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Site selection methodology for deep repository of radioactive waste and prospective sites in Slovakia

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Abstract: The project of assessment of the territory of Slovak Republic from geological viewpoint of suitability for the construction of deep repositories for high-level radioactivity waste and spent fuel in the geological environment of the Western Carpathians started in the year 1993. The paper describes theoretical background of the problem, methodology of the investigation, criteria for the selection of suitable geological environment. 9 areas were selected in Slovakia for further investigation. They include areas covered by igneous rocks (granit, granodiorit, tonalit), metamorphic rocks (phyllit, metavolcanic rocks) and by sedimentary rocks (Paleogene claystone, Neogene carbonate clay).

Key words: radioactive wastes, deep repository, criteria for selection, Western Carpathians

Introduction

All countries, including Slovakia, which use nuclear energy to produce electricity in nuclear power plants, face the problem of spent fuel from reactor and high-level radioactive waste. During the last decade, the problem was solved by transferring this material to the former USSR. This temporary solution was abandoned several years ago. An attitude common to waste disposal in all world is to dispose it to a deep repository. Suitable geological formations and engineering barriers must prevent wastes from entering deep-circulating groundwater and limit the transfer of radionuclides into the biosphere for a very long time (ten to hundred thousand years). Because the whole problem is extremely complex, no country in the world has at present a final repository in operation. It is estimated that the first final repositories in the world could be completed in the second decade of 21st century. Slovakia has a great delay in solving of this problem. On the other hand, countries like ours can use theoretical and practical knowledge of countries which are much more ahead in this matter. At present, the problem of waste produced by 4 reactors in Jaslovské Bohunice (the only Slovak nuclear power plant in operation) is temporarily solved by an interim storage located directly in the power plant.

Methodology of the investigation and criteria for the selection of suitable sites

The problems of final repository for high-level radioactive waste and spent fuel was in the former Czecho-Slovakia solved by the Institute of Nuclear Research in Praha-Řež (NACHMILNER, 1993). A continuation of this work is the project "Repositories of radioactive and dangerous waste in geological environment" financed by the Ministry of the Environment of the Slovak Republic and realised by the Dionýz Štúr Institute of Geology, in co-operation with the Comenius University in Bratislava.

Existing experience from the world shows that there are no unambiguous criteria for the selection of the most suitable geological environment and no rock type may be unanimously declared as the most favourable. Various geological environments provide by their character and structure favourable as well as unfavourable conditions for the construction of a repository. If natural geological barriers are suitably complemented by engineering (technical) barriers and by adjusting the construction and technology of repository construction, the required security level can be reached in most geological environments, guaranteeing long-term security.

Fundamental terms

Schematic illustration of a deep-seated repository in geological environment formed by rocks is in Fig. 1.

Explanations of abbreviations used in paper:

DR - *deep-seated repository*

HGE - *host geological environment*

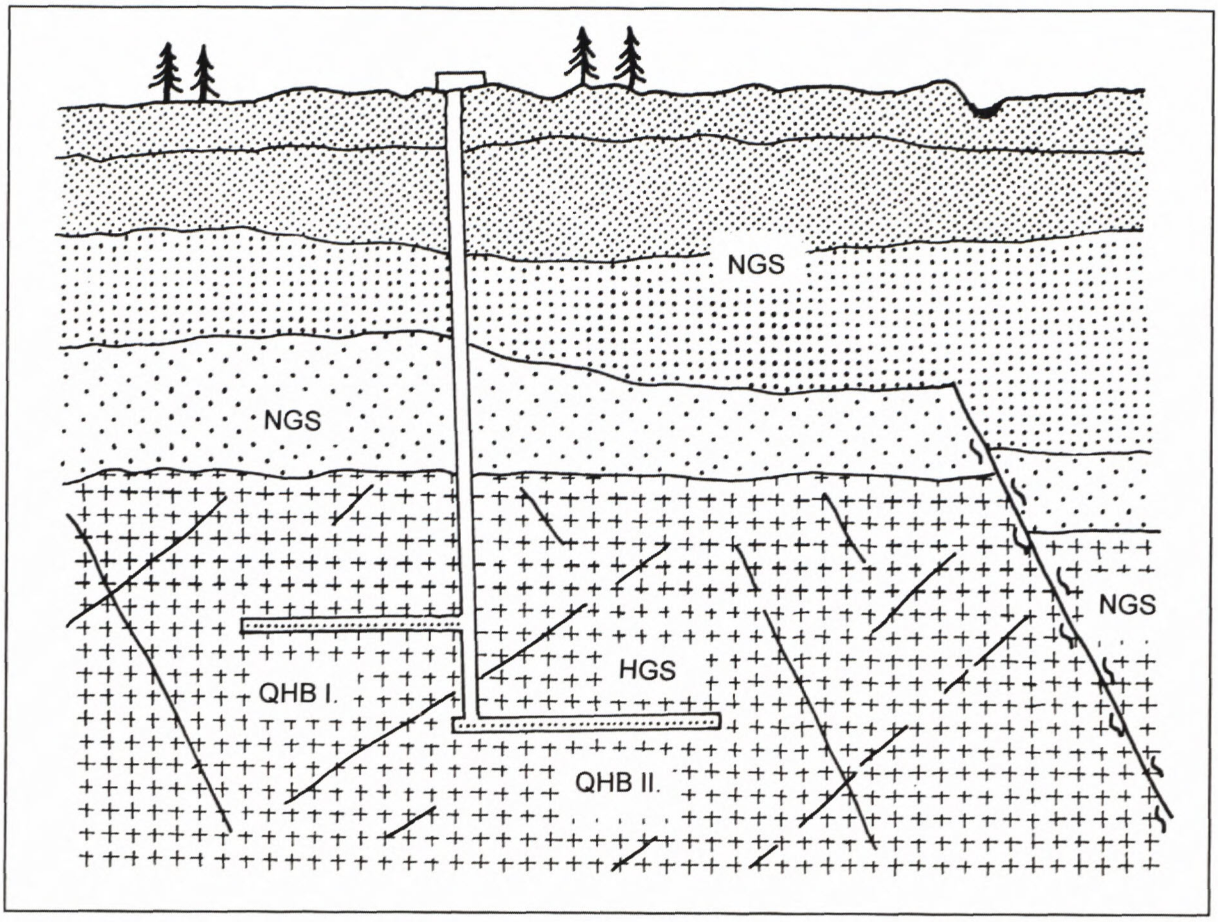

Fig. 1 Deep-seated repository in host environment formed by hard rocks

HGS - *host geological structure*
NGS - *neighbouring geological structure*
QHB - *quasi-homogeneous block*

Deep-seated repository (DR) of high-level radioactive waste and spent fuel is an underground structure, located usually in a depth exceeding 300-500 m below the surface. Part of the repository is a communication shaft and a system of galleries and tunnels, in which the radioactive waste is deposited. Host geologic environment (HGE) is a part of geological environment in which there are favourable conditions for waste deposition. It consists of two separate units: host geologic structure and neighbouring geological structures.

Host geologic structure (HGS) is a part of HGE formed by rocks in their natural state, including fissures and their filling. It is restricted by a geological or tectonic boundary. HGS is composed of several quasi-homogeneous blocks.

Quasi-homogeneous block (QHB) is a part of HGS. It is usually a tectonically restricted body, a layer, lens, or their various combinations. It is formed of rocks in their natural position, including fissures and their filling. It is characterised by high homogeneity of properties and it is separated from HGS by geological elements (faults, limit-exceeding concentration of thermolabile minerals, organic matter etc.), the presence of which is due to their character acceptable in HGS, but not in QHB. HGS may contain several QHBs. In QHB there will be located repository spaces of the deep repository (DR). Underground approach and other (technological) space may be constructed also outside the QHB, but within HGS.

Neighbouring geological structure (NGS) is a part of the rock environment in the surroundings of HGS, formed by rocks in their natural position, including fissures and their filling. NGS due to its character does not fulfil the criteria for HGS, but being in immediate neighbourhood, it affects the conditions in HGS (especially hydrogeology) and it is (will be) affected by HGS and DR. It is separated from HGS by a geologic or tectonic boundary, or by a tectonically (hydrogeologically) important boundary, which, due to its extent and character, cannot occur in HGS. Outer boundary of NGS shall be determined only on the basis of results of further investigations (except the upper boundary, formed by earth surface), the aim of which will be to determine the source and environment of transport ways of groundwater (PV) to HGS, or the environment of escape ways of by radionuclides contaminated PV.

Criteria for the evaluation of geological environment

General characterisation of criteria for the evaluation of geological environment

Evaluation criteria are, in view of the level reached by developed countries in prospecting and assessment of geological environment suitable for deep repositories (DR), on a sufficiently high theoretical as well as practical level. Criteria of geological character are only one of the groups of criteria, decisive for the final situation of a deep repository in geological environment.

According to the recommendations of the International Atomic Energy Agency (IAEA Vienna, 1981, 1982, 1983), criteria for the assessment of geological environment may be divided into exclusive and limiting ones, while:

- exclusive criteria are those which, if not fulfilled, exclude the assessed area, or geological environment, from further investigations. For the exclusion of an area it is sufficient when any of the exclusive criteria is not complied with.
- limiting criteria are those, which limit (restrict) the use of HGE, but they do not exclude it from further investigations. Processes and phenomena defined as limiting criteria have to be identified to determine further geological survey and investigations. Their aim shall be the determination of limiting values of these criteria and to investigate, if the evaluated HGE fall beyond these limits.

Exclusive criteria

Spatial conditions

HGS must have sufficient dimensions to accommodate a deep repository. The extent of the buffer zone (space in immediate surrounding of DR up to the next fault or other unfavourable geological boundary) depends on the character and properties of HGS (sorption capacity, permeability, faulting etc.). Security requirements determine the necessary dimensions of HGS. In plastic rocks it is usually smaller than in solid rocks. According to estimates based on permissible density of waste deposition (distance of containers) and requirements on insulation properties of HGE, HGS has a surface of 8-10 km^2 and a thickness of minimum 200 m (plastic rocks), or 500 m (solid rocks). Minimum depth of DR emplacement in HGE from the surface should vary between 300 and 500 m. A more accurate determination of emplacement depth for a deep repository is based on insulation properties of HGE and the results of a study of geomorphologic evolution of the territory. Maximum depth is limited by natural temperature of HGS, engineering-geological properties of HGS rocks, technologic and economic conditions. With increased depth, the costs increase disproportionally, due to more complicated technology of underground tunnelling.

Hydrogeological conditions

Hydrogeological conditions are principal criteria for the evaluation of HGS suitability. Groundwater is the principal transport medium for chemicals corroding the containers with waste and later on the transport medium for released radionuclides. The direction and rate of groundwater flow across HGE, sorption properties of HGE together with dimensions and depth of HGS must prevent first radionuclides from appearing in the biosphere earlier than in 100 000 years. Their principal activity will be then on sufficiently low level. An environment suitable for the construction of a repository must have a very low permeability and low hydraulic gradient. The value of hydraulic conductivity limit k_f of HGS has been presented by various authors in the range of $1x10^{-9}$ ms^{-1} to $1x10^{-11}$ ms^{-1}. Its permissible value depends on the hydraulic gradient, dimensions of HGS and insulation properties of NGS. The value of hydraulic gradient cannot be determined generally. It is related to concrete geological environment.

Tectonic conditions

Severely tectonically affected HGS and the presence of active tectonic fault in HGE are further exclusive criteria.

Tectonic effects in HGS are different in rigid solid rocks (granites, migmatites, limestones etc.) and in plastic rocks (rock salt, clays, claystones etc.). In solid rocks it results in fissures allowing groundwater circulation, in plastic rocks it causes inhomogeneity and irregularity of the dimensions of a geological body.

In brittle rocks of the Western Carpathians, tectonic processes (germanotype and, above all, alpinotype tectonics) resulted in a thick network of discontinuities (faults and fissures). Fissures, up to a depth of approx. 100 m, provide good conditions for groundwater flow. Deeper on they are usually gravitationally closed and water circulation is low.

Along faults, groundwater flow exists even in substantially greater depth. Soluble rocks are characterised by karst permeability, increasing thus the overall permeability of rock environment.

Plastic rocks, after the formation of various discontinuities, are capable of self-sealing, so that greater groundwater flow along discontinuities is usually exceptional. Fissures are closed already in a depth of several tens of meters (approx. 30 m).

Geomorphologic evolution of the relief

Vertical movements of Earth crust, along with denudation processes, affect in a decisive way the depth of emplacement of a deep repository.

Continuous denudation processes predominating over accumulation lead to gradual change of the relief and uncovering of Earth surface. The denudation process, intensified by vertical movements of Earth crust, may after longer time cause undesirable eroding of the overlier of a deep repository and, in an extreme case, even "emergence" of DR to the surface. To asses possible development of the relief, geomorphologic models are prepared, predicting future relief for a period of possible negative effects on the repository (10^4 up to 10^5 years).

Other criteria

Among other exclusive criteria are security, economic and ecological interests of man. From the viewpoint of the necessity of undisturbed (in the past, at present and in the future) HGE, the presence of old mining works, present mining activities, protection zones of mining areas and future prognostic mineral raw material deposits, which are assumed to be exploited in the future, are taken into consideration. The repository should be situated in a HGS, where survey drilling or other future human interference is excluded.

The presence of groundwater in HGS and below, occurrence of geothermal (prognostic as well) and mineral water in HGE, by legislation protected water-economy territories are further exclusive criteria for the selection of HGE. A legislative restriction is also the existence of protected areas (e.g. national parks, protected land etc.).

Limiting criteria

Hydrogeological conditions in the overlier of host geological environment

The existence of infiltration, transport and accumulation area of groundwater in the overlier of HGS is a limiting factor, which must be given increased attention in following stages of survey. When designing a repository, it is necessary to prevent underground spaces from being flooded due to accidental penetration through access shafts tunnelled across aquifers. Such conditions may be assumed to exist in Inner Carpathian Neogene basins.

Seismic conditions

Internationally accepted limit of seismic tremors is 8°MCS, the majority of Slovak territory complying with this value. Since seismic activity of the Western Carpathians is at present being re-evaluated, it is at this stage of assessment ranked with limiting criteria.

The majority of seismic tremors is usually dangerous only for engineering works situated on Earth's surface. In case of an earthquake in HGE, upper parts of access and ventilation shafts may be damaged, as well as equipment on the surface, while underground parts of the repository are relatively safe. In case that the access shaft is tunnelled across an aquifer, the repository can be flooded.

Direct endangerment of underground parts of the repository may occur only at strike-slip movement of HGS rock along a newly-formed fault. The probability of such phenomenon is however very low, even from long-range viewpoint.

Structural-geological conditions

Unfavourable mode of deposition (steep dip of beds and discontinuity planes, irregular shape of HGS body) allow to assume complex tectonic processes in the past, which disturbed the integrity of the rock massif (brittle rocks) and geometric shape of the body (plastic rocks). Unfavourable structural conditions substantially affect the engineering-geological properties of HGS, which influences the technology of underground tunnelling and security provisions.

Engineering-geological conditions

A deep repository is a large underground work in a considerable depth (approx. 300 - 1500 m), which remains open during construction and operation. After filling and closing of a repository, the rock becomes an environment, where all short- and long-time effects and processes, caused by the presence of deposited waste, are manifested. The values of physical-mechanical characteristics of the rock environment must comply with required conditions.

Rock homogeneity of host geological environment

From the viewpoint of DR security, high homogeneity of HGS rock composition is necessary, and thus also homogeneity of physical-mechanical properties of the rocks. Inhomogeneity of HGS results in lower precision of theoretical analysis of DR security. However, certain signs of inhomogeneity of rock composition or of their properties are to a limited extent acceptable.

Geochemical properties

Geochemical properties of rocks play an important role in long-range security of a repository. Sorption properties of rocks, aggresivity of groundwater, high solubility of rocks etc. influence the selection of suitable location for a DR. Chemical reactions may cause changes of the properties of engineering barriers and thus affect their retention effects on released radionuclides.

Thermal properties of rocks

Spent fuel in an interim repository (before its final deposition) cools down to a technologically acceptable temperature (60 to 140 °C) Deposited waste increases the natural temperature of DR environment. Therefore a HGS with low natural temperature, built of rocks and minerals with high thermal conductivity, is more advantageous. Thermal instability of minerals may result in their alteration and thus secondary change of mechanical properties of the environment.

Mineral deposits

Mineral deposits are acceptable in the overlier of NGS. From the viewpoint of security of a repository it is necessary to determine a limit for the depth or distance from occurrences of mineral raw material from HGS. This distance may be determined only for a concrete HGE.

The application of criteria to assessment of area suitability is to a certain extent problematic due to the fact that it requires detailed characterisation of rock environment. This is (in view of the degree to which Western Carpathian territory has been subjected to geological investigations) at various levels.

With increasing level of geological information it will be possible to apply the criteria on qualitatively quite different level. This, at the same time, assumes a process of continuous updating, complementing and precisifying of selection criteria in the following stages of this project.

The above geological criteria are only a part of criteria, which are decisive for the situation of DR. The distance of DR from inhabited areas, protected natural territories etc. is subject to public discussion or political decision-making.

Method of selection

The assessment of the territory of Slovak Republic was based on the application of internationally determined and applied criteria. The criteria were adjusted according to the required density (scale) of investigation, financial conditions and professional potential of the evaluating institute.

In the first stage, basic evaluation of the territory was carried out by regional geologists - specialists for various regional-tectonic units. Their task was to distinguish a prospective area, where it will be possible to find, with a great probability, a sufficiently large rock massif, in sufficient depth, tectonically unaffected and without active tectonic faults, adequately lithologically homogeneous.

The conclusions of regional geologists were followed by the evaluation of a hydrogeologist - specialist. Selected units were critically assessed especially from the viewpoint of their permeability. From the evaluation it follows that sufficient quantity of basic hydrogeological characteristics are necessary for the required depth level, which are at present not available.

The assessment of the hydrogeologist was decisive for the selection of prospective territories, while the conclusions of geophysical evaluation were taken into consideration as well (Šefara, 1994).

In the second stage, prospective territories shall be subjected to evaluation from the viewpoint of:
- protected mineral deposit territories and prognostic deposits
- protected water-resources management territories
- protected natural areas (national parks, protected land areas etc.)

and others, in the sense of above described criteria.

Further exclusive and limiting criteria will be applied to distinguished territories in next stages of investigation. The following text presents the results of the assessment of the Slovak territory after the first stage of investigation.

Prospective areas of the Western Carpathians for the construction of high-level radioactive waste repository

The aim of the evaluation of the whole territory of Slovakia is to distinguish and characterise those areas in Slovakia where the occurrence of HGE is probable, and to locate in them HGS with an accuracy corresponding to the level of present knowledge.

A great disadvantage of Slovakia from the viewpoint of possible DR construction is the small area of the country (49 013 km^2). Extremely high requirements for such a construction make necessary the evaluation of the territory according to many criteria, while geological criteria are only one group of them.

On the basis of geological and hydrogeological criteria, several prospective host geological environments (Fig.1) were distinguished on the territory of the Western Carpathians. Their brief characterisation is presented below.

1. Tribeč Mts.
2. Žiar Mts.
3. Rochovce
4. Territory between Čierny Balog and Sihla
5. Territory between Lom nad Rimavicou, Kokava nad Rimavicou, Málinec and Detvianska Huta
6. Nižná Slaná
7. Territory between Smolník, Mníšek nad Hnilcom, Prakovce and Poproč
8. Nízke Beskydy Mts. - area of Zborov
9. Juhoslovenská panva Basin (area of Lučenec Basin, SW part of the Rimavská Basin and Cerová vrchovina Hills)

Crystalline complexes

On the basis of the evaluation of Core Mountains belt and the Veporicum (BEZÁK - LUKÁČIK, 1994, KOHÚT, 1995), prospective host geological environment was located in the following areas: granitoid massif of the Tribeč and Žiar Mts., Rochovce granite, central part of the Vepor belt and the territory of metamorphic rocks of the Krakľová zone of the Veporicum (Fig. 2)

Tatricum

Tribeč Mts.

As a prospective territory has been selected an area built of granitoid rocks of the southern, Tribeč-Zobor block. The Zobor Massif, one of the largest in the Western Carpathians, is formed of granitoids characterised by monotoneity, little variable composition, corresponding to massive medium-grained tonalites.

The structure of crystalline complexes in the Tribeč Mts. is affected by the important transversal Skýcov Fault and other accompanying faults of NW-SE direction. Besides cross-wise faults, the granitoid core was to a considerable extent divided by faults of NE-SW direction. Important role was played by strike-slip faults and marginal faults on the contact of granitoids and younger units. The strike-slip faults are not assumed to reach a depth of over 500-700 m from the surface. Below this level, a relatively stabilised granitoid massif is assumed in the Zobor part. Especially in the area between Javorový vrch Hill and Veľký Tribeč, at present there are not known any limiting structural-tectonic phenomena in the present relief of the uncovered plutonic body. Besides this, no indications of ore mineral concentrations are know here. This were the reasons for the selection of this territory for further investigations.

Žiar Mts.

As prospective from the viewpoint of finding a HGS are considered granitoids of these core mountains. They form the predominant part of the crystalline complex and they are represented mostly by varieties with porphyric K-feldspars. Leucocratic aplite-pegmatite granites occur mostly in marginal upper parts of the granitoid body. Two-mica granitoids occur in the central part. Oriented and schistose types, affected by mylonitization, are spatially related to fault zones.

Predominant are faults of NNE-SSW direction, as well as parallel faults partly of SW-NE direction, participating in the segmentation of the crystalline core. Important are marginal faults of NE-SW direction.

At first sight it appears that the crystalline core of the Žiar Mts. is strongly tectonically affected. In reality this granitoid core is the most eroded one among core mountains of the Central Western Carpathians. During the Paleogene and Neogene, the upper, strongly alpinotype-affected (1000 to 1300 m in vertical cross-section) granitoid horizon was eroded away. In this way, the deepest plutonic levels have been exposed, in which protomagmatic structures may be identified. The granitoid core of the Žiar Mts. has on radar images the character of a territory affected only by germanotype tectonics, which makes it an exception in the Western Carpathians (KOHÚT, 1995). The prospects of finding economically exploitable mineral resources in the Žiar Mts. are low.

Veporicum

Rochovce

From available knowledge obtained from the investigation of crystalline complexes, as relatively prospective may be regarded young (Cretaceous) granitoids, which were not affected by tectonic

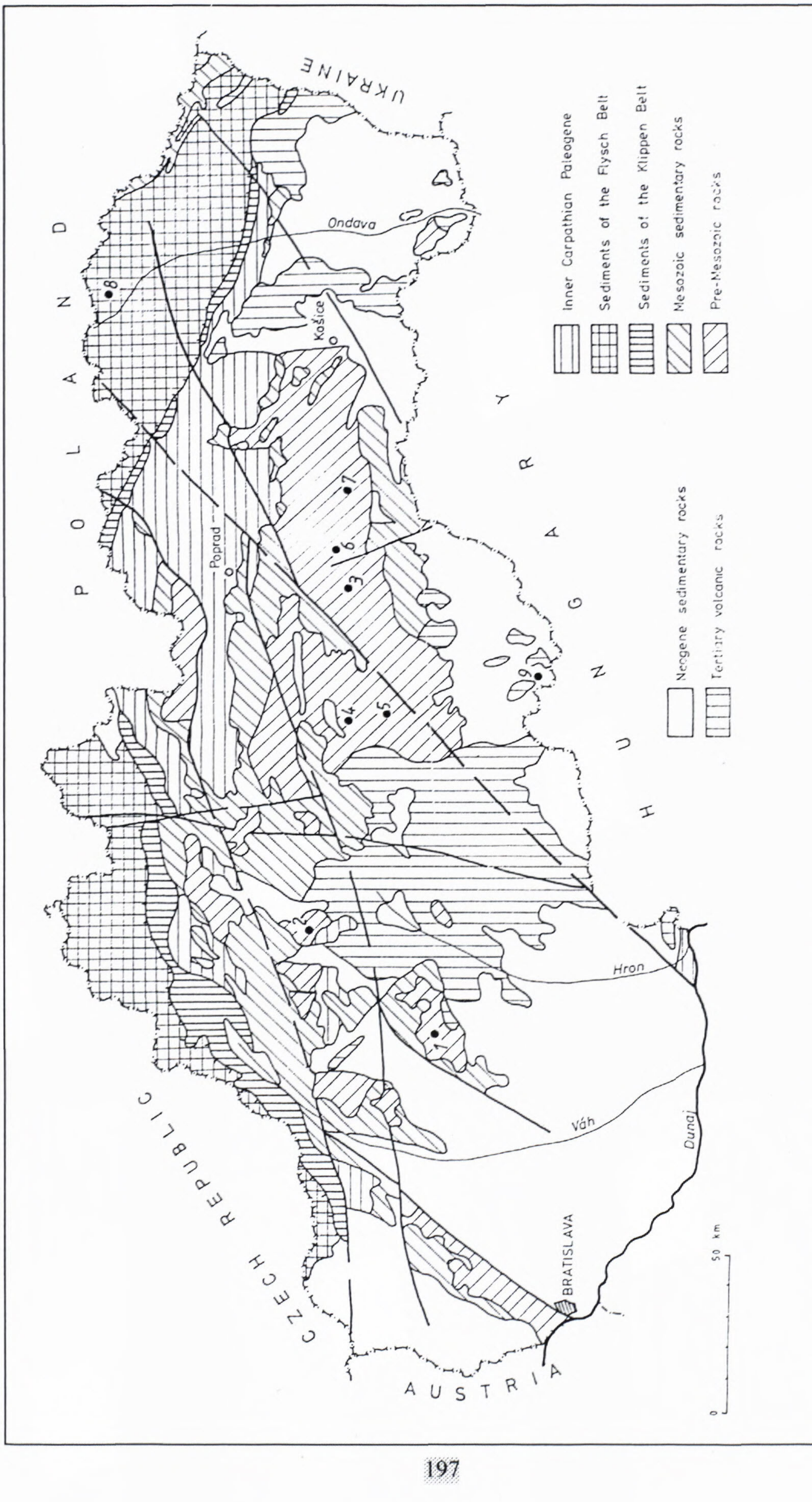

Fig. 2 Prospective areas for the final repository of high-level radioactive waste and spent fuel in the Slovak Republic

processes during the Alpine orogeny. Rheologic disturbance of these bodies may be assumed to be far lower than deformation of older bodies, to which they were subjected in main stages of both orogenies. Such body appears to be the Rochovce granite, identified for the first time by drilling survey (KLINEC et al., 1980).

It is a massive porphyric granite body, little faulted, with isotropic internal structure. It occurs at a depth of about 400 m below the surface and its great depth extent is assumed. Stratigraphically, its formation is dated as Upper Cretaceous (HRAŠKO, 1993). Past investigations of this body were aimed at intrusions accompanying the Mo-W mineralization. Their presence may be an unfavourable factor from the viewpoint of HGE selection.

The most important tectonic lineament of the area is the Ľubeník-Margecany line. The body is on north-east and east submerged along the Štítnik fault system, while in the north it is restricted by the Rochovce fault. The overall tectonic effects on the body are not known.

Territory between Čierny Balog and Sihla

The most frequent petrographic type of the Čierny Balog metamorphic rock are biotite plagioclase paragneisses, in some places with signs of partial anatexis. Characteristic of them are the same metamorphic conditions in all complex, without more significant signs of young recent tectonics, which is the main reason for their being included into further investigations.

The territory between Lom nad Rimavicou, Kokava nad Rimavicou, Málinec and Detvianska Huta

The Vepor pluton is built in another prospective area absolutely predominantly of deformed porphyric granitoids, with several cm large K-feldspar phenocrysts. A smaller area is occupied by biotite granodiorites to tonalites of Sihla type and by a belt of hybrid granitoids in the southern part. In all varieties typical are small bodies or veins of leucocratic granites, aplites and pegmatites.

The Vepor granitoid pluton is the largest one in the Western Carpathians (approx. 60 km in lengthwise direction). Even though it is a complex pluton, consisting of several granitoid rocks and Alpine deformation (recrystallization) has here regional character, due to its size it has been recommended for further investigation with prospects of finding a suitable HGE.

Hydrogeological properties of the rocks of Western Carpathian crystalline complexes in greater depths are so far little known . They may be estimated only from analogies with other territories. From the viewpoint of radioactive waste deposition their main deficiency is their relatively considerable petrophysical heterogeneity, resulting from tectonic effects and in some areas also relatively varied petrographic composition, with frequent alternation of bodies with different petrographic characteristics. An unfavourable result of tectonic disturbance is besides manifestations of disjunctive tectonics, connected with local increase of permeability, also frequent occurrence of mylonitized zones, which may represent in some sections an environment with increased permeability even in greater depths (JETEL, 1994).

To be able to asses reliably the suitability from hydrogeological viewpoint it is however necessary to determine hydraulic parameter values of rocks in the considered depths and their anisotropy. Only on the basis of such data it would be possible to evaluate more strictly the suitability from the viewpoint of hydrogeological and other criteria.

The Paleozoic of the Spišsko-gemerské rudohorie Mts.

On the basis of a study of literature concerning the Paleozoic of the Western Carpathians (VOZÁR, 1994), several prospective host geological environments have been distinguished here (Fig. 2).

Area of Nižná Slaná and territory between Smolník, Mníšek n. Hnilcom, Prakovce and Poproč

From geological viewpoint as potential ones may be assessed selected horizons of the Gelnica Group (Cambrian-Silurian) formed of graphite phyllites and phyllites with intercalations of lydites and carbonates. The above rocks attain thicknesses of several hundreds of meters. They are a part of the Drnovo Formation (Silurian-Devonian).

Experience from mining in Nižná Slaná shows that horizons 450-650 m thick are without groundwater circulation. A disadvantage is however the disturbance of hydraulic continuity and sealing of the environment by mining works, from which the older ones may have not accurately known position. The rocks of the Gelnica Group in the area Smolník-Mníšek nad Hnilcom - Prakovce - Poproč may be basically considered suitable, systematic information on permeability and possible privileged hydraulic communications related to fault tectonics is however lacking. In the near-surface zone of this area, the dependence of concentrated groundwater circulation on the direction of fault lines has been unambiguously proved. Information on the depth extent of this relationship is lacking.

Flysch Belt

Although the Paleogene flysch formations cover a considerable part of the Slovak territory, in view of their lithologic content, mostly carbonate underlying rocks and complex tectonic conditions it is difficult to distinguish in this environment a prospective territory. The only conditionally suitable site, recommended for further investigation, are the Nízke Beskydy Mts. (Fig.2).

Nízke Beskydy Mts.

From hydrogeological viewpoint the principal unfavourable factor for radioactive waste deposition in the Flysch Belt territory is the small thickness of hydraulically homogeneous rock bodies, which could function as strictly defined hydrogeological insulators and serve as a suitable host environment for radioactive waste deposition.

Intergranular permeability of sandstone members of the flysch complex is at present state of diagenetic lithification usually insignificant, so that decisive for groundwater movement is fissure permeability. At the same time, on the basis of the results of a study of spatial distribution of hydraulic parameters in flysch rocks (JETEL, a, b. JETEL et al., 1990), it may be stated that the flysch rock massif displays a high degree of homogenisation, especially in the western section of the Flysch Belt. These facts resulted in greater or smaller suppression of differences in primary permeability and hydrogeologic function of different lithologic type of flysch rocks.

The permeability of flysch rocks in the Western Carpathians is in the first place determined by their present depth, tectonic effects and age of the rocks, while the influence of lithologic differences is not in all parts of the Flysch Belt the same and unambiguous (JETEL, 1991).

As a suitable host environment in the Flysch Belt of the Western Carpathians could be from this viewpoint considered those sections of the Biela Vež Formation of the Magura unit in the eastern part of the Flysch Belt which are in sufficiently thick and deposited in necessary depth.

The value of the hydraulic conductivity k = 10-11 to 10-12 m/s in depths of 300-500 m and more may be considered in this environment - outside the reach of tectonically related fissure zones - to be real.

Selected parts of the Biela Veža Formation would in these depths comply also with other hydrogeological criteria (insignificant groundwater flow velocity, non-existence of exploitable groundwater resources). The possibility of waste deposition in the upper part of the Biela Veža Formation may be however doubted by the problem of prospective carbohydrate deposit occurrence in this territory, or by the probability of survey in more distant future.

On the basis of lithologic content, required depth and thickness of HGE, as well as hydrogeological conditions, as a prospective area has been distinguished the area of Eastern Beskydy Mts., near Zborov.

Inner Carpathian basins

On the basis of geological evaluation of Inner Carpathian basins (VASS-ELEČKO, 1994), prospective environment has been localised in a part of the Juhoslovenská panva Basin (Fig. 2).

Lučenec Basin, SW part of the Rimavská Basin and Cerová vrchovina Hills

The prospective area belongs geomorphologically into the SE part of the Lučenec Basin, SW part of the Rimavská Basin and Cerová vrchovina Hills.

From lithological, structural and spatial viewpoint the most prospective HGS for the localisation of a repository appear to be two lithostratigraphic units? the Séčen schlier of the Lučenec Formation (Egerian) and Lenártovce Beds of the Číž Formation (Kiscellian).

The above lithostratigraphic units form the principal mass of the basin filling. The predominant lighologic type in both formations are siltstones and claystones. Maximum thickness of the Číž Formation in the Lučenec and Rimavská Basins attains over 300 m, in the underlier of the Cerová vrchovina Hills more than 400 m. Maximum thickness of the Lučenec Formation in the Lučenec Basin and Cerová vrchovina Hills is 1200 m, in the Rimavská Basin 1100 m. The thicknesses of both formations increase from the northern margin toward the south (VASS et al., 1989, VASS - ELEČKO et al., 1992). Cumulative thickness of both formations varies between 1400 and 1600 m.

From the viewpoint of hydraulic permeability it is necessary to investigate the HGS in greater detail, especially as far as possible permeability of the Séčen schlier siltstones and permeability along the faults (acidulous water springs) are concerned. In some parts of the HGS there are also sandstone lenses of not very great thickness and extent, which are saturated by fossil marine water.

On the majority of the territory under consideration the overlier of the Lučenec Formation are directly Qarternary sediments of insignificant thickness.

Conclusion

Distinguishing suitable geological structures for the construction of final repository of high-level radioactive waste and spent fuel is a long-lasting process, with the participation of many factors. Geologic conditions are only one of the criteria for final selection.

The aim of our investigation was to distinguish several areas, where detailed investigation and survey would be applied successively, while other relevant characteristics (geologic-tectonic, hydrogeological, geochemical, thermomechanical and thermochemical, geotechnical, seismic, hydrological) would be determined as well as a prognosis of geological and morphologic development within a time range of 10^4 to 10^5 years.

The briefly described potential HGE are a partial result of the at present carried out investigations. Final suggestions of HGE for further investigations may be in part different. The reason for this is the fact that when evaluating geological structure of Slovakia, only some selected criteria were considered. The application of other criteria is the subject of following study.

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