CHAPTER 25

PROGRAMME AND RESULTS OF INITIAL PHASE OF RADIOACTIVE WASTE ISOLATION IN GEOLOGICAL FORMATIONS IN UKRAINE

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Abstract: The concept and a programme for radioactive waste disposal in geological formations of Ukraine have been developed. On the basis of certain criteria, an evaluation of the territory of Ukraine has led to the selection of three geological regions and three types of formations that are favourable for RAW disposal. The programme of research and development includes three stages: preparatory (1993-95), preparatory/experimental (1995 -2004), and preparation for construction (2005-2010). The completion of the preparatory stage resulted in the selection of zones and a number of candidate sites that are favourable for RAW isolation.

25.1 INTRODUCTION

Ukraine has been forced to develop research and development (R&D) programmes on radioactive waste (RAW) management due to their accumulation in significant quantities. This is a result of the rapid development of nuclear power and other RAW-producing industries, as well as the consequences of the Chernobyl disaster.According to the generally accepted point of view, a realistic solution for the RAW disposal problem is isolation in geological formations. The importance of this problem resulted in a research program initiated by the State Committee on Nuclear Power Utilization (Goskomatom), National Academy of Sciences, State Committee on Geology, and some other organizations.

The preparatory stage of research on RAW isolation in geological formations has been completed. Ukrainian scientists have developed the concept and a programme of R&D (experimental and methodological studies on a pilot scale as applied to geological and mining activities). The territory of Ukraine has been assessed as to the conditions for RAW isolation, and geological regions and formations favourable for this purpose have been selected. Regional studies, to be discussed below, have resulted in the selection of a number of favourable zones (areas) within these regions, and candidate sites have been selected. Simultaneously, preliminary analyses of the main engineering and construction problems related to RAW isolation have been made.

However, Ukraine is still lagging considerably behind in the field of R&D as compared to the countries that have been developing their programmes over several decades. Ukraine has established scientific relations with specialists in the field of RAW management. As a result of an international conference on “Isolation of RAW in Geological Formations” that was held September 20-24, 1994 in Kiev, a basis for cooperation in this field has been initiated with eastern European countries.

Investigations on R&D have been sponsored by Goskomatom partly by finances from budgets of participating institutions, as well as by special funds from the State Committee on Science and Technology for individual projects. These investigations are carried out by specialized multidisciplinary research teams, from 23 R&D institutions (Institute of Geological Sciences, State Committee on Geology, Kiev University, Goskomatom, etc.).

25.2 DESCRIPTION OF THE WORK

25.2.1 General Concept

The general concept for RAW isolation in geological formations in Ukraine is based on the experience of advanced countries, IAEAbasic principles and technical criteria adapted to geological, socio-economic and ecological conditions in the Ukraine[1-5]. The principle of long-term (over 10,000 years) RAW isolation is based on the idea of disposal as a geological engineering system that must satisfy a range of conditions (final form of

RAW, disposal in deep geological formations at an appreciable depth, special engineering barriers, etc.).

In the preparatory phase of the R&D programme, certain criteria were adopted, and an evaluation of the territory of Ukraine was carried out[3].As a result, three geological regions (Fig. 25.1) and three types of geological formations, favourable for RAW disposal, have been selected (see below).

The amount of waste to be isolated is (metric tons): spent fuel - 27,000, decommissioned waste - 12,000, Chernobyl zone - 20,500, for a total of about 60,000. The future accumulations of spent fuel are estimated to be (metric tons): year 2000 - 2020, year 2005 - 3725, year 2010 - 5460.

After an appropriate period of cooling, or reprocessing procedure, the spent fuel has to be encapsulated. Technological waste must be conditioned and solidified. As for the Chernobyl zone wastes, there are two variants: straight burial and separation (enrichment) for volume decrease. Two types of canisters have been considered: stainless steel and steel-copper. After being reprocessed in Russia, the spent fuel has to be returned in standard containers intended for burial.

In selecting procedures for repository construction, world experience in underground methods, and current projections were taken into consideration. Our approach is to develop procedures that are the most simple and least expensive. The repository will consist of a wide transport tunnel and system of galleries for disposal (Fig. 25.2). Disposition of the different types of RAW

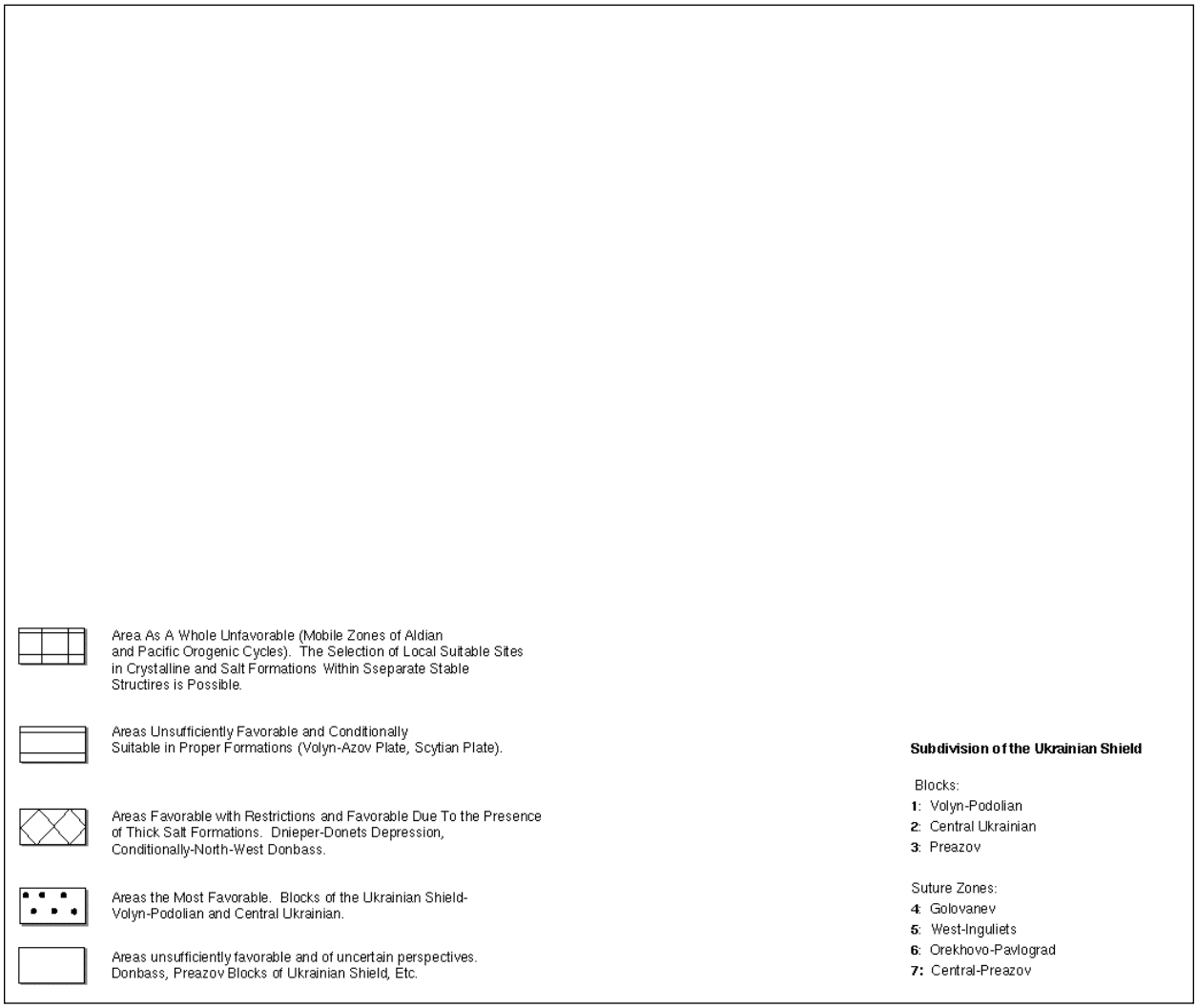

Figure 25.1. Subdivision of the Ukraine on conditions of RAW isolation in geological formations.

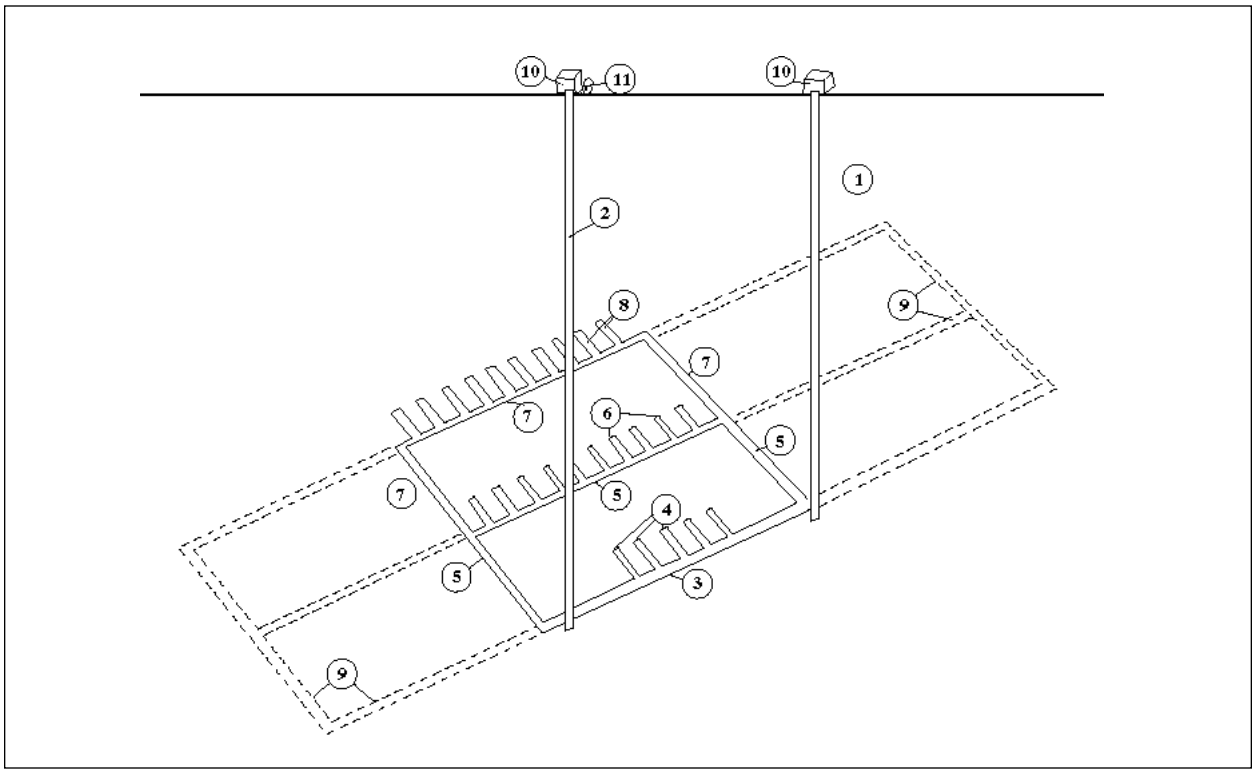

Figure 25.2. Concept of underground experimental laboratory and storage. Legend: 1 - Mine shaft; 2 - ventilation shaft; 3 - crosscut of laboratory; 4 - chambers of laboratory; 5 - crosscut of the first stage of storage; 6 - chambers of the first stage of storage; 7 - crosscut of the second stage of storage; 8 - chambers of the second stage of storage; 9 - crosscut of the following stages ; 10 - mine surface building; 11 - fan installation.

involves: spent fuel in short boreholes in the floor of galleries, and technological waste and Chernobyl waste in special cells in the galleries. The system of engineering barriers includes the matrix, a buffer, containers, compactors, and backfilling material of a bentonite composition. Sometimes, a protective covering is needed on the cavern walls. Special non-blasting methods of excavation for maximum preservation of rock integrity have to be used.

The construction of an underground research laboratory (URL) is planned as the first stage in developing the repository. The investigations in the URL are of a traditional nature but the programme may be shortened using results from actual world experience.

25.2.2 Research and Development Programme

The purpose of the R&D programme is to develop the complex measures needed for RAWisolation (long-term storage and final burial) in geological formations. The programme is based on total safety for the population and environment using principles elaborated by IAEA. The overall programme for R&D includes: site selection and investigation, projections, exploration, construction, testing, exploitation and final closure of the isolation facility. There are seven topical areas: (1) mining/geology (including geological exploration); (2) technology; (3) social; (4) regulatory; (5) legal; (6) management and (7) construction.

The area of mining/geology is actually central and is relatively independent due to its long term duration and the essential value of the data being collected. The main tasks in the mining/geology area are as follows:

1. Conducting theoretical investigations of geological, geochemical, hydrogeological, geomechanical, mining, thermophysical and other problems connected with site selection, exploration, construction, exploitation and closure of the isolation facility, as well as safety and the development of a methodology

of investigations.
2. Evaluation of the territory of Ukraine from the point of view of RAW disposal.
3. Regional studies to elaborate on selection criteria, structures and the selection and evaluation of sites.
4. Supervision of exploration on selected structures and sites.
5. Construction of URL to carry out selected experiments.
6. Perfection of construction and technological parameters for the RAW isolation facility based on the synthesis of exploration data, experiments in the URL etc.
7. Develop a prognosis for the functioning of the isolation facility under the influence of the effects of geological evolution and scenaria of possible catastrophic events (safety analysis).
8. Develop a monitoring system and system of control (management).
9. Provide a basis for controlling construction of the RAW isolation facility.
10. Provide a basis for supervising the exploitation and closure of the facilities.

The programme of R&D includes the following stages:

1. Preparatory - 1993-95
   Goal: elaboration of concepts, selection of sites, exploration;
2. Preparatory/experimental - 1996-2004
   Goal: exploration, construction of URL, collection of experimental data during construction and exploitation of the isolation facility, and
3. Preparation for construction - 2005-2010
   Goal: final preparation for construction of RAW isolation facility (eventually the beginning of the construction).

The durations of these stages are not yet firm and will actually depend on the financial situation.

25.2.3 Methodology of Scientific Investigations.

The generally accepted concept of the repository as a multibarrier, geological/engineering system takes into account that the rock formation, as a main barrier, is the leading factor in determining the safety of long term isolation. That is why a comprehensive investigation of the geological environment provides a foundation for investigations in the area of mining/geology.

The final goal in the preparatory stage of the R&D programme is the selection of site(s) for the isolation of RAW. This goal can be achieved by solving the following tasks in a proper hierarchical sequence that is correlated with the stages of programme investigations mentioned above:

1. Evaluation of the territory of Ukraine from the point of view of RAW isolation;
2. Selection of geological regions and formations potentially favourable for RAW isolation;
3. Regional analysis of potentially favourable formations in a hierarchical sequence. Region-Zone (group of structures)-Local Structure (site), (Fig. 25.3); and
4. Selection and evaluation of sites.

Tasks 1-3 and part of 4 have already been accomplished.

As a result of the evaluation and ranking of 12 geological regions in Ukraine, only three have been selected as favourable for RAW disposal: (1) Ukrainian shield; (2) Dnieper-Donets depression; and, (3) northwestern Donbass. Conditionally, the southwestern slope of the east European platform of the ancient Volyn-Azov plate is under investigation.

The selection of formations in these regions was made on the basis of an initial evaluation of parameters and by analogy with world experience. By mean of this approach, three types of potentially favourable formations have been selected: crystalline, salt and argilaceous. The next step was to carry out a regional analysis of formations.

The hierarchical sequence of investigations (Regional-Zonal-Local) is similar for all formations. The methodology of the selection process on these three levels is based on the usage of a set of mining/geology area models, categorized on different scales according to the level of investigation.

The results of this selection of a set of models (as well as data from social, economic, ecological and other studies) provide the basis for setting up criteria for the selection, comparison, estimation and ranking on zonal and local levels. This set includes three groups of practically equal importance:

I. Safety (technical-geological)
   a. tectonic
   b. neotectonic
   c. seismic
   d. hydrogeologic

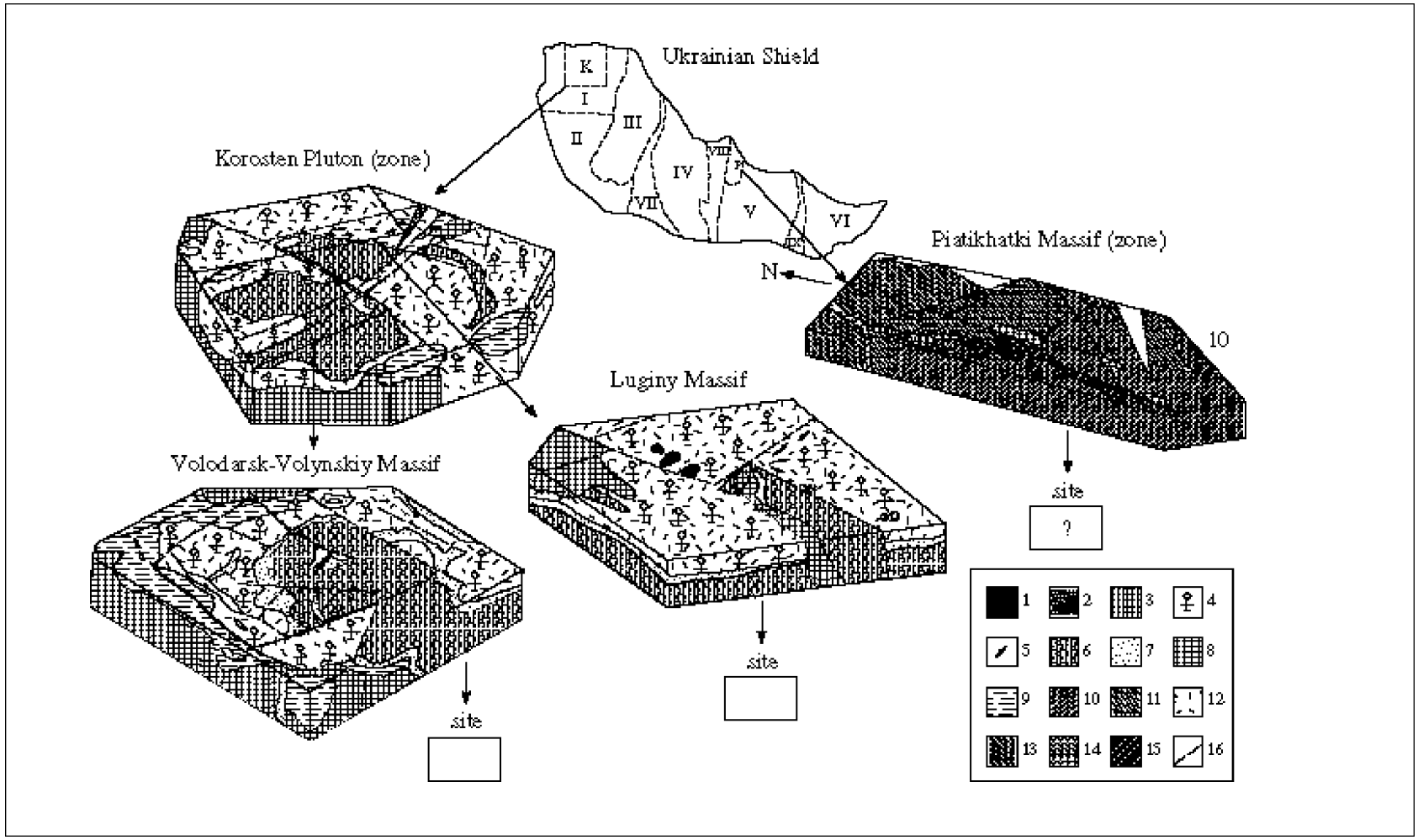

Figure 25.3. Principles of site selection in Ukrainian shield: I - Volyn, II - Podolia, III - Bielaya Cerkva, IV - Kirovograd, V - Near-Dnieper, VI - Near-Azov Pavlograd, VII - West Ingoulets, VIII - Golovanev, IX - Orechovo. Legend: 1 - alkaline syenites; 2 - monzonites, gabbro monzonites: 3 - olivine gobbros, rarely gabbro-peridotites, gabbro-pyroxenites; 4 - granite-porphyries, rapakivi and rapakivi-like granites; 5 - dikes of diabase and gabbro-diababase; 6 - anorthosites, gabbro-anorthosites; 7 - norites, gabbro-norites; 8 - granites (Zhitomir and Kirovograd types); 9 - biotite gneiss, quartzitic sandstones; 10 - plagiomigmatites, plagiogranites; 11 - granites, migmatites; 12 - biotite granites, aplitic and pegmatoid granites; 13 - tonalites, plagiogranites, plagiomigmatites; 14 - andesite and diabase metaporphyry amphibolites; 15 - graphitic and biotites shales, metasand-

e. type of formation
f. goemechanic
g. geochemistry (including waste composition)
h. geomorphologic
i. hydrologic
j. climatic
k. technogenic/ecologic conditions
l. mineral deposits

II. Social-political
a. demographic
b. psychologic
c. contamination from Chernobyl

III. Technologic complexity
a. construction cost
b. technologic complexity

On the zonal and local levels, the results of the social-economic and ecological investigations must be developed in different degrees of detail.

In the areas of mining/geology, the set of models that are being used in the hierarchical sequence of regional investigations includes both static and dynamic aspects. The dynamic aspect must consider two variants: evolutionary and revolutionary (catastrophic, or maximum project risk). Every model has its own tasks, objects and phenomena for investigation, but all models are integrated within the whole set. An understanding of the functioning of the disposal facility has to be developed from an appropriate synthesis of these models.

These models are developed using three kinds of data: theoretical, computational (mathematical, statistical, probabilistic) and experimental. The experimental data are obtained as a result of URL investigations. The dimensions of these models are generally known: near field and far field. The objectives of the investigations for this work are well described in the literature. The main task in analyzing the functioning of a disposal facility is the prognosis of its long term safety. This prognosis has to be developed within a framework that includes scenaria of evolutionary and catastrophic phenomena. One of the terminal tasks of modelling is the estimation of radionuclide behaviour in the biosphere (accumulations in surface waters, sorption by clays and organic matter etc.). The monitoring of an RAW disposal facility may be realized in the near field by means of direct observations *in* situ; in far field, by mean of special boreholes and surface observations.

25.3 RESULTS OF REGIONAL STUDIES

Regional studies have been carried out in the Ukrainian Shield, Dnieper-Donets Depression and Donbass.

In the Ukrainian shield (Fig. 25.3), two zones have been selected as favourable for RAW disposal: (1) Korosten pluton and a group of structures in the middle of the Near-Dnieper area, where the preferable type of rocks, granites and gabbro-anorthosites of Proterozoic age are found; and (2) in salt domes of the Dnieper-Donets depression in the northeastern, and southwestern marginal zones, and in the southeastern part of the Donbass depression, in bedded salt formations. Argillaceous formations of sufficient thickness are spread over the southwestern slope of the east-European platform (Volyn-Asov plates, Cambrian, Oligocene), and in the Donbass-Dnieper-Donets depression. In the latter locations, detailed geological investigations have not yet been carried out.

In the course of regional studies, several candidate sites have been chosen. In the northern part of the Korosten pluton, two favourable massifs (subzones) have been selected, i.e. Luginy and Volodarsk-Volyn massifs. The Luginy massif is composed primarily of granite-rapakivi, and two sites within its limits have been chosen. Eight salt domes that are potentially favourable for RAW disposal have been selected within the boundaries of the Dnieper-Donets depression.

On the basis of the mining/geology models and considering the criteria mentioned above, a ranking of selected sites has been made. Crystalline formations within the Korosten pluton have been ranked as follows: (1) first priority for the Pribytkov and Doroginby sites in the Luginy massif; and (2) second priority for the Novo-Borovaya and Zankovo sites in the Volodarsk-Volyn massif. Within the limits of the Dnieper-Donets depression, sites have been ranked as follows: (1) first priority for the Kaplintsy, Isachki and Yatsyno-Logoviki salt domes in the northeastern marginal zone; (2) second priority for the Dmitrievka, Siniovka, and Romny salt domes in the southwestern marginal zone; and (3) third priority for the Aleckseevka salt dome in the southeastern part of the depression.

Two zones of Permian bedded salt formation have been studied in northwestern Donbass.

25.4 CONCLUSIONS

As a result of completing the initial stage of the R&D programme, certain regional studies have been carried out. The regional studies resulted in the selection of favourable zones of crystalline formations in the Ukrainian shield and salt formations in the Dnieper Donets depression (as well as in northwestern Donbass, where technogenetic activities have to be considered.) Several candidate sites have been selected in favourable zones. The completion of this initial stage leads to the next stage of specialized exploratory geological/geophysical investigations. This stage is much more complicated and much more expensive.

The initial stage of investigations was completed during 1993-95. Such rapid advances were possible due to a thorough understanding of the geology of the territory of Ukraine, the excellent work of the scientific team, and the availability of results from world experience in the field of RAW in advanced countries (USA, France etc.).

Ukraine possesses scientific and technological capabilities sufficient for the effective completion of the necessary R&D related to exploration and URL construction. But the actual economy in the Ukraine provides no reason for optimism that financing sufficient for an effective realization of such an expensive program will be forthcoming. Thus, the possibilities for program support will depend upon a significant increase in national funds and the organization of international cooperation.

The Institutions involved in R&D programmes in waste isolation (as well as the Ministry of Environment Protection and Nuclear Safety) and the State Committee on Nuclear Energy Utilization, as a sponsoring institution, have initiated an annual international conference, "Isolation of RAW in Geological Formations." The first conference was held September 20-24, 1994 in Kiev. This conference has revealed the interest of eastern European countries (Poland, Slovakia, the Czech Republic, Russia, Hungary, Slovenia, Belarus, etc.) in a program of cooperation. A second conference is scheduled to be held in 1995.

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