ACTIVIDADES EN ALMACENAMIENTO DE RESIDUOS RADIACTIVOS DE LOS SERVICIOS GEOLOGICOS DE:

.ESTADOS UNIDOS

.REPUBLICA FEDERAL ALEMANA

.REINO UNIDO

.FRANCIA

.HOLANDA

ENERO 1985

INSTITUTO GEOLOGICO
Y MINERO DE ESPAÑA

S I N T E S I S *

Todos los Servicios Geológicos mencionados, tienen encomendadas las misiones técnicas de selección y evaluación de emplazamientos para depósitos de residuos radiactivos de alta actividad, y en general, también para los de media actividad. En algún caso, cómo el del Servicio Geológico Federal Alemán, su responsabilidad abarca el proyecto del propio emplazamiento (Mina de Gorlaben). La razón fundamental de estas misiones, estriba en que el problema técnico del almacenamiento de residuos radiactivos, es fundamentalmente un problema geológico.

Este servicio técnico, se realiza en todos los casos para el Departamento o Entidad Gubernamental responsable del almacenamiento definitivo.

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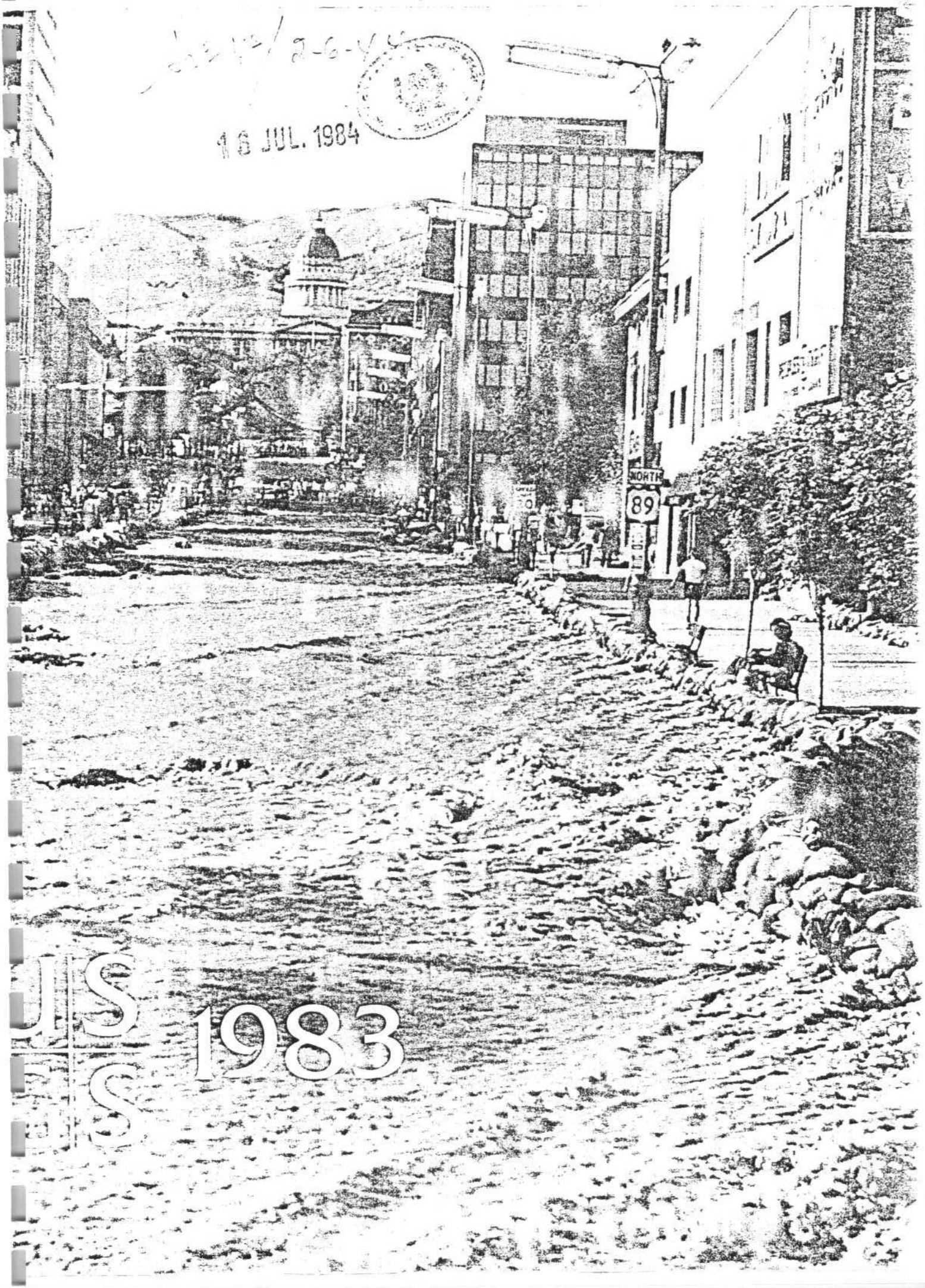
* La documentación corresponde a los Informes Anuales de Actividad de los Servicios Geológicos correspondientes.

SERVICIO GEOLOGICO DE ESTADOS

UNIDOS DE AMERICA (U S G S)



USGS 1983

Hazardous Waste Hydrology

The safe disposal of hazardous waste provides serious challenges to our Nation, States, and local communities. The great variation in nature and degree of hazard from a wide variety of dangerous substances demands that we employ the most scientific management of which our society is capable. The proper collection, interpretation, and use of earth science information is critical to a program of effective control for such wastes.

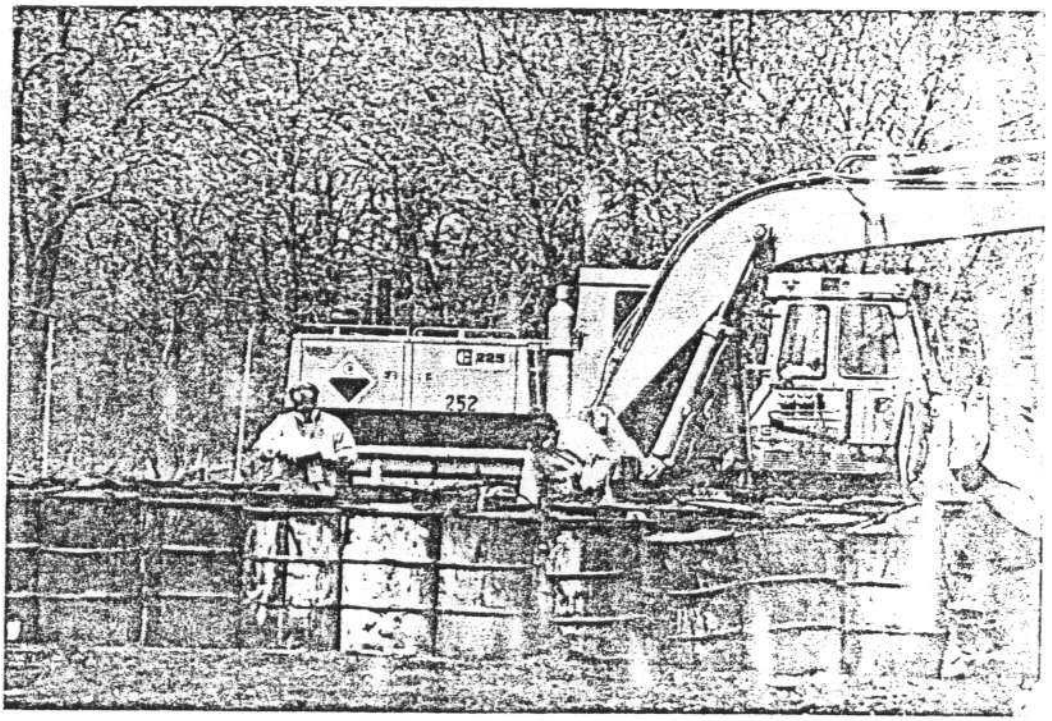
With this in mind, the U.S. Geological Survey, through the Office of Hazardous Waste Hydrology, established a program to focus hydrologic and geologic expertise on the earth-science aspects of safe, effective waste disposal and ground-water contamination problems. The comprehensive program is composed of three elements: high-level radioactive waste, low-level radioactive waste, and nonradioactive toxic waste.

High-Level Radioactive Waste

High-level radioactive waste includes spent nuclear-reactor fuel and material derived from reprocessing nuclear fuel. The waste is characterized by high radioactivity and by nuclides with relatively long half-lives, and it generates considerable amounts of heat in its decay. After more than 30 years of nuclear-power development, a suitable permanent repository has yet to be developed for this type of waste. The most viable disposal concept consists of placing the waste in a deep-mined repository as much as a few thousand feet below the surface of the Earth in which the waste is effectively isolated from man's environment for tens of thousands of years.

The [redacted]e of the Survey high-level waste program is to support the national effort, led by the U.S. Department of Energy, [redacted]s where wastes can be effectively isolated in deep geologic environments. Specific program objectives are to provide techniques for (1) evaluating the chemical interaction of nuclear waste with natural fluids and with the rock and mineral framework of ground-water systems, (2) evaluating transport of waste nuclides by ground water, (3) characterizing geologic and hydrologic conditions at sites under consideration by the U.S. Department of Energy, and (4) screening large provinces of the United States for smaller areas having potentially favorable earth-science characteristics for waste disposal.

The earth science problems associated with this endeavor are complex and incompletely understood. The Survey's High-Level Radioactive Waste Program stresses



Earth science investigations of hazardous waste disposal sites provide site-specific geohydrologic data as well as generic information on the effectiveness of investigation techniques, monitoring systems, and so forth. (Photograph by Stephen C. Delaney, U.S. Environmental Protection Agency.)

Careful techniques being developed and tested through programs of the Office of Hazardous Waste Hydrology are employed to collect ground-water samples from a hazardous waste disposal facility and to safeguard the health of hydrologic technicians. (Photograph by Stephen C. Delaney, U.S. Environmental Protection Agency.)

concept of isolating nuclear wastes by eans of relatively independent multiple iers to waste nuclide migration. A ma- equirement is to identify environments here such multiple natural barriers are elieved to exist. A second major require- t is to identify and understand the crit- hydrogeologic properties and proc- sses that are involved in radionuclide ration from a repository to environ- nts of living organisms.

The Comprehensive Nuclear Waste olicy Act of 1982 defines the timetable responsibility of the Department of ergy in selecting the first and second positories. As specified in the Act, the vey program is designed to provide sultation and support to the Depart- ent of Energy to accomplish this national ission, which includes selecting the first sitory site in 1987 and burial of astes by 1998.

v-Level Radioactive Waste

Low-level radioactive waste is produced ospital, research and industrial facili- and nonfuel-related activities of uclear-reactor operation. It is generally uch less radioactive than the high-level tes, as its characterization implies, and es not generate significant amounts of eat in its decay. Disposal in this country shallow land burial, although ocean ping has occurred in the past.

There are six commercial low-level waste sites in the United States. Three are closed, due wholly or in part to environmental concerns, and a fourth closure is being contested in the courts. Provisions of the Low-Level Radioactive Waste Policy Act of 1980 may result in the establishment of as many as eight new commercial sites by 1990. In addition to these commercial sites, the Department of Energy operates six major and a number of minor low-level waste disposal sites for government-generated waste.

Low-level radioactive waste can pose a threat to human health if contaminants migrate from shallow land-burial sites in concentrations exceeding accepted standards. The principal migration pathway is generally ground water. The objective of the Survey program that addresses this problem is to gain a better understanding of the geohydrologic controls on the migration of radionuclides from shallow land-burial sites. To accomplish this objective, the Geological Survey has been conducting field research studies at five commercial and three Department of Energy disposal sites. Basic research complements the field investigations. Final reports on the first phase of field studies at commercial sites were published in 1983. These and other reports on earth science aspects of low-level radioactive waste disposal will be essential information for individual States or multi-State low-level waste compacts as

they seek new sites in accordance with requirements of the Low-Level Waste Policy Act of 1980.

Nonradioactive Toxic Waste

The safe cleanup and disposal of toxic chemical wastes from point and nonpoint sources is one of the most critical environmental problems confronting the United States. Point-source contamination from leaks, spills, and disposal of these wastes currently imposes high annual costs on the public and private sectors and can seriously affect human health and safety. The number of toxic substances requiring disposal is increasing, as is the quantity of that waste, the latter at a rate of from 3 to 5 percent annually. In New England and New York alone, more than 1,000 wells are known to be contaminated by organic chemicals, affecting the drinking water of millions of people.

Chemicals used in agriculture have been implicated in nonpoint contamination of shallow aquifers throughout the country. Pesticides currently in use are often different from the organochlorine and organophosphorous pesticides used one or two decades ago. Many of the newer pesticides have low soil affinity and high persistence, which allows them to pass unimpeded through the soil and into the saturated zone of the ground-water system.

In some cases, present technology is inadequate to develop technically sound and practical regulations to protect the public from hazardous chemical contamination in a cost-effective manner. Major technical questions are yet to be answered about the behavior of specific chemicals under different hydrogeologic conditions and about the safety, suitability, and economics of restoration and disposal methods.

The Geological Survey has begun an interdisciplinary program to provide the Na-

Research supported by the Office of Hazardous Waste Hydrology is conducted to obtain a better understanding of contaminant transport from hazardous waste disposal areas to local streams and aquifers. (Photograph by Stephen C. Delaney, U.S. Environmental Protection Agency.)

tion with earth-science information necessary to improve waste-disposal practices and to help solve existing and future ground-water contamination problems. The program uses the data bases and experiences of previous Survey work that are specifically relevant to the problem. It is closely coordinated with related programs of Radioactive-Waste Disposal, Regional Aquifer Systems Analyses projects, the Federal-State Cooperative Program, and studies of glacial deposits in the Eastern United States.

The program includes both field and laboratory investigations. Long-term research programs have been established at locations of known ground-water contamination to determine the behavior of specific contaminants in the ground-water system and to develop techniques with which to study them; these sites are near Bemidji, Minnesota, Pensacola, Florida, and Cape Cod, Massachusetts. This research is complemented by investigations of other field problems related to the reliability of predictive models and monitoring strategies for contamination. Geological Survey scientists have begun an appraisal of national ground-water quality to determine the magnitude and trends of the contamination problem. The appraisal is being closely coordinated with State governments.

Technical information developed within each element of the hazardous-waste program is incorporated into other elements of the program. Other Survey programs such as Regional Aquifer Systems Analyses and core research provide additional technical information and support. An early dividend of this coordination has been major support to the Department of Energy, the U.S. Nuclear Regulatory Commission, and State government agencies in the development of waste-disposal siting criteria. This comprehensive approach to solving earth science related problems of hazardous waste disposal places the U.S. Geological Survey in a position to continue contributing highly useful earth science information on this major national issue.

Climate Change

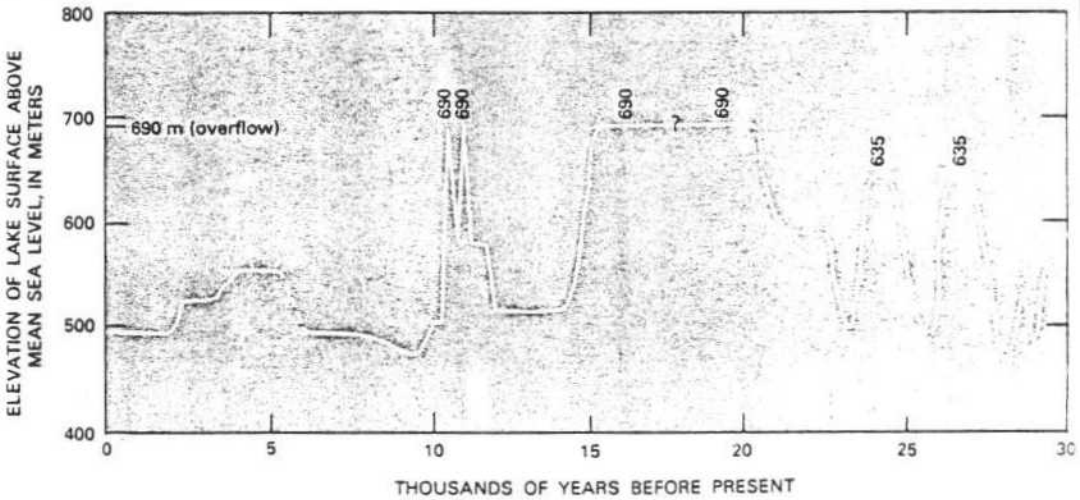
Most people are very much aware of the unusual weather that occurred during the last year. For example, record snows in the Midwest followed by early spring thaws and heavy spring rains caused flooding in a number of places such as Salt Lake City, Utah, and parts of the Southeastern United States. However, different types of geologic studies demonstrate that climate varies over a wide range of time scales from decades to millenia and that the climate changes experienced by modern man represent relatively minor wiggles superimposed on larger scale climatic fluctuations. Geologists are actively involved in the study of ancient climates (or paleoclimates) because much geologic data such as associations of fossils, structure and composition of sediments, and the occurrence of features directly related to glacial processes can provide information on past climates that extends beyond the historical records of man. Such information is essential for understanding current climate and for predicting future climate change.

The water-level fluctuations of ancient Searles Lake, California, shown in the figure, represent one kind of paleoclimate record. Although now dry, Searles Lake was one of about 100 lakes in the Great Basin that extend from the Sierra Nevada of California to the Wasatch Mountains of Utah. These lakes, which were developed in closed basins, are called pluvial lakes (rain lakes) because their water-level changes dramatically with changing climate. During times of cool and wet climate, the pluvial lakes expand, whereas during times of warm and dry climate, they shrink. Through studies of the geology of Searles Valley and cores from ancient Searles Lake, U.S. Geological Survey scientists have been able to reconstruct the history of Searles Lake for the last 30,000 years.

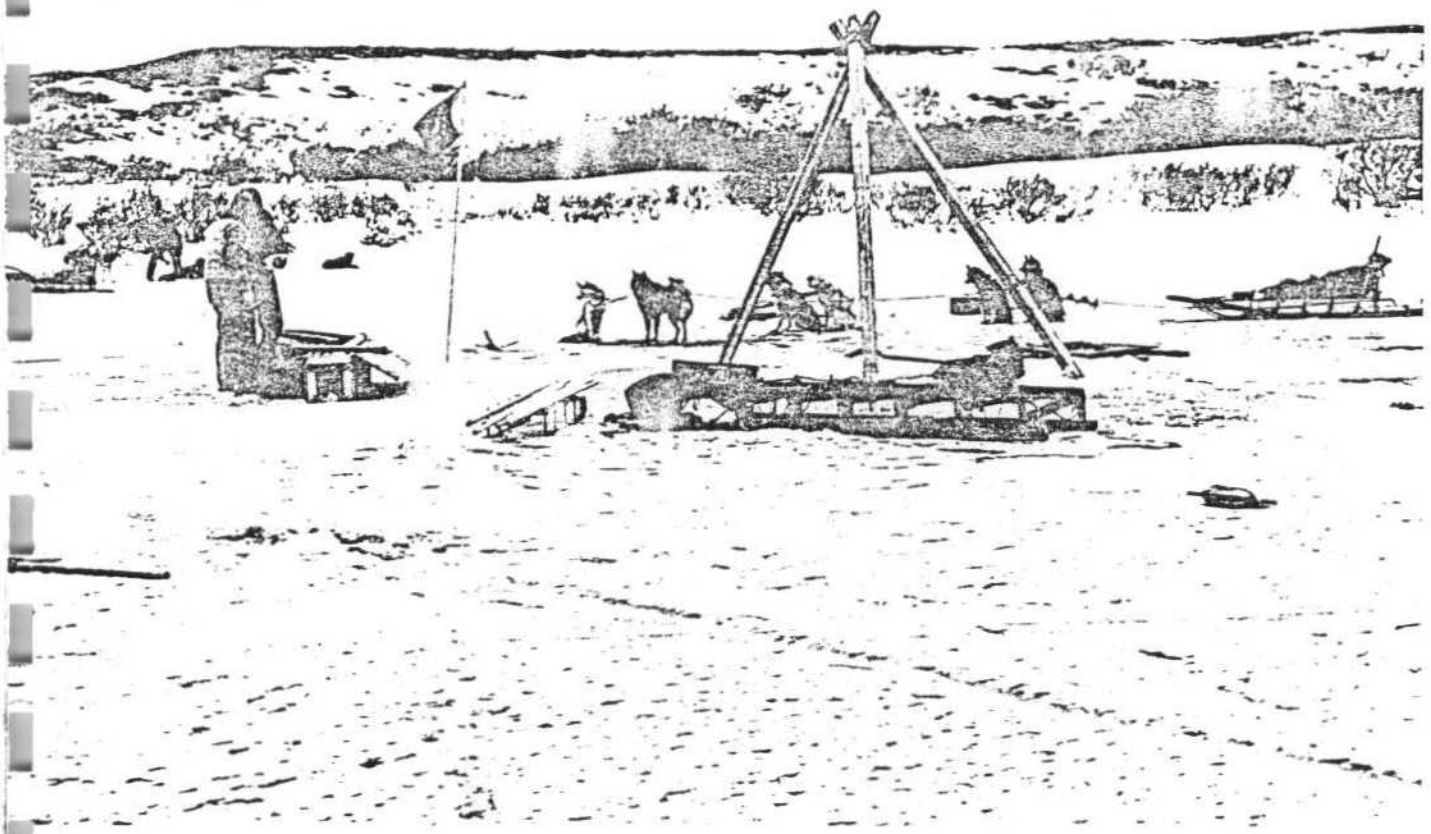
The figure shows that Searles Lake has remained dry or at a relatively low level for the last 10,000 years. In contrast, from 10,000 to 30,000 years before present, the level of ancient Searles Lake was generally much higher, and extreme rapid fluctuations in the level of the lake occurred frequently. Between 15,000 and 20,000 years before present, the lake level rose high enough to flow over the valley rim into the next lower basin. Because changes in the lake level reflect changes in climate, we infer that warm, dry, and relatively stable climates of the past 10,000 years were preceded by a period of cold and wet and more variable climates.

The modern and ancient record of Searles Lake generally matches the history of lake levels determined from many other pluvial lakes in the Great Basin. For example, when Searles Lake was overflowing its basin between 15,000 and 20,000 years before present, Great Salt Lake was greatly expanded and formed part of a huge lake called Lake Bonneville which covered an area of about 19,300 square miles, 17,000 square miles larger than the present Great Salt Lake.

A wide variety of paleoclimate studies indicate that climate has fluctuated regularly in the past; these studies also show that climates as warm as the last



Water-level fluctuations of ancient Searles Lake, California.



Winter sediment-coring operations on St. Michael Island, Alaska. Analysis of fossils in cores provides data for reconstructing climatic history.

00 years have only occurred about 5 cent of the time in the last 700,000 rs. Therefore, we are currently in a of abnormally warm and equitable nate, and, unless man's activities ange the natural system, we expect to change to cooler and more variable tes in the (geologically) near future. Scientists of the Geological Survey con- to investigate the long-term natural bility of climate because this information is necessary both to assess the influence of man's activities on climate and to predict the consequences of future natural, or man-induced, climate change on the Nation's resources. In addition, as part of the Nation's effort to understand climate and climate change as they relate to national goals and needs, the U.S. Geological Survey provides essential information on paleoclimates to the National Climate Program.

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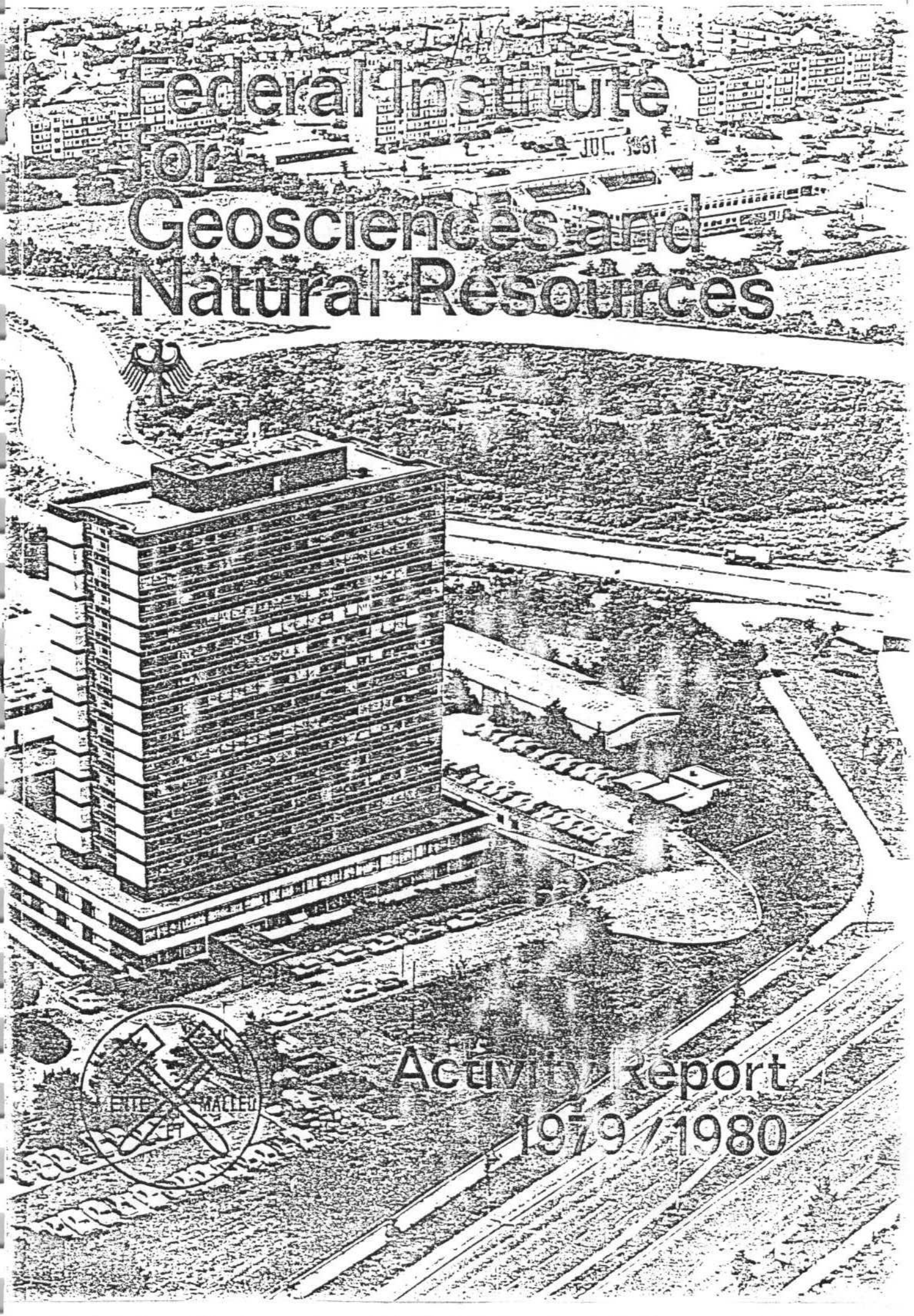
Federal Institute for Geosciences and Natural Resources



Activity Report 1979 / 1980

5. Geotechnical safety / Final disposal of radioactive waste

5.1 Introduction

The research work in this sector contributes to the solution of geotechnical problems connected with **underground and surface construction work;** these problems may be caused by technical innovations or may be concerned with safety or cost effectiveness. The results of the research serve

- to reduce natural hazards and to prevent damage associated with such hazards, and
- to prevent the harmful effects of man's technological intervention in the natural environment.

One especially important aspect of geotechnical safety is the [redacted] which is essentially a geoscientific problem. In this field, the BGR's responsibilities are threefold:

- Research and development

  are concerned with problems defined in the Reactor Safety Committee's report of 1977. In this report, an integrated centre for the end of the nuclear fuel cycle ("Nuclear Entsorgungszentrum"), consisting of a reprocessing plant and a repository for radioactive waste, was stated to be technically feasible and, in principle, acceptable from a safety point of view. Contributions to this research and development work are made in the fields of geology, hydrogeology, geotechnics, geophysics and mineralogy. In the last two years, emphasis has been focussed on the Gorleben salt dome and the [redacted]

- Planning and investigation

  The Federal Institute of Physics and Technology (PTB) in Braunschweig is [redacted] and the relevant investigations. The BGR provides geological and geotechnical support, supervision, and evaluation for the PTB's program of investigation at Gorleben, as well as for their hydrogeological drilling program and deep drilling program.

- Advisory services and assessments

  In this sphere of responsibility, the results of research projects and exploration programs are utilized to facilitate continuous forward planning. These results are interpreted and then made available to the Federal Ministries, Federal Authorities, Commissions and Committees as required.

5.2 Applied research on final disposal of radioactive waste

Mechanics of rock salt

When highly active wastes (HAW) are disposed of within a salt dome, the rock in the immediate vicinity of the repository and the wider surroundings is heated. The thermal and mechanical stability of a salt structure, important for mine safety, is determined essentially by creep and fracture behaviour of the salt rock as a function of stress and temperature. Mechanical tests were therefore carried out, aimed at a derivation of the constitutive laws which describe the rheological behaviour and fracturing of rock salt. The research program includes ultrasonic measurements, uniaxial and triaxial creep tests on cylindrical specimens and uniaxial and triaxial compression tests on cylindrical and cube-shaped specimens.

The results of these experiments have led to the derivation of a **comprehensive materials model for rock salt** which includes characteristic terms for elastic deformation behaviour, the tensor equations for primary (transient) creep, secondary (steady state) creep, as well as criteria for the initiation of fracturing. Using this model, calculations can be made on the stability of mine workings and the integrity of the salt dome using modern numerical methods of continuum mechanics.

This will enable the geotechnical conditions for the stability of the repository to be defined. The purely phenomenological description of the deformation processes observed in

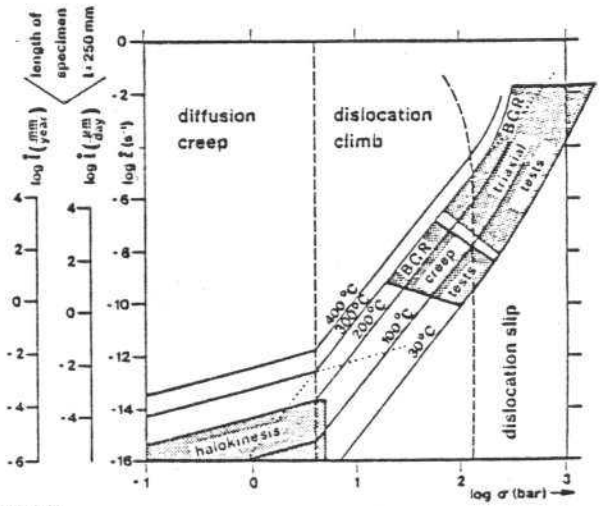


Fig. 5.1

Simplified deformation diagram for rock salt.

the experiments, using suitable mathematical formulas, is supplemented by theoretical studies of the relevant deformation mechanisms. This is necessary to provide a sound physical basis for extrapolation of the deformation behaviour over long periods of time.

Different deformation mechanisms predominate in different ranges of stress and temperature. With increasing stress, **diffusion creep** is taken over by **dislocation climb** and this in turn by **dislocation slip** as the predominant deformation mechanism. Figure 5.1 shows a simplified deformation diagram for rock salt in which the ranges of stress and temperature covered by the experiments is marked.

In order to construct a **deformation diagram** for natural (i. e. impure) polycrystalline rock salt, all data from the literature and from our own experiments were utilized.

An extensive series of tests have been carried out covering a wide range of variation of stress, temperature, strain rate, loading rate and loading path in order to describe the **deformation behaviour** of rock salt and to determine its ultimate strength.

Generally, the ultimate strength of rock salt increases with the hydrostatic pressure up to a certain limit. At higher temperatures, lower values of the maximum bearing capacity were determined (see Fig. 5.2). Likewise at lower strain rates there is a considerable fall in the maximum bearing capacity.

A comparison of triaxial tests on cylindrical and cube samples indicates good agreement of the experimental results and shows that the maximum bearing capacity ($\tau_{o\,max}$) of the rock-salt samples tested is a function of the hydrostatic pressure σ_o, the loading path m, the strain rate $\dot{\varepsilon}$, and the temperature T.

$$\tau_{o\,max} = f(\sigma_o, m, \dot{\varepsilon}, T)$$

Stability of the planned repository mine

Investigations have been started within the framework of the project entitled "Sicherheitsstudien Entsorgung" (studies on safety in disposal and reprocessing) on the **stability of the repository mine** and, in a wider context, the **stability of the salt dome** itself, especially with regard to the thermal stresses caused by heat generation in the radioactive waste. Studies have been undertaken to ensure the safe operation of the mine workings and are necessary to define the conditions for the modelling of the different barriers which are intended to prevent the escape of radioactive material from the repository.

Finite element calculations were carried out based on new or modified **materials models** for rock salt, including statistically determined limits. This method of calculation appears to be especially suited to geotechnical problems since it takes into account both temperature- and time-dependent processes, as well as a wide range of boundary conditions and constraints and is applicable to any desired geometrical shape. Studies on the stability of repository mines make use of the BGR's own FEM computer codes as well as commercial codes (ADINA and ADINAT) to which the BGR has access.

The use of the computer permits a detailed prediction to be made of time-dependent deformation of simple cavities, a complex network of cavities, and of salt domes of given shape, under thermal stress. Figure 5.3 shows the variation of stress with time around a cavity in salt.

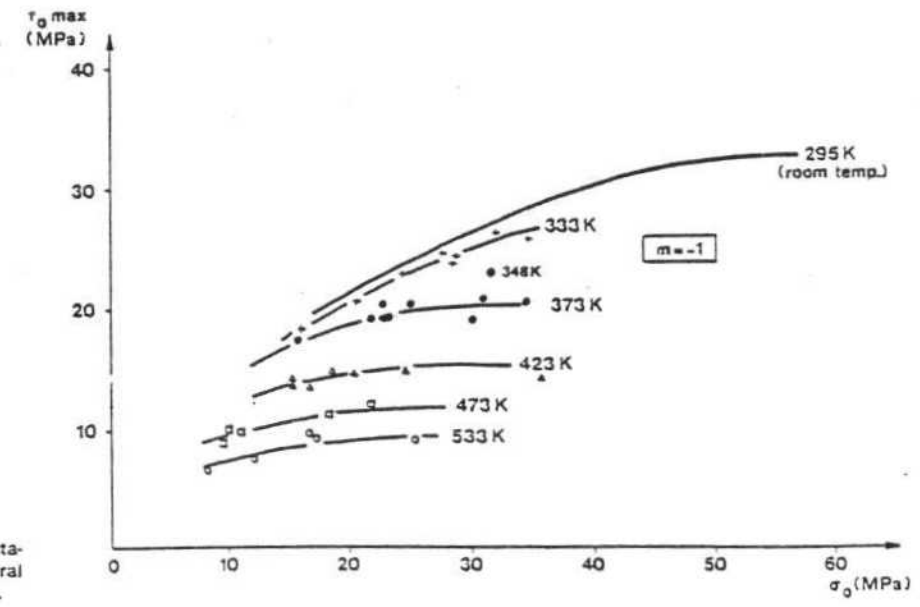


Fig. 5.2

Relationship between maximum octahedral shear stress $\tau_{o\,max}$, octahedral normal stress σ_o and temperature T.

Temperature distribution in the rock around a repository.

A number of computer codes have been written and some existing programs modified on behalf of the Federal Institute of Physics and Technology (PTB) in Braunschweig, as well as in the course of the BGR's own research and development work. Using these codes, the near-field and far-field temperature distribution in the host rock around a repository for heat-generating radioactive wastes can be calculated. On this basis, the geometrical layout of a disposal field can be worked out with respect to the safety limits dictated by the influence of temperature on the mechanical behaviour of materials, the influence of heat production on mine ventilation, etc.

Research work on this project is still in progress; the new emphasis is on the study of the influence of groundwater movement on the natural temperature distribution in the rocks above the salt dome.

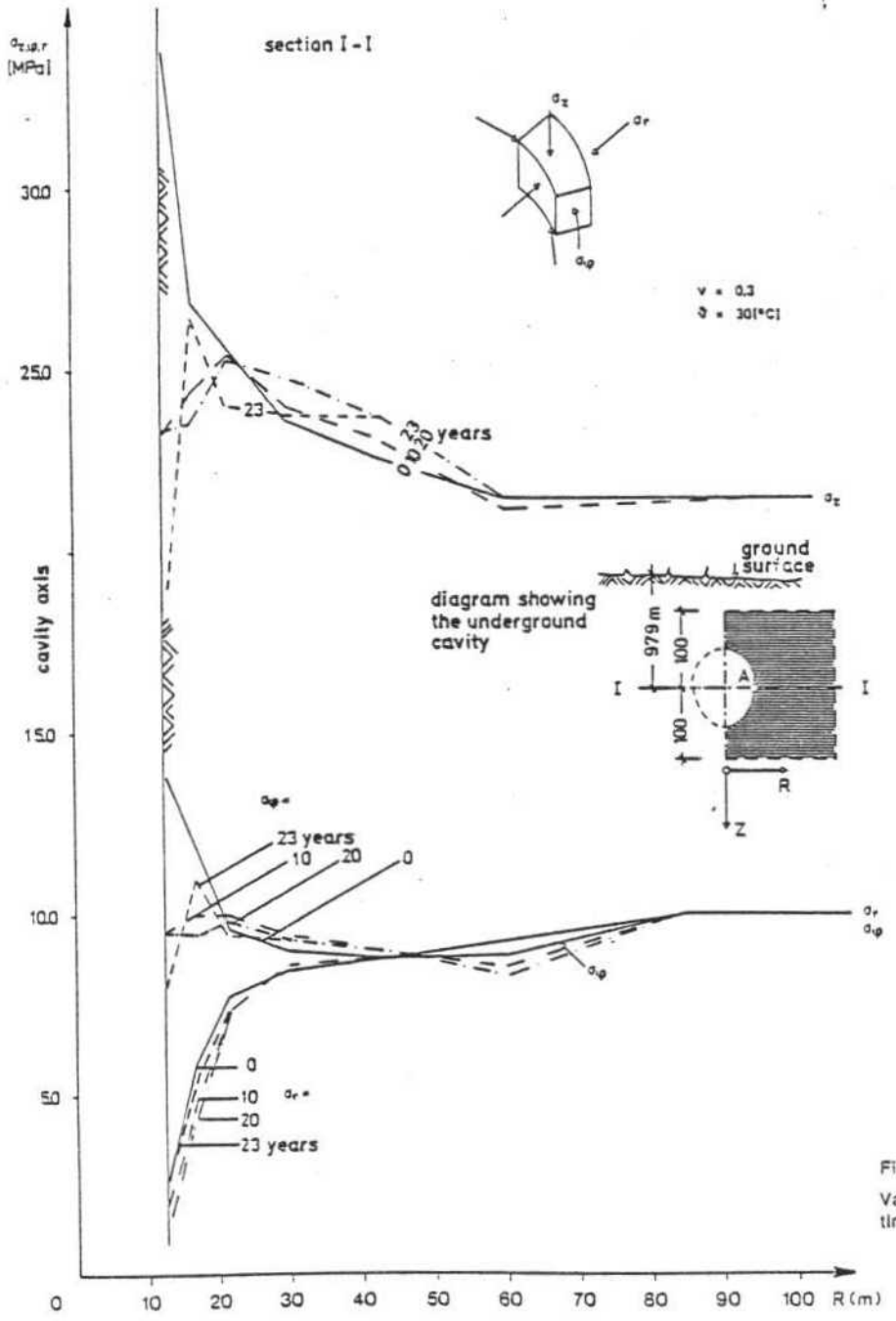


Fig. 5.3

Variation of the stresses σ_z, σ_φ, σ_r with time.

Development of geotechnical testing equipment

The equipment used to investigate the mechanical properties of rocks has been supplemented by **triaxial testing equipment** with an electronically controlled hydraulic system (Fig. 5.4) designed by the BGR. Using this equipment, rock specimens up to a maximum of 100 mm in diameter and 250 mm long can be tested. A load of up to 2000 kN can be applied in the axial direction. A lateral pressure of up to 450 bars can be applied to the specimen using hydraulic oil as a pressure medium in the triaxial cell.

A **multi-channel data acquisition unit** has been developed for the conversion of measured analogue values, such as load, pressure, sample temperature and amount of shortening, into digital form suitable for recording and processing. This unit is compatible with the special requirements of rock-testing technology. Both the electronically controlled hydraulic triaxial testing equipment and the trixial creep test cell are now being used with this recording unit.

A special **temperature control unit** has been developed for our uniaxial creep test rigs (Fig. 5.5); it provides accurate regulation of the temperature in nine heat chambers and operates between 20° and 400° C for experiments lasting over a period of years. The heat chambers permit study of the creep of rock salt under various loads and at different temperatures.

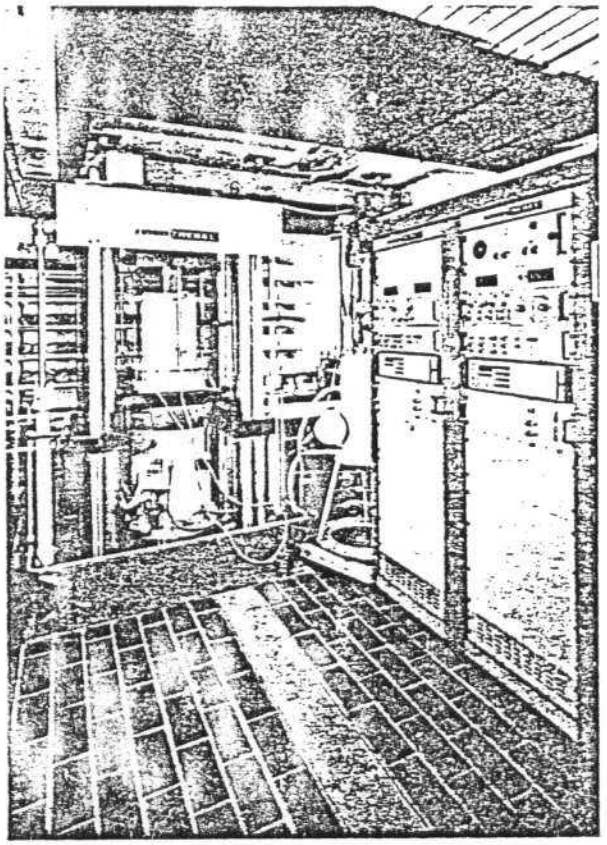


Fig. 5.4

Triaxial test equipment with electronically controlled hydraulic system.

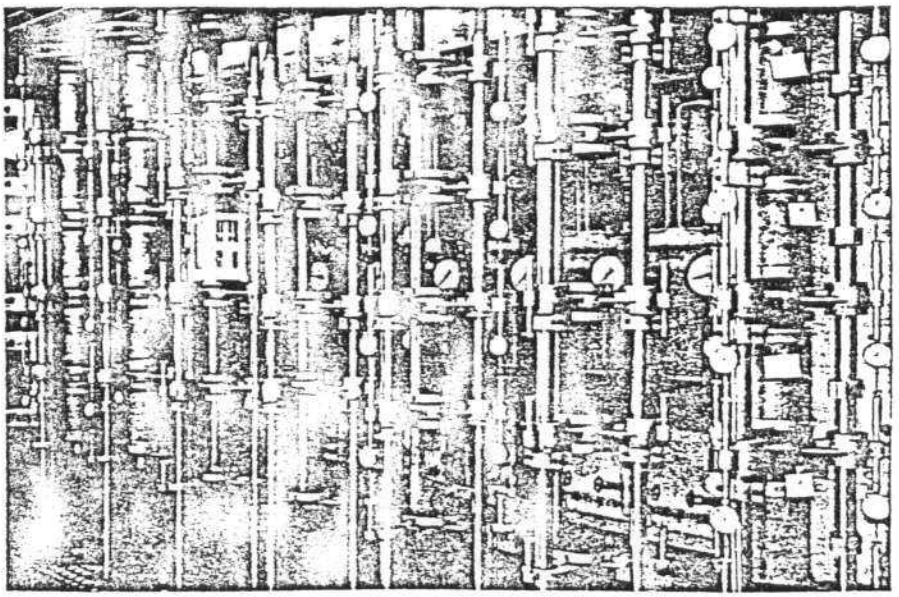


Fig. 5.5

Test rigs for creep experiments.

Development of microacoustic unit for use underground

A microacoustic unit has been developed for continous monitoring of the stability of an old mine pillar in the Asse II mine. The unit has been in operation for 1½ years and has functioned well. The microacoustic unit consists of a sounding probe and a recording and monitoring instrument. The probe is inserted into a borehole in the salt rock and, by means of a piezoelectric sensor, converts the micro-sounds generated by microcracks during deformation of the pillar into electric signals. These are amplified, and processed by a pulse shaping unit for the pulse counter. Thus, for a constant time interval, the event count-rate is measured and is transmitted continuously from the underground monitoring unit.

The variation in event count-rate depends closely on the mechanical processes operating within the pillar. The results so far show that the pillar is not in a dangerous state. Monitoring is to be continued using an improved microacoustic unit.

Electromagnetic borehole methods

A borehole method based on the use of high-frequency electromagnetic waves has been developed jointly by the BGR and a company in a research and development project for studying the interior structure and make-up of unmined salt domes.

High-frequency borehole techniques yield information about structures from 10 m to several hundred metres from the borehole.

Both borehole methods, the absorption and the reflection techniques, were orginally developed for use in salt mines; the reflection technique is now employed as one of the standard techniques for reconnaissance in geology and mining.

Conversion of these methods for use in deep boreholes entails a complete redesigning of the construction of the instruments, firstly because of the size of the borehole and secondly because of the high temperatures and pressures in boreholes.

A significant problem is in the transmission of the high frequency impulses through standard borehole cables to the surface; this is achieved by means of a sampling technique and digital conversion.

Both methods have been thoroughly tested. The reflection method is already in regular use. It works on the same principle as radar, locating rock boundaries at which there is an abrupt change in the high-frequency waves as a function of the distance. Boundaries between anhydrites, claystones, and dolomites can be located, as well as joints containing water or brine. Reflection measurements may be made in one borehole; however, two boreholes may be used with transmitter and receiver units in separate holes. If both reflection methods are combined with studies using the absorption method, then considerable additional information can be gained about the rocks being investigated without any significant increase in cost.

5.3 Investigation of repository sites

5.3.1 Gorleben

Hydrological investigation program

During the last two years, the Federal Institute of Physics and Technology (PTB) in Braunschweig started investigations in the area around Gorleben, the site chosen for a Federal German repository for radioactive waste. A large part of the work, which has now been completed, was an investigation into the geological structure and groundwater regime in the sediments above and around the salt dome over an area of about 300 km². The scientific side of this program was directed by the BGR (Hydrogeology Section).

The BGR is responsible for the scientific planning of the project and, together with the technical construction management, for its coordination. A final report summarizing all of the results will be prepared by the BGR on completion of the project. The program consists of numerous different studies and special investigations in which not only the BGR but many university departments and research organizations are participating.

By the end of 1980, most of the drilling work had been finished, thus almost completing the investigation of the structure and geology of the cover rock. After that, the work will be increasingly concentrated on special hydraulic and hydrochemical aspects and on the Quaternary deposits.

The BGR has carried out several studies for this program, which include

- special palaeontological, geophysical and petrographic investigations on drill cores;
- pedological mapping of the project area at a scale of 1 : 25 000 to determine the distribution of water in the soil using the technique mentioned in Part 4.2;
- calculations of the groundwater movement in the project area using a simulation model;

— development and application of methods for computerized processing of geophysical, geological and geochemical data.
— expert coordination and supervision.

Models for the movement of polluted groundwater

In the case of **an accident in a repository mine** (such as a leakage of water into the mine) the geological formations around the salt dome and the groundwater system which they contain represent the final barrier against radionuclides reaching the biosphere. The main investigations into groundwater movement above a salt dome are being carried out within the framework of the project entitled "Sicherheitsstudien Entsorgung" (studies on safety in disposal and reprocessing). They serve to explain and clarify the mode of operation of this barrier within the limits set by chemical, physical and hydraulic factors which influence groundwater movement. The essential factors, apart from those normally used in groundwater models, are pressure, temperature, spatial distribution of solute in the groundwater, its density, and the physiochemical processes which cause these factors to vary. The acquisition of data for these additional parameters, as well as their evaluation and the development of mathematical models for describing these complex systems, has been begun.

Site-specific data from the Gorleben hydrogeological drilling program were processed, interpreted and then prepared for generally valid statements, independent of site-specific factors. Theoretical models help to clarify the hydraulic and physical processes operating in salinized groundwater under unfavourable conditions. Initial studies are being carried out on the behaviour of polluted groundwater under different geological conditions.

Deep-drilling program

The objective of the Gorleben deep-drilling program is to investigate the **internal structure of the Gorleben salt dome**; it should also yield useful criteria for the siting of shafts. The first three boreholes were sited at distances of 500 m — 1000 m from the edge of the salt dome so that as much information as possible on the evaporite layers and their structure could be obtained from only a few boreholes.

The first hole to be drilled, from 4 Jan. to 19 April 1980, was the Gorleben 1003 borehole. The Gorleben 1002 borehole was sunk between 3 May and 30 July 1980. These two boreholes were directed towards a study of the northwestern flank of the salt dome. Later, the Gorleben 1004 borehole (22 Aug. — 11 Nov. 1980) was drilled on the southeastern flank and was followed in the second half of November 1980 by Gorleben 1005.

By virtue of the boreholes sunk so far a considerable amount of the evaporite sequence is now known. Large parts of the sequence including the Stassfurt rock salt (Na 2), the Leine salt (Na 3), the Stassfurt potash bed, the Ronnenberg (carnallitic facies) and the Main Anhydrite were penetrated several times. In the Gorleben 1004 borehole, the youngest beds of the Leine cycle (z 3) and parts of the Aller cycle (z 4) were encountered.

The drilling operations were carried out under constant geological supervision and preliminary interpretation of the results were worked out. These preliminary results provided a basis for proposals for the siting of further deep boreholes. These are aimed at finding parts of the salt dome which are suitable for the sinking of shafts, as well as broadening our knowledge of the interior of the salt dome generally.

The large quantities of drill core are kept in a specially air-conditioned storehouse until they can be analysed. A program of geotechnical and physical investigation has been developed for cores from the Gorleben salt dome, and a start has been made on the distribution of the core material amongst the various laboratories.

5.3.2 Asse II mine

Stability of the mine

The procedure for authorizing the plans for the disposal of weakly and moderately radioactive wastes in the Asse II mine was begun in 1979 and in this context an **analysis of a possible rock failure** is of crucial importance.

The mining authority requested the BGR to prepare a rock mechanics assessment. Thus, on the basis of various methods of investigation, an analysis of the stability of the entire mine workings, which are situated on the southwestern limb of the Asse anticline, was carried out. The analysis consisted of individual coordinated investigations as follows:

— inspection of extensive mine workings, some of them 60 years old;
— evaluation of surface and underground rock mechanics measurements;
— calculation of the stress and strain field throughout the Asse anticline and around the mine workings on the limb of the anticline. The calculations were based on geotechnical parameters from tests carried out in the BGR laboratories on samples of rock salt.

These geotechnical investigations were completed in 1979 and concluded that the stability of the mine could be guaranteed for a given period. An extension of this period was made conditional upon the results of a future geotechnical survey, further inspections and a reassessment of the findings.

In-situ salt mechanics

If radioactive wastes are to be disposed of in rock salt it is essential to employ in-situ methods to determine the rock **stresses and deformation behaviour** within the salt dome itself. The BGR possesses wide experience and extensive qualitative and quantitative data on the deformation behaviour of most common rocks other than rock salt. Therefore, the relevant instruments and techniques were subjected to in-situ trials within a salt dome in the Asse II mine in order to test their suitability. The compensation method which has been further developed by the BGR is based on a combination of the saw slot and flat jack technique with the BGR displacement gange system. These in-situ trials on the application of this system permit measurement of stress relief in the mine to be taken while drilling and slot cutting is in progress and, at the same time, the stress-release displacement can be compensated by applying pressure to the rock through the flat jack. The trials demonstrated that the techniques for determination of rock stress and deformation behaviour described above are, in principle, applicable to rock salt.

Geothermal investigations

It is essential to consider the possibility of accidental flooding of a repository. In this connection the BGR carried out **in-situ heating experiments** in the Asse II salt mine in order to examine the effect of heat from a highly radioactive source on the surrounding salt rock. The experiments carried out so far have been intended to determine whether the heat from highly radioactive waste could lead to thermally induced fissuring, consequent flooding with brines, and their contamination by contact with the radioactive waste containers. No signs of fissuring were detected during the heating trials in the mine; however, cracks did form in one case when heating was immediately followed by extremely rapid cooling.

Further in-situ thermomechanical experiments by the BGR are concerned with the conditions under which stress can build up to a critical value and are investigated by observations on fissure initiation.

The BGR carried out laboratory and in-situ determination of the thermal conductivities of rock salt and of the surrounding rocks. This was necessary for calculation of the temperature distribution and natural heat flow in and around the salt dome (see Fig. 5.6).

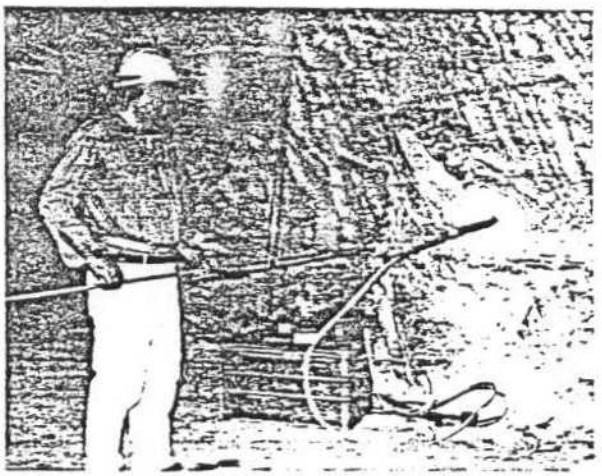


Fig. 5.6
In-situ measurement of thermal conductivity in the Asse II salt mine.

5.4 Applied research and geotechnical projects

Rock stability and the projective qualities of rock

Studies on the **seepage through jointed rock** have been continued in a project on the underground siting of nuclear power plants. The aim of this investigation is an assessment of the degree of resistance offered by rock to polluted water and gas which could escape from the reactor cavity as a result of a accident. Three types of rock in which a future underground nuclear power plant might be sited were chosen for investigation. Hydraulic field tests were carried out on Buntsandstein rock using recently developed apparatus for determining the permeability of the rock, rate of dispersion, dispersion volume, temperature changes, as well as dispersion of the water tracer. The experiment was set up with water injection simulating the conditions of a reactor accident. Figure 5.7 shows the arrangement used in seepage experiments.

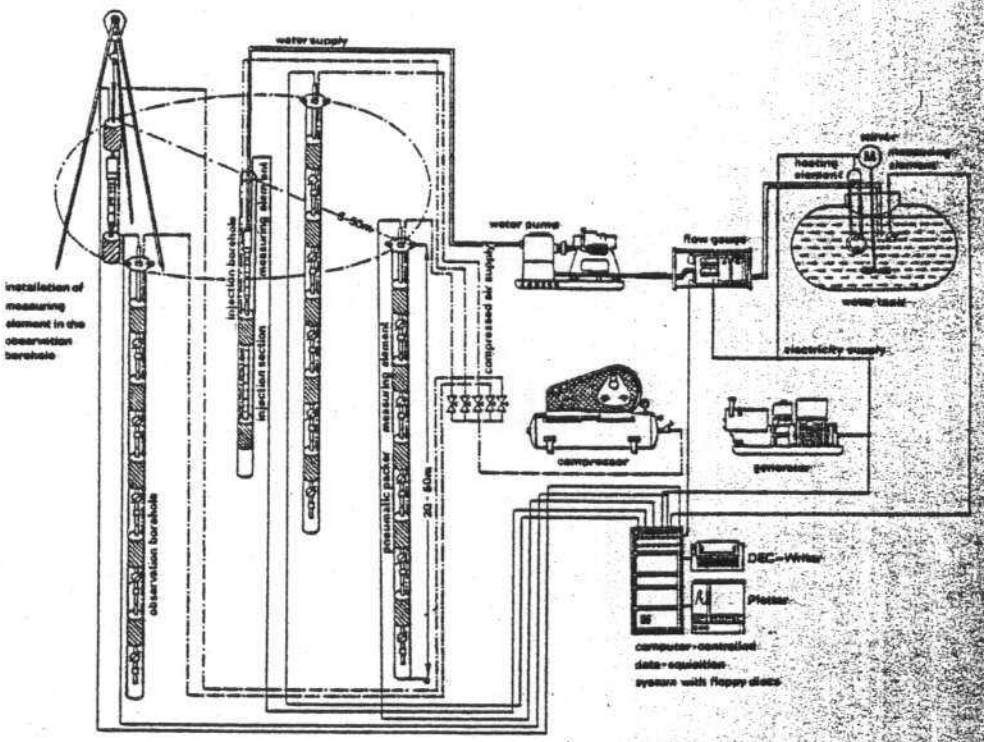


Fig. 5.7
Set-up for seepage investigations.

The BGR made expert assessments for public authorities of the stability of underground sites both during the planning stage and during their operation. Monitoring of rock stress in the walls of tunnels and in rock pillars was done by means of **stress-relief measurements in slots in rock.** This method permits determination of the actual rock stress during the construction of a tunnel and comparison of these with the calculated values. From these results it was possible to draw conclusions about the actual safety margins of the structure or to recommend additional support measures if necessary. Figure 5.8 shows the sawing equipment set up to cut a 100-cm-long slot; stress-relief drill-holes are situated below the saw stand. An example of the results is given in Fig. 5.9 in which the stress-relief displacement and its compensation by the application of a stress with the flat jack are plotted.

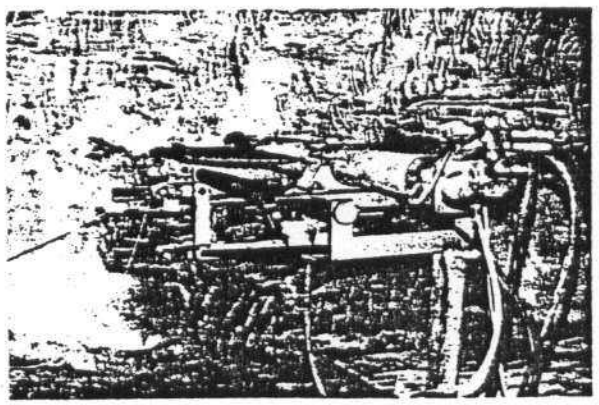


Fig. 5.8
Cutting the saw slot in the mine wall.

In order to achieve a technically and economically satisfactory assessment of the safety of a mine gallery, the stress and its distribution in adjacent pillars must be established. The stress is measured in this case by the BGR system combining the **overcoring method with the stress-relief gauge.** The elastic moduli of the rock are determined by another BGR system making use of a dilatometer taken from a borehole deformation sonde. Our investigations established that load distribution was not uniform within the mine pillars and that some parts of individual pillars were very highly stressed. The results of the survey form the basis for calculating the stability of underground cavities and the planning of support measures.

Preliminary site investigation for nuclear power plants

A most pertinent question in the planning of a nuclear power plant is whether the plant can be built **underground.** There are various alternative types of underground construction. The BGR carried out investigations on siting possibilities in a cavern or in a cut-and-cover construction in a hillside from the points of view of engineering geology and rock

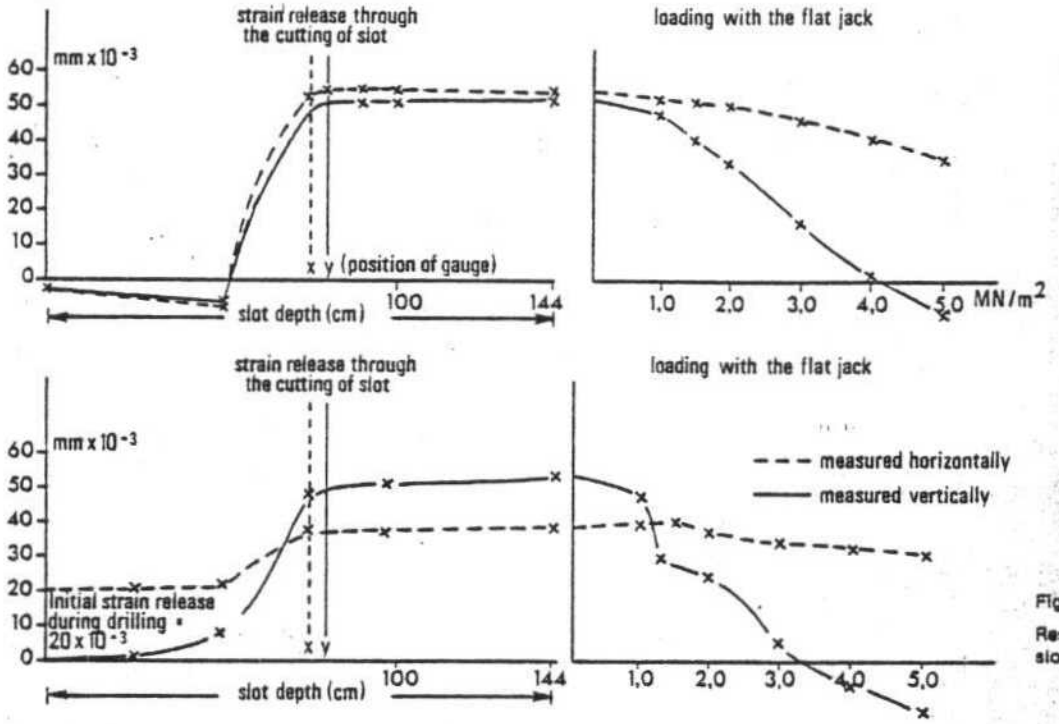


Fig. 5.9
Results: slot-cutting method.

mechanics. The planning of a cavity large enough to hold a reactor and all the accessory plants necessitates assessment of the practicability of such a construction; the protective qualities of rock are being investigated with a view to being able to predict the effects of accidents. On this basis, criteria were set up with respect to engineering geology and rock mechanics for the appraisal of potential underground sites. A number of locations in the Federal Republic of Germany can be demonstrated to be suitable, as well as fulfilling the necessary infrastructural requirements. Thus the planning of this type of construction can go ahead.

Construction of new lines for the German Federal Railways

During the last 8 years the BGR has been providing advice and geotechnical expertise to the German Federal Railways in connection with the construction of new, high-speed lines. At first the work was concentrated on regional aspects connected with the preliminary planning and routing of about 800 km of new lines. Recently, however, activities have been increasingly concerned with special geotechnical problems and individual construction sites for which detailed soil testing and geotechnical investigation have to be carried out. In this respect, the BGR is chiefly involved in tunnel projects and other engineering work associated with rock.

Regular coordination meetings attended by the management of the Federal Railways, the BGR and the consulting engineers ensure that optimal site investigation programs are set up, that the results of current investigations are included in the draft plans for official authorization and in the construction contracts put out to tender.

The systematic collection of geological and geotechnical data during projects such as these represents a new source of information; it includes data on rock behaviour, on the suitability of structural calculations, construction methods and materials for different types of foundation soil. For this purpose, work has been done on a suitable **data-acquisition and information system.** This will prove most valuable as a basis for future construction projects, contributing towards increased safety and cost efficiency.

Underground storage and waste disposal

The BGR contributed towards a joint project on the storage of energy for underground mining involving the pumping of compressed air into a rock cavity sealed with clay. The air pressure in the cavity is kept approximately constant by a column of water. A geotechnical investigation program has been worked out to test the stability and tightness of the rock cavity.

Vibration protection for buildings

Vibration protection is an integral part of environmental protection. Research activity in the field of vibration protection has been continued and intensified within the period covered by this report. The basic principles governing the transmission of vibration (shock) waves in the ground and their capacity to cause damage to buildings have been worked out for various kinds of source. The capacity of vibrations of cause damage is influenced by the following factors:

- the strength of the shock, commonly quoted as the particle velocity;
- the frequency range of the vibration;
- the duration;
- the nature of the building (type, construction and age).

The spread of housing developments to within close proximity of working quarries and the growing public awareness of the need for environmental protection causes frequent clashes between long-term planning for extraction of near-surface mineral resources and the need for building land. To achieve a clearer definition of the areas affected by vibration, the BGR has set up a vibration register covering about 150 important quarries in the Federal Republic of Germany. In this way it is possible to assess the size of the area affected by vibration for a given type of subsurface geology. At the same time, parameters were determined by which a prediction of the type and magnitude of vibrations can be made for a given set of conditions.

The BGR has prepared expert commentaries for several authorities in connection with planning permission and for law courts in connection with legal disputes over vibration. In addition, advice has frequently been provided to industrial inspection authorities during the last two years.

In the period covered by this report, the results of our investigations have been requested by the Bavarian Ministry of Employment and Social Order and the Federal Environmental Agency. The results contribute towards the setting up of guidelines and the definition of standards.

Earthquake-proof siting and construction of nuclear power plants

In order to be able to confirm a nuclear power plant as earthquake proof, special parameters associated with the dynamics of foundation soils have to be determined, e. g. shear

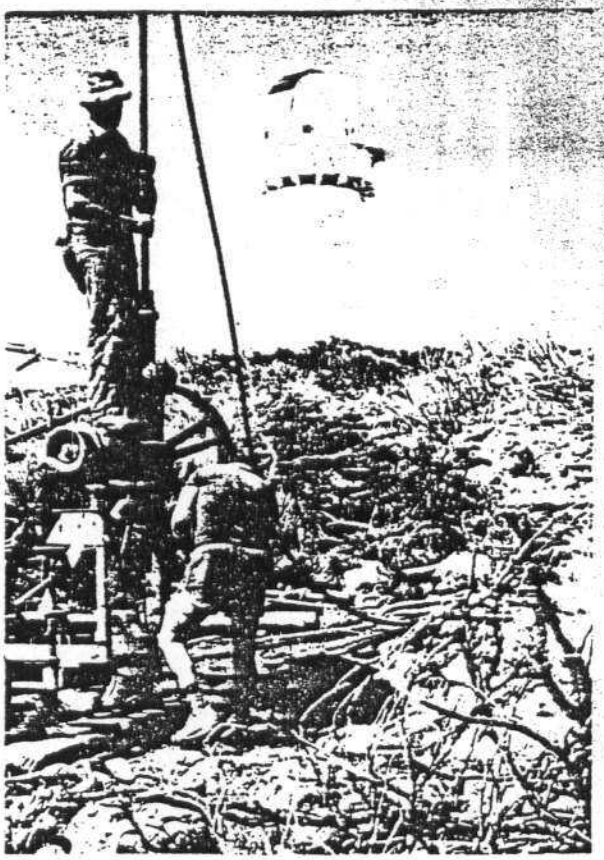


Fig. 5.10

Site-investigation drilling near Izaña, Tenerife, for one of the solar observation towers; an example of German-Spanish cooperation in the field of solar physics.

modulus, damping modulus, and Poisson's ratio. This is done by an investigation of the site using hammer or explosion seismics. An improvement of this survey technique has been achieved by computer processing of the impulses.

Advice on foundations

The Federal Building Directorate has been advised by the BGR for a number of years principally on foundation soils for Federal building projects such as embassies or extensions to ministry buildings. The actual work involves expert assessment in connection with vibration protection as follows:

An expert assessment was made of the stability of an unsafe slope for the Federal Ministry of Regional Planning, Building and Urban Development with respect to the Law on the General Consequences of War. An expert commentary was also prepared for the district government in Darmstadt on the connection between groundwater with drawal by a waterworks and settlement damage to buildings in the town of Nidda. This report formed an essential basis for the adjustment of compensation (see Part 4.3).

During the enquiry in connection with planning permission to use the abandoned opencast oil-shale mine at Messel near Darmstadt as a refuse dump, various problems arose concerning soil mechanics and engineering geology. These were dealth with in an expert commentary prepared by the BGR. The problems were associated with the settling behaviour of the oil shale and the stability of the slope on the western side of the pit where there is a well-known palaeontological excavation site (see Part 4.3).

The BGR advised the Kiepenheuer Institute for Solar Physics in Freiburg on selection of sites for solar observation towers on the islands of Tenerife and La Palma. This involved carrying out investigations into the foundation soil dynamics and engineering geology of the sites (Fig. 5.10).

5.5 Geotechnical projects abroad

Canada

German-Canadian geoscientific cooperation was continued in the field of rock mechanics with stress measurements on Buntsandstein rock in an underground mine. The methods employed by the BGR and the Elliot Lake Laboratory, based on the overcoring method with stress-relief gauges, were further developed and tested.

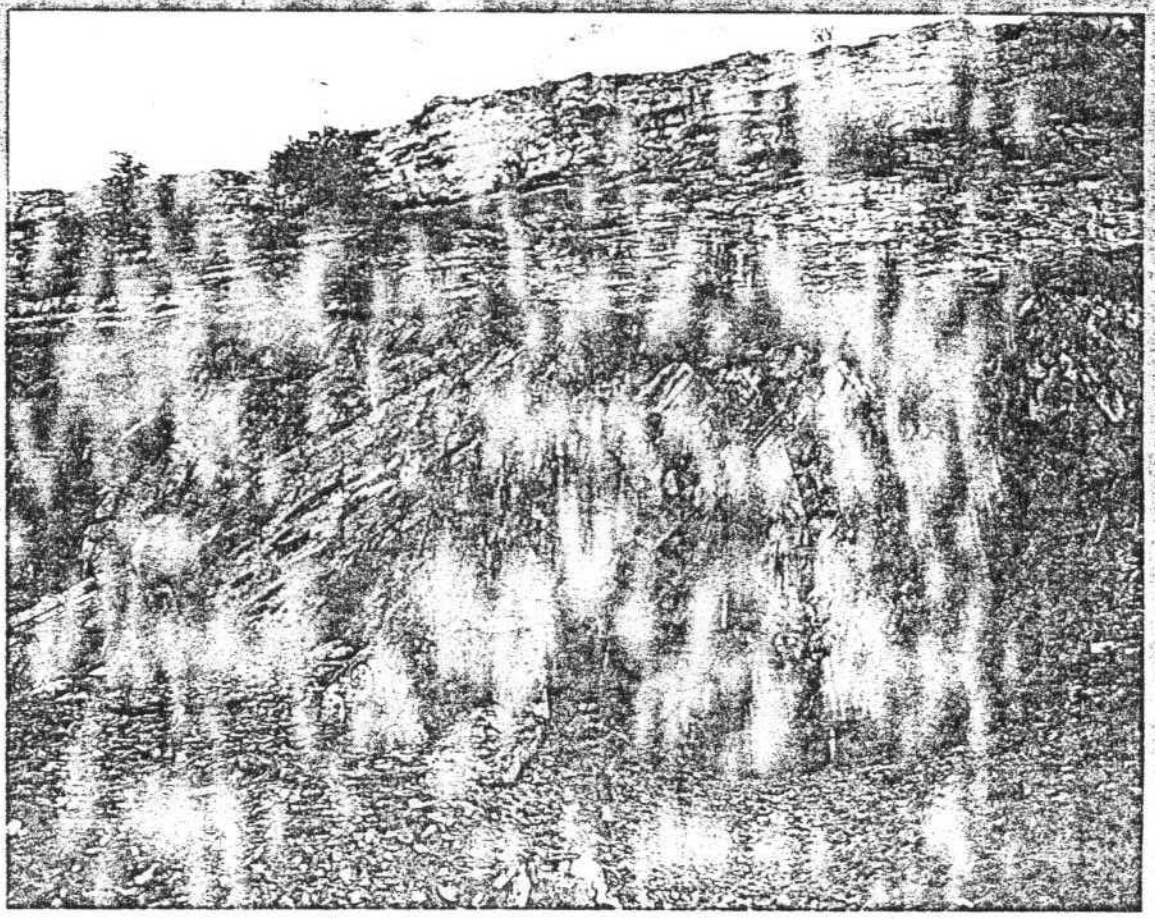
Saudi Arabia

At the request of the Directorate General of Mineral Resources in Jeddah, the BGR drafted and costed a program of engineering geology work comprising part of the 5-year plan.

SERVICIO GEOLOGICO DEL REINO UNIDO (I G S)

Institute of Geological Sciences

Annual Report for 1979



and Miocene limestone cover over basement metamorphic rocks were determined.

Geothermal studies for the European Economic Community and the Department of Energy

The aim of this work is to provide an assessment of the geothermal energy potential of the UK. The project began in 1976 and is financed by the UK Department of Energy and by the EEC; it involves input from the Applied Geophysics, Hydrogeology, Palaeontology, Deep Geology and field units of IGS and from the Chemistry Department of Bath University.

The main emphasis has been on the exploration for sources of hot water which could be used in district heating schemes of the kind now operating in Hungary and in the Paris Basin. In the UK, aquifers at depths sufficient to provide water at useful temperatures (60°C or above unless heat pumps are used) are most likely to exist in the deep Mesozoic basins, particularly in Permo-Triassic sandstones. The recorded increase of temperature with depth in these basins varies considerably, in the range 15 to 50°C/km, and attention has been concentrated on the Wessex, Worcester, Cheshire, West Lancashire, Solway and East Yorkshire/Lincolnshire basins in England, and on the Larne basin in Northern Ireland, where temperature gradients are higher than average. The work in Northern Ireland is described in the reports of the Geological Survey of Northern Ireland and the Hydrogeology Unit. In Great Britain drilling of the first deep exploratory geothermal borehole started in November in the grounds of the Marchwood power station, near Southampton. It is planned to drill to between 2 and 3 km to investigate the structure of the Permo-Triassic, Carboniferous and Devonian rocks, if present, and to test any aquifers they contain.

In the longer term, it may become practicable to fracture impermeable rock artifically at depths of several kilometres, and to heat water to temperatures of 150 to 250°C by circulating it through the system of fractures under pressure; the water would be brought to the surface for use in electricity generation. A preliminary assessment of 'hot-rock' prospects in the UK was completed and a report prepared in the year.

Geophysical borehole logging

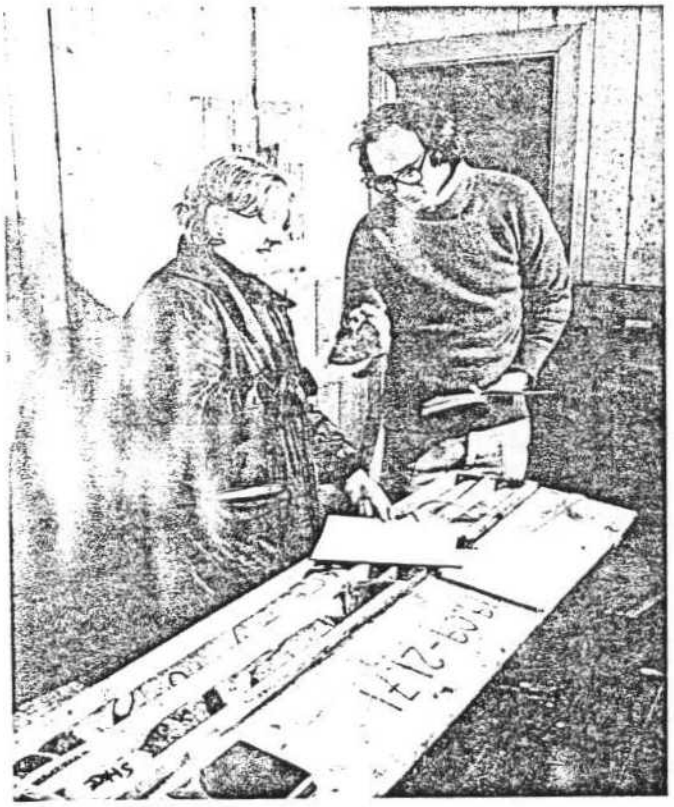
Extensive use was made of the Unit's portable logging equipment which is capable of providing gamma, resistivity, spontaneous potential and temperature logs to a depth of nearly 300 m. In boreholes deeper than this, or where other logs were required (for example sonic, neutron or density logs) a commercial operator was used. Boreholes at Ashington, Chanctonbury, Clare, Farnham, Lees Farm, Nettleton Quarry, Stoneyknowes, Twycross Park and West's Bridge and 9 disused water wells in Tertiary sediments in Hampshire were logged primarily for stratigraphic correlation purposes. Six holes drilled for the Industrial Minerals Assessment Unit Limestone Assessment Project were logged to provide an indication of the clay content of the limestones and six of the holes drilled for the Department of Industry's Mineral Reconnaissance Project were logged to help identify mineralised zones. In three boreholes drilled at Altnabreac, Caithness, by the Environmental Protection Unit, logs were run in crystalline rocks to provide physical properties and to help in the location of fractures.

Environmental Protection Unit

The present work of the newly formed Environmental Protection Unit (ENPU) can be divided into radioactive-waste and non-radioactive-waste (landfill) studies and this report is divided similarly. During 1979 landfill studies were funded largely by the DOE with additional funds for consultancy work coming from local authorities. Work was undertaken on three separate contracts for long-term studies into the geological disposal of radioactive wastes. A programme on the feasibility of the disposal of high-level radioactive wastes to crystalline, igneous, and metamorphic rocks was funded by DOE and the Commission of the European Communities (CEC) through the UK Atomic Energy Authority (UKAEA). Similar work involving argillaceous rocks and evaporites was funded directly by DOE and a programme to evaluate possible geological formations for the disposal of low- and intermediate-level wastes jointly by DOE and CEC. In addition to the CEC there has been close involvement with other international organisations such as the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of OECD.

Research into the feasibility of radioactive waste disposal

The central aim of this research is to determine whether or not high-level solidified radioactive wastes can be disposed of by burial deep underground with an acceptable degree of radiological safety. High-level wastes are the byproducts of processing spent power-reactor fuels, are highly toxic, radioactive and heat-emitting; the heat emission continuing for up to a thousand years. Consequently they present a unique waste-management problem. Present concepts for disposal include engineered entombment in a mined 'repository', which is subsequently backfilled and sealed. Various rock types have been proposed as hosts. The only mechanism by which waste might escape is by solution in groundwater (which may be warm) with subsequent transport to the biosphere. En route to the surface the radionuclides would be subject to physical dispersion by flow and diffusion, and would be retarded or fixed by geochemical sorption processes involving the rock and the groundwater. Solution of this problem can thus be seen to depend on the determination of the physical and chemical nature of the proposed host-rock, detailed appraisals of the regional geological and hydrogeological environments, the ability to predict geological behaviour into the distant future using sophisticated modelling techniques, and also to apply the broad hypotheses of rock and water behaviour to specific lo-



Examining core material from the boreholes drilled at Altnabreac, Caithness, for the programme to study the feasibility radioactive waste disposal.

cations. There is thus a theoretical and generic component to the work aimed at evaluating and modelling all the geological processes which will be active during the life of a repository, and a field component in which realistic data for the theoretical work are sought and in which preliminary geological investigation techniques are examined which can be applied subsequently, when and if repository sites have to be identified.

[redacted] in crystalline rocks and argillaceous or mixed argillaceous and evaporite formations [redacted] during the course of the year as suitable for research (Mather and others, 1979). Field investigations were already well under way in the first months of 1979 at a low-lying research area in granite and metamorphic rocks around Altnabreac in Caithness. Three fully cored boreholes were drilled to 300 m and 24 boreholes to 40 m to begin first investigations into the hydrogeological properties of fractured crystalline rocks at depth and of the weathered superficial deposits which will be significant in the overall hydrologic picture. Drilling ended in May and was followed by a lengthy process of geophysical logging, hydrogeological testing and groundwater sampling that will continue for some years. The site will be used partly to test geophysical and hydrogeological techniques in this relatively new field of research. Rock-core samples were tested for their mechanical properties (essential in evaluating construction techniques and modelling the thermal response of the host-rock) and chemical properties. The chemical data were linked with groundwater chemical data to obtain information on water residence times and regional flow patterns. Isotopic analysis of these carefully collected water samples was carried out in conjunction with the UKAEA at Harwell and will provide data on in-situ chemical equilibria and water at depth. A novel fracture fluid-pressure testing and sampling system was devised for detailed examination of specific zones of interest using water withdrawal techniques to avoid perturbing existing flow systems. This will involve the use of a pump to deliver small volumes of water at a low rate, currently being manufactured for the Unit. Many other IGS units are involved in the Altnabreac work, and the local Field Unit (the Highlands and Islands Unit) collaborated from an early stage, carrying out local and regional mapping and interpretation both prior to and during the drilling.

[redacted] of the behaviour of different sorts of crystalline rocks under repository conditions were initiated in July. During the preceding six months a high-pressure and high-temperature hydrothermal geochemical laboratory (containing large-volume static and dynamic vessels capable of operating up to 2 kB and 400°C) was built at Harwell so that the behaviour and interactions of groundwater, rock, waste and engineered barriers during the thermally active life of a repository can be studied. The aim of this work is to define the mechanism and rate of release of radionuclides in the neighbourhood of a repository, and the geochemical environment for subsequent waste-migration modelling. By the end of the year a preliminary experimental programme to investigate the solution of waste glass and granite in groundwater had been completed and published.

A second laboratory-based project related to radioactive-waste management is the NERC-funded study of sorption interactions of fission-product nuclides with soils and superficial deposits. This is related to leakage of low-level wastes from near-surface disposal sites, accidental spillage of liquid wastes, and migration of wastes from any source into the upper weathered profile of the crust. Preliminary experiments using degraded granite from Altnabreac were initiated, and a powerful multi-channel analyser is on order; in conjunction with a GeLi detector, it will be used for monitoring a wide spectrum of nuclides on exposed soil and rock samples and solutions.

Research into the disposal of [redacted] that emit negligible heat was also being pursued during the year. Since the thermal stability of the host-rock for such disposal is less critical, a wider variety of rock types can be considered, although it is naturally still important that waste migration is restrained. A desk appraisal of the geology beneath existing licensed nuclear sites (such as power stations, research establishments) was completed to determine whether any might be worth investigating for the possible disposal of low-level and medium-level wastes. Work will commence during 1980 on the Harwell site to examine for that purpose the local and regional hydrogeological, chemical and mechanical properties of some Mesozoic formations, as well as the upper zone of the Carboniferous strata thought to underlie them.

[redacted] also involved the Unit in drilling and monitoring at the sites of British Nuclear Fuels Ltd

(BNFL) at Windscale and Drigg in Cumbria. Studies of the geology and hydrogeological regime at Windscale have been continuing for several years, during which time 58 boreholes have been drilled. In 1979 work was completed for the present with the drilling of a further 14 holes to clarify subsurface conditions in particular areas of the factory site. Similar studies at the Drigg low-level waste-disposal site were also completed by further drilling in the neighbourhood of some of the disposal trenches.

Landfill research

The disposal of the hazardous and municipal wastes by landfilling has been the subject of a joint research project with the Atomic Energy Research Authority (AERE), Harwell, since 1974. The main part of the research, which is funded by DOE, has involved detailed studies of existing landfill sites chosen for their representative hydrogeology and the hazardous wastes they have received. Column experiments and controlled field-irrigation experiments using lysimeters have also been undertaken to study the migration of specific pollutants and their interaction with various geological formations.

Although studies have been completed on many of the research landfills, monitoring of pollution plume development continued during 1979 at the Villa Farm disposal site. Here metallic sludges, solvents and oil/water mixtures have been deposited in lagoons excavated beneath the water table in lacustrine sands and clays. Boreholes drilled in 1979 to define the pollution plume have indicated that the pollutants have stratified at the base of a running sand horizon underlain by clay, probably because of a slight density contrast with the indigenous groundwater and the lack of hydrodynamic dispersion in the aquifer.

The topography of the interface between sand and clay controls the distribution of the pollution plume, which consequently does not follow the apparent hydraulic gradient determined from borehole water levels. Within the pollution plume the redox potential is low, causing sulphate reduction. The strongly reducing conditions are thought to assist in the attenuation of heavy metals by precipitation of their sulphides, and further work is under way to confirm this.

A landfill constitutes a heterogeneous pollution source which is leached at varying rates; the composition of the leachate varies depending on waste composition, local climate and method of landfilling. It is thus difficult to investigate quantitatively how pollutants are leached out from the study of waste interactions around existing landfills for which the past history of operation and exact waste compositions are unknown. Consequently, research in 1979 has involved the detailed monitoring of leachate generation and migration from a controlled deposit of domestic refuse above an unsaturated zone of Triassic Sandstone; instruments have been installed to record in-situ moisture-content changes, gas composition, interstitial water composition and temperature. Gas and temperature probes are also installed within the waste, and by drilling through the refuse at frequent intervals, solid samples of the unsaturated zone will be obtained for detailed geochemical analysis.

Preliminary results have shown that, although the waste has not reached field capacity and leachate generation has not yet started, anaerobic biodegradation of the waste has produced hydrogen (up to 8%), carbon dioxide (up to 80%) and methane (up to 13%) which have diffused under concentration and thermal gradients (3°C/m), and possibly under a pressure gradient, into the unsaturated zone, displacing the oxygen previously present. The carbon dioxide has probably lowered the pH of the system which, together with the anoxic conditions, may well inhibit degradation of the organic content of the leachate once it starts to migrate. At present drill samples of the unsaturated zone are obtained for detailed geochemical analysis approximately 1 year after the refuse was emplaced. These studies are an extension of the lysimeter studies at Uffington in which unsaturated Lower Greensand has been irrigated with various compositions of synthetic leachate. Work at that research site was being concluded at the end of 1979, although monolith lysimeters have been extracted for continued irrigation, in particular for heavy-metal desorption studies using an acid leachate composed principally of short-chain fatty acids. A report on the attentuation of iron and its role in the attentuation of heavy metals in Lower Greensand using Mössbauer spectroscopy has also been produced in 1979. This shows that on irrigation with heavy metals the iron originally present as fine particle goethite is converted to a stable ferric gel, which readily assimilates heavy metals and aids in their attentuation.

A further line of research, recently initiated, involves the use of readily available fine-grained waste materials as permeable liners beneath landfill sites to increase the thickness of the unsaturated zone and therefore its attentuation capacity. Columns have been repacked with pulverised fuel ash, foundry sand, sand waste from china-clay extraction, and limestone quarry waste, to be irrigated with synthetic leachate containing heavy metals and short-chain carboxylic acids commonly found in leachate. Apart from this landfill research for DOE, the Unit gives advice to waste-disposal authorities on disposal matters especially with regard to the selection of landfill sites, and it is likely that this type of work will continue to increase.

Geomagnetism Unit

Observatories

The main function of the observatories is to record continuously the Earth's changing magnetic field to a high absolute accuracy and to make the data available.

Cassette-recording fluxgate magnetometers and new absolute-vector proton magnetometers were installed at all three observatories and the storm magnetograph at Lerwick has been given a long-run photographic recorder. Owing to the disruptive effect of North Sea development on the building industry a working party of geomagnet-

SERVICIO GEOLOGICO FRANCES

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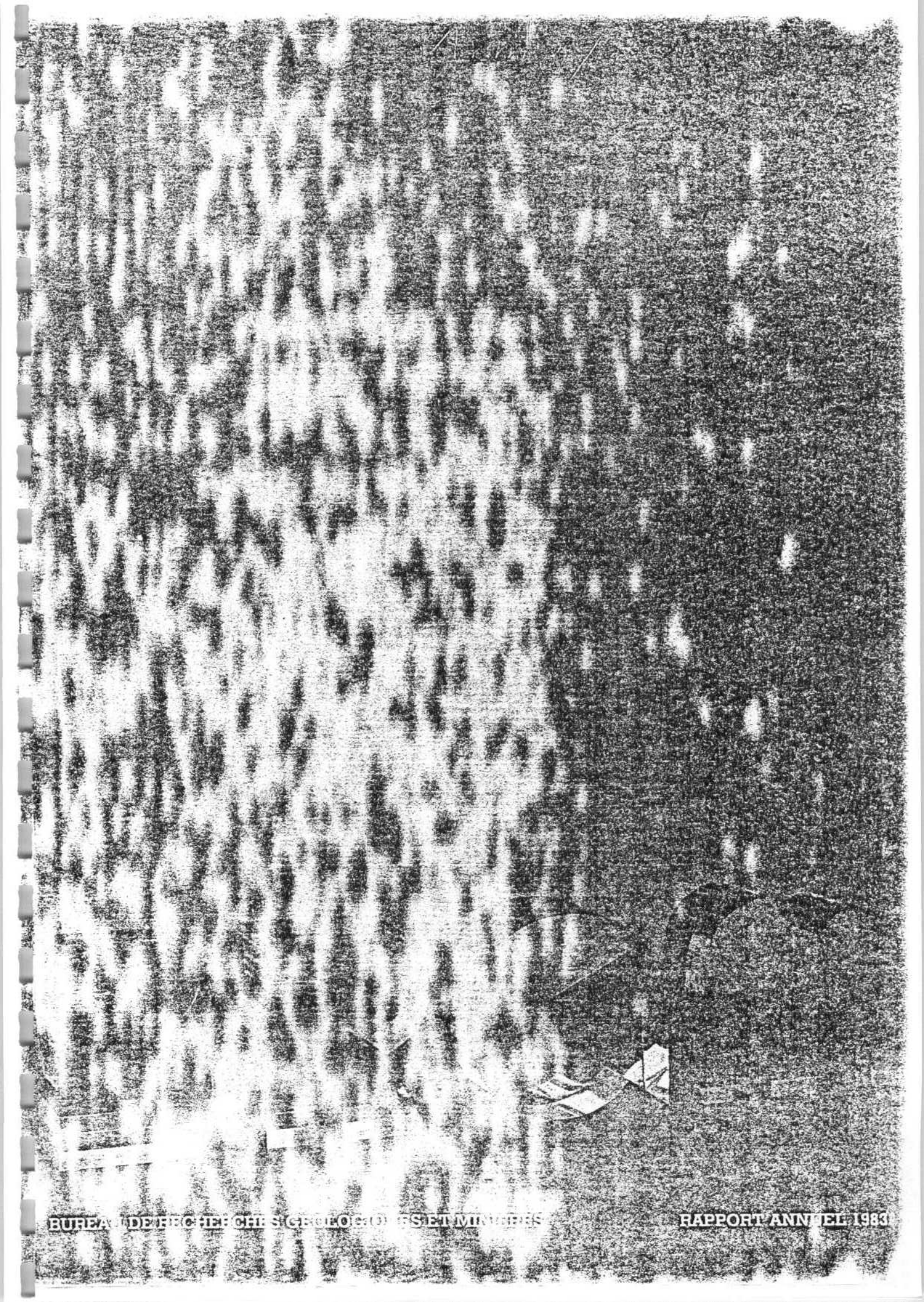


BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

RAPPORT ANNUEL 1983

Des études méthodologiques réalisées en co-financement avec l'Atelier central de l'Environnement, l'Agence française pour la maîtrise de l'énergie et le Comité de la taxe parafiscale sur les granulats, ont intéressé les impacts résultant des divers aménagements ou activités : mines, géothermie, microcentrales hydroélectriques, carrières.

De nombreux constats d'impacts ont été réalisés pour le compte de tiers : projets de fouilles (Coutras), exploitations minières (Rouez, Montredon), activités de microcentrales hydroélectriques (Basse-Normandie), extension portuaire de L'Ile de la Réunion...

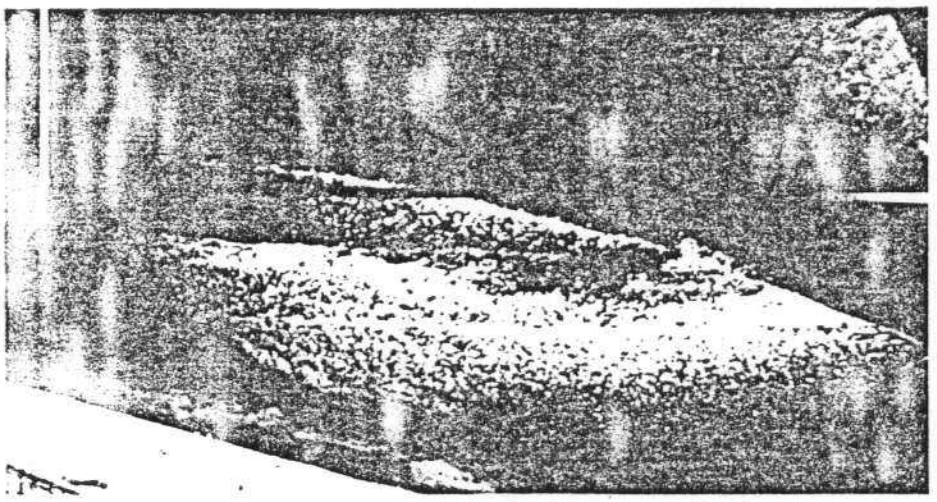
érosion et transport des sédiments

Deux importants programmes de recherche ont débuté en liaison avec le ministère de l'Industrie et de la recherche. Il s'agit d'études concernant, d'une part le processus d'érosion de bassins expérimentaux de la région Provence-Alpes-Côte d'Azur menées en collaboration avec l'Office de recherches scientifiques et techniques d'outre-mer, et d'autre part le phénomène des transports solides et l'évolution du lit de la Loire moyenne, réalisées avec le concours du Laboratoire national d'hydraulique d'EDF.

En 1983, des études pour tiers relatives à ce thème ont intéressé les rivières du littoral Est de la Corse, la vallée de la Tinée,...

STOCKAGES ET ENFOUISSEMENTS PROFONDS : OPTIMISER L'OCCUPATION DU SOUS-SOL

L'objectif commun des recherches entreprises, avec dans certains cas l'appui financier de la CEE, est de contribuer à une meilleure connaissance du milieu profond et à la mise au point de méthodes ou d'outils adaptés à la résolution des problèmes pratiques de stockages de produits solides, liquides ou gazeux, qu'il s'agisse d'hydrocarbures ou de déchets provenant des industries nucléaires. Un effort important a été consacré à déterminer l'évolution naturelle d'un site de stockage à long terme en prenant en compte les différents facteurs envisageables, par exemple la variation des climats ou l'activité tectonique. Dans ce cadre, [redacted] concernant divers types de formations géologiques.



Chatou (Yvelines) : mesures de charriage en laboratoire.

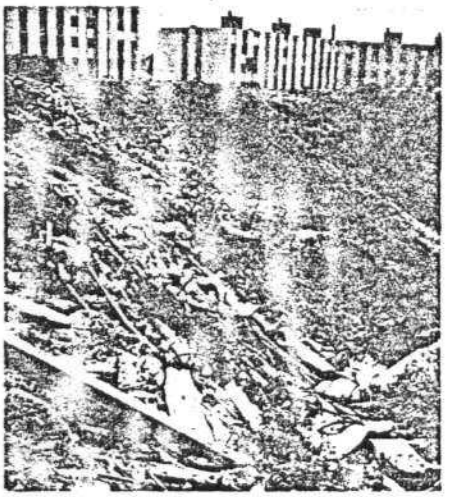
réaménagements

Chaque année, 35 km² du territoire français sont transformés en carrières (à titre de comparaison, la superficie de la ville de Lyon avoisine les 45 km²) dont les plaies dans le paysage ne sont pas toujours faciles à cicatriser. Conscients de cet état de fait, les Pouvoirs publics ont donc institué un système visant à concilier les nécessités de l'approvisionnement en matériaux avec la sauvegarde du cadre de vie en créant, en 1975, une taxe dont le produit permet de financer différents types de réaménagements.

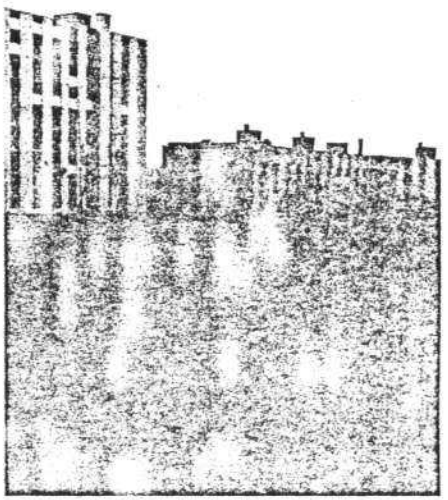
En 1983, le BRGM a été opérateur pour des réalisations de réaménagements (études et montages de projets à Ceyrat, Vandœuvre-sur-Barse, Saint-Césaire,...) et maître d'œuvre sur les carrières de Montmartin, Nogent-sur-Seine, Beautiran,... D'autre part, des études méthodologiques ont été réalisées sur les réaménagements miniers, avec l'achèvement d'une synthèse documentaire internationale, et les réaménagements de carrière à des fins agricoles avec la poursuite d'expériences dans la commune de Passy (Savoie).

Depuis 1975, les demandes de financement ne cessent d'affluer au Comité chargé de gérer la taxe parafiscale sur les granulats.

Carrière de Voiron (Isère) réaménagée en terrain de sports.



Avant



Après

SERVICIO GEOLOGICO HOLANDES

(R G D)

1981

Jaarverslag 1981 Rijks Geologische Dienst Ministerie van Economische Zaken

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verwerkingsmethoden van geofysische gegevens.
- Petrofysisch
Petrofysische evaluaties van exploratie- en produktieputten in Friesland en in de F, K, L en P blokken in de Noordzee.
Verdere ontwikkeling en herziening van geautomatiseerde data-verwerking; bestudering en beoordeling van diverse commerciële software-systemen.
- Reserve-evaluatie
Uitvoeren van volumetrische en 'material balance-berekeningen.
Werkzaamheden ten behoeve van de reserve- en reservoirtechnische data-bank.

Diversen
Coördinerend werk werd verricht voor een vulcanologisch onderzoek door een internationaal team van vulcanologen van de eilanden Saba en St. Eustatius in opdracht van het Kabinet voor Nederlands-Antilliaanse Zaken ten behoeve van de regering van de Nederlandse Antillen. Het rapport, dat een uitgebreide geologische studie en een evaluatie van het vulcanologische risico behelst, is op 1 april 1981 aangeboden aan de Gevolmachtigd Minister te 's-Gravenhage.
Om uitvoering te kunnen geven aan Artikel 29, tweede lid van de Mijnwet Continentaal Plat van 23 september 1965 (Stb. 428) werden werkzaamheden verricht voor de bekendmaking van wettelijk vrijgegeven exploratieboringen op het Nederlandse deel van het Continentaal Plat.
Voorlichting is gegeven aan binnen- en buitenlandse instellingen, bedrijven en particulieren over geologische onderwerpen in Nederland en op de Noordzee.
Ten slotte heeft de archivering van geologische en geofysische gegevens en van gesteentemonsters en ook de opleiding van nieuwe medewerkers tijd en aandacht gevraagd.

Over het werk van de RGD aan het [redacted]

In een aantal landen worden op het ogenblik studies verricht naar de mogelijkheid om radioactief afval in de ondergrond te brengen. Als omhullend gesteente wordt hierbij gekeken naar heel verschillende materialen zoals graniet, bazalt, klei en steenzout. Men bestudeert met name die gesteenten die in eigen bodem voorkomen. Vergelijkende studies komen aarzelend op gang. Er is verder sprake van verschillende soorten en hoeveelheden radioactief afval, verpakkingsmethoden, mijntechnieken en opbergingsgeometrie. Een belangrijk probleem kan zijn het al of niet omkeerbaar zijn van het opbergingsproces. In Nederland is steenzout, een indampingsgesteente, een belangrijke keuzemogelijkheid. Tijdens de Zechstein periode, ongeveer 200 miljoen jaren geleden, werd dit materiaal afgezet in een bekken dat lag tussen het huidige Engeland en Polen. Primair zijn deze lagen honderden meters dik. Zout is echter geologisch gezien relatief instabiel, en gaat onder druk- en temperatuurverhoging zeer langzaam vloeien. Hierbij ontstaan dan zoutkoepels, structuren van vele kubieke kilometers grootte, onder het gelijktijdig dunner worden van het oorspronkelijke pakket. Hierbij worden de lagen – steenzout bevat inschakelingen van ander gesteente – sterk geplooid. Van deze zoutkoepels komen er enkele tientallen voor in de ondergrond van Groningen, Drente en het Nederlands Continentaal Plat. De RGD is, op grond van haar officiële taakstelling, nauw betrokken bij onderzoek van steenzout en zoutkoepels op eventuele geschiktheid voor het gestelde doel. Aan de zoutkoepels onder het vasteland wordt geen onderzoek verricht zolang de Brede Maatschappelijke Discussie over Energie voortduurt. Voor het Noordzeegebied heeft de RGD in 1979-1980, op verzoek van het eigen Ministerie, globaal aangegeven welke zoutstructuren in principe in aanmerking zouden komen. Het aanleggen van een dieptecriterium (bovenzijde steenzout te verwachten op minder dan 1000 m) resulteerde in de volgende lijst (zie bladzijde 36).
De locaties zijn aangegeven op bijgaand kaartje. (fig. 6). Van deze lijst zijn twee grote zoutkoepels gekozen, n.l. L4/5 en L4/7. In de betreffende gebieden is in 1981 marien-geofysisch onderzoek verricht, aangevuld met steekboringen tot enkele meters diepte. Het was hierbij de bedoeling de geometrie van deze structuren met hun afdekkende en omringende lagen beter te leren kennen. Hieruit kunnen o.m. conclusies over de wordingsgeschiedenis worden getrokken, wat dan weer leidt tot inzicht in de toekomstige stabiliteit. Verder konden de verschillende geofysische technieken worden beproefd op hun bruikbaarheid voor het gestelde doel. Tijdens drie programma's is in de loop van het jaar 200 km normale exploratieseismiek, 80 km high-resolution seismiek en 300 km Sparker en Boomer opname gemaakt, het laatste in eigen beheer. De gegevens zijn, samen met reeds beschikbare gegevens, in het najaar geïnterpreteerd. De voorlopige resultaten aan het einde van

*) vroeger NOORA

het verslagjaar waren als volgt. De L4/5 koepel is de oudste van de twee onderzochte koepels. De doorbraak van het steenzout eindigde in het Oud-Tertiair. De afmetingen zijn ± 5 x 5 km op 1000 m diepte.
De L4/7 koepel is jonger, en meet ± 1,5 x12 km op 1000 m diepte. Bij deze koepel is nog wat meer voortgaande beweging van het steenzout te verwachten dan bij L4/5, maar voor beiden is sprake van zeer geringe bedragen.
De bovenkant van het zout ligt op 500 à 700 meter onder zeeniveau. Op beide koepels wordt zgn. caprock verwacht, een residu van de minder goed oplosbare bestanddelen van het steenzout dat aan de bovenzijde van de koepels in oplossing is gegaan. De afdekkende lagen bestaan uit klei, waarop een pakket zand voorkomt. Hierin zijn geulen van pleistocene ouderdom zichtbaar, alsmede enige breuktectoniek. De resultaten zullen in 1982 verder worden uitgewerkt en gerapporteerd.

No.	Blok	Opsporings-vergunning verleend	Winnings-vergunning verleend	Gesloten gebied	Vrij gebied
1	F7/8	x			
2	D-12/15	x			
3	K8/9	x	x	x	
4	K8/11		x		
5	L4	x		x	
6	L4/5	x			x
7	L4/7	x	x		
8	L7/10		x		
9	M2			x	
10	M5			x	
11	M5/8			x	
12	M8	x		x	
13	N4			x	

Overzicht zoutkoepels Noordzee;
situatie m.b.t. de Mijnwet Continentaal Plat.

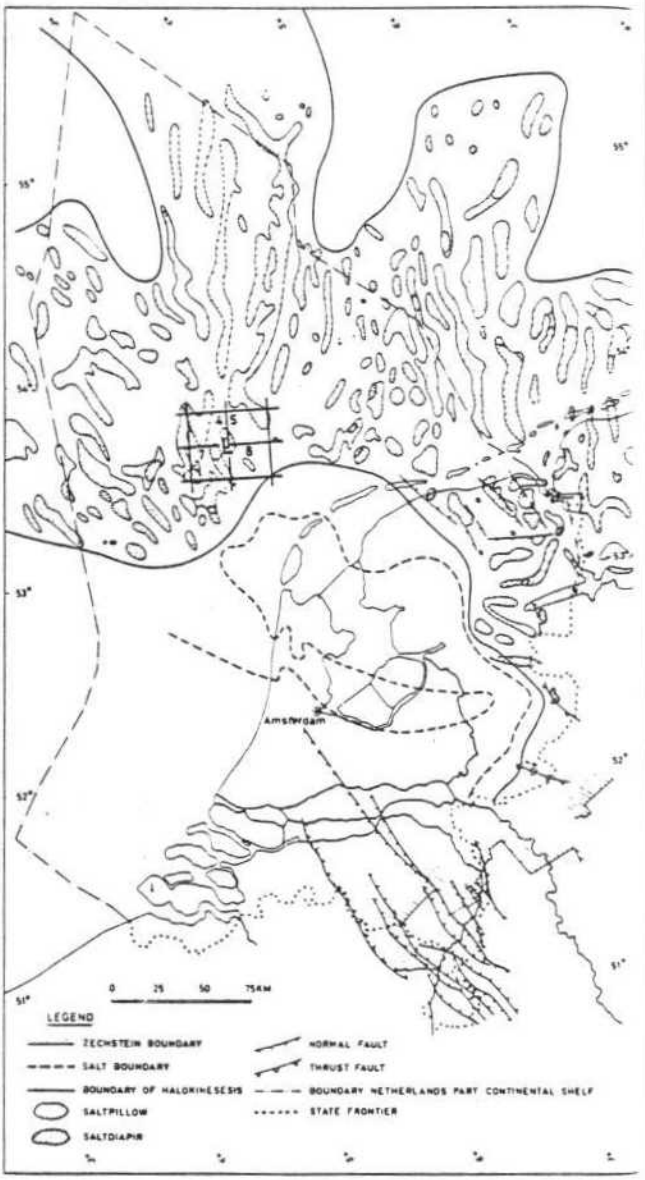

Fig. 6. Overzichtskaart zoutstructuren Nederland. (naar P. Heybroek e.a. 1974 en Harsveldt 1979).
De onderbroken lijn geeft de zuidelijke begrenzing van de zoutlagen in de ondergrond.
De volgetrokken lijn omgrenst het gebied waar het zout in beweging is gekomen en tot zoutkussens (gestippeld) of zelfs tot zoutpijlers (gearceerd) is opgeperst.