NORGES
GEOLOGISKE
UNDERSØKELSE
- NGU -

Annual Report 2017

EVIDENCE

Follow the trail of NGU's wide-ranging activities in 2017.

We have gathered clues that reveal the connections between Earth's core, the ocean floor and the planet Mars. We also join the hunt for rare minerals, gold and map ancient landslide scars.

At the same time, we disclose how geology can help criminal investigators to solve decades old crimes.


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NORGES
GEOLOGISKE
UNDERSØKELSE
- NGU -

2017 Annual Report

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ISSN: 0333-4122

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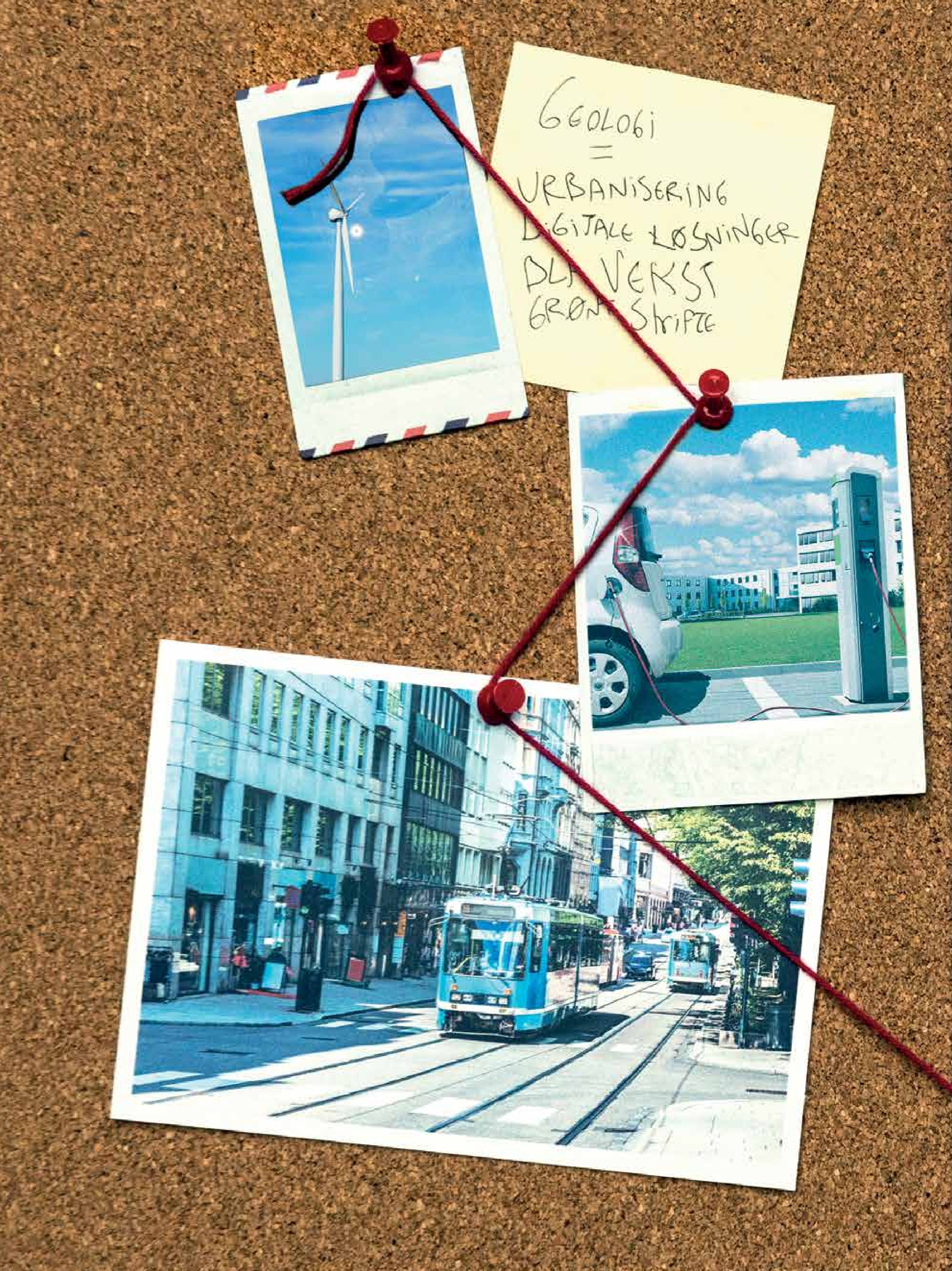


Our daily life

The demand for geological expertise has never been greater. Development, urbanization, industrial expansion and value creation. Blue growth, the green shift, civil security and the holistic management of nature and resources. Everything points to a need for better understanding about the Earth upon which we live, and about the natural resources we require in everyday life.

Through geological, geophysical and geochemical mapping, the Geological Survey of Norway is responding to social needs and ensuring that crucial data about the Earth is accessible to a multitude of users.

The green shift will trigger an industrial transformation driven by new technologies that depend upon numerous new minerals and metals. We will need more industrial minerals, special metals and building materials. For this reason, we need to provide access to data and information about mineral resources in Norway. As of the start of 2018, about half of Norway has been mapped using modern geophysical methods; 77% of northern Norway and 40% of southern Norway. We must ensure that most of the country is mapped using the latest geophysical mapping methods.

An increasing proportion of value creation in Norway in the future will depend upon coastal areas. Value creation will increase in traditional industries, such as fisheries, industry and transport, and in newer industries such as aquaculture, tourism and culture. Blue growth is a priority focus area. To realize the potential for value creation and to ensure sustainable management of land and natural resources, it is essential we have more knowledge about the sea and seafloor. We must also acquire knowledge about the impact of human activity on the environment. Readily accessible and reliable marine basemaps are a prerequisite for ecosystem-based management and sustainable use of coastal areas. Together with the Norwegian Mapping Authority and the Institute of Marine Research, NGU has proposed a marine mapping program to produce a marine basemap of Norway's coastal zone.

Climate change, which is expected to result in more landslides due to the increased intensity of precipitation in Norway, calls for a better overview of potential landslide hazards. Hence, the Norwegian Water Resources and Energy Directorate (NVE) and NGU have prepared a plan and a priority list for mapping of hazardous areas in Norway. We will also continue to cooperate with the Norwegian Space Centre and NORUT on the use of satellite data to identify and monitor areas prone to landslides. Population growth and increased urbanization leads to elevated pressure on urban areas. Hence, in 2017, NGU continued developing tools and data sets to create 3D models of the urban subsurface. Together with the Norwegian Public Roads Administration, Bane NOR and NVE, we have established a national database for ground investigation (NADAG). The database ensures that geological and geotechnical information is accessible to planners and developers. With the support of the co-financing scheme for national digitization projects, NGU has increased access to, and improved the quality of, information about the subsurface. Through new digital reporting routines, open management and use of open a marine mapping services, we have emphasized developing new information portals and customized products for business and land management. NGU will continue to meet the requirements of the EU directive INSPIRE, which through the Geodata Act requires national agencies to establish and operate a network of digital services for searching, viewing and downloading geological data.

In 2017, we continued to be actively involved in EuroGeoSurveys to develop "Mineral Intelligence," including a common database platform focused on improving the mineral statistical data. NGU is an active participant in the Horizon 2020 program and other relevant EU activities. In the period ahead, it is particularly relevant to participate in European projects where geological resources are linked to sustainable solutions for community development.

Morten Smelror
Director

Hunting Rare Minerals

Deep drilling for rare earth metals in the Fen Complex in Telemark began in 2017. Colourful spikes in the first core samples indicate a varied content of special minerals in the rock type rauhaugite deep in the bedrock.

The world exploits increasing numbers of the elements found in the periodic table. Rare earth metals are included in most products that are necessary for the green shift. Demand for these metals is increasing, but as of today, China has nearly gained a monopoly on the extraction and production of the 17 metals of this category.

The Fen Complex, in Nome municipality, may have one of Europe's largest deposits of rare earth metals. Here the researchers investigate the resource potential and look for minerals that can be included in modern and future electronics, such as smartphones, electric and hybrid cars, wind turbines, computers and batteries.

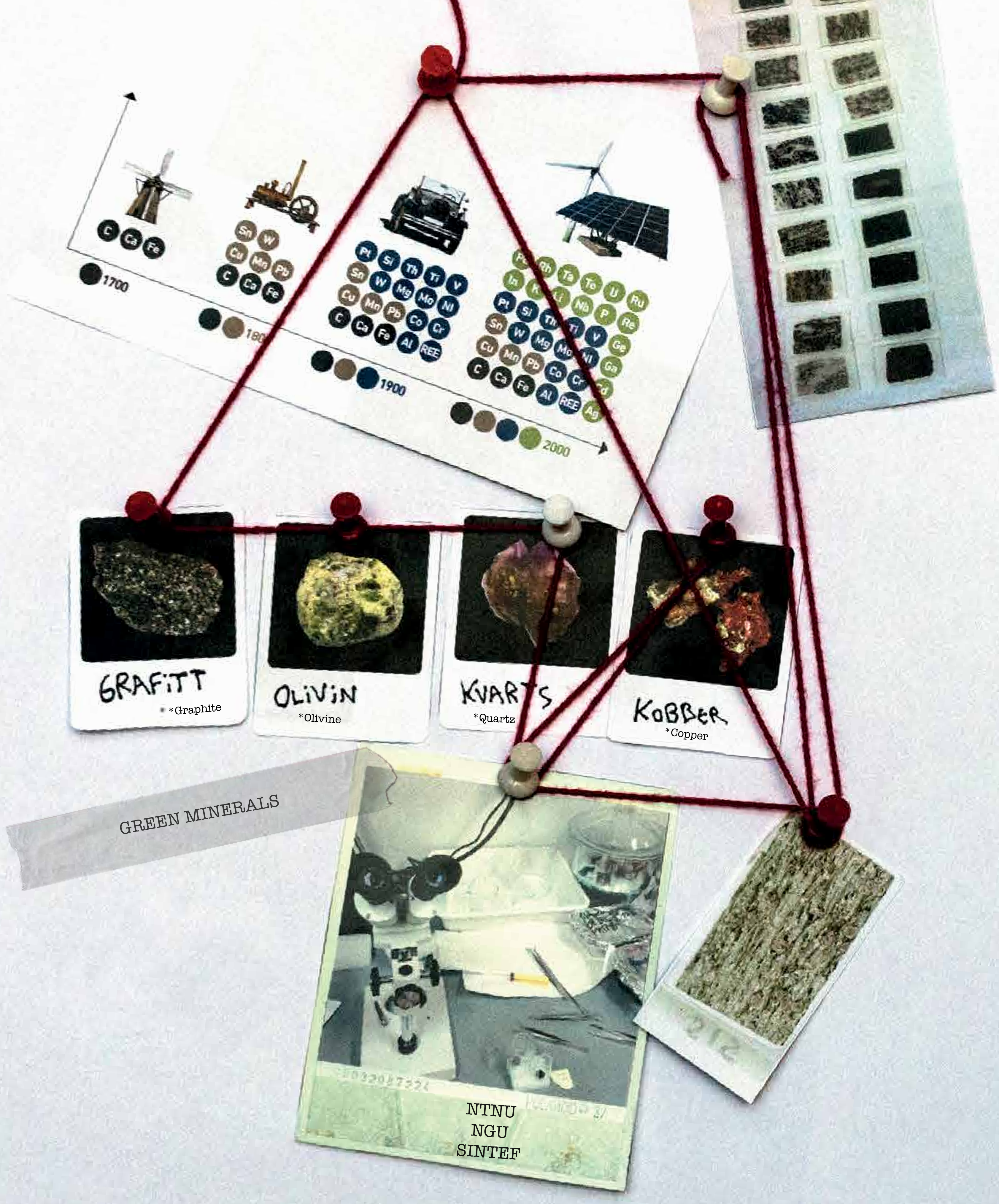
In 2016, the government granted eight million kroner to these surveys. The money was granted based on extensive surveying work on the surface led by the Regional Geologist for Buskerud, Telemark and Vestfold - supported by NGU - and following a rigorous political effort from regional and local politicians in Telemark.

The most important deposits of rare earth metals are found in carbonatites - a group of magmatic rocks consisting mostly of the soft mineral calcium carbonate, typical of the rocks in the Fens Complex.

The rock types in the Fen Complex intruded the Earth's crust from the mantle during volcanic activity about 580 million years ago. Drilling started in an old volcanic area in the autumn of 2017. Two 1,000-meter deep holes in the bedrock of the five-square-kilometre area will reveal the resource potential.

The drillholes are logged with available geophysical methods. Each core is carefully examined and described. All cores are sent for hyperspectral scanning, a type of photography where important details in the rock sample that cannot be seen by the naked eye are revealed. The core's chemical composition will be analysed, and back at NGU in Trondheim, the rock and mineral composition will be investigated and described in detail. Overall, the results will help determine whether the occurrence of rare earth metals in the Fen Complex is suitable for future exploitation.

There has been mining in this area since the 1650's. Until in the 1920's, iron ore was extracted from the Fen Complex, when it was economically profitable. Later, niobium was extracted, an alloying element used to make steel products flexible, mouldable and able to withstand high temperatures. The industry was shut down in the 1960's.



Together into the future

The Geological Survey of Norway has strong and broad relationships with its partners in Norway and abroad for research, management and dissemination. During 2017 a new large-scale cooperative project began: with support from the Research Council of Norway, NGU, NTNU and Sintef will establish a joint laboratory for mineral and materials characterisation (MiMac).

The new joint laboratory will support research that will identify which minerals and materials will be in demand to produce new green technologies and future smart solutions. The Research Council believes that it may have a major impact on business, climate and renewable energy.

The new center will coordinate research and development related to minerals and rocks, which society needs for the future. The green shift requires a more efficient and cleaner mineral industry. Climate emissions will be reduced, and raw materials and waste better utilized. Consumption of building materials, such as gravel, will be greener and more locally sourced. The green shift requires a great deal of commitment to new technology, both in the development of renewable energy and in efforts to reduce the consumption of fossil energy.

Throughout the history of humanity, mineral resources have been crucial for prosperity and development. Each new era is characterized by new mineral resources becoming available, which in turn leads to new technological advances. The Stone Age was replaced by Bronze Age in the same way that green energy should replace fossil fuels.

Some metals and minerals are crucial for the implementation of the green shift. This includes elements that are indispensable to producing climate and environmentally friendly energy, minerals that are directly used for environmental purposes, and substances that ensure efficient production of technology. Many elements and minerals with unique properties are also required for the electrification of the transport sector. Today, most elements of the Periodic Table are available for use.

The global increase in the demand for renewable energy, and the rapid shift to adopting even more advanced technology, drives the accelerating demand for integrated research across the entire value chain, from mineral extraction, to recycling. Copper, phosphate, graphite, rare earth metals, lithium, titanium, olivine and quartz are commonly referred to as "the green minerals."

More investment in the national research infrastructure will provide industry with a competitive edge and enable our scientists to participate within leading international research communities.

Gold in Gisna

34.9 grams. That is the exact weight of the record-breaking nugget sifted out of Gisna river in Trøndelag by gold panners last year.

NGU researchers have examined the gold under an electron microscope. The residual deposits on the surface of the nugget contained tiny fossilized algae, suggesting that the nugget resided in an acid environment for a long time before it was loosened from its host rock. The Gisna river borders Oppdal and Rennebu municipalities in Gisnadalen and past investigations of gold samples from the Gisna River revealed the same fossilized algae. This strongly suggests that the gold nuggets originated from the same source, possibly nearby bedrock, before being eroded away and washed into the river sediments.

The gold nuggets in the river may have been transported long distances by glaciers, and only rarely are significant amounts found. However, when several nuggets appear to originate from the same source, it gives some hope that they came from a deposit in bedrock in the near vicinity.

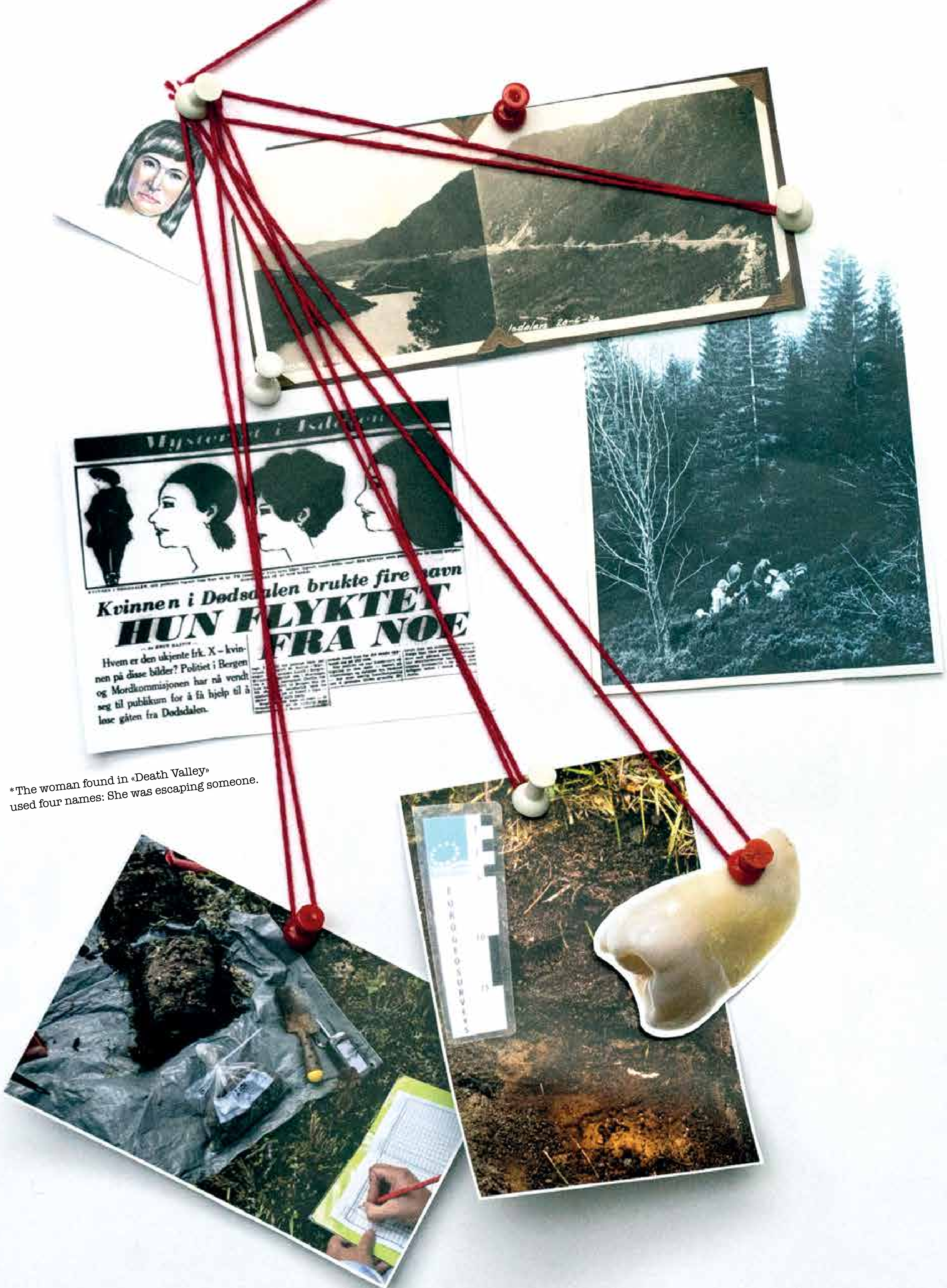
NGU has previously studied the vicinity around the river to locate the possible gold-bearing veins in the bedrock. Amongst other things, geologists have excavated meters of soil and rock, right down to bedrock. Unfortunately, the samples taken showed no presence of gold nor did they find any gold-bearing veins in the vicinity.

In 1758, the first gold mines began to operate in Norway in Eidsvoll after visible gold had been found in a quartz vein located in an old mine once operated by Odalen copperworks. Later, similar gold-bearing quartz veins were found at Bømlo in Telemark and in Bindal in Nordland.

Barely 500 kg of gold were extracted from these quartz veins. Prior to the start of operation of Bidjovagge gold and copper mines in 1985 in Finnmark, gold was a bi-product from copper, zinc and lead production from massive sulphide deposits such as Bleikvassli, Hjerkinn and Joma. By its closure in 1991 Bidjovagge mines produced approximately 6200 kg of gold, worth NOK 508 million.

In 1866, gold was also found in the river bed sediments near Karasjok. After the end of WWII gold has been detected in several other river systems, but the total production has been just over 100 kg.

If you are looking for gold deposits in Norway's river systems, you must both contact and have permission from the landowner. If you find a large enough grain of gold, take a pin or a knife and scratch the surface. This test will help you distinguish real gold from pyrite, or chalcocite, which are both hard and brittle. Gold is a soft and malleable metal which can be easily scratched.



From Earth you came

Soil and teeth have revealed where the mysterious Isdal woman was born and raised. The body of the unidentified woman was found burned and naked in Isdalen in Bergen on November 29, 1970.

New analyses of a substance present in the unidentified woman's teeth, combined with detailed data on agricultural land, contributed to the breakthrough. This woman, with nine false identities, spent her first years in southern Germany, in northern Bavaria, then in her teen years near the Luxumbourg-France border and later in West Germany.

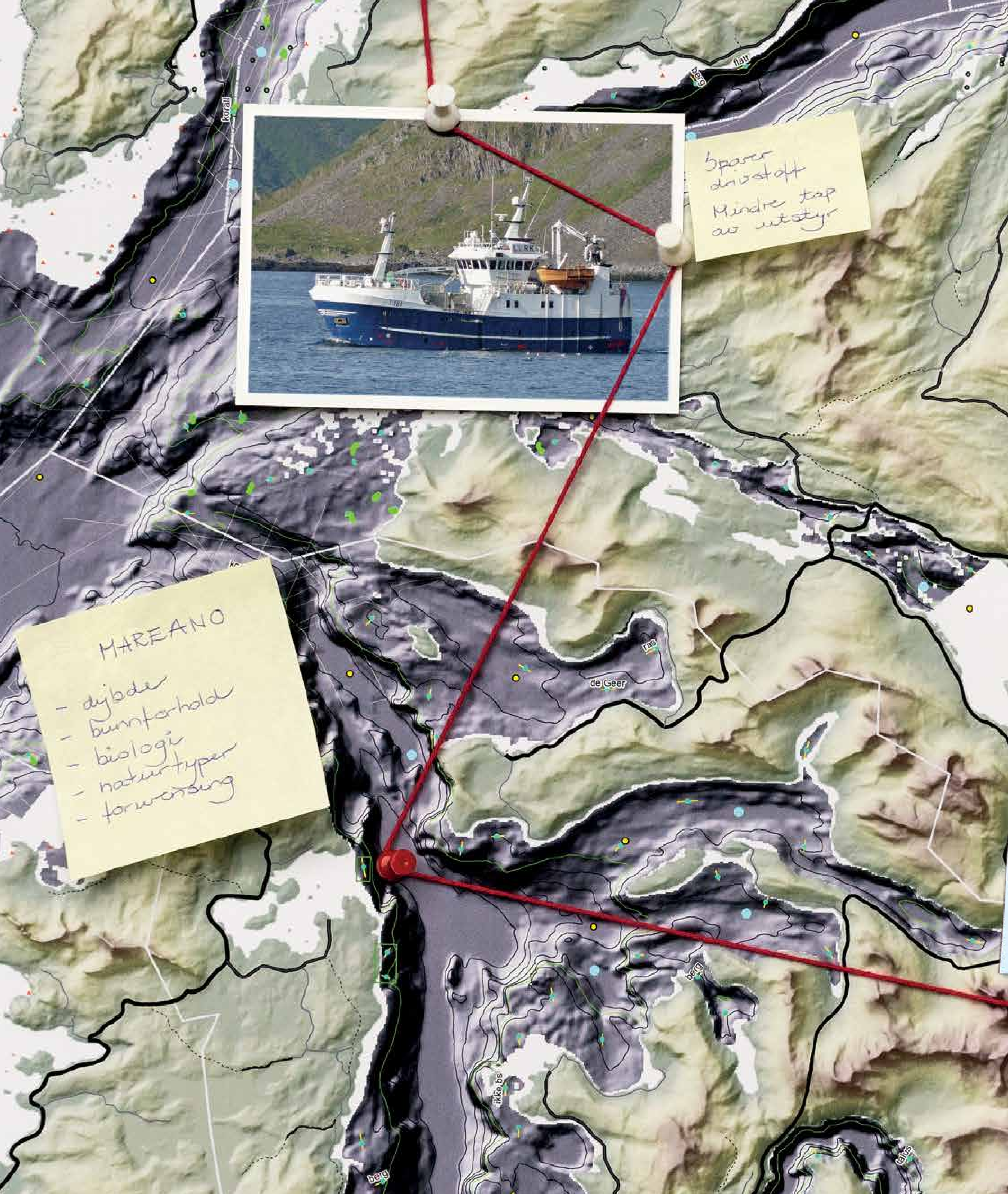
The NGU-led project Geochemical Mapping of Agricultural and Grazing Land Soil (GEMAS), systematically mapped the geochemistry of agricultural land in 33 European countries. Project participants analysed several thousands of samples of farmland soil and grazing land soil for more than 50 elements.

The aim of the project was to create a "soil sample archive" for Europe, to identify potential toxins and deficiencies in agricultural soils that can affect human health. In recent years, the results of the work have also taken a completely different direction; towards criminal investigations, or "forensic geology." The main clue is the element strontium. In the human body, strontium accumulates over time in the teeth and bones via the food we eat. The enamel of the teeth acts as a time capsule and built ups nutrients as the body grows and develops. At the same time, soils have their own fingerprints, where the strontium isotopes vary from place to place. In other words, by comparing the relationship between the strontium isotopes in the dental enamel with the relationship between strontium isotopes in the samples of agricultural soils, we may find out where a person lived while their teeth were developing.

Norway's Kripos, British Scotland Yard, as well as the Australian and Canadian police have shown interest in the GEMAS data sets. The police have also analysed oxygen isotopes in the same way to determine possible drinking water sources.

In addition to identifying the Isdal woman, the same technique has been used in connection to the Oslo Plaza murder. The Plaza woman was found dead in room 2805 on the evening of Saturday June 3rd, 1995. The 21-year-old woman had checked-in as Jennifer Fergate, a Belgian citizen. However, all the information she provided was false. The woman was probably German.

In 2017, NRK made a documentary series comprised of ten short episodes entitled "The Mystery in Isdalen." In this series the producers presented the strontium analysis of the German-born woman's teeth. Later in the fall, VG news reported that the same technique was used to find out more about the Plaza woman.



A whiff of fish

Numerous fishing companies, equipped with trawling rigs, others with long lines, are participating in a test project to actively use new data on seabed types. A few coastal fishermen are also participating. The goal is to achieve more efficient and environmentally-friendly fishing methods. The new data on sea depth and seabed types are now accessible on a total of 13 fishing vessels. The fishing vessels are used in the Barents Sea, South Troms and Søre Sunnmøre.

Having digital data about the seafloor onboard vessels has proven to be very successful in Canada. Fishermen report that they save fuel and lose less equipment.

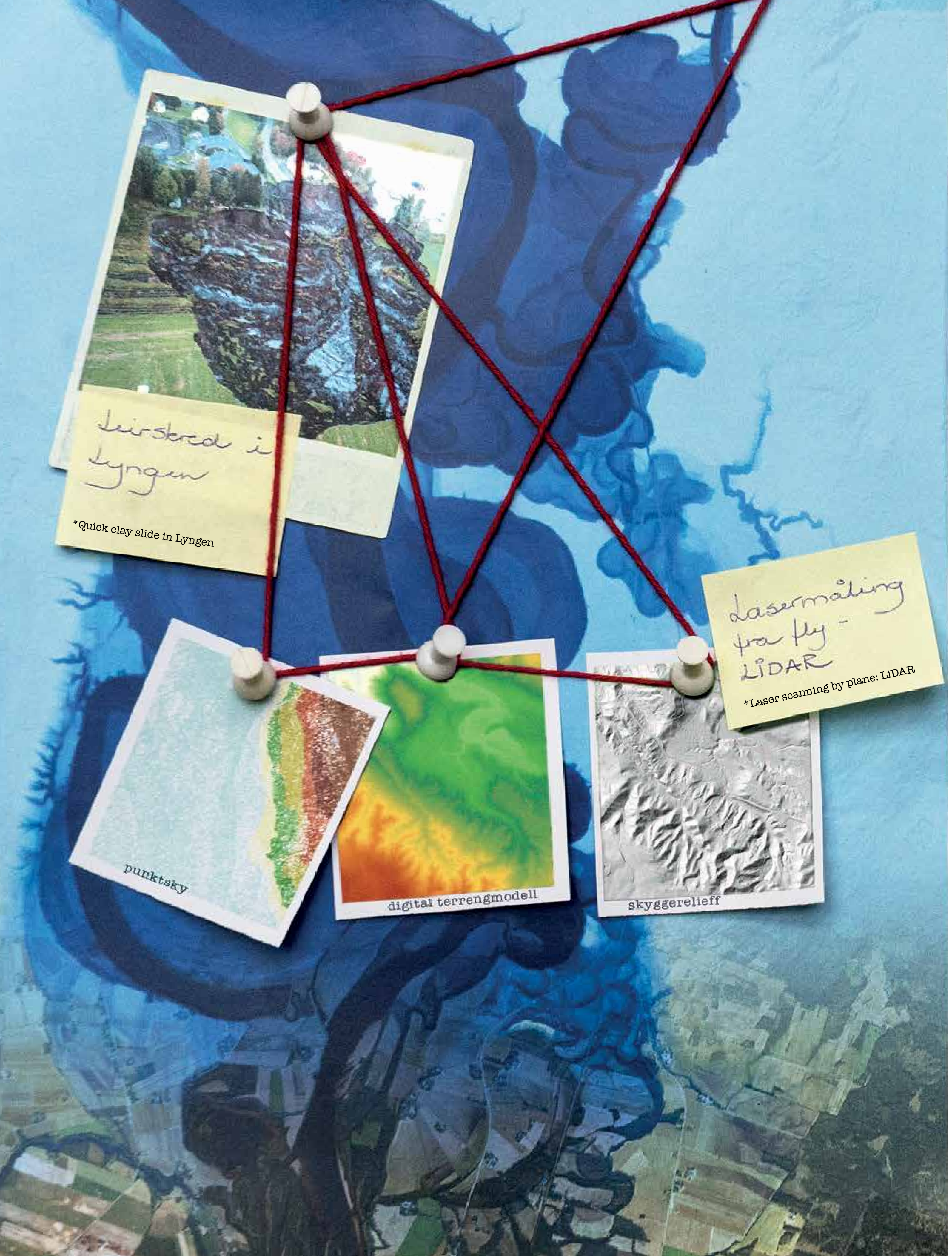
NGU's costal marine geologic projects and the Norwegian mapping program MAREANO are now shedding more light on an increasingly larger area of coastline and open sea. MAREANO maps depth, seabed conditions, biodiversity, nature types, and pollution in the sediments in Norwegian waters. Through this program and the near shore projects, researchers have extensively mapped large and vital fishing areas for depth conditions and seabed sediments. Large sections of NGU's seabed type maps have been adapted to the digital maritime systems used on the bridge.

Tracking data from the Norwegian Fishing Directorate has been plotted against MAREANO maps. This and the Canadian experience both demonstrate a clear relationship between the seabed type and productive fishing sites. More active use of the seabed information from MAREANO can make fishing more efficient, and more environmentally friendly. At the start of 2017, offshore experimental fishing involved using a bottom trawl and line. Inshore, like in Sør-Troms and Søre Sunnmøre, fishing vessels use nets, danish seines, purse seines, shrimp trawls, and long lines.

A new publication based on analyses of video footage from the activities in the MAREANO program shows that there are more than 100 million "trash particles," both small and large, at the bottom of the Barents Sea. Fishing nets and gear account for most of this trash.

In addition, disturbing amounts of tiny particles of plastic waste, micro-plastic, have been found during MAREANO research cruises. Microplastics are used in cosmetics and toothpaste to provide a smoothing or scrubbing effect. Microplastics may also be produced from the degrading and wearing down of large plastic items, such as car tires, ground car tires used in artificial turf, plastic bags, shoe soles and fleece clothing. Ten areas that were sampled show that plastic has spread into large open sea areas. From there, microplastic finds its way to the dinner table. The best way to protect oceans from plastic is good waste management and reduced plastic consumption.

Pictures on the left:
*Saves fuel; reduces the equipment loss
*Mareano: depth, seabed conditions, biology, Nature types, pollution



Stripping away the landscape

Norway's landslide history must be revised. Modern laser technology is helping geologists discover more landslide scars in towns and rural areas. In 2017, researchers discovered that many more landslides have occured in Trondheim than previously thought.

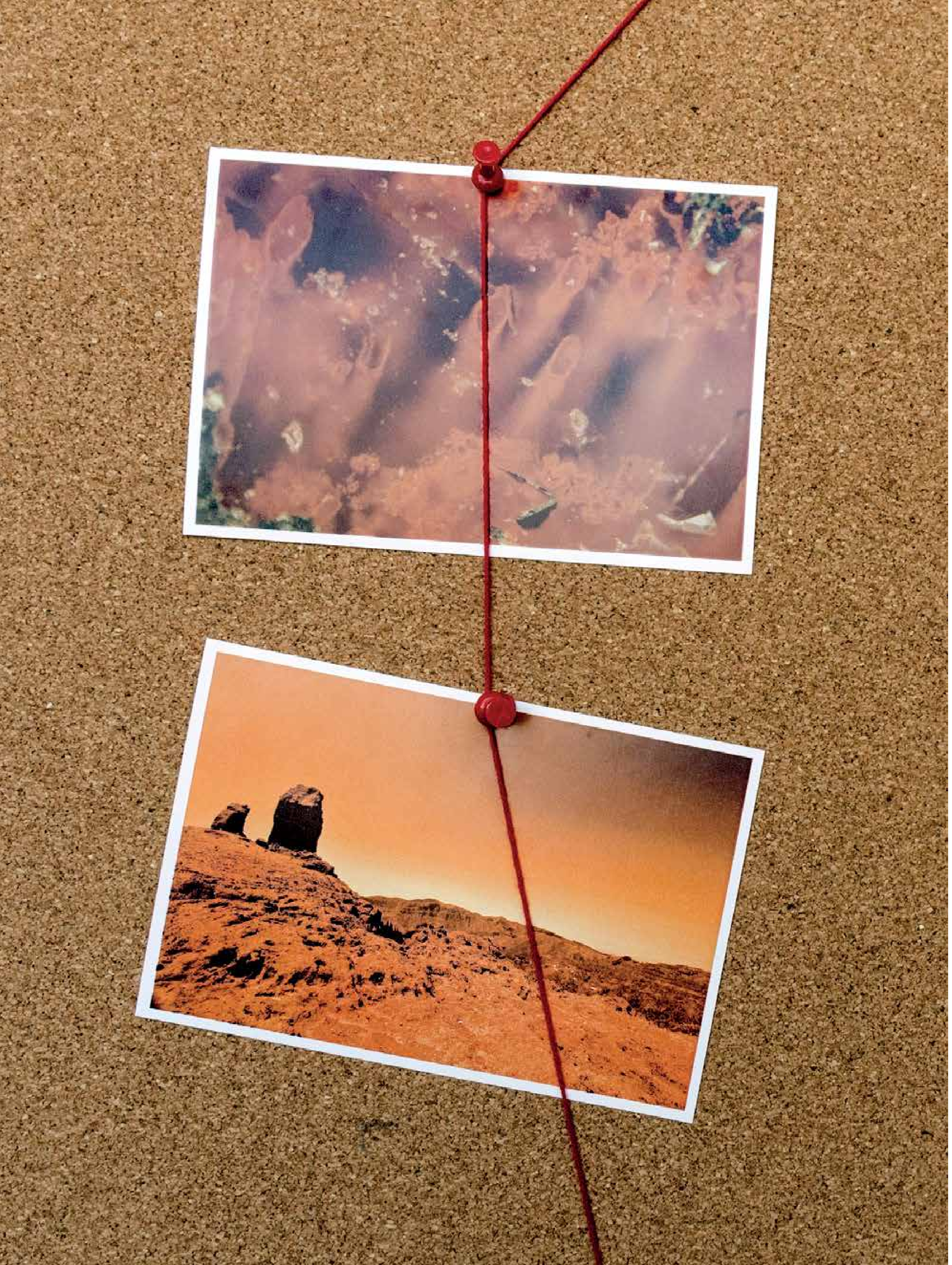
As new areas are mapped, data are entered into NGU's digital mapping services as line symbols, including all the ravines. Most of the landslides scientists find have been naturally triggered over the course of thousands of years. The updated and more detailed data will be relevant for those who create landslide hazard and susceptibily maps, as well as municipal and regional planners.

Aerial laser scanning, known as LiDAR scanning, allows the researcher to "see" detailed topography under shrubs and trees. By digitally stripping the landscape of vegetation, researchers have a better view of the area than when they use standard aerial images and map by foot.

The word "LiDAR" is an acronym for "light detection and ranging". LiDAR transmits optical laser light in pulses, light that cannot be seen by the naked eye. Lidar equipment measures the time it takes for the light to return to the scanner. A narrow laser beam moving rapidly across the landscape can map topography with very high resolution. LiDAR data can be collected from airborne or land-based vehicles, from fixed instruments on a tripod, or from offshore installations. Airborne LiDAR scanning is often used to create high-resolution maps, while the ground-based scanning provides detailed three-dimensional models in steep slopes for areas too difficult to view from a plane or helicopter.

Laser scanners using LiDAR technology can in principle be used to identify all types of objects in three dimensions, depending on the distance between the artificial light source and the surface mapped, ranging from small objects to large landscape areas. Laser scanning is an example of how new technology combined with good digital tools can serve to streamline mapping and improve the quality of geological maps. LiDAR is just one example of a broad range of methods that have revolutionised geology in the last decades. A closely related example is Airborne Geophysical Surveying (aircraft and helicopters), which can measure the magnetic properties, radioactivity and electrical conductivity of the Earth's surface.

Today, rugged PCs and tablets give Norwegian geologists direct access to their digital data in the field, with high-resolution data from GPS, laser, radar and satellite measurements.



From Meldal to Mars

Has life ever existed on Mars? Now rock samples from Meldal, Norway might help answer the question.

An international team, including NGU researcher Tor Grenne, recently identified the world's oldest known life forms. They found traces of microscopic organisms that lived in the hydrothermal vents on the ocean floor more than 3770 million years ago. This is old, considering that the age of the Earth is around 4600 million years and that the oldest traces of life on land about 460 million years.

The primitive organisms themselves are not preserved, but they can be identified by the thin threads and tube-like structures left in fine-grained iron minerals. The tiny structures have characteristic shapes and branches, like the bacteria found today living in the metal-rich hydrothermal vents on spreading centres on the ocean floor. In the hot water, very special bacteria live by oxidizing iron and turning it into rust, a kind of iron oxide that eventually transforms into the mineral hematite.

Researchers conclude that the structures in the rock were left by micro-organisms. Along with the unique structures, they found graphite, apatite and carbonate, which are typical of transformed biological material. In addition, there are small round structures, so-called rosettes and granules, which are formed during the decomposition of bacterial residues on the seabed.

At Løkken in Meldal there are very well-preserved microscopic, thread-shaped traces of bacteria that lived on the ocean floor on 480 million years, also by hotsprings. These organisms look like those found in the ca. 3770 million years old rocks in Canada and are important for interpreting the more altered structures in the Earth's oldest sedimentary rocks.

These findings about Earth's earliest known life forms are very important for understanding the history of our planet and how life has evolved. The results support past speculations that early micro-organisms originated near heat sources associated with submarine volcanism.

The new discoveries can also help identify life on other planets and solar systems. The first forms of life arose surprisingly soon after the surface became cool enough for water vapor to condense and form the first seas, a few hundred million years after formation of the solar system. At that point, there may have aslo been simple life forms on Mars, before it cooled, lost its atmosphere, and its surface water turned to ice. Liquid water is considered a basic prerequisite for all life.

The US space agency NASA has received rock samples from Meldal. The samples will be used to test the instruments SHERLOC and PIXL, which will travel to Mars in 2020. The instruments can detect carbonate, hematite, quartz and apatite like that found in the rock jasper at Løkken. Thus, rock samples from Meldal can also contribute in the search for traces of past life on Mars.

Traveling from the center of the Earth

Under the Earth's crust, the rock flows around a few centimeters each year. analyses. When the glowing mass - or magma - rises upwards and approaches the surface, it can form a magma chamber. When the pressure in the chamber becomes too high, the magma breaks through to the surface.

An eruption of a submarine volcano may go undetected, but an eruption on land may send magma down the flanks of the volcano as lava, ash or mud, or into the air as ash and rock fragments.

An example of this is the 1815 eruption of Mount Tambora in Indonesia. Two years after the volcanic eruption, the bicycle was first used as a means of transport. Hence, NGU has reported that this volcano indirectly resulted in the global use of bicycles and that on the 200th anniversary of June 12, 2017, we encouraged staff and the public to turn up to work on their bicycles.

The April 1815 eruption was the most powerful volcanic eruption in modern times and stemmed from a stratovolcano on the island of Sumbawa in today's Indonesia. The volcano, which today has a diameter of 6 kilometers, dischanged a powerful column of flames and and violent lava flows.

The eruption led to death and destruction on the island of Sumbawa, and to extreme changes in weather conditions around the globe. The crops failed in the Northern Hemisphere and the following year - 1816 - became known as the year without summer.

In Europe, the volcanic winter followed several years of bad crops. As a result, livestock was slaughtered to prevent famine and death. Horses, which were necessary for transport, had to pay with their lives. At this time, German inventor Karl von Drais took to task finding a new means of transport that could replace the horse. He presented "Die Laufmaschine" (running machine), which is the predecessor of the Velocipede. On 12 June, 1817, he undertook a several kilometer bike ride from Mannheim to Schwetzinger Relaishaus.

Thus, an isolated volcanic eruption led to a global impact on the climate. In the same way, local reductions in greenhouse gases can also had a global effect. That's why NGU urged as many people as possible to ride a bike instead of driving a car on the birthday of the bicycle.

NGU received several media reports on this mysterious story - and many followed our encouragement to cycle, including geologists in Ireland and Germany. During this period, two of our own researchers were conducting field work on the island with the world's northernmost active volcano: Beerenberg. On the Jan Mayen in the Atlantic Ocean, it was not about volcanic eruptions, but about gaining new knowledge of past climate change. This vulnerable Norwegian island is the only land area on the northern hemisphere where warm and cold ocean currents meet each other.

If we understand what has happened, it is also easier to foresee what can happen. The volcanic eruption in 1815 taught us this: there is only one Earth.

Cash accounts: Income and expenditures 2016-2017 (mill. kr)

Income	**2016**	**2017**
Annual Grant	176,8	169,1
Income from allocations and transfers	27,1	28,5
Sales and rental income	46,9	49,0
Total Income	250,8	246,7

Expenses	**2016**	**2017**
Salaries and related costs	162,7	152,7
Depreciation	9,3	9,2
Other expenses	79,3	84,8
Total Income	251,3	246,7
Total result	-0,5	0

Overall production of reports, publications, presentations and maps for NGU 2012-2017

Type	2012	2013	2014	2015	**2016**	**2017**
NGU reports	80	47	49	66	63	37
Articles in scientific journals and books	173	137	159	142	165	127
Articles in other publications	37	23	21	28	29	47
Presentations and lectures	447	440	417	382	424	383
Forskning.no	15	21	13	14	12	12
Bedrock and Quaternary maps	14	15	10	24	11	7

NGU Employee statistics

	2012	2013	2014	2015	**2016**	**2017**
Total staff	211	219	225	227	202	203
With MSc Degree	143	153	160	163	148	148
With PhD Degree	72	77	82	80	74	70

What the numbers tell us

In 2017, NGU continued to work in accordance to the guidelines embodied its Strategic Plan 2017-2020, as well as the major targets and tasks provided in Prop. 1 S (2016-2017) and the 2017 allocation letter from the Ministry of Industry and Fisheries (NFD). NGU has in principle reached its targets and 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 68% of NGU's financing is direct government grants. As of January 1, 2016, began NGU operating under the accrual basis of accounting. The overview displays accounting figures for 2016 and 2017 after accruel methods.

In 2016, NGU received a total allocation of 169,1 million towards expenditures. This includes the grant from NFD and smaller grants for other public agencies. Included in the NFD funds, are earmarked grant of approximately 28.5 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 reported in reports, scientific journals and lectures for different audiences. The scientific production of articles at NGU is extremely high compared with similar institutions at home and abroad. NGU has a low sickness absence rate. In 2017, the absence rate was 5.4%.

For more details, please refer to the NGU's annual report to the Ministry of Trade, Industry and Fisheries (NFD), available through NFD website and ngu.no.

NGU's main goals:

- Increase mapping geological resources
- Increase the availability of geosciences knowledge that can be use land-use planning and construction activities
- Increase knowledge of geological processes and how Norway was formed
- Ensure good management and tailoring of geoscientific knowledge
- Strengthen communication and dissemination of geosciences knowledge

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