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Possibilities for developing deep radioactive waste repository in Lithuania

Mélységi radioaktív hulladéktároló telepítésének lehetőségei Litvániában

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(3 Figures)

Key words: radioactive waste, safe management, repository, geological criteria, geological structure, selection of geological formation

Tárgyszavak: radioaktív hulladék, biztonságos kezelés, hulladéktároló, földtani feltételek, földtani szerkezet, földtani formációk kiválasztása

Abstract

The majority of radioactive waste in Lithuania is accumulating at the Ignalina Nuclear Power Plant (INPP); the latter is located in the northeastern part of Lithuania, near lake Drukshiai. The project of INPP construction was started in 1972; exploitation of the first reactor began in 1983, and in the second began in 1987. There are two RMBK–1500 reactors with a total electric power capacity of 2600 MW and a thermal power output of 8400 MW in INPP.

The radioactive wastes of INPP are separated into 3 categories according to the respective levels of their radioactivity. The waste of the first (I) category has a low radioactivity level- 7.4×10^4 - 3.7×10^6 Bq/kg. The waste of the second (II) category is the intermediate activity level 3.7×10^6 - 3.7×10^9 Bq/kg waste. The waste of high radioactivity level is more than 3.7×10^9 Bq/kg – such as control rods (pivots) and spent nuclear fuel elements – are ascribed to the third (III) category. 1400 m^3 of the category I , about 330 m^3 of category II and about 180 m^3 of category III waste have been forming in INPP every year. There is about 30 000 m^3 of radioactive waste accumulated in INPP. This volume could reach about 50 000–100 000 m^3 before the end of NPP exploitation.

Safe management and repositories for radioactive waste represent a new problem for Lithuania, because in the Soviet Union these problems were solved by central institutions in Moscow.

Since 1996 the „Law on Nuclear Energy" of the Republic of Lithuania has been the general order for radioactive waste disposal. The preparation of the Law on radioactive waste management is going on now. Lithuania signed „The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" in 1997.

According to the recent waste management plan, the I and the II categories of radioactive waste from INPP can be disposed in landfill repository, but for the III category waste a deep geological repository must be constructed.

The geological structure of Lithuania could be suitable for a deep repository for radioactive waste. The territory of Lithuania is in the northeastern part of the East European platform. A crystalline basement occurs at depth of between 200–2300 metres below the land surface. The sedimentary cover consists of the deposits of all geological systems (*Fig. 1*). Vendian and Cambrian deposits are terrigenous (e.g. claystone, clay, gravelstone, sandstone, siltstone); Ordovician and Silurian deposits are of a carbonate type and clayey (e.g. limestone, marl, dolomitic marl, dolomite, claystone, clay); Devonian deposits are also of a carbonate type, sandy and clayey (e. g. sandstone, sand, clay, dolomitic marl, dolomite, etc.); Carboniferous deposits are sandy and clayey; Permian deposits are represented, in general, by limestone, anhydrite and rock-salt; Triassic deposits are clayey; Jurassic - clay, siltstone, sandstone; Palaeogene and Neogene - sand, silt, clay; and Quaternary deposits are till, sand and gravel.

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According to the results of geological investigations, some geological formations can be preliminarily selected for a deep repository for radioactive waste: 1) rocks of Crystalline basement, 2) Lower Cambrian clay; 3) Permian sulphate deposits; 4) Permian rock-salt; 5) Lower Triassic clay. The sites for a deep radioactive waste repository may be selected in these formations, according to suitable tectonic, hydrogeological, engineering geological conditions, international considerations and legal documents of the Republic of Lithuania.

Összefoglalás

Litvánia radioaktív hulladékának legnagyobb része Litvánia ÉK-i részén, a Drukshiai-tó mellett fekvő Ignalina Atomerőműben (INPP) képződik. Az INPP építése 1972-ben kezdődött, az első reaktort 1983-ban, a másodikat 1987-ben adták át. A két RMBK–1500-as reaktor teljes villamosenergia kapacitása 2600 MW, a hőenergia termelés 8400 MW.

Az INPP radioaktív hulladéka a radioaktivitás mértéke szerint három osztályba sorolható. Az első (I) kategóriába a kis radioaktivitású hulladékok kerülnek ($7{,}4\times10^4$–$3{,}7\times10^6$ Bq/kg). A következő (II) kategórába a közepes aktivitású ($3{,}7\times10^6$–$3{,}7\times10^9$ Bq/kg), míg a harmadik (III) kategóriába (>$3{,}7\times10^9$ Bq/kg) a nagy aktivitású hulladékok, például a szabályzórudak és a kiégett fűtőelemek tartoznak. Évente 1400 m^3 I, kb. 330 m^3 II és kb. 180 m^3 III kategóriájú hulladék keletkezik az INPP-ben, ami a mai napig összesen kb. 30 000 m^3 radioaktív hulladék felhalmozódást jelent. Az atomerőmű bezárásáig a teljes mennyiség elérheti az 50 000–100 000 m^3-t.

A radioaktív hulladék biztonságos kezelése és tárolása újkeletű probléma Litvániában, mivel a Szovjetunió idejében az ilyesfajta problémákat a moszkvai központi intézetekben oldották meg.

1996-ben a Litván Köztársaság atomenergia törvényben fektette le a radioaktív hulladéklerakással kapcsolatos általános szabályokat. Jelenleg a radioaktív hulladékkezeléssel kapcsolatos törvény előkészítése folyik. Litvánia 1997-ben aláírta „A kiégett fűtőelemek kezelésének biztonságáról és a radioaktív hulladékok kezelésének biztonságáról szóló közös egyezmény"-t.

A jelenlegi hulladékkezelési tervek szerint az INPP-ből kikerülő I és II kategóriába tartozó radioaktív hulladékok elhelyezése történhet felszíni körülmények között, a III kategóriába tartozókat viszont mélységi tárolóban kell elhelyezni.

Litvánia földtani szerkezete lehetővé teszi mélységi tároló létesítését. Litvánia a kelet-európai platform ÉK-i részén fekszik, ahol a kristályos aljzat 200–2300 m mélységben kezdődik. Az üledékes takaró a legkülönfélébb földtani képződményekből tevődik össze (*1. ábra*). A vendi és a kambriumi üledékek szárazföldi keletkezésűek (agyagkő, agyag, konglomerátum, homokkő, aleurolit), az ordovíciumi és a szilur üledékek karbonátosak és agyagosak (mészkő, márga, dolomitos márga, dolomit, agyagkő, agyag), a devon üledékek karbonátosak, homokosak és agyagosak (homokkő, homok, agyag, dolomitos márga, dolomit, stb.), a karbon üledékek homokosak és agyagosak, a permi üledékeket általában mészkő, anhidrit és kősó reprezentálja, a triászban agyagos üledékek, a jurában agyag, aleurolit és homokkő, a paleogénben és a neogénben homok, aleurit és agyag, míg a kvarterban till, homok és kavics rakódott le.

A földtani kutatások eredményei szerint a következő földtani formációk alkalmasak mélységi radioaktív hulladéktároló létesítésére: 1) kristályos aljzat; 2) alsó-kambriumi agyag; 3) permi szulfátos üledékek; 4) permi kősó; 5) alsó-triász agyag. A mélységi tároló bármelyik formációban történő elhelyezése függ a megfelelő tektonikai, hidrogeológiai és mérnökgeológiai adottságoktól, a nemzetközi elvárásoktól, valamint Litvánia törvényeitől.

Introduction. State of the problem

The Ignalina Nuclear Power Plant (INPP) is located in the northeastern part of Lithuania, near lake Druksiai (*Fig. 1*). The construction of INPP was started in 1972; exploitation of the first reactor began in 1983 and the second began in the 1987. INPP has two RMBK–1500 reactors with a total electric power capacity of 2600 MW and a thermal power output of 8400 MW.

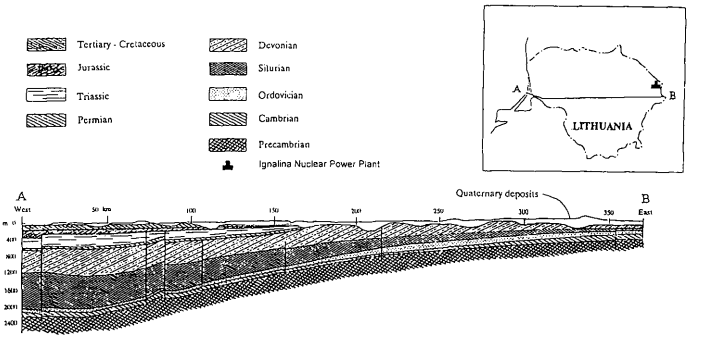

Fig. 1 West–East geological cross-section (line A–B) of Lithuanian bedrock (KADŪNAS 1992)

1. ábra Ny–K irányú földtani metszet Litvánián keresztül

The radioactive waste of INPP can be separated into 3 categories according to the respective levels of their radioactivity. The waste of the first (I) category has a low radioactivity level – $7.4 \times 10^4 - 3.7 \times 10^6$ Bq/kg. The waste of the second (II) category is of intermediate activity level – $3.7 \times 10^6 - 3.7 \times 10^9$ Bq/kg. The waste of high radioactivity level – more than 3.7×10^9 Bq/kg, such as – control rods (pivots) and spent nuclear fuel elements – ascribed to the third (III) category. With respect to solid wastes, 1400 m^3 of category I, about 330 m^3 of category II and about 180 m^3 of category III (except spent fuel) have been forming in INPP every year (*Table I*). A total of about 38 000 m^3 of all types and categories (solid and liquid) radioactive waste have so far accumulated in INPP. This volume could reach about 50 000–100 000 m^3 before the end of the exploitation of INPP. The volume of solid wastes of high radioactivity (except spent fuel) could reach about 4000 m^3 before this time.

Classification of solid radioactive wastes

A szilárd radiaktív hulladékok osztályozása

Table I – I. tábla

Category	Radioactivity	Volume, accumulating per year
I low level	$7.4 \times 10^4 - 3.7 \times 10^6$ Bq/kg	1400 m^3
II intermediate level	$3.7 \times 10^6 - 3.7 \times 10^9$ Bq/kg	330 m^3
III high level	$> 3.7 \times 10^9$ Bq/kg	180 m^3

Safe management and repositories for radioactive waste represent a new and important problem for Lithuania. The Ministry of Energy of Lithuania, in co-operation with a Swedish Nuclear fuel and Waste Management Company,

prepared the „Suggested Overall Plan for Management of Radioactive Waste in Lithuania" in 1995. There was only a general view the possibility of a deep repository for high radioactivity level waste in this plan. A deep geological repository for spent fuel was described in the „Strategy of radioactive waste management" in 1997. Therefore it is very important now: 1) preliminarily to investigate the geological structure of Lithuania with regard to its suitability for a deep waste repository, 2) to foresee the possibilities of this repository, 3) to select the most suitable sites, satisfying the international requirements, 4) to create scientific and practical programmes 5) and to educate the local specialists so that they can implement them.

Since 1996 the „Law on Nuclear Energy" of the Republic of Lithuania has been in operation and it describes the general regulations for radioactive waste disposal. Lithuania has signed „The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management". After long discussions „The Law on Radioactive Waste Management of the Republic of Lithuania" was adopted this spring.

According to the recent waste management plan, the I and the II categories of radioactive waste from INPP can be disposed in a landfill repository, but for the III category waste a deep geological repository must be constructed. As mentioned above, the III category waste includes spent compounds of the reactor and elements of spent fuel. The problem of developing a deep geological repository for radioactive waste will be also important if the Ignalina NPP is closed.

Geological investigations for a deep radioactive waste (RW) repository site

Site selection for a deep RW repository is a complex long-term process and it consists of several stages – general understanding at the beginning and detailed investigations at the end (LOMTADZE 1978). The following stages of geological investigations will be necessary:

1) prospective (review) investigations;
2) preliminary investigations;
3) detailed investigations;
4) underground investigations for repository construction.

1, The aim of the prospective investigations is to collect and assess archive and published data about geological, tectonic, seismic, hydrogeological, engineering geological, environmental geological conditions of the territory of Lithuania. The requirements of International Atomic Energy Agency to with regard the selection of the geological formation for the construction of a deep RW repository need to be observed. Furthermore, the requirements of State laws on territorial planning and land-use and social-economical factors also must be considered at this stage of the investigations.

Later, three more stages must be carried out.

2, The aim of preliminary investigations is to select the site for a deep RW repository in the most suitable geological formation. In this case several sites must be selected. The preliminary investigations must be carried out in each of them.

3, The aim of detailed investigations is to describe the engineering geological (geology, tectonics, hydrogeology etc.) conditions and to provide the necessary data for construction in the selected site.

4, The aim of underground investigations with respect to repository construction is to determine the impact of groundwater and other factors which would affect the repository in the natural geological environment. These are investigations having long-term implications. The methodology for these investigations will be property established only when the first three stages of the investigations are performed.

Project at LGT

The project for the first stage (prospective (review) investigations) of this long-term work was approved and started at the LGT this year (1999). The title of this project is „Evaluation of the territory of Lithuania according to the suitability for the deep repository for radioactive waste".

According to international recommendations (IAEA 1981, 1989; SAVAGE 1995), a safe deep repository for radioactive waste disposal can be constructed only in a deep-lying (depth > 200 m) geological formation. The long-term safety of high level radioactive waste disposal has to be based on the multibarrier concept to avoid the movement of radionuclides from the repository to the environment. These barriers have to be: engineered barriers, the host rock and the geological environment. It is, nevertheless, recognised that the geological barrier plays the major role in assuring long-term safety. Therefore the site selection for a deep geological radioactive waste disposal repository is a primary and complex task. The requirement for selecting radioactive waste disposal repository is to assure long-term (not less than 10 000 years) human and environmental safety (protection) from radioactive pollution (SAVAGE 1995).

Given international recommendations and the data of similar investigations from foreign countries specialists of Geological Survey of Lithuania decided to select a geological formation for a deep RW repository using 3 groups of criteria:

1, geological,
2, radiation (radiological) safety,
3, territorial.

The criteria for the first and the second group have already been determined quite clearly.

1, The major geological criteria are: structure of the formation, density of tectonic faults, hydrogeological situation, geochemistry of the rocks and others (see *Table II*)

2, Major radiation safety criteria are:
maximum individual dose < 0.1 mSv/y,
individual risk < 10^{-6}/y.

3, Territorial criteria, mentioned in the international recommendations and reports from several countries are:
30 km distance from the State boundary,
10 km radius from urban territory (planned for operational period).
However, there are no special territorial requirements related to RW repository construction in the State laws of the Republic of Lithuania. This is continuous co-operation with governmental organisations is foreseen for the determination of all territorial criteria during the LGT project.

Geological criteria for deep repository of radioactive waste (according to IAEA recommendations (IAEA, 1981, 1989))

A radioaktív hulladék mélységi tárolásának földtani feltételei

Table II. – II. tábla

Index	Requirements (safety criteria)
Tectonic stability	Should not be in an earthquake zone
Rock stability	Rocks must remain in their natural conditions; can not be changed for millions of years
Occurrence of the formation	Large territory
Depth from the land surface	>200 m
Thickness	Not less than 25 m
Inclination slope	Not more than several degrees
Homogeneity	Should not be soluble intercalation or linzes with solutions
Geochemistry	Should not be hazardous chemical compounds
Hydrogeological conditions	Should not be water filtration
Geotechnical properties	Must assure long-term life of constructed underground caves.
Occurrence of mineral resource deposits	Repository should not be constructed in the deposit of mineral resources.

Assessing the suitability of the geological formations for high level radioactive waste repository construction the following data about the territory must be evaluated:
- Geographical conditions;
- Tectonic, neotectonic conditions and seismic situation;
- Hydrogeological conditions (stratification of hydrogeological section, hydrodynamic and hydrochemical properties of low permeability layers and aquifers, water exchange between the aquifers, hydrodynamic relationships between shallow and groundwater etc.);
- Composition of geological formation, its physical, chemical and mechanical properties (conductivity, porosity, solubility, absorption properties, radioactivity, thermal conductivity and capacity, temperature gradient etc.);
- Occurrence of geological processes;
- Environmental geological situation.

All the data about the geological structure of Lithuania are have been collected by the at LGT. This information can be divided in to four main groups:

1) borehole data,
2) geological, geophysical mapping data,
3) raw material prospecting and exploration data,
4) results of special geological investigations.

There are data about more than 2600 deep boreholes (depth more than 200 m) in the computerised State geological information system. Geological mapping on a scale of 1: 200 000 covers all the territory of Lithuania. This scale was selected as a working scale for the graphical information in the project. Some geological formations (systems) were investigated in detail during the prospecting and exploration project for oil, rock salt, anhydrite and other mineral resources. The reports of different geological investigations will be used (as well as the archive data) for the selection of the geological formation for the HLRW repository.

Finally, to compare the suitability of different geological formations and to show graphically the results of the project GIS technologies and MapInfo software will be used.

Short description of the geological structure of Lithuania

The geological structure of Lithuania is suitable for a deep repository for radioactive waste. The territory of Lithuania is in the north-eastern part of the East European platform. A crystalline basement occurs at a depth of 200–2300 metres below the land surface. The sedimentary cover consists of the deposits of all geological systems (*Fig. 1*). Vendian and Cambrian deposits are terrigenous (claystone, clay, gravelstone, sandstone, siltstone); Ordovician and Silurian deposits are carbonate and clayey (limestone, marl, dolomitic marl, dolomite, claystone, clay); Devonian deposits are carbonate, sandy and clayey (sandstone, sand, clay, dolomitic marl, dolomite, etc.); Carboniferous deposits are sandy and clayey; Permian deposits are represented, in general, by limestone, anhydrite and rock-salt; Triassic deposits are clayey; Jurassic deposits clay, siltstone, sandstone; Palaeogene and Neogene deposits: sand, silt, clay; and Quaternary deposits are till, sand and gravel.

According to the results of the geological investigations some geological formations can be selected on a preliminary basis for the deep repository for radioactive waste (SAVAGE 1995): 1) rocks with a Crystalline basement, 2) Lower Cambrian clay; 3) Permian sulphate deposits; 4) Permian rock-salt; 5) Lower Triassic clay.

Rocks with a crystalline basement

In Lithuania a crystalline basement occurs at a depth of 200–2300 metres below the land surface (*Fig. 1*). This is represented by Proterozoic rocks: metamorphosed granulite facies in Western Lithuania (gneisses, schists, enderbites,

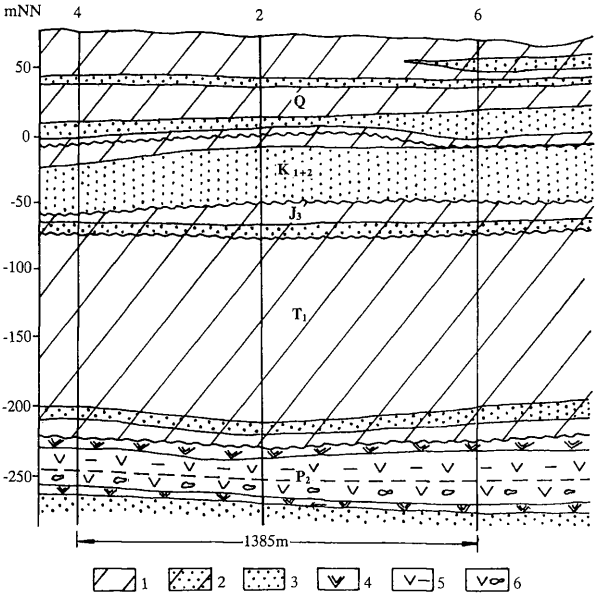

Fig. 2 Geological section of Pagirai anhydrite deposit. 1 aquitard, 2 medium permeability, 3 aquifer, 4 gypsum, 5 banded anhydrite, 6 spotted anhydrite

2. ábra A Pagirai anhidrit lelőhely földtani szelvénye. 1. vízzáró, 2. közepesen áteresztő, 3. vízáteresztő, 4. gipsz, 5. szalagos anhidrit, 6. foltos anhidrit

charnokites) and amphibolite facies in the Eastern part of Lithuanian territory (amphibolites, gneisses, granites). There are intrusions of basic rocks (gabbro, diabases) in crystalline basement rocks. The geotechnical properties of this massif have been investigated in south-eastern part of Lithuania (MARFIN et al. 1982).

Lower Cambrian clay

The oldest part of the Lower Cambrian – i.e. Baltija group – consists of a compact clay formation. This formation occurs in Eastern Lithuania at a depth of 300–500 and more metres. The clay is very compact and consists of hydromica (from 60–65 to 85–90%, kaolinite (from 3–5% to 25–30% and chlorite (from 3–5% to 10–15%) minerals (PASKEVICIUS 1999). There is some intercalation of sandstone in the Lower Cambrian clay.

Permian sulphate deposits

The entire layer of these deposits is 40–60 m thick and occurs in the Southern and South-western parts of Lithuania covering an area of more than 12 000 km^2. This layer lies at a depth of 150–790 m. Most of these deposits (70–80%) consist of anhydrite. Permian gypsum which 5–8 m thick occurs above the anhydrite layer and gypsum which is 3–5 m thick lies below the anhydrite. In the Kaunas district i.e. the Pagiriai deposit (*Fig.* 2) the exploration of anhydrite has been carried out. Resources of 81.5 million. tonnes of anhydrite have been evaluated there. The project for the exploitation of anhydrite by underground mining has been prepared. According to this project, the free underground cavities after the exploitation of anhydrite can be used for a repository for radioactive waste (KADUNAS 1993).

Permian rock-salt

The upper Permian rock-salt basin comprises almost the whole Kaliningrad region (Russian Federation). Only the Northern edge of this basin can be detected in the Southwestern part of Lithuania. This territory has been investigated using seismic methods. According to the seismic data, salt is expected to occur in the form of single domes. The supposed salt bed was determined using the diagrams of an electric log in the oil prospecting boreholes. The prospecting and evaluation of Usenai rock-salt deposits have been carried out in Silute district (SAULENAS 1997). There were 2 deep boreholes drilled with a core in the Usenai deposit (*Fig.* 3). According to the drilling and seismic data, the area of the salt dome is 2.5 × 3.0 km. The evaluated thickness of the rock salt in the central part of the deposit is 56.5–69.0 m, and the supposed thickness about 75 m.

Lower Triassic clay

The Lower Triassic deposits occur in the Western and South-western parts of Lithuania at a depth of 250–350 m and are more than 200 m thick. In general the sequence consists of dense clay. The most important compounds of the clay are hydromica and montmorilonite minerals. There are many siltstone and some sandstone intercalations in the sequence of the Lower Triassic deposits (SUVEIZDIS 1994).

Expected results

The results of our project

– will show the possibilities for deep geological RW repository in Lithuania.

– will provide the substantiation (related with RW management) for the decisions of the State Government, specialists of economics and environmental security,

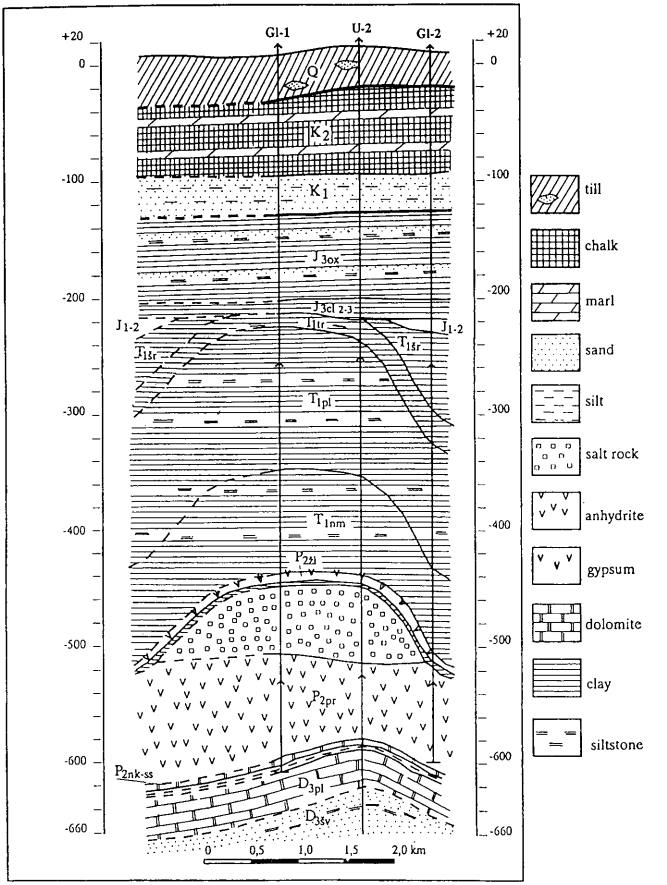

Fig. 3 Geological cross-section of Usenai deposit (SAULENAS 1997)

3. ábra Az Usenai lelőhely földtani szelvénye (SAULENAS 1997)

– will provide the information for further stages of geological investigations for deep RW repository site selection.

Conclusions

We have a problem in Lithuania – The Ignalina Nuclear Power Plant and 414 m^3 of solid high activity Radioactive Wastes.

We could solve this problem by using a geological formation in Lithuania which is suitable for a deep RW repository.

We have to give the clear answer to this question.

This is why we have to carry out the project which represents the first stage of geological investigations – to evaluate the territory of Lithuania according to its suitability for a deep RW repository.

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