Jūras Banys, Algimantas Grigelis, Ginutis Juozapavičius,
Anicetas Štuopis, Ignas Vaičeliūnas, Gediminas Motuza Matuzevičius,
Saulius Gadeikis, Valentinas Baltrūnas, Saulius Gegieckas

THE UNDERGROUND RESOURCES OF LITHUANIA

Anyone who gazes into the depths of the Earth definitely sees not just rock: they behold the memory of life itself. Since times immemorial, the depths of the Earth have been a source of discoveries and progress for the human. Everything that has provided conveniences for our civilization, be it the first stone tools or cutting-edge modern technologies, needs the planet's hidden treasures: metals, oil, gas, minerals, underground water. Without them, there would be no steam engines or electrical grids, cars or airplanes, transistors or microchips, social networks or renewable energy.

Geology is a science that helps us understand the origin, age, structure, surface, and depths of the Earth. Seeking to reveal both the physical structure of the planet and the interaction between the layers of the Earth and evolution of Life, it encompasses the natural sciences and engineering technologies. The lithosphere, hydrosphere, and atmosphere are the material base for the domain of life, while the human-created anthroposphere

The question arises regarding our capacity to wisely use the resources we have inherited from nature and to ensure their availability for future generations. It is encouraging that Lithuania has a wide variety of resources. Guided by the principles of sustainable development, geologists – from explorers of depths to soil scientists – are working consistently to enable our country's growth and simultaneously a delicate equilibrium between its economic needs and the protection of the natural environment.

Our planet – a tiny orb in the boundless universe **–** is unique and irreplaceable, and we must understand, protect, and preserve it.

Lietuvos žemės gelmių turtai (The Underground Resources of Lithuania) is intended for wide readership as well as for public administrators and the local authorities. It answers the question of whether Lithuania has any useful mineral resources. When the idea for such a publication arose at the Lithuanian Academy of Sciences, the executive editor Academician

Algimantas Grigelis swiftly prepared a publishing programme and brought together a powerful team of authors, who are highly qualified specialists in geology and business.

Geologists have a message for Lithuania: Earth is beautiful, rich, and unique. I am very grateful to the contributing authors, editors, publishers, and printers for their dedicated and productive teamwork in preparing this exceptional publication for the benefit of the nation, society, and science.

Geological Structure of Lithuania

Lithuania is the only country in the Baltic region where sedimentary rocks from all twelve geological periods of the Phanerozoic eon, i.e., the period from 541 million years ago to the present, can be found. The geological exploration of the territory, including the shelf of the Baltic Sea, is at a very high level. It is based on deep boring data, detailed stratigraphic classification schemes at the level of paleontological zones, petrographic and geochemical studies of rocks and sediments, and data from deep geophysical measurements and tectonic analysis.

The results of these wide-ranging and multifaceted studies are summarised in the geological map of Northern Europe, Land and Sea, at a scale of 1:4 000 000. The map shows the distribution of all types of rocks on the surface of the Earth before the beginning of the Quaternary period, i.e., 2.59 million years ago (to the present), by their relative age, while the deep tectonic structure is shown in geological profiles. This is a very broad generalisation based on a project carried out by the Norwegian Geological Survey (Fig. 1).

The geological development of the territory of Lithuania, i.e., the distribution of terrestrial and marine conditions, was determined by the formation of large tectonic structures. These include: the Baltic Synclyse, the Masurian-Belarusian Anticline, and the Latvian Saddle – first-order structures belonging to the East European Precambrian Craton.

When combined into a single geological column, it will consist of two structural stages. The lower structural stage comprises crystalline, magmatic, metamorphic, and sedimentary rocks of the Proterozoic, pre-Ripheian age, which lie at a depth of 200 m to 2300 m below sea level. The upper structural stage consists of sedimentary rocks starting from the Ediacarian (Vendian) period and ending with the Quaternary period. The consolidated graph of the geological column (Fig. 2) shows that although sedimentation did not occur during certain periods, we find 'representatives' of all geological systems in the continuous geological cross-section.

This statement is explained by the paleogeographic curve, which shows how marine (ocean) and continental (land) conditions changed

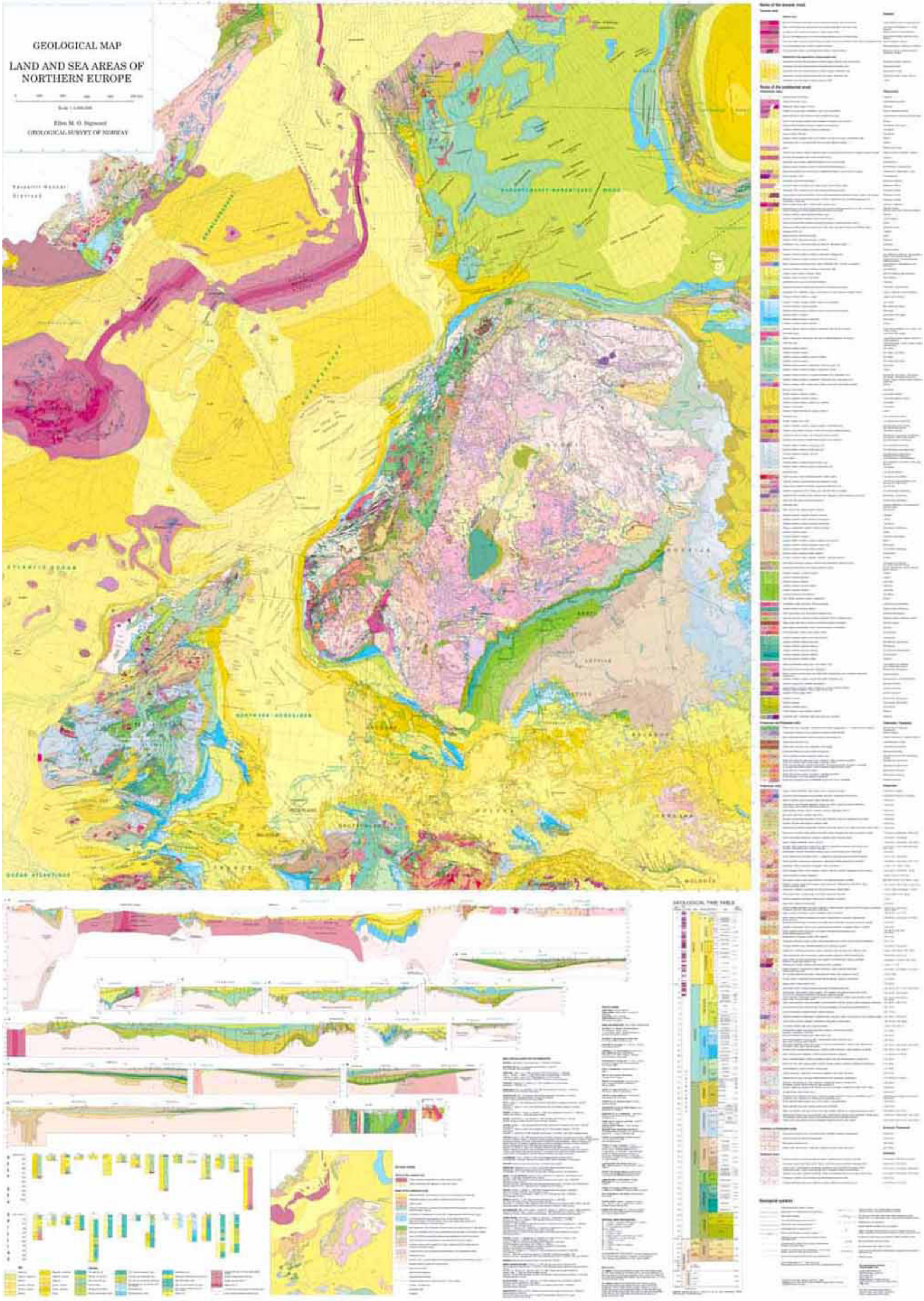

Fig. 1. Geological Map. Land and sea areas of Northern Europe. 1:4 000 000. 2002. Compiled by Ellen M. O. Sigmond (ed.) et al. Geological Survey of Norway, Trondheim. Available at: *www.ngu.no*

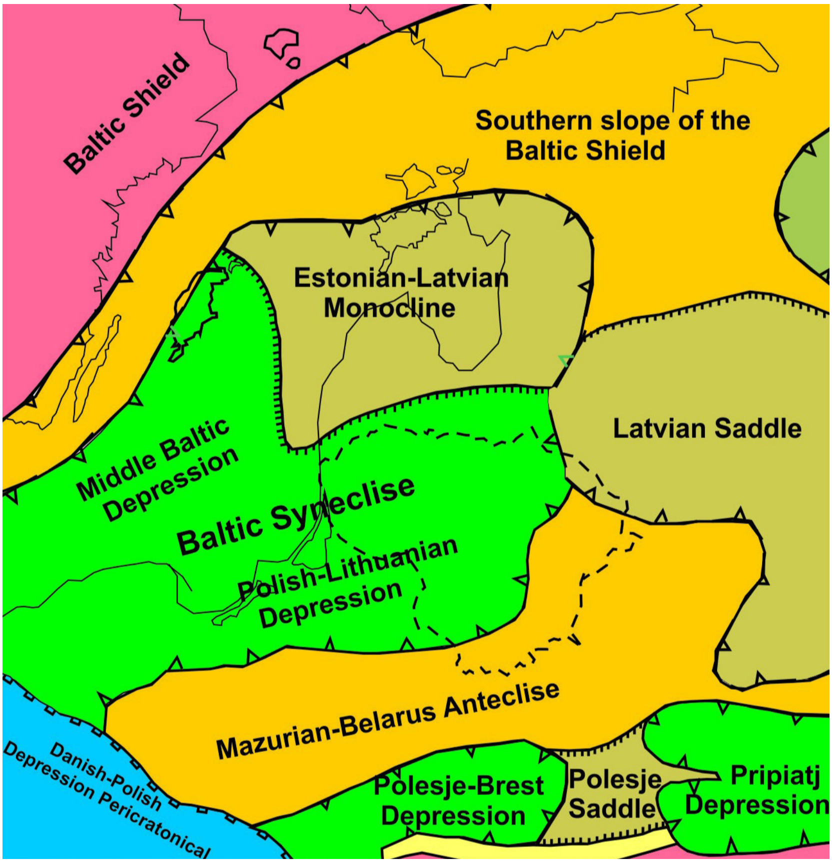

Fig. 2. The tectonic setting of the Baltic region. After Povilas Suveizdis, 2003

over time. This phenomenon was caused by sinking or rising, the so-called oscillatory (epeirogenic) slow movements of Earth's crust, the lithosphere. Thus, in some areas of Lithuania, the iron group metals, or precious metals, rare earth ores formed in Precambrian (Proterozoic) crystalline basement. During the Phanerozoic eon, deposits of non-metallic minerals, hydrocarbons (oil and possibly dispersed hydrocarbons such as shale oil and gas), and porous sediments (freshwater or mineral water accumulations) formed in sedimentary rocks. Some of these treasures from the entrails of Earth are exploited to meet the needs of society, while others may still be awaiting further exploration and their turn to become useful.

Non-Metallic Raw Materials

Over the past four million years, the ability to use non-metallic raw materials (rocks) for food preparation, shelter, and combat elevated the primates of the East African savannah to modern *homo sapiens*. Since then, all stages of human development have been closely linked to society's ability to harness the resources in the entrails of the Earth.

Sixteen types of non-metallic minerals have been explored at various levels in Lithuania. These include rock salt, anhydrite, dolomite, peat, freshwater limestone, amber, gypsum, glauconitic sand, limestone, chalk marl, quartz monomineralic sand, clay, gaize, sapropel, sand, and gravel. So far, 921 deposits have been explored in detail, 1192 have been generally explored, and 504 prospective areas have been identified. Only resources from deposits explored in detail may be used.

Lithuania has sufficient reserves of the most important and widely used raw materials. Mainly, these are everyday raw materials used to improve people's well-being: gravel, sand, clay, crushed rock, limestone, clay, and gaize for cement production. They are also consumed the most. Peat is also abundant and has recently been increasingly used in the production of growing media. This is an extremely important type of mineral resource, because without adding organic matter to soil that is constantly used and becomes depleted, it is impossible to expect sufficient food supplies for a rapidly growing population.

All resources of deposits explored in detail are considered state property. These deposits cover 1.35% of Lithuania's territory, with an *in situ* value of €1.4 billion. The value of the extracted raw materials increases several times over. Non-metallic minerals play a particularly significant role in the structure of Lithuania's national wealth. Explored in detail, a unit of area containing these deposits generates 41 times larger state property than a unit of a forest area, 23 times larger value than a unit of a protected area, and 2.5 times more value than a unit of state road area.

These data on the detailed exploration of mineral resources and their value point to the abundance of resources in the subsoil in the territory of Lithuania. However, not all of them will be used to meet the needs of society, because the politicians elected at the state and municipal levels often see different priorities for ensuring the well-being of society, which are detached from the need to provide for the daily use of underground resources, products, and structures made of them.

Only 62% (1.855 billion m^3) of the resources that have been explored in detail are available for use, and only 35% of the territory (1.35 billion m^3) of the areas that have been generally explored could be explored in detail and prepared for extraction. Deposits of non-metallic raw materials are distributed very unevenly across the country's territory. This is determined by the subterranean structure of Lithuania. All mineral deposits that have been explored in detail, except for the Pagiriai anhydrite deposit, are accessible for exploitation through quarries. This structure of the subsoil has resulted in significant differences in the availability of valuable mineral resources among Lithuanian municipalities. Akmenė, Trakai, Pakruojis, Jonava, and Kaunas districts are five richest municipalities in terms of the quantity of usable resources explored in detail in the depths of the earth.

In addition to the usual raw materials that are used daily and in large quantities (gravel, sand, dolomite, peat, limestone, clay), the marble category resources of the Pagiriai anhydrite deposit, which are of exceptional purity and decorative properties, are close to breaking into the market. The first underground mine has been designed to reach this deposit, which is not only a source of chemicals and binding construction materials, but also a top-class decorative stone, whose rich blue varieties (angelite) are used to make jewellery (Fig. 3).

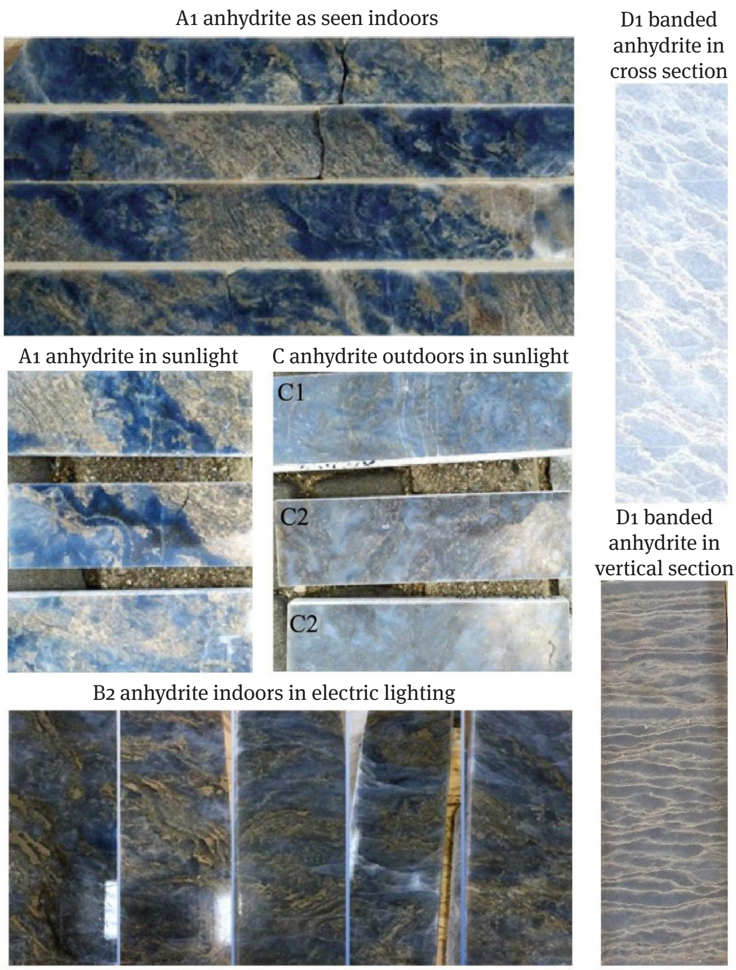

Fig. 3. Decorative stone from anhydrite deposits

Another highly valuable but still little used mineral resource is sapropel, which accumulated in post-glacial lakes and in some marshes below the peat layer. The most important property of sapropel is that it mineralises slowly and releases nutrients gradually. This supplement stimulates the activity of various systems and organs in animals and increases their resistance to disease. Sapropel, which contains biologically active substances and possesses excellent thermal and plastic properties, is used in medicine, especially in balneotherapy, veterinary medicine, and in production of vitamin-rich ointments and bath extracts. The moisture

Fig. 4. Innovative technologies for preparing sapropel and inserting it into the soil. Examples of crop yields

content of natural sapropel exceeds 93%, and almost all of it is bound in its colloidal structure. Without breaking these colloidal bonds, sapropel slowly dries out in the air and irreversibly turns into useless ceramics. This is the main factor limiting its use. Innovative technologies for breaking down colloidal bonds, removing bound water, and introducing a sapropel-based soil conditioner into the plant root zone developed by Lithuanian businesses have resulted in the creation of the Scarabaeus agricultural machine, which creates conditions for a breakthrough into the market (Fig. 4).

Detailed research and exploration are still pending for the large dome-shaped bodies of rock salt found in western Lithuania in the lower reaches of the Nemunas River.

Detailed research and exploration are still pending for the large dome-shaped bodies of rock salt found in western Lithuania in the lower reaches of the Nemunas River.

Groundwater

In Lithuania, groundwater is an invisible yet highly valuable natural resource and the main source of drinking water. Its studies enable the assessment of both the quantity and quality of resources, as well as potential threats arising from climate change and human activity.

Groundwater is an important renewable resource, formed primarily through the infiltration of atmospheric precipitation. The intensity of infiltration depends on climate, soil properties, relief, and other factors. Its chemical composition is shaped by natural influences such as climate, hydrological conditions, biogenic processes, and microbial activity, as well as geological and hydrogeological factors including rock composition, tectonic faults, and hydraulic gradients. Human activities – industry, agriculture, and urbanisation – also alter water composition, cause pollution, and reduce resource quality.

In Lithuania, fresh groundwater is contained in four main hydrogeological systems:

1. the Quaternary system – the most widespread and widely used for drinking water,
2. the Cenozoic–Mesozoic system – important in southern Lithuania,
3. the Upper Paleozoic system – significant in the Žemaitija region, and
4. the Upper–Middle Paleozoic system – supplying fresh groundwater to north-eastern Lithuania.

In addition, 20 groundwater basins have been identified across the country, which help improve resource management and monitoring (Fig. 5).

Reliable total freshwater groundwater resources in Lithuania are estimated at 3.73 million cubic metres per day. Most of the reserves (about

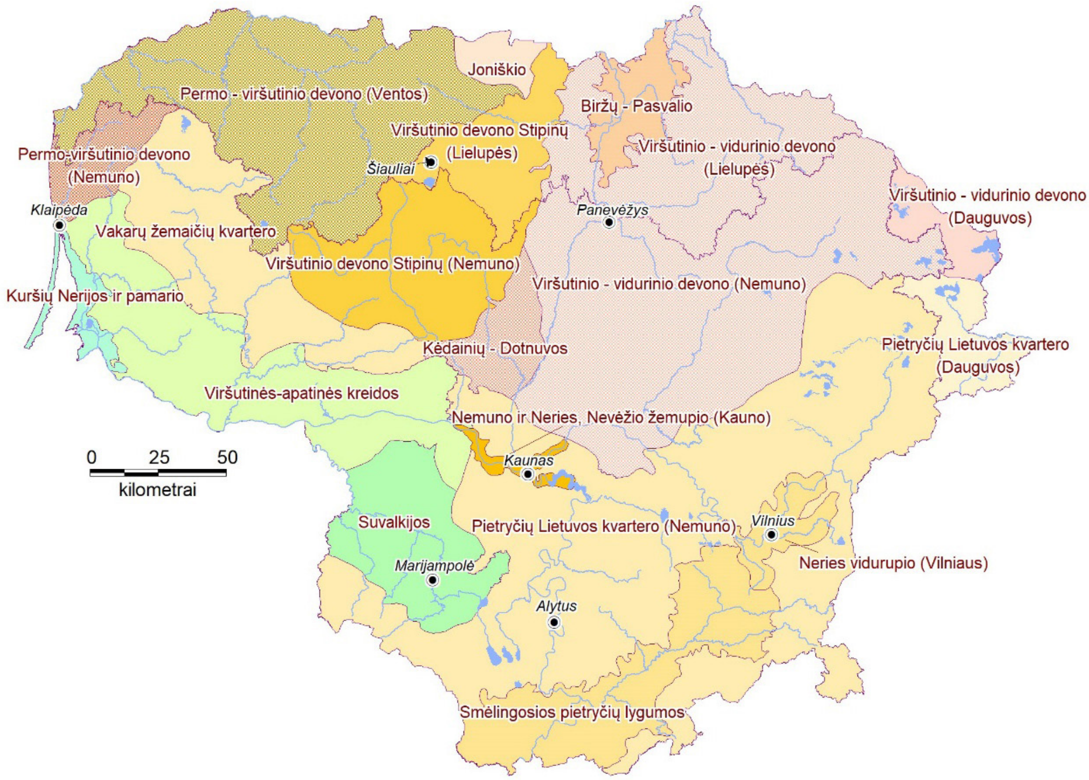

Fig. 5. Groundwater basins (www.lgt.lt)

65%) are stored within aquifers of the Quaternary system. Due to favourable geological conditions and high demand, the largest resources are concentrated in Vilnius (~1.18 million m^3/day) and Kaunas (~0.66 million m^3/day) counties. Although groundwater resources are abundant, only about 15% are currently extracted, leaving significant reserves and strong potential for sustainable use. The quality of freshwater strongly depends on geological conditions. The main quality concerns include naturally elevated concentrations of iron, manganese, and fluoride.

Alongside its freshwater resources, Lithuania's mineral water and brines are also valuable. Mineral water is defined as groundwater with a content of total dissolved solids (TDS) of ≥1 g/L, and it is classified according to mineralisation levels, ranging from very low to brine. Mineral waters and brines occur in various geological formations, from Proterozoic crystalline rocks to Quaternary deposits, and display diverse chemical compositions. Sodium-chloride waters are the most common, though sulfate, bicarbonate, and mixed types are also found. Mineral water is used for therapeutic treatments, drinking, and spa services, while brine

(>35 g/L) contains industrially valuable trace elements such as bromine, iodine, and strontium. The main mineral water resorts are Druskininkai, Birštonas, Palanga, and Likėnai. Lithuania has 44 mineral wellfields with confirmed resource of 8,650 m^3/day, yet extraction amounts to only about 700 m^3/day (Fig. 6).

Shallow geothermal energy represents another important subsurface resource with great potential for sustainable energy development. Influenced by solar radiation, atmospheric conditions, and deep heat flow, it utilises heat stored within geological strata at depths of up to ~250 m (Fig. 7). In Lithuania, groundwater temperature becomes stable at the depth of 15–20 m and increases by approximately ~1–1.5°C/100 m. Shallow geothermal energy is accessible almost everywhere, and its utilisation is simple and cost-efficient. By 2025, Lithuania had installed over 2,200 geothermal systems, mainly for heating and cooling of individual houses and businesses, with a combined capacity exceeding 47 MW.

Groundwater, mineral water, and shallow geothermal energy constitute a vital group of natural resources in Lithuania. When properly managed and monitored, they ensure secure drinking water supply, therapeutic resource potential, and opportunities for sustainable energy development.

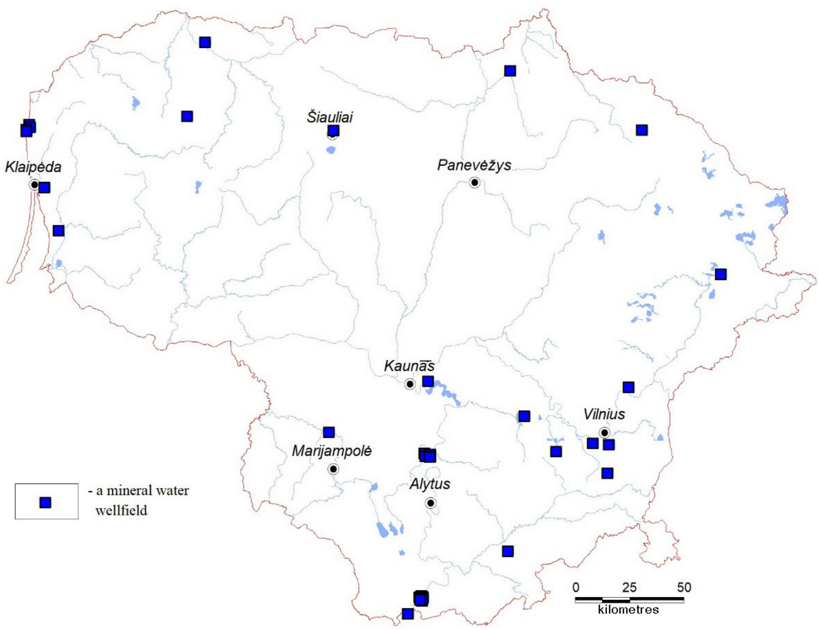

Fig. 6. Mineral water wellfields (www.lgt.lt).

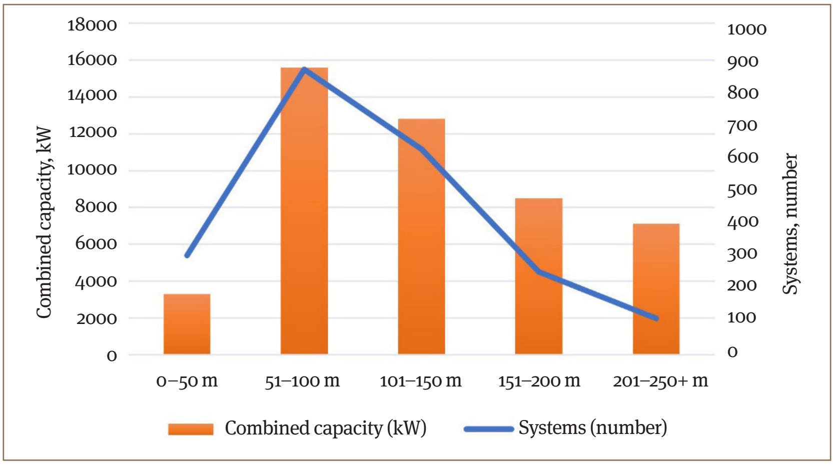

Fig. 7. Number and total capacity of geothermal systems by depth (Štuopis, 2025).

Hydrocarbons

Oil and gas, the hydrocarbons found deep underground, are among the most important types of mineral resources. They are the main source of energy for industry and households, and a raw material for the chemical industry.

Hydrocarbons are natural fossil fuels formed in steadily sinking marine basins over very long geological periods in the Earth's past from organic remains of animals and plants, which accumulate at the bottom of sinking seas along with sediment. As they sink further, they are covered with thick layers of later sediment; these layers enriched with organic matter undergo anaerobic, i.e., oxygen-free, conditions and high temperatures, as a result of which the organic matter begins to decompose into simpler petroleum and later gaseous hydrocarbons.

Under the impact of the pressure of the sedimentary layers, some of these hydrocarbons migrate and can accumulate in porous rocks, where they can form traditional oil and gas deposits in tectonic structures. Another part of hydrocarbons remains in the parent rocks where they were formed due to molecular bonds; these are known as dispersed or shale hydrocarbons (Fig. 8).

Global oil and gas resources and production are constantly rising. From 2013 to 2023, detailed exploration of oil reserves worldwide increased from 1,490.25 to 1,569.06 billion barrels, i.e., an increase of 79.1 million barrels or almost 5%. Over the same ten-year period, oil extraction increased from 72.5 to 73.2 million barrels per day, i.e., by 0.7 million barrels or 1%.

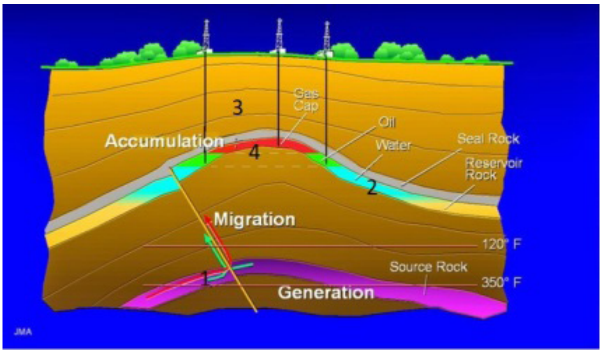

Fig. 8. Hydrocarbons deep underground. 1 – source rock and dispersed hydrocarbons, 2 – reservoir, 3 – cap rock, 4 – conventional hydrocarbon deposit. After Craig, 2020

In Lithuania, 18 oil fields, from which oil is extracted, have been discovered in the rocks of the Cambrian period. The initial geological oil reserves of these deposits amount to 24,150 m^3, with 8,106 m^3 extracted. Oil is extracted in the Kretinga district and Palanga (Telšiai tectonic scarp deposits) and in Klaipėda and Šilutė districts (Gargždai uplift zone deposits). From 1990 to 31 December 2024, approximately 5,596,000 m^3 of oil was extracted in the country. At the end of 2024, the remaining extractable resources amounted to 2,131,970 m^3. In 2024, 27,850 m^3 of oil was extracted in Lithuania, marking a decrease of about 7% from 2023. In addition, it was established that dispersed hydrocarbons are present in the dark-coloured clayey rock layers of the Silurian and Ordovician periods in south-western Lithuania (Fig. 9).

Oil extraction is declining, but it could be stabilised and significantly increased. There are real grounds for this: the search for new deposits (Kintai structure), tertiary extraction methods (Gargždai uplift zone), exploration and extraction in the Baltic Sea, and research into dispersed hydrocarbons. The main obstacle to oil exploration and extraction is the negative attitude of state institutions towards this activity. Due to such an approach, the state loses approximately €1 billion in revenue from special taxes (royalties) alone.

Oil exploration and extraction activities are of great importance for understanding the country's underground layers. For example, in western Lithuania, this work has made it possible to identify a significant geothermal anomaly. Consequently, one can consider the use of geothermal resources for energy production and storage, as well as the possibility of using salt water from deep aquifers in balneology, fisheries, road maintenance, and other areas.

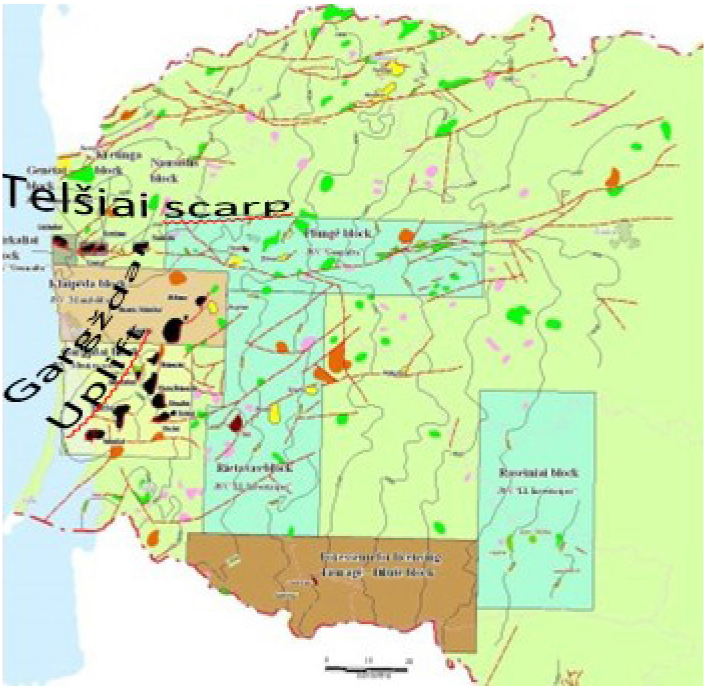

Fig. 9. Tectonic structures in the Cambrian period reservoir in western Lithuania. After Zdanavičiūtė, 2012b.
Black – oil reserves (oil fields); brown, green, purple, yellow – different structures, by the degree of exploration (reliability)

Awareness of the reservoirs deep underground creates realistic conditions for the use of natural cavities for gas storage or carbon dioxide sequestration in the depths of south-western Lithuania.

Metal Ores

In Lithuania, metal ores may occur in the Precambrian crystalline basement, which was formed between the Orosirian period (onset of orogeny at ~1.89 Ga) and Calymmian period (the youngest cratonic intrusions at ~1.5 Ga). The first deposit of iron ores was discovered in 1974, close to the town of Varėna, in the course of the geological mapping of the crystalline basement. Later, few more bodies of iron ore regarded as occurrences were discovered in the vicinity. They are concentrated in the band extending for about 20 km in the N-S direction and form the Varėna Iron Ore Zone (VIOZ). The iron ore consists of magnetite and serpentine with relics of olivine. Magnetite and pyroxene ores appear more rarely. The amount of serpentine and magnetite, and, correspondingly, the grade of ores are highly variable. Magnetite ores appear in association with clinopyroxene, orthopyroxene and rarely apatite rocks. The bodies of these rocks occupy on the surface of the crystalline basement, the areas up to 1 sq. km, and were traced to a depth exceeding 1 km. The depth to the basement in the areas of the deposit is 355–387 m.

The total resources of the Varėna deposit at a depth of up to 800 m are estimated at 540 Mt, with high-quality ore resources amounting to 142 Mt. The host rocks of the Varėna deposit are a sequence of supracrustal rocks, primary psammitic and volcanic. A particular feature is the layer of dolomite, whose origin is still debated.

In the VIOZ, particularly in the rocks of the Varėna deposit, numerous anomalies of the rare-earth elements (REE) were found. The sum of REE oxides, in particular LREE (La, Ce), reaches several per cent. The predominant mineralogical forms are monazite, apatite, and allanite. The time of formation of REE mineralisation is different. Some occurrences are associated with iron ores and related rocks, while others are located in the bodies of granitic intrusions and zones of cataclasis within them (Fig. 10).

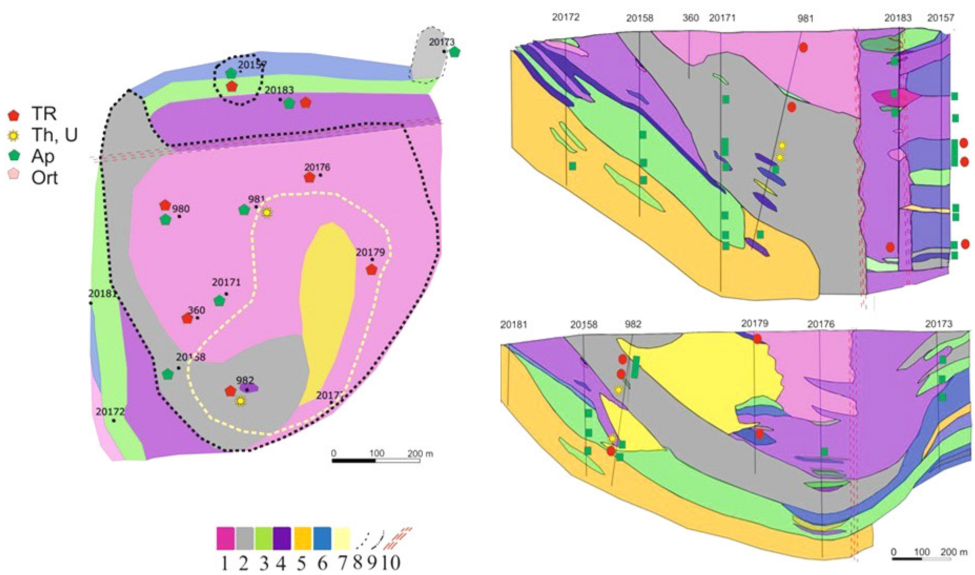

Fig. 10. Approximate structure of the Varėna Iron deposit on the surface of the crystalline basement and sections. After Motuza, Kirkliauskaitė, 2015. Symbols show the generalised primary composition of the bodies of particular rocks: 1 – gneiss, primary sandstone or felsic lava; 2 – serpentine-magnetite rock (ore); 3 – amphibolite, primary basalt; 4 – serpentine rock; 5 – clinopyroxene-biotite-quartz-feldspar gneiss, primary dacite; 6 – pyroxene rock; 7 – dolomite marble; 8 – limits of the orebody; 9 – limits of the body of dolomite marble; 10 – fault zones. Coloured figures indicate occurrences of REE, apatite, Th, and U.

In fault zones cutting through the youngest granitic rocks, mineralisation of copper and molybdenum is located. Mineralisation of these elements continues down the whole depth of Marcinkonys-7 borehole drilled in the Kabeliai batholith. The concentration of Mo is up to 1–2%, Cu – 5–6%. The granite hosting mineralisation is affected by hydrothermal alteration. The age of mineralisation estimated by Re-Os method is 1.485 Ga.

Lithuanian Soils

In a broad sense, soils are an object, in particular, of engineering geology that is based on various disciplines of geology as such, and also closely connected with geotechnics, a branch of civil engineering. An overview of the development of engineering geology in Lithuania shows its rapid progress after the Second World War and in the 1990s, after the restoration of Independence.

Nowadays, the engineering geology in Lithuania is focused on the survey of the Quaternary deposits, which are directly used as a foundation and environment for engineering constructions and buildings. Apart from this, in the northern part of country, in places the Quaternary cover reaches several metres; it is underlain by pre-Quaternary hard rocks, such as dolomite, chalk, gypsum, and marl.

Soils and rocks in the area of active construction impact are classified into stratigraphic genetic types from a geological point of view, and into groups, subgroups, types, and species from an engineering point of view. The most relevant geological phenomena in Lithuania are those (1) caused by the following natural and anthropogenic processes: those arising from surface water activity (steep river slopes, cliffs, ravines, gullies, ditches, ravines, terraces, islands, sea coast cliffs, beaches, horns), (2) caused by surface and underground water activity (swamps, marshy land, karst), (3) caused by the effect of gravity (landslides, rockfalls, debris flows, debris flows, mudslides), (4) caused by wind activity (hollows, dunes, depressions), and (5) processes caused by human economic activity (quarries, artificial soil deposits, excavations, embankments, dams, quays, technogenic sinkholes, deformation of structures and road surfaces).

Thus, all collected and systematised engineering geological data make a basis for engineering geology mapping that allows, first at all, for planning and construction of the objects of infrastructure while saving natural resources, and assessing territories that are sensitive to land pollution, floods, erosion, or seismic hazards. On the other hand, engineering geology mapping is used as a basis for environmental planning and disaster prevention assessments, also in detailed territorial planning of urban development and, taking into account natural conditions, for prediction of long-term urban strategies. Thirdly, the engineering geology information becomes a database for decision-makers, investment assessment, and national security.

Protection of the Underground

According to the Law on the Underground of the Republic of Lithuania, protection of the underground means activities and measures aimed to protect the valuable properties of the underground from physical, chemical, biological or other negative influence occurring as a result of natural processes or human activity, full or partial restoration of these properties, and rational exploitation of the underground resources. Negative impacts on the underground arise from natural processes or human economic activities. After the restoration of Lithuanian independence in 1990, the first editions of laws regulating the investigation, use, and protection of the underground were adopted. In the field of underground management, the responsibilities of state institutions are divided among the Government of the Republic of Lithuania, the Ministry of Environment, and the Lithuanian Geological Survey under the Ministry of Environment.

Numerous cases have been identified when mineral deposits have been built over, polluted by the enterprises established in water supply protection zones, or groundwater was polluted by industrial, agricultural objects and landfills, or large-scale energy facilities constructed near active tectonic faults. This led the Lithuanian Geological Survey and the Institute of Geology to initiate specialised research on the geological environment. Geological mapping focuses on identifying and mapping technogenic pollution sources and assessing groundwater vulnerability and dynamics. Based on fundamental geological data, a set of three maps at a scale of 1:50,000 were compiled: (1) surface litho-morphogenetic regionalisation map, (2) a geopotential map, and (3) an eco-geological (land-use regulation) map. The outcomes of these studies and map compilations were summarised in the national scientific programme 'Lithosphere' and the monograph *Lietuvos žemės gelmių raida ir ištekliai* (2004; Evolution of Earth Crust and its Resources in Lithuania) (Fig. 11).

Experience gained over the last fifty or so years in constructing, operating, and monitoring the impact of major engineering structures on the underground enables the evaluation of planning, design, and geological assessment of past errors. For instance, the Ignalina Nuclear Power Plant project was prepared without considering the potential seismicity of the region. The assessment of the geological environment and available data for the city of Šiauliai and its water supply areas revealed

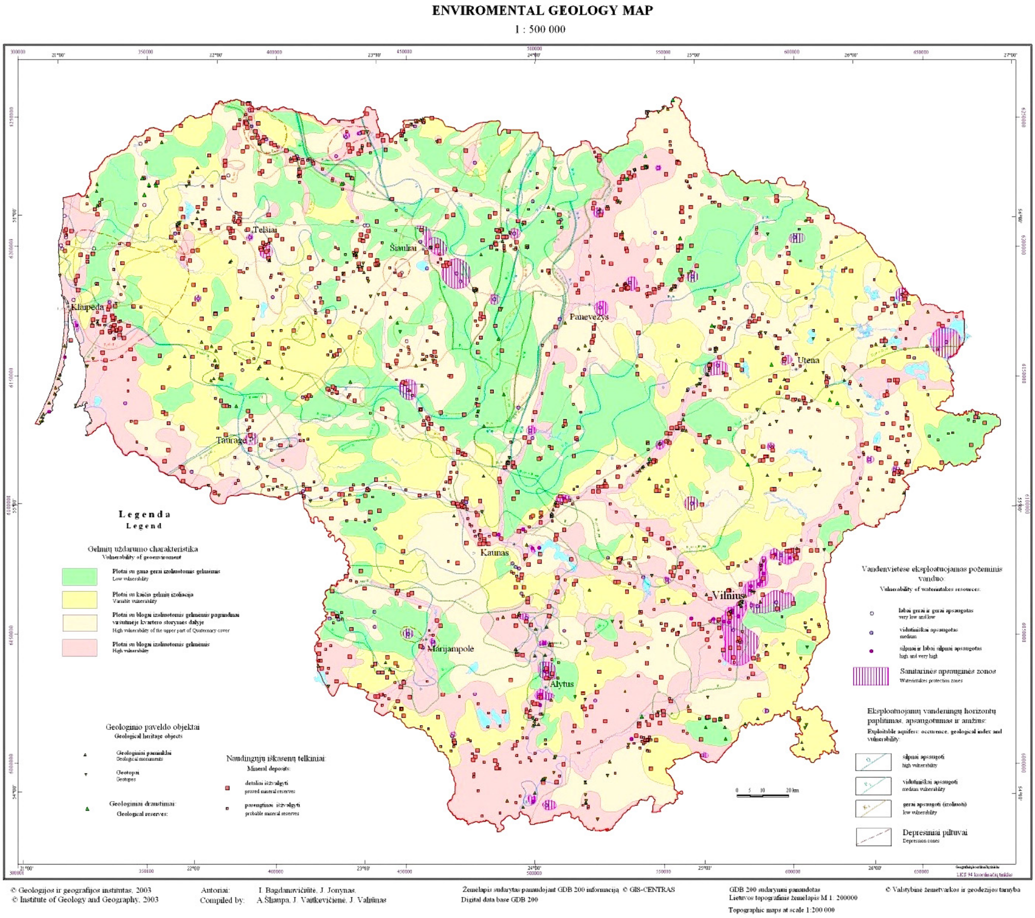

Fig. 11. Map of geological environment protection and eco-geological use of the territory of Lithuania. 1:1 000 000. Compiled by Ingrida Bagdanavičiūtė, Jonas Jonynas, Aleksandras Šliaupa, Julija Vaitkevičienė, Jurijus Valiūnas. From: Šliaupa A., Valiūnas J., 2004, in: *Lietuvos žemės gelmių raida ir ištekliai* (2004).

a complex geological and tectonic structure influencing the recharge of aquifers. In the northern part of Vievis, a town in Elektrėnai municipality, a large oil depot was designed, and tanks were installed in fine-grained, water-bearing sands exposed during earthworks. Economic considerations influenced the decision to locate the Vilnius regional municipal landfill in an abandoned gravel quarry in Kazokiškės.

Geological heritage sites are classified by legal status as state-protected nature monuments, state-protected geoheritage sites, and municipally protected geoheritage sites. Among nature reserves, the Law on Protected Areas distinguishes geological and geomorphological reserves. Among non-living nature heritage sites, geological, geomorphological, hydrogeological, and hydrographic types are listed. Currently, there are 273 state-protected geoheritage sites in Lithuania, including 130 nature monuments and 53 sites protected by municipalities (Fig. 12).

To implement the provision of the Underground Law, to the effect that underground protection consists of purposeful actions and measures, it is essential to emphasise the necessity of geological environment research and evaluation within territorial planning, and in the documentation for the planning and design of specific objects. Among such activities, the development of geological environmental cartographic models (a set of special maps) of various scales is particularly relevant. The data presented and the issues discussed align with one of the priorities of the National Sustainable Development Strategy (version of 4 August 2011) – protection and management of natural resources. One of the key directions for achieving this priority in Lithuania is the conservation and utilisation of the country's natural environment and resources in cases of extreme situations.

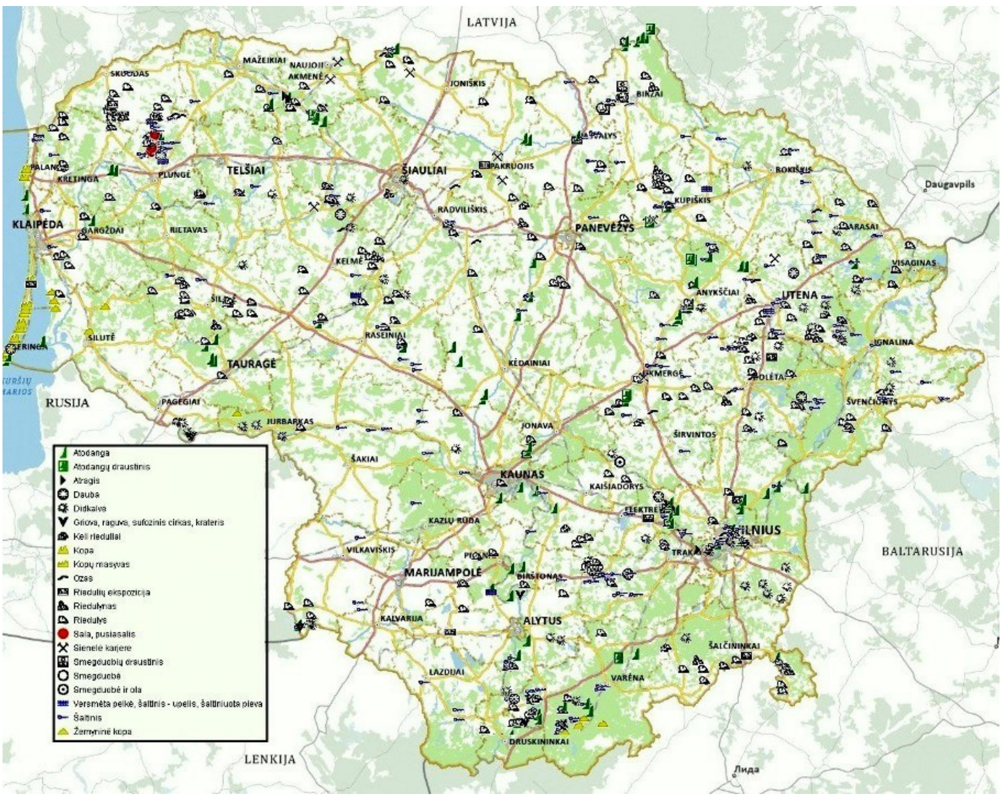

Fig. 12. Map of geotopes of Lithuania. From: Lietuvos geotopai, 2025

The Role of Subsurface Use in Sustainable Development

Seeing the rapid depletion of the Earth's resources and pollution caused by humanity, progressive politicians, social activists, economists, and cultural figures are starting environmental and social movements. In response to this, the concept of sustainable development was for the first time officially presented in a 1987 report by the United Nations World Commission on Environment and Development. According to this concept, 'sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs'.

In Lithuania, as in the rest of the world, the core meaning of the concept of sustainable development remains unclear, and the classic definition allows for various interpretations of the term. This makes it difficult to assess the subsurface utilisation from the perspective of sustainable development, as this topic has been hardly examined. The prevailing public opinion is that the extraction of subsurface resources is incompatible with nature conservation and, therefore, with sustainability. Furthermore, the term *gelmėnauda* (the approximate English term is 'subsurface use') is a Lithuanian neologism used only by some geology specialists, and its meaning is not defined in any legal acts or terminology dictionaries. The term 'subsurface utilisation' should be understood not only as the use of mineral resources or groundwater for the benefit of society but also as other valuable properties of the subsurface of the earth' (geothermal energy, subsurface cavities, a friendly geological environment, or a reliable foundation for buildings), as well as intangible phenomena that are important for the welfare and education of society.

When assessing geological activities and their prospects in Lithuania, there is an evident link between subsurface utilisation and Goal 6 (clean water and sanitation), Goal 7 (affordable and clean energy), and Goal 9 (industry, innovation and infrastructure) of the United Nations' 2030 Agenda for Sustainable Development.

Since only groundwater has been traditionally used in Lithuania, geologists not only find it and prepare it for exploitation but also protect it from pollution or unsustainable use (Fig. 13).

Geologists are the main initiators of the use of deep geothermal energy and perform some of the most important work in harnessing shallow geothermal, wind, and solar energy. Without mineral resources and engineering geological investigations, sustainable industry could not develop, and infrastructure projects, urban renewal, and expansion would come to a halt.

Fig. 13. A well being drilled near the Viekšniai dairy in 1929. *Fourth and fifth left*, geology professor Mykolas Kaveckis (?) and Juozas Dalinkevičius, both from the Minerology Department of the University of Lithuania

It is easy to see the connection between geological activities and Goal 11 (sustainable cities and communities) and Goal 12 (responsible consumption and production) of sustainable development and even with such seemingly unrelated Goal 14 (life below water) or Goal 15 (life on land).

Overall, geology is one of the key scientific disciplines for the implementation of sustainable development, as it is based on a research-driven long-term perspective on the evolution of the Earth, and the current practical activities of Lithuanian geologists are focused not on the exploration of mineral resources, but on their protection and the conservation of subsurface resources.

The Final Remarks

According to the Constitution of the Republic of Lithuania, the depths of the Earth belong to the State, which is the sovereign of the state territory. The Underground Law regulates the rules for the management of these resources and establishes requirements for their rational use and protection. The Ministry of Environment and the State Geological Survey, which is subordinate to the ministry, are responsible for supervising activities in this area.

The authors promote the concept of sustainable development criteria declared by the United Nations and the European Union, which, on the one hand, provides for the protection of biological diversity and geological heritage, and on the other hand, sets goals that correspond to the importance of deep scientific research and of safe exploration in creating a 'green-blue' sustainable economy. These goals include a sustainable environment, clean water, affordable food and housing, accessible and clean energy, and a dignified and safe living environment.

Lithuania has all the necessary local subsoil resources to create national prosperity and meet the needs of society. Although the field of geology is not large in terms of its scope of activity at the national level, it is absolutely necessary to ensure the smooth running of the country's economic activities. There is a triad operating in this field: (1) geology professionals needed by the country are trained at Vilnius University, (2) scientific research is conducted by Vilnius University, Vilnius Gediminas Technical University (VILNIUS TECH), Klaipėda University, and the State Research Institute Nature Research Centre, (3) the needs of applied practical geology are met by geology, engineering geology, and hydrogeology companies that join the Association of Geological Companies, as well as several oil exploration and production companies.

A concluding insight for society is that the Lithuanian geological community cherishes the noble traditions of its profession and is motivated and focused. Geology is an important part of the road map of a successful country, but the management models for this sector and the relevant fields of science are currently facing challenges, seem somewhat outdated, and are awaiting reforms.

In: *Lietuvos žemės gelmių turtai* / sudarė Algimantas Grigelis. – Vilnius: Lietuvos mokslų akademija, 2026. – 512 p.: iliustr.