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Geology for Tomorrow's Society: Some Nordic Perspectives

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1. Introduction

To develop and sustain our societies, we need reliable access to minerals and raw materials, energy and water. With an increasing World population and emerging economies in underdeveloped parts of the World, the pressure for more natural resources will continue to rise. A good knowledge of geological resources is therefore essential for our future development. With increased urbanization and future global climatic changes, we need to better understand the human impacts on the environment, both on global and local scales. On long term the availability of geological resources and living space to house our populations are limited. Therefore, building the societies for Homo sapiens futurensis challenges us to have a holistic and international perspective of the natural resources and the environment. The present paper gives examples of how some of the key questions and challenges are addressed by the Nordic geological surveys.

2. Homo sapiens futurensis – An urban species

Over the twentieth century there has been a rapid urbanization of the world's population. In 1900 around 13% of the global population lived in urban areas, in 1950 the proportion was 49%, while today the majority (>50%) of people worldwide live in towns or cities. This number is expected to further increase to between 60-65% in the next 30-40 years. Urbanization rates vary between countries. It is estimated that more than 90% of the urban growth will occur in developing nations, and 80% will take place in Asia and Africa (UNFPA 2007, http://web.unfpa.org).
The urbanization of the World is often referred to as the "Urban Millennium" or the "tipping point". Along with this development we are also facing a global tipping point in the world's economic order. According to PricewaterhouseCoopers EU stood for 25% of the global value creation in year 2000, followed by the USA with 23%, while China was left far behind with 7%. This will change dramatically. Towards 2030 China will stand for 19% of global value-creation, USA 16% and EU 15%. India will reach a remarkably 9%. Hundreds of millions of people will be lifted from poor living conditions up to standards which we in the west take for granted. This new economic development will demand an increased global consume of natural resources.
If we also add the given the prognoses that the world population will increase from 6,9 billion today, and to 9 billion in 2050, the picture is pretty clear. There will be an enormous

demand and battle for natural resources; food, water, energy and minerals. This situation will demand us to find new innovative solutions for resources management and use of materials. While we today dispose of our electronic and other modern consumables when they become tired, either for an upgrade or because it is cheaper to replace them than it is to repair them, Homo sapiens futurensis will have a different approach. In the years in front of us, the concept of urban mining will be established as a standard in the New World. Recycling of metal-containing consumables like cell-phones will not only be profitable, but most likely also be required as we only have finite resources with which to build them. According to some estimates (http://urbanmining.org) up to 30 times as much gold can be found in cell phone circuitry as can be found in the gold ore processed in gold mines (some 150 grams, or 5.3 ounces, per ton, compared to a measly 5 grams, or 0.18 ounces per ton). To add to that, the same quantity of cell phones also contains 100 kg of copper and 3 kg of silver, as well as numerous other materials. After the devices are processed and the materials separated, these valuable metals can be sold on as high quality raw materials to build new products, which in turn also can recycled.

Fig. 1. The city of Trondheim (area: 342 km^2), with a present population of 175 000 citizens. In 2050 the number of citizens is expected to be 220 000. Presently, 80% of the Norwegian population lives in urban areas (Photo: Edelpix).

As the populations are crowding up in urban areas, there will also be a shortage of space available for the physical growth. In many urban areas the only solution is to go underground. The challenge is to provide city planners, development engineers, decision makers, and the public with the geo-science information required for sound planning. This requires knowledge and competence in engineering geology, hydrology, geochemistry, as well as basic geomorphology and stratigraphy in order to build a three-dimensional model of the underground that will be taken into use. The information derived from various sources such as topographic and hydrological data, geological maps and borehole logs, have to be compiled in a digital format and stored in geo-referenced databases in the form of point, linear, and polygonal data. The data is then processed by Geographic Information Systems (GIS) to integrate the various sources of information and produce graphic 3D-models and maps describing the geological infrastructure beneath the city surface.

3. Fennoscandian mineral supplies

Today we see an increased interest in exploration and investments in mineral production all over the world. The main drivers of new investment are the high prices of raw materials, which are making new mines – and the reopening of older ones – more profitable. The use of most metals versus GDP per capita, grows almost logarithmically before it flattens at the levels of industrial countries. In simple terms; while the current per capita use of copper in China is around 2,5 kg, the similar figures in Japan and Germany are around 4-5 times as high. Consequently, the significant growth in China's economy and strong demand for minerals has lifted price of copper with more than 300% the past 10 years. Comparable situations also exist for most other metals, not to mention rare-earth-elements (REE), which are critical elements in the evolving green technology.

Since significant amounts of unexploited mineral resources are located in Nordic areas, the global urbanization and hunt for new mineral resources will be one the major driving forces leading the future development in the Nordic countries. The Fennoscandian Shield comprises a diversity of geological settings containing large resources of mineral deposits (Eilu, 2010). The resources include industry mineral for a number of applications and uses, energy minerals and not at least important metals. One could specially mention the Norrbotten and Västerbotten counties in Sweden, which are well established key mineral deposits provinces. Today, Kiruna-Malmberget is the worlds largest mining operation north of the Arctic Circle. Several new deposits are in the beeing developed, and there are planned investments for more than 30 bill. SEK in the mining sector.

Exploration and exploitation of mineral resources has for long been a priority area in Finland. As an example four gold mines have been opened in Finland since 1980. The most recent mine, Kittilä, opened in 2008. It is the largest gold deposits in western Europe with a resource of 5,7 Moz. Ore output from mines in Finland since 1950 is now at a peak, and is expected to further increase in the nearest years. Recently, Finland has launched a new national mineral strategy with the following vision towards 2050: "Finland is a global leader in the sustainable utilization of mineral resources and the minerals sector is one of the key foundations of the Finnish national economy". Sweden and Norway are now following Finland, and have started to develop their own strategies for the mineral sectors. In Norway, steps are taken to increase the coverage of relevant geological and geophysical information of the northern counties Finnmark, Troms and Nordland, where a four-year program with a total budget of 100 million NKr now is started within the frame of the government's Northern territories strategy (i.e, the MINN Program 2011-2014).

One of the primary goals for the Nordic geological surveys is to develop national and cross-border maps and databases of the bedrock geology and the mineral resources. The collective mission is to make this information and data easily accessible to all possible end users in industry, governmental agencies, public administrations and technical offices. The Fennoscandian Ore Deposit Database (FODD; http://en.gtk.fi/ExplorationFinland/fodd) is a comprehensive numeric database on metallic mines, deposits and significant occurrences in Fennoscandia. The maps and the database have been compiled in a joint project between the geological surveys of Finland, Norway, Russia and Sweden. The database contains information on 1300 mines, deposits and significant occurrences across the region. Of all deposits listed in the database, 56% have not been exploited at all. However, a number of these might well be economic in the future with additional reserves based on further exploration. FODD contains information on location, mining history, tonnages and commodity grades with a comment on data quality, geological setting, age, ore mineralogy and mineralization styles, genetic models, and the primary sources of data.

Fig. 2. Copper deposits at Repparfjord in Finmark. The Fennocandian Ore Deposit Database (FODD) contains information on 1300 mines, deposits and significant occurrences across Norway, Sweden, Finland and NW Russia (Photo: Jan Sverre Sandstad, NGU).

4. Access to clean water

Clean water is essential for any society. However, over larger parts of the globe clean water is in short supply. Many water reserves are over-exploited and polluted. Human health is endangered by the use of water which, either for natural reasons or because of pollution, contains harmful constituents. Groundwater for water supply purposes is often better and cheaper than surface water and is the most important drinking water source in many densely populated areas of the world. Groundwater reserves are renewable to the extent that the reservoirs are replenished, either directly or indirectly, by rainfall. However, groundwater is an invisible resource, which requires relatively large investments for mapping and monitoring, so the centralized management of knowledge and data concerning groundwater is of considerable economic value for society.

In Norway, NGU is responsible for mapping and monitoring of groundwater resources, and managing the national groundwater database. An important task is to develop fundamental data for groundwater management in accordance with the EU's Water Directive and associated subsidiary directives. According to the regulations, water resources shall be characterized and monitored to ensure that they have a good ecological status. In collaboration with the Norwegian Water Resources and Energy Directorate, NGU has been operating a nationwide monitoring network for untouched groundwater resources since 1977, covering groundwater levels, temperatures and water quality (Frengstad & Dagestad, 2008).

The conditions in Norway, Sweden and Finland differ considerably from most other countries within the EU as regards groundwater deposits, population density and pollution load. In general, Nordic groundwater sources provide good qualities of drinking water. Bottled mineral water is already being exported from Norway and profitable export of freshwater in bulk is in the pipeline. Europe consumes increasing amounts of bottled mineral water, and bottled water, usually derived from groundwater, is rapidly becoming the main drinking water supply.

Fig. 3. Groundwater is the largest and most reliable of all freshwater resources. In many areas most drinking water is groundwater; up to 80 % in many European countris and Russia, and even more in North Africa and the Middle East (Photo: Edelpix).

In 2010 more than 1900 "mineral water" brands were officially registered in Europe. In a recent, innovative, study conducted by EuroGeoSurveys, analysis of bottled water was used to provide indicators of the groundwater chemistry at the European scale (Reimann & Birke, 2010). The study included 1785 bottled water samples, representing 1247 locations all over Europe. The water was analyzed for more than 70 parameters (geochemical elements). The influence of geology in determining element concentrations in bottled water can be recognized for a significant number of elements. One example is the high values of chromium related to the occurrence of ophiolites, another is the high values of arsenic, fluorine, potassium, rubidium and silicon in bottled water coming from sources related to volcanic rocks. However, the natural variations are very large, usually an order of magnitude of three or four, and for some elements up to seven (Reimann & Birke, 2010). The study documented that very few analyzed samples (less than 1%) showed values exceeding maximum admission concentrations for mineral-water, as defined by the European Commission (Reimann & Birke, 2010).

The quality and hydro-chemical fingerprints of the groundwater is controlled by many factors, including rainfall chemistry, climate, vegetation and soil zone processes, the interactions between the minerals in underground and the water, groundwater residence time and mineralogy of the aquifer (Reimann & Birke, 2010). The EU Water Directive further provides scope for its practical implementation to be adapted to the natural condition in each country (Frengstad & Dagestad, 2008). Watercourses, groundwater and coastal water must be viewed in context, and the people who live upstream should resolve any problems in collaboration with those who live downstream regardless of administrative or national boundaries. Given the potential changes in watershed and the flow-regimes in our waterways due to forthcoming climatic change, access to water might be a major source to severe conflicts in the year ahead of us. Meeting these challenges, the Water Directive gives us a golden opportunity to make a common European effort to secure water resources for the future, and to provide stable and sustainable conditions for both the environment and future human generations.

5. Green energy beneath our feet

The greater use of more environmentally friendly energy is a national goal for many countries. In Norway, government has stated that it will "continue the effort to adapt national energy production and energy use, which will also have benefits in terms of climate policy, through the follow-up of the goal to introduce new environmentally friendly energy production and savings". The increased use of ground source heat—energy stored in bedrock, groundwater or sediments—will be an important contributor.

The thermal state in the shallow crust (i.e. less than 1000 m depth) is sensitive to surface effects, such as geological conditions (radiogenic heat production, terrestrial heat flow, thermal conductivity), terrain effects such as topography and slope orientation, climatic conditions (mean annual surface temperature) and human activity (land-use such as urbanization and farming).

A number of quantitative models from geothermal low activity, Nordic areas, show that at shallow depths down to a few hundred meters, mean annual surface temperature is the main factor controlling subsurface temperature (Slagstad et al., 2008). Geological variation in the underground such as heat flow, heat production and thermal conductivity first become significant at depths around 1000 m and deeper. Since ground-source heat for household heating is commonly extracted from shallow boreholes between 100 and 200 m depths, the effects of variation in heat-flow and heat-production has no impacts on the amount of heat that is extractable from the ground. This means that the key factors controlling the effect and economy of installations for extracting geothermal energy at shallow depths, are mainly linked to the overburden (cover deposits) and the hydro-geological activity in the underground (Slagstad et al., 2008). Obtaining such information is thus needed to obtain the maximum geothermal outcome from the underground.

The potential of shallow geothermal energy can be further increased by using a underground storage system. Geothermal energy, solar energy and waste-heat from large buildings and plants can be stored in the underground by a Underground Thermal Energy Storage (UTES) system, as the ground has proved to be an ideal medium for storing heat (and cold) in large quantities and over several seasons of years (Midttømme et al., 2008). In the Nordic countries UTES systems are mostly used in combination with Ground-Source Heat Pumps (GSHP). Today, more than 15 000 GSHP systems exist in Norway, extracting about 1,5 TWh heat from the underground. Two of the largest closed-loop GSHP systems in Europe, using boreholes as ground heat exchangers, are located in Norway (Akershus University Hospital and Oslo Gardermoen International Airport) (Midttømme at al., 2008).

In many countries, we are now approaching breakthroughs in utilizing geothermal sources as important energy suppliers. In addition to using the energy from the shallow-ground, many countries have areas with high thermal gradients in the underground. On average the temperature of the Earth increases with about 30°C/km (Lund et al., 2008). However, many places have significant higher gradients, for example where we have anomalous heating of rocks by decay of radioactive elements, where we have intrusions of magma from depths, or where there are have very thin crust associated with volcanic activity. One profound example is Iceland, with its sub-aerial exposures of the Mid-Atlantic Ridge, manifested by active rift zones extending from northeast to southwest on the island. The active volcanism produces a high heat flow to the surface, caused by magmas emplaced in the upper crust. This heat is extracted from both “high temperature fields” within the active volcanic zones and “low temperature fields” outside these zones. The heat is extracted as hot water and steam and is used for district heating, industrial purposes and power generation, offering a cheap and environmentally benign source of energy for the Icelandic society (Smelror et al., 2008).

Fig. 4. The Blue Lagoon on Iceland, where people can enjoy the hot water generated from the geothermal powerplant seen in the background. (Photo: Halfdan Carstens).

6. Living on polluted ground

The rapidly growing use of materials leaves larger and larger amounts of waste which have to be taken care of. Waste management and recycling is becoming increasingly important. For many years, NGU has been mapping pollution in densely populated areas. In towns and cities, there are areas where the ground is extensively polluted as a result of previous industrial discharges, fires in urban areas, road traffic and the combustion of coal and waste. The problems are linked in the first instance to heavy metals, arsenic, PAH and PCB.

Studies on the links between polluted ground and health have shown that it is not necessarily on industrial sites we have the most significant pollution problems. People come in contact with the soil pollution in the city center areas more frequent than they do with contamination from the most polluted industrial sites. Examples from the Nordic cities Oslo, Bergen, Trondheim, Tromsø and Copenhagen, as well from New Orleans have shown that it is moderately polluted urban soil in children’s play areas that represents the greatest health hazard (Ottesen & Langedal, 2008; Ottesen et al., 2011). Children can come into contact with polluted ground through skin contact, by breathing in air-borne dust or gases, or by eating soil and licking their fingers. Studies have shown that around 10% of all children eat approximately 200 milligrams of soil per day, some even more (Ottesen & Langedal, 2008).

Fig. 5. Children eat soil, and in many cities moderately polluted urban soil in children's play areas represents the greatest health hazard (Photo: NGU).

The results from the studies of soil pollution at nurseries in the Norwegian cities led the Parliament in 2007 to approve a plan to map the soil pollution and to carry out clean-up operations at nurseries and school playground all over the country (Ottesen et al., 2011). Here it must be mentioned that the results of pollution-mapping in Oslo showed the greatest pollution to be in the oldest districts. All together, action was necessary at 38% of the city's 722 nurseries (Ottesen & Langedal, 2008).

The example above is just one showing the need for careful investigations of the ground of our urban areas. Another central theme is the spreading of environmental toxins from the land to the sea, where buildings in towns and cities act as an active pollution source for metals and PCB. The geological surveys and the national environmental agencies should continue to ensure that pivotal environmental problems are placed on the agenda and that the necessary measures are implemented. One such measure will be to prepare and implement the use of hazard maps for soil pollution in all the major city municipalities. In this respect, the recent EuroGeoSuveys project on mapping of the chemical environment of several major urban areas in Europe represents a major contribution (Johnson et al., 2011).

7. Facing geohazards

Human activity affects and transforms the environment around us. The land we build and live on is not always stable. The risk of natural disasters such as earthquakes, rock-falls, landslides, avalanches, floods and tsunamis must be assessed in relation to existing and planned settlements and infrastructure. One important task at the geological surveys is to evaluate and map areas with potential rock-fall and landslide hazards (Bargel et al., 2008). In Norway, this work has been intensified the recent years, and in order to assist the municipal authorities in obtaining a better overview of rock-fall and landslide processes and risk, a national landslide database (www.skrednett.no), presenting awareness- and risk-maps, has been developed.

Landslides, rock-falls and avalanches are important geological processes in the Nordic landscape. Slow displacements through time may cause instabilities and bedrock failures. If large rock-falls and landslides run into narrow fjords or alpine lakes they may trigger tsunamis, damaging near-shore settlements and infrastructure (Harbitz et al., 2006). The three natural disasters causing the largest number of deaths in Norway in the 20th century involved large rock-slides in a narrow lake in Loen (1905 and 1936) and in Tafjord (1934) (Nadim et al., 2008). Currently, several unstable mountain-sides in western and northern Norway are being monitored to follow movements. A center for monitoring the unstable mountain-side at Åkneset in Storfjorden, and other areas in the Møre-Romsdalen District, is established at Stranda (www.aknes.no). Here is also a early-warning system, which will alarm the around 3000 inhabitants in the small communities along the fjord, and the up to 30 000 tourists visiting the World Heritage Site in Geiranger per day in the summer months, when the risk of a major rock-fall and following tsunamis has reached a given threshold, and an evacuation should take place.

Fig. 6. Prekestolen at Lysefjorden, SW Norway. Rock-falls and landslides that will run into narrow fjords and create tsunamis which will damage near-shore settlements and infrastructure, represent potential large geohazards in Norway (Photo: Edelpix).

Fine-grained marine sediments cover large lowland areas of middle and eastern Norway, and large areas in southwestern and middle Sweden and Finland. Dilution of salt by groundwater flow leads to the formation of quick clay. Such processes may lead to highly unstable conditions, and fatal quick-clay slides can occur. Glacial tills on steep mountain slopes may collapse during periods of intense precipitation, and trigger debris flows. With changing climatic conditions and more extreme rainfalls in some exposed regions, the frequency of such natural hazards is expected to increase in the years to come. An important task for the geological surveys has been to produce maps showing which areas are subjected to potential quick-clay slides. Such awareness- and risk-maps have become an important tool for areal planners working on local and regional scales.

Recent incidences in Norway have demonstrated the risk for slides along the fjord-shores. Urban development and building of new infrastructure along the waterfronts creates risk for triggering slides in unstable areas. One example is the Kattmarka quick clay slide, which took place on 13 March 2009 close to the city of Namsos. The slide involved between 300 000 and 500 000 m^3 clayey soils and destroyed several homes, fortunately without serious injuries to persons. The slide was triggered by blasting taking place in connection with ongoing construction for widening the local road.

Another example is in the harbour of the Trondheim City, where a road construction triggered a sub-marine slide in 1990. In the bay of Trondheim landslides are recurrent phenomena, and recent and ongoing development of the area, including land reclamation and extension of harbor facilities, have increased concerns about the stability of the shoreline slopes (L'Heureux et al., 2010a). A recent study by L'Heureux et al. (2010b), using detailed morphological analysis of slide scars combined with limit equilibrium back-analyses, suggests that the presence of softer and more sensitive laminated clay-rich beds within the Trondheim harbour delta-deposits facilitates translational, slope failure, by acting as slip planes. Additional pre-conditioning factors promoting instability include the loading of the weaker clay-rich beds through delta progradation, and local over-steepening and artesian groundwater pressure at different underground levels. For the recent landslides in the Trondheim harbor, anthropogenic factors like embankment fillings and vibrations from construction works are considered the most likely triggering mechanisms (L'Heureux et al., 2010b). The results illustrate the importance of detailed morphological analyses, combined with a geological model including the physical/geotechnical characteristics of sediments on land and in the fjord, in order to perform a proper assessment of the shoreline slope stability.

Identification and monitoring of ground deformation can be accomplished using a number of surveying techniques. Since the early 1990's satellite-based radar interferometry has been used to identify large ground movements due to earthquakes and volcanic activity. Data stacking methods that take advantage of a growing archive of radar images, as well as increasing computing power, have led to a large increase in the precision of the technique. Both linear trends and seasonal fluctuations can be identified using the Permanent Scatterers technique. By using InSAR-technology, it has been possible to measure the degree on vertical subsidence due to compaction of the land-fills placed on the outer delta of Trondheim by an accuracy of mm per year (Dehls, 2004, 2005). By applying such novel techniques, it is possible to monitor small-scale, but critical, movements in the harbour, and other places in Trondheim City.

The cities and urban areas of the Nordic countries are small compared to megacities found in the Worlds more populated areas. But as elsewhere in the World, the major part of the population growth is within the already most populated areas, and an increasing part of the infrastructure is developed underground. The communities that invest in good knowledge-bases of geo-scientific information will have better means to secure optimal planning processes and underground operations. There are number of examples of how lack of basic geological and hydrological knowledge and data has caused serious problems. When building new road- and railway-tunnels near Oslo in Norway, cave-inn and water-leakage have been prominent problems (i.e. the Romeriksporten, Oslofjord, Hanekleiv and Hasle tunnels). The construction of the Romeriksporten tunnel led to drainage of the watercourses in Østmarka, lowering of groundwater levels and subsequent subsidence and damage to buildings (Olesen & Rønning, 2008). The final construction costs increased three-fold relative to the budget.

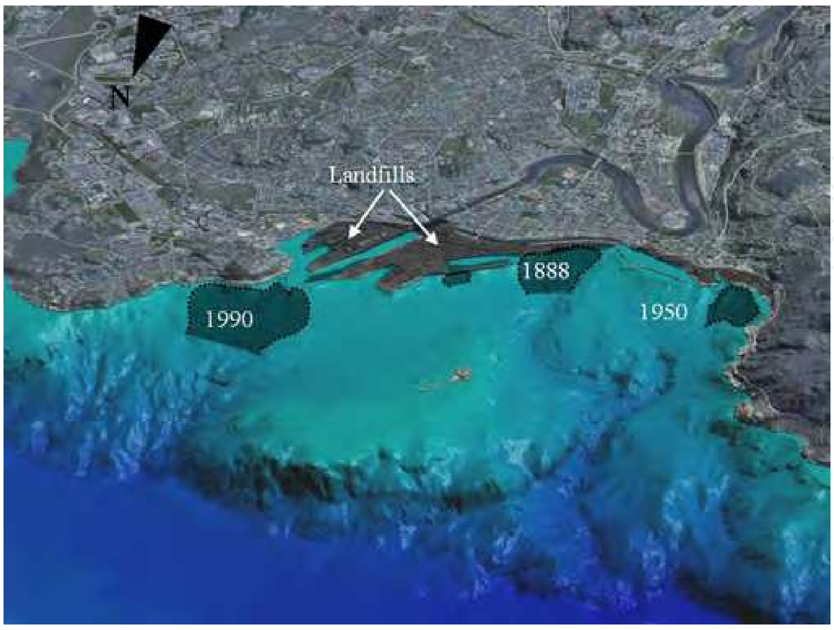

Fig. 7. Topographic/bathymetric view of the city of Trondheim, showing the landfills and the locations of submarine slides occurring in the years 1888, 1950 and 1990. (Illustration: NGU).

When the a central part of the Hanekleiv tunnel on the main road E18 in Vestfold south of Oslo caved-in on the 1st day of Christmas 2006 one of the national newspapers consulted a recent awareness map for tunnel-planning made by the Geological Survey of Norway (NGU) some months before. The map shows the distribution of weakness zones in the bedrock due to deep weathering, and is based on regional geophysical measurements and field observations (Olesen et al., 2007; Olesen & Rønning, 2008). The question was raised (also on the prime-time national TV-news): “Why has this geological information not been taken into account when the tunnel was built?”

Another example of critical use of geological information in an urban area comes from the UNESCO World Heritage Site Bryggen in the city of Bergen, western Norway. Since 2002, an intensive monitoring scheme has shown damaging settling rates caused by deterioration of underlying cultural deposits. Lowering of the ground-water level and increased content of oxygen in the cultural layers has caused damage of the wooden historical buildings (De Beer & Mathiessen, 2008). The monitoring has focused both on chemistry and quantity of groundwater and soil moisture content in the saturated and unsaturated zone, as well as registration of movement rates for buildings and soil surface. The documented preservation conditions within the cultural deposits as well as oxygen and moisture-content fluctuations in the unsaturated zone have a significant correlation with the different groundwater flow dynamics found throughout the site. By understanding the flow regime in the ground beneath the wooden buildings, means can be taken to stop the damaging development. The investigations demonstrated that groundwater and soil-moisture monitoring, combined with 3D transient modeling are potentially effective routines to improve the understanding of preservation conditions in complex archaeological surroundings and, therefore, protection of archaeological deposits in situ.

Fig. 8. The level and quality of groundwater are decisive for preserving valuable archaeological occupation layers in their original position, such as at UNESCO World Heritage Site Bryggen in Bergen, western Norway. “Groundwater data from NGU is helping to save Bryggen in Bergen”, Jørn Holme, Head of the Norwegian Directorate for Cultural Heritage (Photo: Edelpix).

8. Managing knowledge

The Nordic geological surveys are active within almost all fields in which society has a need for geo-scientific knowledge and geological information, of which a few are described above. During the period of their existence, the surveys have generated a substantial amount of information on the Earth’s crust, its natural resources, its processes, and on the geological history of Nordic areas.

The geological surveys are part of the fabric of the societies. At the core of the institution’s tasks are management of knowledge that has been collected over generations and the mediation of this knowledge to the various users in society. Their collective mission is to make this geological information and data easily accessible to end users in industry, government agencies, government institutes, public administrations, technical offices, academia and research institutes, as well as for private individuals (Smelror et al., 2008). The development, operation and maintenance of national databases and maps of geological properties and processes therefore represent key tasks. From these databases, users can extract fundamental data and processed information which will help them to carry out their tasks, regardless of whether they are operating within the mineral industry, the consultancy sector, public administration or research and education.

Traditionally, geological maps and technical reports have been the main products, but today the products provided by the surveys cover a large spectrum of geological, geophysical and environmental databases, maps, models, cores and geological samples, literature and internet-based news- and service-pages. The formats and distribution protocols of geological data products have been jointly developed by the Nordic national communities and the EU (INSPIRE) spatial information community. Through the recent One-Geology project the European geological surveys have demonstrated that they can work and share data according to common standard in an interoperable way to create a common product, like on the dynamic digital (on-line) geological map of Europe (www.onegeology-europe.org).

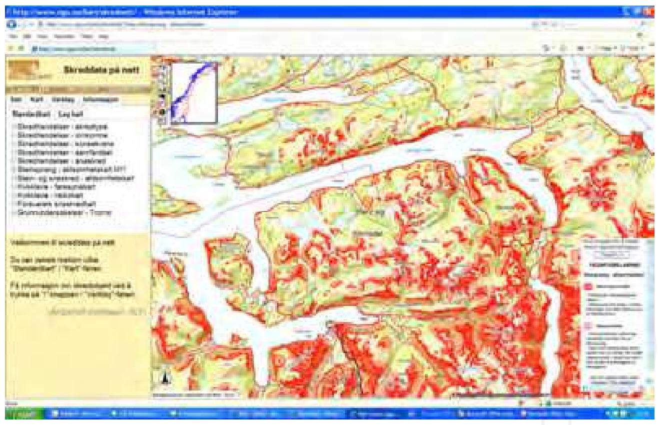

Fig. 9. The Norwegian database and map service of areas potentially at risk for landslides and avalanches provide direct access vital information to areal planners at local and national levels. (Source: www.skrednett.no).

However, in general data distribution policy varies between the countries; consequently, in some of the surveys supply of selected information or materials is chargeable by law. Others, like the Geological Survey of Norway, have made the information available on an open access basis. The internet is currently being developed as the main distribution channel as it gives easy access to key information for all users. The accessible databases are updated continuously. Over the history of the Nordic surveys, and at present, securing the growing volumes of geological and environmental information has consistently proved to be efficient and economically advantageous for society.
According to the Chinese philosopher and reformer Confucius (551 BC - 479 BC), "the essence of knowledge is to have it and to apply it". We believe is essential also to "share it".

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We are increasingly faced with environmental problems and required to make important decisions. In many cases an understanding of one or more geologic processes is essential to finding the appropriate solution. Earth and Environmental Sciences are by their very nature a dynamic field in which new issues continue to arise and old ones often evolve. The principal aim of this book is to present the reader with a broad overview of Earth and Environmental Sciences. Hopefully, this recent research will provide the reader with a useful foundation for discussing and evaluating specific environmental issues, as well as for developing ideas for problem solving. The book has been divided into nine sections; Geology, Geochemistry, Seismology, Hydrology, Hydrogeology, Mineralogy, Soil, Remote Sensing and Environmental Sciences.