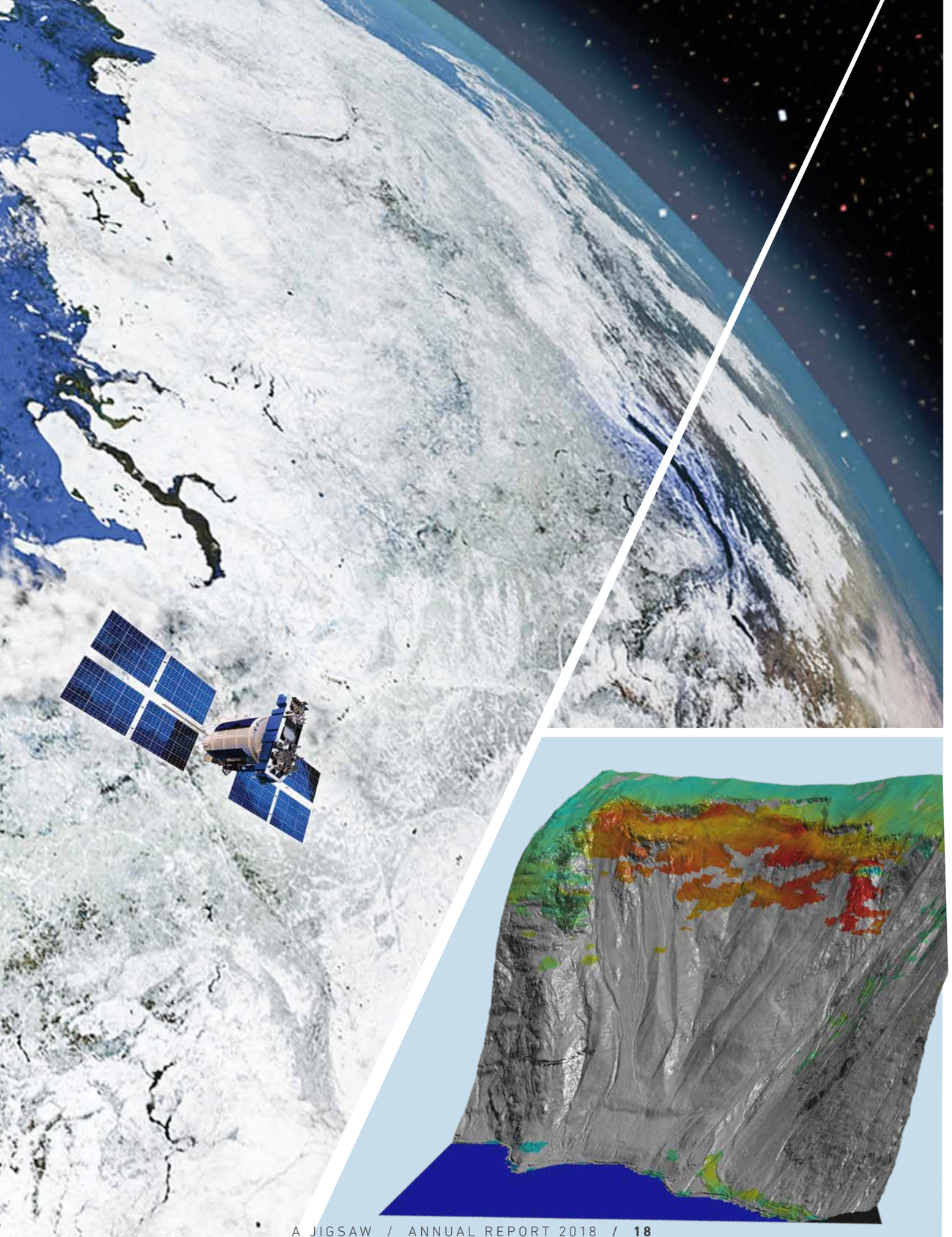
Norway’s nature-based heritage deserves protection in the same way as its culturally based heritage. This extensive rock archive in Trøndelag contains 750,000 metres of drill core retrieved from Norwegian bedrock, as well many other geological materials.

More minerals, many of them new, are increasingly being used in the development of modern technology. Analytical techniques are, in addition, advancing year by year. An archive of the geology of Norway is therefore an essential resource. The Geological Survey of Norway owns and operates this critical archive of Norway’s geological heritage. The National Drill Core and Sample Centre was established in 1991, four years after mining operations at Løkken Verk were terminated. NGU is currently responsible for collecting cores from drilling operations throughout Norway. Former staff at the mine were, initially responsible for activity at the drill core store. The main goal of the archive is the preservation of knowledge of the ore- and mineral deposits in Norway. Drill cores from exploration and mining operations were transported to Løkken, where the material was registered and systematized as well as possible.

The archive has, over the years, been expanded to include natural and building stone, samples from general geological mapping, geotechnical material, marine geological samples, and geochemical materials. The archive now contains rock samples collected in the course of 100 years of exploration for and extraction of mineral resources in Norway. The replacement cost of the collection can currently be estimated at approximately one billion kroner (= thousand million in English usage).

The “earliest acquired” samples stored at the Centre are from drilling operations at Løkken Gruber in 1906. The geological age of the oldest rocks in the Centre, a representative sample of a unit of gneiss from Kautokeino in Finnmark, is an incredible 2,975 million years: this gneiss is the oldest rock found in Norway.

The Centre can be considered as a library in which the book pages are of stone. Most of the archive is freely accessible to representatives from industry, the professional communities and the public.



The joint venture which we, at the Norwegian Space Agency, have with NGU and NVE in InSAR Norway, is a pillar for our programme on the operational use of satellite data from the European Copernicus programme and Sentinel satellites. Together we have developed a world-leading national service.

Christian Hauglie-Hanssen, Managing Director
Norwegian Space Centre

AS SEEN FROM AFAR

The Earth's surface is in continual movement. We can, by using radar measurements from satellites, the method called radar interferometry or InSAR, map deformation in the landscape, for example subsidence in cities and movements in unstable mountain slopes.

The outcome out of the collaborative project is a new, innovative, open-access mapping service which allows users to see where both buildings and ground surfaces are moving throughout the country.

The Geological Survey of Norway (NGU), the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Space Centre launched, in 2018, the nationwide, internet-based mapping service for InSAR data. The service offers InSAR data for the whole of Norway. The research institute Norut, now part of NORCE (Norwegian Research Centre AS), has been a key partner in the development of this technology.

InSAR is a method for measurement of ground movement. Measurements from satellites, called radar interferometry or InSAR, enable us to map deformation on a mm. scale, e.g. subsidence in cities or in unstable slopes in the terrain

A radar satellite emits pulses of radar energy, which move like waves towards Earth's surface. When such a pulse of radar energy scatters across the Earth's surface, a part of the signal is reflected back to the radar satellite.

The reflected signal is assembled into an image. We can, by combining measurements at two different times from the same area, we can determine the extent of ground movement during that period – with a high level of precision and accuracy. One can, by combining measurements recorded over time, create a time series over the movements.

NGU uses InSAR to map and monitor rock landslides, as well as to detect and measure urban subsidence. The method is particularly useful in terrain that is difficult to access, such as unstable rock slopes. InSAR also works well in cities, where buildings and roads reflect the radar signals, so that it is well-suited for mapping e.g. subsidence along harbour-front areas.

InSAR Norge uses measurements from two Sentinel-1 satellites, which are part of the EU's Copernicus programme. The satellites acquire images over Norway every six days. Copernicus operates with a so-called open-data policy. The raw data is freely available to anyone, but specialized software is required to process the ground movement data.

> ***The results from the NGU study on continental uplift in Aust-Agder are essential to our understanding of land use during the Stone Age. The study includes what could be the best shore-line-displacement curve developed anywhere on Earth. This curve is also an important dating tool for shoreline settlements which were once populated by of hunters, gatherers and fishermen.***
>
> *Gaute Reitan, excavation manager, University of Oslo, Cultural History Museum's E18-Project Tvedestrand-Arendal*

WHERE'S THE BEACH?

The sea level, just after the last Ice Age, was 60 - 85 m. higher in Aust-Agder than it is today. Now, 11,600 years later, a new highway (E18) has been built between the Tvedestrand and Arendal, in southern Norway. Archaeologists and geologists, however, joined forces before the construction vehicles began work on the site.

Archaeologists need to know the exact location of the past shoreline prior to excavation for a Stone Age settlement. A shoreline displacement curve is a reconstruction of the shoreline through time - which is where geologists have their role.

Continental uplift due to the melting of glaciers resulted in changes to the shoreline up to several metres within just a few hundred years. Geologists, after extensive field-work, extracted drill core samples from a total of 28 lakes and marshes. They carried out laboratory examinations of the cores - looking for shell, plant and animal remains. The could then, after applying dating methods, identify precisely where the shoreline stood at any point in time.

The reconstruction of the shoreline presented a surprisingly large variation over 20-30 km. Detailed work has ensured an accurate interpretation of the geological development of this section of shoreline, from the time that the glaciers melted to the present day.

The research continues, but already scientists know that the Ra moraine, the largest and most famous terminal moraine in Norway, is almost 1,000 years younger than once thought. Furthermore, it seems that the Ra moraine was formed after a 2,000-year long period during which the entire southern coast was ice-free, up to 1 km. inland. At the same time, archaeologists examined 34 Stone Age sites on the 23-km-long E18 route. The age of these archaeological sites ranges from ca. 9,000 to 1,700 years B.C. They studied burial mounds and sunken lanes dating from the Iron Age.

The Quaternary mapping project in Tvedestrand and Arendal resulted in many practical findings, two scientific papers and several chapters in the book "The Stone Age of the coast of Aust-Agder". One of the articles was, in 2018, honoured with an NGU award for "Publication of the Year".

> ***The work of the Geological Survey of Norway is an important contribution to Society. We are looking forward to gaining knowledge through the on-going mapping of the bedrock in our municipality. Our cooperation with NGU is excellent.***
>
> *Tor Peder Lohne (Sp), Mayor of Drangedal*

THE LANGUAGE OF BEDROCK

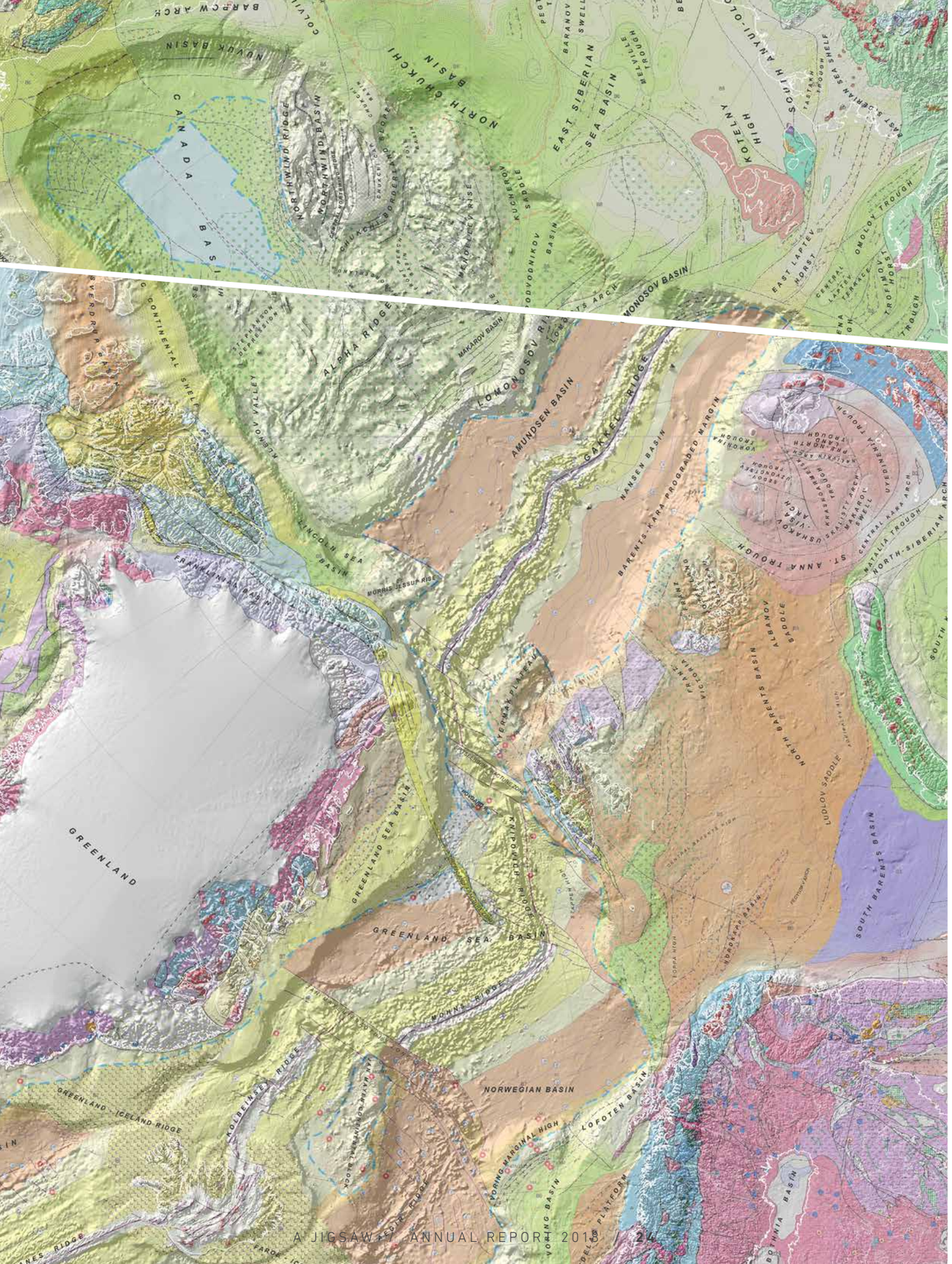
The bedrock in two municipalities in Telemark "speaks", but what it is "telling us" needs to be "translated" into a language that everyone understands. Resources and subsurface have been prioritized in a project involving numerous NGU geologists, the Regional Geologist for Buskerud-Vestfold-Telemark, students and other partners.

The geologists mapped the bedrock in the municipalities of Drangedal and Nissedal. Primarily, the maps reveal the composition of the bedrock, but it is the next step that is important; namely, "decoding". The maps and data will indicate a rock's potential applications and where builders and planners should take caution before starting an excavation. Geologists can, rather than simply identifying a rock-type as granite gneiss, go further, and explain that this rock is suitable for crushed stone or as a structural foundation.

Extensive fieldwork and laboratory analyses allow geologists to prepare a general map which provides an overview of crushed-stone resources, radon hazards, as well as faults or weaknesses (due to e.g. weathering) in the bedrock.

The concept is, in relation to land-use planning, smart and straightforward, leaving less to chance for the inhabitants in general. It is good to know, before deciding which areas to regulate for residential development, whether there are valuable resources in the subsurface or if the bedrock has high levels of the radioactive gas, radon. Before building roads and tunnels, planners and engineers need to know the location of fault zones and zones of highly weathered, even rotten bedrock.

It was an immense task to assemble all the project components within the four-year deadline, but the municipalities remained very cooperative and interested. The 4-year project was called BITE (Bedrock Infrastructure in Telemark). 97 person-field days were used within the two municipalities in 2018. Ten geologists, from four teams at NGU, worked in the project.



“For many years, NGU has been an actively promoting international cooperative mapping.

Oleg Petrov, Director General, Karpinsky Russian Geological Research Institute - VSEGEI

ACROSS BORDERS

A new geological map can help clarify where the national boundaries should be drawn in the Arctic Ocean. The map was presented at a Norwegian-Russian workshop in Trondheim in 2018.

The large, international mapping cooperation project in the Arctic, led by Russia, has led to the achievement of a shared understanding of the geology in the area. The new map is a tectonic map which shows the structural construction of the crust, and how it was formed and deformed throughout geological time. Joint mapping has previously resulted in a basic geological map of the bedrock, two geophysical maps, and an overview of the mineral resources of the Arctic.

The new tectonic map has been approved by the International Commission on the Geological Map of the World (CGMW).

Geologists have worked extensively on the map. Numerous samples were collected, examined and analyzed. Several countries have invested much work in logistical support, such as providing access to submarines and icebreakers in the mapping.
The results of this cooperation have had great importance for the scientific understanding of the geology of the Arctic region. The information has now been disseminated and has become important in several fields, including teaching and education in general. All countries can use this shared database for their projects.

The new map is one contribution to the effort of defining where the national boundaries should be drawn in the Arctic Ocean. The United Nations Convention on the Law of the Sea (the Convention) points out that coastal nations have rights to the continental shelf, even where it extends beyond 200 nautical miles from the coast. The new map can, in the Arctic, be used to clarify these limits.

The Ministry of Natural Resources and Environment of the Russian Federation and the Federal Agency for Mineral Resources initiated international cooperation in the polar region already in 2003.

The work is the result of a collaboration between the geological surveys, various agencies and several research institutions in the United States, Canada, Denmark, Sweden, France, Germany, Norway and Russia.

The cooperation in the Arctic will continue. Future work will include an update of the comprehensive atlas: “The Geological History of the Barents Sea” (published in 2009) which describes regions of the Barents and Kara Seas.

CASH ACCOUNTS: INCOME AND EXPENDITURES 2016-2018 (MILL. KR)

	2016	2017	2018
Income			
Annual Grant	176,8	169,1	179,4
Income from allocations and transfers	44,7	45,0	63,4
Sales and rental income	29,4	32,6,0	24,4
Total Income	250,8	246,7	267,1
Expenses			
Salaries and related costs	162,7	152,7	156,5
Depreciation	9,3	9,2	9,5
Other expenses	79,3	84,8	101,1
Total costs	251,3	246,7	267,1
Total result	-0,5	0	0

OVERALL PRODUCTION OF REPORTS, PUBLICATIONS, PRESENTATIONS AND MAPS FOR NGU 2017-2018

Product Type	2017	2018
NGU reports	37	32
Articles in scientific journals and books	127	138
Articles in other publications	47	65
Presentations and lectures	383	330
Forskning.no	12	20
Printed bedrock and Quaternary maps	7	25

NGU EMPLOYEE STATISTICS

	2017	2018
Total staff	203	196
With university degree	148	143
With PhD Degree	70	64
Number of foreign employees	72	73

WHAT THE NUMBERS TELL US

NGU continued, in 2018, to work in accordance to the guidelines embodied its Strategic Plan 2017-2020, as well as the major targets and tasks stated in Proposition 1 S (2017-2018) and in the 2018 allocation letter from the Ministry of Trade, Industry and Fisheries (NFD).

NGU has, in principle, reached its set targets, has fulfilled the requirements and guidelines that are outlined in the allocation letter and has remained within the given budgetary framework and financial guidelines.

NGU runs on a balanced budget. About 67% of NGU's financing is in the form of direct government grants.
NGU, as of January 1, 2016, began operating under the accrual basis of accounting.

The accounting overview displays figures for 2016, 2017 and 2018 according to accrual methods.

NGU received, in 2018, a total allocation of 179,4 million towards expenditures. This includes the grant from NFD, and a debit authorization Norwegian Environmental Agency and IKT. Included in the NFD allocation, is an earmarked grant of approximately 28.9 million kroner for the MAREANO Mapping Programme

NGU's databases are available through our website www.ngu.no. In addition to the databases, our work is documented in reports, in scientific journals and in lectures for various audiences.

NGU's absence rate in 2018 was 4,7%.

For more details and key statistics, please refer to the NGU Annual Report to the Ministry of Trade, Industry and Fisheries (NFD), which is available through the NFD website and at ngu.no.

NGU's main goals:

- Increase mapping of geological resources
- Increase the availability of geoscientific knowledge that can be use in land-use planning and constructi on activities
- Increase knowledge of geological processes and of the geological development of Norway
- Ensure good management and appropriate user-adaptation of geological knowledge
- Strengthen communication and dissemination of geological knowledge