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LPDR no

TRIP REPORT 7/8/87/J.BUCKLEY

MEMORANDUM FOR: Mysore S. Nataraja, Section Leader
Geotechnical Engineer/Design Section
Technical Review Branch
Division of High-Level Waste Management

FROM: John T. Buckley
Geotechnical Engineer/Design Section
Technical Review Branch
Division of High-Level Waste Management

SUBJECT: TRIP REPORT FOR SECOND MEETING OF THE NEA ADVISORY GROUP ON IN-SITU RESEARCH AND INVESTIGATIONS FOR GEOLOGICAL DISPOSAL (ISAG) OECD, PARIS, FRANCE, JUNE 23-25, 1987.

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Mr. A. Barbreau	(France)
Ms. Andre'-Jehan	(France)
Dr. W. Brewitz	(F.R. of Germany)
Mr. Haruto Nakamura	(Japan)
Dr. Minoru Yamakawa	(Japan)
Mr. Fritz Kautsky	(Sweden)
Mr. Robert Lieb	(Switzerland)
Dr. Erik Frank	(Switzerland)
Mr. Pat Bourke	(United Kingdom)
Mr. John Black	(United Kingdom)
Dr. Lynn Tyler	(United States)
Mr. Charles Voss	(United States)
Mr. B. Come	(CEC)

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/S/

John T. Buckley
Geotechnical Engineer/Design Section
Technical Review Branch
Division of High-Level Waste Management

E
Attachments:
As stated

0004

JUL 31 1987

OFFICIAL CONCURRENCE AND DISTRIBUTION RECORD

MEMORANDUM FOR: Mysore S. Nataraja, Section Leader
Geotechnical Engineer/Design Section
Technical Review Branch
Division of High-Level Waste Management

FROM: John T. Buckley
Geotechnical Engineer/Design Section
Technical Review Branch
Division of High-Level Waste Management

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DATE: 87/07/31

DISTRIBUTION w/o Enclosure

HLWM/SF	NMSS RF	RBrowning, HLWM	MBell, HLWM
JBunting, HLSE	JLinehan, HLOB	RBallard, HLTR	JBuckley, HLTR RF
MNataraja, HLTR	DGupta, HLTR	JPeshel, HLTR	NTanious, HLTR
JPearring, HLTR	LYang, HLTR	DTiktinsky, HLTR	HLTR RF
PDR	DGalson, HLOB	SCoplan, HLOB	

CONCURRENCES

ORGANIZATION/CONCUREE	INITIALS	DATE CONCURRED
HLTR/JBuckley	JB	87/07/31

Original Sent

(Mailed by the WMDCC)
8/4/87 4:20 p.m.
Date / Time

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encl. to memo for Nataraja from JBuckley 4/2.2.1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 31 1987

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Attachments:
As stated

APPENDIX A

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

SEN/RWM(87)6

RESTRICTED

Paris, drafted: 30th March 1987

dist: 13th April 1987

CONVOCATION

Or. Eng.

STEERING COMMITTEE FOR NUCLEAR ENERGY

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Second Meeting of the NEA Advisory Group on In Situ Research and Investigations for Geological Disposal (ISAG)

OECD, Paris
23rd-25th June 1987

The second meeting of the NEA Advisory Group on In Situ Research and Investigations (ISAG) will take place at the Château de la Muette, 2 rue André Pascal, Paris 16ème on 23rd-25th June 1987. The meeting will start at 10.00 a.m. on the first day.

Please note that the security arrangements in force at the OECD include the obligation to present an identity document bearing a photograph. This document will be requested at the time of issuing delegates' cards for the meeting. It should also be presented subsequently together with the card every time OECD premises are entered from the outside.

The following agenda is proposed for the meeting:

PRELIMINARY AGENDA

1.	OPENING OF THE MEETING	
2.	ADOPTION OF THE AGENDA	SEN/RWM(87)6
3.	APPROVAL OF THE SUMMARY RECORD OF THE FIRST MEETING OF ISAG	SEN/RWM(86)8
4.	APPROVAL OF ISAG TERMS OF REFERENCE BY RWMC	SEN/RWM(86)8

- Report by the Secretariat/Chairman of discussions on ISAG at the RWMC meeting on 11th-12th June 1987

03 933

5. RECENT DEVELOPMENTS IN MEMBER COUNTRIES

- as this topic was covered so comprehensively at the first meeting of ISAG only brief up-dates will be required from those attending both meetings. It is suggested that participants provide 30 copies of a 2-3 page written summary of the main developments. For any group attending for the first time more comprehensive presentations may be made.

6. PROGRESS OF NEA ACTIVITIES OF INTEREST TO ISAG

(i)	Crystalline Rock Programme Directors Group (CRPDG)	C.ROCK/DOC(86)2
(ii)	International Stripa Project	RWM/DOC(87)1
(iii)	Natural Analogue In Situ Studies	RWM/DOC(87)7
	- Alligator Rivers Project, Australia	
(iv)	Performance Assessment Advisory Group (PAAG)	SEN/RWM(87)2
	- Workshop on Near-field Studies for LLW &ILW - Joint initiatives with ISAG - HYDROCOIN/INTRAVAL	

7. PROGRESS OF ACTIVITIES UNDER THE AEGIS OF ISAG

(i)	Report of discussions at ISAG Consultant Group meeting on 16-17 February	ORAL REPORT ISAG/DOC (87)5
(ii)	Proposed Report on In Situ Research and Investigations in NEA Member Countries for Radioactive Waste Disposal	ISAG/DOC(87)2
	- Participants are invited to review the draft report, in particular, the sections dealing with research and investigations in their areas. Subject to satisfactory resolution of these comments, the intention is to recommend that the report be published by the OECD in 1987, after clearance with the RWMC by correspondence.	
(ii)	Increasing Interaction between In Situ Research and Investigations and Modelling - Report of the Consultant Group	ISAG/DOC(87)3
	- The consultant group recommended the preparation of a <u>questionnaire</u> to gather information on the priority areas for interaction. The group is invited to review the questionnaire and agree to its distribution to	

ISAG & PAAG via the RWMC. A consultant group comprising representatives from ISAG & PAAG will meet in the Autumn to review the findings

(iii) Provisional Programme for a Workshop on Excavation Effects on the Engineering and Performance of a Mined Underground Repository for Radioactive Wastes (Paris, 18-20 November 1987) — ISAG/DOC(87)4

- the preliminary programme for the workshop is presented for information and comments

(iv) Proposed Workshop on Backfilling and Sealing Materials for Underground Repositories for Radioactive Wastes (1988) — ORAL REPORT

- This workshop was agreed at the first ISAG as a necessary follow-up to a workshop on excavation effects. ISAG is invited to advise the Secretariat on the the scope, programme, content and timing of the workshop and make recommendations to the the RWMC accordingly

(v) Increasing Information Exchange - Proposal for RWMC Newsletter on Technical and Policy Developments in Radioactive Waste Management — RWM/DOC(87)8

- The Secretariat will inform ISAG of the decisions of the RWMC concerning plans for a new NEA Newsletter in the area of performance assessments and in situ research and investigations

8. DISCUSSION OF POSSIBLE FUTURE ACTIVITIES OF ISAG

- Participants are invited to table proposals for any new initiatives. For example, ways to promote deeper understanding of the development and application of site investigation techniques in the context of radioactive waste management; this is part of the scope of ISAG but it not currently addressed by the group

9. ANY OTHER BUSINESS

10. DATE OF NEXT MEETING

<u>Note</u> In order to avoid producing too many copies of each document, participants are kindly requested to bring to the meeting all the documents distributed in advance.

APPENDIX B

SCK/CEN

NC87/46/D6100/BN/mvg/R-82

GEO-TECHNOLOGIE

Mol, 19th June 1987

NEA ADVISORY GROUP ON IN SITU RESEARCH AND INVESTIGATIONS FOR GEOLOGICAL DISPOSAL

(ISAG)

NOTE FOR DISTRIBUTION

Paris, 23rd-25th June 1987

(second meeting)

LAST DEVELOPMENTS ON THE HADES PROJECT

Mol, Belgium

B. NEERDAEL, A. BONNE, D. DE BRUYN

INTRODUCTION

The URL constructed on the site of the Belgian nuclear research establishment (CEN/SCK) at Mol (Belgium) has been the starting point of an extensive in situ research programme in deep clay.
Specific in situ investigations in the field of corrosion behaviour of various structural materials and waste forms are being carried out in representative conditions. Important contributions have also been made to the understanding of the hydrology in the clay body and the adjacent layers, to the geotechnical aspects of gallery construction in deep clay and to the radionuclide migration.

This R&D-programme is performed in the framework of research contracts with the CEC and (since 1983) the National Waste Management Authority (ONDRAF/NIRAS). All these experiments were already presented at the previous ISAG-meeting and detailed in background papers.

During the last 8 months efforts were devoted to the preliminary studies and investigations in preparation of the extension of the URF towards a pilot size unit. The excavation of a new gallery, called "test drift", started March 1987.

HADES DEMONSTRATION/PILOT PHASE

For the moment most efforts in the HADES-demonstration pilot programme concerns the construction of a test drift. The construction of the test drift is intended to upscale the construction capabilities in non frozen deep clay to real scale (about 5 m diameter tunnelling) and to perform demonstration tests on heat transfer, radiolysis and active source handling, material interface interaction tests, emplacement and backfill tests.

This 45 m long gallery (Fig. 1), lined with concrete blocks, consists of first a 4.7 m long access gallery (with a 2.64 m inner diameter) connected to the existing shaft (and opposite to the URL) followed by a 1 m long monolithic transitional zone and finally completed by a 40 m long test drift (with a 3.5 m inner diameter) equipped with access ports to the clay body.

The construction of the test drift is performed in the frame of the European Atomic Energy Community's costsharing research programme on radioactive waste management and disposal.
The construction by ANDRA (National Agency for Radioactive Waste Management, France) of a 13.5 m experimental gallery lined with sliding steel ribs according to the convergence-confinement principle is scheduled to start mid-November 1987 and to last for about 2.5 months.

A future large pilot gallery, allowing to perform mock-up tests on real scale first and experimental disposal of various waste types (in a retrievable manner) at a later stage are still foreseen in the programme but delayed with respect to original schedule. Only preconceptual studies for a larger pilot facility will be undertaken before 1990 and the very detailed architecture and particular design studies are to be undertaken in the first half of the 90ies

TEST DRIFT (TD) - OUTLINE OF THE PROGRAMME

The test-programme of the TD includes :

1. construction and operation (including a general monitoring and auscultation) of the test drift ;
2. mine-by test (mining technology) ;
3. Cerberus-test (validation test for radiation and heat impact) ;
4. Materials Interface Interactions Tests (MIITs) ;
5. Gallery Heating Test (GHT) ;
6. dummy emplacement and backfill test ;
7. optionally : reduced scale radioactive validation test.

The time schedule for the various actions in the above programme areas are given in Table 1.

Presently an operational period until 1997 is scheduled. Preference has been given to launch the long lasting tests with radioactive sources immediately after the construction of the test drift and the adaptation of the hoisting system.

CONSTRUCTION AND OPERATION OF THE TEST DRIFT / MINE BY TEST

The objective of this test (Fig. 2) is to validate the geotechnical modelling of gallery construction and behaviour in a plastic clay formation. Auscultation instrumentation was already installed in the host rock above and below the position of the TD before the excavation and construction of it was launched. The initial state is already established and the monitoring of the excavation response is already made the excavation works. A series of complementary geotechnical measurements in the clay mass and measurements of deformation and pressure build-up in the gallery lining will be undertaken progressively along the progress of the gallery construction. The length of the TD (40 m lined with concrete blocks) is representative for continuous construction conditions.

For practical reasons all activities related to general operation and maintenance of the TD, as well as the general auscultation in the host rock (total pressures, interstitial pressure, temperature, Eh/pH, moisture content, etc) and monitoring of the TD (ventilation, data acquisition/ transmission systems etc) are inserted in this programme area.

CERBERUS-TEST

(CERBERUS = Control Experiment with Radiation for the BElgian Repository for Underground Storage). CERBERUS is a technological test aiming at evaluating by simulation the impact in its immediate near field by a HLW-source (50 years cooling time). This test is conceived to be representative as well for the in-gallery emplacement concept as for some aspects of the in-hole emplacement concept. The simulating source of this experiment is planned to be a 15kCi Co-source combined with an electrical heater, both emplaced during 5 years in a cased hole in the clay in the floor of the TD. Auscultation will be developed in the clay and in the gallery structure. The concept of the CERBERUS-test allows a very limited number of additional studies on backfill and structure materials (dry and wet). A sampling and analysis of the clay and components of the experimental set-up are planned at the end of the test.

MATERIALS INTERFACE INTERACTIONS TESTS (MIITs)

The objective of these tests is to define the performances of a few, for Belgium, relevant radioactive waste forms (glass, concrete, bitumen), package and backfillmaterials as they interact in and with an argillaceous environment. The test focusses on the evaluation of the long-term in situ corrosion of the components and the surface interactions in backfilled holes in clay. The surface interactions refer to labelled waste forms, canister drum (perforated), backfill materials, clay and interstitial clay water.

GALLERY HEATING TEST (GHT)

The objective of this test is to demonstrate by simulation the behaviour of a concrete lined gallery structure and its surrounding clay mass in a

temperature field. This a situation that will occur in the early stages of the normal evolution of the repository galleries filled with heat generating wastes.

One provisionally foresees to perform this test by heating up the wall of the gallery by means of an intrados heating blanket with a thermal output of about 500 Watts per metre of gallery. This test will be positioned so that the auscultation of the mine-by test can be used also for the GHT.

DUMMY EMPLACEMENT/BACKFILL TEST

The objective of this test is to prepare the emplacement of real waste types according to the in-gallery implacement concept and to demonstrate backfilling techniques for this particular concept. This test is planned to be performed in the portion of the TD built according to the ANDRA principles.

REDUCED SCALE RADIOACTIVE VALIDATION TEST

The objective of this test is to validate the concept of the in-gallery emplacement of a particular HLW-type and to evaluate the reliability of the auscultation and monitoring instrumentation which will be needed for the long-term demonstration with real waste type at 1/1 scale. The test will be conceived such that the waste packages are emplaced in the TD in a retrievable way.

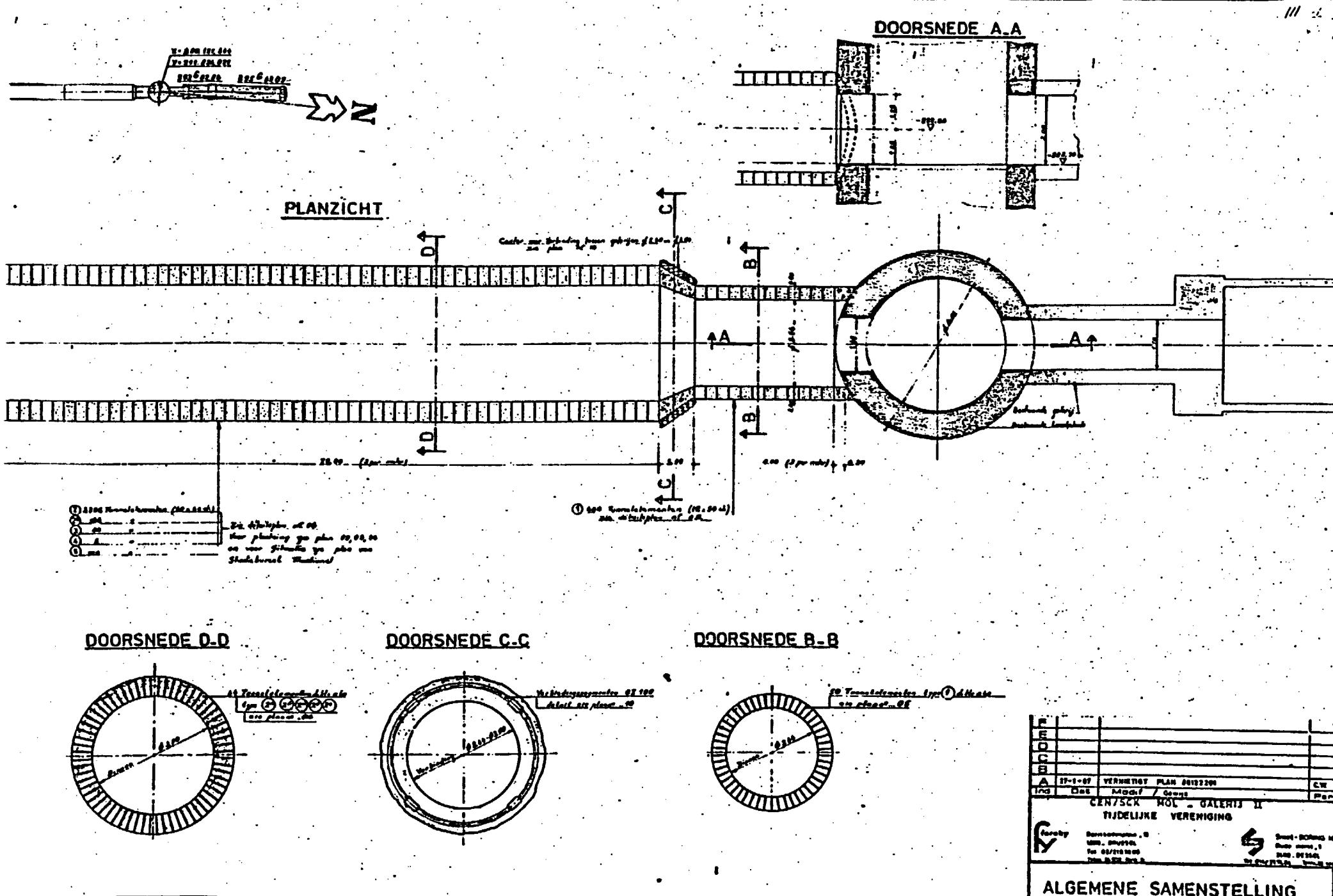
DOORSNEDE A-A
PLANZICHT
DOORSNEDE D-D
DOORSNEDE C-C
DOORSNEDE B-B
CENTSCK MOL - GALERIJ II
TIJDELIJKE VERENIGING
ALGEMENE SAMENSTELLING
86 12 22 01

Fig. 1.

GE/027/87

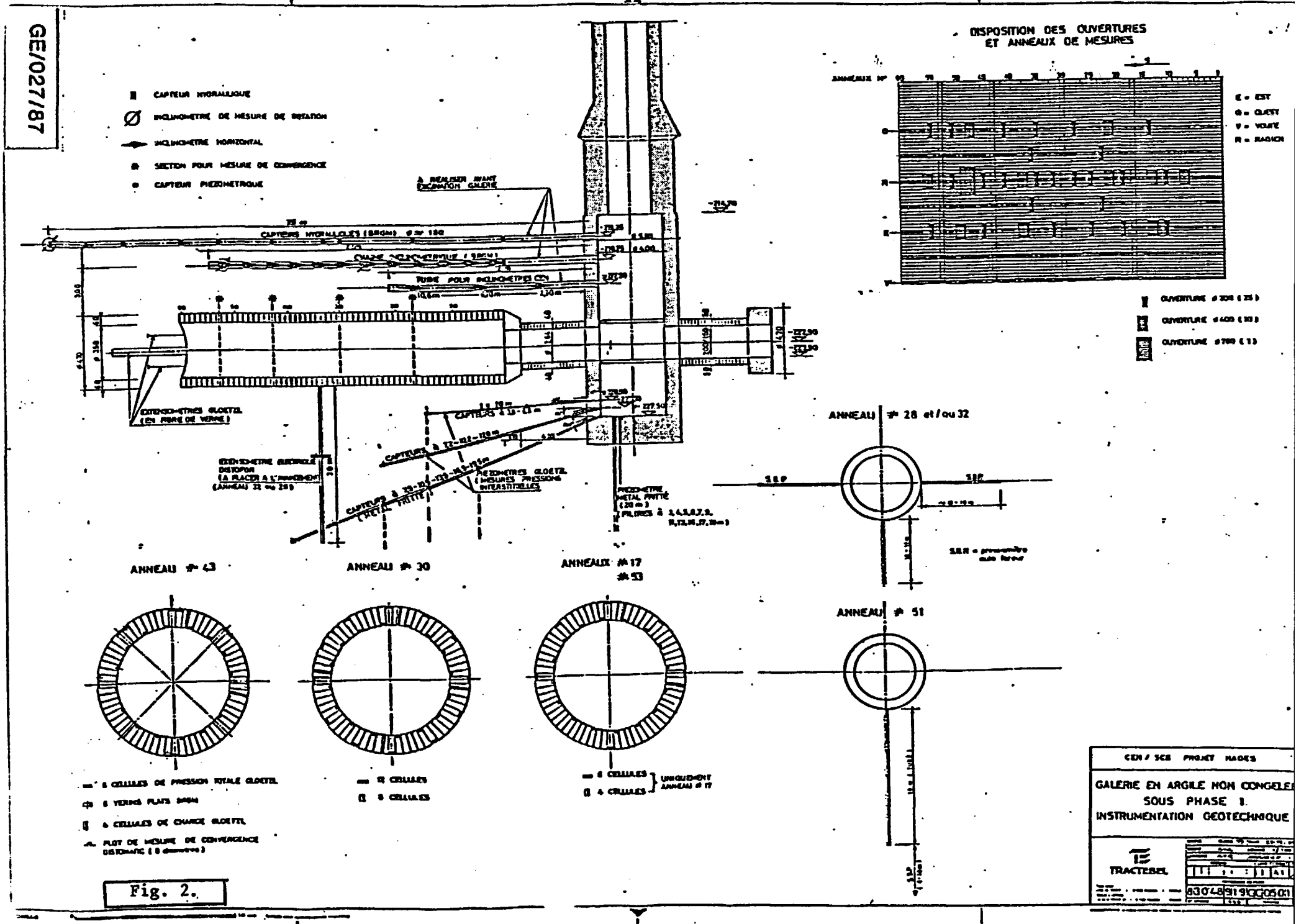

Fig. 2.

Table 1.

PLANNING HADES DEMONSTRATION/PILOT PHASE
PILOT(E).PL / 17:04:07

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998-on
TEST DRIFT												
CONSTRUCT. & OPERATION OF EXTENDED TEST DRIFT												
construction	XXXXX											
infrastruct. /equipa.		XXX										
emplac. gen. auscult. eq												
adapt. hoist system	XX											
constr. hoist system	XX XX											
placem. hoist system	X											
operation and survey	XXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
MINE-BY TEST												
test modeling	XXXXXX	XXXXXX										
emplacement	X											
(excavation and lining)	XXXX											
follow-up	XXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX				
evaluation short term		XX		XX								
evaluation long term								XX				
CERBERUS												
test design	XXX											
test modeling	XXX											
purchase, assembling	XXX	XXX										
emplacement		XXX										
follow up			XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX					
partial withdrawal (sampling)								X				
sample analyses								XX				
evaluation								XXX				
rehydratation backfill								XXXXX	XXX			
disassembling									XX			
overall evaluation									X			
MATERIALS INTERFACE INTERACTIONS TESTS												
test desing		XXX										
test modeling		XXX										
purchases, assembling		XXX										
emplacement			XXX									
follow-up			XXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XX				
disassembling, sampling								XX				
sample analyses								XX				
evaluation								X				

PLANNING HADES DEMONSTRATION/PILOT PHASE
PILOT(E).PL / 17:04:07

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998-c
GALLERY HEATING TEST												
test design			XXX									
test modeling			XXX									
purchases, assembling				XXX								
emplacement				XXX								
start/follow-up					XXXXXX	XXXXXX	XXXXXX	XXXX				
disassembling, sampling								XX				
sample analyses								X X				
evaluation								XX				
DUMMY BACKF./EMPL. TEST												
test design				XXX								
test modeling				XXXXX								
design handling equipm.				XXX								
constr. handl. equipm.					XXX							
design. backf. equipm.					XX							
constr./purch. backfill equip./water./instrum.					XXX							
backf. gal. AVDRA						X						
emplacement instrument.					XX							
performance of test						XXX						
follow-up						XX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
evaluation									XXX			
OPTIONALLY: REDUCED SCALE RADIO-ACTIVE VALIDATION TEST												
preconcept	XX											
adaption Panela-facil. and fabrication cans	XX	XXX	----------	----------	----------	XX						
storage/transport		XXX	----------	----------	----------	----------	----------	----------	X	XXXX		
final concept						XXXXX						
modeling						XXX	XXX					
license							XXX	XXX				
characterisations								XXX	XXX			
constr. surface handling system						XXX						
adaption underground handling system								XXX	X			
construction & purchase backfill instr.& water.									XX			
purchase and emplacement of instrumentation									XXX	X		
dummy tests										XXXX		
emplacement										X	XXXXX	
follow-up												X XXXXXXX
retieval												
sampling and analysis												
final evaluation												

Table 1/Page 2

THE UNDERGROUND RESEARCH LABORATORY - STATUS REPORT TO ISAG

G.R. Simmons, Atomic Energy of Canada Limited; 1987 June

The URL is a dedicated geotechnical research facility being constructed in southeastern Manitoba (Figure 1) to address the following objectives:

- to assess airborne, surface and borehole survey techniques for characterization of the subsurface geological and hydrogeological environment in plutonic rock,
- to assess the changes in physical and chemical conditions in the rock mass and groundwater caused by excavation of the URL, and
- to perform experiments relevant to assessing the performance of the disposal system being considered in Canada for nuclear fuel waste disposal.

The activities in the URL are designed to achieve these objectives. The URL also provides a suitable facility for cooperative and commercial research. The current developments and planned extensions to the URL are shown in Figure 2.

Construction of a 260 square metres office extension was completed. The extension provides additional office space for attached staff, an enlarged map and drafting area, a computer terminal room and a second conference room. It is connected via a corridor to the existing office building and will accommodate the increased staff associated with current URL programs.

Excavation of the 240 level access heading and the station for the ventilation raise extension were completed and installation of trackwork, ventilation bulkheads and mechanical services on the 240 level was completed. Concrete floors have been poured in the Shop/Instrumentation Test Room and 240 level Shaft Station. Installation of other permanent services is in progress.

Development and Characterization to the 240 Level

Monitoring of the hydrogeological instruments in the shaft continued. Analysis and reporting of the geotechnical work from the shaft sinking phase of the URL development program is nearing completion. Recently, reports and papers were completed on the following work:

- the biaxial stresses measured during shaft sinking (Lang et al. 1986)
- the residual strain tests (Lang et al. 1986)
- the displacements measured during shaft sinking (Thompson et al. 1986)
- the integration of experimental and construction activities at the URL (Kuzyk et al. 1986)
- geomechanical instrumentation applications at the URL (Thompson & Lang, 1987)

- the coupled near-field hydrogeological and geomechanical experiments in the shaft (Lang et al. 1987)

- a summary of the Engineered Excavation Program work completed to date (Kuzyk et al., 1987),

Analysis of work done to date in the 240 level characterization program is underway:

- monitoring of the hydrogeological instrumentation installed in boreholes from the 130 and 240 Levels continued throughout the period,

- Room 205, the instrument shop, was excavated and instrument assessment tests were conducted on vibrating wire stress meters and deflectometers. Analysis of the results is under way. The vibrating wire stress meters were overcored in April and additional stress measurements were done to assess their performance.

  A preliminary assessment of the Room 205 deflectometer data indicates that, in its present form, it does not have sufficiently good repeatibility, stability, or sensitivity for our requirements. Considerable development would be required to make this instrument capable of measuring the very small displacements that occur around the URL excavations. No further development work is planned at present. These instrument assessment tests were done to help selected instruments for the Operating Phase experiments.

- The geology of the 240 Level is being assimilated and documented.

The Room 209 instrument array, is being used as a modelling trial validation for groups that may participate in the modelling full operating phase Excavation Response Experiment. Four modelling groups; AECL, and the University of Alberta in Canada, and LBL and LLNL in the USA; are predicting the coupled hydrogeological and geomechanical response of the rock mass surrounding the array by determining the responses that were measured by the array of instruments installed in Room 209. The modellers prediction reports and the instrument results report will be presented at a meeting in late June.

Excavation of the 25 m of Room 209 that comprise this test began 1986 October 21 and was completed November 25. The instrumentation array monitored the geomechanical response of the rock mass and the hydrogeological pressure response in a discrete fracture that is essentially perpendicular to the axis of Room 209. The rock mass response is a result of the excavation and temperature changes in the rock caused by the warmer air in the new heading. Stereo photography and geological mapping of the exposed rock in the new excavation is complete. A report on the instrumentation results geology, and the excavation records has been prepared. It will be issued when the modelling reports are received.

An agreement has been signed with SKB of Sweden. They are contributing to the 240 Level characterization program and have access to the existing data and to all future work in the program. In 1987 March the first SKB representative arrived at the URL as an attachment to the project. He remained until mid-May.

Development and Characterization to the 440 Level

A Subsidiary Agreement has been signed between the US/DOE and AECL covering a cooperative program to 1989 September 30. Two tasks under this agreement involve the URL program: extension and characterization of the URL facilities to a depth of 465 m, and joint planning of seven large-scale multidisciplinary experiments and demonstration tests.

The extension of the shaft from the current depth of 255 m to the proposed final depth of 465 m and the development of a ventilation raise from the 240 to the 440 levels requires that both the main shaft and the ventilation raise be excavated through Fracture Zone #2 (see Figure 3) situated 20 to 40 m below the 240 level of the URL. Fracture Zone #2 is being extensively characterized and will be grouted prior to the ventilation raise excavation.

Characterization and Grouting of Fracture Zone #2

In 1986 June a program of geotechnical drilling, testing and instrumenting was begun to assess the characteristics of Fracture Zone #2 in the area where the shafts will penetrate it and to provide geotechnical data on conditions along the access shaft excavation. Characterization of the fracture zone comprises geological interpretation of borehole core, hydrogeological testing in the fracture zone, determination of the in situ stress above and below the zone and instrumenting the fracture zone with hydrogeological and displacement monitoring instrumentation. These data are being used to design a suitable program for stabilizing the fracture zone, by controlled grouting, where it will be penetrated by the ventilation shaft. The instrumentation will monitor the response of the zone during grout injection and subsequent excavation of that shaft.

A total of 35 hydrogeological and geomechanical characterization boreholes were drilled from the 240 level into the fracture zone. Detailed hydrogeological testing was performed, including rock deformation measurements using the sliding micrometer, the Trivec deflectometer and the Bof-Ex extensometer during some tests.

All characterization data obtained are being compiled and analyzed. The following conclusions were reached:

- in situ rock stresses in the immediate vicinity of the Fracture Zone #2 are extremely variable. It is not presently possible to accurately predict the stress in any given area.

- the detailed geology of the fracture zone is variable and complex; including a broad range of rock quality from highly altered (to clay) to completely sound. Fractures vary from healed, to tight, to open, including some with clay and other mineral infillings. The thickness of the fracture zone varies from a few metres up to 30 metres thick - the latter typically reflecting fractured splays to the principal portion of the zone.

- hydrogeologic characteristics of the zone vary significantly across the area investigated with broad regions of very tight (e.g., hydraulic conductivities of 10^{-10} to 10^{-12} m/sec) conditions, regions of high permeability (up to hydraulic conductivities of 10^{-5} m/sec) as well as an area near the shaft of high permeability but limited recharge.

- the characteristics of Fracture Zone #2 in the area where the access shaft will penetrate it are of the "tight" variety (permeability of $\approx 10^{-9}$ m/s). Grouting in the access shaft is not required for controlling water inflow to the shaft.

Based on these observations the decision was made to perform a limited-scale grouting methodology demonstration where the access shaft will penetrate Fracture Zone #2. In developing the grouting method for this demonstration the following points were considered:

- the presence of clay consistency materials within the fracture zone is an impediment to achieving a grouted zone of permanency. The concept of jet washing using a high pressure directional nozzle with an air shroud has been developed for use in grout holes.

- tight fractures are beyond the capability of normal grouting technology using standard materials, therefore extra fine grind cements will be utilized to better penetrate the tighter fractures.

A brief grouting technology demonstration was performed adjacent to the access shaft in Fracture Zone #2 to develop experience with the capabilities and operational problems of jet washing and injection grouting with the fine grind cement grout. The demonstration was conducted in April and May and comprised the drilling of an observation borehole and two grouting boreholes. The two grouting boreholes and one of the hydrogeological characterization boreholes near the access shaft were grouted. EM tomography and acoustic emission monitoring was done in conjunction with the trials to ascertain their ability to indicate "where the grout went".

A full grouting experiment will be planned for the ventilation raise which has been located in an area of high hydraulic conductivity. The grouting will be done in advance of the raise boring of the shaft probably in late 1988.

Research on grout materials and mix designs is active at the University of Sherbrooke Alternative cements and admixtures have been characterized in detail and the grout recommended for use in the trials and the vent raise grouting utilizes Type 50, sulphate resistant, cement reground to 600 blaine fineness, 5 to 10 percent silica fume additive, water cement ratios will be in the .4 to .5 range with the necessary fluidity being achieved by adding up to 1% super plasticizer. Sample grout mixes were used during the demonstration test.

The revised Environmental Screening Document describing the URL project including the shaft extension was completed in 1987 February when WNRE-523.1 "Supplement to Environmental Screening for the Atomic Energy of Canada Limited Underground Research Laboratory near Lac du Bonnet and Pinawa, Manitoba" was issued.

Shaft Extension Probe Borehole

The shaft probe borehole reached its planned final depth of 250 m on February 20. Five CSIR, 32 Swedish State Power Board (SSPB) and six high pressure borehole deformation gauge tests were completed down to 110 m depth. No successful tests were completed between 120 m and 250 m because of core discing. The CSIR and SSPB cell results were compared in tests at depths between 15 and 22 m. There is good agreement between the four CSIR and six SSPB tests, although the SSPB results are more scattered than the CSIR results. Below the 15 m depth (beyond the operating depth for the CSIR equipment) the SSPB cell was used to a depth of 105 m. The six high pressure borehole deformation gauges were completed at about 110 m depth.

SKB borehole radar, AECL acoustic televiewer, AECL borehole television and standard geophysical surveys were conducted in the borehole. Hydraulic fracture testing was also conducted in May. The data from these tests are being analyzed. Hydrogeologic instrumentation will be installed in the borehole when testing is complete.

Shaft Extension Program

A detailed plan is being finalized for characterizing the shaft extension. Plans for characterization of the shaft extension after completion and characterization of the 440 level are also being prepared.

Design of the shaft extension is complete. The specifications and drawings for No. 8. - Shaft Extension Contract were reviewed, finalized and issued for tender to five pre-qualified shaft sinking contractors. Following completion of the evaluation process, the contract was awarded to J.S. Redpath Limited early February. Modifications to the hoisting system and shaft bottom preparations began June 01. Sinking operations will commence early July on a 24 hour, 7 day per week basis and continue through to 1988 September.

To facilitate development of a full-face blast design for the shaft sinking, full-face blast designs were used during excavation of some 240-level access tunnel. Indications are that full-face shaft blast rounds will provide acceptable final wall quality, if the fly-rock from the blasting can be accommodated without damaging shaft installations.

References and Publications

Kuzyk, G.W., Lang, P.A. and Peters, D.A. (1986). Integration of Experimental and Construction Activities at the Underground Research Laboratory. In Proceedings of the 6th Canadian Tunnelling Conference, Niagara Falls, 1986 October 29 to 31.

Lang, P.A., Everitt, R.A., Ng, L. and Thompson, P.M. (1986). Horizontal in situ stresses versus depth in the Canadian Shield at the Underground Research Laboratory. In Proceedings of the International Symposium of Rock Stress and Rock Stress Measurement, Stockholm, Sweden, September 1986.

Lang, P.A., Ng, L. and Thompson, P.M. (1986). The effect of residual stress and drill hole size on the in situ stress determined by overcoring. In Proceedings of the International Symposium on Rock Stress and Rock Stress Measurement, Stockholm, Sweden, September 1986.

Simmons, G.R. 1986. "Atomic Energy of Canada Limited's Underground Research Laboratory for Nuclear Waste Management". In Proceedings of Geothermal Energy and Advanced Technology International Symposium, Tohoku University, Sendai, Japan, 1986 November 06-08. Also issued as Atomic Energy of Canada Limited Report AECL-9283.

Thompson, P.M. and Lang, P.A. "Geotechnical Instrumentation Applications at the Canadian Underground Research Laboratory". In Proceedings of the 2nd International Symposium - Field Measurements in Geomechanics, Japan, 1987 April.

Thompson, P.M. and Lang, P.A. (1986). Rock displacements measured during URL shaft sinking. In Proceedings of the Second International Conference on Radioactive Waste Management, Winnipeg, Canada, September 1986.

Favreau, R.F., Kuzuk, G.W., Babulic, P.J., Morin, R.A. and Tienkamp, N.J. (1987). Use of Computer Simulations to Improve Blast Quality . Annual CIM Conference, Toronto, 1987 May.

Kuzyk, G.W., Babulic, P.J., Lang, P.A. and Morin, R.A. (1987). Blast design and quality control procedures at Atomic Energy of Canada's Underground Research Laboratory. In Proceedings of the 13th Annual Conference of the Society of Explosives Engineers, February 1987.

Lang, P.A., Chan, T., Davison, C.C., Everitt, R.A., Kozak, E.T. and Thompson, P.M. (1987). Near-Field Mechanical and Hydraulic Response of a Granitic Rock Mass to Shaft Excavation. In Proceedings of the 28th US Symposium on Rock Mechanics, 1987 June 29 to July 1.

Thompson, P.M. and Lang, P.A. (1987). Geomechanical Instrumentation Applications at the Canadian Underground Research Laboratory. In Proceedings of the 2nd International Symposium - Field Measurements in Geomechanics, Japan, 1987 April.

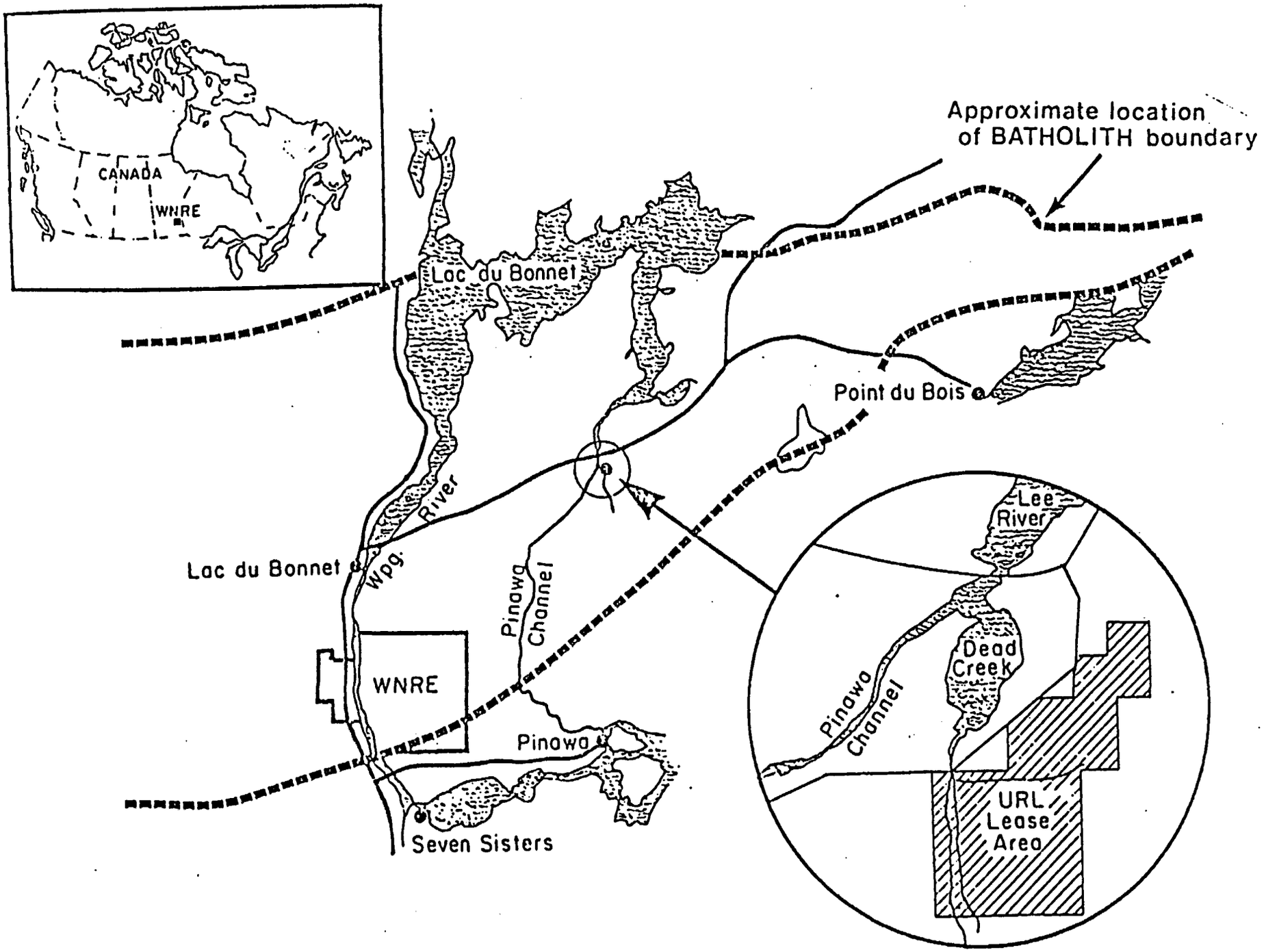

FIGURE 1 : The Underground Research Laboratory Lease Area and Location

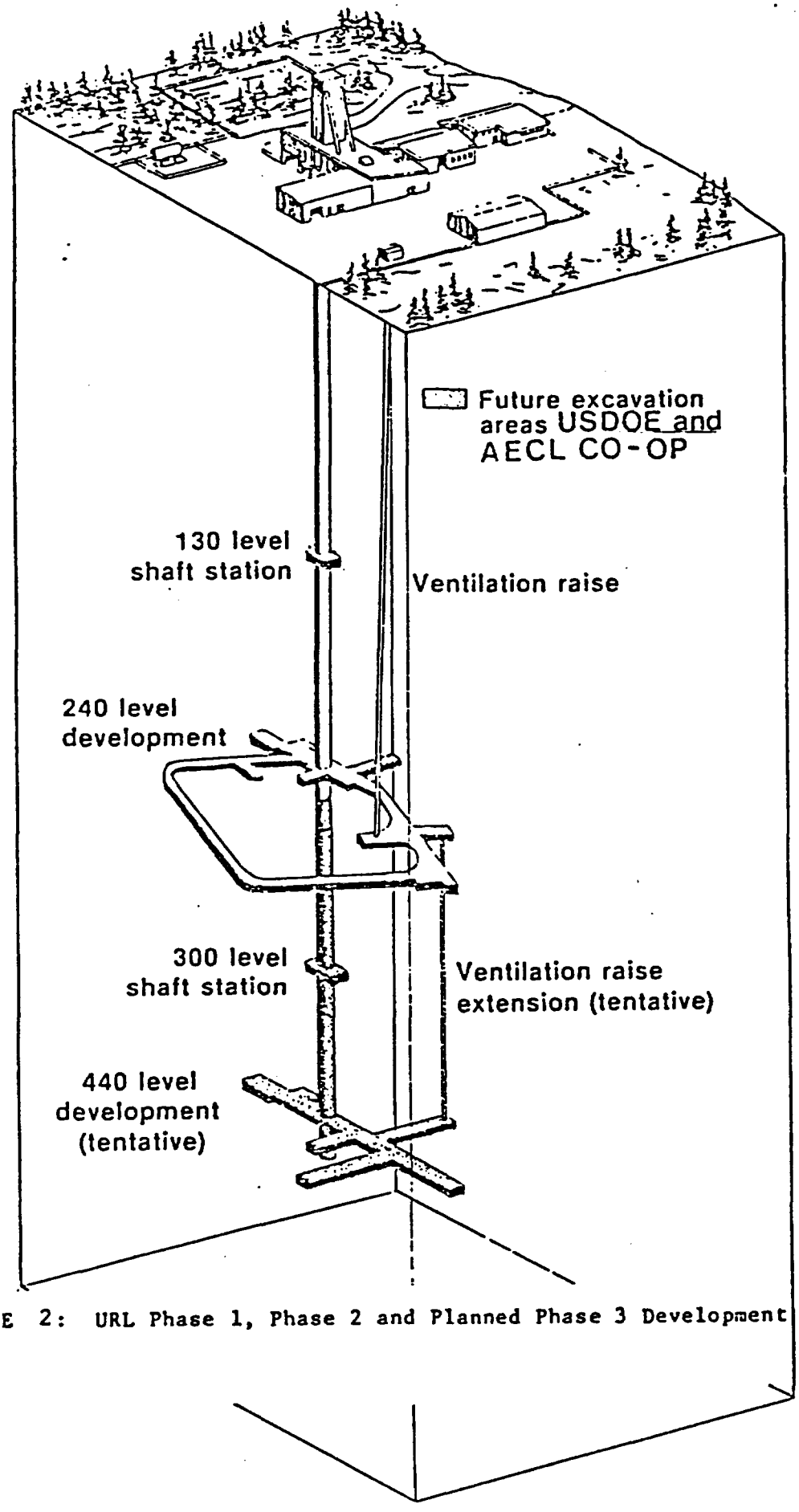

FIGURE 2: URL Phase 1, Phase 2 and Planned Phase 3 Development

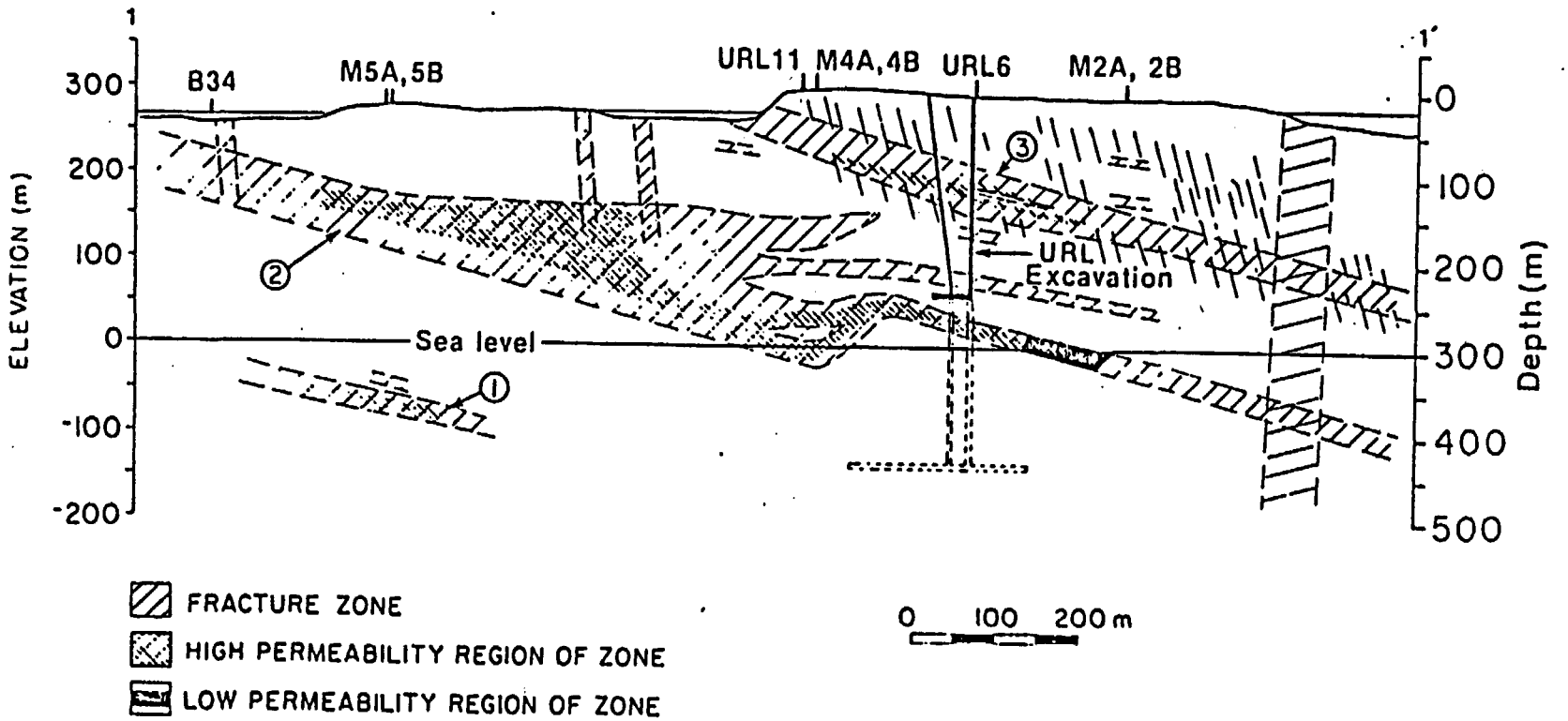

FIGURE 3.: Simplified Geological Cross-Section of URL Site Along 1-1' of Figure 19

SHORT REVIEW OF THE FINNISH SITE INVESTIGATIONS

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MANAGEMEMENT OF LOW- AND INTERMEDIATE- LEVEL WASTE

In the field of low- and intermediate- level waste management, plans for the construction of repositories are ready and building operations will take place in 1988-1992. Repositories will be situated in the crystalline bedrock in the two power-plant areas of Finland, Lovisa and Olkiluoto, at a depth of about 100 meters. The experience gained in the geological, geophysical and hydrogeological investigations of the power-plant areas can be partly utilized in the investigations preparatory to the disposal of the spent nuclear fuel.

SITE INVESTIGATIONS FOR THE FINAL DISPOSAL OF SPENT NUCLEAR FUEL

At the first stage of the site investigations in 1983, 327 bedrock blocks about 100 sq.km in area were selected. Site selection resulted at the end of 1985 in the selection of 101 investigation areas between 5 and 10 sq.km in area.

In 1986, more detailed site investigations failed because of the opposition of local people; however, in the spring of 1987, five sites were chosen for further investigations. One of the five sites is the Olkiluoto power-plant area, which was chosen apart from the special site selection program besides being used as a model area in safety calculations made by the The Technical Research Centre of Finland.

On two of the sites selected, Romuvaara and Veitsivaara, field surveys started in the spring of 1987. The Romuvaara area at Kuhmo represents the oldest granite gneiss complex of the Archean basement, while the other area, Veitsivaara, Hyrynsalmi parish, represents an Archean granite formation. Both areas are characterized by the occurence of

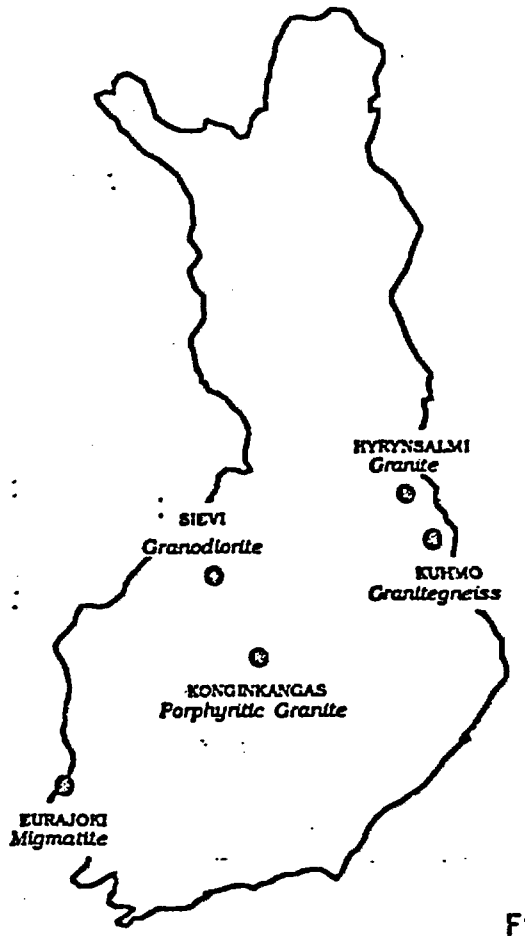


Fig. 1

old Archean crystalline rocks (Fig.1). The age of both areas is more than 2.6 Ga years, and the rocks have undergone a polyphase deformation.

The Finnish power company Teollisuuden Voima is responsible for the site investigation as a whole and the Geological Survey of Finland is mainly engaged in the geological investigations.

The investigations on the two sites have started with a generic review of bedrock maps and data. Structural analyses are made of stereo air photos and geophysical maps. Field surveys started with profile measurements over a wide area and the surrounding fracture zones, the VLF, VLFR, magnetic total and vertical component methods being used along with an electromagnetic radar ground survey. Later the measurements have been continued systematically along a denser and more regular network.

TIMETABLE FOR FIELD INVESTIGATIONS

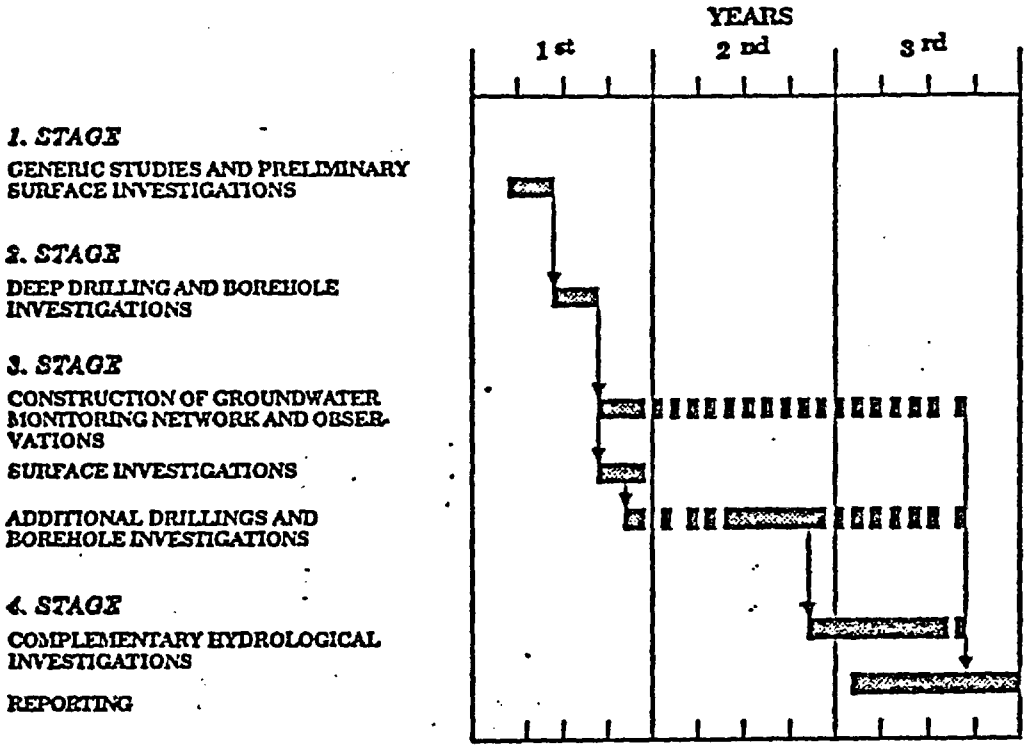


Fig. 2

In conjunction with geophysical studies, a detailed geological mapping of the outcrops is being made with extra samples taken from covered parts of the bedrock. After two months of preliminary investigations, the first deep hole is being drilled at the end of June 1987 and additional percussion drill holes will be made shortly afterward toward improving the preliminary hydrogeological model based on the first single hole measurements. Investigations on one area will take approximately 3 years (Fig. 2).

In conjunction with these preliminary studies, an evaluation of the suitability of the area is being carried out by Teollisuuden Voima (Industrial Power Co) as well as by the Finnish Centre for Radiation and Nuclear Safety. If the site is not found to be suitable the investigations will be transferred to the place next on the selection list. Between 5 and 10 sites will be studied before the year 1992, when two or three sites ought to be selected for more detailed investigations.

After the drilling phase, the geophysical and hydrogeological borehole measurements willbe correlated to the information on the bedrock surface and preliminary models will be constructed of both of the hydrogeological data and the bedrock structures. Also the stability of the bedrock will be kept under observation during the next ten or more years by establishing points for geodetic measurements. The investigation program is presented in Fig. 3.

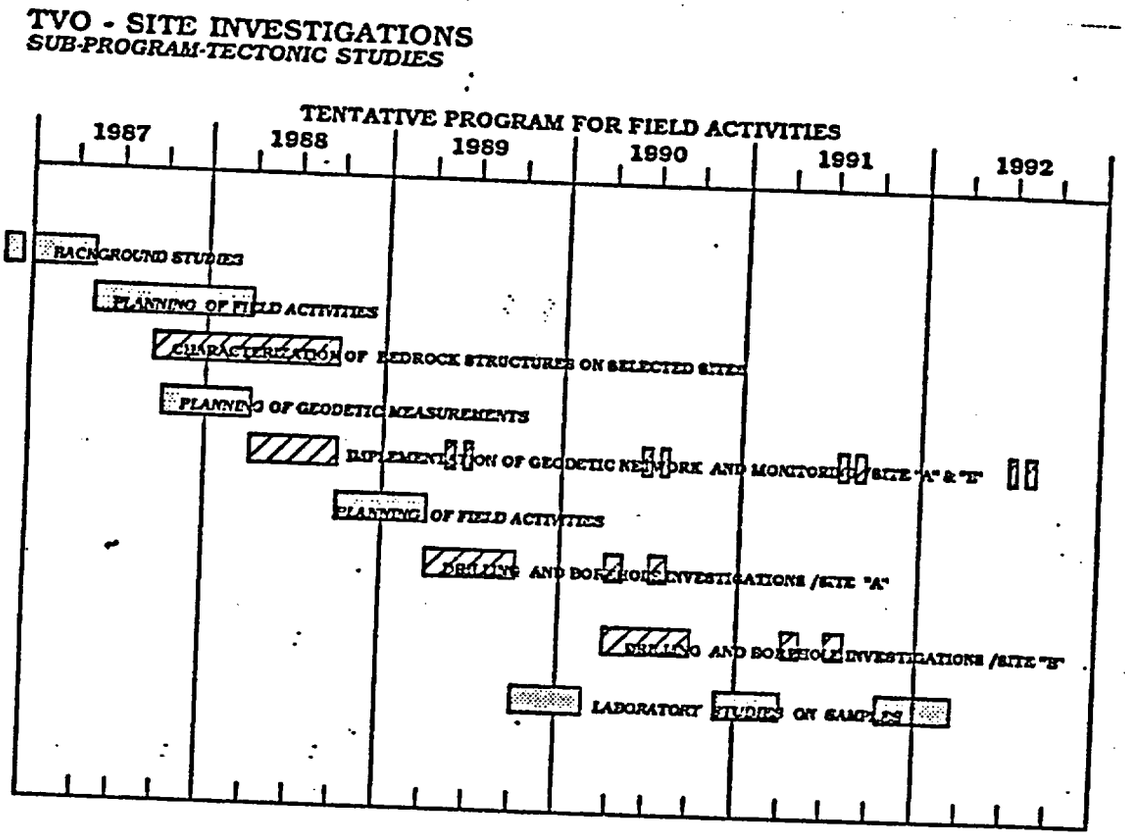


Fig. 3

FAR-FIELD GROUND-WATER SURVEY

The deep groundwater is being studied throughout the country by the Geological Survey. Financed mainly by the Ministry of Trade and Industry, the Finnish Center for Radiation and Nuclear Safety and Teollisuuden Voima Co, the survey is being made by using old prospecting drillholes, which often extend to depths of some 600 - 1000 meters. Ground-water layers with a higher salinity have been found in most of the prospecting drillholes at approximately 400 - 500 meters. It is important to study the depth of the saline water layers

inside the typical investigation areas and compare the results to measurements which have been made in fracture zones or in different types of rocks.The study is also concerned with water/rock interactions and the natural ground-water flow as well as the possible effects of natural thermal gradients on the far-field ground-water flow. A great deal of investigation is needed to complete the far-field ground-water flow model. The most comprehensive and effective ground-water surveys are made by Finnish power companies in site investigations but some new publications on ground-water surveys made mostly outside these areas are listed below:

Blomqvist, R.G., Lahermo, P.W. and Lahtinen, R., 1987. Geochemical profiles of deep groundwater in Precambrian crystalline bedrock of Finland. Exploration '87, Conference proceedings (in press).

Kukkonen, I.T., 1987. Vertical variation of apparent and paleoclimatically corrected heat flow densities in the Central Baltic Shield. Journal of Geodynamics, Vol. 8, Nr. 1, Sept. 1987 (in press).

Nurmi, P.A. and Kukkonen, I.T., 1986. A new technique for sampling water and gas from deep drill holes. Can. J. Earth Sci. 23, 1450 - 1454.

Nurmi, P.A., Kukkonen, I.T. and Lahermo, P.W., 1987 Geochemistry and origin of saline groundwater in the Baltic Schield. Journal of Applied Geochemistry (in press).

June 11. 1987

RECENT DEVELOPMENTS IN SITE INVESTIGATION IN FRANCE

GEOLOGICAL DISPOSAL

Having got, late December 1986, the authorization from the Government to start a site investigation campain, ANDRA has announced, at the end of February. 1987, the location of the four prospection areas.

- The "Departement" of AISNE in the north-western part of the country for the clay site.
- The "Departement" of DEUX-SEVRES in the central western part of the country for the granite site.
- The "Departement" of MAINE-ET-LOIRE in the western part of the country for the schists site.
- The "Departement" of AIN in the central eastern part of the country for the salt site.

This announcement, made site after site, about every two weeks, created very important emotion and reactions in the population. A large effort has been made to inform and to discuss locally with everybody showing a deep concern. After three months of contacts and meetings (private or public) the situation is still unstable but it seems that nobody will really strongly oppose to the beginning of investigation program. It is hoped so to be able to start and develop normally the field measurement program during summer.

Then it is possible to update the general agenda for repository construction.

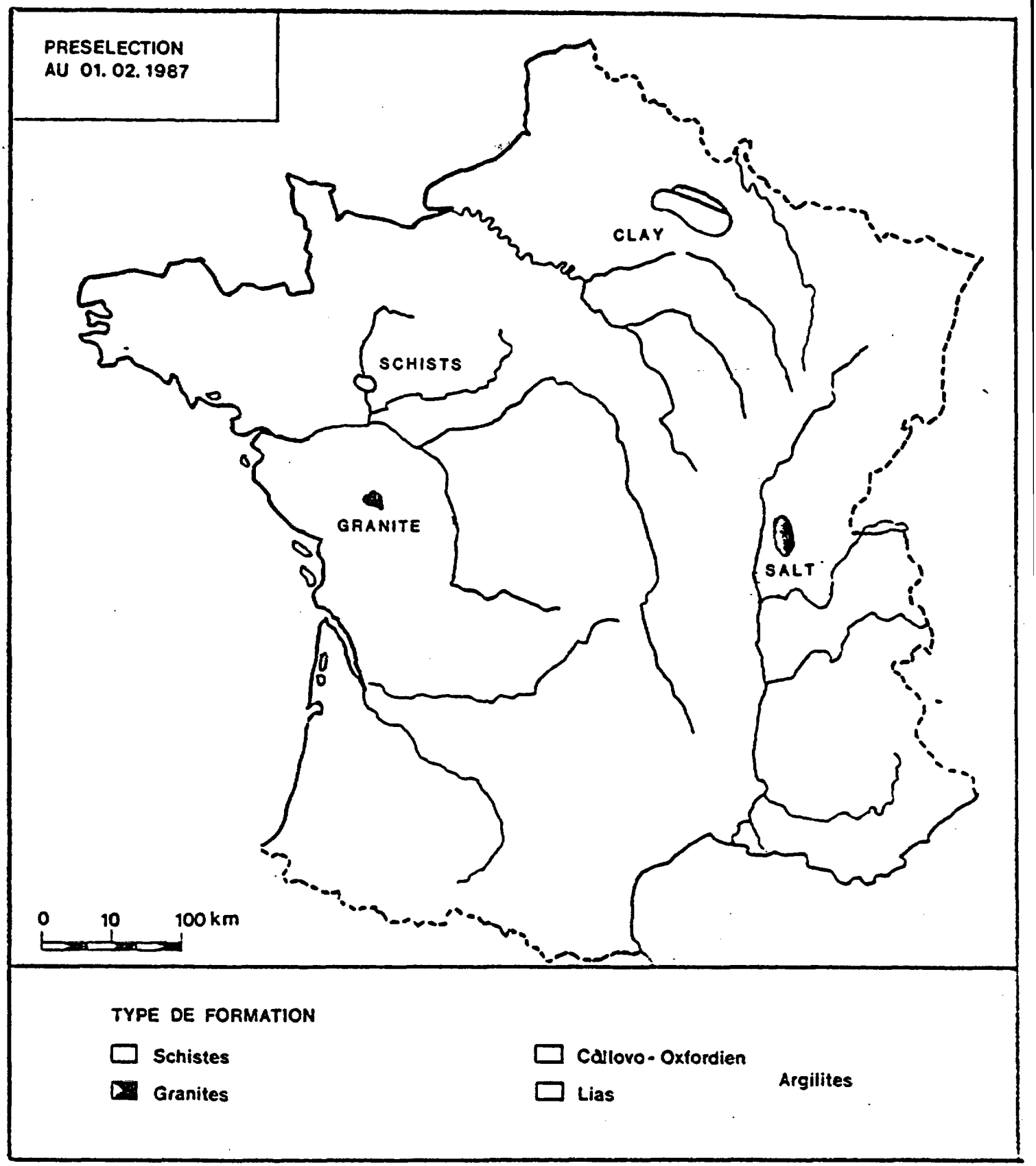
1987-1990 - Investigation from the surface by geophysical technics and drillings on the four sites.

At the end of 1990 - Selection of one candidate site among the four sites investigated.

1991-1995 - Qualification of the candidate site including in particular and for this purpose the construction of an underground laboratory. If the findings of this program are positives, the application for repository construction, including a project description and a safety report, will be sent to the licensing authority at the end of 1995.

The licensing procedure being supposed to last two years, construction could start late 1997.

The first part of the repository is aimed to receive, in the beginning of the 2000', transuranic waste presently stored, while vitrified waste will have to be stored for a longer period of time for desactivation probably up to year 2010.


PRESELECTION
AU 01. 02. 1987
CLAY
SCHISTS
GRANITE
SALT
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10
100 km
TYPE DE FORMATION
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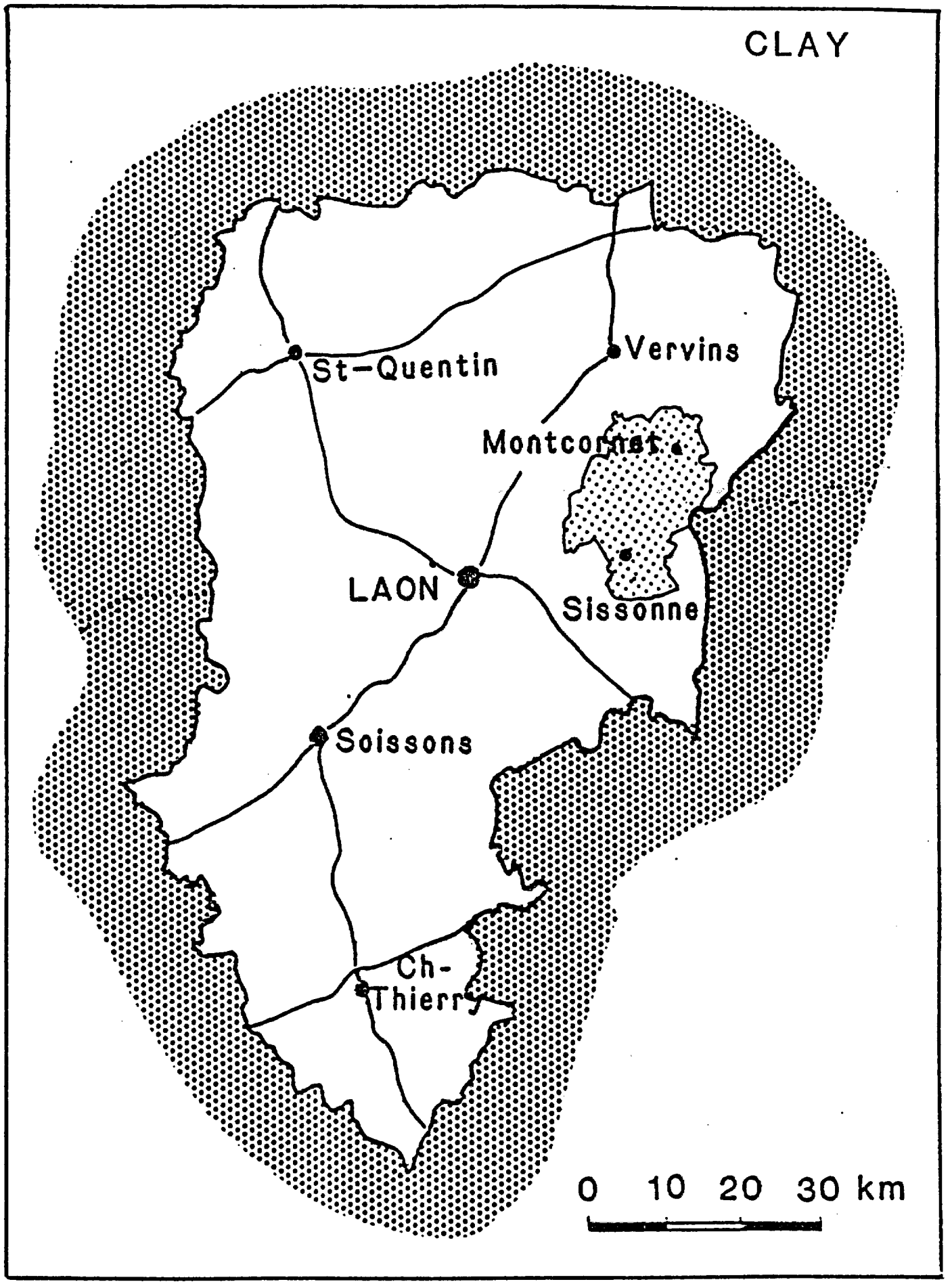
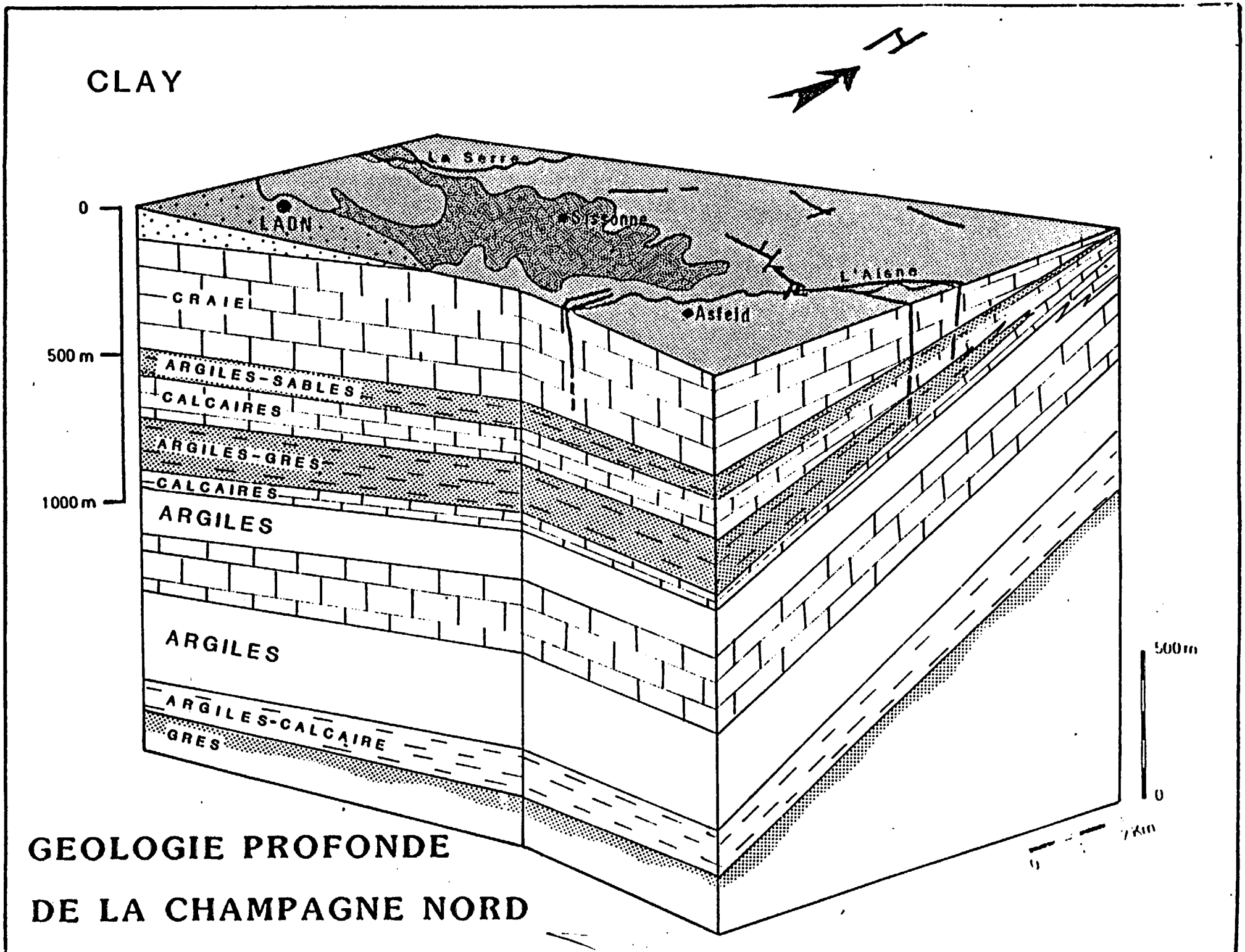
Argilites

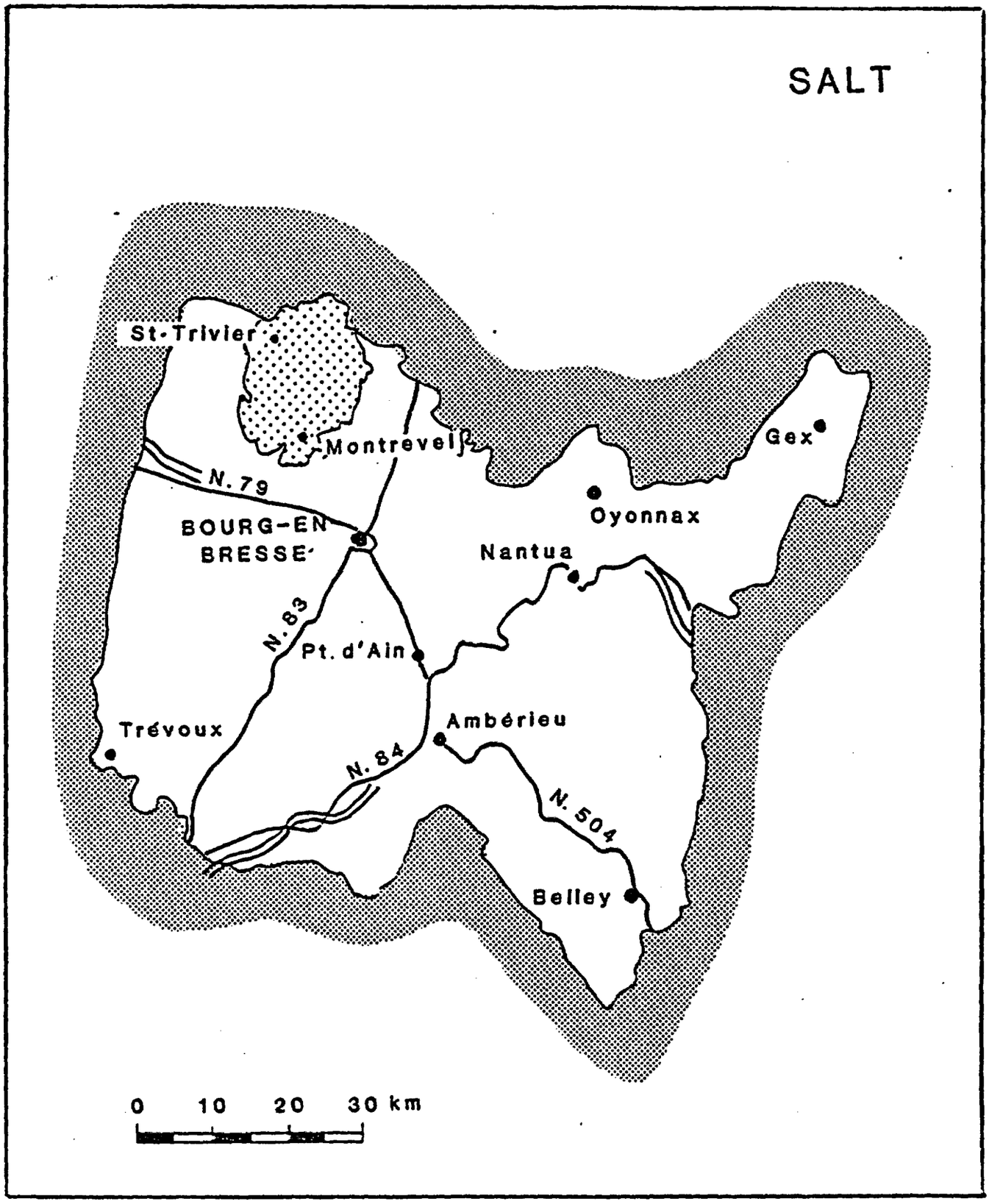
SITUATION DE LA ZONE DE RECHERCHE DANS LE DEPARTEMENT DE L'AISNE



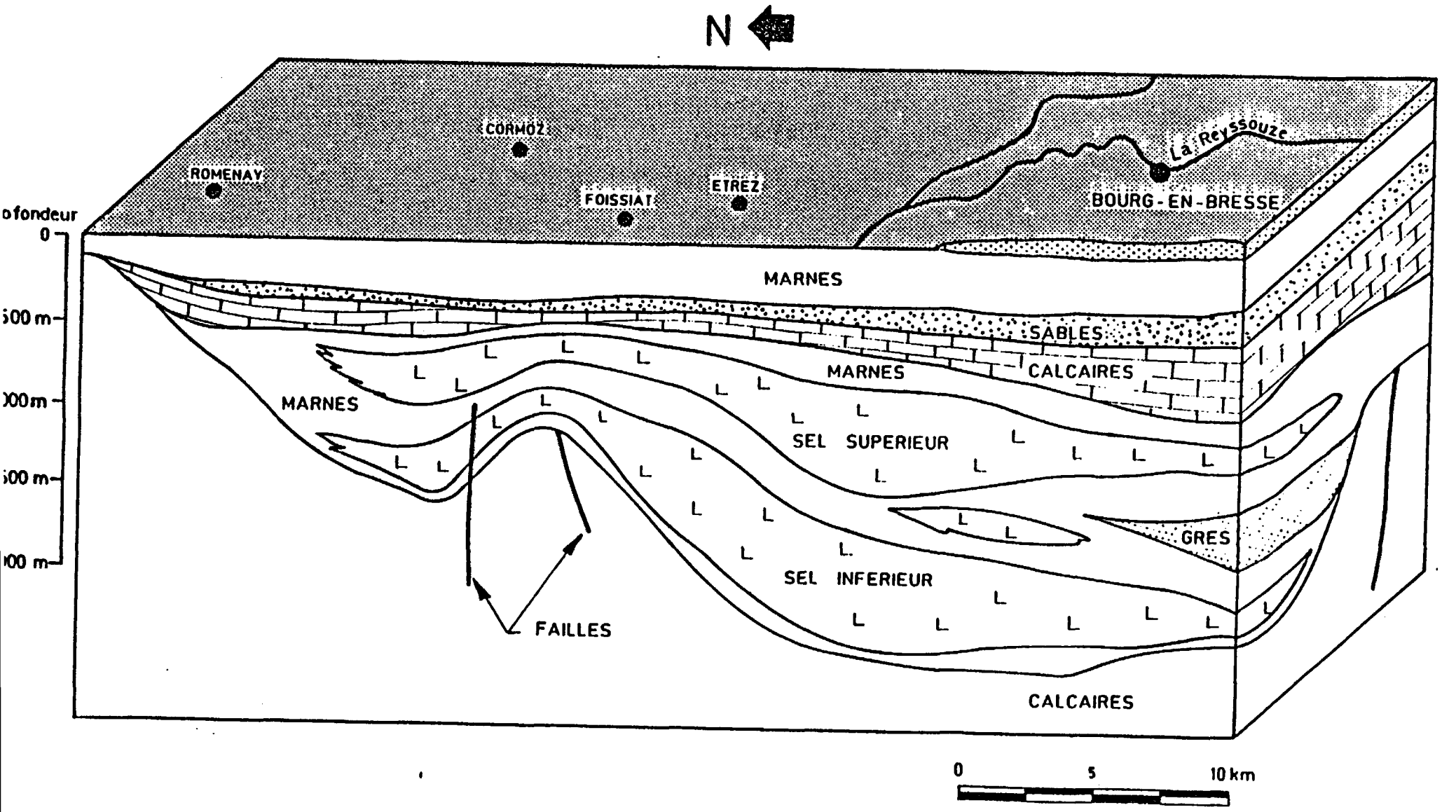


GEOLOGIE PROFONDE DE LA CHAMPAGNE NORD

SITUATION DE LA ZONE DE RECHERCHE DANS LE DEPARTEMENT DE L'AIN

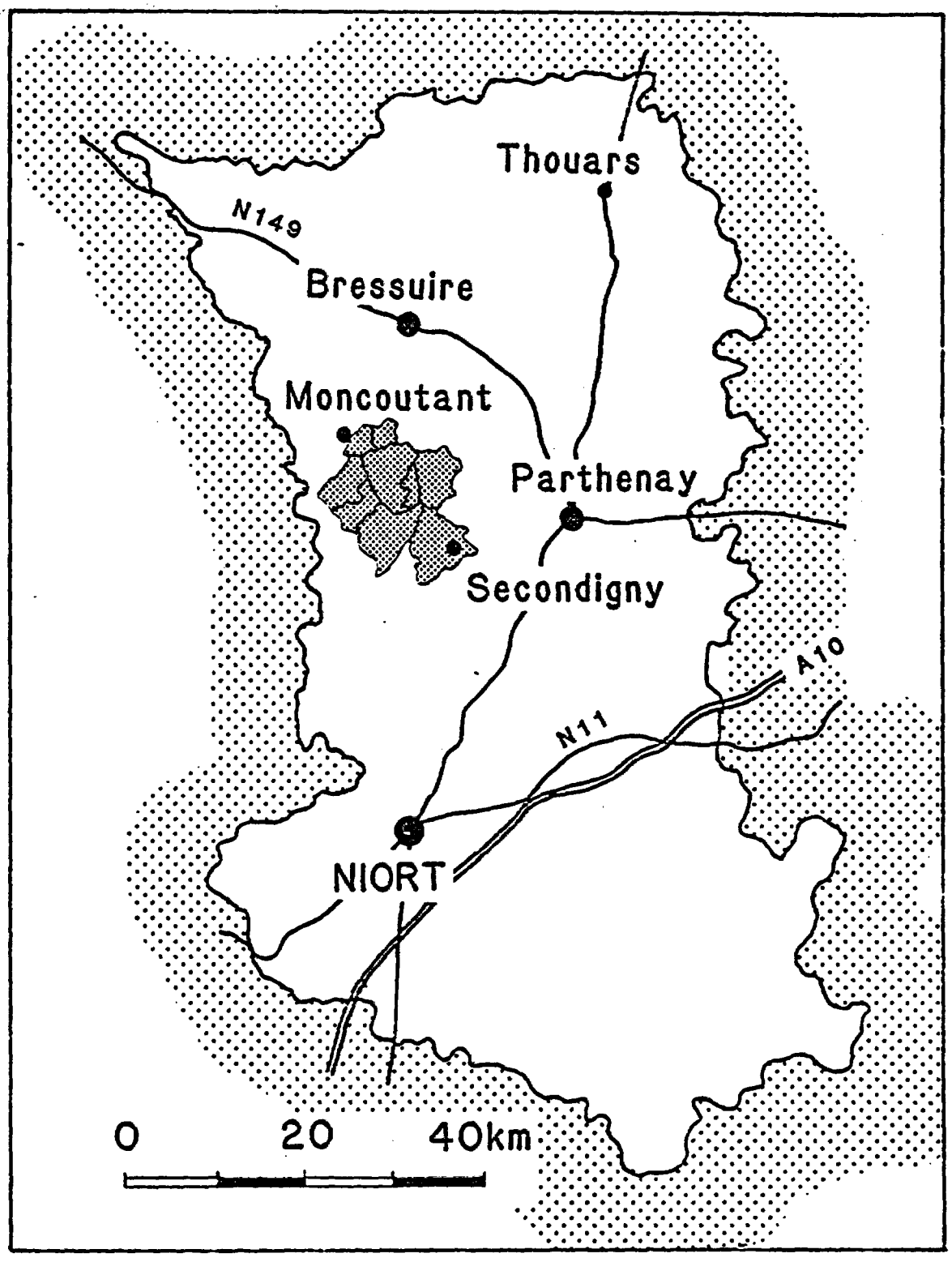


SALT



BLOC DIAGRAMME DU BASSIN BRESSAN

GRANITE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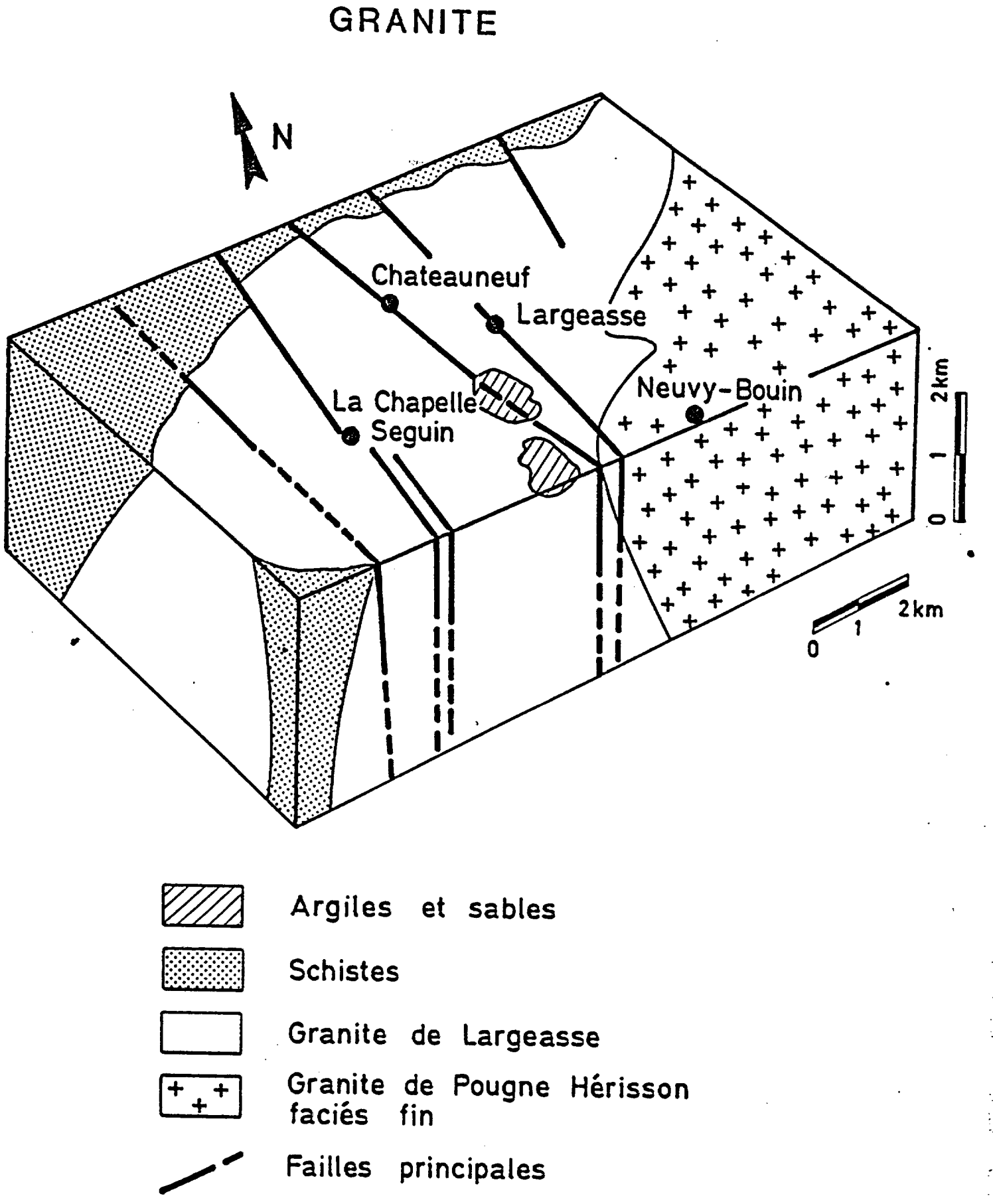
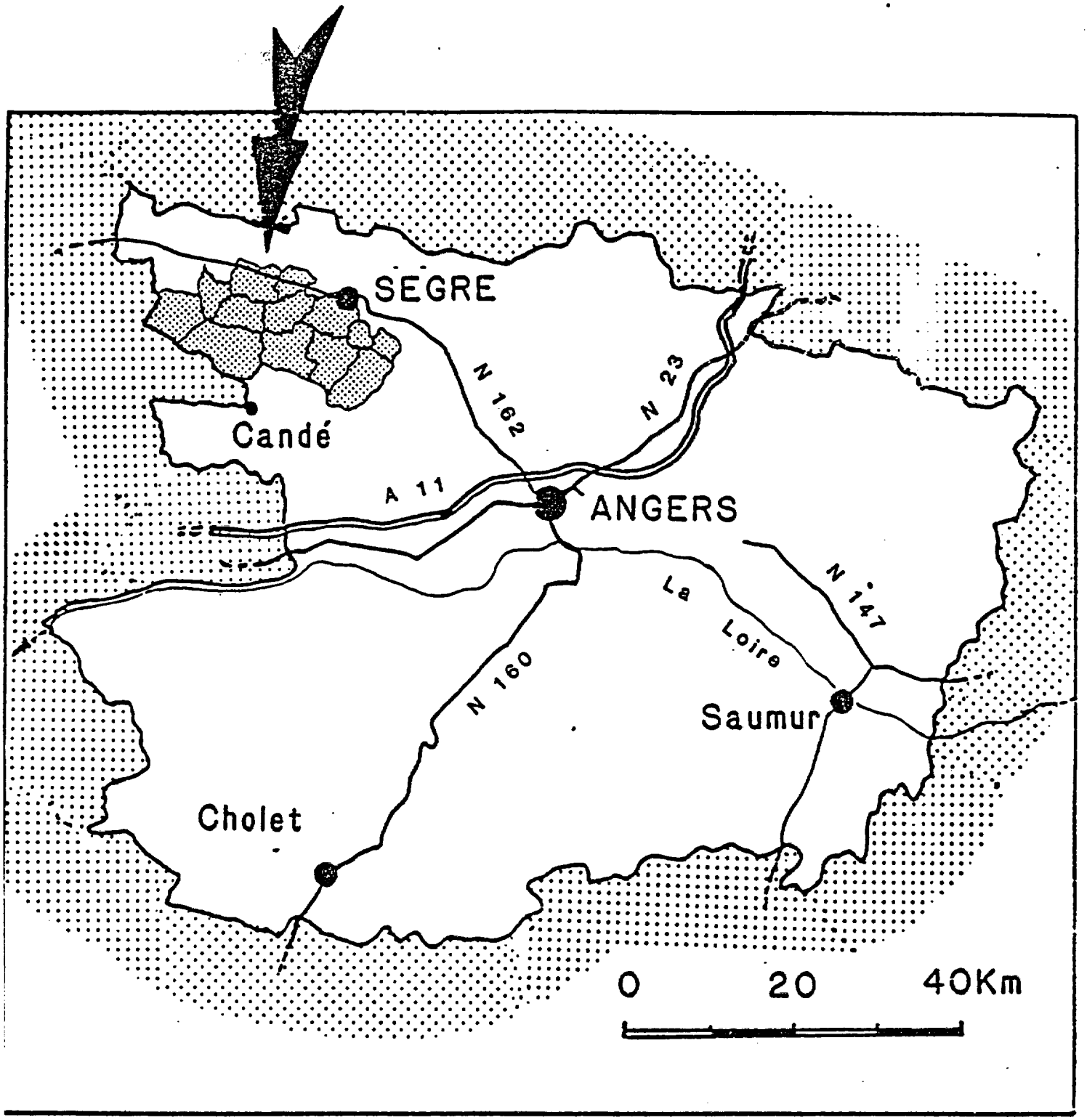


BLOC-DIAGRAMME DU MASSIF
DE NEUVY-BOUIN

SCHISTS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N 23
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ANGERS
N 147
La Loire
N 160
Saumur
Cholet
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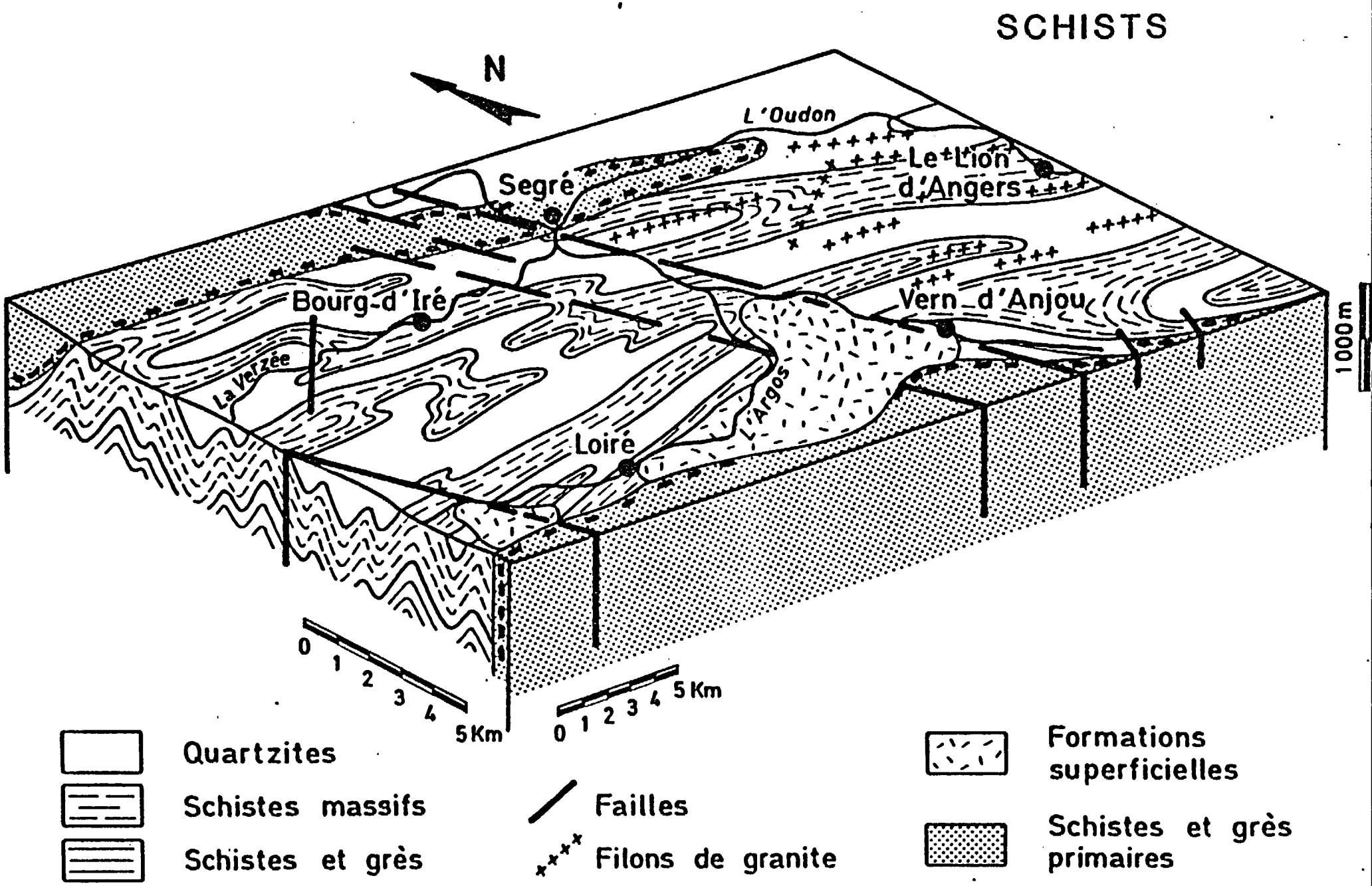
20
40Km



BLOC-DIAGRAMME DE L'ANTICLINAL DU LION D'ANGERS

O C D E - A E N

GROUPE CONSULTATIF SUR LES RECHERCHES
ET ETUDES IN SITU POUR L'EVACUATION DES DECHETS RADIOACTIFS
DANS LES FORMATIONS GEOLOGIQUES

PARIS 23-25 JUIN 1987

NOTE SUR LES ETUDES EFFECTUEES PAR L'INSTITUT DE PROTECTION ET DE SURETE NUCLEAIRE

COMMISSARIAT A L'ENERGIE ATOMIQUE
- INSTITUT DE PROTECTION ET DE SURETE NUCLEAIRE - FRANCE -

A. BARBREAU
-IPSN - Département de Protection Technique -

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1 - Laboratoire souterrain d'études expérimentales et de méthodologie de FANAY-AUGERES - TENELLES.

Etude Hydro-Thermo-Mécanique.

Cette étude, co-financée par la CCE, se propose de simuler l'influence sur la fracturation et la perméabilité du granite, d'une source chauffante représentant l'effet du dégagement thermique d'un stockage de déchets. Elle a été décrite dans un rapport distribué lors de la réunion précédente de l'ISAG.

La chambre expérimentale et maintenant terminée et tous les capteurs de mesures et systèmes d'acquisition de données sont en place ainsi que les cinq radiateurs de chauffage.

L'expérience de chauffage doit commencer début juillet 1987. Le chauffage, à puissance constante (1KW), durera 50 jours.

2 - Laboratoire d'étude in situ de l'argile

Des recherches sont en cours actuellement pour le choix d'un site favorable à l'implantation d'un tel laboratoire dans lequel seront réalisées des études sur les propriétés de barrière du milieu argileux et le développement de méthodes de mesure. Plusieurs sites possibles ont déjà été préselectionnés. Le projet pourrait démarrer vers le début de 1988.

3 - Etude de la circulation de l'eau dans les terrains salifères en couche.

Cette étude est réalisée dans une mine de potasse d'Alsace (MDPA)

L'évaluation de la perméabilité de la roche sera tentée grâce à l'estimation de l'âge des eaux par emploi de chronomètres permettant la datation d'eaux très anciennes : mesures bas niveau des activités en carbone 14, teneurs en isotopes de l'uranium, en hélium 4 et chlore 36. Ces teneurs seront mesurées avec précision grâce à la spectrométrie de masse par accélération de particules permettant de traiter des prises d'essai très réduites. Couplées à l'utilisation des traceurs naturels chimiques et isotopiques ; ions majeurs, traces, traceurs isotopiques constitutifs de la molécule d'eau $^{18}0$ et D, traceurs isotopiques des éléments en solution (espèces aqueuses du carbone et du soufre), ces mesures permettront de distinguer entre différentes origines possibles pour les fluides (eaux météoriques, eaux originaires des terrains sus-jacents, eaux anciennes) et de comprendre leur évolution, leur interaction avec la matrice et leurs relations avec les nappes aquifères environnantes.

4 - Géoprospective.

Cette étude concerne le terrain d'essai IPSN à AURIAT (Massif Central).

Elle comprend :

- L'étude de la néotectonique de la région d'AURIAT qui est en cours avec le BRGM (Bureau de Recherches Géologiques et Minières). Elle doit comprendre la comparaison des nivellements, la recherche des marqueurs superficiels, l'utilisation de photographies aériennes etc...

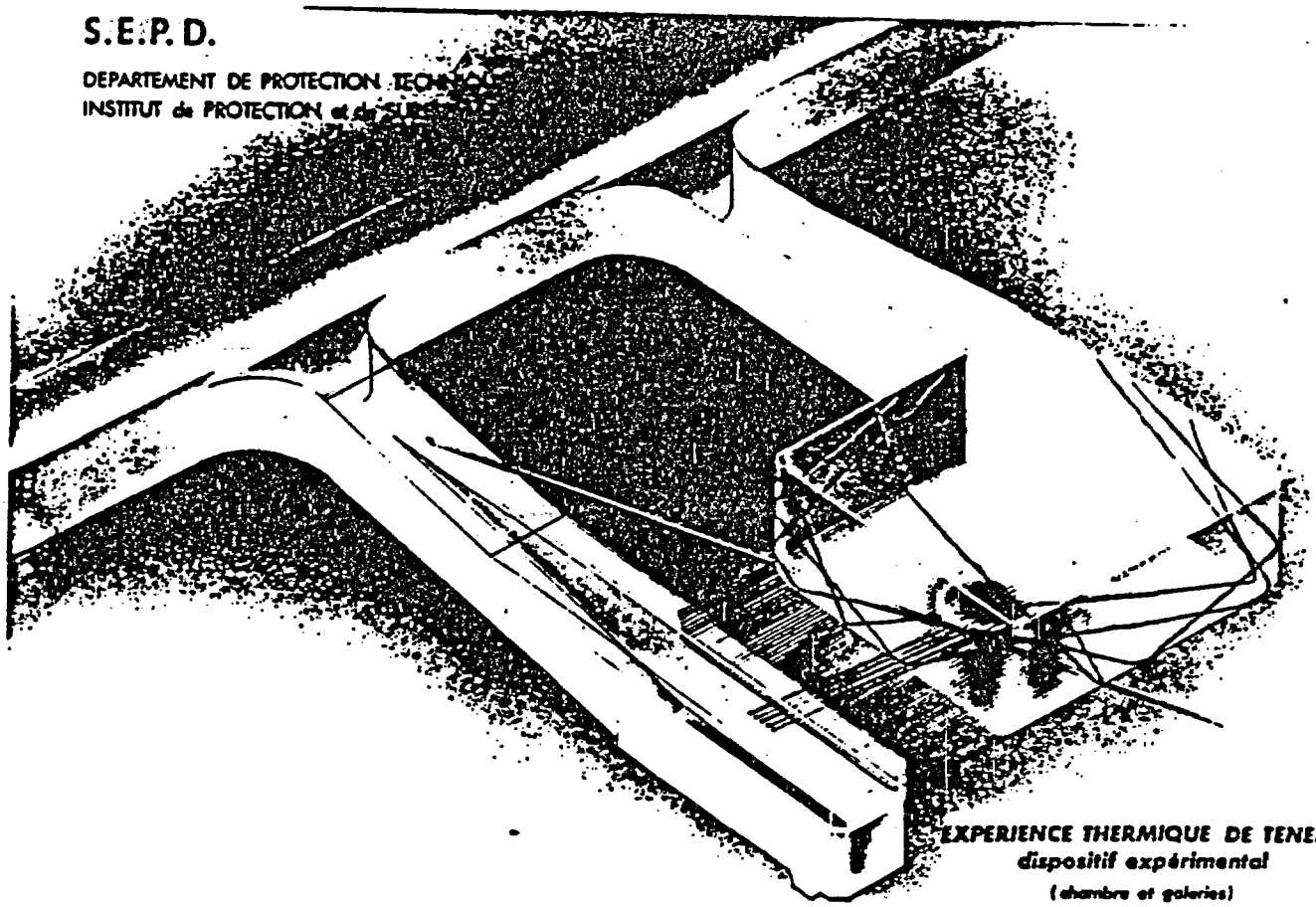
- L'étude de la variation du niveau des mers au moyen du rapport isotopique $^{16}O/^{18}O$

- L'étude de l'évolution du climat au moyen des pollens.

- L'étude des phénomènes glaciaires et périglaciaires.

S.E.P.D.

DEPARTEMENT DE PROTECTION TECHNIQUE
INSTITUT de PROTECTION et de SURETE



EXPERIENCE THERMIQUE DE TENELLES
dispositif expérimental
(chambre et galeries)

1st Progress Report on R & D Activities Concerning In Situ Investigations for Radioactive Waste Disposal in the Federal Republic of Germany

(Summarized record for the 2nd meeting of the NEA Advisory Group on in situ research and investigations for geological disposal Paris, 23rd - 25th June, 1987)

by W. Brewitz*)

Of the three sites being investigated for radioactive waste disposal in the Federal Republic of Germany two, the Gorleben site and the Konrad mine, are at the stage of site confirmation and licensing since the Asse mine is being used as an underground R & D facility only. During the last 9 months some progress has been achieved at all three sites.

A. Gorleben site

On September 1st, 1986, the actual sinking of shaft No. 1 was started after freezing the country rock down to the salt formation and mining the shaft collar 40 m into the quarternary. In May 1987 the caprock of the salt dome was struck 239 m below surface. Unfortunately, a fatal accident occurred when a support broke and fell down hitting the miners working on the footwall of the shaft.

Presently all work has been stopped while the accident is being investigated by the mining authorities. In shaft No. 2 the shaft collar has reached a depth of 39 m.

Both shafts will be sunk down to 965 m below surface and will have an inner diameter of 7.5 m. The exploration of the salt dome will take

*) Gesellschaft für Strahlen- und Umweltforschung mbH München
Institut für Tieflagerung, D-3300 Braunschweig, FRG

place at 840 m-level. Drifts will be developed 9 km to the east and 5 km to the west, opening up an area of about 12 km^2, and will have - including all cross cuts - a total length of app. 25 km. In addition, about 50 - 60 km of boreholes will be drilled underground in order to obtain a complete picture of the internal structure of the salt dome. Main question is the existence and the extension of the main anhydrite which is of utmost importance for the selection of the disposal areas inside the salt dome.

The investigation programme for the shafts as well as for the salt dome itself has been laid down by PTB at a conceptual stage. According to the present time schedule both shafts will be completed in 1989. The underground development shall be done till 1993 accompanied by geological and geotechnical in situ research.

B. Konrad mine

At present the licensing authorities are examining the plan for the proposed repository submitted by PTB. There is some discussion about the long term safety of the site and the parameters used for model calculations. It is being hoped that by additional informations problems will be overcome in the near future so that the schedule for the start of the disposal operation will not be affected.

C. Asse Mine

Development of mine and testing of borehole techniques

The central area of the salt anticline was developed from 800 m-level down to 925 m-level for the excavation of additional test fields in previously unworked areas of the mine. Main shaft Asse 2 was sunk down to its new depth of 956 m; installation of the suspended new cage guiding below 750 m-level and of the shaft lining followed

on. The haulage and signalling equipment were put into operation according to schedule in April 1987, while minor installations have still to be done. Parallel to these activities the development of a ramp down 956 m-level took place, shaft-landings were set up at 800 m-, 850 m- and 925 m-level, and development activities were begun at 850 m-level.

A test field with an excavation volume of approximately 3.000 m^3 has been mined at 850 m-level, which serves for a thermomechanical in situ test of the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR).

The observation drifts for the testing of a bulkhead construction were completed at 878 m-level. At present the measurement cavities are under construction and the preliminary works for the boreholes to be drilled subsequently are underway.

According to the German concept the final disposal of heat developing high-level waste and intermediate-level waste of the upper activity category is to take place in 300 to 600 m deep boreholes in salt. This is to bring about an optimum dissipation of the heat developed by radioactive decay, thus keeping the heat load on the host rock well below critical levels.

A new method for the sinking of vertical deep boreholes with a diameter of up to one meter by a dry-drilling process was developed and patented within the scope of this project. Basis of this development is a planetary drilling head which permits the pneumatic transport of cuttings from a large diameter borehole by means of an integrated cell wheel pneumatic machine. The development of this new drilling technique supplied the prerequisites for the planned HLW and ILW emplacement tests and there have already been successful initial usages.

The preparatory works for the drilling of the 300 m deep borehole with a diameter of 1000 mm are taking place as scheduled. At present the drilling equipment is being set up at the 800 m-level with the required locating works and casting of the foundation for the support. Actual drilling will begin in July and will probably last 3 months.

Furthermore, the technical performance of a 600 m deep borehole with a diameter of 600 mm is to be realized. Delivery of the 600 mm drilling head with an automatic direction adjustment device is foreseen for October 1987. Thereafter, two 600 m deep boreholes are to be drilled. The first borehole is to be started at the 800 m- or 750 m-level in the course of this year. Start of the drilling of the second borehole is foreseen for March 1988. This borehole will be used by Netherlands Energy Research Foundation (ECN) for some in situ tests, including heating experiments and convergence measurements.

Present status of in situ tests

1. High-level waste test disposal

After some delays in the production of the 30 radioactive canisters at Battelle Pacific Northwest Laboratories (PNL), the filling of the canisters with high-level radioactive glass, containing Cs-137 and Sr-90, has been finished. Preliminary analyses of glass composition show that the surface dose rate and heat load of most canisters reach the specifications within the desired accuracy. The main further steps are welding of the lids, leak checks and decontamination of the canisters by electropolishing. These steps and the details of quality assurance have still to be approved by the Bundesanstalt für Materialprüfung (BAM), the responsible licensing authority.

The measuring and the emplacement boreholes in the underground tests field are completed and the installations are continuing smoothly. The systems for the canister guiding and gap monitoring inside the steel tube linings have been tested successfully at ECN, Petten, and can now be manufactured. Other technical components for handling and emplacement of the radioactive canisters are still being manufactured and will be partly delivered until the end of 1987. Due to the final definition of quality assurance methods the manufacturing of some components and complete installation will be delayed by about three months, shifting the final date for the completion of the in situ test field into 1988.

2. Investigations for the disposal of ILW

All temperature measurement probes have been installed in the test field at the 800 m-level of the Asse salt mine and regular control measurements are being carried out. In order to complete the geotechnical instrumentation some more boreholes have to be drilled. After finishing the emplacement boreholes the sealing rings and mounting plates for the borehole slides were installed. The borehole installations have been manufactured at Kernforschungsanlage Jülich (KFA) in Jülich and will be fitted shortly so that the preliminary experiment (with electrical heaters) can be started in October 1987.

Further works regarding this project are carried out by KFA Jülich. By a concept study the repository- and sealing techniques for the ILW-boreholes will be developed.

3. Investigations for the direct disposal of spent fuel elements

During the first half of 1987 the concept for the geotechnical instrumentation of the tunnel emplacement test was further developed by GSF in accordance with the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) which participates with its own programme. On the basis of model calculations the distances between the heatable large size emplacement casks were changed from 1 to 3 m. The temperature limit of 200 °C at the surface of the containers remained unchanged, however. The plan for the mining of the test drifts has been approved by the Mining Authorities. The mining activities for the development of the observation drifts at the 750 m-level of the Asse salt mine will start end of June.

In situ tests were already carried out by the Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE) with a view to the selection of a suitable backfilling techniques. At a test location on the 750 m-level of the Asse salt mine the soil mechanical data of loose material (smaller than 50 mm) used by means of pneumatic or slinger stowing are being determined. The in situ tests for pneumatic stowing have been concluded.

4. Construction of mine dams in salt formations

A two-piece bulkhead, consisting of a supporting element and a sealing element, is to give evidence of its technical feasibility and functioning (i. e. stability, imperviousness to brine and gas tightness) in prototype for the final repository at Gorleben. The project is carried out in co-operation with the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and the Deutschen Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe (DBE).

Subsequent to approval by the Mining Authorities in December 1986, GSF began with the mining of the underground test field. Development of the traversal observation drifts for monitoring of the bulkhead components has practically been completed. By the end of June 1987 drilling of the measuring boreholes will be started according to schedule for the instrumentation of the observation drifts.

A test plan consisting of

- porosity and permeability measurements
- geotechnical investigations
- geophysical measurements to monitor the near field
- recording and processing of measurement data and evaluation of data for long-term safety analyses
- accompanying laboratory investigations of construction materials for the abutment of the bulkhead and the sealing system

was set up for management and co-ordination of the scientific investigation programme by GSF.

Currently DBE is intensively engaged with the planning for the supporting and the sealing system in co-operation with industrial firms and university experts.

5. Backfilling and sealing of boreholes, chambers and drifts in a radioactive waste repository

The backfilling of cavities using suitable filling materials and the respective sealing systems are an important part of the so-called "multibarrier system" of a repository for radioactive wastes. In order to optimize these components GSF is carrying out the following investigation programme:

- geotechnical in situ measurements in backfilled chambers for determination of interactions between backfilling material and rock mass

- monitoring of already existing sealing systems

- laboratory tests for the determination of mechanical and hydraulic parameters on construction materials for chamber seals and on backfilling material

- rock mechanical investigations for backfilling and sealing of disposal boreholes.

GSF co-ordinates its investigations with the requirements set by PTB for the backfilling of the planned final repository mine at Gorleben. The project is being supported by the Commission of the European Communities.

OUTLINE OF IN-SITU RESEARCH AND INVESTIGATIONS ON GEOLOGICAL DISPOSAL IN JAPAN

M. YAMAKAWA
Waste Isolation Resarch Section
Chubu Work,
Power reactor and Nuclear Fuel
Development Corporation (PNC)
Japan

Introduction

The essential purpose for In-Situ experiments by PNC is to demonstrate that the multibarrier system for geological disposal of the high level radioactive waste is feasible under the geological environment of crystalline and sedimentary rocks on the basis of rational scientific evidences. The performance assessment for the isolation of radionuclides in the geological system is therefore considered highly neccessary in order to assess the system in relation to the characteristic of natural and engineered barries. It is particulary important to study the capacity and stability of natural barrier since the earthquake and excavation may have considerable influence on the rock dynamics, heat transfer as well as groundwater flow in the deep geological environment.

PNC is playing an important role on the national program, following the Five Years-Term Program for Resarch and Development of Geological Disposal for High Level Radioactive Waste, released in Nov.1986 by Japanese Atomic Energy Commission (AEC) of Science and Technology Agency (STA), Japanese government.

As long as In-Situ experiments are concerned, PNC has carried out the resarch on radionuclides migration as one of the geochemical aspects of natural analogue study. The fundamental investigations of flow mechanism and geochemical characteristics of groundwater, the corrosion test on the materials for the engineered barrier and deep borehole investigations on geological environment constitute the major part of the activity utilizing the Tono Tertiary sandstone-type uranium deposit located near Chubu work, PNC.

On the other hand, in the galleries of the Hosokura Pb-Zn vein-type deposit hosted in Tertiary green tuff, the preliminary nonradioactive

tracer(Br and I) test in the single fracture system and the corrosion test on the materials for the engineered barrier have been conducted.

In addition to the STRIPA project and the cooperative research at AECL, PNC is now on the final negociation to participate in the international cooperative research at Mol institute. PNC is also interested in the Alligator River Analogue Project with AAEC, Australia sponsored by OECD/NEA is currently considered to join as the member of associate participant.

Summary of In-Situ Experiments to date

1. In-Situ Experiment in Tono Uranium Deposit and Adjacent Area

   (1) The research on natural U-Th series radionuclides migration revealed no remarkable disequilibrium which indicates the fact that there was no significant migration occurred in the area.

   (2) It has also become evidence that Uranium content of the groundwater is not high in spite of high bicarbonate content which reflects the reducing environment.

   (3) A special section was prepared in the gallery (130m deep in granitic rock) for a series of corrosion test. A set of short boreholes(1.5m) was drilled in the floor of the chamber and spcimen of boro-silicate glass, and various materials for canister and overpacking were placed in those holes.

   (4) In the same section as corrosion test, a preliminary investigations on groundwater flow was conducted utilizing Ar and He gasses as tracer material injected into the boreholes to lead the following data;

Travel Time	0.6cm/hr	
Flow Direction	East to West	
Hydraulic Conductivity	2×10^{-6}cm/sec	(by Hydraulic Recovery Test)
Bicarbonate-type Water		

   It was also recognized that He gas is more favorable than for the purpose of experiment.

   (5) As a result of geological investigation of a deep borehole (563m depth) in the granitic rock, three major patterns and alteration types of the fracture systems have revealed. Further reseach on the flow mechanism and geochemistry of

groundwater and cross-hole geophysics are considered neccessary in order to assess the performance of granitic rock in the deep geological environment.

2. In-Situ Experiment in the Hosokura Deposit
(closed in Nov.,1986. In-Situ experiment was completed in March,1987)

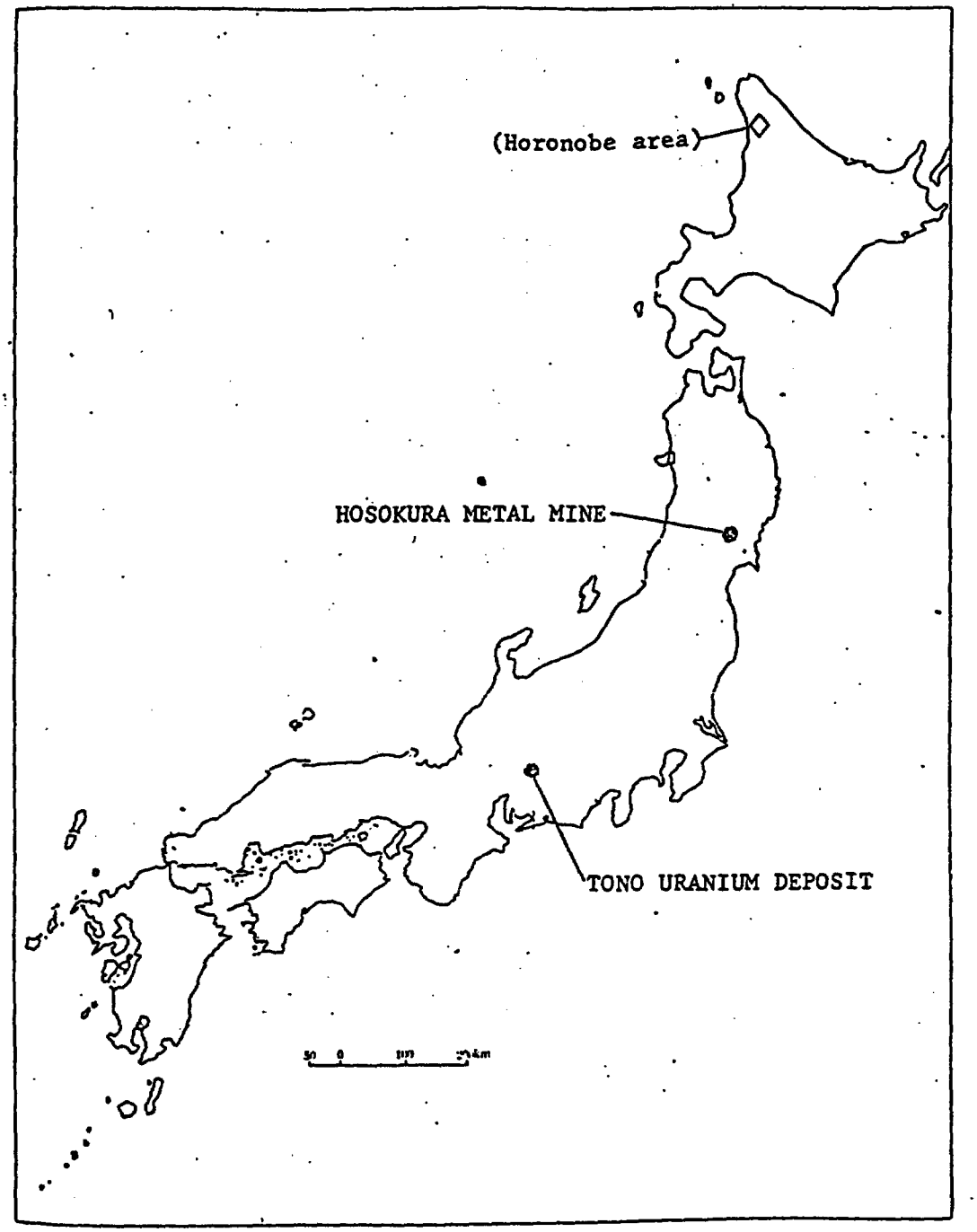
(1) The preliminary nonradioactive tracer(Br and I; 96-106ppm) test in the single fracture system in the test room(420m depth) of the gallery was carried out within a period of three months in order to develop the methodology and technology for measurements. As the result, dissolved oxygen content of out-flow of groundwater after tracer injection trends to decrease gradually up to about 15% with negative value of Eh and decreasing number of pH. Data processing and interpretation is on the way.

(2) The corrosion test data on materials for engineered barrier located in the short borehores have been collected at regular intervals for a total period of two years.

(3) In order to contribute to develop a quantitative evaluation system on the constraction of geological repositry which is closely related to seismic characterization, rock dynamics and groundwater flow in the deep geological environment, the sets of data from In-Situ experimental site as well as from ground surface have been obtained for a comprehensive study for the influence of earthquakes.

3. Underground Research Laboratory at Horonobe, Northern Part of Hokkaido.
Prior to the construction of the underground research laboratory, a preliminary borehole investigations for the site characterization at the deep geological environment was carried out. PNC is now on the way to evaluate the area.

LOCATION MAP OF IN-SITU EXPERIMENTS TEST AREA



Parkstrasse 23
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Nagra
Nationale
Genossenschaft
für die Lagerung
radioaktiver Abfälle

Cédra
Société coopérative
nationale
pour l'entreposage
de déchets radioactifs

Cisra
Società cooperativa
nazionale
per l'immagazzinamento
di scorie radioattive

NEA Advisory Group on In Situ Research
and Investigations for Geological Disposal (ISAG)

Paris, 23th - 25th June 1987

SOME RECENT DEVELOPMENTS IN SWITZERLAND

by

R.W. Lieb

Lb/Me
June 18, 1987

1. OVERVIEW

The Swiss concept for nuclear waste disposal envisages a ILLW repository in a mined cavern system with horizontal access (Fig. 1) and a HLW repository consisting of a series of horizontal tunnels (dia. 2.20 - 3.50 m) at a depth of some 1200 m below biosphere surface (Fig. 2). The ILLW repository must be operational by the end of the century; it is likely to be situated in the alpine area of Switzerland. The facilities for HLW are required by the year 2020. Their location is envisaged in the crystalline bedrock or possibly in a sedimentary formation in northern Switzerland. The feasibility of both types of repositories in Switzerland has been demonstrated to the authorities by Nagra in its reports "Project Gewähr 1985" (PG 1985). Specific (i.e. repository - orientated) field investigations were available for PG 1985 in respect of the HLW concept only. They consisted of extensive geophysical explorations and six up to 2500 m deep boreholes. For the ILLW facilities, geological and hydrogeological information was limited to data gained from surface mapping and records from the construction of a hydropower scheme respectively a road tunnel in two of the regions concerned.

The HSK, a government department entrusted with the technical aspects of nuclear safety in Switzerland has recently submitted to the federal authorities its report on PG 1985. Based on this report the government will have to decide in due course on the further operation of the five nuclear power stations in Switzerland.

In situ work for the selection of the ILLW site has now commenced. At Oberbauenstock (OBS) in central Switzerland geophysical measurements have been made and test drilling as well as hydraulic testing is in progress from a nearby road tunnel. The host rock at OBS would be a hard (some-

what fractured) marl formation. The same stratum extends to another potential site, Wellenberg (WLB) in a neighbouring valley for which permitting for site investigation (boreholes and test tunnel) has just been initiated. It is hoped that field work at WLB can start in mid 1988. In situ work of a similiar scope as at OBS is scheduled for September 1987 at Piz Pian Grand (PPG, gneiss). PPG is the second of the three potential sites for which testdrilling (but no testing tunnels yet) has already been authorized by the federal government. The start of field work at the third location, Bois de la Glaive (BdG, anhydrite) is still being delayed by local legal action. The comments by HSK to the technical feasibility of the ILLW repository countain few and comparatively minor reservations only.

Most of the HSK report of course focusses on the HLW concept. In essence the feasibility demonstrated by Nagra is confirmed by HSK. However, in HSK's opinion some important questions re performance assessment need further clarification. They are mentioned in para. 2 below. HSK is also concerned about the difficulties which they envisage in prognosticating reliably the structure and properties of the crystalline formations in Switzerland. HSK therefore recommends that the comparative investigation of sedimentary formations as host "rock" which was originally planned for the early 1990es, is advanced. Nagra is therefore presently initiating a corresponding 2 to 3 year program, commencing with "stock taking" and probably ending with a closer analysis of one or several specific options in northern Switzerland.

2. QUESTIONS RE PERFORMANCE ASSESSMENT

HSK requests that high priority is given to the further clarification of the following questions:

- **Flowpath' in the Crystalline Bedrock**

  Certainty on the nature and significance of the real flowpath' is of greatest importance since they govern to a large degree the retention mechanism

- **Matrix diffusion, Sorption**

  They both play an important role in nuclide migration. It is essential to understand them better and to be able to assess the relevant parameters

- **Stress Corrosion of the Container**

  Could lead to early failure of some containers. Probability and consequences to be analysed

- **Longterm Stability of Bentonite**

  Rheological behaviour and chemical stability of highly compacted bentonite in the near field environment (steel corrosion, groundwater composition, gas)

- **Colloids and Microorganism**

  The general (state of the art) knowledge on the possible effects of colloids and (related to it) microorganism is insufficient

- **Validation of Models**

  Further validation and verification of models by field observation/tests, incl. the study of natural analogues.

3. GRIMSEL TEST SITE 1988 - 1990

The first investigation program for the Grimsel Test Site (GTS) was established in 1982/83. It was initiated in 1984 and is now nearing completion. The scientists/investigators concerned were asked at the beginning of 1987 to account for knowledge and experience gained and to propose a continuation of existing tests or suggest new investigations in order to fill the most important needs for further know-how or experience in respect of in situ work.

Simultaneously the performance assessment group identified from their point of view the important areas/questions in the performance assessment which could partly be clarified by in situ tests at the GTS. In doing so, they also consulted with the investigators in order to jointly determine in which of the four fields understanding/validation, methods, instrumentation and execution the requirements were highest.

In situ - and PA - spezialists then jointly considered the proposals and requirements in two workshops. They modified some and scrapped other proposals and thereby established the GTS program for 1988 to 1990. The table shown in Fig. 3 was a useful guide in this process. It will also serve as a basis for possibly conceiving further tests to fill the requirements in those shaded areas which are not sufficiently covered by the present scope of the program 1988 - 1990.

Fig. 1 Perspective overview of ILLW repository

Fig. 2 Perspective overview of HLW repository

Fig. 3 Areas of Uncertainty re Performance Assessment

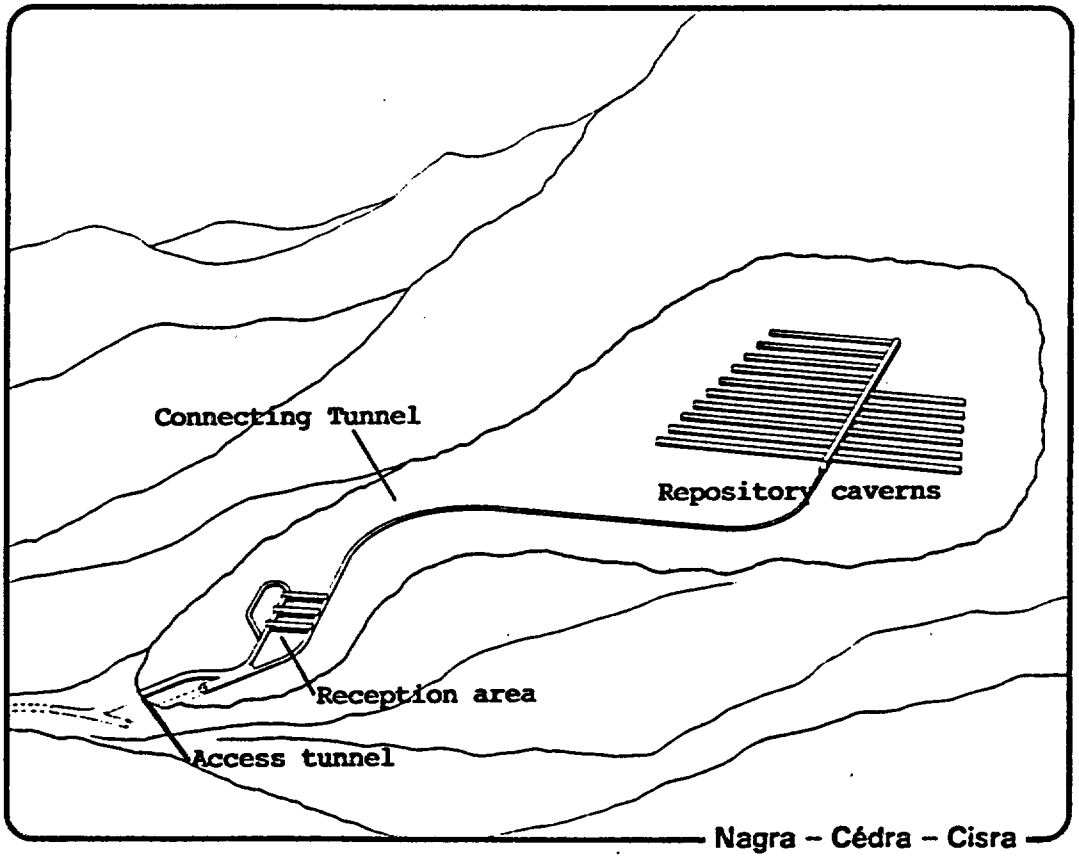

Fig. 1: Perspective overview of ILLW repository

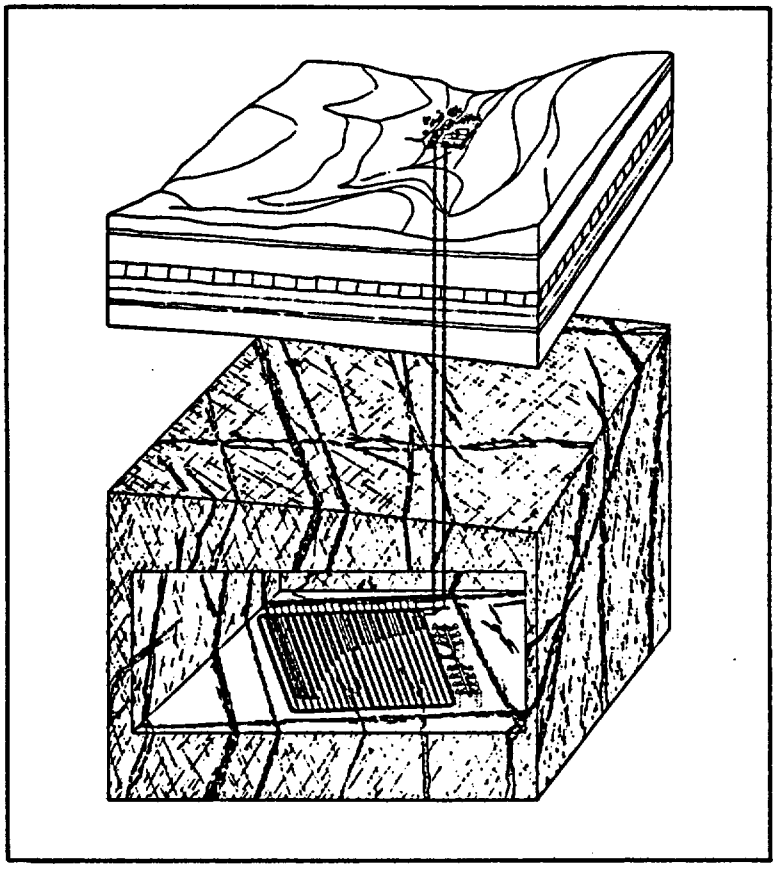

Fig. 2: Perspective overview of HLW repository

AREAS OF UNCERTAINTY RE PERFORMANCE ASSESSMENT

Nagra, Switzerland
Grimsel Test Site

Areas of Uncertainty	Understand Validate	Methods	Instru-mentation	Execution
Hydrology around Underground Excavations				
- GTS simulating a Repository, incl. Fracture Statistics ↔ Hydraulics	BK2, HPA MOD	NFH, BK2 MOD	NFH VE2	HPA, NFH VE2
- Determination of i, k around Tunnel, incl. Validation	BK2, VE2 MOD	HPA, NFH VE2, MOD	HPA NFH	HP, HPA NFH
Geophysics ↔ Hydrology				
- in Single Fracture	FRI	FRI HPA		FRI HPA
- in Fracture Network		UR BK2	UR	UR
Nuclide-Migration				
- Validation (e.g. Nat. Analogues)	MI2			
- In situ Test "Retardation" (Single Hole Tracer Test)		MI2		HPA FRI
- Channeling (Inflows to Tunnel)		MI2, NFH VE2, FRI		HPA NFH
- Characteristics of Fracture Network incl. Volumes of Fractures, Pores		FRI, UR BK2, HPA		FRI
Geo-Hydrochemistry				
- Sampling (Colloids, Eh etc.) incl. Validation, Analogues	NFH	NFH MI2	NFH MI2	NFH
- Interaction Water/rock incl. Validation, Analogues	MI2	MI2		MI2
Gastransport				
- Technical Barriers				
- Geosphere incl. excavation effects				
Consequences of the Excavation Effects				
- Rockmechanics (longterm)				MI2
- Hydraulics	NFH	NFH, AU2 FRI		NFH, AU2 FRI
Quality of Backfilling/Sealing				
- Technique for Filling/Sealing		VSB		VSB
- Testing for Effectiveness		VSB HP		VSB VSB

15.06.87
LS/Me

LEGEND TO TABLE "AREAS OF UNCERTAINTY"

1. Meaning of the vertical columns

   - **Areas of Uncertainty**

     Important areas/questions in the performance assessment which can partly be clarified by in situ tests at the GTS

   - **Understand, Validate**

     Tests which contribute to the understanding of the phenomena or to the validation of our understanding

   - **Methods**

     Activities which contribute to the development of the methodology (i.e. to the optimizing of the testing procedures)

   - **Instrumentation**

     Activities which contribute to the selection or the development of instruments suitable for the particular test

   - **Execution**

     Activities which contribute to train or test the consultants and contractors which may be involved in the execution of the particular test at a type 2 test site.

2. Shading, Fill-in

   - Shaded are squares where requirements are high

   - Filled-in are the GTS tests now envisaged for the period 1988 - 1990

3. Tests at the GTS from 1988 to 1990

UR	Underground Radar (to mid 1988 only)
US2	Underground Seismic Testing (contd.)
NM2	Tiltmeters (contd.)
FRI	Fracture Zone Investigation
SVP	Tunneling Advance Prediction
BK2	Fracture System Flow Test (contd.)
HP	Hydraulic Potential (contd. to end 1988)
HPA	Determination of Hydraulic Parameters
NFH	Near Field Hydraulics (mostly index tests)
VE2	Ventilation Test (contd.)
MI2	Migration Test (contd.)
AU2	Excavation Effects (only methods and execution as for as applicable also to marl formations)
WT	Heat Test (contd. to end 1988 only)
VSB	Borehole sealing (short test 1987 only)
MOD	Hydrodynamic Modelling

Recent Developments in UK Nirex Programme
Report to ISAG June 1987

Investigation of Four Clay Sites

From last autumn to this spring, four clay sites have been investigated for suitability for shallow burial of low level waste.

All four sites were found to have little water movement. It is assessed that, with well engineered burial, they could easily contain waste within required safety criteria for hundreds of years. Containment of long (10^3 to 10^5a) lived activity may tend to approach the safety limits a little more closely depending on the detailed inventory of the waste.

A possible long term problem arising from slow H_2 and CH_4 gas generation from corrosion of steel and degradation of organic material has been speculatively identified for shallow burial. Because of the good containment by engineered and geological barriers, these might be weakened by the gas pressures consequently produced. Solution of this problem could incur further costs in addition to the substantial costs already estimated for shallow burial to high safety standards.

Notwithstanding the satisfactory safety position and noting the costs, Nirex recently recommended to HMG Department of the Environment that, for financial reasons, they should not proceed with plans for shallow burial of low level waste. Instead they propose deep burial together with intermediate level waste. The Secretary of State for the Environment accepted this conclusion in a statement to Parliament on 1st May 1987 and work at the four sites has now ceased.

In-situ Fracture Flow Research

Field work on fracture flow has started this year at a research site on shale in Cornwall. The objectives of this work are to extend the previous study of flow through fractures in Cornish granite with attention to hydraulic connection between individual faults or fouled zones and large numbers of smaller fractures in less damaged rock. Channelling of flow in fractures and flow behaviour at fracture intersections will also be investigated.

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18th June 1987

IN-SITU RESEARCH ON RADIOACTIVE WASTE DISPOSAL - THE BRITISH GEOLOGICAL SURVEY CONNECTION UPDATE JUNE '87

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1. Background

The B.G.S. is involved in six field-based studies at present :

1. Finishing work on combining hydrogeological and geophysical measurements in the Crosshole Programme of Stripa Project Phase II.
2. Continuing work on natural analogues both in the U.K. and elsewhere.
3. Continuing work on the migration of radionuclides in a shallow glacial sequence.
4. Finishing work on a geochemistry research programme linked to the four shallow sites investigated by NIREX.
5. Starting work on an integrated site characterisation and model validation programme within Stripa Phase III.
6. Continuing work on an integrated hydrogeological and geophysical study of faults in mudrocks (in collaboration with ISMES of Italy)

The work is quite varied and is reported in a number of different ways and in different places. For the purposes of this review, the projects listed above are described in slightly more detail below.

2. 1. The Crosshole Programme of Stripa Phase II

The integrated interpretation of all the methods has been completed and, although it took more time than was originally envisaged, the results are all being published by the Stripa Project currently. the hydraulic work has focussed on the need for a versatile interpretation method to cope with networks of channels within fractures. The "fractional dimension" interpretation method treats geometry as a variable and seems to have many of the desired characteristics for dealing with hydraulic tests in fractured rocks.

2.2. Natural analogues

The recent work at Poços de Caldas in Brazil (funded jointly by SKB,NAGRA AND UK DOE) is slightly different from earlier work in that it contains a proportion of on-site testing. This comes about because of the desire to integrate the geochemistry derived from the analysis of the rock and groundwater samples with a reasonable knowledge of the current hydrogeology. Some boreholes have been drilled and basic packer testing has been carried out.

The work is regularly reported to the Natural Analogue Working Group of the C.E.C. (Côme and Chapman, 1986).

2.3. Tracer tests in glacial sediments

In order to validate the use of laboratory batch sorption experiments and the mathematical models incorporating both groundwater flow and reactive mass transport, used in site safety assessments, a series of field tracer tests have been performed. The original site comprised a group of about 10 boreholes, up to 10 m deep, distributed over several square metres in a confined unconsolidated

glacial sand horizon at Drigg in Cumbria.

In a new round of work another site has been developed where tracer studies will be carried out over larger distances (up to 30m). Hydraulic profiles at 8cm vertical spacing have been carried out in the area of the test (previously characterised using a resistivity probe). Six piezometers have been installed through the total thickness of the aquifer to monitor water level variations around the perimeter of the test array.Specialised drilling techniques using an internally flushed blanked well screen to eliminate outside disturbance around fully penetrating water injection and tracer release wells have been tested in a 3m deep, 1.2m diameter, test well built at Keyworth.

Natural organic material dissolved in groundwater has been removed from a 250l bulk sample using a DEAE resin (Diethylaminoethylcellulose) and fractionated into fulvic and humics (humics are insoluble at pH 1). The work is regularly reported, forms part of the CEC "Mirage" programme and is carried out in conjunction with Delft Soil Mechanics Laboratory.

2.4. Geochemistry linked to NIREX shallow sites

Four sites were chosen in the U.K. by the Nuclear Industry Radioactive waste EXecutive (NIREX) for detailed evaluation as to their suitability for low level waste disposal. The sites all contain clay at the surface and the proposed disposal method was by "engineered trench". The UK government announced in May 1987 the abandonment of the shallow sites programme, to be replaced by the assessment of deep sites for LLW and ILW.

Profiles of pore-water composition have been obtained through vertical sections of mixed sediments representing the four previous LLW sites. Pore-water samples have so far been obtained from 45 of these drillcore samples, and chemical and isotopic analyses are in progress.

An example of preliminary data on the pore-water chemistry is shown by data from the 50 metre-thick sequence of Tertiary London Clay at the coastal Bradwell site in Essex. The London Clay here is overlain only by thin drift deposits whilst it is underlain by Tertiary Sands and the Chalk. The preliminary groundwater model for this site suggests upwards flow from the Chalk into the Tertiary Sands and vertically through the low permeability (10^{-7}m/s) London Clay. The aim of the chemical and environmental isotope measurements is to obtain evidence which confirms, or otherwise, this conceptual model of water flow. The data should give at least a qualitative indication of whether diffusive or advective water and solute movement is occurring. In the examples shown, the vertical profile in chloride concentration is not a uniform trend across the clay section, suggesting that heterogeneous flow might be occurring (in faults or zones of slightly higher permeability?) or that the profile preserves the signals from changing boundary concentrations over time. Stable O and H isotope data will be a valuable independent indicator of heterogeneities in the pore-wates themselves; comprehensive analyses are in progress now.

The timewise evolution of pore-water profiles will be simulated by means of diffusion-advection modelling. It is hoped that this will enable the different influences of flow regimes (ie diffusion versus advection) and of transient changes in boundary water compositions to be resolved.

2.5. Stripa Phase III

Phase 3 of the Stripa Project has just started (Sept 86). Almost half the experimental budget is due to be spent on the programme known as *Site Characterization and Validation* . The idea of the programme is to mimic a site investigation of a repository site and use its results as a simple form of model validation. The programme consists basically of five stages: initial measurements, initial model predictions, detailed measurements, detailed predictions and final evaluation. It is designed as an iterative programme whereby the field measurements (of geometry and hydrogeology) will influence the form of the modelling and vice versa.

The geometry of the crystalline rock at the so-called "virgin site" has been largely defined by the geophysical techniques of radar and seismics (both single and cross-hole configurations). The measurements have been made in five boreholes totalling 1000m which have been drilled to surround the virgin site (150m x 150m x 50m). These same boreholes are just about to be used by B.G.S. to make single borehole hydraulic measurements using a new "active packer" technique. The idea of this system is to structure the testing so that only the most relevant hydrogeological features are measured in detail. The geometry derived from the geophysics together with the pattern of fracturing mapped in drifts and boreholes, will be combined with the hydrogeological measurements within the initial model of the site. The modelling is being carried out by the U.K.A.E.A. in collaboration with two U.S. groups. Based on the needs of models at this stage, further geometrical and hydrogeological measurements will be made.

The SCV project is a multi-disciplinary project involving research groups from a number of countries. The programme of work is described by Anon (1986) and all work will be reported in the Stripa Project report series.

2.6. Faults in clays

This is a new project which started in summer 1986. It is part-funded by the CEC and the UK DOE and is being carried out in collaboration with ISMES of Italy. The aim of the project is to investigate a fault in a mudrock. Firstly the fault will be identified by geological mapping and then by geophysical methods (principally seismics and resistivity). Following this a pattern of boreholes is due to be drilled to depths down to 100m to investigate the properties of the rocks, measure the groundwater regime and provide samples for laboratory analysis. A difficult practical aspect of this

work is the intention to drill into the plane of the fault at depth.

A site has been found in Britain which contains a reasonable thickness of mudrock underlain by an aquifer and contains a fault. The site in southern Britain has been investigated primarily by electrical geophysics and plans for seismic work to confirm depth interpretations are in hand.

Planning permission is likely to be applied for in the next few months and drilling work is expected to start in late 1987.

3. Summary

Although there is no underground research laboratory in the U.K. there are a number of sites where in-situ research is being carried out. Almost all the continuous work is being sponsored by the U.K. Dept. of Environment. The work at Drigg, the "fault site" and Stripa are all progressing steadily and concern the measurement of properties both for site investigation purposes as well as inclusion in a safety model.

STATUS OF OCRWM ACTIVITIES

NEA-ISAG Meeting, June 23-25, 1987

Site Characterization

The main area of effort has been in the preparation of the site characterization plans for the candidate repository sites in tuff, basalt and salt rock masses. The Nuclear Waste Policy Act requires that the plans for characterizing the host rock be submitted and reviewed before the characterization programs can begin. The characterization plan for the tuff site in the State of Nevada is in final preparation and should be submitted for review by the Nuclear Regulatory Commission and representatives from the State of Nevada and Indian Tribes by the end of the summer. In addition to the preparation of the characterization plan, some prototype tests of non-standard in situ tests and equipment are being performed in the experimental facility in G-Tunnel.

The characterization plan for the basalt site in Washington State is scheduled to be completed within several months of the Nevada plan. Prior to the sinking of the two shafts to the underground test facility for the basalt site, an extensive hydrology field testing program will be undertaken. The objective of the tests are to obtain hydrologic base line data prior to the drilling of the two exploratory shafts which will likely perturb the hydrologic regime. Prototype testing will also be undertaken for some of the equipment and testing being considered for characterizing the basalt rock mass.

The site characterization plan for the salt site in the State of Texas is in the early stages of development and should be ready in approximately one year. Reconnaissance activities are underway to assist in the development of the site characterization plan.

Foreign Programs

Selection and evaluation of possible granite rock masses within the United States for a second high-level nuclear waste repository has been postponed and a majority of the effort in this area has centered on international cooperation with foreign programs in Canada, Sweden, and Switzerland. The U.S. Department of Energy has recently signed an agreement with NAGRA for a cooperative technical program concerning the modeling of flow and transport through fractured rock and the interpretation and modeling of field data required for performance assessment. Researchers from Lawrence Berkeley Laboratory will participate in the joint three-year effort. Work is scheduled to begin this year.

U.S. participation in the Canadian research program is concentrated in the design of several experiments to be performed in the lower level of the Underground Research Laboratory. The URL shaft is currently being deepened for construction of the lower area where a mine-by experiment and pressure tunnel tests are planned. Surface-based hydraulic fracturing measurements were recently performed at the research site by U.S. investigators to estimate the in situ stress state at the URL site.

In addition to the international studies, the Department of Energy is also funding research at several laboratories in the U.S. to develop methodologies for characterizing the mechanical, hydrological, geochemical, and combined (coupled) behavior of fractures in rock. The objective of these small-scale laboratory investigations is to understand the basic hydrologic and geochemical behavior of the fracture surfaces and fracture infilling under the range of conditions expected during the construction, operations, and postclosure periods of the repository. The results of these studies will be used to evaluate the fracture data from mapping and the exploratory borehole core samples collected during site characterization.

One method being developed to facilitate the correlation of laboratory and field data is a laser-optic device for characterizing the fracture surfaces. The size and spacing of asperities, thickness of infilling, the calculated aperture and fracture porosity, and changes in these parameters with changing conditions can be evaluated using the laser-optics technology. This data is being correlated with the hydrologic behavior of the fractures in the laboratory studies under the various thermal and mechanical environments expected. This information may eventually be used to estimate the hydrologic conditions in the field (porosity, hydraulic transmissivity) based on the fracture mapping and core sample data and through correlation of the laboratory data with field experiments data to estimate the effect of scale.

WIPP IN SITU TESTING
STATUS REVIEW

June 1987

Presented by L. D. Tyler
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The WIPP In Situ Test Program supports the WIPP mission as defined by Public Law to demonstrate the safe disposal of radioactive waste from the United States defense programs. The in situ test activities were presented at the October 1986 meeting of the Advisory Committee. This presentation will provide a status of the WIPP test program with highlights of some of the more significant accomplishments. This presentation will start with the Plugging and Sealing Program, followed by the Thermal/Structural Interactions Program, and finish with the Waste Package Performance Program.

The Plugging and Sealing test activities currently are focused on three major areas. The first is the in situ evaluation of seal components for shafts and storage panel isolation. The Small-Scale Seal Performance Test is in its third series of testing, which is the emplacement and evaluation of salt and salt-bentonite consolidated block. A feasibility study for manufacturing and identifying block parameters has been completed. A block manufacturing machine has been built and is operating underground in the WIPP facility. The blocks have been manufactured and emplaced in eight 1-m-square openings. The tests are instrumented to determine hole closure, block compaction, and flow performance of the block seals. The first and second series of testing are the vertical and horizontal expansive concrete seal tests which have been emplaced for some time. In addition to measuring the flow through the seal systems of these tests (i.e., seal, seal-salt interface, and salt formation), the in situ flow characteristics and permeabilities of the Salado salt formation are being measured to determine excavation damage effects that are potential seal bypass paths. Another significant activity which is important to sealing a salt repository is the amount of brine which is released from the salt crystal boundaries, not inclusions. It has been found that brines that are locked in the salt are released and move to the man-made opening due to the pressure difference between the room pressure and the pore pressure in the salt. The consolidation of crushed salt and brine inflow coupled with shaft closure measurements have allowed the development of a preliminary systems model of the seal system for evaluating and developing design conditions for the WIPP seal system. The results of the preliminary analysis shows the sensitivity to the shaft closure, brine inflow from the salts, salt consolidation, and aquifer flow into the shaft.

The major accomplishment for the Thermal/Structural Interactions Program has been the development of a computerized data management and reduction system. To date two very interesting sets of data have been reduced. The first set of data is the mining sequence measurement for Room D, a six-m-square room, 100 m long. The data shows the displacements measure for each pass of the

mining machine. We have found that the early displacement histories of a room are required to understand subsequent closure behavior. The second set of data is for the heated pillar test in Room H. The measurements are for a cylindrical salt pillar, 13 m in diameter and 10 m high. The room is a 13-m annulus around the pillar. The first year of operation of this test was at ambient temperature. After the first phase of operation, heat was applied to the surface of the pillar. The primary objective of this test is to verify the constitutive model for the salt. These two data sets will provide an important part of the data base for resolving the difference between the model predictions based on laboratory data and the in situ observations. The model predictions underpredict the room closure by at least a factor of three. Because of the predicted difference, extensive investigations are underway to examine the data and the constitutive models being used. The investigations of the constitutive models have lead to the formulation of a coupled creep-plasticity model which shows promise for resolving the prediction difference.

The Waste Package Performance activities are divided into two major areas. The simulated Defense High-Level Waste (DHLW) addresses the canister, backfills and waste form behavior in situ for a heat-producing glass waste. The current in situ tests in WIPP are of simulated DHLW waste packages at reference and overtest conditions. Two different designs are being tested. In addition to full-scale package tests, in situ materials tests have been initiated. The Materials Interface Interaction Tests (MIIT) involve the emplacement of disks of different nonradioactive glass wasteform in contact with different canister materials and salt. The test assemblies are placed in drill holes with heating elements in saturated brine. Waste form samples were provided by the following eight countries: Canada, Belgium, England, Federal Republic of Germany, France, Japan, Sweden, and the United States. Six-month samples from the MIIT have been recovered and distributed to participants for analysis. The other major area of investigation is the Contact-Handled (CH) and Remote-Handled (RH) Transuranic (TRU) Wastes. The RH-TRU tests have been emplaced for full-scale simulation of the canisters and backfills. The CH-TRU tests have been started in both a reference and overtest state. Both tests involve testing containers and different room backfills. The reference test is being conducted at ambient conditions and the overtest is in a heated brine saturated environment.

Most of the tests described are multiyear tests of up to five-years duration. The tests have extensive instrumentation, which require computerized data acquisition systems. In addition, a computerized data reduction and management system has been developed. The data base currently being worked on is from over 5,000 instruments which are being read six times daily. The data is being retained as part of the WIPP quality assurance files.

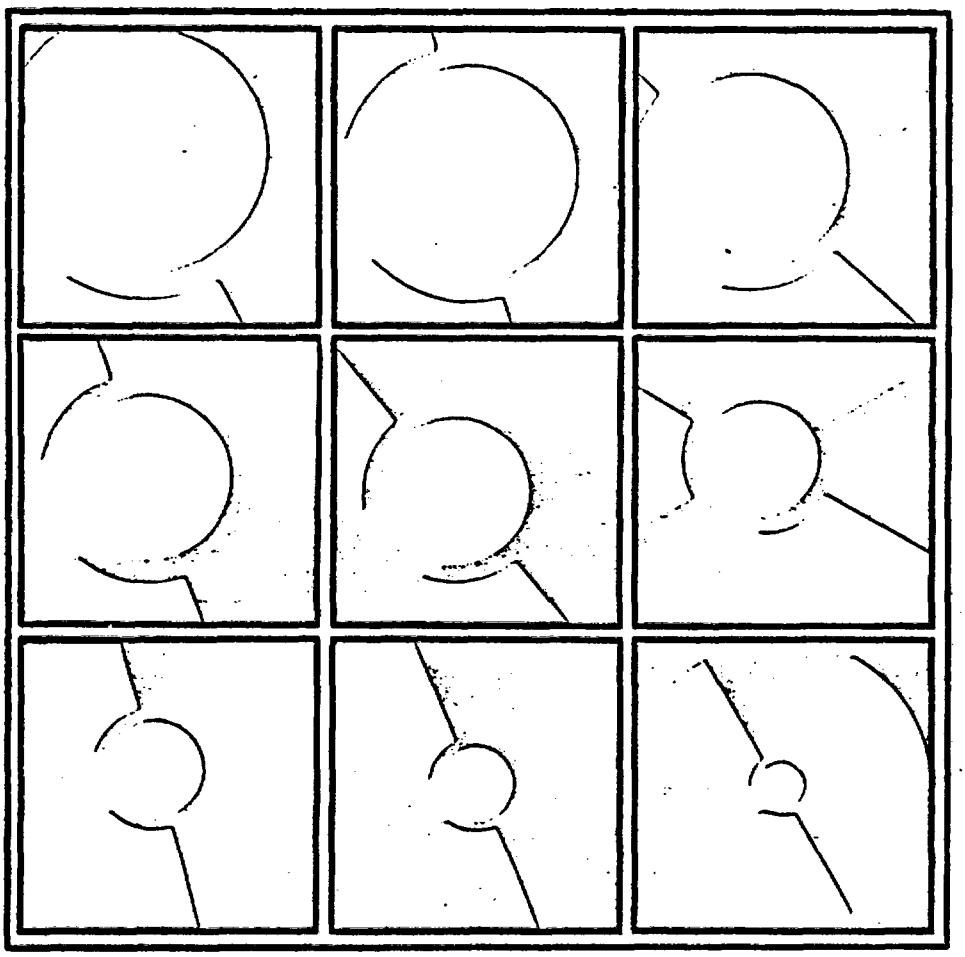
In summary, the WIPP in situ test program has initiated a number of extensive tests. These data, coupled with the predictive models, will provide the basic data for demonstrating safe disposal of radioactive waste from United States defense programs.

RWD 87/4

THIRD R & D PROGRAMME ON "MANAGEMENT AND STORAGE OF RADIOACTIVE WASTE" (1985 - 1989)

PROGRESS OF R & D ACTIVITIES IN THE FIELD OF GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

MARCH 1987



FOREWORD

The third R & D Community programme on "Management and Storage of Radioactive Waste" (1985 - 1989) comprises two parts: one dealing with waste management studies and associated R & D activities (Part A) and the other with the construction and/or operation of underground facilities open to Community joint activities (Part B).

This document puts together progress reports of cost-sharing contracts of this Programme signed as of 31st December, 1986 related to geological disposal of radioactive waste.

EXTRACT OF ANNUAL PROGRESS REPORT 1986

(TO BE PUBLISHED AS CEC REPORT No. EUR 11089 EN)

Directorate-General "Science, Research and Development"

The HAW project: demonstration facility for high-level waste disposal in the Asse salt mine

Contractor: GSF-IfT, Braunschweig, FRG
Contract-No.: FI1W/0003/D
Working Period: January 1985 - December 1986
Project Leader: T. Rothfuchs

A. Objectives and Scope

Since 1968 the GSF has been carrying out research and development programs for the final disposal of high-level radioactive waste (HLW) in salt formations. The heat producing waste has been simulated so far by means of electrical heaters and also cobalt-60-sources. In order to improve the final concept for HLW disposal in salt formations the complete technical system of an underground repository is to be tested in a one-to-one scale test facility.

To satisfy the test objectives thirty high radioactive canisters containing the radionuclides Cs-137 and Sr-90 will be emplaced in six boreholes located in two test galleries at the 800 m-level in the Asse Salt Mine. The duration of testing will be approximately five years.

For the handling of the radioactive canisters and their emplacement into the boreholes a complete disposal system consisting of transportation casks, transportation vehicle, disposal machine, and borehole slider will be developed and tested. The actual scientific investigation program is based on the estimation and observation of the interaction between the radioactive canisters and the rock salt. This program includes measurement of thermally and radiolytically induced water and gas release from the rock salt and the radiolytical decomposition of salt minerals. Also the thermally induced stress and deformation fields in the surrounding rock mass will be investigated carefully.

The project is funded by the BMFT and the CEC and carried out in close cooperation with the Netherlands Research Foundation (ECN).

B. Work Program

B.1. Elaboration of the test plan and the supporting documents for the licensing procedure.

B.2. Development and procurement of the technical componenents for handling and emplacement of the radioactive canisters.

B.3. Procurement and installation of the data collection system.

B.4. Mining of the test field, drilling of the boreholes, installation of the measuring equipment and preparation for the emplacement of the HLW canisters.

B.5. Test disposal including operation of electrical tests for comparison and assessment of the technical components.

B.6. In situ measurements of released water and gas from the salt, of thermally induced stress and deformation in the rock mass, and performance of seismic and ultrasonic measurements.

B.7. Accompanying and complementary laboratory investigations to ensure the transferability of the results to other sites.

C. Progress of work and obtained results

State of advancement

The test disposal of high-level radioactive waste canisters in the Asse salt mine will be performed with a view to the planning, design and licensing procedure for a national repository in the FRG. In the working period 1985 to 1986 most emphasis has been given to the final development of the technical components and the preparation of the underground test field. Therefore, in situ results from the interaction between the HLW canisters and the rock salt are not available at this time. The present schedule of the project foresees the emplacement of the radioactive canisters in May 1988.

1. Elaboration of the test plan

The test plan was prepared in 1984/1985 and the final version was issued in December 1985/1/. It contains a detailed description of the scope, issues, and objectives and also of the test program.

Nearly all the technical papers including the design calculations could be submitted to the responsible licensing authority (Bergamt Goslar).

2. Development and procurement of the technical components

The design of most components for handling and emplacement of the radioactive canisters was completed in 1985. The final development and construction proceeded very well in 1986. Most of the purchase orders could be placed to start fabrication of the components partly in late 1986.

The Asse internal transportation cask Asse TB1 which needs a type B(U) certification by the Physikalisch-Technische Bundesanstalt (PTB) has undergone its fall test (Figure 1) very successfully. The required fire tests will be performed in early 1987.

The development of the canister guiding system (CGS) as well as the gap monitoring system (GMS) to derive the tube deformation has been completed by ECN. The layout of both systems (see Figure 2), which will guarantee the retrievability of canisters, has been accepted by the licensing authorities. The test programs have been developed and adapted according to suggestions of TÜV. The prototype for CGS and GMS as well as the test rigs themselves are in the final stage of construction.

The development of the heaters which simulate the canisters during the prewarning heatup and the operational phase of the HLW test field are in the final stage of design.

3. Procurement and installation of the data collection system

The design for the Data Collection System (DCS) hardware has been finished in 1985, and the components have been delivered to ECN. The full-scale installment of the DCS takes place in Petten as well as the thorough testing of the different components.

The development of the DCS software has partly been finished. The application software of data transport and handling controlling the heaters and generating the tube deformation data and alarms is being specified and partly under development.

4. Mining and preparation of the test field

The underground test field, consisting of two parallel galleries, each 60 m long, 10 m wide, and 8 m high, was completely mined in 1985. By the end of 1986 about 70 % of the measuring boreholes were drilled and about 60 % of the extensometers and 40 % of the stressmeters could be installed.

5. Test Disposal

Due to delayed fabrication of the radioactive canisters and the time consuming final definition and specification of retrievability requirements and technical components the time schedule of the project is delayed. The emplacement of the radioactive canisters is now foreseen for May 1988.

6. In situ measurements

First in situ measurements were already started prior to the mining of the test field. A so-called stress monitoring station was installed in the pillar between the two galleries approximately 3 m above the floor of the test room. The measurements indicated a vertical stress component of about 14 MPa prior to the mining activities which increased to about 19 MPa after mining of the galleries. The resulting deformation of the pillar could be observed by measuring the room closure between the pillar wall and the opposite gallery wall which amounts to approx. 70 mm after 510 days (see Fig. 3). However, to evaluate the absolute displacement of the pillar wall it is necessary to wait for the results of the pillar extensometers which will be installed later. Additional geochemical measurements show that CH_4, CO_2 and H_2S are present in rock salt and are released to drilled boreholes at natural mine temperature.

The special instrumentation developed for obtaining the salt pressure from borehole tube deformation is in the final stage of design. The acoustic measuring techniques to be used for crack detection are further tested, the necessary equipment is in the final stage of fabrication so that it can be installed at the beginning of 1987.

7. Accompanying laboratory investigations

The laboratory program accompanying the test disposal is concentrated on the influence of parameters concerning the geochemical and mechanical aspects of HLW disposal that cannot be studied in situ. These are mainly variation of temperature, dose, dose rate, stress, strain and mineralogical composition of the salt.

Theoretical calculations on the neutron irradiation of the rock salt indicated that after a five year emplacement of HLW the following maximal activities may be found: Na-24: 52 Bq/cm^3, P-32: 17 Bq/cm^3, S-35: 1700 Bq/cm^3, Cl-36: 420 Bq/cm^3, Br-82: 178 Bq/cm^3.

References

/1/ Testplan zur HAW-Versuchseinlagerung im Salzbergwerk Asse, Gesellschaft für Strahlen- und Umweltforschung mbH München - Institut für Tieflagerung (1985)

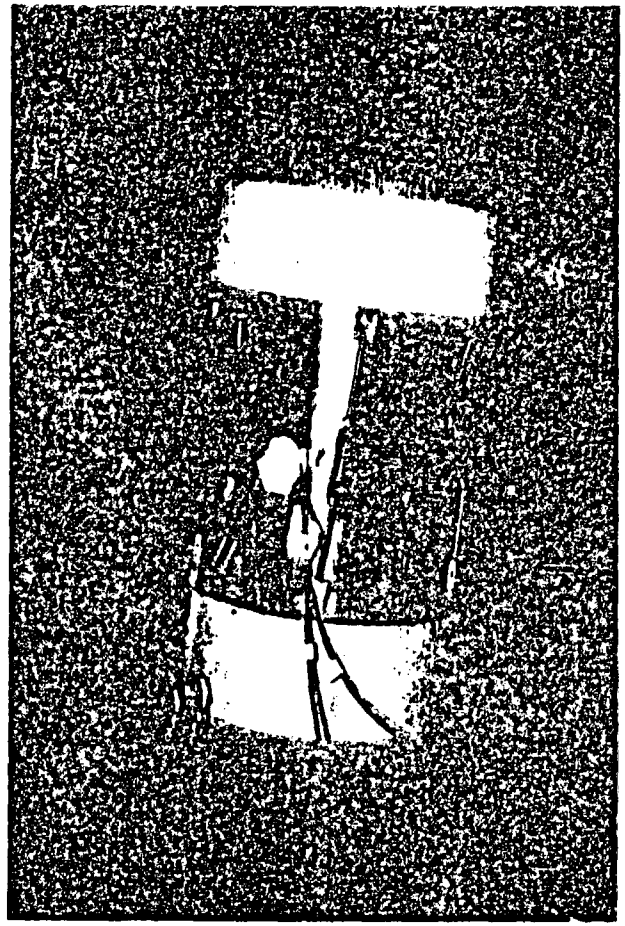


Figure 1: 1:4-model of the transportation cask Asse TB1 after the fall test

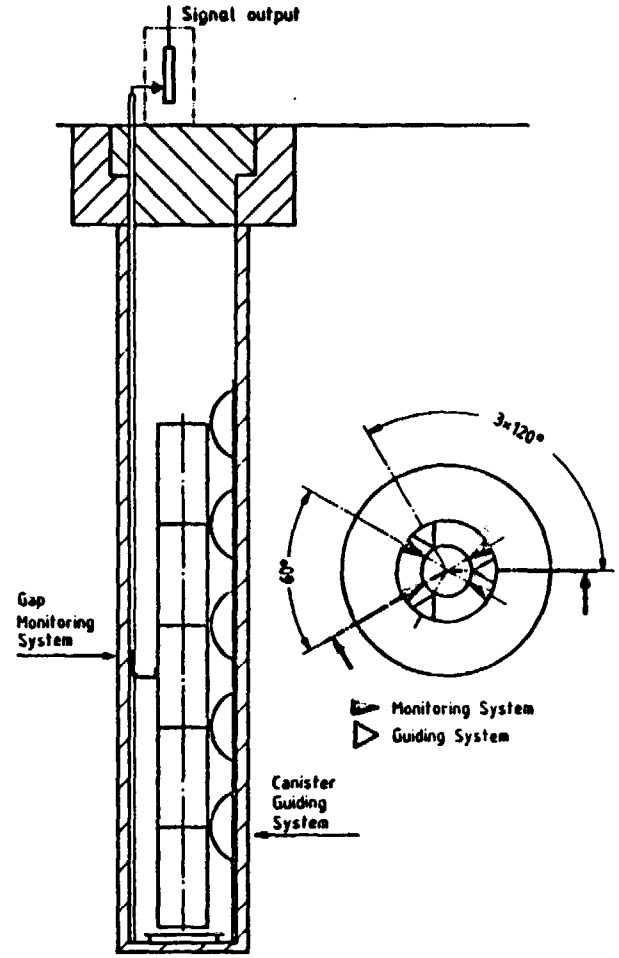


Figure 2: Schematic layout of the canister guiding system and gap monitoring system

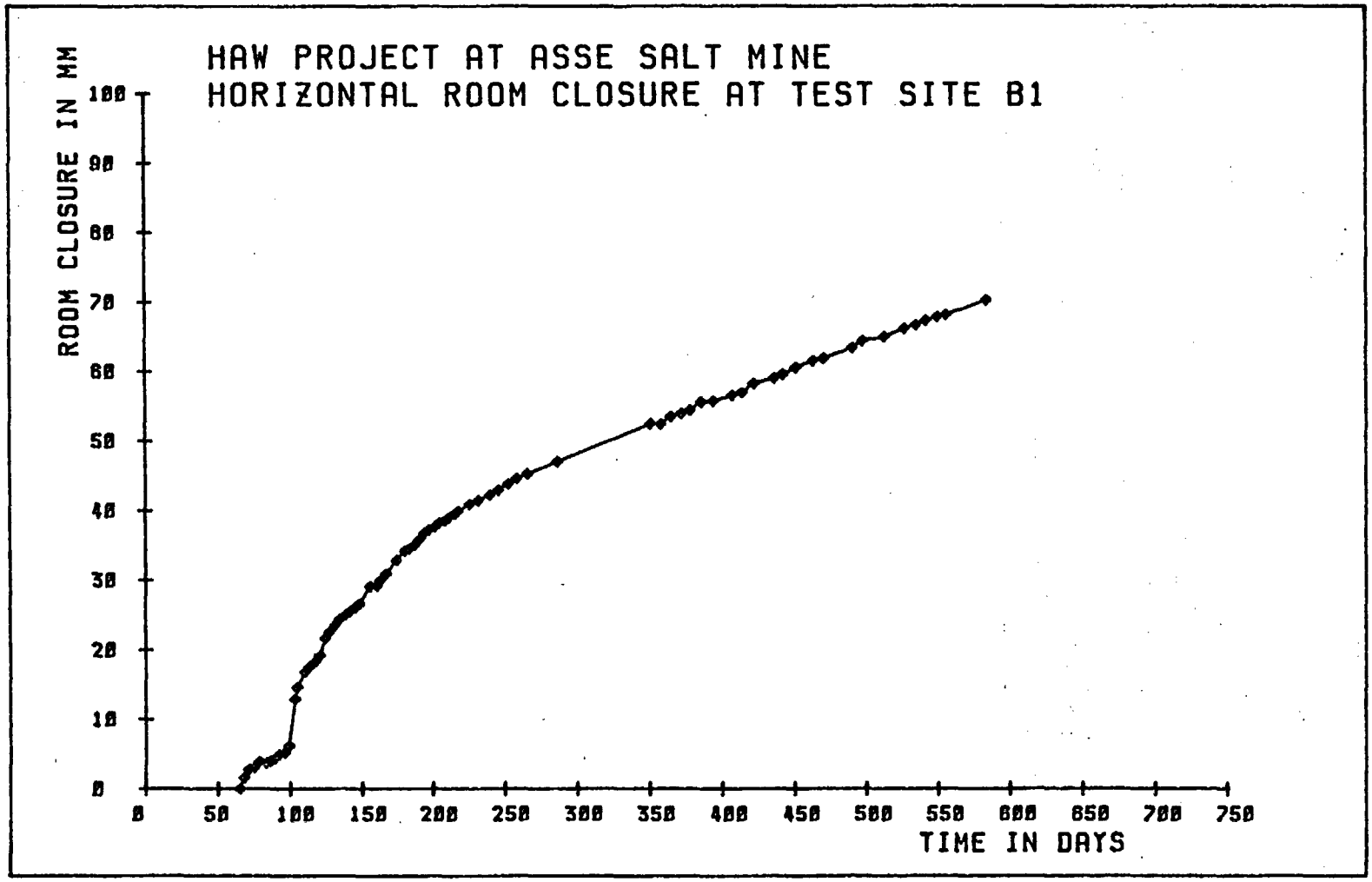


Figure 3: HAW-Project - Horizontal Room Closure at Test Site B1

List of publications

KESSELS, W.: Operational Principle, Testing and Applications of the AWID-Flat Jack for Absolute Stress Determinations Using Voltage Measurements. Rock Mechanics and Rock Engineering 19, 165 - 183 (1986)

STAUPENDAHL, G: Geomechanical Aspects of in situ Experiments and of Laboratory Investigations on Rock Salt Samples from the Asse Salt Mine. Ecole d'Eté de Thermocécanique des Roches, Alès 9-12 Sept. 1986, Proceedings (to be printed)

STIPPLER, R. et al.: Bereitstellung von Komponenten für eine HAW-Versuchseinlagerung. Jahrestagung Kerntechnik '86, Aachen, 8-10 April 1986, Deutsches Atomforum e. V. Bonn, Proceedings pp. 285-288.

SCHLICH, M. K.: Simulation der Bewegung von im natürlichen Steinsalz enthaltenen Feuchte im Temperaturfeld. Ein Beitrag zur Problematik der Endlagerung hochradioaktiver Abfälle, Teil I-Text, Teil II-Abbildungen. Dissertation TH Aachen (1985). Gesellschaft für Strahlen- und Umweltforschung mbH München. GSF-Bericht 2/86 (1986)

The HADES project : a pilot underground facility in the argillaceous layers located under the Mol nuclear site with a view to demonstrating the feasibility of radioactive waste disposal

Contractor : SCK/CEN, Mol, Belgium
Contract N° : FI1W/0004/B
Duration of contract : January 1985 - December 1989
Project Leader : A.A. Bonne

A. Objectives and Scope

In 1974 SCK/CEN launched a R&D-programme concerning the possibilities for disposal of high level solidified and alpha-bearing radioactive wastes in a continental stratiform clay formation (Boom clay) situated below its own site. Site investigations, safety studies, repository design, conceptualisations and in situ research confirm progressively the favourable characteristics of the host rock and the site for disposal of radioactive wastes.

Many particular areas require further studies and tests on a larger scale and in situ demonstrations under realistic conditions. The areas identified are related to the construction on an industrial scale of an underground repository in plastic clay, the operation of an underground facility, the interaction between the repository and the immediate surrounding geological medium and the safety. These technological tests, studies and demonstrations will contribute to increase the confidence in the technical practicability, the economical feasibility and the safety of the disposal option in deep clay.

The direct demonstrations deal with the constructability of real scale galleries without particular conditioning of the rock, the choice and dimensioning of a realistic lining and support system, the interaction between the underground structures and the immediate geological environment, the influence of heat and radiation upon the underground structures and the immediate geologic environment, the handling of hot and radioactive canisters, the backfilling and its behaviour in time, the performance of various system components during the operational phase and monitoring systems.

B. Work Programme

The demonstration/pilot phase of the HADES project is developed in two phases, which are complementary to each other and in part parallel.

B.1. Phase I : the construction and operation of a test drift with tests related to :

- B.1.1. mining technology (digging, lining, extrados backfilling, rheology) ;
- B.1.2. radioactive waste disposal (experimental emplacement, backfilling, degradation of waste matrices and migration of radionuclides, in situ irradiation of clay, thermo-mechanical behaviour of clay and gallery structures, monitoring and auscultation systems).

B.2. Phase II concerning :

- B.2.1. construction of a pilot facility with a new shaft and extended gallery, experimental disposal pipes, connecting chamber and utility structures ;
- B.2.2. tests and observations on handling, emplacement, backfilling and retrieval of dummies and finally actual radioactive wastes.

The performance of B.2 is scheduled beyond the actual contract period.

C. Progress of work and obtained results

State of advancement

The construction design of the test drift of phase 1 of the HADES demonstration/pilot phase is completed. Two tunnelling concepts were selected for the test drift : a stiff tunnel lining concept with concrete liners is foreseen for the first section of the test drift ; ANDRA (F) proposes a second section of the drift to be supported by sliding steel ribs ; the plans, construction procedures and measurement programme satisfying the requirements for investigating the capabilities and conditions for tunnelling with stiff lining were established. All construction related issues for this test drift portion are on schedule.
The geotechnical auscultation of the clay mass (mine-by-test) around the section of the test drift with stiff lining has been defined and constructed. Some measuring devices, part of the mine-by-test programme (piezometer profile), were already installed at the end of 1986
Efforts were devoted to a preliminary design study for testing the in situ behaviour of clay, of structural materials, of backfilling and of the concrete gallery lining in a combined radiation-heater test.

Progress and results

1. Test drift construction works

According to the design developed at present, the works on the HADES site will include :

- an opening in the crossing chamber at the bottom of the actual shaft, the size of the opening will be limited because of the size of the presence of metallic reinforcement rings in the crossing chamber ;
- the first part of about 4 m length the gallery passes through the disturbed clay which has been frozen during the construction of the access shaft. It is foreseen to use a concrete lining in this section for ease of emplacement and cost reduction ;
- a connection plug of reinforced concrete, enlarging the test drift to a circular section of 3.5 m inner diameter,
- the main portion of the test drift, of 3.5 m inner diameter, 20 m long, circularly lined with concrete blocks.
  The "final" design for this gallery foresees 3 rings of concrete blocks per meter (64 blocks per ring), each ring having a thickness of 60 cm.
  The concrete segments will be prefabricated at 2 mm tolerances with regard to the theoretical dimensions and will have a characteristic resistance of 55 MPa when tested at 28 days, with a maximum standard deviation of 4 MPa.
  The water-cement ratio will be as low as possible and in any case lower than 0.45. The final porosity will be minimal and in any case lower than 4 percent. The cement should be resistant to sulphate attack.
  The intercalary plates, 8 mm thick, will be of the "Linex" type and previously treated in order to be imputrescible.
  The void space between the concrete segments and the excavated wall will be backfilled directly after positioning of each ring, with a non-clayey material of continuous granulometry, appropriate for later injection. This injection will take place every 3 m and at least once a week ;
- the placing of several special frames, designed to provide access to the clay body is foreseen during construction works ;
  The number of openings was reduced in order to fit better to the planned experimental programme and includes the following :
  - 760 mm diameter opening : 1,
  - 400 mm diameter opening : 10,
  - 200 mm diameter opening : 25.

Andra proposes to build as a test a section of a drift with sliding ribs as support. Braces and plates between the ribs act as liners of the drift wall and allow to make extrados injections in order to ensure the continuity. Special joint elements will allow a limited sliding when a predefined stress threshold is reached. The dimensioning and engineering of this section of the test drift is in progress. A safety device is foreseen in order to stop any irregular or important convergence of the sliding drift lining.

2. Mine-by-test around the stiff section of the test drift

The planned geotechnical programme is briefly described hereafter. It is to be noted that several types of measurements are foreseen to allow cross-checking and improvement of the interpretation.

- Convergence measurements on the lining

  Five sections of the drift will be equipped with convergence studs before emplacement. At each section, four diameters will be measured using the "distomatic" device of Telemac. By this device the distance variations between two opposite points anchored in the lining are measured.

- Underground topographic surveying

  The position of the gallery in X, Y, Z will be regularly controlled. Equipment, space between the measurement sections and timing are to be settled.

- Pressure build-up on the lining

  Three of the five measuring sections will be equipped with pressure cells behind the lining and load cells between the concrete segments. In the most representative section, centered in the test drift, 12 total pressure cells are foreseen to be positioned in order to measure radial stress. Also 8 load cells are foreseen in this section. Emplacement methods, dimensions and types as well as possible inclusion in concrete segments are now further studied.

- Deflectometers

  Two horizontal inclinometers of 12 and 23 m length and a tassometer series (35 m) are foreseen in the roof of the drift in order to record the deformations in the clay due to the excavation works.

- Pore water pressure measurements

  Piezometers (screens) and hydraulic pore water pressure cells (Gloetzl) were installed starting from the crossing chamber and extending to different distances from the new drift in order to quantify the pore water dissipation expected during excavation.

- Clay front auscultation

  Convergence measurements in the last ring of the gallery will be complemented by deformation measurements at the clay front. Steel rods or multi-point extensometers will be anchored at different distances in the clay front.

3. Geotechnical auscultation of the clay

In addition to the geotechnical auscultation just described in the framework of the mine-by-test, a test is planned to determine the coefficient of the earth pressure at rest. This test is to be performed by a self boring pressuremeter immediately after the construction phase at a greater distance from the test drift. This test will not only give information about the observed pattern of in situ lateral stresses but also about in situ properties of clay such as undrained shear strength and in situ moduli.

4. Combined radiation/heater test

A concept has been developed for performing a combined radiation and heating test in the clay mass in the floor of the test drift. Preliminary calculations indicate that a combined radiation/heater test may well simulate the near-field of a stack of 50 years aged HLSW. The most appropriate configuration is obtained by a linear Co-60 radiation source of 13 kCi, taken between two linear heaters (one above and one below the linear radiation source). For this test possibly loaded at 2 m below the floor of the test gallery the aim is to study the effects of such a source on the clay environment, the structural materials (hole casings, gallery lining) and backfill materials. Further development of the concept of the radiation/heater test is needed.

List of publications

L.H. Baetslé, A. Bonne, P. Dejonghe
The HADES demonstration project for radwaste disposal in deep clay
Proceed. Int. Conf. on Rad. Waste Management, Winipeg, 7-11th Sept. 1986.

Development of the methodology of Geoprospective study of a repository site

Contractor : Bureau de Recherches Géologiques et Minières
B.P. 6009
45060 ORLEANS CEDEX - FRANCE
Contract n° : FI IW/0048
Working period August 1986 - December 1986
Project Leader P. PEAUDECERF - J. FOURNIGUET

A. Objectives and scope

Since 1981, the BRGM has been working on the development of a method for systematically studying all the factors which might influence the evolution of a waste storage site and their interactions. One of the work phases consisted in a relative quantifying of the links between the factors and in modelling them so as to complete realistic scenarios. These operations are carried out with a simulator called CASTOR ("Construction automatique de scénarios d'évolution d'un site de stockage de radionucléides" Automatic design of scenarios evolution of a radionuclide storage site).

The first simulations showed that a few main mechanisms governing site evolution should be represented more realistically.

They are essentially those concerning climate variations, weathering and erosion processes and relationships between stress and hydraulic parameters. The simulation programme will have to be modified accordingly to take these mechanisms and their interrelationships into account simultaneously.

This work should make the CASTOR code operational when applying the methodology to specific sites.

B. Work programme for 1986

The whole study must revolve around two main aspects:

- increasing knowledge of mechanisms which appeared essential in earlier work:
  - climatology
  - weathering-erosion
  - relationships between stress and hydraulic parameters.
- improving the modelling of the phenomena and the representation of results obtained.

Considering the date at which the contract was signed, it was decided that the first work would be concerned with the complex mechanisms and with the noless complicated mechanisms of erosion.

C. Progress of work and obtained results

At the contract was signed in August 1986, only a few months of the second half year could be given over to the study.

During this period, two of the numerous selected themes were worked upon:

Mechanisms of Erosion and Mechanisms of Climatic Variations.

This work is done on a shared-cost contract with the European Atomic Energy Community as part of its research and development programme on the management and storing of radioactive waste (related studies only).

C.1 - Erosion mechanisms

The climatic conditions envisaged are those between the Mediterranean and temperate types on the one hand, and periglacial conditions on the other.

The first research concerned the catchment basins in the southern subalpine ranges about 10 km NNW of Sisteron.

Sediments liable to erosion are produced in the following successive stages:

- disaggregation of a thin surficial film, producing a friable layer, 15 to 20 cm, thick,
- washing down or mass-movement of this loose layer to gully bottoms by rain-drop impact,
- transportation of this material by traction or in suspension, by water flowing in the gullies and channels.

The main parameters to be considered are:

valley slopes
exposure to direct sunlight
dip of sediments
nature of vegetation cover.

Among the first results, two important points must be emphasized:

- the exponential variation of erosion with rain intensity,
- the discontinuous nature of erosion phenomena; various types of threshold effects exist and it can be reckoned that only 25% of annual rainfall is erosive.

C.2 - Climatic mechanisms

Climatic variations are of considerable importance as they have varied consequences. Several aspects had therefore to be considered:

a. Mathematical formulation of past and future climatic fluctuations checked by astronomic parameters, calculation and plotting of forecast curves.

b. Search for present-day climatic equivalents to compare with the Quaternary climates reconstituted by conventional geological methods. These comparisons enable quick and empirical access to the temperature and rainfall conditions to be used for calibrating the calculated climatic curves.

c. Phenomena induced by the existence of inlandsis: under the ice or on its edges.

During the second quarter of 1986, only points b and c were treated.

Climatic equivalents: a thorougly reference search enabled the collection of data on temperatures (average and extreme values) and rainfall (total, distribution) over Europe. These data resulted in quantification of present climates using indices and zonation maps. Past successive climates will next have to be identified with present synchronous but juxtaposed climates.

Induced phenomena

Among the phenomena induced by the presence of inlandsis, three seem to bring about large scale mechanical modifications:

- the contorted structures in the sediments deposited by ice,
- glaci-tectonics affecting both the glacial sediments and their substratum,
- tunnel valleys, capable of excavating trenches several hundred metres deep.

Long-Term Rheological and Transport Properties of Dry and Wet Salt Rock

Contractor: University of Utrecht, Netherlands
Contract N°: FI1W-0051-NL
Duration of Contract: 01/07/86 - 30/06/87
Project Leaders: C.J. Spiers (author), H.J. Zwart

A. Objectives and Scope

Previous work at Utrecht has shown that small amounts of inherent or added brine can strongly influence the long-term rheological and transport properties of salt rock via processes such as fluid-assisted diffusional creep and recrystallization /1, 2/. Fluid-assisted recrystallization has also been shown to be capable of strongly reducing ("annealing out") radiation damage in salt /3/. The objectives of the present programme are as follows:

1) Characterisation of the long-term constitutive behaviour of salt rock, taking into account such parameters as fluid content, fluid pressure, grain size, and confining pressure.
2) Further characterisation of the dependence of creep-induced dilatancy and permeability in salt rock on parameters such as pressure, temperature, fluid pressure, and deviatoric stress.
3) Determination of the time-dependent compaction creep and permeability characteristics of dilated salt rock, granular salt (backfill), and anhydrite rock, under dry and wet conditions. Special attention will be given to the determination of an optimal (i.e. fast compaction/recrystallizing/sealing) "recipe" for granular salt backfill.
4) Preliminary determination of the rate of recrystallization (hence stored energy reduction) of γ-irradiated salt rock as a function of parameters such as specific stored energy, temperature, brine content, and brine impurity (Fe^{3+}) content.

B. Work Programme

B.1. Rheological experiments (triaxial testing of coarse and fine-grained salt rock).
B.2. Creep-induced dilatancy/permeability tests.
B.3. Compaction creep/permeability tests.
B.4. Radiation damage/recrystallization studies.

C. Progress of Work and Obtained Results

Summary

During 1986, investigations were directed at the compaction creep behaviour of wet granular salt (backfill recipe), at the long term deviatoric creep behaviour of Asse salt rock under steady-state conditions, at deviatoric creep in artificially prepared fine-grained salt rock, and at the influence of temperature and brine content on recrystallization in irradiated salt rock. The compaction work on wet granular salt has proceded encouragingly, the experimental results showing excellent agreement with theory. Preliminary compaction creep laws have been developed and a preliminary backfill recipe proposed. The deviatoric creep work has resulted in a "best estimate" constitutive law for creep of salt rock under in situ conditions. The recrystallization studies have suffered delays but clearly indicate that provided trace brine is present, recrystallization leads to much more efficient annealing of radiation damage in salt than the well-known solid state reactions. The general status of the work programme is as follows:

- B1 - progressing encouragingly, but slightly behind schedule.
- B2 - delayed.
- B3 - excellent progress with granular salt, anhydrite work delayed.
- B4 - experimental programme complete, analysis of results still in progress.

Progress and Results

1. Rheological Experiments on Salt Rock

Deviatoric creep experiments have been performed on natural Asse salt rock under conditions of constant strain rate and without added brine. These tests have confirmed that results obtained from our previous stress relaxation tests (1, 2), i.e. that fluid assisted effects become important in natural salt when the confining pressure is sufficiently high to suppress dilatancy. Long-term creep experiments have also been performed on artificially prepared, fine-grained salt rock (∿ 1% brine), using the stress stepping technique. Once again, the results are closely consistent with our earlier data (1, 2) and confirm that the low-stress creep of brine-bearing salt occurs by fluid-assisted diffusional transfer (FADT). Analysis of our entire data set has yielded the following "best estimate" constitutive law for creep of brine-bearing salt by this mechanism

$$\text{Diffusional creep rate } \dot{\varepsilon}(DC) = (1.25\times10^{-9})\left[(8.25)T-2350\right]\sigma/Td^3 \ (s^{-1})$$

where σ is the applied differential stress (MPa), T is absolute temperature (K), d is grainsize, and where $\dot{\varepsilon}(DC)$ is thought to be insensitive to actual brine content provided trace brine is present. To a first approximation, this low stress creep law can be added to the well-known BGR creep law (high stress, dislocation mechanism) to obtain the general constitutive equation $\dot{\varepsilon}(net) = \dot{\varepsilon}(BGR) + \dot{\varepsilon}(DC)$ for natural salt (non dilatant conditions).

2. Creep-Induced Dilatancy/Permeability Tests

As a "by-product" of the experiments reported above, data regarding the dependence of creep-induced dilatancy on pressure, temperature and deviatoric stress was slowly accumulated during 1986. However, this data has not been analysed. No specific dilatancy/permeability tests have yet been performed.

3. Compaction Creep/Permeability Work

Compaction creep experiments have been performed on wet granular salt to determine the constitutive compaction behaviour and to test theoretical models. The results show that under backfill/cement-relevant conditions, compaction creep occurs by diffusion controlled FADT (see C.1.) and can be described by a constitutive law of the form

$$\text{Volumetric compaction creep rate } R = A.P^a/d^b.e^c$$

where A is a temperature dependent term, P is the applied effective pressure, d is grainsize, e is volumetric strain, a = 1, b = 3, c = 2. This law applies for P < 3-4 MPa, d < ∿ 5 mm, e > 15%, brine contents down to a few percent, and for initial porosities in the range 35-45%. At volumetric strains e > 15%, c increases rapidly reaching a value of ∿ 5 at e = 20%. Over the entire range of conditions investigated so far (e ≤ 30%, P < 4.5 MPa), the experimental data are best described by an empirical relation of the same form as the above but with a ≅ 1.5, b ≅ 3, c ≅ 3. The data have been used to help develop a preliminary "fast compacting" backfill recipe - see Table 1.

4. Radiation Damage/Recrystallization Studies

Hydrostatic annealing experiments have been performed on pre-irradiated salt rock samples (Dose = 1-10 Grad) at T = 70-120°C, P = 10-30 MPa using added brine contents in the range 0-0.5 wt%. Stored energies have been measured using solution calorimetry and DSC methods. Recrystallization rates have been determined by image analysis of sectioned material.

Most samples annealed with brine contents > 0.1% exhibit relatively rapid recrystallization and reduction of stored energy. However, the data analysed so far show a wide scatter, making determination of the dependence of recrystallization rate on stored energy, temperature and brine content difficult. Nonetheless, it can be inferred that provided brine remains present (> 0.1%), recrystallization is a much more rapid annealing mechanism, under the conditions of interest, than purely solid state reactions.

References

/1/ SPIERS, C.J., URAI, J.L., LISTER, G.S., BOLAND, J.N. and ZWART, H.J., The Influence of Fluid Rock Interaction on the Rheology of Salt Rock, Commission of the European Communities, Publication EUR 10399 EN (1986).

/2/ URAI, J.L., SPIERS, C.J., ZWART, H.J. and LISTER, G.S., Nature, 324 (No. 6097), 554-557 (1986).

/3/ URAI, J.L., SPIERS, C.J., PEACH, C.J. and ZWART, H.J., University of Utrecht, (OPLA) Report REO-2/TR1 (1985).

Table I. Preliminary "fast compacting" salt backfill recipe (d = grain-size).

Material	Mass fraction (%)
Matrix of finely powdered salt ($d < 0.5$ mm)	~ 75
Coarse-grained salt filter ($1 \leq d \leq 5$ cm)	15-20
Geochemical Barriers: clay/anhydrite/Fe_2O_3 ($d < 0.5$ mm)	~ 2
Brine	~ 5

COMPARISON OF COMPUTER CODES FOR SALT FOR GEOLOGICAL DISPOSAL OF HIGH-LEVEL WASTE PROJECT COSA PHASE II

Contractor : Atkins Research and Development, Epsom, UK.
Contract No : FI1W/0054/UK
Duration of Contract : 1 November 1986 - 31 October 1988
Project Leader : N.C. Knowles

A. OBJECTIVES AND SCOPE

Research into geomechanical aspects of RAW repositories in salt formations has been active in the European Community for nearly two decades, with particular interest being placed on problems of heat producing waste. Central to this work is the prediction of stresses and deformations in the host strata, for which a number of computer codes have been developed /1/. A preliminary exercise ("COSA 1") to compare the ability of the different codes has recently been completed /2/ and has provided a limited "snapshot" of the current European capability to predict the behaviour of rock-salt under well defined conditions. The purpose of the present contract is to extend the comparison to more complex but realistic situations.

Comparison problems in the first phase were relatively simple, and a number of difficulties to do with modelling of the in-situ behaviour of rock salt were deliberately avoided. The present exercise is directed at comparisons of realistic in-situ behaviour. Emphasis will be placed on the characterisation of material behaviour by individual participants. Other modelling topics to be addressed include the representation of 3-D behaviour by 2-D models, algorithms for treating the thermal and geomechanical discontinuity at the moment of encapsulation of the waste canister, the influence of non-homogeneities within the strata and far-field boundary conditions.

There are 9 participants in the exercise, each acting as a sub-contractor to the co-ordinator. In addition an independent expert will provide advice as necessary on aspects of salt rheology (Table 1).

B. WORK PROGRAMME

B.1 To agree, at plenary meetings, suitable in-situ benchmark problem(s) to be solved by participants.

B.2 Co-ordinator to prepare discussion documents and circulate to participants as necessary.

B.3 Co-ordinator to prepare and circulate detailed specifications of agreed problem(s).

B.4 Participants to solve agreed benchmark problem(s) to the best of their ability using appropriate codes, according to the specifications produced by the co-ordinator.

B.5 Co-ordinator to collect and compile results and other data from participants.

B.6 Co-ordinator to prepare draft reports for discussion at plenary meetings to be held approximately every six months.

B.7 Co-ordinator to prepare and issue final reports taking account of participants' comments.

C. PROGRESS OF WORK AND OBTAINED RESULTS

Statement of advancement

As indicated above, the project is still very much in its infancy : A plenary meeting has been held at which an in-situ benchmark problem was selected. A specification is being prepared, prior to solution of the first part of the problem. Hence, B1 is completed and B2 is progressing normally.

Progress and Results

A plenary meeting, held on November 26-27, 1986 in Brussels, agreed that a selection of the experiments performed by ECN in the 300m dry drilled borehole in the Asse mine in W Germany would be the basis for the exercise ('Benchmark 3').

This decision followed extensive discussion about suitable "problems" which in practice are very limited. The attributes of the ideal problem were listed as :

i) in-situ test
ii) realistic timescale
iii) adequate thermal loading
iv) well established behaviour
v) well posed problem in terms of the availability of data describing geometry, loading and material behaviour
vi) unfamiliar to participants
vii) relevant to European needs

Because the field is so specialist it is apparent that conflict between the latter two attributes is inevitable. Thus some participants have already performed calculations for the Dutch experiments. Moreover they are familiar with the difficulties inherent in characterising the in-situ material behaviour in a form suitable for predictive modelling. Nevertheless it is felt that the experiment has many positive aspects and particular care will be taken to try to ensure that the objectivity of the exercise is not compromised by the prior experience of some participants.

The first stage consists of modelling the isothermal free convergence of the borehole, over a period in excess of 800 days. A draft specification is being prepared which will be circulated to participants for comment by the end of January, 1987. It is hoped that the results of the isothermal free convergence calculation will be discussed at the next plenary meeting, set for the end of June 1987.

Table 1 : List of organisations involved in COSA II

ATKINS R&D - Epsom (UK)	Co-ordinator
FORAKY & LGC - Brussels (B)	Calculation Team
GSF - Braunschweig (D)	Calculation Team
KfK - Karlsruhe (D)	Calculation Team
RWTH - Aachen (D)	Calculation Team
CEA-DEMT - Saclay (F)	Calculation Team
EMP - Ecole des Mines - Fontainebleau (F)	Calculation Team
LMS - Ecole Polytechnique - Palaiseau (F)	Calculation Team
ISMES - Bergamo (I)	Calculation Team
ECN - Petten (NL)	Calculation Team
Technical University Delft (NL)	Salt Expert

List of Publications

PIPER D., LOWE M.J.S.L., KNOWLES N.C.,
Atkins Research & Development EAD Report 29.09.86 (1986)

KNOWLES N.C,
Workshop on Mathematical Modelling for Radioactive Waste Repositories, Madrid (Spain) Dec 10-12 1986, Proceedings in press.

References

/1/ BROYD T.W., et al. CEC EUR Report 8669 (1985)

/2/ LOWE M.J.S.L., KNOWLES N.C., CEC EUR Report in press (1986)

Title : Study of backfilling and sealing materials for radioactive waste repositeries : tests and controls on reduced scale: disposal holes and galleries.

Contractor : Solétanche-Entreprise S.A.
6, rue de Watford
F - 92000 NANTERRE

Contract N° : FI 1W/0057/F

Duration of contract : February 1987 - March 1990 (38 months).

Project Leader : D. GOUVENOT

A. Objectives and Scope

- The purpose of this programme is to study rheological, thermal, microstructural and retention characteristics of backfilling and sealing materials. The formulation of these materials will be proposed by Solétanche and CEA;
- After laboratory tests, four of these materials will be selected and used into two vertical and horizontal scale models. Control tests will be performed on these models - during and after the backfilling to test the efficiency of the process;
- The first partner STMI (Société des Techniques en Milieu Ionisant) was replaced by the CEA (Commissariat à l'Energie Atomique).

B. Work Programme

B.1. Laboratory studies

B.1.1. Theoritical studies : proposition of 16 formulations of backfilling materials.

B.1.2. Preselection tests based on rheological characteristics (viscosity, rigidity, shrinkage, workability limit, bleeding).

B.1.3. Selection of 4 materials :

- rheological studies;
- studies on hardened materials : shrinkage, water content, permeability, resistance to aggressive water, behaviour at high temperature, retention of radioactive elements, microstructure.

B.2. Experimental studies

B.2.1. Vertical reduced scale models

Test on 2 identical models will be performed.

- studies of filling technique and instrumentation;
- control tests on fresh and hardened materials in laboratory and in situ;
- improvement of backfilling techniques.

B.2.2. Horizontal models

The same tests will be done on vertical models.

C. Progress of work and obtained results

The work will start on the 1st of February.

The schedule of the first part of the research is :

- February to March 1987 : theoritical studies and selection of 4 formulations.
- April 1987 : preparation of the samples for the further tests.
- May to July 1987 : mechanical characteristics determination;
  permeability test;
  ageing at 120°C.
- August to October 1987 : durability;
  thermal characteristics;
  microstructure.
- May to October 1987 : percolation and diffusion of radioactive elements at CEA's facilities.
- November 1987 to January 1988 : lixiviation tests.
- August 1987 and January 1988 : interim reports.
- February 1988 : start of the second phase : construction of the scale models.

Research on backfilling and sealing of rooms and galleries in a repository in salt

Contractor: GSF/IfT, Braunschweig, FRG
Contract No.: FI1W/0059/D
Working Period: 01.09.1986 - 31.12.1989
Project Leader: Dipl.-Ing. W. Fischle

A. Objectives and Scope

Backfilling and sealing materials are to prevent resp. to delay the inflow of brine or water into a repository or to reduce the transport velocity of nuclides in fluids in case of a hydrogeological incident. The backfill also serves as a filling agent for voids and is to act as a mechanical stabilizer. Technical concepts are to be developed and also tested in situ under increased temperature conditions. The parts of the field into which radioactive wastes have already been emplaced by means of different techniques are to be sealed by bulkheads maintenance-free from those parts of the disposal field still in operation. The sealing systems being developed need to be tested in situ.

B. Work Programme

B.1. Soil mechanical laboratory investigations on gravity stowing to determine backfilling characteristics.

B.2. Geotechnical in situ measurements in the vicinity of chamber 8a, 532 m-level and in the backfilled carnallite stopes at the 750 m-level of the Asse salt mine to determine the interaction backfill/rock.

B.3. Performance of large-scale load consolidation tests on backfilling materials at the Asse salt mine.

C. Progress of work and obtained results

The focal point of the soil mechanical investigations on gravity backfill was to determine the load consolidation behaviour of the bulk material which accumulates in the form of pneumatic- resp. gravity stowing as a consequence of operational activities in the Asse salt mine or which is obtained during gallery mining using a part face heading machine.

As a result it can be said that

- settlement decreases with increasing charge density
- it increases with low load velocity
- settlement increases with increasing moisture content under the same bulk density conditions.

The average settlement rates of the inserted backfill subside relatively fast. During the initial months they range between 1.5 and 4 cm per month, later only between 1 to 3 cm per year.

An evaluation matrix to determine the material parameters of backfilling materials was set up and supplemented by an evaluation matrix for backfill according to technical, safety-relevant criteria.
This scheme is suited for a comparative evaluation of backfilling materials.

The southern lateral road to the east at the 750 m-level of the Asse mine, which had been backfilled over a length of 280 m with crushed salt, was sealed by a bulkhead during the months August/September. The salt concrete was composed of cement: fly ash: water: salt as 1 : 0.5 : 0.65 : 1.15 (wt.%). The flat cells in the roof area indicate that no compression has occurred so far.

The accompanying investigations on the consolidation behaviour of the samples, which were carried out after their 28 days storage in the mine, rendered the following characteristics: Density 1.01 kg/dm^3, E-module (dyn.) 26.02 GPa, compression module (dyn.) 0.2, uniaxial compression strength of cube 30.41 MPa, compressive strain 1.47 %.

A measurement apparatus was developed which enables determination of the permeability of these materials to brine or other liquids supplementary to the laboratory investigations on backfilling materials; the experimental platform has been set up at the 490 m-level. The permeability added values found by means of these tests are compiled in Table 1.

The geotechnical measurement instrumentation has been completed in the course of backfilling of chamber 8a, 532 m-level. The maximum values to date for the pressure build-up in the pillar left for support range at 2 x 10^6 Pa (parallel to strike) in E/W-direction and 4.5 x 10^5 Pa (cross-cut) in N/S-direction. The deformations of the pillar, which are measured using extensometers, are negligible. They range within 0.5 to 1 mm per year.

List of publications

HÄNSEL, W., Laboruntersuchungen nichtsalinarer Versatzmaterialien am Beispiel der Schachtanlage Konrad, GSF-Bericht T-249
KAPPEI, G., Geotechnical Investigations on Backfill Materials in the Asse Salt Mine, GSF-Bericht T-250
KAPPEI, G., Activities Concerning Plugging and Sealing in the Asse Salt Mine, GSF-Bericht T-251
KAPPEI, G., Federal Republic of Germany/Backfilling and Sealing Program Outline, GSF-Bericht T-252

Table 1: Results of permeability tests on the experimental setup to determine the permeability of backfilling and sealing materials

Sample	Pore Volume n (%)	Permeability added value k (m/s)
Solid rock salt	0.5	$7{,}0 \times 10^{-11}$
rock salt grit (solidified/compacted with 300 bar)	16.0	2.7×10^{-6}
rock salt grit (solidified/compacted with 600 bar)	12.4	5.2×10^{-7}

Study of the thermal behaviour of clay-based buffer materials on reduced scale mok-ups and in underground laboratory

Contractor: CEA - Fontenay aux Roses
Contract N°: FI1W-0061 F(CD)
Working Period: July 1986 - December 1989
Project Leader: M. DARDAINE

A. Objectives and Scope

Clay material could be used as components of engineered barriers put in place between high level waste canisters and host rock.

The purpose of this work is to compare the behaviour of different types of materials, homogeneous or mixed, simultaneously submit to thermal and humidity gradient. Only the early stage of the storage, the so called "dried stage" is simulated in this work.

The instrumental study requires at first the design and construction of an experimental device to reproduce the actual physical conditions of the waste disposal : temperature and water content. In a second step, in collaboration with CEN/SCK, an in situ heat transfer experiment will be carried out in MOL underground experimental facility. An electrical heater will be surrounded with buffer and backfill materials. The whole system will be instrumented with temperature, moisture and pressure sensors. The test will be supported by heat transfer modelling.

B. Work Programme

B.1. Research and Development of water content sensors :
- thermal sensor
- capacitive sensor.

B.2. Design and construction of an experimental heat transfer device. Experiments and modelling.

B.3. Properties of backfill materials, determined in the underground experiment facility at MOL (Belgium). In situ experiments of heat transfer and modelling.

C. Progress of work and obtained results

State of advancement

The heat transfer study of highly compacted clay materials used as engineered barriers begins with the research and development of small scale sensors for in situ water content measurements.

Two kinds of sensors are preliminary choosen because the physical phenomena they measure strongly depend on the water content of the studied material. It concerns a thermal sensor for thermal conductivity measurement and a capacitive sensor for the dielectric constant measurement.

After calibration, these sensors may be able to give local values of the water content and so, allow water profile determination in order to estimate the existence of water migration into the clay material due to thermal gradient.

Study concerning the adjustment of the thermal sensors is going forward and leads, in collaboration with Institut de Physique du Globe (University of PARIS VI), to the construction of prototypes for preliminary measurements. The development of capacitive sensors, in collaboration with Laboratoire Central des Ponts et Chaussées (PARIS) is at the beginning.

A testing cell is under operation to test each kind of sensor in clay materials under actual conditions of temperature, pressure and water content.

The second part of the study concerns the heat transfer device project for which all the technical specifications and construction drawings are now defined.

Presently two preliminary heat transfer experiments are undertaken on medium sized cylindrical crowns of highly compacted clays to get practical informations concerning their thermal behaviour.

Progress and results

- The thermal sensor (see fig. 1)

  The thermal sensor consists of a copper wire used as electrical heater and a thermistance which gives temperature value through resistance measurement. Both copper wire and thermistance are introduced in a hollow stainless steel needle and connected inside a plastic head respectively with a stabilized alimentation and a multimeter.

  The sensor is able to measure at transient state, the thermal conductivity of a material in which it is immersed. In practice, it is put in place in an hole previously drilled in the material. When voltage is applied, the needle transmits an heat flow by unit of length Q (W/m.s) through the material, the temperature $\theta(t)$of which increases as shown in fig. 2.

  A study by monitoring several parameters is undertaken to estimate the influence of the needle calorific capacity, the connection resistance at the needle-material interface and the thermal conductivity of the material, on the time at which the linear relationship $\theta = f(\ln t)$ is valid. In all cases it is shown that this time never exceeds 50 seconds.

  The first measurements implemented with prototype sensors give encourageing results. At present time, their limited number does not allow to definitly conclude on this process reliability.

- The capacity sensor

  Several methods exist for the determination of material dielectric constant. In general, they consist of capacity measurement of a condensator including the material and two electrodes which form the sensor.

  The work program consists at first in choosing among methods for measuring capacities of condensators which are the more suitable for clay materials.

Simultaneously, preliminary measurements of capacities are carried out on highly compacted clay samples at various densities and water contents. A Q-meter is used to estimate experimental relationships between these previous parameters.

- A cell is manufactured which allows to submit a highly compacted clay sample to different temperatures, pressures and water contents. At the bottom of the cell are placed an electrical heater and an hydration pipe connected to a water tank. The diameter of the sample is ten centimeters and it is 20 cm high.
  At the top of the cell, there is a stress sensor for measuring the swelling pressure which appears during the sample hydration.
  On the walls of the cell are placed several tight outlets across which it is possible to introduce thermocouples. One of them is specially designed to introduce a thermal sensor.
- Heat transfer study through highly compacted clay materials
  Two simple experiments of heating medium sized crowns of highly compacted clays (external diameter = 230 mm, height = 170 mm) were carried out respectively during 4 and 147 days.
  In the two cases a pseudo-stationnary state appears for which the temperature near the heater increased respectively up to about 110°C and 80°C. During the tests, bulk density measurements are undertaken along a radius by a gamma densitometry method. Thus it is possible to calculate the corresponding water content variations. It is shown that during the experiments the water content sample variations are only due to water evaporation process.
  The main technical specifications of the heat transfer device (see fig.4) are now defined. The material consists of an assembly of three cylindrical crowns (total height : 800 mm, external diameter : 340 mm, internal diameter : 80 mm). The heater includes three independant parts with a total power of 2400 watts.

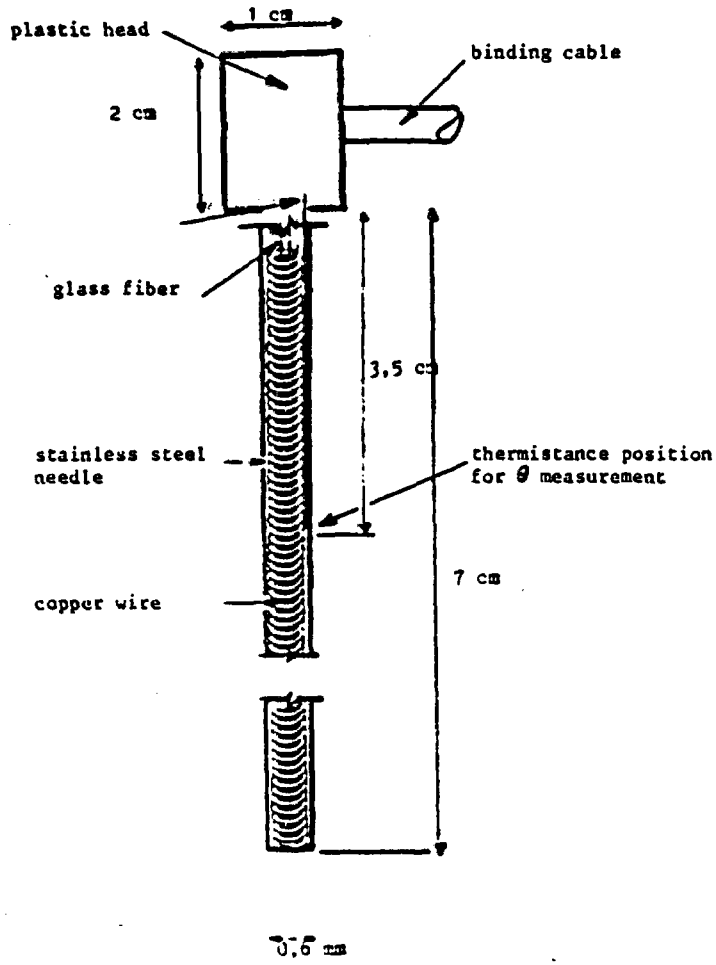


FIGURE 1 : SCHEMA OF THE THERMAL SENSOR PROTOTYPE

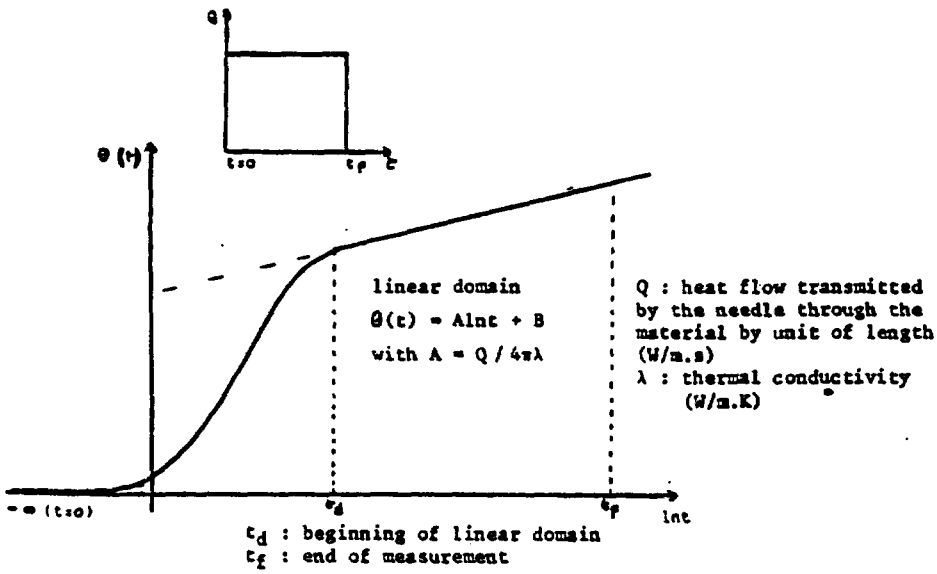


FIGURE 2 : EXPERIMENTAL RELATIONSHIP BETWEEN TEMPERATURE INCREASE AND TIME.

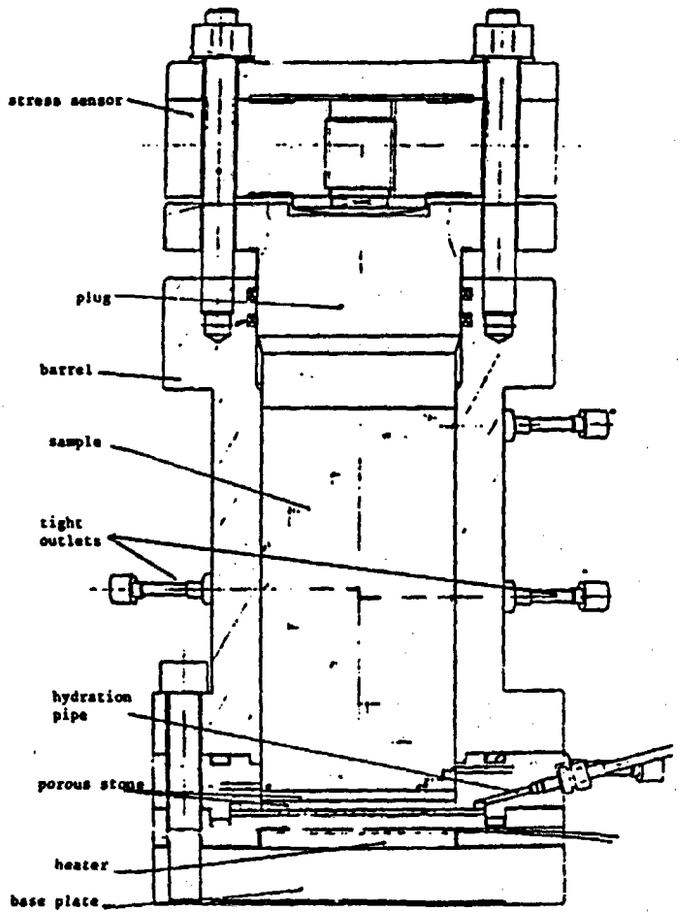


FIGURE 3 : SENSOR TESTING CELL

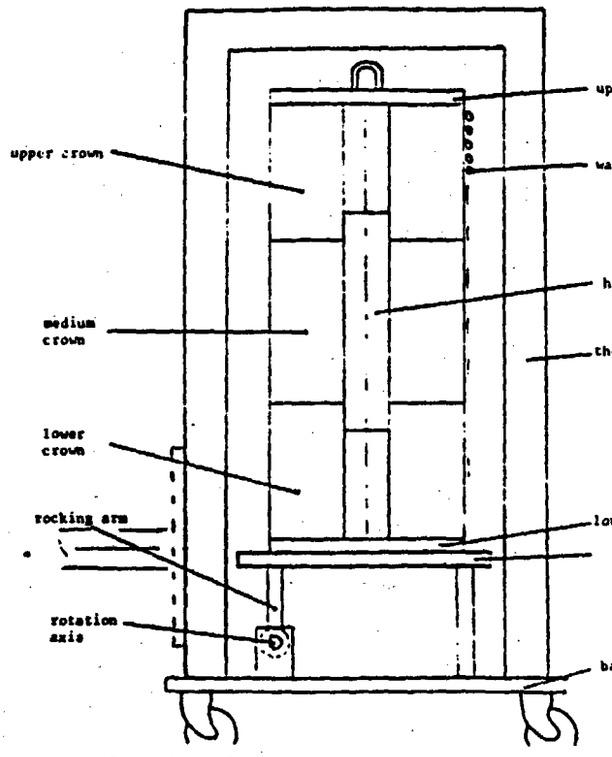


FIGURE 4 : HEAT TRANSFER DEVICE - SCHEMA PROJECT

In Situ Determination of the Effects of Organics on the Mobility of Radionuclides in Controlled Conditions of Groundwater Flow

Contractor:	British Geological Survey, Keyworth, Nottingham
Contract No:	FI1W/0064/UK
Duration of Contract:	July 1986 - June 1989
Project Leader:	G.M.Williams

A. Objectives and Scope

The broad objective is to verify by means of *in situ* field tracer tests, predictions of the mobility of radionuclides in a shallow glacial sand aquifer, having taken into account the potential effects of organics (natural and introduced) on radionuclide speciation and mobility.

The tracer tests will be undertaken in a remote part of the low level radioactive waste site at Drigg. Prediction of their outcome is based upon detailed hydraulic characterisation of the field site, coupled with laboratory studies of radionuclide sorption and organic complexation. Liaison has been established with the University of Wales Institute of Science and Technology for radionuclide speciation modelling, Loughborough University for direct speciation measurements, and the Delft Soil Mechanics Laboratory for solute transport modelling.

B.Work Programme

The project is divided into a number of research areas as follows:-

(1) Aquifer characterisation and instrumentation - Involves the determination of aquifer hydraulic properties, its geochemistry, mineralogy and groundwater composition, particularly the nature and amounts of natural organics (humic and fulvic acids) and colloids. Development of instrumentation to monitor groundwater composition and radionuclide migration.

(2) Characterisation of complexes and colloids - interlaboratory comparison within the CEC, to characterise, and determine stability constants with selected radionuclides, for commercially available humic acid and natural organics from Drigg, Mol, Ispra etc. A parallel excercise is underway for colloids.

(3) Laboratory sorption studies - will include batch sorption experiments to determine the effects of natural organics on radionuclide sorption, kinetic measurements, and direct speciation determinations attempted on radionuclides in groundwater after equilibration with the sediment.

(4) Modelling - Speciation models will be used to predict the speciation of radionuclides in the sorption experiments and help to determine the important mobile species in the field test. Deterministic flow modelling will aid in the design of the borehole array for the tracer tests and form a basis for reactive mass transport models.

(5) Field tracer experiments - initial tracer tests will compare various conservative tracers (^{131}I, Cl, and ^{3}H) and provide background data on the hydraulic characteristics of the aquifer. Subsequent tracer tests will involve reactive radionuclide species with the addition of organic solutes.

C. Progress of work and results obtained

State of advance

The project is now underway and a suitable field location has been identified for the tracer array. Groundwater and sediment samples have been obtained for preliminary laboratory analysis and for speciation studies and characterisation of natuaral organics. Progress has been made on the characterisation of the Aldrich Humic acid as part of the COCO study. Laboratory sorption experiments have been started along with preliminary groundwater flow modelling. Capital equipment has been ordered and borehole instrumentation designed and prototypes contructed.

Progress and results

(1) Aquifer characterisation and instrumentation (B1)

The area of the test has been characterised using a specially developed narrow diameter focussed resistivity probe. Over twenty profiles have been recorded to an average depth of 8m on a regularly spaced 3m grid and the detailed morphology and electrical resistivity of the aquifer determined. The sand aquifer is interbedded between two continuous clays, and although the sand varies in thickness and elevation, a suitable area has been identified for construction of the array. A laboratory resistivity cell to correlate resistivity with porosity has been constructed and preliminary results are available.

Specialised drilling techniques using an internally flushed blanked well screen have been developed to eliminate outside disturbance around fully penetrating water injection and tracer release wells. Stainless steel multilevel probes, and a compatible coring device have been manufactured to obtain groundwater and sediment cores at monitoring locations. Of a more practical nature, two portacabins have been set up as a radiochemical field laboratory and office/mess room with electrical power and water supplies.

(2) Complexes and colloids (COCO excercise, B2)

Humic material has been removed from a 250l bulk sample of groundwater using a DEAE resin (Diethylaminoethylcellulose). The absorbed humics are desorbed by elution with 0.5 M NaOH. A field system has also been developed to speciate ionic from organically complexed material in groundwater by passing samples through a series of three columns containing DEAE cellulose, a cationic resin and finally an anionic column.

Work on the COCO exercise using the Aldrich Humic has involved the analysis of major and trace metals (which gave good agreement between ICP-AES and AAS methods) and the determination of E_4/E_6 ratios which indicate the proportion of aliphatic to aromatic components (5.31 and 5.35 on two separate samples). An infra-red spectrum has also been obtained which shows absorbance at 2850 and 2920 cm^{-1} which has been used in one method of humic classification. Other work recently initiated includes the determination of functional groups (hydroxyl, carbonyl, phenolic and carboxylic). Potential organics to be considered in the experiment are acetate (breakdown product of cellulosic materials in the waste) and EDTA (used as a decontaminant) so GC and ultrafiltration methods for their analysis and that of their degradation products are being developed.

As part of the colloid sampling intercomparison excercise groundwater was taken in January 1987 from a public supply borehole at Markham Clinton in Nottinghamshire, using ultrafiltration equipment. Analyses are not yet available.

(3) Laboratory sorption studies (B3)

Detailed plans for the laboratory work have been formulated and work is underway but there are no results to report to date. A contract has been let to Loughborough University for

speciation work commencing January 1987.

The behaviour of ^{85}Sr, ^{60}Co, ^{137}Cs and ^{131}I will be studied in batch experiments under a range of experimental conditions, to try to elucidate the effects of both natural and anthropogenic organic compounds on radionuclide sorption. Initially all experiments will be carried out under aerobic, atmospheric conditions, using subsamples of the bulk 'standard' sand, silt and groundwater. The first matrix of experiments will be based on the scheme on table 1.

Each batch sorption test will be performed in triplicate to enable the calculation of distribution coefficients (R_d's), on which some confidence can be placed. In selected cases isotherms and reaction kinetics will also be measured. The rock/water system will be fully equilibrated before the addition of the radionuclide spike. All fluid samples will be ultrafiltered, prior to radiometric analysis, using an Amicon ultrafiltration cell with a filter cut-off of ≤500 Daltons MW, and both the filtrate and unfiltered sample analysed. Once samples are prepared for counting on the Philips PW 4580 batch gamma-counter, acidification will be used where appropriate to stabilise the samples. Information gained from this series of experiments will be used to design the in-situ field tests.

Table 1

WATER	Natural	Minus HA†	Natural & ††Org.	Minus HA & Org	Natural . & Org	Minus HA&Org
			Equilibrated*		Unequilibrated**	
ROCK						
Natural Sand	X	X	X	X	X	X
Sand Minus HA	X	X	X	X	X	X

†Minus HA - natural organics removed by alkaline extraction (sediment) or adsorption by DEAE cellulose (water)
††Org is either acetate or EDTA added to natural groundwater
*Equilibrated - radionuclide spike and 'organic' pre-equilibrated in water to allow complex formation before exposure to sediment
**Unequilibrated - 'organic' added in sorption experiment after exposure of radionuclide to sediment/water system

(4) Modelling (B4)

Details of the modelling work have been agreed with UWIST and a sub-contract has been let. No detailed work has yet been undertaken.

(5) Field tracer experiments (B5)

A safety case has been submitted to the relevant authorities for permission to undertake tracer tests in spring '87. Formal permission is still awaited.

Development and application of a retention properties measurement system in a geological environment using radioactive tracers in the drill-hole (self-contained probe FORALAB)

Contractor : CEA/IPSN - CEN CADARACHE - F 13108 Saint Paul lez Durance
Contract N° : FI1W/D065
Working period : 36 months
Project Leader : J. Porcheron

A. Objectives and Scope

Radionuclides from a subterraneous waste storage place have to force their way through, and interact with, several barriers prior to reaching the geological medium itself.

They are diluted by the subterraneous water which, by modifying their chemical structure, settles them into a final balance with the medium.

The purpose of this study is to determine the delay term of the radionuclides during their migration through the deep geological environment.

It became evident that it was preposterous to attempt in-laboratory duplication of the prevailing parametric conditions of the natural medium, whether physical, chemical or biological.

To avoid the uncertainties connected to laboratory experiments, the probe "FORALAB", whose performances had already been ascertained during the preceding contract (WAS 3/7-83-7 P), was developed to permit studying the radionuclide sorption-desorption phenomena in a geological environment in a condition of equilibrium with undisturbed subterraneous waters.

The probe need not simulate the environment as it is plunged into it.

The contract scope is the "in-situ" qualification of the probe, using a dual tracing system, i.e. Tritium and Eu on the one hand, Pu and Np on the other hand.

The probe will then be operated in 3 geological sites, of some interest for the Community, i.e. AURIAT (granite), MOL (clay) and GORLEBEN (salt), in order to assess the containment properties of these environments.

The probe is essentially composed of a pump, a syringe, a 20 mm dia., 200 mm long test column and 40 sampling pots. Its double insulation is a safety against drill-hole pollution.

B. Work Program

B.1. Probe Qualification

The probe will be checked for performance in the hole drilled in the granitic site of AURIAT.

The column, filled with Fontainebleau sand, will be traced by means of Europium and Tritium.

The drill-hole water will be circulated in the column for one day before the tracer injection.

B.2. Tests on the Reference Sites

The tests will be performed in the deep holes at AURIAT, MOL and GORLEBEN.

The columns will be filled with a mixture of Fontainebleau sand and 1 to 3 % clay from the site.

The radionuclides used will be Am, Pu and Np.

Each column will be Tritium-calibrated before each individual test.

B.3. Finally the results from each individual test will be mathematically processed to yield the delay terms and the adsorption isotherms of each pollutant used.

C. Work Progress and Results Obtained

C.1. State of Advancement

The probe is presently up-to-80 % achieved.

The various stages have already been tested, first individually, then jointly.

The dependability of the various components was the principal matter of concern of the tests which simulated tracer injections under a pressure of 150 MPa and tracer collection in the fraction collector.

The test results showed that the system and its components had performed in a reliable and reproducible way but the peristaltic pump showed itself unreliable : its stability of operation during the test period could not be kept under control.

Consequently, another device had to be used ; that is, a piston pump as currently used in high pressure chromatography. Such pump was found appropriate after ascertaining its reliability, and is now being incorporated.

The various stage interconnection pipes, fitted for the tests, were flexible with a view to future modification. They are now replaced by metal pipes, as was contemplated.

The Laboratory truck has been delivered.

C.2. Prequalification Test

A test under 100 MPa is now under way.

This test consists of injecting Tritium-traced water into a column filled with Fontainebleau sand (0.25 mm grade). The actual working speed is 3.10^{-3} cm.s^{-1}.

The test, which is manually controlled, will encompass the entire experiment, including the mathematical processing of the column response.

The water is circulated by a high pressure pump similar to that to be installed.

The Role of Organics in the Migration of Radionuclides in the Geosphere

Contractor: Risø National Laboratory, DK
Contract N°: FI1W/0066
Working Period: July 1986 - December 1987
Project Leader: Lars Carlsen

A. Objectives and Scope

A review on the possible role of organic species in the ground water on the migration behaviour of radionuclides in the geosphere is required. Considerable amounts of data are available. They are, however, rather scattered throughout the literature.

An experimental study as well as theoretical considerations in the influence of organic complexing agents on the sorption, and hence migration behaviour of radionuclides are of fundamental interest in attempts to evaluate the possible transport of released radioactive waste with ground water.

Characterization of naturally occurring organics, e.g. humic and fulvic acids is of general interest due to these polymeric species omnipresence in the terrestrial environment and to their known complexing abilities towards metal ions.

B. Work Programme

B.1. Review of available literature on the influence of organic compounds including experimental and theoretical data obtained at Risø

B.2. Batch-type experiments to elucidate the influence of organics on radionuclide sorption

B.3. Column-type experiments to elucidate the influence of organics on radionuclide migration

B.4. Theoretical study to elucidate the effect of complex formation on radionuclide migration

B.5. Participation in the joint programme on characterization of humic acid samples

C. Progress of Work and Obtained Results

Summary

Preparation of the review paper is in progress. The major part of the available literature has been collected. Valuable informations has been obtained through personal contacts to institutes in the United States.
A series of batch-type experiments has been carried out, demonstrating decreased sorption as function of increased ground water ionic strength as well as increased organic ligand concentrations. EDTA and citric acid have been chosen as models for possible ligands found in ground waters. Eu(III) and Co(II) have been used as models for the possible radionuclides.
Column-type experiments have not yet begun.
Theoretical studies visualize enhanced mobility of radionuclides in the presence of complexing agents. Studies on equilibrium reactions have begun. Sofar only one humic acid sample (the sodium salt of a commercially available humic acid) has been received. The analyses are in progress

Progress and Results

1. Review (B.1.)

Based on conventional literature search as well as personal contacts the major part of the relevant literature has been collected. A selection of otherwise only with difficulty accesible reports was obtained through visits at Battelle Columbus and Battelle Northwest laboratories. Valuable personal contacts to research groups activily working in the field of organics in the terrestrial environment and their influence on radionuclide migration were connected. The planning of the report has been carried out. The report will include sections on 'organics present in the geosphere' (naturally occurring as well as artificially introduced), 'the behaviour of organics in the geosphere' (stability, decomposition, migration), 'complex formation with radionuclides', and 'influence of organics on the radionuclide sorption/migration'. Experimental results obtained in this lab will be included in the last section.

2. Experimental and Theoretical Work (B.2., B.3., B.4.)

Batch-type experiments for model systems have been carried out. These systems have used a Dowex50 ion exchange resin as the solid phase to mimic e.g. the well established ion exchange capacity of clays. The 'ground water' systems have been mixtures af NaCl and $CaCl_2$, the total concentration being varied in the range of 0.1 to 0.001 molar. The molar fraction of calcium was studied in the total range, i.e. 0.0 to 1.0 in steps of 0.1. We studied the sorption of cobalt (as model for the transition metals) and europium (as model for the rare earth elements as well as the trivalent actinides). The radionuclides were present in concentrations of approx. 10^{-7} molar. EDTA and citric acid were studied as representatives for naturally occurring low molecular organic acids (citric acid) and artificially introduced complexing agents (EDTA), respectively. The concentrations of the ligands were varied in the range of 10^{-8} - 10^{-3} molar.
The experiments were carried by rippling approx. 1 gr. of the ion exchange resin (equilibrated with the 'ground water') with a portion of the ground water containing the appropriate radionuclide and the ligand in the appropriate concentration. The distribution coefficients were determined by gamma-counting, both the liquid and the solid phase being analyzed.
As mentioned above decrease in the distribution coefficients was observed upon increase in the ground water salt concentration in agreement with our previously obtained results /1/. On increasing the ligand concentration a pronounced decrease in distribution coefficient was noted, the effect of

EDTA being significantly more pronounced than for citric acid, which was expected based on the complexity constants /2/. The more interesting feat ure to be noted was that even at ligand concentrations as high as 10^{-3}, i.e. 3-4 orders of magnitude above that of the radionuclide, a distribution coefficient different from zero could be calculated. Hence, even in the presence of rather high amounts of ligand, minor sorption could be detected. However, these effects may not necessarily be refound by coulumn-type experiments, which will be carried out in the comming period.
The theoretical work has been carried out by application of the COLUMN2 computer code, developed at Risø /3,4/. Assuming the decreased sorption of the complexed species the enhanced migration could be demonstrated. Preliminary studies on equilibrium systems /4/ strongly suggested that terms as effective retention factors and average elution times have to introduced in order to explain migration behaviour.

/1/ BO, P., and CARLSEN, L., Eur.Appl.Res.Rept.-Nucl.Sci.Technol. 3, 813-873 (1981)
/2/ NILSSON, K., JENSEN, B.S., and CARLSEN, L., ibid. 7, 87-148 (1985)
/3/ NIELSEN, O.J., CARLSEN, L., and BO, P., Risø National Laboratory Report Risø-R-514 (1985)
/4/ CARLSEN, L., NIELSEN, O.J., BO, P., and DITLEVSEN, C., Risø National Laboratory Report Risø-M-2533 (1985)

Actinoide migration phenomena in groundwater: colloid generation and complexation with natural organics

Contractor: Institut für Radiochemie, TU München

Contract No.: FI 1W/0067

Duration of contract: Sept. 1986 - Dec. 1989

Project leader: J.I. Kim

A OBJECTIVE AND SCOPE

Various geochemical processes may govern the migration of actinides in deep geological aquifer systems: hydrolysis reaction, redox reaction, complexation with inorganics as well as organics and colloid generation.. Experience suggests that the colloid generation and complexation with natural organics, e.g. humic substances, appear to be the significant geochemical phenomena with regard to actinide migration in many different aquifer systems.

The contract research deals, therefore, with the colloid generation of representative actinides and their complexation with natural organics, particularly humic substances in different groundwaters. The results are expected to give an insight into the migration mechanisms of actinides in the geosphere.

B WORK PROGRAMME

B 1. Actinide colloid generation in groundwater

- Characterization of colloids
- Generation mechanisms of actinide pseudocolloids
- Quantification of colloid generation as a migration medium for actinides

B 2. Actinide complexation with natural organics

- Characterization and complexation study
- Humic substances as organometallic colloids
- Mobility of complex species and colloids in aquifer systems
- Quantification of actinide mobility by humic substances

B 3. Interlaboratory comparison exercise on complexation with natural ligands (COCO-group: TUM, CEN/SCK, KUL, CEA-FAR, Risø Nat. Lab., BGS, IRC-Ispra)

- Intercomparison of characterization methods
- Separation and production of natural humic acids present in the reference sites
- Determination of stability constants and intercomparison of the results

C. PROGRESS OF WORK AND OBTAINED RESULTS

1. State of advancement

Characterization of colloids and humic substances in selected Gorleben groundwaters has been carried out. Since the work is being in progress, only the preliminary analytical results are presented, which show a clear correlation between the DOC concentrations and trace heavy metal concentrations in groundwaters. The dissolved organic carbon (DOC) in groundwaters under investigation appear to consist mainly of humic acid and fulvic acid. These acids are found to be present as an organometallic colloidal species generated through aggregation with trace heavy metal ions of groundwater constituents. The investigation is, therefore, carried out for the characterization of groundwater-colloids and humic substances in parallel.

For the intercomparison exercise, a commercial humic acid (Aldrich: Na salt) is purchased, purified to an acid form and distributed to 6 laboratories of the COCO group. As a site specific reference, humic acid is extracted from one of Gorleben groundwaters (Gohy-573), purified and distributed also to the laboratories.

2. Characterization of humic substances in some Gorleben groundwaters

In groundwaters from Gorleben area, the DOC concentration is varying over a wide range, from less than 0.1 mg C/L to near 100 mg C/L. The DOC is identified as either humic acid or fulvic acid by a commonly used acid-base process [1]. A typical distribution of the two acids in selected Gorleben groundwaters can be seen in Table 1. A decrease of the DOC concentrations is accompanied with an increase of the fulvic acid fraction, while the humic acid fraction decreases. Both acids account for the major part of DOC. The distribution characteristics of the two acids, as shown in Table 1, remains valid for a large part of Gorleben groundwaters.

Table 1: Composition analysis of DOC in selected Gorleben groundwaters

Groundwater	DOC (mg C/L)	Humic acid (%)	Fulvic acid (%)
Gohy-73	97.4	81	14
Gohy-92	40.7	93	7
Gohy-333	10.6	81	17
Gohy-613	5.7	47	37
Gohy-202	3.4	29	59
Gohy-571	0.8	~0	~100

A new gel-chromatographic method for the size fractionation of humic acid and fulvic acid is under investigation in order to elucidate their non-aggregated molecular size. For this purpose, their methylation [2] and the use of a particular dipolar-aprotic nonaqueous solvent are under consideration. The definite results are not yet available for the moment but will be given in the next report.

The carboxylic contents of two different humic acids (purified to acid form) from one of the Gorleben groundwaters (Gohy-73) and from Lake Bradford (Florida State Univ.) are determined by a well known pH titration [3]. The results are found to be within the range of 4.0 ~ 5 meq/g humic acid.

3. Correlation of trace heavy metals with humic substances in groundwaters

Three groundwaters containing different amounts of DOC are selected and analysed for major elements and trace heavy metal contents. The groundwater constituents are given in Table 2 for major constituents and in Table 3 for trace constituents. As shown in Table 2, no direct correlation can be observed between concentrations of DOC and major constituents, neither cations nor anions. However, a direct correlation of DOC concentrations with trace heavy element concentrations is evident in Table 3, except divalent elements like Ba^{2+}, Sr^{2+} etc. All trace elements of oxidation state greater than 2+ are found in a larger quantity in groundwaters with higher DOC concentrations. The relationship between them is proportional, suggesting that the trace heavy metal ions favor the humate complexation. The preponderant trace heavy metal ions in these groundwaters is Fe, which, according to given redox potentials (Eh > 100 mV), may be present as trivalent ions.

Provided the complexation capacity of humic acid or fulvic acid may correspond to the content of carboxylic group of these acids (4.0 ~ 4.5 meq/g of dry weight), nearly all Fe(III) ions are loaded on humic substances being present through humate complexation. The Fe(III) loading will amount one third of the complexation capacity. The rest capacity may be complexed with other trace heavy metals shown in Table 3. Such metal loaded humates (also fulvates) behave like colloids as well as soluble ion exchangers (see below).

4. Humate colloid generation of trace heavy metal ions

Whether or not the trace heavy metals found in groundwaters under investigation (Table 3) are present as colloids is investigated by ultrafiltration. For this purpose one of the three groundwaters (Gohy-73) with a substantially high DOC concentration is selected, because this groundwater shows higher concentrations of trace heavy metals. The ultrafiltration results are given in Table 4, which shows the filtration effects at 100 nm and 15 nm pore sizes. The elements having oxidation state greater than 2+ under normal conditions can be almost quantitatively filtered at the pore size of 15 nm, whereas the divalent elements like Ba, Sr and the

Table 2: Concentrations of major components in three selected groundwaters from Gorleben aquifer systems

Element		Gohy-73 (pH = 7.8)	Gohy-1012 (pH = 8.2)	Gohy-1061 (pH = 8.2)
Na^+	(10^{-3} mol/L)	25.3	10.9	2.8
Mg^{2+}	(10^{-5} mol/L)	10.5	6.2	9.9
Ca^{2+}	(10^{-4} mol/L)	2.6	2.6	2.6
Cl^-	(10^{-3} mol/L)	8.2	9.4	2.8
Br^-	(10^{-6} mol/L)	2.6	1.9	2.1
NO_3^-	(10^{-5} mol/L)	96.8	<0.5	2.6
SO_4^{2-}	(10^{-5} mol/L)	0.3	18.4	19.6
PO_4^{2-}	(10^{-5} mol/L)	<0.02	1.1	0.6
SiO_3^{2-}	(10^{-4} mol/L)	2.6	6.0	3.9
HCO_3^-	(10^{-3} mol/L)	16.3	3.3	2.0

Table 3: Concentrations of DOC and trace inorganic elements in three selected groundwaters from Gorleben aquifer systems

Element		Gohy-73 (pH = 7.8)	Gohy-1012 (pH = 8.2)	Gohy-1061 (pH = 8.2)
DOC		97.4 mg C/L	7.8 mg C/L	2.0 mg C/L
Ba	(10^{-7} mol/L)	3.7	0.7	0.9
Ce	(10^{-8} mol/L)	70.4	3.2	1.7
Cr	(10^{-8} mol/L)	39.1	4.2	1.7
Eu	(10^{-9} mol/L)	10.9	1.8	0.9
Fe	(10^{-6} mol/L)	48.6	3.7	1.3
Hf	(10^{-9} mol/L)	6.2	0.4	0.2
La	(10^{-8} mol/L)	26.3	1.6	0.8
Nd	(10^{-8} mol/L)	27.0	2.3	1.0
Sb	(10^{-9} mol/L)	2.2	1.6	0.73
Sc	(10^{-9} mol/L)	38.9	6.3	0.4
Sm	(10^{-9} mol/L)	45.0	4.2	2.3
Sr	(10^{-7} mol/L)	20.7	8.4	2.6
Th	(10^{-8} mol/L)	10.5	0.3	0.2
U	(10^{-9} mol/L)	11.0	5.5	0.5
Zr	(10^{-7} mol/L)	12.8	1.7	0.4

amphotere element Sb are much less filtered. As expected the Br^- ion remains in the solution. The filtration results suggest that trace heavy elements with oxidation state greater that 2+ are strongly associated with the soluble humic substance, in other words, they are present as humate colloids.

The trace heavy metals found in this groundwater are chemically natural homologues of actinides and some fission products, which represent elements with oxidation state of II, III, IV and VI. Based on the results shown in Table 4, it is possible to anticipate the extent of humate colloid generation of actinide ions in a given groundwater containing humic substances.

Table 4: Filtration effects on trace heavy metal concentrations in Gohy-73 groundwater (DOC: 97.4 mg C/L)

Element	Filtrate from 400 nm Ø	percent filtered on filters of 100 nm Ø	~15 nm Ø
Ba	3.7×10^{-7} mol/L	50	55
Br	2.6×10^{-6} mol/L	<4	<3
Ce	70.4×10^{-8} mol/L	90	99
Cr	39.1×10^{-8} mol/L	78	83
Eu	10.9×10^{-9} mol/L	72	87
Fe	48.6×10^{-6} mol/L	88	98
Hf	6.2×10^{-9} mol/L	72	90
La	26.3×10^{-9} mol/L	84	~100
Nd	27.0×10^{-8} mol/L	93	~100
Sb	2.2×10^{-9} mol/L	36	46
Sc	38.9×10^{-9} mol/L	78	89
Sm	45.0×10^{-9} mol/L	~100	~100
Sr	2.1×10^{-8} mol/L	48	52
Th	10.5×10^{-8} mol/L	80	~100
U	11.0×10^{-9} mol/L	65	81
Zr	12.8×10^{-7} mol/L	64	91

5. Interlaboratory comparison excercise

As a part of the CEC coordinated project MIRAGE II, the group involved in the research area 2 agreed to launch a joint action in the field of complexation of selected radionuclides with humic acids present in different geological formations. This action starts off by an intercomparison of methods in each of the laboratories concerned. For realizing this action, TUM has prepared the following reference materials and delivered to the laboratories involved in the research area 2.

a) Humic acid (Na salt) from ALDRICH Co.	50 g each
b) Humic acid (H form): purified to an acid form the ALDRICH HA (Na salt)	50 g each
c) Humic acid (H form): separated from Gorleben groundwater (Gohy-573) and purified to an acid form	2 g each

REFERENCES

[1] STEVENSON, F.J., Humus Chemistry, John Wiley + Sons, New York (1982)
[2] WERSHAW, R.L. and PINCKLEY, D.J., Science 189, 906-907 (1978)
[3] BORGGAARD, O.K., Acta Chem. Scand. A26, 121-122 (1974)

Title : Interactions between organic substances and transuranic elements
Contractor : CEA-IRDI/DRDD/SESD/SCPCS - Fontenay-aux-Roses - FRANCE
Contrat n° : FI1W/0068
Duration of contract : 1985-1989 **Project leader** : M. BILLON-Mme MOULIN

A. Objectives and Scope

The presence of natural organic ligands (humic-fulvic acids) as complexing agents of cations in the deep or shallow aquifers could have a great influence on the mobility of radionuclides in the geosphere /1/.

The study of radionuclides interactions with humic materials constitutes a research area of major importance : up to now the systems cations - humic substances are not well known partly due to a lack of knowledge in the humic substances field (structure, properties, ...). The purpose of the present research is to define in the most complete way : firstly, the properties and characteristics of humic materials, secondly the formation conditions and binding strengthes of humic-radionuclides species.

A chromatographic technique /2/ is retained to study the associations occurring between transuranic elements and humic materials which will be well characterised by different physical and chemical methods. Developments in humic substances analysis (potentiometry, size exclusion chromatography) and on the chromatographic method (chomatographic support, detection,...) will be performed.

The final objective of the programme is to conclude on the contribution of humic substances to the possible transport of radioactivity in the geosphere via groundwaters.

A collaboration with the KBS is undertaken in this research area.

B. Work Programme

B.1. Isolation and characterisation of humic substances

B.1.1. Concentration of humic materials from natural groundwaters : sampling, concentration, fractionation.

B.1.2. Characterisation of humic materials by different physical and chemical methods : elementary, mineral, functionnal, potentiometric and molecular weight (size) analyses.

B.2. Interactions between humic coumpounds and transuranic elements

B.2.1. Development of the chromatographic method chosen for the complexation studies (choice of chromatographic support, system of detection).

B.2.2. Measurement of interaction constants with this chromatographic method as a function of various chemical parameters (pH, ionic strength, metal and ligand concentrations).

B.3. Inter-laboratory comparison exercice on characterisation of humic materials and on complexation of radionuclides with these substances.

C. Progress of work and obtained Results
State of Advancement

A review of the different ways to concentrate humic materials from natural waters has been made : the procedure using an anionic resin /3/ (without any previous water treatment) has been chosen. The prospecting of different sites for sampling granitic deep groundwater (Fanay-Augères) has begun with encouraging results.

The chromatographic technique used for the complexation studies has been improved on the detection system : the method which was first developed with inactive elements (Eu, U, Th, Cu) is applied to radioelements (α and/or γ emitters). Different on-line detectors have been compared and studied : silicium, liquid and solid scintillation detectors. The last of them was chosen.

Experiments with Americium have been made in the different media. Batch studies have determined the appropriate conditions of work in citrate and carbonate buffer systems. Some column experiments with Am and the on-line detector in citrate buffer corroborate the batch studies.

The general work progress status is a follows : B.1., B.2.1., B.3. are progressing normally, B.2.2. is delayed.

Progress and Results

Humic Substances Isolation and Characterisation (B.1.)

The humic substances with which we are working are coming from two origins : a granitic site which could be qualified as a reference site (Fanay- Augères) and a commercially source (ALDRICH Company) which permits to have large quantities of humic materials to develop the experiments.

Prospecting of fissures or boreholes in galeries of different depths (- 260 to - 360 m) has begun. Different water samplings have been made in Fanay-Augères in order to evaluate the dissolved organic carbon (DOC) of the deep groundwaters. (B.1.1.).

To isolate humic and fulvic acids from natural granitic waters we have to concentrate the organic fraction due to the fact that the organic carbon content is very low (≈ 1 mg/l). After a litterature survey of the different procedures on water concentration the resin method was adopted. The described procedure (with the KBS collaboration) is represented on Figure 1.

The characterisation of humic materials (B.1.2.) by different analysis methods is in good progress : elementary, mineral and infrared spectroscopy analysis don't pose any problems and give precious informations on the nature of humic materials (actually the commercial humic acids are studied).

Interaction studies between transuranic elements and humic substances (B.21).

In the chromatographic method development the detection system has been particularly studied in order to have a on-line detector based on the radioactive properties of transuranic elements. The table I summarizes the advantages and drawbacks of three systems : a silicium diode, a solid scintillator detector and a versatile scintillation detector (α, β, γ). The solid scintillator detector /4/ has been retained. This instrument allows the measurement of alpha emitter concentrations in solution continuously by the use of a glass scintillator with very good sensitivities. Elements like Am, Pu, Np, U could be detected. In our case the main emphasis is put on Americium. The figure 2 shows a chromatogram obtained for an injection of Americium with this detector.

In order to apply the gel filtration technique to active elements (the demonstration of this method was made for inactive elements Eu, Th, U, Cu) some batch experiments were undertaken in different buffer systems. Two conditions are required : the predominance of anionic species in the solution and the absence of retention of the species on the chromatographic support. In citrate buffer 10^{-3} M, 10^{-2} M, 10^{-1} M (pH 4.5 - 5 - 6) these conditions are verified, in carbonate buffer it is limited by the americium solubility /5/.

The interlaboratory comparison exercice (COCO) is running in good progress. Another report will be made in a different way (B.3.).

List of publications

- LESOURD-MOULIN V., Rapport CEA-R-5354 (1986).
- MOULIN V., in "Chemie und Migrationsverhalten der Aktinoide und Spaltprodukte in natürlichen aquatischen Systemen", PTB - Bericht (Vorträge des 66.PTB-Seminars), Münich, 24-25 Avril 1986.

References

/1/ CHOPPIN R., ALLARD B., Handbook on the Physics and Chemistry of the Actinides, North-Holland Publ. Comp., Amsterdam, 407-429 (1985).

/2/ LESOURD-MOULIN V., Rapport CEA-R-5354 (1986).

/3/ PAXEUSN, ALLARD B., OLOFSSON U., BENGTSSON M., Scientific Basis for Nuclear Waste Management IX, Werme Ed., Vol 50, 525-532 (1986).

/4/ ROBERT A., SELLA C., HEINDL R., Nuclear Instr. and Methods in Physics Research, 225, 179-184 (1984).

/5/ VITORGE P. and al., Rapport Technique DRDD n° 67, Rapport final 1983-1984, Octobre 1985

Table I Different on-line detectors studied

	Silicium Diode	Glass Scintillator	Versatile Scintillator (Liquid or Solid Scintillation)
Nuclearisation (Facility to put in a glove-box)	Yes	Yes	No
Geometry of the detector	2 π	2 π	4 π
γ Radiation detected	No .	No	Yes
β Particles detected	No	Possible	Yes
α Particles detected	Yes	Yes	Possible (never studied)
Limit of Detection for Am			
. Static	-	10^{-9} M/l	-
. Dynamic	4 µg injected	6 ng injected	-

Figure 1 Concentration - Fractionation and Purification Steps of Natural Humic Substances from deep Groundwaters

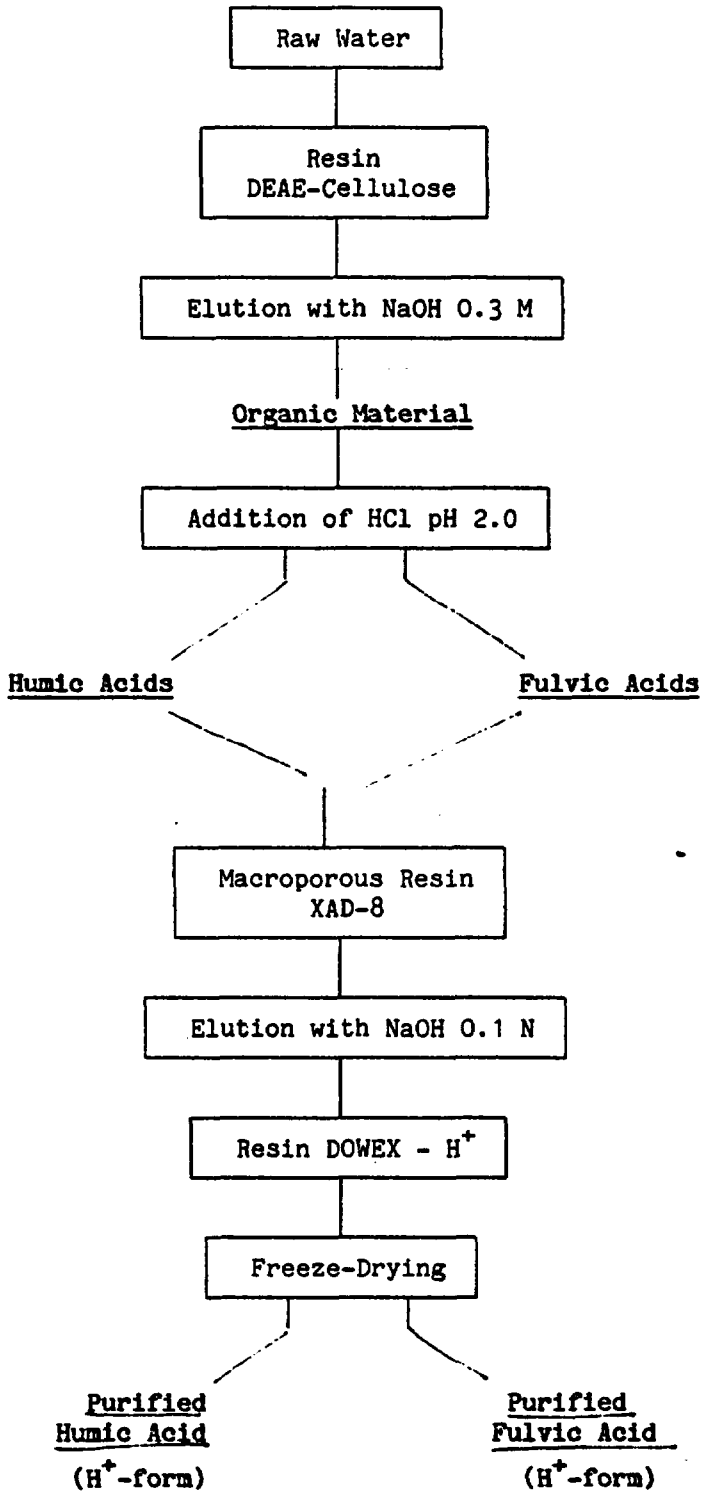
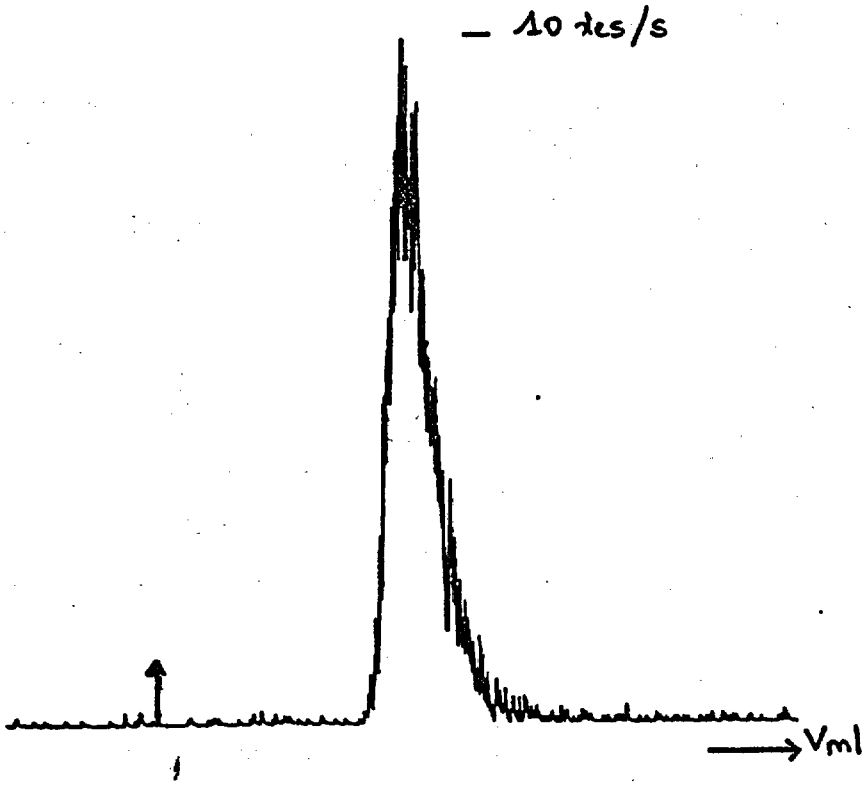


Figure 2 Injection of 72 ng of Am on Sephadex G 15 column in 0.1 N citrate buffer, pH 4.5, I = 0.5 M
Detection : glass scintillator detector



Natural analogues of radionuclide migration in granitic rocks through the study of palaeo-hydrothermal alteration

Contractor : BRGM - Orléans, France
Contract no. : FI 1W/0072/F (CD)
Working period : August 1986 to August 1988
Project leader : P. Peaudecerf

A. Objectives and scope

Mineralized zones in granitic rocks which have been influenced by hot water (hydrothermal activity) over long geologic periods may be considered as useful natural analogues of the conditions occurring around a heat-producing repository in granite. Study of these zones gives valuable information about the migration and retention of elements analogous to the radionuclides present in the repository.

Development of research on one or more sites of former hydrothermal activity in a granite environment will enable an approach to the problems of migration and retention of elements such as the rare earths, uranium and thorium which are themselves analogous to the radionuclides in their geochemical behaviour. The time scale will be that of the geologic environment of 0.1 to 1 million years. The volumes considered will take into account the far field (pervasive alteration) and near field (vein alteration) phenomena. The final aims of this programme are :

1. To define the physicochemical conditions of the alteration examined and the mineralogical carriers of the elements analogous to the radionuclides
2. To test on existing programmes (PATH) or on those being developed, the data supplied by the direct approach (validation of thermodynamic parameters, assessment of the reaction kinetics on natural examples).

B. Work programme

B.1. Petrographic and mineralogical investigation of the various events which have affected the system.

B.2. Analysis of the analogue element carriers in two parts :

B.2.1. Separation of the primary and secondary phases developed by the alteration and quantitative analysis of the analogue elements in the separated phases and in rock samples;

B.2.2. Location of analogue elements by nuclear methods. From these data the mass balance and the distribution and mobility of the analogue elements during the palaeoalteration will be established.

B.3. An indirect approach by using mass transfer codes on major trace and analogue elements to mobilize the geochemical behaviour of the alteration systems.

C. Work progress and results obtained

Summary

Following the signing of contract FI 1W-0072-F in October, it was decided to proceed to selection of an additional site for the study of palaeo-hydrothermal alteration enabling the continuous two- or three-dimensional analysis of a system. This selection was made after a period of exploration during which thirty or so sites were visited in Brittany and the Massif Central.

Once the selection was made, an inter-disciplinary field programme, involving mineralogists and geochemists, took place for a first sampling to enable commencement of the various investigations. Work progress as follows:

B.1. and B.2.1. are under way and the other phases should normally follow on.

B.2.2. A part of this is in progress.

B.3. Development of new software enabling modelling.

Progress and results

Since the contract was signed as recently as October 1986 and considering the time needed to obtain the various data for programme completion and processing, it will be difficult to present a coherent and complete evaluation of the results.

Field-work

This consisted of an inter-disciplinary field programme involving petrographers, geochemists and structural geologists whose objective was to make a preliminary study of the site and an initial sample selection.

During this campaign, a constant-scale survey was made by photomapping to locate the sample points and for computerizing the results.

1. Mineralogy

The mineralogical studies are under way. Their aim is twofold:

1. The investigation and quantitative analysis of the destabilization of the primary igneous phases.
2. The investigation and quantitative analysis of the formation of the new hydrothermal phases.

2. Geochemistry

Analyses of the main and trace elements from the various facies recognized in the field are under way. They will enable a first assessment of the alteration.

3. Location of the trace elements by nuclear methods

The first part of this programme is under way. From a study of apatite and zircon fission tracks, the age of emplacement of the granite and of the hydrothermal system will be determined. From a study of the fission tracks, micromapping of uranium distribution will be made from thin sections. The other operations will depend on the results of the mineralogical study.

4. Modelling

The new programmes required for modelling are being developed and tested on actual examples.

5. Comment

In the context of a thesis, work is progressing on the Langenberg site with aims similar to those of parts B.2.1. and B.2.2. of the present work programme.

The results of these investigations could be included during the modelling of the present project.

Natural Analogue Studies of Radionuclide Migration

Contractor: British Geological Survey/NERC, Keyworth, Nottingham,UK.
Contract No: FI1W/0073/UK
Working Period: July 1986 - June 1989
Project Leader: P J Hooker

A. OBJECTIVES AND SCOPE

It is important to be able to validate and support models of long-term predictions of radionuclide migration in the geosphere. The main aim of this research is to examine natural geochemical discontinuities and gradients as analogues of radionuclide transport in sediments. The mechanisms of processes of mobilisation, advection, diffusion and retardation for natural decay series elements and iodine and bromine will be addressed. This will entail some development of the techniques for measuring small concentrations and the speciations of these elements in both the solid and pore water phases. Analytical determinations by alpha spectrometry and neutron activation analysis will be carried out by SURRC (Dr A B MacKenzie) under sub-contract. Support in modelling will come from co-operation with Ecole des Mine de Paris, Fontainbleau.

B. WORK PROGRAMME

B.1. Phase 1986-1987.

B.1.1. Site investigations

B.1.1.1. Collection of fresh Loch Lomond sediments; analysis of I and Br depth profiles; preliminary modelling for effective diffusion coefficients.

B.1.1.2. Pilot investigation of I, Br, U and Th gradients across marl/clay boundaries in a well characterised sediment core from Lundin Castle, Fife, eastern Scotland.

B.1.2. A desk study of surface diffusion as a solute transport process for major cations through clays, with implications for trace radionuclide migration.

B.2. Phase 1988-1989.

B.2.1. Site investigations will be concentrated on measuring and modelling the speciation and mechanisms of distribution of I, Br, U and Th in the Loch Lomond and Lundin Castle sediments.

B.2.2. Application of the desk study conclusions to a field investigation of Ca and Na gradients in a mixed sediment sequence with reference to radionuclide migration.

C. PROGRESS OF WORK AND OBTAINED RESULTS

State of advancement

Previous results obtained on Loch Lomond sediments have demonstrated the need to elucidate the chemical forms of the I and Br distributions in the pore waters and in the marine band deposits. A precipitation cum ion exchange speciation method is being developed (by SURRC) to distinguish between e.g. soluble iodide and iodate, and a gas chromatography technique is being explored (by BGS) for determining pore water organo-iodine compounds. Arrangements have been made to collect fresh cores in the Spring of 1987.

Preliminary results obtained in the pilot Lundin Castle core study indicate significant bromine concentration and uranium activity ratio differences across the marl/clay boundaries; in contrast, there is no evidence of iodine being present. Analytical measurements are continuing.

The general work progress status is as follows: B.1.1. is progressing on time and normally. B.1.2. is progressing slowly.

Progress and results

1. Site investigations (B.1.1.)

B.1.1.1. Loch Lomond

Experiments are being conducted at SURRC with the specific aim of improving techniques for the identification of bromine and iodine speciation in Loch Lomond sediment interstitial water. These developments are necessary because of the small concentrations encountered. Instrumental neutron activation analysis (INAA) is being applied for simultaneous determination of iodine, bromine and chlorine. The suitability of this method is demonstrated by the results shown in Table I.

The counting rates were obtained for solutions containing 1µg each of Cl, Br and I irradiated for 1 minute in a thermal neutron flux of 3×10^{12} ncm^{-2} s^{-1} followed by a 30-minute decay period before counting on contact with a 80cc Ge(Li) detector. The sensitivity of the technique could easily be improved if required by longer irradiation, longer counting time or use of a larger detector.

Two approaches are being attempted to differentiate between halide, halate and organo-halogen speciation.

i) Silver precipitation.

The solubility data in Table II suggest that a simple scavenging technique using AgCl carrier could be used to distinguish the three chemical forms being considered The steps proposed are

a) Irradiate the sample
b) Add 10mg Cl^- and precipitate with excess Ag^+
c) Filter and count the activity of the precipitate
d) Reduce the halates remaining in solution to halides and repeat the scavenging
e) Count the organo-halogen species left in solution.

Provided the $BrO3^-$ concentration is less than about 30ppm this technique should give a rapid and simple analysis for Br. The separation between I^- and IO_3 is less effective and is being refined.

ii) Ion exchange separation.

Investigations so far indicate

a) 100% uptake of Cl^-, Br^-, I^-, ClO_3, BrO_3^- and IO_3^- can be achieved from neutral and alkaline solutions using BioRad AG 1X8 anion resin.

b)100% elution of each of these species can be effected using nitric acid or KNO_3 solution.
c) Partial separation of the halides from halates.
Work is continuing on both the silver precipitation and anion exchange techniques; the eventual method may involve a combination of both.

BGS has a gas chromatography method for detecting sub-ppm levels of dissolved alkyl iodides and bromides; the main problem is one of interference from other organic compounds in the pore water.

B.1.1.2. Lundin Castle

The core material was provided by Dr D D Harkness of the NERC Radiocarbon Laboratory who is in collaboration with St Andrews University researching the site. The sediments represent a fossil shallow lake environment. The core is about 6m long and consists of a series of alternating marls and clays. A very pronounced clay horizon corresponding to an age of several thousand years was sampled at its top and bottom boundaries. XRF analysis failed to detect iodine in any of the samples. However, activation analysis show marked differences for Br and other elements between the marls and the clay (Table III). There are also significant uranium activity ratio differences across the boundaries as well (Table IV). Experiments are continuing.

2. Surface diffusion study (B.1.2.)

From the research carried out by the Fluid Processes Research Group at the Harwell Research Site, a need has emerged to support the hydrogeological model for the surrounding area of Mesozoic sedimentary rocks with geochemical data belonging to the major cations, particularly calcium and sodium, in the pore water phases. It is proposed to initiate a desk study of the theoretical implications of the solute-surface diffusion process which may be important for the migration of radionuclides through what are generally considered impermeable microporous media viz. buried clay horizons. It is important to assess the contribution of this particular surface mechansism in the overall migration scheme for a radionuclide solute in a clay formation, and to analyse the sensitivity of the changes in the net transport rate to a variation in each one of the controlling parameters. So far the desk study has been limited to a literature search of key papers.

List of publications

Hooker, P.J. and Chapman, N.A. 1986. Euratom activities in natural analogues. Presented at the 6th Technical Meeting of the Co-operative Agreement between EURATOM and AECL, 9th & 10th October 1986, Brussels.

TABLE I: INAA for the halogens

Element	γ-Photopeak Counting Rate cps	1σ uncertainty for 5 minute count.
Cl	4.4	3.0
Br	0.44	16.0
I	2.6	4.3

TABLE II. Water solubilities of halides and halates

SPECIES	SOLUBILITY g/100 ml at 25°C
Ag Cl	8.9×10^{-5}
Ag ClO_3	10
Ag Br	8.4×10^{-6}
Ag BrO_3	0.196
Ag I	2.8×10^{-7}
Ag IO_3	0.003

TABLE III: INAA results for Lundin Castle sediment samples

SAMPLE	Na %	K %	Sc	Cr	Fe %	Co	Relative Br
1. UPPER MARL	0.08	0.15	2.3	22	2.3	4.0	4.2
2. CLAY (TOP)	0.60	1.9	17.9	139	4.9	20.2	2.6
3. CLAY (BOTTOM)	0.47	1.7	20.0	153	4.8	27.6	1.0
4. LOWER MARL	0.10	0.24	3.3	21	1.7	5.9	6.2
	Cs	La	Sm	Eu	Hf	Ta	Th
1. UPPER MARL	0.7	5.1	1.0	0.23	9.2	ND	1.7
2. CLAY (TOP)	3.3	42.2	7.4	1.8	65.4	1.8	11.7
3. CLAY (BOTTOM)	3.0	47.9	8.7	2.2	68.3	2.3	13.9
4. LOWER MARL	0.8	6.4	1.4	0.28	12.8	ND	1.9

Concentrations in ppm unless otherwise stated. ND - not detected.

TABLE IV: Uranium in Lundin Castle sediments

SAMPLE	^{238}U dpm g^{-1}	^{234}U dpm g^{-1}	$^{234}U/^{238}U$
1. UPPER MARL	1.15 ± 0.03	1.72 ± 0.05	1.49 ± 0.04
2. CLAY (TOP)	2.04 ∓ 0.04	2.17 ∓ 0.04	1.06 ∓ 0.02
3. CLAY (BOTTOM)	1.97 ∓ 0.04	2.05 ∓ 0.04	1.04 ∓ 0.03
4. LOWER MARL	1.30 ∓ 0.04	1.85 ∓ 0.05	1.42 ∓ 0.05

Long-term diffusion in rock : natural analogue

Contractor: UKAEA, Harwell Laboratory, UK
Contract No: FI1W/0074/UK
Working Period: 1.7.86 - 1.7.87
Project Leader: Mr. P.J. Bourke

A. Objectives and Scope

Diffusion through rock is important as a mechanism both for radionuclide transport in rock without water flow and for retardation of transport in flow through fractured rock. Laboratory measurements of diffusivity and porosity of various rocks of interest are being made but, because of the low values being obtained, measurements cannot be obtained over more than centimetre distances in conveniently short times.

It is unknown whether or not the pores through which diffusion occurs in centimetre test specimens are continuous through greater thicknesses of rock. The observed porosity may be either all of open, inter-connected pores or partly of pores closed at one end. If some of the pores which are continuous through the centimetre specimens terminate over greater distances, a model assuming all the measured porosity to be open is invalid.

The principle of the method to be used is to measure the diffusion of chloride from the sea into rocks which have been below water level in harbours and sea walls for known, long times. Cores of these rocks will be obtained and sectioned. Analyses of these sections for chlorine will provide the reqired data. The objectives of this contract are therefore to study diffusion which has occured naturally over long distances and times and to test the validity of the different models compatible with the short-distance laboratory data.

B. Work Programme

B.1. Identify a site where a granite block, from a known locality, has been immersed in sea water for a known length of time.

B.2. Obtain permission from the relevant authorities to retrieve the granite block.

B.3. Lift block from the sea and drill through it to obtain cores.

B.4. Cut the core into sections and measure the amount of chloride within the pore water of each section.

B.5. Calculate the effective diffusion coefficient of the granite from an analysis of the chloride concentration profile within the block.

C. Progress of work and obtained results

A suitable site has been identified and permission to retrieve the block has been obtained. The block will be lifted on 2.2.87.

In summary, items B.1. and B.2. are complete. It is anticipated that B.3. will be completed on 2.2.87. Items B.4. and B.5. will be completed by 1.7.87.

Geochemical Modelling

Contractor: Chemistry Department, Risø National Laboratory, DK
Contract N°: FI1W/0079/DK
Working Period: July 1986 - July 1988
Project Leader: B. Skytte Jensen

A. Objectives and Scope

The final objective of the project is to provide a versatile and easily used geochemical programme package, the WHATIF series. The programmes will handle multielement adsorption processes, ion-exchange as well as co-precipitations and allow for an easy introduction of new data and reaction schemes.

B. Work Programme

B.1. Arrange the programmes for easy introduction of new reactions and data.

B.2. To enlarge the database such that the programmes can handle most elements of environmental concern.

B.3. The formation of polymeric species and homocolloids will be introduced and discussed.

B.4. Oxygen pressure/concentrations will be introduced as input parameter. Redox potential will be discussed.

B.5. The existing WHATIF series will be used as the frame, when the new programmes are written in PASCAL.

B.6. The need and possibility for establishing an expert-system for environmental geochemistry will be considered.

C. Progress of work and obtained results

Summary

The work progress status is that B.1.-B.6. are progressing normally, closely following the rewriting and reshaping of the WHATIF programmes in the PASCAL language. New procedures for handling co-precipitation and multielement ion-exchange have been constructed and tested.

Other procedures for a selfadjusting calculation of the simultaneous speciation and precipitation-dissolution reactions are also developed and tested on systems comprised of a limited number of elements. In this relatively simple system a complete reaction-path calculation can be done within a few minutes. It is intended to explore the possibility of making a general procedure handling any combination of elements found in ground waters.

The final structure and content of the database(s) will await the results of the project "Geochemical databases", No FI1W-0080-DK.

Geochemical Databases

Contractor: Chemistry Department, Risø National Laboratory, DK
Subcontractor: INTERA Technologies, Texas, USA
Contract No: FI1W/0080/DK
Working Period: July 1986 - July 1988
Project Leader: B. Skytte Jensen

A. Objectives and Scope

The final objective of the project is to develop a database management system and to collect an internally consistent dataset for geochemical modelling of phenomena arising in connection with geological disposal of radioactive waste. This does not only comprise the data for actual waste components, but also for the major components in the media which the waste may encounter.

B. Work Programme

B.1. Development of a database management system. INTERA.
B.2. Fix range of conditions taken into account. INTERA and Risø.
B.3. Write discussions of arguments for choosing or omitting reactions with data. INTERA and Risø.
B.4. Collect relevant data, both old and new. INTERA and Risø.
B.5. Final presentation of database and database management system.

C. Progress of Work and Obtained Results

Summary

Till now, the major effort has been concerning B.2., i.e. choosing ranges of conditions within which the data collected should be reliable. For the majority of applications, consistent data in the temperature range 0-100°C are considered satisfactory. The effect of pressure on chemical equilibria will have to be considered in the case of deep disposal sites, especially so because increase in pressure generally will increase the solubility of ionic solids. The pressure effect will be discussed and the thermodynamic data necessary for its calculation included in the database.

The effect of ionic strength on the geochemical equilibria will be discussed as well as methods for extrapolating experimental data to conditions of zero ionic strength.

The data will apply to geochemical models using the ion-pair concept, which is useful for describing solutions of moderate ionic strength.

The formation of polymeric species and homocolloids in ground water systems will be discussed to clarify, which role they may play in such systems. If their formation is considered significant, the relevant data will be included in the database.

The data in the database will be presented as the logarithm of equilibrium constants as a function of temperature and pressure, i.e.

$$\log(K) = F(T,P)$$

as an interpolation formula.

The data will in addition contain information on literature source, a rating of data quality and for solid phases in addition and indication of its probability of formation under given conditions. This last rating will to a certain extent take care of kinetic factors not considered in geochemical calculations. Similar ratings may be given to redox-reactions whose rates of attaining equilibrium are known to vary from fast to extremely slow.

The development of the database management system, B.1., is in good progress, as is the search for data, B. 4. Discussions, B.3., will be presented as an introduction to the final report.

Migration of radionuclides by high concentration brine: finalisation of the METROPOL code.

Contractor : RIVM, Bilthoven, NL
Contract No. : FI1W/0081
Working Period : November 1986 - December 1986
Project Leaders : Ir.P.Glasbergen, Ir.A.Leijnse

A. Objective and Scope

One of the key problems for the safety of disposal of radionuclides in salt, is the transport of radionuclides by high concentration brine after a possible release of radionuclides from a salt dome repository. An initial contract (383-83-7 WASNL) was carried out in the period 1983-1984. This original project consisted of the development of (a family of) computer codes (METROPOL) that can deal with transport of radionuclides by groundwater in case of high density gradients.

The objective of the present contract is to complete the development of the METROPOL code, including pre-and post-processing facilities and testing of the code for situations with extreme density differences.

B. Work programme

B.1. Inclusion of an adaptive time integration scheme to make the long simulation times feasible.
B.2. Documentation of the codes developed so far.
B.3. Development of several postprocessing facilities, like e.g. particle tracking, contouring, etc.
B.4. Inclusion of physical realistic boundary conditions, especially concerning the dissolution/precipation of salt at the salt dome/ groundwater interface.
B.5. Testing and validating the code.
B.6. Inclusion of physico/chemical processes and thermal effects.

Note, that points B1 through B5 are not carried out sequentially.

C. Progress of work and obtained results.

So far, three computer programs in the METROPOL family are operational:
METROPOL-0 : a 3-D mesh generator
METROPOL-1 : a steady state groundwater flow model with constant density.
METROPOL-2 : a transient groundwater flow model with constant density.

The documentation for these programs is in draft version finished. The programs have been extensively tested.

METROPOL-3 : a transient model for the transport of high concentration brine, is at the moment being tested. Some numerical problems remain to be solved, mainly with respect to the time integration procedure.

Post processing programs have been developed that can generate 3-D path lines or pressure and/or concentration contours in 2-D cross sections.

Theoretical work has been carried out with respect to 1) the formulation of boundary conditions in case of high solute concentrations and 2) the formulation of the basic equations.

Publications

/1/ F.Sauter and N.Praagman:
A simulation model for the transport of radionuclides by groundwater in the vicinity of a salt-dome. Proc. 6th Intern Conference on Finite Elements in Water Resources, Lisboa, 1986.

/2/ S.M.Hassanizadeh:
Derivation of basic equations of mass transport in porous media, Part 1. Macroscopic balance laws. Advances in Water Resources ; 9:196-206 (1986).

/3/ S.M. Hassanizadeh:
Derivation of basic equations of mass transport in porous media, Part 2. Generalized Darcy's and Fick's laws. Advances in Water Resources ; 9:207-222 (1986).

The 600 m bore hole project: "Development of a surveillance method during dry-drilling of a 600 m deep bore hole in salt and performance of geotechnical measurements in the 600 m hole"

Contractor: Netherlands Energy Research Foundation (ECN)
Petten, The Netherlands
Contract No.: FI-1W1/0084
Working Period: August 1986 - December 1986
Project Leader: T.C. de Boer

A. OBJECTIVES AND SCOPE

During the dry-drilling experiment performed under contract with the Commission of the European Communities in the framework of its previous R&D programme (1980-1984), it was obvious that the applied techniques were limited with respect to the maximum diameter and depth. In fact, a hole with a diameter of 30 cm and a depth of 300 m was succesfully drilled. Since then, a dry-drilling technique was developed for larger diameters and depths.

This technique will be tested by drilling a bore hole with a diameter of 60 cm, typical for a disposal hole, and a depth of 600 m. As there is a need for an alternative for the reconnaissance drilling of each individual bore hole in a HLW repository, a surveillance method during the dry-drilling will be developed in cooperation with GSF. In the 300 m hole of the previous programme, several experiments concerning the creep behaviour of the salt were performed at ambient and elevated temperatures. The convergence measurements of the diameter as a function of the depth of the hole gave insufficient results, i.e. the convergence as a function of the lithostatic pressure could not be checked. As this parameter is important, lithostatic pressure tests will be performed (see figure 1).

The project is funded by the Ministry of Economic Affairs, ECN, BMFT, GSF and CEC and carried out in close cooperation with GSF-Institut für Tieflagerung Braunschweig, FRG. In a first phase, free convergence measurements over the length of the hole and a non-isothermal lithostatic measurement will be carried out. In a subsequent phase of the current five year programme, not covered by the present contract, additional non-isothermal lithostatic measurements at two other levels and isothermal lithostatic measurements will be performed; all these results will be used for the validation of analytical techniques and computer codes such as GOLIA.

B. WORKING PROGRAMME

B.1. Design, construction and testing of a surveillance method.
B.2. Exploration and experiments.
B.2.1. Geochemical exploration.
B.2.2. Isothermal convergence measurement.
B.2.3. Non-isothermal lithostatic pressure measurements.

C. PROGRESS OF WORK AND OBTAINED RESULTS

State of advancement

The present concept of the licensing authorities is to have a reconnaissance drilling for bore holes with large diameters. With a working surveillance method these reconnaissance drillings may be reduced. Therefore there is a need to develop a surveillance method during dry-drilling.

The present database for thermo-mechanical computer code validation, consisting of the ECN 300 bore hole experimental data, needs to be complemented with free convergence and lithostatic pressure data from a 600 m deep bore hole to be drilled in a relative undisturbed environment.

1. Development of a surveillance method (N. Jockwer, GSF)

Laboratory and in-situ investigations have shown that rock salt contains different gas components trapped within small inclusions and pores or adsorbed to the crystal boundaries. Calculations on the liberation of these gases indicated that it is possible to determine them within the flushing air and to determine layers with higher porosity and gas content. Technical concepts have been developed and analytical systems for the gas determination are now in selection.

2. Exploration and experiments

2.2. Isothermal convergence measurements.

"Prediction of the isothermal free convergence of the 600 m deep bore hole" (J. Prij et al.).

Due to the time dependent constitutive behaviour of rock salt, a bore hole in a salt formation will show a time dependent deformation behaviour. The driving force for this deformation is the difference between the stress state at the bore hole wall (where the radial stress is zero) and in the salt at large radial distance from the bore hole where the state of stress is equal to the lithostatic state of stress.

The deformation process is governed by a set of differential equations consisting out of the equilibrium equation, the compatibility equations and the constitutive equations. In the case of a deep bore hole in a large salt formation the geometry is rather simple which makes the equilibrium and compatibility equations relatively simple.

If the constitutive behaviour of the salt can be described with a combination of elastic and secondary creep behaviour, than an analytical treatment of the bore hole deformation behaviour is possible. For a more complex constitutive behaviour, however numerical methods are needed, several authors have stated that the material behaviour of salt can be approximated accurately with the secondary creep /1-5/.

In this report an analytical treatment of the convergence will be used to obtain a prediction of the behaviour of the 600 m hole, based on an extrapolation of the measured convergence in the 300 m bore hole /6/.

Some numerical results are given in table I and figure 2. Here the time to reach some discrete convergences is given for the depths considered. It is clear from the results that there is an enormous difference in the convergence at the various depths. From the analyses it can be seen that the relatively small gradient in rock pressure is mainly responsible for these differences. The geothermal gradient has a smaller influence.

In this report, predictions have been given for the convergence of the 600 m bore hole. For the prediction the concept of a normalized convergence and normalized time is used. This concept could be extended in

such a way that a prediction of the convergence can be made with a minimum number of material properties. The basis for the prediction is the measured isothermal convergence in the 300 m bore hole in the Asse [6].

The prediction shows that the rock pressure has a very large influence on the convergence while the geothermal gradient has a smaller influence. The prediction of the convergence will be used for the design of the measuring devices.

References

/1/ ROLNIK, Helene, Dimensionner aujourd'hui un stockage de déchets de haute activité dans le sel gemme: Quelle théologie? These de l'école nationale supérieure des mines de Paris. Le 13 septembre 1984

/2/ OTTOSEN, N.S., KRENK, S., Mechanics of gas and oil cavities in rock salt. Bygningsstatiske Meddelelser, Danish Society for Structural Science and Eng., Vol. 53, no. 1, 1982

/3/ Autorenkollektiv. Festigkeits- und Verformungsverhalten von Steinsalz und Grundlagen der Beuchnung des Spannings- und Verformungszustandes des Salzgebirges um untertägige Hohlraume. Freiberger Forschungshefte A598, 1978

/4/ WALLNER, M., Entwicklung eines konsisten Stoffgesetzes für das mechanische Verhalten von Steinsalz aus Laborversuchen. Proc. of a Techn. Session on "Rock Mechanics" CEC, Brussels, April 27, 1983

/5/ PRIJ, J., MENGELERS, J.H.J., On the derivation of a creep law from isothermal bore hole convergence. Netherlands Energy Research Foundation ECN, Report ECN-89. January 1981

/6/ PRIJ, J. et al., Measurements in the 300 m deep dry-drilled bore hole and feasibility study on the dry-drilling of a 600 m deep bore hole in the Asse II salt mine. Contract WAS 335-83-NL. Final report EUR 10737 EN, 1986

Table I. Time in days to reach the radial convergence u_h at several depths in the 600 m bore hole

DEPTH (m)	RADIAL CONVERGENCE u_h (mm)						
	2,5	5	10	20*)	30	50	100
100	238	785	2557	7101	11704	20909	43923
200	87	280	978	2691	4515	8164	17284
300	36	112	367	1118	1911	3499	7467
400	16	49	160	499	870	1614	3472
500	8	22	74	235	420	790	1714
600	4	11	37	117	213	406	889

*) The convergences at the right side of this line are based on an extrapolation of the measured data.

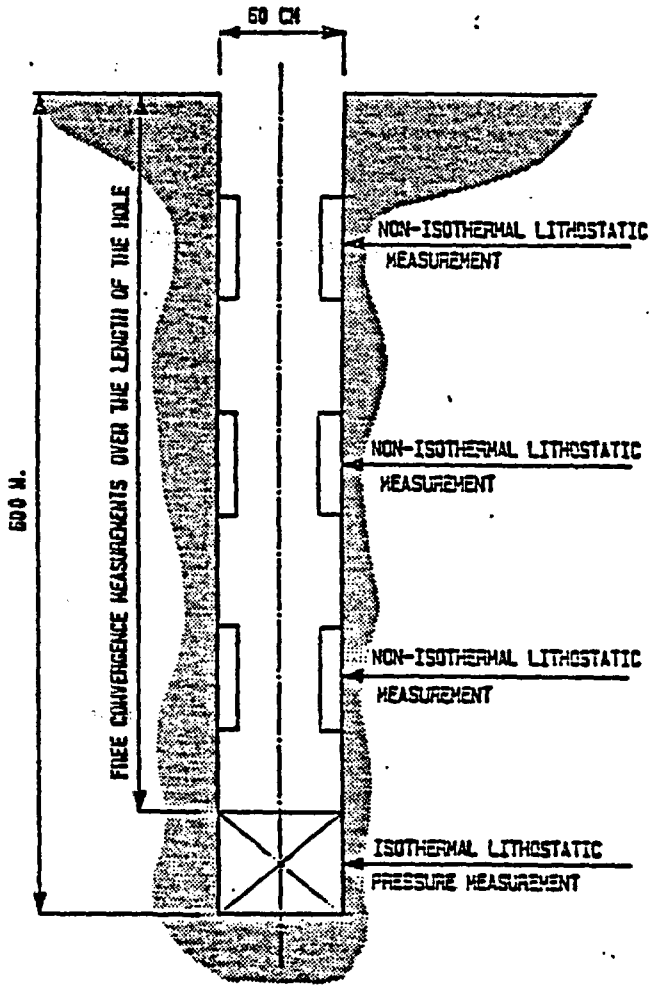


Figure 1: Sketch of the 600 m bore hole measurement set-up

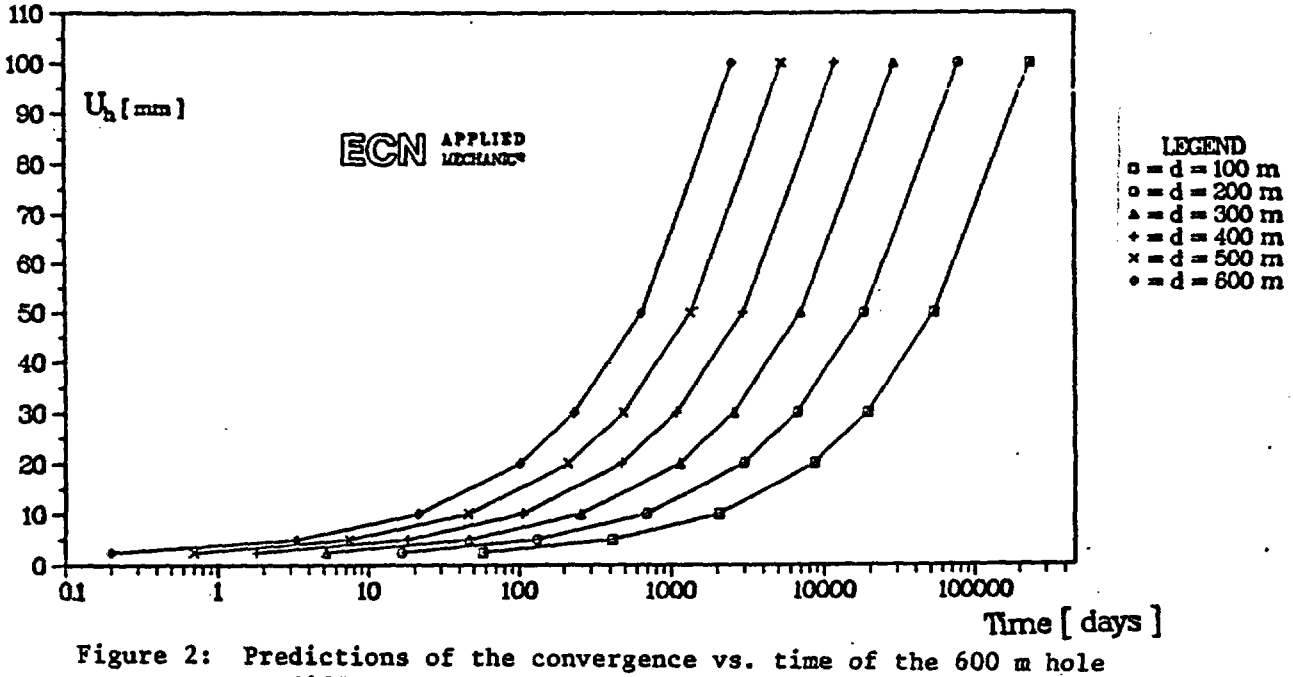


Figure 2: Predictions of the convergence vs. time of the 600 m hole at different depths

Faults in clays: their detection and properties

Contractor: BGS, Keyworth, Nottingham, UK

Contract No.: FI1W/0085/UK

Contract Period: April 1986-March 1989

Project Leader: N.A.Chapman

A. Objectives and Scope

Faults occur in most mixed sedimentary environments but their effects on regional groundwater flow patterns are poorly understood. The hydrogeological significance of faulted clay layers is of particular relevance where mudrocks are potential host formations for radioactive waste repositories.

In cooperation with ISMES of Italy two faults through clay layers will be studied (one site in the UK and one in Italy). The project has three objectives :-

1. To develop suitable geophysical techniques to detect water bearing faults in clays. These techniques will aim to differentiate between hydraulically active faults and those which are either sealed or non-water bearing.
2. To measure the hydrogeological properties of faults in sequences of mudrocks and aquifers. This will be achieved by measuring the hydraulic and chemical properties of the fault directly and by measuring the effect of the fault on the underlying aquifers.
3. To define suitable techniques for use in site investigations and methods for assimilating faulted boundaries into flow and transport models in clays and mixed sediments.

B. Work Programme

B.1. Desk study to evaluate a number of potential UK study sites; selection of two preliminary sites.

B.2. Initial geological and geophysical investigations of the preliminary UK sites; selection of the final study site.

B.3. Development of geophysical techniques for fault identification.

B.4. Detailed geophysical survey of the study site.

B.5. Borehole drilling.

B.6. Wireline geophysical logging of the boreholes.

B.7. Hydrogeological testing of the boreholes.

B.8. Synthesis of the results to evaluate the significance of the fault.

C. Progress of work and obtained results

State of advance

A desk study has been completed which identified 10 potential UK sites from which two preliminary sites have been selected. Plans for the intial evaluation of these two sites are well advanced. A review of single borehole geophysical logging has been carried out to determine which of the techniques might yield useful results within the project.

B.1. is completed,

B.2. and B.3. are progressing.

Progress and results

1. Site selection (B.1.,B.2.)

Desk studies of Mesozoic sedimentary basins within the UK have been carried out to identify potentially suitable locations for field sites. The sites had to broadly meet a pre-determined set of criteria which fall into three groups :-

1. Geological criteria
   a. Shallow overburden above the mudrock
   b. Faulted mudrock between 30-60m thick
   c. Aquifer underlying the mudrock
   d. Throw of fault to be greater than 50% but less than 100% of the mudrock thickness
2. Hydrogeological criteria
   a. Suitable hydraulic conductivity contrast between the mudrock, aquifer and fault
   b. Identifiable flow boundary conditions and driving potentials
   c. Potential for hydrogeochemical assessment
3. Geophysical criteria
   a. Suitable seismic reflectors in the mudrock and velocity contrast between the lithologies
   b. Remote from built up areas to avoid interference effects

In addition to these criteria the site should have no major topographic features in the immediate vicinity. Sites were initially selected on the basis of the limited geological information that was readily available and a list of ten potential sites was drawn up. None of the sites met all the criteria exactly, and it is clear an ideal site will not be found and that some compromises are inevitable. The two most promising sites, Wombleton airfield in the Vale of Pickering, Yorkshire and Down Ampney near Swindon, Wiltshire were chosen for further investigation. Summaries of the information which has been collected for these two sites are given below. These sites have been visited and negotiations with landowners for access to carry out preliminary geophysical surveys have been completed.

Wombleton airfield

The geology predicted at the site is :-

Formation	Lithology	Thicknes (m)
Kimmeridge Clay	clay	} 35-120 combined
Ampthill Clay	clay	} thickness
Corallian	sandstone + limestone	18-36
Oxford Clay	clay	> 20

A number of faults have been located in the region by seismic surveys and the fault throw at the site is likely to be about 50m. Yorkshire Water Authority investigations identified hydrogeological anomolies in this area which may be associated with the faulting. The nearest water abstraction borehole is approximately 4km distant and the frequency of faulting probably means the aquifer is isolated from major pumping influences. If the fault density around Wombleton airfield is as great as that identified by nearby seismic surveys then care may be required to choose the most hydrogeologically significant fault.

Down Ampney

The geology predicted at the site is :-

Formation	Lithology	Thickness (m)
Oxford Clay	clay	20-80
Kellaways Beds	sands + clays	9-24
Cornbrash	sandy limestone	5-10
Forest Marble	limestone, clay + marl	12-24
Great Oolite	oolitic limestone	15-50

Geophysics and field mapping indicate a fault density of about 1 every kilometre and the fault throw at the site is likely to be about 20m. A Thames Water Authority groundwater development scheme initially identified the faults and resulted in detailed geological mapping and geophysics. The site is most likely located within the region of influence of local water supply boreholes.

2. Single hole geophysics (B.3.)

The single hole geophysical logging has two main aims :-

1.Provide calibration data for the detailed surface and cross-hole geophysical surveys which will consist chiefly of seismic and resistivity techniques.

2.Characterise the differences in geophysical properties between the faulted zone and the unfaulted formation and consequently make interpretations of porosity, strength and mineralogy differences.

Support for the surface geophysics requires resistivity and sonic logging to obtain in-situ resistivity and p- and s-wave velocity profiles. This logging cannot be effectively performed through cemented or uncemented plastic casing and thus the logging will have to be performed in the open borehole. Experience at the Harwell Research Site has shown that

it is not possible to readily measure the s-wave velocity of mudstones from single borehole geophysics and therefore it is proposed that the standard borehole compensated log should be run to obtain simply p-wave velocities. It is proposed that resistivity should be measured by a focussed tool with a range of depths of investigation so that correction can be made for any borehole effects. It is also necessary to measure the spatial position of the boreholes in order that reliable results may be obtained from cross-hole seismic experiments and if plastic casing is used this could be carried out in the completed boreholes

Differences in geophysical properties between the faulted zone and the unfaulted rock mass may be determined by conventional logs which, in addition to the resistivity and sonic measurements outlined above. This implies that natural gamma, neutron porosity and density logs should be carried out. It should be possible to identify variations in lithology and porosity across the fault zone by the interpretation of this suite of logs.

It seems likely that the fault zone may also be characterised by an increased density of fracturing and therefore performing logs which identify fractures, such as the borehole televiewer, the fracture identification log or the formation micro scanner, has been considered. However the limited chance of explicitly identifying fractures in sedimentary rocks from a mud filled borehole by these methods, and the high cost of such techniques does not justify their use on this project.

The proposed suite of single hole geophysical logs, which was chosen on technical grounds, is :-

Microlaterolog
Dual laterolog
Borehole compensated sonic
Natural gamma
Density
Neutron porosity
Caliper

These logs should be performed in at least one vertical borehole penetrating the aquifer and one inclined cross-fault borehole. It is also proposed that deviation surveys should be carried out in each of the boreholes after being completed with plastic casing.

Cost estimates have been obtained for performing the above programme of logging which suggest that it can be carried out in the UK within the proposed budget. In order to obtain consistent logging results throughout the project the cost of carrying out the Italian logging using a British contractor was investigated but was found to be prohibitive. A document was submitted to ISMES for discussion proposing that the above suite of logs be performed in the UK and that ISMES should find a suitable Italian contractor to carry out a similar logging programme. These proposals have been accepted by ISMES.

METHODOLOGY FOR APPLICATION OF ELECTRIC AND ELECTROMAGNETIC BOREHOLE TECHNIQUES FOR DETAILED EXPLORATION OF FRACTURED ROCKS

Contractor : BRGM, Geophysics department, Orléans, France.
Contract n° : FI1W/0086/F.
Duration of contract : July 1986 - June 1988.
Project leader : P. VALLA.

A. OBJECTIVES AND SCOPE

The aim of the research work is first to complete the technical developments of three borehole geophysical methods for which prototypes have been built, and second to develop a methodology for these tools applied to detailed investigation of fractures.

These tools are :

- ELIAS, an electrical imaging technique to investigate the borehole wall and determine the depth, strike and dip of conductive or resistive fractures,
- ROMULUS-ERIC, a set of induction transmitter-receiver probes to point out conductive fractures and measure their conductance with a one to a ten meters radius of investigation,
- ARLETT, a three axis induction receiver used together with a surface electromagnetic transmitter, to help assess the geometry of the more conductive fractures in a ten to one hundred meters range.

The first and third systems are still in the technical development stage while the second is now operationnal. Numerical modelling of the methods is needed to fully assess their capabilities.

B. WORK PROGRAMME

1. Technical and theoretical development of electric and electromagnetic probes.
1.1. ELIAS
1.1.1. Final step of prototype development
1.1.2. Design of data acquisition and processing software
1.2. ROMULUS-ERIC
1.2.1. Design of modelling software for thin sheet conductors
1.2.2. Set up of a catalog of theoretical response curves
1.2.3. Study of complex geometry of thin conductors
1.3. ARLETT
1.3.1. Study of improvements to be made in the probe design
1.3.2. Development of a new prototype
1.3.3. Numerical modelling

2. Field tests and methodological studies
2.1. Technical field tests of ELIAS and ARLETT
2.2. Methodology for detailed exploration of fractured rocks
2.2.1. Data acquisition on available test sites
2.2.2. Data processing and interpretation
2.2.3. Analysis of results and methodology assessment

C. PROGRESS OF WORK AND OBTAINED RESULTS

State of advancement

The work done during this first semester of the programme has dealt with technical development of ELIAS and ARLETT probes (steps 1.1.1. and 1.3.1.) and with numerical modelling of ROMULUS and ERIC probes (step 1.2.1.).

For the former, most of the work has been focused on the development of an orientation module to be included in both ELIAS and ARLETT probes. Testing of components has shown that temperature drift might be a problem. First tests of the integrated module are planned for 87 first quarter. A one-axis auxiliary probe named REMI has also been assembled to help design the ARLETT probe. The first field test has been made and has shown the need for a better phase precision. The technical development of probes is a few months behind of schedule and increased work is planned for 87 first semester.

As for numerical modelling of ROMULUS and ERIC, the basic equations of the modelling scheme for modelling induction tools in the low induction number range has been established. A computer programme has been written based on these equations to obtain theoretical curves for thin sheet conductors.

Progress and results

1. Orientation module for ELIAS and ARLETT probes (step 1.1.1.)

Based on previous studies, the orientation module design includes two servo-inclinometers and three fluxgate magnetometers. Individual components testing has shown a temperature drift. For magnetometers the drift is similar for each sensor so it should be of no consequence. However, for inclinometers the drift is different for each sensor and problems might occur. Further testing of the assembled sensors has also pointed out a few misalignment problems which have been solved, except for the inclinometers for which the supplier is to be questionned.

An electronic board has been designed for digital data transmission and dynamic tests are to be made.

2. Numerical modelling for ROMULUS and ERIC probes (step 1.2.1.)

Starting from Maxwell equations and using a generalized reciprocity theorem scheme, the basic equations have been established to describe induction electromagnetic systems in the low induction number range (or "near-zone"). An algorithm has been implemented on a HP-9000 microcomputer, which, up to now, is dealing with a thin conductive plane or half-plane. A set of theoretical curves, such as the one shown in figure 1, has thus been computed as a tool for the interpretation of ROMULUS and ERIC logs.

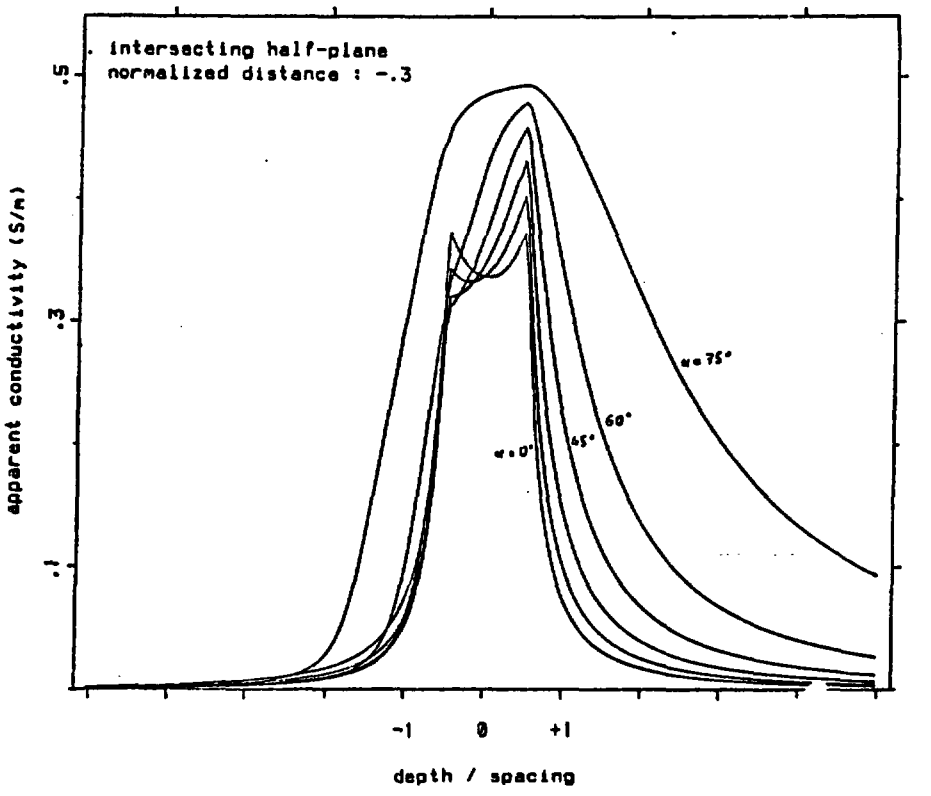
3. Preliminary study of ARLETT probe (step 1.3.1.)

While the orientation module is being developped, a simplified version of the ARLETT probe has been designed and built. It is the REMI probe which is an one-axis (axial) induction receiver, to be used with the MELIS frequency domain electromagnetic surface receiver. The measurements are performed one depth and one frequency at a time on both the probe output signal and a reference signal from the transmitter, in order to obtain the transfer function (in-phase and out-of-phase). A stacking process is used

to improve the signal-to-noise ratio, which can be checked with the standard deviations.

A first field test has been made for the REMI probe in order to check the complete system particularly in term of sensitivity. The test hole was the Echassières GPF borehole (Deep Geology Programme) which has been drilled through 1000 metres of cristalline rocks, micashists and granite. However the hole is now blocked at 400 metres and no major fractured zone occurs in the open zone. This step was thus a technical one. A borehole EM transmitter, named EMMA, has also been used to make reciprocity checks.

The results show that the amplitude measurements agree with theoretical free-air computations (due to high resistivities the secondary signal is small) but that the phase is not measured with an appropriate accuracy (cf. figure 2). The problem might come from the reference link from the transmitter and further tests are needed to analyse and hopefully solve the problem.



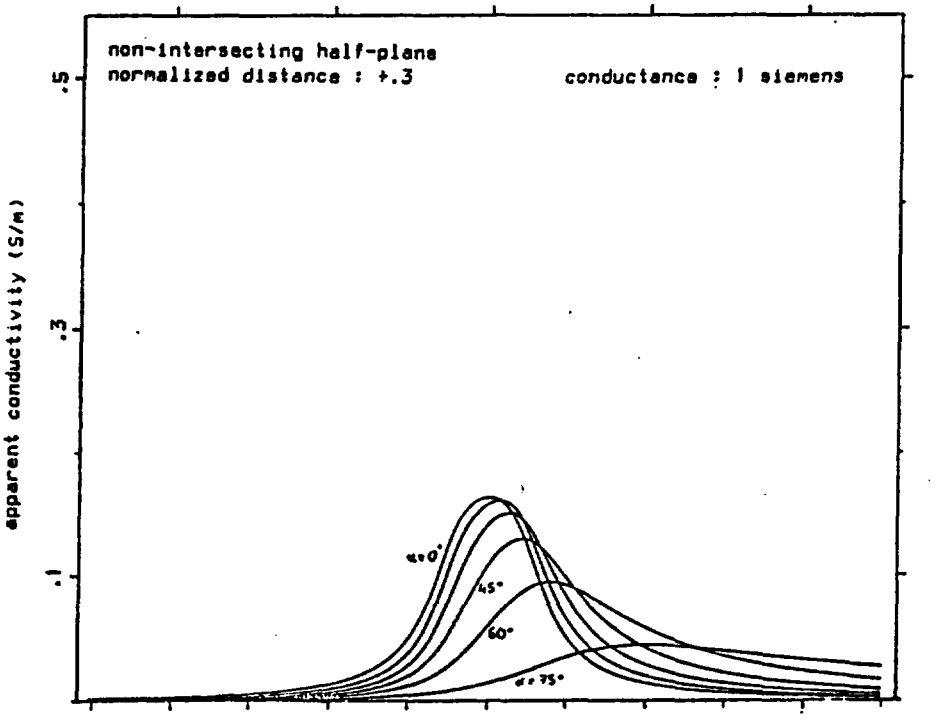


Figure 1 : Theoretical response of induction logging tools (ROMULUS-ERIC) for a thin conductive dipping half-space.

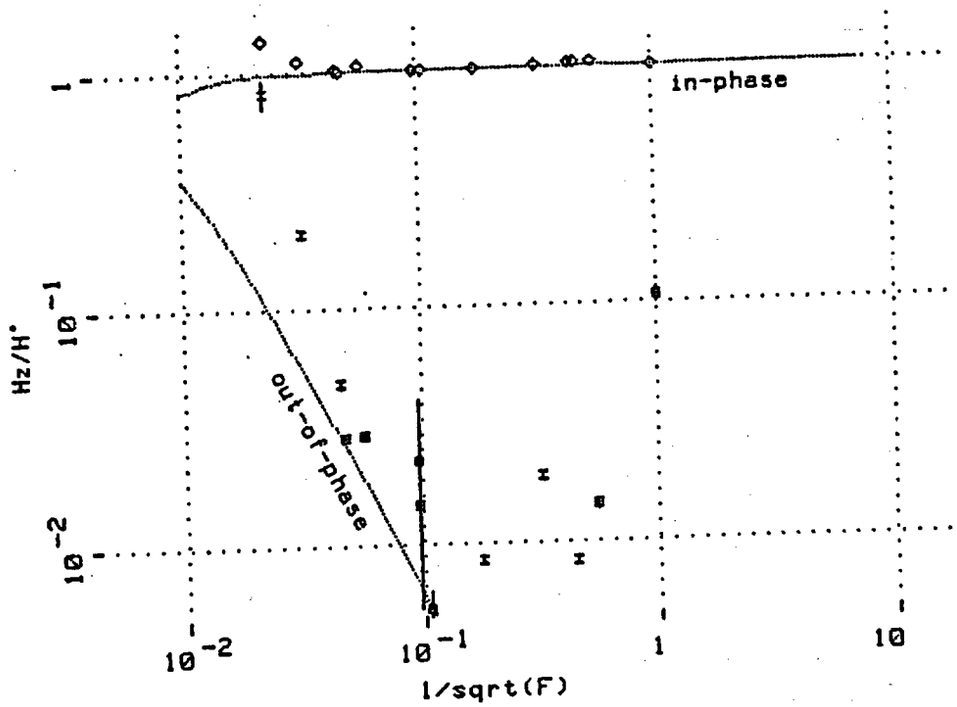


Figure 2 : Comparison of REMI field data measurements with theoretical response for a 2000 ohm.meter half-space at 150 m depth.

Development of a self-contained drill-hole chromatographic probe

Contractor : CEA - CEN CADARACHE F 13108 Saint Paul lez Durance
Contract N° : FI1W/0087
Working period : 36 months
Project Leader : J.M. Vinson

A. Objectives and Scopes

The study of the transuranian nuclide migration from radioactive waste storage places is based on the knowledge of the natural environment and, in particular, of the chemical composition of the water : the transfer vector.

In addition to major elements, the water also contains trace elements which play a prominent part not only on the general equilibrium, but also on the radionuclide migration possibility.

This is in particular the case of the Lanthanides, present in the granitic and argillaceous environments, whose role of sorption competitors with respect to the Actinides has been exhibited throughout numerous experiments.

The scope of this contract is to manufacture and operate a chromatographic probe to be used in a deep drill-hole, so designed as to acquire a representative sample under conditions of equilibrium of the natural environment, to preconcentrate it by elimination of the saline content and to store it for ulterior analysis at the surface.

B. Work Program

B.1. Process Development
B.1.1. Principle laying-down and delineation. In-laboratory model.
B.1.2. Definition of final probe design after study on model. Realization and adjustment on CADARACHE site.
B.2. Probe Qualification in the Deep Drill-hole of AURIAT
B.3. Application to 3 reference sites

C. Work Progress and Results Obtained

Summary
The preconcentration, Lanthanide separation and analysis processes have been studied.
According to the results obtained, the probe design has to be slightly modified to allow for a future coverage of other trace elements by the system, and also to restrict to laboratory execution only the most critical separation operations.
The displacement pump which is the most critical component of the probe has been studied and is now under test.

Progress and results

1. Laboratory model

The purpose of the first stage is to implement, in the laboratory, all the processes required for realizing the experiment.

1.1. Preconcentration

The natural Lanthanide concentrations are too low for being determined by titration.

Two possibilities have been studied according to the versions contemplated for the probe design (Fig. 1) :

- concentration on pre-column
- direct concentration on separation column head.

The average yield figures obtained for concentration factors of 10^3 are listed in the following table.

Table 1 - Results of the preconcentration on column head

Metal. ion	Average area (for 3 analyses)	(Max. deviation / %)	Area for each 10µl injected δ_r	Yield (δ/δ_r)
Lu	395883	6.4	515112	77
Yb	465282	10.9	597046	78
Tm	547046	8.9	696641	78.5
Er	610212	8.5	776648	78.5
Ao	775534	0 (1	820304	94.5
Dy	718235	13.9	751218	96
Tb	662403	5.0	869949	76
Gd	797569	3.8	1004488	79
Eu	861667	8.6	1009821	85
Sm	684880	24.1	651452	105
Nd	710217	23.3	704062	101
Pr	626303	23.6	624574	100
Ce	717149	12.6	796388	90
La	728448	14.9	807849	90

The study is being carried on to improve those results.

1.2. Elution gradient (Fig. 2)

The separation column, several types of which were studied, includes grafted silice with sulphonate functions (Nucleosil S.A. or Pertisil SX).

The mobile phases are solutions of hydroxyisobutyric acid (HIBA) and de-ionized water.

. Phase A : distilled de-ionized water.

. Phase B : 0.2 M HIBA with pH = 4.6.

The gradient is accomplished in two linear sections :

1) from 0 to 35 % of B in 15 mm.
2) from 35 to 100 % of B in 15 mm.

The following table shows the reproducibility of the measurements, and Figure 3 shows the Lanthanide separation.

Table 2 - Reproducibility of measurements

Metal. ion	Area average (over 4 analyses) a	Height average h	Max. deviation % a	Max. deviation % h
Lu	584434	49107	1.9	5.3
Yb	664080	50602	5.4	4.05
Tm	787232	60849	1.3	6.0
Er	895730	68477	0.35	4.9
Ao	958745	71018	7.3	5.9
Dy	925465	67673	4.0	5.7
Tb	990864	65250	4.5	5.1
Gd	1162719	67896	7.3	4.9
Eu	1139068	61856	5.5	6.8
Sm	764207	39410	6.6	1.2
Md	776750	42228	1.7	1.1
Pr	677446	34731	6.8	2.3
Ca	889534	46908	4.0	3.5
La	909784	46225	1.5	2.7

1.3. Analyses

After complexation through Arsenazd I, the Lanthanides are analysed in 585 mm spectrophotommetry.

The limits of sensitivity are in the range of 10^{-10} moles for each ion. They may be improved either through realignment of the system or by employment of spectrophotommetry as an analytical technique.

Both possibilities are being investigated.

2. Study and realization of the probe

2.1. Design

The results gained from the laboratory study led us to redesign the drill-hole-incorporated tool.

From the prospects offered by chromatography, regarding both cations and anions, it may be inferred that the in-laboratory application of several gradients would allow a more complete analysis of the trace elements.

The high carefulness required for achieving the gradient makes it more relevant to proceed in laboratory. It is then possible to design a probe which, in lieu of a fractions collector, is made up of banks of chromatographic columns (cationic and anionic) used both for collecting and for preconcentrating purposes.

It would also be possible to multiply the spots for a more complete analysis.

A pumping system coupled to a permanent elution system would avoid the fixation of monovalent cations (the most numerous), permitting the saline load separation.

The process is under study.

2.2. Pumping system

The first probe realization stage consisted of studying such modifications of a chromatography pump as were necessary to meet drill-hole conditions.

Conventional chromatography pumps are designed for horizontal operation, whereas the drill-hole requisite is verticality.

The mechanical changes made necessary have been studied.

The tests for flowrate reproducibility in connection with the modifications of the dead volumes are in progress.

In the second stage, the electronics had to be modified commensurate to the limited electric power supplied via the conductor cable.

Now the pressure drop in the chromatographic columns calls for a far greater power value than is normally applied according to standards.

The first results, however, are very promising.

2.3. Next steps

Our commitment is now proceeding with the following matters :

1. In-laboratory study of the gradients applied to all trace elements.
2. Improvement of performance regarding the Lanthanides.
3. Final adaptation of the pump.
4. Improvement of the saline load separation.
5. Design of column banks for cation and anion collecting and concentrating purposes.

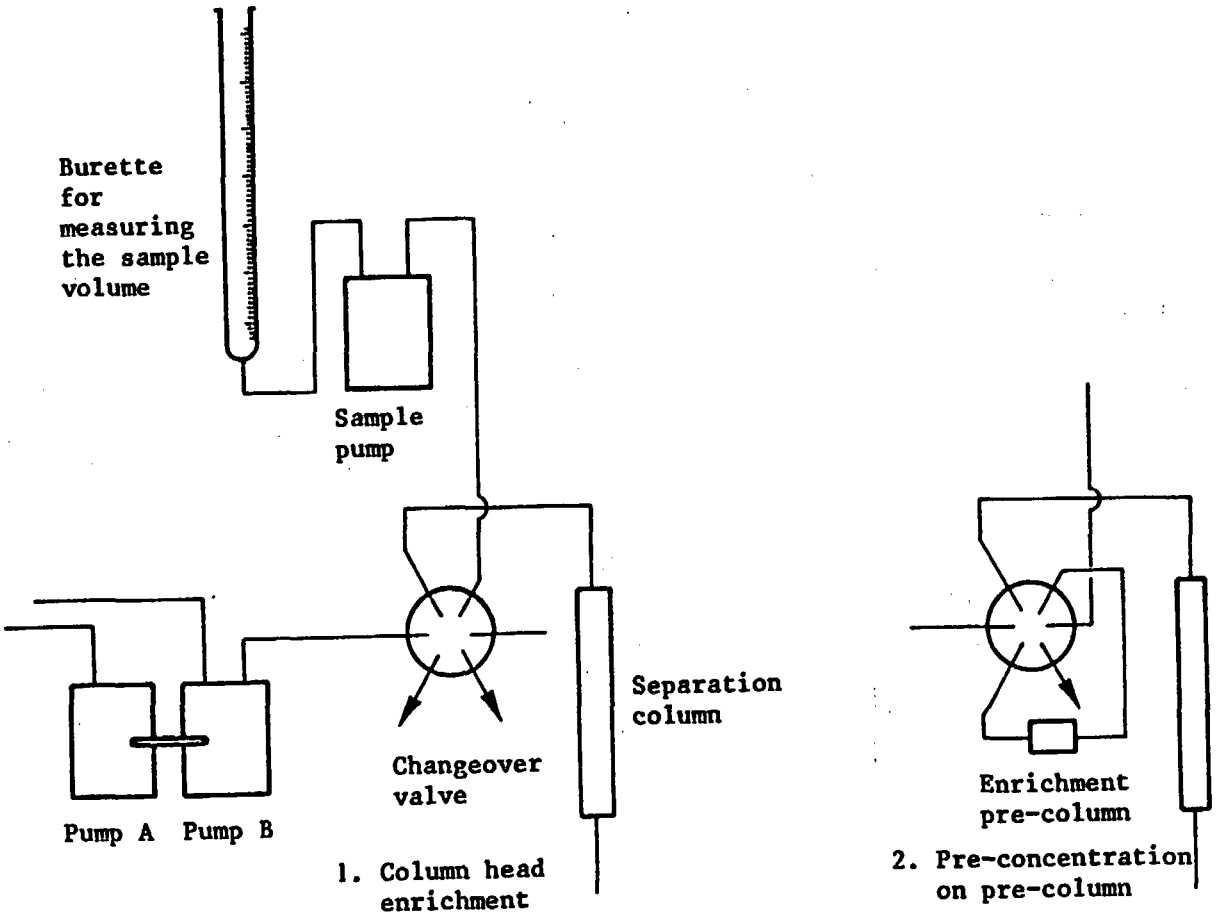


Figure 1 - Modification of the injection system for preconcentration

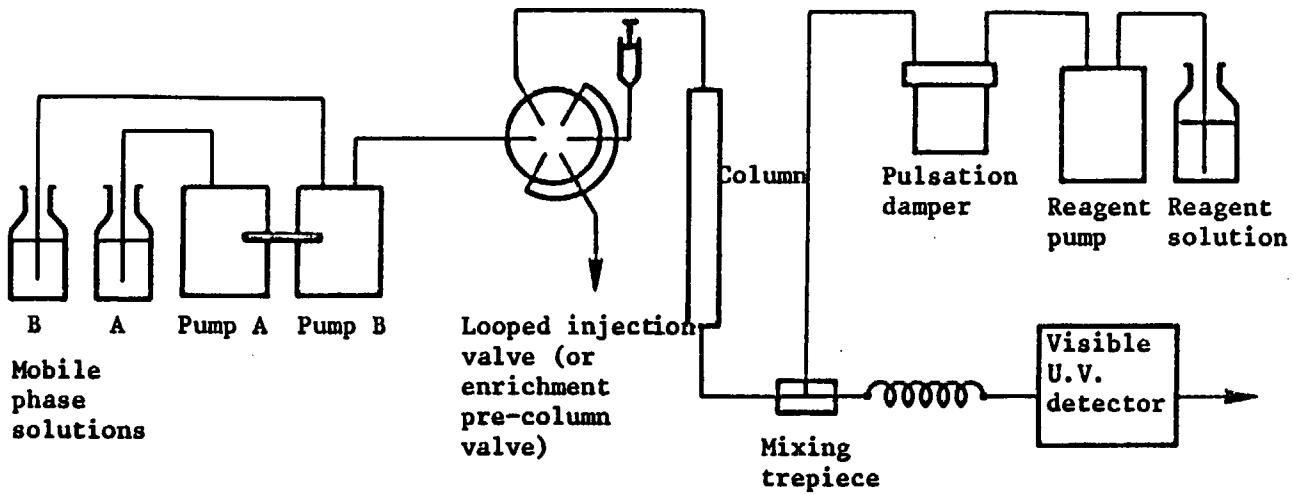


Figure 2 - Test setup schematics

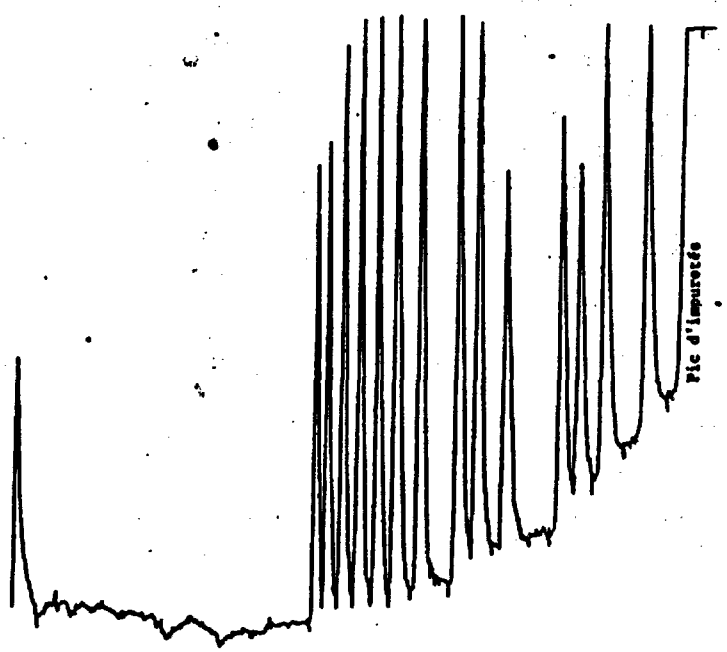


Figure 3 - Lanthanide elution on NUcleosil column
Gradient in two sections

The Detection and Measurement of Faults in Clay

Contractor: University of Exeter, Exeter, UK.
Contract No: FI1W-0088-UK (H1)
Working Period: September 1986 - August 1989
Project Leader: Dr. E.M. Durrance

A. Objectives and Scope

If faults occur in the rock mass surrounding a nuclear waste repository, there is a risk that the return of hazardous radionuclides to the biosphere will take place by migration along these zones of higher permeability. However, the detection and characterisation of faults is difficult, especially in soft rocks such as clay, and little development of techniques has taken place. The objective of this programme is to develop techniques that will be suitable for routine use in both the preliminary and detailed stages of site investigation. The approach used is based on the observation that faults act as zones of preferential migration in the natural degassing of the Earth. Soil gas exploration methods are applied to detect zones of anomalous gas geochemistry. The procedure followed is based upon samples obtained from a depth of about 0.5m along a series of traverse lines. Once a fault has been located, spiking of the high permeability zone from a borehole drilled to intersect the fault plane, will take place with specific gases of different compositions. The ground will then be resurveyed to determine the migration characteristics of the gas within the fault. Test sites in the UK and Italy are to be investigated in co-operation with BGS (Keyworth) and ISMES (Rome). BGS and ISMES are responsible for site selection and the drilling programme, but some trials will be conducted at sites near Exeter.

B. Work Programme

B.1. Equipment development.
B.2. Site selection.
B.3. Soil gas geochemistry.
B.3.1. Reconnaissance soil gas surveys measuring ^{4}He, ^{220}Rn, ^{222}Rn, O_2, CO_2 and some organic gases.
B.3.2. Detailed soil gas surveys of anomalous zones identified in the reconnaissance surveys.
B.3.3. Spiking of vertical boreholes and resurvey of soil gases.
B.3.4. Spiking of inclined boreholes and resurvey of soil gases.
B.4. Modelling and interpretation of results.

C. Progress of work and obtained results

Summary

The main effort has been in the development of a mobile laboratory for soil gas analysis at remote sites. This has involved the modification of a vehicle to house a ^4He mass spectrometer and its ancillary equipment. Electronic methods of O_2 and CO_2 analysis have been acquired and modified for soil gas work. An integrated system has been built to allow measurement of these gases with ^{220}Rn and ^{222}Rn. Minor alterations to the CO_2 analyser will permit analysis of some organic gases, but samples for CH_4 analysis must be returned to Exeter. Plastic syringes appear to be adequate for obtaining and transporting these samples. Special soil gas probes have also been built. Possible sites for trial surveys have been identified near Exeter. Literature review, database construction and the development of computer programmes for data presentation and processing are in progress. The programme is approximately on schedule.

Progress and results

The initial period of work has been devoted to items B.1., B.2. and B.4.

1. Equipment development (B.1.)

Analytical systems for gas analysis have been mounted in a vehicle suitable for remote site access. The vehicle now houses a ^4He mass spectrometer and associated pumps, transformers, inlet system and coolant storage facility. Provision to utilise mains electrical power from a supply near a remote site is available as an alternative to mobile generators. Electronic CO_2 and O_2 analysers have been modified and tested for use in soil gas work, and suitable housing constructed in the vehicle. An inlet manifold has been designed and built to enable sampling and analysis of ^{220}Rn and ^{222}Rn to be compatible with CO_2 and O_2 sampling. Analysis of some organic gases is possible by modification of the CO_2 analyser, but CH_4 must be analysed at Exeter. Trials have been run of suitable sample acquisition and transfer systems. Simple plastic syringes of the type used for rapid analysis of ^4He samples appear adequate for delayed CH_4 analysis. Soil gas probes suitable for integrated analysis of different gases have been designed and built. Minor modification of the vehicle construction has been necessary to accommodate the laboratory.

2. Site selection (B.2.)

A desk study of geological maps and reports has been carried out of possible sites in Dorset and Somerset, where the positions of faults cutting clay formations are known from nearby occurrences of displaced boundaries of other rock types. A number of such sites have been identified as suitable for trial surveys. Some assessment of faulted clay formations in Devon has been made in the field following a similar desk study. The geology of these areas is well known from detailed borehole information. The soil gas signatures in these areas are, as yet, unknown. Preliminary approaches have been made about access to the sites. Reconnaissance surveys should commence in February 1987.

3. Modelling and interpretation (B.4.)

A literature search of soil gas data has been carried out and a review is in preparation. Collation of soil gas results from different geological environments is taking place. Computer programmes for data presentation and processing are in the course of development.

Studies of disposal possibilities in geological formations : investigation in granite media

Contractor: CEA - Fontenay-aux-Roses, F
Contract N°: 127.80.7. WASF (avenant n°1)
Working Period: since december 1982 - february 1986
Project Leader: A. Barbreau

A. Objectives and Scope

Methodological and instrumental studies are still going on, following the geological studies of the Auriat deep exploration boreholes.
Aside from these, a new experiment has been undertaken on the "Thermo-Hydro Mechanical" behaviour of granite. This THM experiment aims at studying the variation of the characteristics in a large volume of granite under a thermal flux, at a depth of 90 to 100 meters below the ground surface. This volume includes a free surface of 10 m x 10 m and a thickness of 3 m.

B. Work Programme

B.1. Methodological and instrumental studies
B.2. Thermo-Hydro-Mechanical Experiment
B.2.1. Geological studies for preselection and selection of site
B.2.2. Excavation of the experimental room
B.2.3. Drilling of instrumentation boreholes
B.2.4. Emplacement of the gauges
B.2.5. Measurements
B.2.6. Interpretration with 2D and 3D codes

C. Progress of work - preliminary results

Methodological and instrumental studies

A borehole water sampler, electrically triggered from the surface, has been devised. It allows the collection at the surface of water samples, under the hydrostatic pressure of the sampling level. The methods previouly used at Auriat required clumsy transfer operations, from a sampler to a transport bottle.

The Auriat granitic body has been retained as an experimental site for the research of deep water outlets and the study of the deep water contribution to springs and rivers. Geochemical and isotopic analyses (^{13}C, ^{3}H, ^{18}O) have been performed, it is not yet possible to be positive as to the presence of waters of deep origin at the surface : the investigation area will be extended around the granitif body itself.

Fracturation studies on borehole walls require improvements on the optic camera. The "borehole televiewer" (Ultra sonic or acoustic televiewer) as tried in other countries (Canada, Switzerland) is being considered.

Chemical equilibriums in the deep underground waters depend on the pressure, on the temperature and on the minerals within contact either from the rock itself or from the fracture filling. When a water sample is brought to the surface, it is modified by the contact with the atmosphere and is no longer representative of the deep conditions. pH and Eh values as measured at the surface differ from those that prevail in the deep. pH and Eh probes have been made, allowing direct in-situ measurements of these parameters.

Thermo-Hydro-Mechanical experiment

The underground chamber site is situated 25 km NNE of Limoges. The experiment started with the structural exploration of the Saint-Sylvestre granitic body. This body has been subjected to extensive mining for uranium ore.

The IPSN experiments do not plan to prepare an underground repository in this area. The studied zones show a high density of fractures, the depth is shallower than 100 m from the surface. Furthermore, they are uranium rich and the reserves may not have been fully discovered.

Among several possible sites, the Tenelles mine has been chosen because of the fracture density, of water saturation and the easy access through a way shaft.

After that selection, a fracture study in the drift allowed the choice of the place which appeared most favorable for the experimental room.

Both sides of the drift were then explored by two cored boreholes (fig.1).

The South-East zone, cut-across by exploration borehole S'1, was finally selected on the basis of fracture orientation and density, with reference to the planned room floor.

Despite the presence of fractures with a permeability of 10^{e-7} m/s, it was not possible to measure water flows, so that water saturation remains dubious. Nevertheless, permeability measurement remain possible, so that changes in the aperture of the fracture will be evaluated.

The excavation work is now finished, and the installation of the heat source is under way. It will be placed below the center of the experimental room, at a depth of 3 meters (fig. 2).

It is made of 5 cyclindrical heaters, 1.5 m in length, placed at 30 cm form each other. They will be placed in 146 mm diameter boreholes drilled from a lateral drift. The total power output will be 1 kW.

The study of the effect of the dissipated heat in the rock volume encompassing the source, in all directions and specially in the ascending vertical way, up to the horizontal free surface (about 100 square meters) in the experimental room, requires the knowledge of the following physical parameters :

- temperature,
- deformation and displacement in the medium and at the free surface, on the floor of the room,
- mechanical stress in the medium,
- permeability (in boreholes),
- water pressure (if any),
- water flow on the room walls (if any).

Different probes will thus be distributed in the volume situated between the room floor and the heaters.

Measurements will be done during both the heating and cooling phases, each of which will last from one and a half to tow months, the duration of the whole experiment being from three to four months.

The position of the probes has been determined according to a theoretical preliminary study, showing the heat distribution in the medium :

66 (temperature gauges) will be placed as follows :

- 33 in the rock body
- 12 on borehole extensometers
- 19 on surface extensometers

Deformations in the rock body will be measured in boreholes equiped with extensometers : 3 such extensometers will be dused, made up of 4 displacement gauges each.

The measurement of surface displacements is important in this experiment, the aim of which is to simulate any possible deformation and displacements of the ground surface above a high-level waste underground repository. 18 automatically recorded surface extensometers will be used, plus 20 reference studs for manual measurements.

The displacement of the room walls will be measured by three dimensional triangulation with the help of an invar-wire distancemeter.

Conclusion

The different instrumental studies aim at completing the tools necessary for the characterization of the geological medium.

The THM experiment required geological studies at different scales (200 m in the drift, 50 meters in the boreholes, 2 to 3 meters on the room floor) allowing the control and quantification of the natural characteristics of the medium. The comparison of the results should allow an improvement of the structural methods of study.

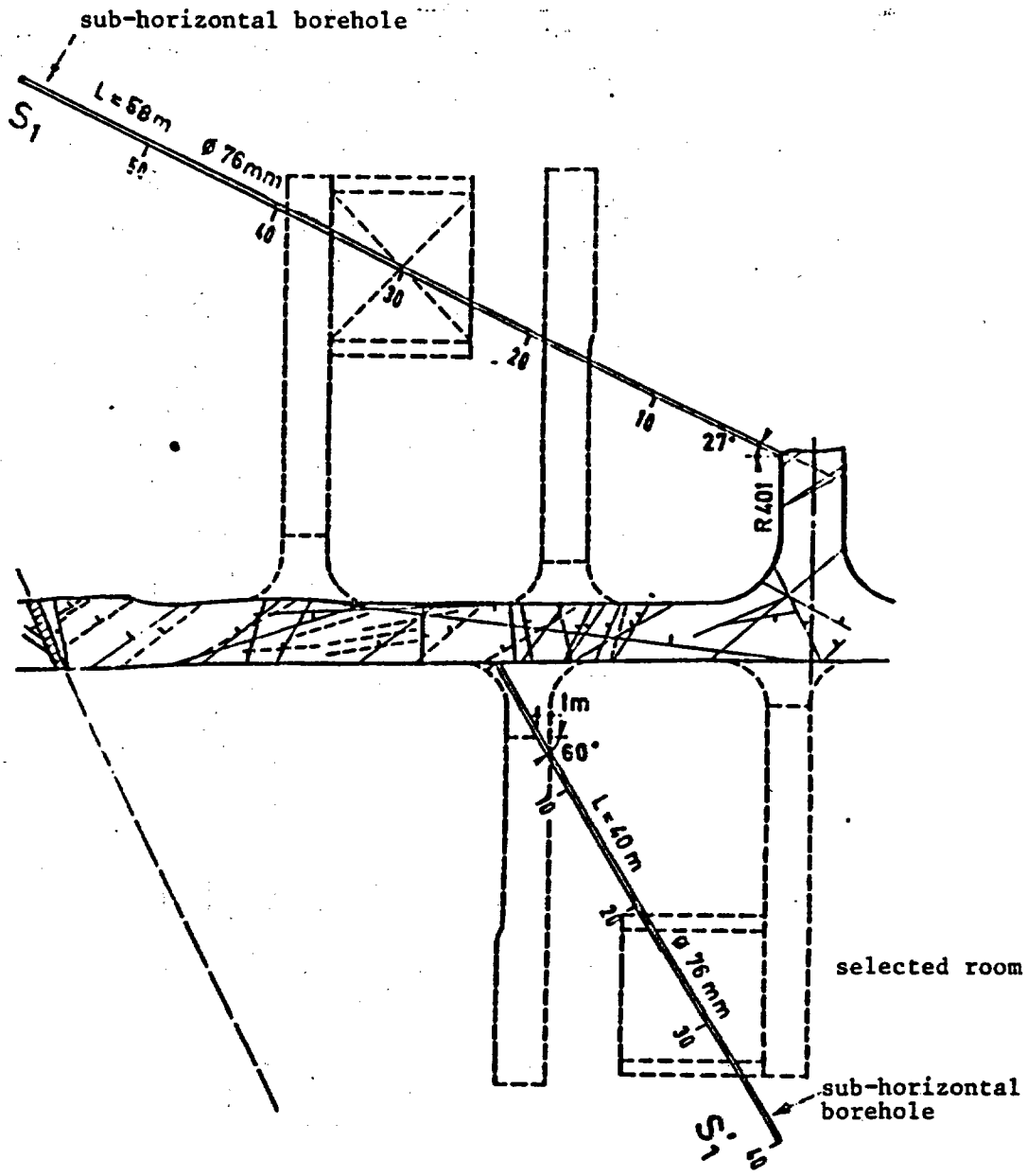


Fig.1 - Location of the two sub-horizontal boreholes and and final site of the experimental chamber

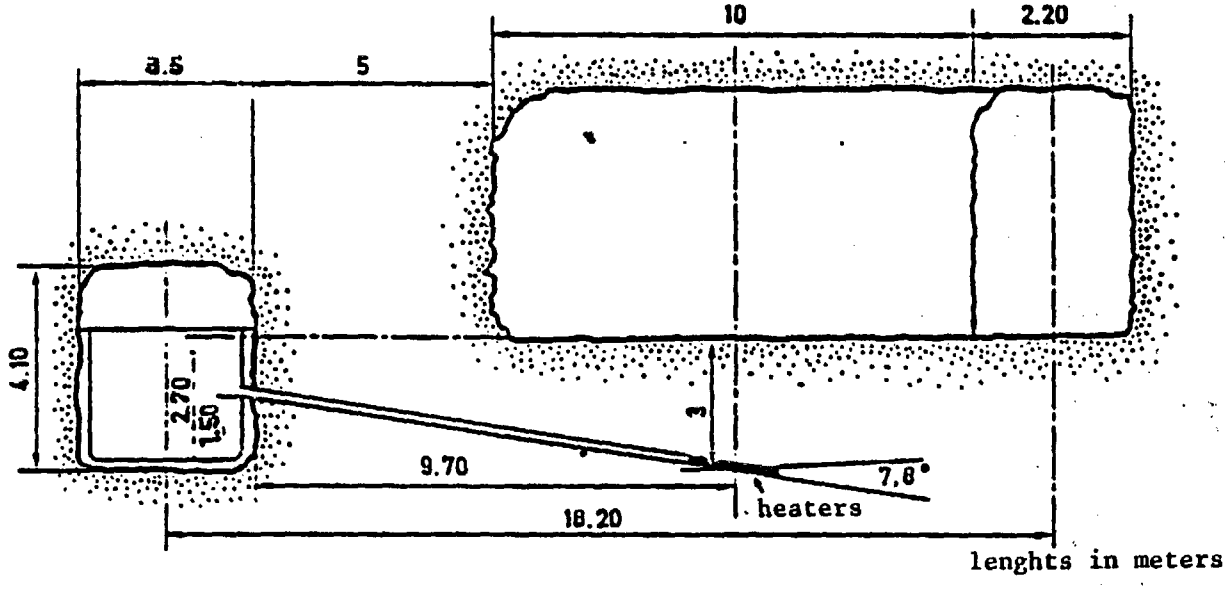


Fig. 2 - Selection across the experimental room and the service drift, showing the position of the heat source

Use of an Underground Cavity as a Test Facility for Radioactive Waste Disposal in Clays

Contractor: ENEA, CRE CASACCIA, ITALIA
Contract N°: 337 - 83 - 7 WASI
Working Period: Jannuary 1984 - December 1986
Project Leader: E. Tassoni

A. Objectives and Scope

Researches have been carried out by ENEA on the Italian territory with the aim of identifying a site suitable for a deep experimental laboratory in a clay formation.

During the tunnel excavation at the choosen site a set of measuring instruments is placed to record the stress changes and the strain behaviour of the clay rock. Moreover the structure of the rock mass and the nature of its discontinuities is described to obtain a more reliable basis for the interpretation of the results which will be obtained from the in situ tests.

Finally an heating experiment is carried out into boreholes drilled in the tunnel floor to record the variations induced in the surrounding clay by a simulated radioactive waste canister.

The final objective of this programme is to carry out a set of experiments under high lithostatic stress, like those in a future waste repository.

B. Work Programme

B.1 Surficial and deep geological investigations to identify local stratigraphy and structural elements.

B.2 Description of the discontinuities in the clay rock during the tunnel excavation.

B.3 Chemical, mineralogical and granulometric analyses on clay samples coming from the tunnel.

B.4 Geotechnical tests carried out on big clay block (30 X 30 X 30 cm) coming from the tunnel.

B.5 Microbiological study to ascertain the bacterial presence and activity in an ancient clay basin.

B.6 Measurements of total pressure and deformation in clay rock and of deformation in the tunnel lining during the excavation.

B.7 Heating experiment using an electric heater simulating the waste and instruments measuring the changes of clay physical parameters.

C. Progress of work and obtained results

State of advancement

During the 1986 the excavation of the tunnel in the Pasquasia mine has been completed. The discontinuities present in the clay rock have been described and several samples have been cut from the clay wall to carry out mineralogical, chemical, granulometric analyses and geotechnical tests which are running. During the excavation different geothecnical instruments, like total pressure cells, strain ganges, extensometers and steel bolts have been installed in the clay and in the tunnel lining to study the displacements and stresses caused by the tunnel excavation in the rock mass. A very preliminary layout of the heating experiment has been made and the suitable instruments are identified. Moreover the surficial investigations have been quite completed and the local stratigraphy has been defined. The general work progress status is as follows:

.B.1.,B.3 and B.4 are progressing normally

.B.2.,B.6 are completed

.B.5.,B.7 are lightly delayed.

Progress and results

B.1. Surficial and deep geological investigations

As a result of site selection studies ENEA decided to install the underground laboratory in a tunnel adjacent to the inclined access adit of the Pasquasia mine (potash salts) in Central Sicily. The Pasquasia mine is placed in the late Miocene Solfifera Series which outcrops in the central Sicilian Basin filled up with a huge quantity of plastic sediments and gravity slides varying in age from the middle Miocene to the Quaternary.The underground laboratory, 50 m long, has been located about 160 m below the surface in a Pliocene clay formation. The geological investigations have shown that, at the laboratory site, the local clay level has a vertical thickness in the range from 90 to 100 m. It is overlain by clayey sands of Middle Pliocene age and is underlain by marly Pliocene limestones (trubi). The contact between clays and "trubi", which is parallel to the clay and "trubi" stratification, dips approximately north with a variable inclination, averaging 18° at the laboratory site.

B.2. Description of the discontinuities in the clay rock

To carefully describe the discontinuities in the clay mass and their nature a description of the structure of the rock has been carried out during the excavation about every 2 m, with particular attention to some important parametres like orientation of joints or faults, as well as their spacing roughness aperture, filling and seepage.The description has been carried out both on the front and on the side-wall of the tunnel; about 300 discontinuities have been identified and described. The results of this work will be very important for the interpretation of future in situ experiments.

B.3. Chemical, mineralogical and granulometric analyses

During the excavation about sixty clay blocks (30 X 30 X 30 cm) have been collected . The following analyses have been carried out on each block:

- mineralogical analyses on the tout-venant and on the <2μ clayey fraction by means of X-ray diffractometry.
- clay water content (by weight) by drying the samples in oven at 105° C for about 24 hours.
- granulometric analysis by means of sedigraph apparatus.
- carbonate content (by weight) by means of apparatus for CO_2 gravimetric determination

B.4. Geotechnical tests

Clay big blocks, sampled during the excavation, are tested in edometric and triaxial cells to determine the most important geotechnical parametres. The preliminary values of these parametres are as follows:

- undrained shear strenght	1-2 MPa
- cohesion	0.25 "
- friction angle	35°
- elastic modulus	98 MPa
- permeability coefficent	$2.5\ 10^{-12}$ m/sec

B.5. Microbiological study

The bacterial content of Pasquasia clay sediment will be directly counted by epifluorescent microscopy using a new method of concentration of the sample. At least three samples will be analysed under many replications to know if the bacteria are also present in Pasquasia deep clay sediments; in fact sediment bacteria, if present, are very important because they are involved in chemical trasformations of materials and their activity can determine both different chemical behaviour of radionuclides and anaerobic corrosion of steel structures in sulphate containing sediments.

B.6. Measurements of tunnel deformation

In order to determine the disturbance caused in clay by the tunnel excavation two instrumented sections have been installed at stations 18 and 36 m respectively. In these sections the following measurements have been carried out:

- clay displacement by means of multiple steel rod extensometres placed 6.5 m long boreholes.
- clay convergence by means of steel bolts, cemented at the clay walls.
- rib deformation by means of vibrating wire strain ganges
- radial pressure between clay and lining by means of total pressure cells.

B.7. Heating experiment

An heating experiment is being planned to study the thermal effects in the clay formation under high lithostatic stresses. The experiment will consist in embedding a multiple heater at a depth from 10 to 20 m under the tunnel floor. The dimensions of the cylindrical heater will range from 5 to 10 cm in diameter and from 2 to 4 m in height. The maximum specific power will be 500 KW/m^3 The annulus between the heater and the borehole wall will be filled up with a sealing material, like a mixture of cement and bentonite. Around the heater many different instruments will be placed at different distances ranging from 0.5 to 2.0 m. Temperature measurements will be carried out by means of thermocouples or thermoresistances, strain measurements by means of borehole probes able to measure three-dimensional displacements and pore pressure measurements by means of electric piezometres.

APPENDIX C

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

C.ROCK/DOC(86)2

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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Summary Record of the Ad Hoc Meeting of Directors
of Crystalline Rock Projects

held in Paris on 3rd-4th November 1986

Present:

Mr. HANCOX (Canada)
Mr. RYHANEN (Finland)
Mr. LEFEVRE (France)
Mr. BARBREAU (France)
Mr. BARTHOUX (France)
Mrs. ANDRE-JEHAN (France)
Mr. ARAKI (Japan)
Mr. YAMAKAWA (Japan)
Mr. NODA (Japan)
Mr. DEL OLMO (Spain)
Mr. HUERTAS (Spain)
Mr. BJURSTROM (Sweden)
Mr. AHLSTROM (Sweden)
Mr. ROMETSCH (Switzerland)
Mr. McCOMBIE (Switzerland)
Mr. FEATES (United Kingdom)
Mr. GINNIFF (United Kingdom)
Mr. RUSCHE (United States)
Mr. COOLEY (United States)
Ms. MANN (United States)
Mr. ORLOWSKI (CEC)
Mr. VENET (CEC)
Mr. SHAPAR, Director General NEA
Mr. OLIVIER, NEA

A full list of participants is attached as Annex 1.

OI 070

1. OPENING OF THE MEETING

1. Mr. Shapar warmly welcomed participants on behalf of NEA and expressed his satisfaction to see that all the Directors of Crystalline Rock Projects had responded favorably to the invitation to this ad hoc meeting. He recalled the background, notably the US proposal at the origin of this initiative enhance cooperation about crystalline rock projects at the Director level. He also proposed to elect Mr. Ben Rusche (US, DOE) as chairman, which was unanimously accepted.

2. Mr. Ben Rusche thanked all participants and stressed that the meeting should take the form of an informal exchange of views among Directors of crystalline rock repository projects in order to establish the need or otherwise for enhanced collaboration in this area. The main objective was to achieve a broader awareness of the status of each others programmes as well as international cooperation in order to identify subjects for initiatives at national level (see annex 2). Any new activity should not duplicate ongoing programmes of the NEA or CEC and the ad hoc Group was not intended to replace established international fora but rather to complement them. A plan was adopted for the meeting consisting first of all of presentations of each programme, followed by discussion of particular issues and potential initiatives for enhanced cooperation. Attention was drawn to the guidance notes provided with the Agenda and particularly to Enclosure 6 on draft terms of reference for a possible Crystalline Repository Project Directors' Group (CRPDG).

2. PRESENTATION OF NATIONAL PROGRAMMES

3. A list of the written contributions is provided as Annex 3. Participants were requested to follow a specific format in preparing the written text, in particular to give budgets, schedules, government requirements, as well as technical and non-technical issues. The following is a brief summary of the main points mentioned.

4. Dr. Hancox (AECL, Canada) presented a summary of the Canadian Nuclear Fuel Waste Management Program which is in the sixth of a ten-year concept assessment phase. Both granitic and gabbroic plutons as well as some surrounding metamorphic rocks are being investigated in the provinces of Ontario and Manitoba. A clear distinction is maintained between R & D aimed at concept assessment and that associated with concept implementation, so as to enable field research for the former to be carried out unhindered. Regulatory requirements and acceptance criteria were outlined as well as the supporting R & D; the annual budget for research is about 45 million Canadian dollars. Particular emphasis was given to current and planned activities at the Underground Research Laboratory located near the Whiteshell Research Establishment. A number of technical and non-technical issues currently of concern were outlined. In particular, the need to ensure that the rationale for the differences between particular national approaches in setting long term safety criteria should be clearly understood. Also the need for innovative approaches to tackle the NIMBY (Not In My Back Yard) syndrome which affects site selection was stressed.

5. Mr. Ryhanen (TVO, Finland) outlined the Finnish Programme for Nuclear Waste Management including plans to deal with low and intermediate level waste

and spent fuel from the Olkiluoto and Loviisa nuclear power plants. A concept assessment report for a repository for spent fuel was presented to the Finnish government in 1985 as well as a list of potential areas for field investigations. Problems had been encountered in gaining permission to carry out field investigations due to public opposition. Of several non-technical issues raised, community acceptance of field investigations and the final repository were highlighted as a major problem area.

6. Mr. Lefevre (CEA, France) presented a review of geological disposal of radioactive waste in France. The organisation charged with responsibility for disposal of low level, high level and transuranic waste is the National Agency for Radioactive Waste Management (ANDRA) while the Institute of Protection and Nuclear Safety (IPSN) of the CEA carries out safety studies including field research. Four rock types will be studied as potential hosts for an underground repository, two in sedimentary rock - clay and salt, and two in hard rock - granite and schists. A national inventory of potential sites was completed in 1983; from this, 30 zones were chosen and it is intended that site investigations will be carried out on the most promising ones. The aim is to choose a site by 1989 where an "underground site validation laboratory" could be established as a first step towards the construction of a final repository for transuranic waste and, eventually, some high-level waste. The planned budget of ANDRA for 1986-94 is 1500 million Francs (US $220 million); the budget of IPSN for geologic disposal research is currently 20 million Francs (US $3 M) per annum but will increase during the 1990-94 period. The main non-technical issue at the current time arises from the delay in acquiring the agreement to go ahead with site specific investigations, which in turn may lead to delays in the final implementation of disposal.

7. Dr. Araki outlined the Japanese programme for high level radioactive waste management. A phased approach to site selection is adopted with concurrent in situ studies at a specifically designed underground laboratory. The latter is located at Kasama in the north of the main island of Japan, where heater, migration and corrosion experiments are being carried out. Expenditure to date on R & D has been $17.8 million, while the projected expenditure in 1986 is $6.4 million and in 1987 is $12.7 million. Major technical issues at the present time centre on the main objectives of the R & D programme i.e. the identification of a candidate site, the development of an acceptable assessment methodology etc. Of particular interest to Japan would be the possibility to use radioactive materials in experiments carried out at underground research laboratories.

8. Mr. del Olmo informed the Group of the main features of the policy towards radioactive waste management in Spain including legislative controls, financing, options considered for the disposal low and high level waste and the strategy for the selection of a site for a final repository to be operational by 2010. Mr. Huertas outlined the background to the establishment of an underground research laboratory (IPES) in northwest Spain. Three phases of development are planned: (i) 1986-89, construction and hydrogeological characterisation; (ii) 1990-94, experimentation; and (iii) 1995-2000 demonstration.

9. Dr. Bjurström presented the Nuclear Power Waste Management Programme in Sweden, making reference to legislative controls, basic guidelines followed and administrative arrangements. The management of the back-end of the nuclear fuel cycle in Sweden involves a combination of storage and disposal

facilities some of them being already implemented. Currently the main emphasis of R & D is devoted towards establishing a final repository for spent fuel in granitic rock. The cost of radioactive waste management in Sweden to date was put at 5300 MSEK (US $750 M) with a projected expenditure of a further 39300 MSEK at 1986 prices (US $6000 M). The Swedish Nuclear Fuel and Waste Management Company (SKB) had recently submitted a 6-year R & D programme plan to the Swedish government which is currently under review by some 50 Swedish organisations and 20 organisations from abroad. Mr. Ahlström described the main features of the programme. It provides for research and site investigations at 12-14 sites leading to the choice of 2-3 candidate sites for the repository for spent fuel. Provisions is also made for the development of an underground research laboratory at one of the possible sites. At the URL, pilot scale and in situ tests, demonstration and validation experiments are proposed. An integral part of the programme is the active participation by Sweden in several international projects to provide supporting information on technology development and increased confidence in safety assessments.

10. Dr. Rometsch described the high level waste disposal programme in Switzerland of NAGRA, the national cooperative for radioactive waste management, in the context of the overall Swiss situation. The most recent achievement of the first regional study phase of the programme (1978-90) was the completion of a major feasibility study - Project Gewähr. The response of the Government to the report is now expected in mid 1987. When this regional study phase is completed the detailed characterisation of 1 or 2 sites will be carried out (1990-2010) in advance of construction of a repository (2010-2020) and then full operation (2020). Again international cooperation/collaboration plays a major supporting role to domestic R & D. Currently expenditure is around 40 million Swiss Francs (US $25 M) per annum and it is estimated that the cost of the programme, up to and including construction, will be around 1.5 billion Swiss Francs (US $1 Billion) with a further 1.5 billion Swiss Francs required to complete operations i.e. around 3-4% of generation costs. Current issues including the coupling of disposal issues with considerations of the future use of nuclear energy, the provision of sound information for public consumption and technical and socio-economic influences on the allocation of manpower and resources were highlighted. Also the development of proven and accepted site characterisation methodologies was one of several technical issues mentioned.

11. Dr. Feates informed the Group of the current strategy of the United Kingdom on the disposal of radioactive wastes. A decision was taken by the British Government in 1981 to store high level wastes for at least 50 years and consequently no site specific research would be carried out in the U.K. for the time being. However, the U.K participates in relevant international programmes, in particular those involving field research, as well as selected laboratory studies. Performance objectives had been established and, largely in response to public pressures, the concept of Best Practical Environmental Option had been developed as a method for judging the most appropriate methods of disposal for particular types of waste. Mr. Ginniff outlined the current work of NIREX, the Nuclear Industries Radioactive Waste Executive which is carrying out site investigations on four potential sites for the disposal of low level radioactive waste. Attention was now being turned to intermediate level waste where several different alternatives were being examined including mined cavities on land or under the coastal seabed and from artificial islands. He indicated that it would be difficult to establish an underground research laboratory due to public opposition; local opposition to site investigations of any kind were highlighted as the major non-technical issue.

12. Mr. Rusche provided the Group with a number of remarks on the programme of the Office of Civilian Radioactive Waste Management of the US, DOE. The passing of the Nuclear Waste Policy Act in 1982 represented a major milestone in radioactive waste management in the United States. Among other things, it specified methods of disposal, site selection procedures, timetables and provided the funding via a charge of 0.1 cent per net KWhour of electricity generated. The first repository for high activity waste will be chosen from 3 sites recently recommended for site characterisation which have different geologies i.e. tuff (Nevada Desert), basalt (Hanford Reservation, Washington) and bedded salt (Deaf Smith, Texas). Total site characterisation costs for each site would be about $1 billion [During later discussion, it was made clear that this global figure includes expenses not directly related to technical and scientific activities on the site. The latter actually represents only about 50% of the total cost]. The site exploration activities for the second repository had recently been indefinitely postponed which meant that all site specific work on crystalline rock was at a halt, although technology work was continuing through participation in field projects abroad and by selected laboratory and performance assessment activities. As such international cooperation plays a major role in the US DOE R & D programme on crystalline rock. The integrated waste management system for the US includes a monitored retrievable storage facility to receive, package and handle fuel from the eastern part of the country and to serve as a limited interim storage facility. The MRS will be proposed by the US as soon as legal injunctions are lifted.

3. PRESENTATION OF ON-GOING INTERNATIONAL ACTIVITIES

13. Mr. Orlowski presented a general overview of the R & D activities on geological disposal as part of the Programme on the Management and Storage of Radioactive Waste of the Commission of European Communities. The Commission's radioactive waste management research activities began in 1975 to examine costs and establish joint conclusions on safety and feasibility among members of the European Community. There now exists a substantial multi-disciplinary programme involving not only direct activities carried out at research establishments of the CEC, but also by sponsoring research on a shared cost basis in individual Member countries. The Commission is in the process of extending this type of arrangement to R & D carried out at several in situ research/demonstration facilities i.e. Mol, Belgium (clay) and Asse, FRG (salt) and it is hoped that a URL in crystalline rock will also be sponsored in the foreseeable future. The total annual budget is around 4 million European Units of Account (US $4 M).

14. Mr. Olivier presented a review of the Ongoing Programme of the OECD Nuclear Energy Agency in the field of radioactive waste management with particular emphasis on geological disposal of highly active waste. The NEA Radioactive Waste Management Committee has recently established two new standing groups of direct relevance to discussions on enhanced cooperation on crystalline rock technology. The NEA Advisory Group on In Situ Research and Investigations for Geological Disposal (ISAG) met for the first time on 18th-19th October 1986 to discuss possible joint activities in the area of in situ research. A number of initiatives had been agreed on a technical level including: (i) establishing a consultant group to examine the link between experimentalists and modellers; (ii) sponsoring workshops on excavation

response and on backfilling and sealing materials and techniques; and (iii) exploring ways for increasing information exchange (a) among specialists and (b) to a wider audience. In addition, the Performance Assessment Advisory Group had been established to carry out a similar function to ISAG in the area of performance assessments and to help coordinate the growing number of RWMC activities in this area. The main thrust of its work is to develop confidence in performance assessments among the technical community. The agreement on a Cooperative Programme for the Exchange of Scientific and Technical Information Concerning Nuclear Installation Decommissioning Projects was cited as a possible example of the kind of flexible agreement that could be considered should a formal agreement on collaboration among crystalline rock repository projects be developed.

4. DISCUSSION OF TECHNICAL AND NON-TECHNICAL ISSUES RAISED UNDER ITEMS 2 AND 3

15. The various written contributions presented under Item 2 contained an outline of technical and non-technical issues; a summary of these is provided as Annex 4. The Chairman opened the discussion on enhanced cooperation by referring to several points raised during the previous day. During considerable discussion a number of comments were made which are summarised below:

(i) It would be useful to compare information provided in the programme summary documents for example on technical objectives, costs, regulatory needs, specific issues of current concern etc. For example, striking differences on global cost figures were explained at the meeting, revealing notable differences in accounting practices. Such comparisons could help dispel possible misunderstandings over different approaches among countries having similar ultimate goals i.e. establishing repositories in crystalline rock;

(ii) There is a need to promote a common understanding of various national site selection procedures and their respective background. For example, the reasons why a particular approach adopted in one country is different from another, and why a particular number of sites are selected for investigation in different phases;

(iii) On the issue of site characterisation:

- there is a need to understand the scope of site characterisation approaches and, if different, the rationale behind them;

- there is a need to exchange views on the content of a site characterisation programme and on the extent to which in situ experiments are necessary as a preliminary to the decision to establish a final repository. For example should a horizontal gallery be driven through the complete extent of a planned repository in order to provide detailed information rather than rely on borehole data;

- An exchange of views would be desirable on the ability to account for unexpected findings in site characterisation, for example, in designing seals for previously undetected fracture zones;

(iv) On the subject of underground laboratories, it was considered that their purpose may be significantly different. The first generation of such laboratories, like Stripa, were designed essentially to develop and improve methodologies for its characterisation and engineering research, notably on backfilling and sealing techniques. A second generation of laboratories, such as the one planned in France, have a different objective: they will be located at a site which could be considered potentially suitable for the location of a final repository. Their main purpose is to confirm, after further characterisation work, the validity of the site with a view to using it for an actual repository. In this respect, the comment was made that underground laboratories in general are useful in bringing together teams of trained and experienced individuals able to provide in due course the information required for site characterisation, validation and eventually construction. Furthermore, in addition to the complementary work which can be made at different underground laboratories, these facilities prove very useful in a public relations perspective.

(v) An exchange of views on the extent to which post-closure monitoring is necessary may be beneficial. This was highlighted as an issue of major importance in the public's eyes.

(vi) Similarly, an exchange of views on the various approaches to demonstration of technical feasibility and safety might be useful;

(vii) A comparison of legislative and administrative approaches among OECD Member countries may be beneficial in order to better understand the reasons for the adoption of specific approaches.

16. In addition, the meeting identified a number of advantages and disadvantages in comparing the radioactive waste management situation in the various countries. It was considered, however, that advantages would be much more significant if some of the issues mentioned above could be further discussed, the differences between national programmes explained and the background behind decisions at national level better known.

5. DISCUSSION OF INTEREST IN ENHANCED COLLABORATION AND FUTURE ACTIONS

17. With the benefit of the above considerations, the Chairman opened discussion by posing two questions: (i) Is there value in a group composed of directors of crystalline repository projects meeting on a regular basis? and (ii) If so, to what extent should this be formally recognised? During the ensuing discussion it was considered that two types of discussion could be usefully held: firstly on common technical issues and secondly on national approaches to waste management including social and political-related issues and decision making. Further, discussions would be most beneficial if restricted to the area of crystalline repository programmes rather than

including those investigating other geological media. In addition, any regular arrangement should not adversely affect national programmes. It was also considered that the mechanism of meeting within the framework of the NEA Radioactive Waste Management Committee was useful, particularly if kept reletively informal and a fairly flexible approach adopted.

18. With regard to future actions, the Chairman said that each participant has particular interests and therefore there was a need to proceed cautiously so as not to produce adverse results. There was value in exchanging information and pursuing personal contacts among project Directors and merit in using the existing mechanism of the NEA. It was recognized in this context that only a few countries (i.e. Sweden and Canada) have already chosen crystalline rock for hosting their future repositories, while others (i.e. Switzerland) are concentrating their efforts on this rock type without having really taken a firm decision for the future. In other countries (i.e. France, USA) the choice of a rock type is in general largely undecided. In this context the grouping of a small number of countries may be quite appropriate for specific aspects of crystalline rock programmes. Following a short discussion of draft terms of reference for the setting-up of a Crystalline Repository Project Directors Group (CRPDG) it was considered that although no points of contention were raised it was too early to formally establish the group by adopting specific terms of reference. The topic could be addressed at the next meeting. Subsequently, the Group agreed the following course of action:

(i) recognise and announce that the meeting was held;

(ii) agree to meet again in about one year time; notably to review broad issues of interest to all participants.

(iii) recognise that individual Member countries may elect to work together using existing mechanisms.

6. MEETING RECORD STATEMENT

19. The Group agreed that within two weeks the NEA Secretariat should prepare a summary record of the meeting after consultation with Mr. Rusche in his capacity of Chairman of the ad hoc Group and Dr. Rometsch in his capacity of Chairman of the RWMC. A report would subsequently be made to the next meeting of the RWMC based on this summary record.

7. CLOSING REMARKS

20. The Chairman warmly thanked participants for their cooperation and endeavours that helped make the meeting a thorough success. Dr. Rometsch expressed the appreciation of the participants for the United States having taken the initiative in suggesting the meeting and for taking the chair.

ANNEX 1

CRYSTALLINE REPOSITORY PROJECT DIRECTORS' GROUP (CRPDG)

Paris, 3rd-4th November 1986

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ANNEX 2

ENHANCED COLLABORATION ON CRYSTALLINE ROCK TECHNOLOGY FOR REPOSITORIES

BROAD AIMS OF DIRECTORS MEETING ON 3-4 NOVEMBER 1986

- To provide a forum in which directors of major crystalline rock projects can review the current status of development and consider additional measures (complementing the existing international activities) to enhance cooperation and collaboration amongst their programmes.

Specific Objectives

- To review crystalline rock programmes, with interest focused upon key technical and non-technical issues.

- To promote mutual understanding of similarities and differences in strategies or in choice of technical options among the Directors.

- To assess the level of interest in enhanced cooperation, note potential relevant areas and discuss the range of mechanisms which might be employed.

- To decide upon further actions aimed at enhanced collaboration and, in particular, upon the value of formalising a project directors' group which would meet periodically.

- To agree to a statement on the outcome of the meeting to be forwarded to the RWMC of the NEA in response to the action agreed at its meeting on 8-9 July 1986.

ANNEX 3

List of documents distributed at the meeting

Program Summary Sheet, Canadian Nuclear Fuel Waste Management Program, AECL, Canada.

Finnish Programme for Nuclear Waste Management TVO, Finland.

Geological Disposal of Radioactive Waste in France, Studies in granite formations, CEA-ANDRA, France.

National Program for the High Level Radioactive Waste Management - Special positions and issues for Common Interest, Japan.

Nuclear Power Waste Management Programme in Sweden, SKB, Sweden.

High-level Waste Disposal Programme, NAGRA, Switzerland.

Programme summary, UK Department of the Environment.

Programme of the Office of Civilian Radioactive Waste Management, US Department of Energy.

R & D Programme on the Management and Storage of Radioactive Waste, CEC.

Ongoing Programme of the OECD NEA in the field of Radioactive Waste Management, NEA.

ANNEX 4

Issues of major importance to one or more Crystalline Repository Programmes

a) Non-Technical issues (social/political and/or regulatory).

1. Developing Public Credibility/Confidence.
2. Site selection process.
3. Post-closure monitoring needs.
4. Demonstration of disposal technology.
5. Linking of RWM with discussions on the continuation (or not) of nuclear power use.
6. Providing adequate information for the public.
7. Allocation of man-power to areas of technical and/or socio-political priority.
8. Local opposition to site investigations.
9. Local opposition to repository siting.
10. Obtain permission of landowners to carry out investigations.
11. Obtaining government permission to procede with next phase of site selection programme.

b) Technical Issues

Performance assessment

1. Waste form degradation processes.
2. Radiochemical/geochemical data bases.
3. Radionuclide transport in buffer materials.
4. Performance of sealing materials.
5. Groundwater flow characteristics.

6. Radionuclide migration in geosphere.

7. Development and refinement of safety criteria and guideline for disposal.

8. Quality assurance procedures.

9. Bedrock stability.

10. Integration of performance assessment methodologies.

11. Verification and validation of performance assessment models.

Site characterisation

12. Development of proven and accepted site characterisation methods.

13. Definition and extent of site characterisation programmes.

Engineering

14. Alternative repository designs.

15. Development of disposal facilities for low- and intermediate level wastes.

16. Development of interim storage facilities.

Note: The above list is based on a brief review of issues highlighted as being of importance by participants in the ad hoc meeting of Directors of Crystalline Repository Projects.

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

RWM/DOC(87)1

RESTRICTED

Paris, drafted: 12th May 1987

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Or. Eng.

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Progress Report on the International Stripa Project

1. This note is intended to inform the Committee of progress within the International Stripa Project, in particular on the impending completion of Phase II and the latest developments on Phase III. Since the seventeenth RWMC, a meeting of the new Technical Sub-group (TSG) has been held in Helsinki on 24th-26th March when, in particular, the technical details of Phase II as well as the early findings and plans for Phase III were critically appraised. The resultant proposals were considered by the Joint Technical Committee (JTC) on 5th-6th May at the OECD in Paris. The following background and developments can be reported.

Progress on Phase II

2. Phase II of the project was started in 1983 and will be completed by the end of June 1987. The main aim was to develop techniques to assess the geology, hydrology and hydrogeochemistry of potential sites for the disposal of radioactive wastes, as well as to perform tests to examine groundwater flow within fractured rock and assess properties of a backfilling and sealing material. It contained research grouped under five headings:

(i) Development of Crosshole Measurement Techniques - to determine the location, extent, thickness and physical properties of fracture zones. It involves the development of radar, seismic and hydraulic methods.

(i) The 3-D Migration Experiment - to show the spatial distribution of water flow paths in fractured crystalline rock and to make model validations and if needed, modifications.

(iii) Hydrogeological Characterization of the Ventilation Drift Area - to characterize fracture permeability fracture porosity and the groundwater flow system.

(iv) Hydrogeochemical characterization of the Stripa Groundwaters - to interpret the origin and evolution of Stripa groundwater and to develop field monitoring techniques.

(v) Borehole, Shaft and Tunnel Sealing Test - to test the rate of maturation of sodium bentonite plugs and to investigate the practicality of using bentonite for plugging purposes.

3. Based on the numerous conclusions from Phase II, it is clear that each of the main objectives has been met. The studies have led to the considerable advancement of both the investigation techniques and practical knowledge available for repository siting and engineering design. An essential step forward in the understanding and detection of fractures has been made although further progress is required to gain a more complete understanding of groundwater flow. Also, sealing materials now exist for all applications required in developing and closing a repository. The reporting of Phase II work will be completed by August 1987 when an executive summary will be prepared, similar in format to the one recently published for Phase I.

Progress of Phase III

4. Canada, Finland, Japan, Sweden, Switzerland, the United Kingdom and the United States will contribute funding for the 5-year Phase III programme which will cost around 112 million Swedish Crowns (about $18M). The formal agreement is being circulated to signatories at the current time. This phase builds on the findings of earlier work with the following areas being studied:

(i) Site Characterization and Validation - to characterize and and prepare validated models of the geologic and hydrologic conditions in a previously undisturbed block of Stripa granite by using the most up-to-date techniques and numerical models. A five-stage programme of investigations, predictions and validation will be carried out in order to test the ability to predict groundwater flow within fractured crystalline rock.

(ii) Groundwater Flow Path Sealing - to test fracture sealing candidates by: (a) reviewing candidate grouting materials and techniques; (b) selecting candidates for study; (c) investigate physical properties; (d) assess longevity; and (e) carry-out a pilot test at Stripa. The two main candidate materials are cement based and montmorillonite-rich clay based grouts.

(iii) Channeling Experiments - to estimate water residence times in fractures; investigate dispersion mechanisms and mixing properties; and the available sorption surface of fractures. This will involve single and double borehole testing of single fractures to give an indication of transmissivity variations and the frequency and configuration of channels.

(iv) Development of High Resolution and Directional Radar - to further develop single hole and crosshole radar techniques so as to: (i) estimate dip and strike (orientation) from single hole measurements; (ii) show the structural details of fracture zones and (iii) further evaluate 3-D interpretation techniques.

(v) Improvement of Techniques for High Resolution Borehole Seismics - to develop improved high resolution seismic equipment that will function both in single-holes and cross-holes. As with (iv) this builds on Phase I and II work with the overall aim of further developing site investigation techniques.

Dissemination of Information

Consistent with the completion of Phase I, the JTC agreed to several actions regarding information dissemination to a wide technical and non-technical audience. An executive summary and a video film will be produced and a scientific symposium will be organised in order to present the results and conclusions from Phase II together with the plans for and preliminary findings of Phase III.

Future Meetings

Developments on the above proposals will be discussed at the next meeting of the TSG which will be held in the United Kingdom on 22nd-24th March 1988 and at the next JTC meeting which is planned for 14th-15th June 1988.

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

RWM/DOC(87)7

RESTRICTED

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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

NEA Sponsorship of the Proposed International Alligator Rivers Analogue Project

1. Following discussion of possible initiatives by the RWMC in the area of natural analogues at the sixteenth and seventeenth meetings, discussions have continued within the Performance Assessment Advisory Group (PAAG) in order to provide guidance and recommendations. This note outlines the results of these deliberations and presents a proposal for establishing an international project sponsored by the NEA based on research work carried out since 1981 in the Northern Territory of Australia to be known as the International Alligator Rivers Analogue Project.

Recent Developments

2. It is widely agreed that particular natural analogues i.e. a natural (including man-made) occurrence of materials or processes which are analogous to those expected to be associated with a radioactive waste repository, can be useful by increasing our knowledge of certain complex processes that need to be modelled as part of a performance assessment of a radioactive waste disposal system. They can either be qualitative or, more preferably, quantitative in nature, both types help to increase confidence in predictions made using mathematical models.

3. In 1985, the CEC established a Natural Analogues Working Group (NAWG) to bring together modellers and earth scientists, in particular, so that the maximum benefit can be obtained from analogue studies with respect to the safe disposal of radioactive waste. The most recent meeting of the NAWG was combined with a CEC Symposium on Natural Analogues in Radioactive Waste Disposal which was held in Brussels on 28th-30th April 1987. At this symposium it was clearly recognised that natural analogues can play a major role in increasing confidence in predictions and by helping to validate predictive models that incorporate certain long term processes. Future efforts will, in particular, be directed towards seeking ways to validate performance assessment models by using, at least in part, natural analogues.

4. Given the established CEC work on natural analogues, which involves several non-CEC countries, the activities of the NEA in this area have been restricted to participation as an observer in the NAWG, as well as more general discussions within PAAG. However, the increasing internationalisation of the Australian Alligator Rivers Analogue activity, led to a proposal being made by Australia at the sixteenth RWMC meeting for an international project to be established on the lines of the NEA Stripa Project [see SEN/RWM(85)6]. The proposal was referred to the PAAG for consideration and guidance. Subsequently, a series of discussions took place which culminated in a presentation being made by the Australian delegate to the second PAAG meeting on 16th-18th March 1987. The recent work at Alligator Rivers was described with particular emphasis on the application of the research at Alligator Rivers to performance assessments. PAAG was informed that studies began at Alligator Rivers in 1981 with support from the US Nuclear Regulatory Commission (NRC) and in 1986 the UK Department of the Environment also sponsored work at the site. The Japanese Atomic Energy Research Institute (JAERI) has also carried out collaborative studies. The Group learned that an international project starting in mid 1987 was in the process of being negotiated by the Australian Atomic Energy Commission (AAEC) involving the participation of the Australian Nuclear Science and Technology Organisation (ANSTO, formerly the AAEC), Japan (JAERI), the United Kingdom (DOE) and the United States (NRC); a document outlining the detailed proposals formed part of the presentation to the PAAG meeting. Following some discussion on the merits of natural analogues and of the proposals, the group recognised the high value of natural analogue studies to performance assessments. Also, following confirmation that the role of the NEA Secretariat in support of the Alligator Rivers Project would be similar to that required by the Stripa Project, i.e. participating as an observer in the Joint Technical Committee (JTC) of the project, being kept informed of developments, producing overview reports, providing reports to PAAG, ISAG and the RWMC, etc., PAAG agreed to recommend to the RWMC that the NEA sponsor the Project. However, on the subject of the need for more broad information exchange activities, PAAG recognised that the present CEC initiative for information exchange on natural analogues was sufficient to meet current requirements [see SEN/RWM(87)2].

First Joint Technical Committee Meeting

5. Subsequent to discussion within PAAG, the first meeting of the Joint Technical Committee of the proposed International Alligator Rivers Project was held on 24th April in London. Representatives from ANSTO, JAERI, UK DOE and US NRC were present as well as from SKI (Sweden), PNC (Japan) and OECD/NEA. The proposed technical programme, budget, organisation and a draft agreement for the project were each discussed. With regard to the technical programme, six sub-projects are proposed i.e.:

(i) Modelling of radionuclide migration
(ii) Geohydrology at Koongara
(iii) Uranium/Thorium Disequilibrium Studies
(iv) Transuranic Nuclide Studies
(v) Fission Product Studies
(vi) Colloid Studies

Broad details of these are provided in the programme proposal distributed at the sixteenth RWMC. These sub-projects were each agreed in principle, although the highest priority was assigned to modelling studies.

With regard to possible participation in the project, firm interest was expressed by ANSTO, JAERI, UK DOE and US NRC while SKI, indicated that it would be interested in contributing to modelling studies, especially to facilitate the link to the SKI initiated INTRAVAL project. Also PNC, Japan said that it was actively considering participation.

6. Given the positive interest in participation shown by those at the meeting, the following actions were agreed:

(i) the proposed start date would be 1st September 1987

(ii) an agreement would be drawn-up based on the one contained in the proposal document

(iii) a technical annex giving broad programme objectives would be prepared based on the recommendations of the JTC.

(iv) followint the consideration of the proposal by the NEA RWMC, the draft agreement plus technical and financial annexes would be distributed by the NEA by 1st July

(v) a Modelling Task Group would meet early in the project to work-up the technical details of the modelling programme. Representatives from each participant would be invited to attend.

Recommendations

7. The Committee is invited to consider the recommendation of the PAAG and recent developments outlined herein and agree to recommend to the Steering Committee for Nuclear Energy to support the setting up of the International Alligator Rivers Analogue Project as an NEA Project on the lines of the existing International Stripa Project. The Committee is also invited to note the recommendation by the PAAG that no additional activities are considered necessary given the established mechanism provided by the CEC Natural Analogues Working Group.

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

SEN/RWM(87)2

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STEERING COMMITTEE FOR NUCLEAR ENERGY

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Report of the Second Meeting
of the NEA Performance Assessment Advisory Group (PAAG)
16th-18th March 1987

The second meeting of PAAG was held in Paris from 16th to 18th March. A detailed report is given in the record below. The most pertinent points to be mentioned from the meeting are:

* Participation from Member countries has been further increased and in its present composition PAAG combines high competence and broad overview in performance assessment matters to guide the RWMC in its programme.

* The first day of the meeting was devoted to information exchange on recent developments within the performance assessment area in Member countries and at NEA.

* Proposals to increase resources devoted to computer codes and data bases in the radioactive waste management area at the NEA Data Bank were discussed. Noting that the NEA Data Bank already actively supports a number of well-established projects within NEA, such as the ISIRS, the TDB and the work of the PSAC User Group, PAAG strongly supported the proposals to provide increased support from the NEA Data Bank in these and related areas.

* Questions related to the identification and selection of scenarios for performance assessments of nuclear waste disposal were considered by PAAG to be a high priority area. It endorsed the proposal to review in depth the present experiences and to discuss further, within a small working group, a set of important issues on scenarios. To collect basic information a questionnaire has been set up and will be sent to the Member countries. A progress report from the working group and a draft review report will provide the background for a one-day topical session on scenarios in conjunction with the next meeting of PAAG.

* The organization of a workshop on near-field assessment was discussed. PAAG agreed to focus the workshop on near-field assessments of repositories for low- and intermediate level waste.

* PAAG took note of the present activities within the PSAC User Group and endorsed its plans for future intercomparison exercises.

* PAAG noted also the progress made on the Thermochemical Data Base (TDB) and recognised the need to provide at national level a more official and greater financial support to the specialists involved in the evaluation of the Data Base. PAAG agreed to propose that this role could be played by the ISIRS Executive Committee, with appropriate adjustments in its composition to reflect this broader mandate.

* Based on a report of preliminary conclusions from the NEA Workshop on Uncertainty Analysis for System Performance Assessments recently held in Seattle, PAAG discussed with great interest the subject of uncertainties. It was concluded that particularly the conceptual uncertainties would have to be considered in more detail. Decisions would be taken at the next PAAG meeting before which the proceedings of the workshop in Seattle will be available.

* PAAG agreed to recommend to the RWMC that OECD/NEA sponsor the International Alligator Rivers Analogue Project. The AAEC, US NRC, UK DOE and JAERI are prepared to provide funding for this project. No other NEA initiatives in the area of natural analogues were considered necessary for the moment, as these are covered by a group organised by the CEC.

* Among other issues discussed by PAAG were:

  - methods and procedures to assign research priorities
  - how to transmit results of performance assessments to the public
  - operational safety of nuclear waste repositories
  - quality assurance.

  These would be taken up later on in the work of PAAG.

Performance Assessment Advisory Group (PAAG)

Summary record of the Second Meeting held at OECD, Paris
16th-18th March 1987

Present:

Mr. Hardy, Australia
Mr. Marivoet, Belgium
Mr. Bragg, Canada
Mrs. Wuschke, Canada
Mr. Storck, Federal Republic of Germany
Mr. Vieno, Finland
Mr. Peltonen, Finland
Mr. Lewi, France
Mr. Van Kote, France
Mr. Gera, Italy
Mr. Mishima, Japan
Mr. Muraoka, Japan
Mr. Andersson, Sweden
Mr. Papp, Sweden (Chairman)
Mr. Hadermann, Switzerland
Mr. McCombie, Switzerland
Mr. Zurkinden, Switzerland
Mr. Grimwood, United Kingdom
Mr. Hogdkinson, United Kingdom
Mr. Thompson, United Kingdom
Mr. Coplan, United States
Mr. Liebetrau, United States
Mr. Cranwell, United States
Mr. Turner, United States
Mr. Cadelli, CEC
Mr. Sartori, NEA Data Bank
Mr. Wanner, NEA Data Bank
Mr. Olivier, NEA
Mr. Carlyle, NEA
Mr. Chamney, NEA
Mr. Ruegger, NEA
Mr. Thegerström, NEA

Item 1: Opening of the meeting

1. The meeting was opened by Mr. Olivier who welcomed participants to this second meeting of the NEA Performance Assessment Advisory Group (PAAG). He noted with satisfaction the interest of Member countries in the group as manifested by the level of participation to this meeting. He expressed his confidence in that the group would be able to have constructive discussions and to work effectively in spite of the large size of the group. He then invited the chairman of PAAG, Mr. Papp to take over the meeting.

2. Mr. Papp recalled that this was the second meeting of PAAG, noting that PAAG's own proposals were now being initiated and developed. He welcomed all the participants and in particular those who participated for the first time, namely:

- Mr. Hardy from Australia
- Mr. Bragg from AECB, Canada
- Mrs Wüschke from AECL, Canada, replacing Mr. Wikjord at this meeting
- Mr. Storck from F.R.G.
- Mr. Peltonen, Finland
- Mr. Gera, Italy
- Mr. Mishima, Japan
- Mr. Coplan, US NRC as official US representative and Mr. Liebetrau, Mr. Cranwell and Mr. Turner, participating as observers for US DOE, US NRC and the US Defense Waste Program respectively.

Item 2: Approval of the Agenda

3. The Chairman referred to the agenda given in PAAG/DOC(87)1 and called on Mr. Thegerström to briefly explain the contents. He said that there were three main purposes of this meeting:

- information exchange between PAAG members on recent developments in the performance assessment area within their Member countries (Item 5 on the agenda)

- information update on NEA activities in performance assessment related areas and in other areas (item 6 on the agenda)

- presentation and discussion of proposed PAAG activities (item 7 - item 13 on the agenda).

Emphasis should be on the discussion of new activities and it was proposed that the meeting be planned so that items up to and including item 6 be covered during the first day. The agenda was adopted in full.

Item 3: Approval of the minutes of the first meeting of PAAG

4. Comments had been received from Dr. Cadelli, CEC and the following amendments should be introduced in SEN/RWM(86)4:

On page 10, item 17 , substitute lines 5 to 7 with: ....."*site specific assessment for repositories in clay, granite, salt and the sub-seabed are being carried out. Reference sites were chosen and the selection was based for each option (Mol, Auriat, Gorleben and GMC) on the availability of a maximum of information on the site and the host rock. Variant sites were also added*"....

Substitute last line with: ....."*assessment of intermediate level and alpha bearing waste called PACOMA*".

By that the minutes of the first meeting of PAAG were approved.

Item 4: Comments on PAAG activities at the last meeting of the radioactive waste management committee (RWMC)

5. The Chairman briefly related the discussion of PAAG matters at the last RWMC meeting with special reference to paragraphs 7, 13, 15, 16 and 17 in SEN/RWM(86)6. Thus he recalled that the Committee had expressed great interest in PAAG and that it had endorsed its terms of reference underlining the need to report to the Committee on suggested initiatives indicating their order of priority. To reflect this, the following addition is introduced in the terms of reference of PAAG [SEN/RWM(86)4, page 2]:

v) report regularly to the RWMC on proposed initiatives by PAAG.

6. The Chairman further recalled that the RWMC had agreed that Australia should be invited to the next PAAG meeting. He also referred to item 11 on the agenda, where Mr. Hardy would inform PAAG on the Australian proposal for an OECD/NEA sponsored international project on natural analogue studies at Alligator Rivers.

Item 5: Recent developments in Member countries

7. Participants briefly updated PAAG on developments since last meeting in the area of performance assessment in their respective country or organisation. Since most of the presentations were supported by written contributions that were distributed during the meeting, the content of the presentations are not related in these minutes. A list of all written material is attached in appendix 2 and further copies can be obtained from the NEA Secretariat.

Item 6: Progress of NEA activities in performance assessments and related areas

8. Mr. Thegerström made a brief introduction to this item recalling that further discussion of the future activities related to databases and codes would be held under item 7. Item 6 was thus intended mainly as an information update on the NEA activities, while item 7 would deal with the question of how to maintain and develop some of these activities to the best benefit of Member countries.

9. Mr. Ruegger gave a brief update of developments within the ISIRS project [3] [15]. He mentioned that all data submitted to date have been loaded into the data base, which now contains data relative to 2600 sorption experiments. He reviewed the answers given to requests for ISIRS data and he pointed out that the best can be obtained from ISIRS when the user interact directly himself with the system as in a case where a French scientist from CEA worked with ISIRS for several weeks at the NEA Data Bank in Saclay. Thus this is encouraged whenever feasible. He also said that efforts are being made to make the ISIRS more user-friendly both for loading of data and for data searching. The efforts are directed towards adoption on micro computers as far as possible. Finally, he mentioned that NEA plans to hire a consultant to upgrade the present data base in selected areas by collection and loading of new data to ISIRS.

10. Mr. Wanner described recent developments of the NEA Thermochemical Data Base (TDB) [4]. He mentioned that the reviewers on uranium met in December last year. The meeting had been very fruitful and similar meetings with the review teams on americium and technetium are planned for beginning of next Autumn. The Uranium reviewers decided at their meeting that a few experiments should be performed to certify some very basic uranium reaction data upon which the thermodynamic data of most other uranium species critically depend. They also decided that organic complexes of uranium should not be taken into account at this stage as it would further delay the publication of the uranium book, which is now planned to appear at the end of this year. It was also mentioned that a short course on the use of the code MINEQL/EIR will be held on 25th-26th March at the NEA Data Bank. There will be 10 participants from 7 countries which is about optimum for a course with an intense interaction between teachers and participants.

11. Mr. Carlyle informed on activities within the Probabilistic Systems Assessment Codes (PSAC) User Group [12] [16]. One meeting of PSAC had been held in London on 11th-14th November 1986. In conjunction with that meeting a one day topical workshop was held on the "Reduction of Research Codes to PSAC Sub-models". The Level 0 intercomparison exercise to test executive modules of PSA Codes has been finalized, the results have been compiled and a level 0 draft report is under preparation. Further intercomparison exercises are being planned on comparison with exact solutions and on hypothetical disposal systems, one for deep disposal and one for shallow disposal. A plan is also being prepared for the next two years activities within the PSAC User Group. It will outline the broad objectives of the group and clarify the future orientation of the groups' work on intercomparison exercises. The next PSAC meeting will be held in Stockholm in June and hosted by SKB. A topical meeting on justification of probability density functions will then also be held.

12. Mr. Sartori informed about the work and services of the NEA Data Bank in support of the PSAC User Group. He first mentioned that there has been a marked increase in requests for codes in the radioactive waste management area during the last years. In co-operation with members of the group, the NEA data bank develops standard interface formats especially as regards the pre-processing and post-processing of input data and of results. Random number generators and sampling modules have been collected, tested and made available to the group.

13. Mr. Cranwell asked if it would be acceptable to the PSAC User Group if the Sandia group would join the group at this stage. Mr. Carlyle said that it would pose no problems and that the Sandia group would be welcome to participate in the work. He mentioned that several groups have joined PSAC after having participated as observers at one meeting to get an insight to the work done by PSAC.

14. Mr. Carlyle informed briefly about the activities of the Advisory Group on In-Situ Research and Investigations for Geological Disposal (ISAG) [5]. He mentioned that ISAG held its first meeting in October 1986. Similar to PAAG, its role is to inform and advise the RWMC on activities in the area of in-situ research and field investigations. Among the initiatives taken by ISAG at its first meeting were the preparation of workshops on (a) excavation response as a result of repository construction and (b) backfilling and sealing materials and techniques. (a) is planned to be held in November this year in Paris. A report, for wide distribution, on R&D activities in the area of in-situ research and demonstrations

will be prepared. Ways to increase interaction between experimentalists and modellers will also be explored by ISAG (see further item 10 below). The next meeting of ISAG will be held on 23rd-25th June this year.

15. Mr. Olivier gave some brief informations on the Crystalline Rock Program Directors Group (CRPDG). In response to an initiative by Mr. Rusche, head of the US DOE Office of Civilian Radioactive Waste Management, the NEA organised an ad hoc meeting at directors level with participation of countries having an interest in nuclear waste disposal in crystalline rocks. Questions discussed at the meeting dealt mainly with national programme strategies and the processes and costs for site characterization and site selection. It was recognized at the meeting that there are existing mechanisms for co-operation at different levels between these countries. The group agreed to meet again in about one year time, notably to review broad issues of interest to all participants. A report would be made to the next meeting of the RWMC.

16. Mr. Andersson updated the PAAG on recent developments within the HYDROCOIN project. Two workshops and co-ordinating group meetings had been held during the period, one in Japan, May 1986 and one in the Netherlands, November 1986. The level 1 report, on code verification, has been finalised and it will be printed by NEA as soon as the co-ordinating group has given its final clearance. All level 2 (validation) and level 3 (sensitivity and uncertainty analysis) cases have been defined and most of the calculations should be finished at the time of the next workshop which will be held in Washington D.C. in May. This would, according to previous planning, be the last HYDROCOIN workshop. However, in response to the wish of many participants, it will be considered to arrange, if needed, a final workshop at the end of this year. The level 1 report would thus appear this year while the reports on level 2 and 3 would probably be published during 1988. Mr. Andersson pointed out that there is an interest and need to secure the safe deposition and storage of all data related to Hydrocoin case definitions and calculation results. New groups who would like to use these data for testing of their own codes and modelling methodologies could then benefit from easy access to such a data base. The NEA data bank might be well suited to provide this follow up service on Hydrocoin.

17. Mr. Andersson also mentioned briefly the plans for INTRAVAL, a project for validation of geosphere transport models. Two ad-hoc group meetings have been held to plan the project and a third ad hoc group meeting will be held in Stockholm from 2nd to 3rd April. It is believed that subsequent to this meeting formal invitations to participate could be sent out. The project structure will be very similar to that for HYDROCOIN. The only exception being that a technical committee is foreseen in INTRAVAL to help the project secretariat with the technical/scientific planning and evaluation of the project.

18. Mr. Thegerström informed about the plans for an NEA Newsletter on Radioactive Waste Disposal. The broad objective would be to provide brief and concise information on activities at NEA and in Member countries. The scope would be R&D related to nuclear waste disposal and national programs as well as selected topical subjects. The information provided by members of RWMC, PAAG, ISAG at meetings would be used as primary information sources. In addition, voluntary contributions from individuals in Member countries would be welcome. When appropriate, a systematic collection of information on selected topics might be

made as in the previous newsletter on radionuclides migration in the geosphere. A draft newsletter would be prepared for discussion at the RWMC meeting in June.

19. Mr. Carlyle presented the preliminary conclusions from the NEA Workshop on Uncertainty Analysis for System Performance Assessments held in Seattle, on 24th-26th February in co-operation with the US DOE. He handed out a draft document highlighting the major issues discussed at the workshop and conclusions/recommendations. He mentioned that a summary of discussions and conclusions will be prepared for inclusion into the proceedings that will be published by NEA later this year.

20. The PAAG took great interest in this subject and several points of discussion or clarification were raised. The distinction between numerical uncertainties and conceptual uncertainties was underlined. While the treatment of parameter uncertainties is well advanced, for instance through the work of the PSAC User Group, it was noted that the conceptual uncertainties are often more difficult to treat but also very important in order to understand the overall uncertainties in performance assessments. One way to handle this would be to use several conceptual models and to compare the results. Another aspect mentioned was that some uncertainties might be eliminated "by decree" by regulators in their choice of indicators or time periods of concern.

It was agreed that most important is to get an understanding of where the highest uncertainties are to be found and to quantify these where possible. Some of the issues raised will be considered further in connection with the NEA work on scenarios (item 8 below). It was agreed that the proceedings of the Seattle workshop will be sent to PAAG members and that the summary and recommendations should be incorporated into a discussion paper to be presented at the next PAAG meeting when any possible further initiatives in this area would be discussed.

Item 7: Needs and priorities for computer related activities in system performance assessment of nuclear waste disposal

21. Mr. Olivier made an introduction to this item. He outlined its relation to the future programme of work for the NEA Data Bank that will be discussed at the NEA Steering Committee Meeting on 28th-29th April. He said that the comments and advise of PAAG as to the plans in RWMC/DOC(86)6 would be submitted to the Steering Committee before its meeting. He underlined that the document had been worked out with the help of consultants from several Member countries on the request of the RWMC. Members of the RWMC, of the Executive Committee of ISIRS and of PAAG had also been consulted.

22. Mr. Thegerström briefly reviewed the content of the plans in RWM/DOC(86)6. He underlined that the main purpose is to reinforce the competence and resources of NEA in providing effective services to back up its co-ordinating role in international co-operation projects involving advanced computer codes and data bases. He also summarized the written comments that had been received.

23. The Performance Assessment Advisory Group confirmed the need for the high priority to be given to activities related to long-term performance assessment of disposal systems and the associated computer-based techniques. Noting that the NEA

Data Bank has already begun to support, on a modest scale, a number of well-established projects within NEA, such as the ISIRS System, the Thermochemical Data Base (TDB) and the work of the PSAC User Group (Probabilistic Systems Assessment Codes User Group). PAAG strongly supported the proposals concerning the future of the NEA Data Bank in the area of radioactive waste management. In particular, PAAG welcomed the role of NEA and of the Data Bank as a catalyst and co-ordinator for international activities on performance assessment and agreed that increased efforts in this field would enhance considerably the credibility of performance assessment tools. PAAG also agreed in general with priorities indicated in document RWM/DOC(86)6 with regard to the work on data bases and on computer codes and with the type of services to be provided by the Data Bank. However, the group advised the Secretariat to carefully keep under control the amount of work involved. It was also confirmed that NEA itself would probably not play an active role in the carrying out of actual performance assessment calculations.

24. As a conclusion, therefore, the need for NEA to reinforce its competence and resources in an area of high priority and under rapid development was clearly recognised, particularly if the Agency is expected to continue to remain in the forefront of activities in the field of performance assessment through PAAG and the RWMC. A great deal of efforts is currently devoted at national level to the development of improved methodologies and scientific tools for performance assessment. In this context, it appears desirable for NEA to aim essentially at upgrading these efforts through international co-operation that will promote increased confidence in data bases and computer programmes being used for performance assessment.

25. Under this item PAAG discussed also a proposal to establish a "Geochemistry" Group to assist in the development of the TDB project. The group agreed with the need to provide at national level a more official and greater financial support to the specialists involved in the evaluation of the Data Base. Instead of setting up a new group, PAAG agreed that the ISIRS Executive Committee could play this role, with appropriate changes in its present composition in order to reflect this broader mandate and possible changes of the membership, and also the likely integration of the ISIRS project in the normal programme of work of the NEA.

Item 8: Working group on identification and selection of scenarios for performance assessment of nuclear waste disposal

26. Mr. Thegerström introduced this item. As decided at the first PAAG meeting brief overviews on scenario issues had been collected from PAAG members and a small consultant group had been convened to help propose further NEA activities in this area. The work up to now was documented in PAAG/DOC(87)2.

27. The PAAG considered the scenario issues as a high priority area. It endorsed the proposal to review in depth the present knowledge and experiences and to discuss further a set of important issues on scenarios at an international level within NEA.

It agreed to set up as proposed a small working group or extended consultant group to deal with these issues. It pointed out that this group should start to consider the technical issues like terminology, general approaches and methodologies as a first priority before entering into discussions on more

philosophical or regulatory related issues. It stressed the need to keep the work strongly linked directly to PAAG. It agreed to explore the possibility of compiling a scenario catalogue with the help of the proposed questionnaire and it gave some advice as to the formulation of the questionnaire. It pointed out that the NEA might consider to hire one or two consultants to help evaluate and prepare further background material and the review report. It proposed that PAAG itself be given the opportunity to discuss scenario-related questions in depth at its next meeting on the basis of the document prepared by the working group.

28. In view of the proposals given and the subsequent discussions the following actions are foreseen:

- The Secretariat will send out, after due completion in view of comments provided by PAAG, the questionnaire to PAAG. PAAG members will provide as complete answers as possible to the questionnaire within less than two months from they receive it.

- The working group will be established on the basis of the answers received and in consultation with PAAG members.

- The Secretariat will, possibly with the help of one or two Consultants prepare further the review report and other background materials for consideration at a working group meeting to be held this autumn.

- A progress report from the working group and draft review report will be provided in advance of the next PAAG meeting. Preparations will be made to arrange for a one-day topical discussion of scenarios related issues in conjunction with the next PAAG meeting.

- Based on the discussions at the next PAAG meeting further directions and priorities will be given for the NEA work on scenarios.

Item 9: Workshop on near-field studies/modelling

29. Mr. Thegerström related the proposed objective and scope of a workshop on the near-field [PAAG/DOC(87)3]. In line with the follow-up of conclusions reached on this point by PAAG at its first meeting one of the objectives was set out to be to discuss the possible needs in this area for verification/ validation of models and databases through international co-operation.

30. Many different viewpoints on this subject were expressed by PAAG members. The need to focus on some specific aspects of all the different near-field issues was pointed out. After some discussion, it was agreed to focus the workshop on near-field assessment in conjunction with disposal of low and intermediate level waste, including waste containing radionuclides with long half-lifes. Integrated near-field assessments and modelling as well as the effects due to the presence of large amounts of concrete and other conditioning materials in the near-field would be part of the workshop program. Focus would be on chemical rather than thermo-mechanical effects.

Item 10: The interaction between experimentalists and modellers

31. Mr. Carlyle introduced this item by referring to discussions at the NEA Workshop on performance assessments in October 1985 when, among other things, the link between modelling and field/laboratory observations was discussed, and discussions at the first meeting if ISAG. Increasing interactions between experimentalists and modellers was considered of high priority by ISAG and was the main item on the agenda of a small meeting of ISAG members in mid-February, when it was decided to issue a questionnaire to ascertain the most important issues so that any future initiatives to increase interaction between performance assessments and in situ investigation at an international level could have a firm foundation.

32. PAAG noted developments on this issue within ISAG and the importance of maintaining communication between experiments/in situ investigations and modelling, both at national and international levels and that this was a topic that concerns both ISAG and PAAG. It was therefore agreed that both groups should participate in fulfilling the following actions:

- The NEA Secretariat will prepare a draft questionnaire to be sent for comments to ISAG and PAAG during April/May
- The final version of the questionnaire would be agreed at ISAG meeting in June,
- It would be distributed to PAAG and ISAG for completion over Summer,
- The results would be considered by a consultant group of performance assessors and in situ researchers/investigators from PAAG and ISAG in the Autumn.

Item 11 Natural Analogues

33. The Chairman in introducing this item recalled that it had been discussed at the first PAAG meeting as well as at the last meeting of RWMC. He also recalled that the RWMC had expressed considerable interest in this subject and had agreed that the NEA Secretatiat should maintain close links with the CEC group. It had also agreed to invite Australia to the next PAAG meeting and had proposed that PAAG should consider further the need for new initiatives in this area and advise the Committee on the most appropriate NEA involvement, in view of what is already being done at an international level.

34. Mr. Hardy gave a presentation of the AAEC evaluation of uranium ore bodies in the Alligator Rivers Province as analogues of radioactive waste repositories. He outlined the advantages of natural analogue studies to help understand and to get long-term evidences of important phenomena and processes in the near-field as well as for migration in the geosphere. He mentioned results on very slow migration of uranium (100 min million years), evidences for matrix diffusion and for retardation of I-129. He also highlighted experimental difficulties i.e. the need to be able to measure very low levels of I-129 and Pu, which make it necessary to apply state-of-the-art methodologies. Alligator Rivers studies had been started in 1981 with support from US NRC from 1981 to 1986 and a contract from UK DOE in 1986. There had also been informal collaboration with JAERI.

35. As regards the future programme at the Alligator Rivers an international project to be started 1st of July 1987 is now being proposed to interested countries by Australia. Four Organisations, AEC, US NRC, UK DOE and JAERI, are prepared to provide funding for this project and other organisations have expressed interest in participating in different ways without direct funding. The details of the project proposal are given in a document that was distributed to PAAG. Mr. Hardy said that he considered it to be important that the project now was consolidated into an international project sponsored by OECD/NEA. He therefore asked the PAAG to give its support for NEA-sponsorship of the Alligator Rivers Analogue Project and to advise the RWMC accordingly.

36. In the subsequent discussion it was clear that PAAG recognised the high value of Natural Analogue studies. Consequently PAAG found it appropriate for NEA to give a support to the project. On the specific question whether PAAG would recomment NEA to sponsor the Alligator Rivers project, the three countries having indicated their interest to join Australia in the full project, JAERI Japan, UK DOE and US NRC, considered a NEA sponsorship to be of high value to the project. Mr. Olivier clarified the implications of a NEA sponsorship. As the practical set-up of the project was more or less complete it would not require additional work by NEA. The project would be given the status of an international OECD-project and at the practical level NEA would be involved in the project secretariat and help organise workshops and publish the main reports. PAAG agreed to recomment to the RWMC that NEA sponsor the project.

37. Mr. Cadelli informed about the CEC activities in the area of natural analogues. The CEC has set up a natural analogue working group. This is a small research oriented working group. Participation is open to specialists without restriction to CEC-Member countries. Two meetings have been held with the working group the last was in Interlaken in June 1986. A final document (EUR 10672) from this meeting will soon be released.

CEC is organising a broad symposium on natural analogues. It will be held in Brussels in the last week of April. A planned meeting of the CEC working group on natural analogues has been postponed from November to beginning of next year. Mr. Cadelli also mentioned that the IAEA will hold an Advisory Group Meeting on the usefulness of natural analogues in performance assessments in Vienna in November.

38. The PAAG considered the present CEC arrangements for information exchange on natural analogues as sufficient. Apart from the sponsoring of the Alligator Rivers project there is thus today no need for further NEA initiatives in this area. The need for close co-ordination between all the international organisations was underlined in order to avoid putting too much burden on the limited group of experts already heavily involved both at a national level and in international activities.

Item 12 Methods and procedures to assign research priorities

39. The Chairman introduced this item as being of concern in most waste disposal programmes. It had been raised by Mr. McCombie at the first PAAG meeting. Mr. McCombie said that it was basically a question of how to allocate available resources in a R&D programme. It was very much related to the site-investigation

programmes and site selection procedures. Some of the questions raised during the discussion were:

- rationales for decisions on breadth and depth of site- characterisation programmes
- when are we satisfied with our state of knowledge and with remaining uncertainties in a particular area?
- how do we use performance assessments as a tool for decisions in site characterisation programmes and in site selection?

40. This topic was considered to be related to discussions under Item 10 in that the assignment of research priorities often involved interaction between experimentalists and modellers. It was therefore agreed that this topic would be considered as a separate item during the joint meeting of a few ISAG and PAAG members in the Autumn and a report with recommendations would be prepared for the next meeting.

Item 13 Proposal for additional activities

41. No specific additional activities for immediate action were proposed. Several items were mentioned however that might be considered later on in the work of PAAG.

- The role of experts in public information. How to transmit results of performance assessments to the general public.
- Operational safety of nuclear waste repositories.
- Multiattribute analysis in site selection processes.
- Quality assurance in general and possibilities for NEA to assist in particular.

Item 14 Any other business

42. Mr. Olivier mentioned that the had been approached informally by the IAEA concerning very preliminary plans for a large international symposium in 1989 on performance assessments of nuclear waste disposal (no title has been set). Mr. Olivier mentioned that the present NEA policy is to concentrate its efforts on smaller workshops on well defined subjects but that he would like the opinion of PAAG on the need for a symposium and the type of NEA involvement in that case. After some discussion, it was concluded that:

- NEA should basically keep to its present principle to mainly organise workshops on specific subjects.
- There is some merit to present results in an area in a broader way from time to time.
- If a symposium on performance assessment is organised in 1989 the NEA and PAAG should get directly involved in the planning and organisation of the meeting.

Item 15 Date of next meeting

43. The next meeting of PAAG is planned to be held in January 1988. A proposal for exact dates will be sent before the Summer.

Appendix 1

2nd MEETING OF THE NEA PERFORMANCE ASSESSMENT ADVISORY GROUP (PAAG)

2EME REUNION DU GROUPE CONSULTATIF DE L'AEN SUR L'EVALUATION DES PERFORMANCES DES SYSTEMES D'EVACUATION

16th-18th March 1987

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(Secretary: Mrs. Iris De Meyère)

APPENDIX 2

List of documents for second PAAG meeting
16th-18th March 1987

A. DOCUMENTS SENT OUT IN ADVANCE

1.	SEN/RWM(86)4	Report on the first meeting of the NEA Performance Assessment Advisory Group, 12th-14th May 1986
2.	SEN/RWM(86)6	Summary Record of the RWMC Sevententh Meeting
3.	SEN/ISIRS(86)2	Summary Record of the Sixth Meeting of the Executive Committee, 26th June 1986
4.	PAAG/DOC(87)4	Progress in the Development of NEA Thermochemical Data Base (TDB) since the 1st Meeting in May 1986
5.	SEN/RWM(86)8	Summary Record of the first meeting of the Advisory Group on In Situ Research and Investigations for Geological Disposal (ISAG), 28th-29th October 1986
6.	C.ROCK/DOC(86)2	Summary Record of the Ad Hoc Meeting of Directors of Crystalline Rock Projects, 3rd-4th November 1986
7.	EN/S/1600	Circular letter
8.	RWM/DOC(86)6	Needs and Priorities for Computer Related Activities in System Performance Assessment
9.	PAAG/DOC(87)3	Proposal for a NEA workshop on near-field assessment
10.	PAAG/DOC(87)2	Identification and Selection of Scenarios for Performance Assessment of Nuclear Waste Disposal

11. Discussion notes on scenario issues from PAAG members:

- CEC
- Finland
- France (ANDRA)
- Japan
- Sweden (SKB + SKI)
- Switzerland (Nuclear Safety Inspectorate)
- Switzerland (NAGRA)
- United Kingdom (BNFL)
- United Kingdom (NIREX)

8. DOCUMENTS DISTRIBUTED AT THE MEETING

NEA documents

12. PSAC/DOC(87)1 NEA Probabilistic Systems Assessments Codes (PSAC) User Group. Summary Record of the Fourth Meeting held at the Department of the Environment, London 11-14 November 1986.

13. PAAG/DOC(87)5 Proposal for the establishment of a NEA "Geochemistry" group for the NEA Thermochemical Data Base (TDB) project

14. ROOM DOCUMENT No. 1
NEA needs and priorities for Computer-Related Activities in Waste Disposal System Performance Assessments - Responses from Member countries

15. Summary of the oral report on the ISIRS Project (Note by the Secretariat)

16. The Activities, Objectives and Recent Achievements of the NEA Probabilistic Systems Assessment Codes (PSAC) User Group [Paper presented at Waste Management 87', Tucson]

17. Draft Summary of decisions of the 2nd PAAG meeting

Contributions from participants

18. The Alligator Rivers Analogue Project (Australia)

19. Recent developments in Performance Assessment in Belgium

20. Regulatory objectives, requirements and guidelines for the disposal of radioactive wastes - Long-term aspects (Canada)

21. Recent developments in performance assessment for the Canadian nuclear fuel waste management program (Canada)

22. Development in performance assessment in Germany (Federal Germany)

23. Developments in performance analysis of nuclear waste disposal in Finland between May 1986 and March 1987 (Finland)

24. Main developments in France in the area of performance assessments since the last PAAG meeting (May 1986) (France)

25. Andra's Programme (France)

26. Radioactive waste management policy in Japan

27. A guideline to radionuclide concentrations of low-level radioactive wastes to be disposed of by landfill (Japan)

28. Current schedule of R&D for geological disposal in Japan

29. Handling and final disposal of nuclear waste; SKB R&D Programme 86 (Sweden)

30. Performance assessment in Sweden - Recent developments

31. Notes on the status of repository performance assessment in Switzerland

32. Progress with Radiological Assessments for Nirex in the United Kingdom

33. Recent progress in environmental assessment work relating to low-level waste disposals at Drigg, Cumbria in the UK

34. Progress during 1986/87, UK DOE

35. Notes concerning the use of "scenarios" in post-closure radiological risk assessment, B. Thompson, UK DOE

36. NRC announces intention to revise definition of high-level nuclear waste (USA)

APPENDIX D

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

ISAG/DOC(87)5

RESTRICTED

Paris, drafted: 22nd May 1987

dist: 27th May 1987

English text only

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

IN SITU ADVISORY GROUP (ISAG)

Discussion Paper for ISAG Consultant Group Meeting
Paris, 16th-17th February 1987

This report is provided for the information of ISAG members. It was prepared as a discussion document for the meeting of a consultant group which was convened to consider the future programme of ISAG. It was prepared by the Secretariat based on a number of written contribution from various ISAG members and the results from previous activities by NEA.

4930

CONSULTANTS MEETING

THE FUTURE PROGRAMME OF THE NEA IN SITU ADVISORY GROUP

OECD/Nuclear Energy Agency

Paris, 16th-17th February 1987

NEA/ISAG CONSULTANTS MEETING
16th-17th February 1987

AGENDA

DAY 1

Item 1 Brief review of actions and recommendations from first ISAG Meeting on October 1986 SEN/RWM(86)8

Item 2 CRPDG

Item 3 Discussion of the form and content of the proposed state-of-the art report on In Situ Research and Investigations in OECD/NEA Member countries.

Item 4 Discussion on Ways to Improve Communication and Interaction between Performance Assessors and In Situ Rechearchers and Investigators

DAY 2

Item 5 Preparation of outline programme for workshop on excavation response

Item 6 Discussion of publication of an NEA newsletter

Item 7 Preparation of outline meeting statement

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NOTE: (i) The meeting will be chaired by Dr. Arnold BONNE.

(ii) Participants in the meeting will be:

Mr. Bonne	CEN/SCK, Belgium
Mr. Simmons	AECL, Canada
Mr. Brewitz	GSF, Federal Republic of Germany
Ms. Andre-Jehan	ANDRA, France
Mr. Zuidema	NAGRA, Switzerland
Mr. Weidmann	NAGRA, Switzerland
Mr. Bourke	AERE, United Kingdom

(iii) The meeting will began at 1.30 pm on 16th February at NEA offices, 38 boulevard Suchet, Paris 16ème

Item 2: Discussion of the form and content of the proposed stated-of-the-art report on In Situ Research and Investigations in OECD/NEA Member countries

The following is based on comments received from Canada. It is suggested that the report concentrate on 'Current In Situ Research Programs in Underground Laboratories for Nuclear Fuel Disposal' rather than include R&D orientated towards site evaluation in general. The following report outline has been suggested:

(1) General Introduction including the various media
(2) Historical Review of Completed Research Programs
(3) Programs in Clay and Argillaceous Media
(4) Programs in Crystalline Rock Media
(5) Programs in Salt Media

Each of (3), (4) and (5) should cover:

- Introduction to media, laboratories and participants
- Discussions of each laboratory and its program
- Supporting research in host country and other countries
- Areas requiring further development or study

(6) Summary and conclusions.

It is suggested that the group discuss this outline as a basis for deciding the scope and format for the report. It is intended that the first draft be prepared for distribution in advance of the next ISAG meeting in June so that the document can be finalised at the meeting.

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Item 3 Discussion on Ways to Improve Communication and Interaction between Performance Assessors and In Situ Rechearchers and Investigators

SUMMARY

The attached paper provides background for discussions within the consultants group on ways for ISAG to improve communication and interaction between performance assessors and in situ researchers and investigators. A number of general commentaries on this topic have been received by the Secretariat, but only a few concrete recommendations for action. One recommendation was received, however, that seems to focus on the problem at hand i.e.

> "Workshops involving both the performance assessors and the field investigators are an essential step in increasing interactions between performance assessors and field investigators. A series of such workshops including participants from the world's technical community should be sponsored and supported. Essential information to be provided by the performance assessors for these exchanges should focus on identifying which uncertainties are amenable to quantification and possible reductions by in-situ testing and what information is needed to validate models. Results of sensitivity studies should be used to indicate which parameters are critical to the analysis and should be conveyed to planners of in-situ tests. Similarly, parameters critical to design should be identified. It is also important that field investigators convey to modelers and performance assessors the practical limitations of available testing procedures."

The groups opinions are sought on the above proposal.

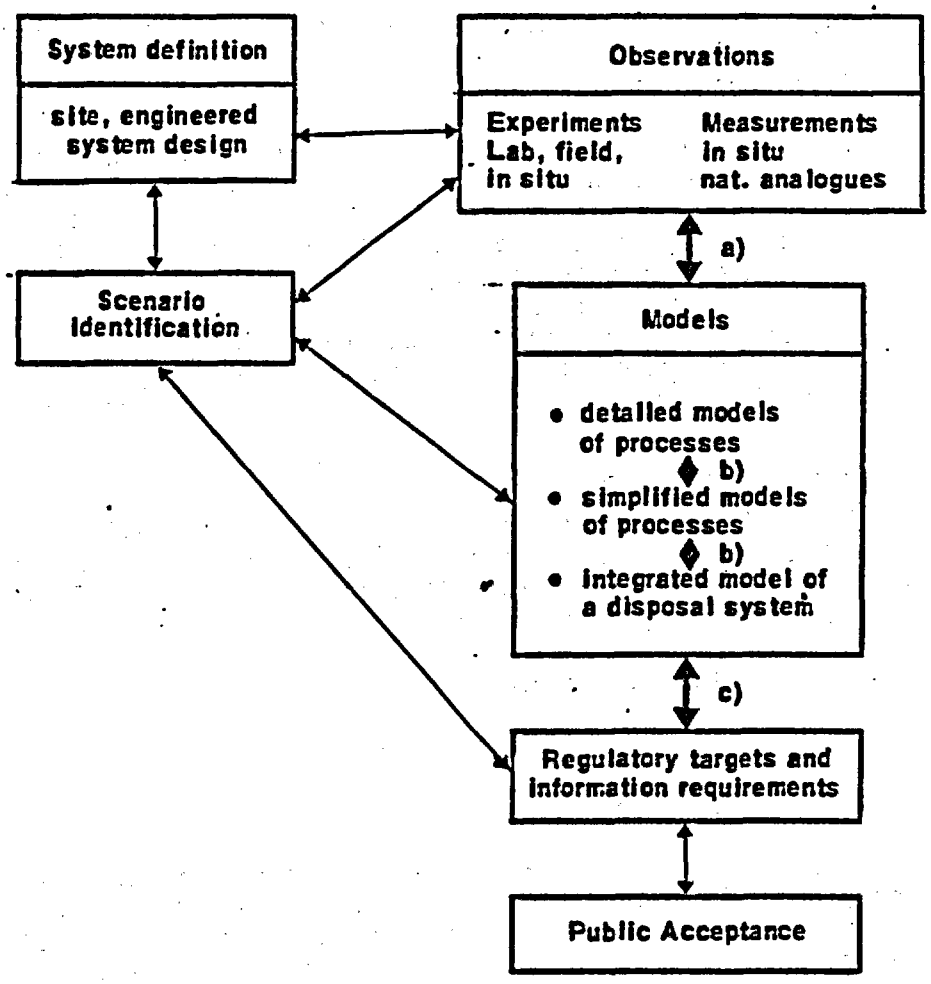
DISCUSSION DOCUMENT

Ways to Improve Interaction Amongst Performance Assessors and In Situ Researchers and Investigators

INTRODUCTION

The interaction between modellers and site investigators was considered in some detail at an NEA Workshop on Systems Performance Assessment for Radioactive Waste Disposal held in Paris on 22nd-24th October 1985. At this meeting a review was carried out of the main linkages between particular elements of system performance assessments for radioactive waste disposal, to identify areas where improvements can be made and suggest ways of carrying these out. Figure 1 gives a diagrammatic representation of the main linkages. It is perhaps useful to recall the main points arising during discussion on the link between model development and field/laboratory observations as well as the recommendations made so that the consultant group may take these into account in recommending a course of action to ISAG.

LINKAGES IN SYSTEM PERFORMANCE ASSESSMENTS



a) Link between the development of models and observations (validation)
b) Link between detailed models and simple models and Link between separate models and an integrated system model
c) Link between the output of performance assessments and regulatory requirements.

It was generally agreed at the workshop that, in order to carry out comprehensive performance assessments, it is essential to develop a thorough understanding of the processes involved, fully characterize the system being modelled and possess a complete data base for use in making predictions. The key issues raised in terms of understanding the linkage between model development and field/laboratory observations were:

i) How to make reliable predictions of future behaviour?

ii) How to take account of uncertainty in predictions? and

iii) When has sufficient site characterisation been achieved?

The linkage between model development and field/laboratory observations was felt to represent an interactive process of site and system characterization. Initially, the available system characterization data are used to develop preliminary models for use in setting initial performance allocation goals, designing and directing further experiments to improve the site characterisation data base and alter, if necessary, the conceptual models. Ultimately, the goal becomes one of developing an observational data base that supports the validity of the detailed subsystem models for the range of site conditions that are important to performance assessment needs.

1. Model Validation

The problem here arises from the fact that "full validation", in the context of complete confirmation of used theories and parameter values, can never be achieved. Attempts to validate a model generally encompasses one or more of the following procedures:

- laboratory experiments;
- field tracer experiements, and
- natural analogues.

It was felt that laboratory and field experiments, if properly conducted and carefully designed, are of use in model validation, particularly for short time scales. However, several problem areas associated with laboratory and field experiments were identified. These were 1) sampling procedures can alter the properties of samples; 2) time and spatial scales for experiments are short compared to time and spatial scales involved with repository performance assessments; 3) difficulty in simulating properties of the system at repository depths; 4) lack of laboratory data from test sites; and 5) uncertainties concerning groundwater flow.

Information from natural analogues was also felt to be useful in model validation, especially with respect to long time scales. Problems with natural analogues, however, arise from the lack of good analogues in the time range of 1000 to 100 000 years and in defining initial boundary conditions. Also, almost all useful information which can be obtained from natural analogues relates to chemical processes and is of little use in groundwater flow modelling.

Possible Solutions

Since full validation was felt to be impossible, one approach suggested was to develop an international consensus on a strategy for validation work with the objective being to reach some agreement on the range of applicability of different modelling approaches and reasonable assurance that the models provide a good representation of the processes occurring. The degree of validation would be different for different models depending on their role in performance assessment. The need for more carefully designed experiments for the purpose of model validation was also suggested. It was felt that to achieve this, there was a need for close collaboration between field and laboratory experimentalists, geologists and modellers. The use of natural analogues despite their shortcomings, was felt to be useful in answering some of the important questions regarding long term assessment of processes in the natural environment. Further investigation into the use of natural analogues was recommended. Finally, international benchmarking programs such as INTRACOIN and HYDROCOIN were felt to be extremely useful for addressing the problems of model validation. The benchmarking program INTRAVAL and that proposed within the NEA User Group for Probabilistic Systems Assessment Codes will also be very useful in the model validation effort.

2. Data

Concerns about performance assessment data can best be classified as 1) availability of data; 2) acquisition of data; and 3) use of data. Problems with the availability of data arise from the degree to which data will be available for model development (for example, fracture data for use in a dual-porosity model) and the bias injected by overlooking the original purpose of previous data collection efforts. For example, oil well exploration data provide a convenient source of existing data on deep systems but the drill stem testing techniques commonly used to measure hydraulic properties have the potential for routinely excluding any of the higher permeability measurements because of the limitations of the technique. Identification of bias is important to both the use of existing data in models and the design of new data collection efforts.

Problems with data acquisition can arise from the sample size, frequency (spatial variation), the tools and instruments used to collect data, and interpretation and extrapolation of data. For example, observations and measurements of parameters are made at "points" within the system. However, characterisation of the variability of these parameters in space and time is typically required to model and make performance assessment predictions. Thus, the "point" information needs to be extrapolated over the spatial and time domains. A more complicated situation arises for parameters that cannot be measured directly (e.g. permeability and dispersivity), but must be determined indirectly through inverse modelling techniques.

Problems associated with the use of data can arise from the misuse of previously collected data, (as discussed above), use of so-called "lumped" parameters (e.g. distribution coefficients), and use of homogeneous data in a heterogeneous system.

Possible Solutions

Careful use of data, improved measurement techniques, close collaboration between experimentalists and modellers, and well-defined data

acquisition programs were all suggested as possible solutions to the performance assessment data problem. Issues that need to be considered and addressed when field data are used and when planning and designing data acquisition programs were suggested. They include:

- How should small-sample data be averaged to obtain equivalent large-sample estimates for our performance assessment models? Is it necessary, and is it appropriate?

- What effect does variability in sample size have on our ability to obtain estimates for the spatial distribution of the data set, and what effect will this have on our estimates of spatial correlation lengths?

- How important is it that many of the parameter interpretation theories were developed for a homogeneous world while the real world is heterogeneous?

- For inversely determined parameters in a heterogeneous world, what is the appropriate relationship between:

  . the perturbation stimulus;

  . kind, number, locations, and sampling size of response observations;

  . model used for test interpretation;

  . the sampling size of the test; and

  . the band width of spatial frequencies the test can detect.

Other issues of importance when using data and when planning data acquisition programs were:

- Purpose of the assessment and stage of the assessment program.

- Conceptual model or models for the system.

- Performance assessment approach (e.g. detailed or bounding) and the theory associated with this approach.

- Scale or sampling size and frequency of sampling in both space and time

- Kinds of tools or instruments used to gather the data or make observations.

- Methods used to interpret and extrapolate these measurements or data.

3. Uncertainty

Several sources of uncertainty in performance assessment were identified. These included 1) data; 2) models; 3) human error; 4) future events; 5) time and spatial scale effects; and 6) understanding basic physical and chemical processes. It was felt that a major effort in developing

confidence in our performance assessment predictions would be in reducing, quantifying, or bounding the uncertainties associated with all important components involved in making performance assessment predictions.

Possible Solutions

Uncertainty analysis should be an integral part of any performance assessment methodology, regardless of the performance objective required by the regulatory agency. Several techniques for performing uncertainty analysis currently exist. Some of the more commonly used are 1) the classical "Monte Carlo" simulations; 2) differential analysis techniques; and 3) experimental design methods. Other more recent approaches are 1) the development of stochastic models; 2) geostatistical methods such as kriging; and 3) so-called statistical inverse methods. Additional work in this area needs to be encouraged, such as that proposed in the Level 3 HYDROCOIN program and international workshops on uncertainty analysis. The recent activities of the NEA in the formation of a consultant group on uncertainty analysis is a step in the right direction.

Comments from ISAG Members

Examination of the various contributions shows that the above workshop considered most aspects of the link between performance assessors and in situ investigators but perhaps with a bias towards the needs of performance assessors rather than the limitations to carrying out field studies, and also the need to refine site investigation methodologies and techniques to provide the right sort of information. Piet Zuidema (NAGRA) suggests there are 3 types of field investigation/experiment (ANNEX 1), i.e.

- site characterization for a potential repository to ensure that all relevant information is available for system assessments;
- experiments for validation purposes to enhance confidence in the models used; and
- experiments to investigate the reliability of exploration tools to reduce the risk of the unexpected [see Annex 1].

It is possible that some initiative in each of these areas could be initiated, for example workshops, working group etc. Rudolph Matalucci cited the SNL work under the WIPP programme i.e.

1. The technology development program prior to initiating the in situ tests focused on the procedure and long-term process necessary for model/code validation. This program included the following activities but were not limited to these:

   a. Performing benchmark studies were made using a well defined typical geomechanical problem.

   b. Obtaining and analyzing laboratory data for model development and verification.

   c. Involving modelers in the early planning for the in situ tests.

2. The planning for the in situ testing program included the collective efforts of modelers, analysts, principal investigator, experiment engineering and management at all stages of development. A peer review process utilizing a panel of consultants was applied to ensure that the tests were justified and adequately defined. More specifically, the following steps were taken:

   a. The model validation objectives for each test were clearly stated.

   b. Test configuration and measurement locations were carefully evaluated to ensure that the test met validation objectives.

   c. Theoretical and modelling personnel were involved in recommending test geometry and layout and in performing scoping calculations using available models.

   d. Modelers prepared pretest reference calculations to predict response of each test prior to test initiation.

3. The in situ data being acquired will be analyzed by the modelers and other analysts after it is reduced to a manageable format. The analysis process will involve a comparison between pretest predictions and in situ data. Appropriate evaluations of the models used in these comparisons will be made during the validation process. Modelers and testers will be involved in the final peer review process where judgments can be made on the adequacy of the models for use in design and performance assessment.

Charles Voss, PNL (DOE) suggests that there may be a lack of communication between modelers and field investigators. He suggests the use of a 'data request format' in the form of a questionnaire in order to 'force' communication and help eliminate inappropriate modelling approaches and site investigations (Annex II).

Gary Simmons (AECL) indicates that the key to integrating detailed performance assessment modellers with experimentors is to have them work on common projects i.e. analyses/experiments/investigations. These sentiments are echoed by Pat Bourke (AERE) who stresses joint involvement at the planning and application stage, the latter for review/quality assurance purposes.

POSSIBLE ACTIONS

Examining the various contributions and the recommendations seems to suggest that there is much concern about the need for improved communication between assessors and modellers, but less certainty on the type of action required from ISAG.

Mysore Nataraja (NRC) suggests that:

"Workshops involving both the performance assessors and the field investigators are an essential step in increasing interactions between performance assessors and field investigators. A series of such workshops including participants from the world's technical community should be sponsored and supported. Essential information to be provided by the performance assessors for these exchanges should focus on identifying which uncertainties are amenable to quantification and possible reductions by

in-situ testing and what information is needed to validate models. Results of sensitivity studies should be used to indicate which parameters are critical to the analysis and should be conveyed to planners of in-situ tests. Similarly, parameters critical to design should be identified. It is also important that field investigators convey to modelers and performance assessors the practical limitations of available testing procedures."

Whatever initiative is to be recommended in this area, it is important to be aware of other development at NEA, in particular, within the PAAG and other international groups, such as the CEC's Natural Analogues Working Group, and initiatives at a national level such as the HYDROCOIN and INTRAVAL groups. However, should we accept Dr. Nataraja's suggestion, then the first workshop could be on excavation response.

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Item 4: Preparation of an Outline Programme for a Workshop on Excavation Response

BACKGROUND

It was agreed at the first meeting of ISAG that workshops should be held on 'excavation response' during repository construction and 'backfilling and sealing' during the operation and closure of a repository. It was agreed that excavation response should be considered first and hence the concultant group is requested to recommend an outline programme for a workshop, probably to be held in late autumn 1987.

In Annex I, Piet Zuidema discusses the principle technical aspects of excavation response, describing the 'decompression zone', formed due to excavation of tunnels and shaft, as a possible short-circuit pathways for the transfer of any degradation products from emplaced radioactive waste. Swiss studies of hydraulic conductivity deformations and geophysical properties before and after excavation revealed negligeable differences. But, open questions remain on:

- were the right parameters measured?
- were the detection limits of the different tools low enough?

In addition, from the modeler and experimentalist viewpoint, three problems exist i.e.

- how do we assess the importance of excavation effects prior to the construction of a gallery?
- what is the reliability of experiments to measure excavation effects?
- what is the optimum design of an experiment to measure excavation effects?

In the USA (see Annex III) the need to consider the 'disturbed zone' is enshrined in Law. The NRC has prepared a Generic Technical Position (GTP) on the 'Interpretation and Identification of the Extent of the Disturbed Zone' in the High Level Waste Rule - 10 CFR 60. It specifies that changes in the host rock caused by (a) stress concentrations, (b) construction and excavation, (c) thermomechanical effects and (d) thermochemical effects, should be evaluated. Examples of excavation response tests are also given i.e.

1) CLIMAX FACILITY - At this facility which is in granite at the Nevada Test Site a mine-by test was performed. In this fully instrumented test, actual spent fuel and guard heaters were installed and the response to excavation of a parallel drift was measured. In addition a modelling study was performed before the test and after the test to attempt to reproduce the actual rock mass response. A document entitled "Post Test Calculations and Preliminalry Data Analysis for the Spent Fuel Test - Climax", (UCRL-53688) was prepared in December, 1985 and contains the results of the modelling study.

2) G TUNNEL - Geomechanical tests were performed at the G-tunnel facility in welded and non-welded tuff. These include a full scale heated block test. Although no full scale mine-by tests were performed in this facility, an attempt has been made to examine the rock mass response from this test. A reference on this test is "Final Report: G-tunnel Heated Block Experiment" (SAND-84-2620).

3) NEAR SURFACE TEST FACILITY - Large scale geomechanical and thermomechanical tests were conducted at the Near Surface Test Facility in Basalt. These tests include a heated block test, and large and small scale heater tests. A reference on these tests is "Summary of Near-Surface Test Facility Results and their Application to Repository Design", (RHO-BW-SA-256 P) and 2).

POSSIBLE ACTIONS

There are several alternatives with respect to the format the workshop could follow. Perhaps the first question to be answered is: Should it be host rock specific, or have sessions covering different rock types, or just take the best examples irrespective of rock type? Several commentators favour host rock specific approaches, however, Charles Voss (Annex II) suggests concentrating on what worked and what didn't work. Under this proposal, each country would describe upto three underground experiments as case histories, with particular emphasis on parameters monitored, the test design and implementation, the instrumentation used, the accuracy and robustness of the instrumentation used, their success or failure, data interpretation and recommendation for improvements.

Mysore Nataraja (see Annex III) suggests that the workshop(s) could aim to make recommendations on observing, measuring and quantifying excavation response under the following conditions: (a) excavations using boring machines; (b) excavations created by controlled/smooth wall blasting and (c) uncontrolled drilled and blasted excavations. Both vertical shafts and horizontal underground excavations should be considered as well as various rock types. In addition, thermal effects over a long operational time period should also be considered.

It was also suggested by Gary Simmons, that a workshop trying to deal independently with all three media types would be too unwieldy due to the large number of people that would be involved and the diversity of the subjects that would need to be covered. It was emphasised that in the licensing a waste disposal facility it will be necessary to demonstrate the ability to measure the immediate and time dependent changes that occur in the rock mass and to simulate the response mathematically, therefore, topics for a workshop should include:

- current knowledge on excavation response (USA, Switzerland, Sweden, Canada, etc.)

- mathematical methods available to simulate the mechanical-hydraulic coupled response of the rock mass to excavation

- instrumentation and methods available for quantifying the instantaneous and time dependent response of a rock mass to excavation.

It is suggested that we use this format (intended for a crystalline rock workshop) as the basis for developing an outline programme for one or perhaps a series of workshops on excavation response.

ANNEX I

PAPER PREPARED FOR THE NEA/ISAG CONSULTANT MEETING

Piet Zuidema, Nagra, Switzerland

interactions between performance assessment and in-situ investigations

1. main objectives for field experiments/investigations

The main rationale behind all field experiments is the necessity to construct a repository and to show compliance with (safety) criteria in future. The most challenging issue is reliable predictive modelling of system performance. Several activites are necessary to obtain a model readily applicable for assessments (Fig. 1). One can distinguish the following 3 main types of field investigations/experiments:

- site characterisation for a potential repository to ensure that all relevant information is available for system assessment
- experiments for validation purposes to enhance confidence in the models applied
- experiments to investigate the reliability of exploration tools to reduce the risk of the "unexpected."

The first type of investigation is site-specific; sometimes however, it can deliver information relevant for the other two topics as well. For the other two types of experiments, rock laboratories of the first generation (non-site-specific) can be used. Besides allowing for these experiments, first generation rock laboratories give the chance to collect field experience already before a specific site has been chosen. This can be valuable because no special care has to be given to avoid unintended destruction of barrier functions of the investigated rock. Additionally, the modellers have the opportunity to get some "field" experience from the modelling point of view.
Finally, it should be mentioned that rock laboratories can be used for "demonstration" experiments on a 1:1 scale.

2. Site investigations at a potential repository location

The requirements for a site investigation are as follows:

- disturbance of the site by the investigation should be minimized (non-destructive tools, optimized geometry of investigation galleries etc.)
- all necessary data should be sampled with sufficient accuracy.

Already when defining selection criteria for potential repositories some thoughts should be given to easing these requirements (eg. complexity of host rock, easy access for site characterization etc.).

In order to minimize disturbance of a site an approach in phases should be chosen. In a first phase the principal suitability has to be confirmed to such an extent that additional investigations during later phases (normally significantly more expensive) can be justfied. During the first stage non-destructive investigation tools should be applied to the largest possible extent. The main objectives of the first phase should be:
- confirmation of concept validity
- information to optimize later phases

In later phases all essential data to construct a repository must be sampled. This requires information on:
- data base for performance assessment
- information for construction purposes

The requirements on the performance assessment database are defined by the modellers. This database should include:
- information to decide on the relevant scenarios (identification of "model structure" and "important processes")
- information to properly identify and define the appropriate conceptual models
- information to evaluate the needed model parameters including their likely range of variation

The investigation programme must be designed jointly by modellers and experimentalists to make sure that all necessary parameters are evaluated with sufficient accuracy with appropriate, reliable tools. To decide on the amount of information and on the needed accuracy a close interaction with the modelling work is required. Because of the uncertainty in the (measured) data a partially probabilistic approach should be chosen for decision making (Fig. 2).
The questions faced in designing a satisfying experimental programme can be listed as follows:
- what must be measured with what accuracy?
- do we have an adequate conceptualization of the processes/systems? Not all details observed in the field can be represented in a model. This requires simplifications and can lead to models where the parameters cannot be measured directly.
- how representative are point observations (REV vs. observation volume)?
- what is the scale dependence of measured properties?
- how can the "unexpected" be minimized?

All this requires a good interaction between modellers and experimentalists. On one hand the modellers must be fully aware that the available input-data from a site investigation are always limited due to limited available timespans for site-investigations and to unavoidable deficiences in measurement methodologies. On the other hand the experimentalists should be aware that not every detail

from the site investigation can be included (explicitly) in the models.
Often it is not easy to overcome this discrepancy and as a consequence there is today a tendency to measure all (easily) measurable properties without fully considering their potential use at later stages.

3. Experiments for validation purposes

As indicated validation plays a vital role. To validate performance assessment models different approaches can be chosen:
- validation of process models by especially designed experiments (eg. migration experiments)
- validation by natural analogues

In the first case one can make sure that the initial conditions and the boundary conditions of the performed experiments are (at least in theory) sufficiently well known. The main drawback of the first type of experiment is however the limited timespan available to perform the experiment.
Validation by natural analogues often provides the opportunity to analyse "experiments" which have lasted for long timeperiods. One of the main disadvantages is, however, the unknown or only approximately known initial and boundary conditions.
Both types of experiments require careful coordination between modellers and experimentalists in order to make sure that all relevant parameters are evaluated.

4. Experiments to investigate the reliability of exploration tools

It is obvious that the reliability of site investigation methods is a crucial point in performance assessment. Therefore one needs an estimate on the reliabilty of the investigation tools. This can be done by "validation"-experiments as they are planned eg. in the Stripa phase 3 (eg. prediction by geophysics with subsequent excavation to verify the predictions) or by an intercomparison of different techniques (eg. intercomparison of different geophysical techniques at the Grimsel rock laboratory). These exercises often show where additional research for tool development is necessary. This requires some interactions with the performance assessors to make sure that emphasis is put upon those tools which measure relevant parameters.

5. "demonstration" experiments

"Demonstration" experiments are sometimes useful for trying complex technology in a 1:1 scale (eg. remote emplacement of waste containers). These experiments do not always have only technical objectives but can be valuable with respect to public acceptance etc.

excavation response

1. Introduction

Decompressed zones due to excavation around access shafts or tunnels could in principal form potential short-circuits from a repository to the biosphere. Therefore the characterization and quantification of the disturbed zone with respect to transport properties (hydraulics etc) is highly relevant.

2. How can excavation damage be measured?

In the Swiss programme the potential importance of excavation effects was recognized and an experiment to investigate these effects was performed at the Grimsel rock laboratory. However, it is not easy to decide what should be measured to be sure that those excavation effects relevant for system performance are really detected. The following parameters were measured in the rock mass before and after excavation:
- hydraulic conductivity
- deformations
- geophysical properties (p-waves, E-moduli)

The comparison between measurements before and after excavation showed that hardly any significant differences in hydraulic conductivity could be observed. No correlation could be established between the comparatively small changes in rock mechanical and geophysical properties on one side and the hydraulic conductivity on the other side. The main open questions at the moment are:
- were the right parameters measured?
- were the detection limits of the different tools (esp. hydraulic tests) low enough?

These questions have not been completely answered up to now. As long as these questions are not answered, no final conclusions can be made on the importance of excavation effects.

3. Potential problems

For the performance assessor and the experimentalist there exist 3 problems:

- how do we assess the importance of excavation effects prior to the construction of an investigation gallery (where these effects can be measured)?
- what is the reliability of experiments to measure excavation effects?
- what is the optimum design of an experiment to measure excavation effects?

With regard to the first question one possible approach is to evaluate the excavation effects from the theoretical side. One can apply rock mechanics theory and calculate potential deformations, but the question then arises as to what effects these deformations have on the hydraulic properties of the decompressed zone. Some experiments reported in literature indicate that the increase in hydraulic conductivity due to shear displacements can be enormous. However, there are serious doubts about the applicability of these laboratory experiments in the field.

With respect to the second and third question no final answer can be given today.

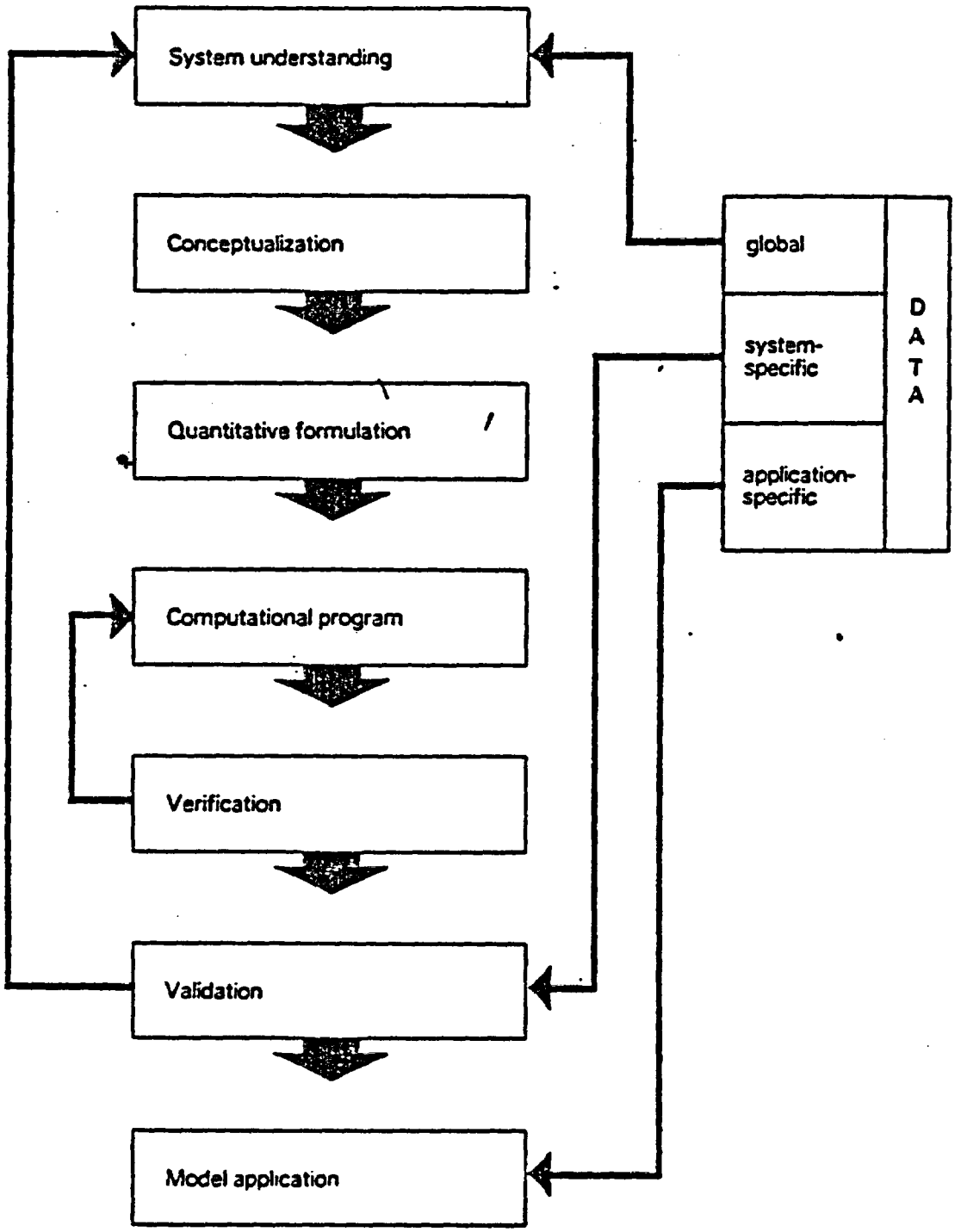

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Figure 1

decision logic with addition of new information

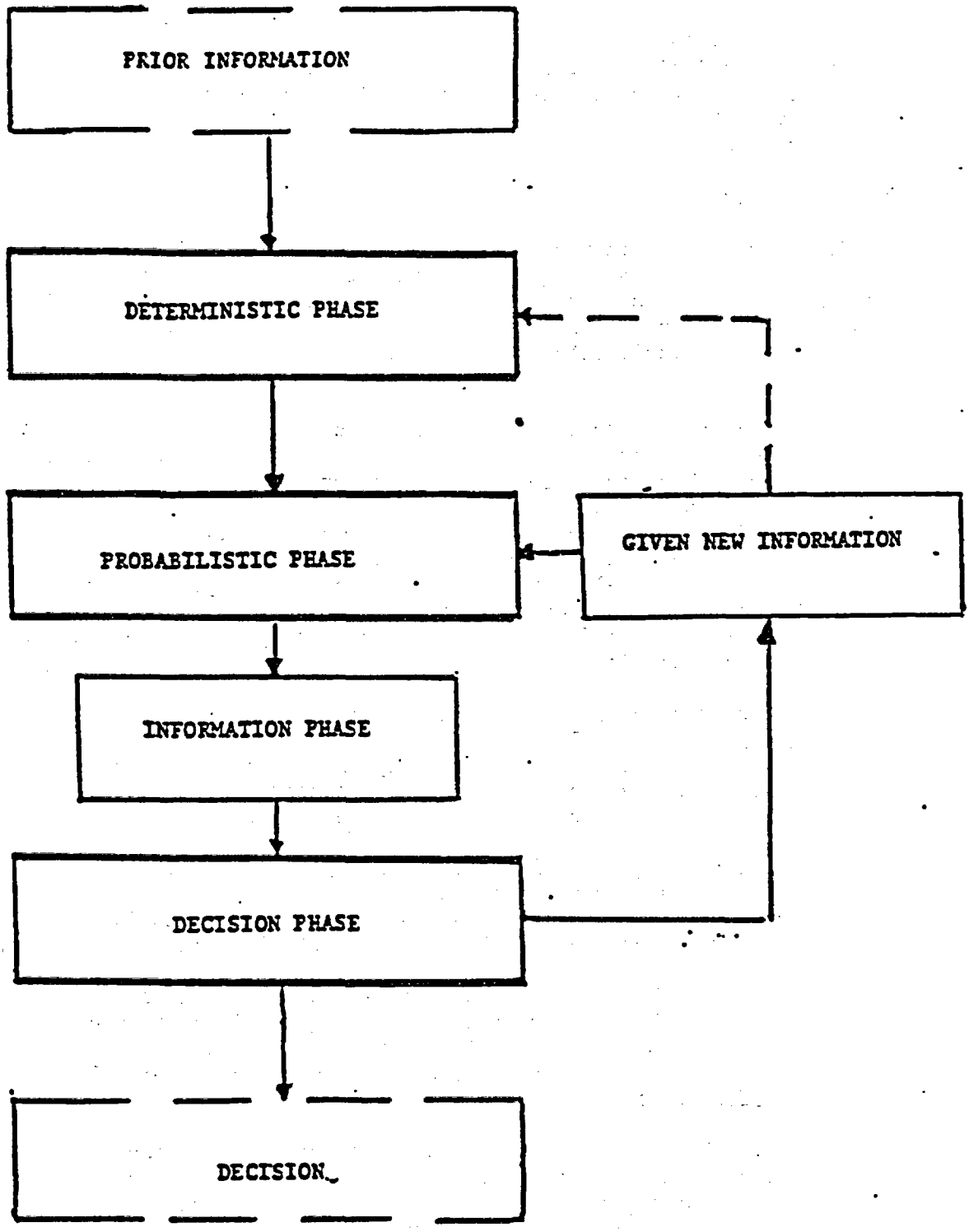

Figure 2

11/86

Battelle

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January 27, 1987

Mr. Stefan Carlyle
Division of Radiation Protection and Waste Management
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38, Boulevard Suchet
75016 Paris, France

Dear Mr. Carlyle:

Per your request in the December 16, 1986 correspondence, I have assembled comments regarding 1) improving the interaction between performance assessment modelers and field test investigators and 2) possible excavation response studies. I hope the consultants find them of some value in their February meeting.

1) Increasing the interaction between modelers and field investigators — As is the case in most situations involving more than one person, a lack of communication is often responsible for many problems that arise. In the case of modelers and field investigators, a majority of the problems are likely the result of a misunderstanding of the kind of model the field data is supporting. Ideally, the design of the field test and the interpretation of the data should reflect the modeling method being employed and the assumptions upon which it is based.

For example, a continuum model of a fractured rock mass requires several input parameters that can vary depending on the assumptions used. Assuming the Young's modulus and rock strength are identified as the necessary input, the investigator could in turn provide any of the following:

for Young's modulus - a modulus based on small intact samples, a rock mass modulus based on a large-scale test, an estimated rock mass modulus based on a reduced intact value, a rock mass modulus based on empirical relationships, etc.

for rock strength - the strength of small intact samples, the rock mass strength from a large-scale test, rock mass strength based on empirical relationships, rock mass strength based on intact values and some conceptual model for jointed rock masses, etc.

All of the above data are correct depending on the application. The large-scale or estimated rock mass values would be appropriate for a continuum model but a discontinuum model would use the intact values. Ideally, the field

investigator should be told the assumptions or hypotheses that form the basis of model for his consideration, comment, and/or testing. He should also be encouraged (or required) to provide any additional information concerning the properties or behavior of the rock he feels may be useful. This information may result in a revision of the assumptions and the model.

The field investigator should also have some idea as to the significance of the data he is providing. If the results of the model are highly sensitive to one or more parameters, the field tests to obtain these data should reflect the need for greater accuracy. If the requested information is part of an existing data base rather than the objective of an future field test program, the limitations and uncertainties associated with the data should be included.

How this communication can best be accomplished is, of course, the problem at hand. One possibility is to develop a data request format in the form of a questionnaire to formalize the exchange of information between the modelers and the field investigators. The questionnaire would solicit information regarding the type of model being used, the assumptions and hypotheses upon which it is based, the input parameters needed, and the sensitivity of the output to these parameters. The completed questionnaire would then be sent to the field investigator for review, comment, and the requested information. In addition to the values for the requested parameters, the questionnaire would also require statistical information for each of the parameters such as distributions, data interpretation methods, etc.

This approach forces communication of the types of information that are necessary if the needs of the modelers are to be met. If we assume the field investigators want to cooperate with the modelers, we can conclude that while they try to provide the type of data requested, they are sometimes uncertain as to what exactly is being asked for. A standardized data request format would provide the background information necessary for the field investigator to respond to the modeler's needs while also informing the modeler of the background of the data. In addition, the process provides documentation for quality assurance records, encourages consistency among investigators, and provides a common basis for discussion that can be improved upon through periodic review and discussion. The methodology could also reduce the amount of wasted effort by identifying inappropriate modeling approaches early on in their development.

2) A workshop on excavation response — I recommend that the workshop be organized around two basic topics: what worked; and what didn't work. At this time, there have been a fair number of field experiments to study the response of a rock mass to underground excavations. A pragmatic approach to assess the success and failures in these experiments would be of certain benefit to researchers involved in designing future tests. The result of the workshop would be a document describing the types of parameters monitored, the test design and implementation, the instrumentation used, the accuracy and robustness of the instrumentation, success or failure of the instrument for its intended use, data interpretation, and subsequent or recommended improvements in the instrumentation and test designs.

   In order to limit the size of the workshop, I suggest that the ISAG member from each country recommend three underground experiments as case histories for the workshop. The project engineer from each of the experiments would be invited to participate in the workshop and would be responsible for providing information according to an agreed upon content. This would limit the size of the workshop to a fairly small number of participants and focus the information presented.

If you or the consultants have questions or require clarification of any comment, please do not hesitate to contact me.

Sincerely,

Charles Voss

cc. R. Stein
A. Jelacic
C. Cooley

ANNEX III
Comments from Mysore NATARAJA (US, NRC)

1. Interaction Between Performance Assessment Modelers and In-situ Testing Researchers -

Workshops involving both the performance assessors and the field investigators are an essential step in increasing interactions between performance assessors and field investigators. A series of such workshops including participants from the world's technical community should be sponsored and supported. Essential information to be provided by the performance assessors for these exchanges should focus on identifying which uncertainties are amenable to quantification and possible reductions by in-situ testing and what information is needed to validate models. Results of sensitivity studies should be used to indicate which parameters are critical to the analysis and should be conveyed to planners of in-situ tests. Similarly, parameters critical to design should be identified. It is also important that field investigators convey to modelers and performance assessors the practical limitations of available testing procedures.

2. Excavation Response -

The NRC has established performance objectives for high level waste geologic repositories. One of these performance objectives states "The geologic repository shall be located so that the pre-waste-emplacement ground water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1000 years or such other time as may be approved or specified by the commission". The important aspect of this performance objective with respect to excavation response is the determination of the extent of the disturbed zone. The definition of the disturbed zone is given in 10 CFR 60.2. In order to present guidance to the Department of Energy on the determination of the disturbed zone, the NRC has prepared a Draft Generic Technical Position (GTP) on the "Interpretation and Identification of the Extent of the Disturbed Zone in the High-Level Waste Rule (10 CFR 60)". As stated in the GTP the calculation of the extent of the disturbed zone should be evaluated by the changes in the host rock caused by a) stress concentrations, b) construction and excavation, c) thermomechanical effects and d) thermochemical effects. In addition, the extent of the disturbed zone should be calculated on a site specific basis taking into account the rock mass response at the respective site.

The Nuclear Regulatory Commission (NRC) has also prepared a Generic Technical Position on In-Situ Testing During Site Characterization for High Level Waste Repositories. In this GTP, the NRC has presented its position on what constitutes a satisfactory site characterization testing program to meet the performance objectives of 10 CFR 60 (including the determination of the disturbed zone).

The GTP states in section 5.1 that for the examination of excavation response (including the determination of the disturbed zone), the in-situ test program rationale should incorporate the following:

a) Scale effects should be minimized - ie, Tests should be of sufficient size in order to measure the rock mass behavior accurately (eg. highly jointed rock should be tested on a different scale than rock which has very few joints)

b) The rock mass in its natural condition should be observed and tested - ie, in-situ tests should be performed on rock that has similar discontinuities, stress field, temperature, etc. to the host rock that is being characterized.

c) Coupled/Interactive processes should be directly observed -ie. coupled behavior (thermal, mechanical, hydrological and chemical) should be examined in-situ where possible.

d) Host rock variability should be evaluated - The testing program should evaluate the variability in geology (eg, joint patterns and spacing), hydrology and geochemistry.

In addition, the GTP in section 5.4 describes the in-situ geomechanical tests that the NRC expects to see in an in-situ testing program. The following are the suggested Geomechanics tests that should be performed:

a) The Geomechanics tests should measure a representative volume (eg, block tests) in order to predict the constitutive behavior and potential failure mechanisms of host rock (including determination of the disturbed zone).

b) The Geomechanics tests should demonstrate repository construction (eg, mine-by tests), emplacement, retrieval and observation of full-scale response of underground openings by simulation.

An example of an acceptable testing approach for examining excavation response and the determination of the disturbed zone is the use of full scale room simulation tests to demonstrate that geomechanical performance models can adequately predict the in-situ response of the host rock. The conditions that will be found at the repository (eg, heated rooms, jointed conditions etc.) should be simulated as closely as possible. A goal of the testing program should be to develop a constitutive model of the rock mass behavior that can be validated by in-situ tests. The test should be fully instrumented (eg, measure displacements, temperatures, stresses, damaged zone properties, etc.) in order to determine the importance of the parameters that can be measured in-situ and to focus the tests on the key parameters.

We believe that the committee should review available documents of large scale excavation response tests that have been performed at DOE's testing facilities. Examples of such work are as follows:

1) CLIMAX FACILITY - At this facility which is in granite at the Nevada Test Site a mine-by test was performed. In this fully instrumented test, actual spent fuel and guard heaters were installed and the response to excavation of a parallel drift was measured. In addition a modeling study was performed before the test and after the test to attempt to reproduce the actual rock mass response. A document entitled "Post Test Calculations and Preliminary Data Analysis for the Spent Fuel Test - Climax", (UCRL-53688) was prepared in December, 1985 and contains the results of the modeling study.

2) G TUNNEL - Geomechanical tests were performed at the G-tunnel facility in welded and non-welded tuff. These include a full scale heated block test. Although no full scale mine-by tests were performed in this facility, an attempt has been made to examine the rock mass response from this test. A reference on this test is "Final Report: G-tunnel Heated Block Experiment" (SAND-84-2620).

3) NEAR SURFACE TEST FACILITY - Large scale geomechanical and thermomechanical tests were conducted at the Near Surface Test Facility in basalt. These tests include a heated block test, and large and small scale heater tests. A reference on these tests is "Summary of Near-Surface Test Facility Results and their Application to Repository Design", (RHO-BW-SA-256 P) and 2).

Recommendations

The committee should study and recommend acceptable approaches to observing, measuring and quantifying excavation response under the following conditions: (a) excavations using boring machines; (b) excavations created by controlled/smooth wall blasting; and (c) uncontrolled drilled and blasted excavations. Both vertical shafts and horizontal underground excavations should be considered as well as various rock types. In addition, thermal effects over a long operational time period should also be considered in the committee's final report.

.ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Advisory Group on In Situ Research and Investigations
for Geological Disposal of Radioactive Waste (ISAG)

OVERVIEW REPORT ON STATUS OF IN SITU R&D IN OECD MEMBER COUNTRIES

1. The attached working document represents the first draft of a report provisionally entitled: "In Situ Research and Investigations for Radioactive Waste Disposal in OECD/NEA Member Countries." It represents the fulfilment of an action placed on the Secretariat at the first meeting of ISAG. [redacted]

2. As background, the format of the report was discussed at the ISAG consultants meeting in February when it was agreed that it should take the form of a booklet for which the target audience would be "interested scientists", not necessarily specialists in this area of study. As such, the report attempts to describe the status of in situ research in the context of current radioactive waste management thinking in OECD Member countries, the CEC and NEA. Sections 1-6 aim to explain why in situ research is carried out and what are the main areas of study. Section 7 provides an overview of in situ R&D in each Member country, as well as describing the CEC and NEA activities in this field.

3. [redacted]

(i) Assuming the overall format is sound, is Section 6 "In Situ R&D activities" comprehensive enough? For instance, should the report have an annex listing the major types of in situ experiments/demonstrations carried out on a medium by medium basis?"

(ii) The descriptions of national and international programmes in Section 7 are based on the reports presented at the first ISAG meeting. Consequently there is some variation in the content. Could ISAG members review the material provided in the relevant section to ensure that it describes the following:

(a) Organisations responsible for in situ research

(b) Overall scheme for implementing disposal main including policy lines, timescales, budgets, etc

(c) The names of in situ facilities, the objectives of each and the major experiments carried out and planned.

(iii) Again on Section 7, could the representatives concerned provide several (2-3) key references to support the text; the current list does not wholly contain references that can be easily acquired in the general literature. Also some sections indicate a need for diagrams representing either a complete facility or individual experiments. could participants supply these or provide references from which they can be obtained?

4. Finally, the following steps in the production of the report are proposed:

(i) Review of first draft by ISAG at second meeting, June 1986

(ii) Revised draft to be prepared by Secretariat over summer 1987 using any revised material provided by ISAG members

(iii) Second draft to be distributed to the group for review in September 1987

(iv) Final texts delivered to publishers in French and English by 30th November 1987

(v) Publication of report by 1st January 1988.

5. The group is invited to consider the report in the light of the above comments and agree follow-up actions.

IN SITU RESEARCH AND INVESTIGATIONS FOR RADIOACTIVE WASTE DISPOSAL

IN OECD/NEA MEMBER COUNTRIES

FIRST DRAFT

May 1987

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

NEA ADVISORY GROUP ON IN SITU RESEARCH AND INVESTIGATIONS FOR GEOLOGICAL DISPOSAL (ISAG)

FOREWORD

The NEA Radioactive Waste Management Committee (RWMC) of the OECD Nuclear Energy Agency (NEA) is an international committee composed of senior government and industry experts in the area of management and disposal of radioactive wastes. It is charged with reviewing and orienting NEA activities in this field so as to promote widespread understanding and information dissemination during NEA Member countries and organising activities of mutual interest and benefit. Such activities include developments in the treatment, storage, transport and disposal of radioactive waste.

In 1986 the RWMC established the NEA Advisory Group on In Situ Research and Investigations for geological disposal (ISAG) which has a mandate to help coordinate in situ research, investigations and demonstrations activities in NEA Member countries; it acts as a kind of club of underground research laboratories. Its main function is to provide a forum for information exchange and plan joint initiatives at an international level.

One of the first initiatives of ISAG was the preparation of an overview report on in situ research and investigations in Member countries. Members of the group provided information on national programmes at the first meeting of ISAG.

This report is based on a synthesis of the contributions and provides an explanation of the reasons why geological disposal is the most favoured option for the disposal of high level waste and spent fuel as well as some alpha bearing wastes, and gives an overview of the main aims and elements of in situ research and investigation activities.

CONTENTS

1. INTRODUCTION

1.1 Current thinking in OECD Member countries on the methods and procedures for the disposal of radioactive wastes arising from nuclear power generation, in particular, highly active heat generating wastes, is based on a substantial body of scientific research and development work carried out since the late 1940's. This has embraced exploratory consideration of a wide variety of options, through the evaluation of conceptual designs, to the adoption of preferred concepts and, in recent years, the devotion of considerable effort towards concept implementation. The latter includes developing procedures for carrying out site selection, conducting detailed design and feasibility studies and, perhaps of most importance, performing safety assessments. An integral part of each of these is the need to carry out research in situ at either a generic or actual site so that:

(i) the appropriate site investigation techniques are available;

(ii) detailed designs can be demonstrated to meet design standards; and

(iii) that performance assessment models can predict post-operational safety with confidence.

1.2 This report presents an overview of the status of understanding of in situ processes relevant to the deep disposal of radioactive wastes and gives a broad outline of recent developments and progress in OECD Member countries.

2. THE DEEP GEOLOGICAL DISPOSAL CONCEPT

2.1 Although most types of radioactive wastes could be disposed of using deep disposal, more economic alternatives are available for those possessing relatively low levels of short-lived activity. Burial on land at shallow depth in an engineered repository is one such alternative which is currently practiced, for example in France, the United Kingdom and the United States. Deep disposal several hundred metres below the surface is considered to be an appropriate solution for wastes arising from nuclear power generation containing long lived and/or heat generating radioelements [see Fig. 1]. In order to fully explain the main aims of disposal of radioactive wastes into deep geological formations, it is first necessary to outline the main features of radioactive wastes. These can be broadly classified as high-level waste from reprocessing operations, encapsulated spent fuel elements (both heat generating) and alpha-bearing waste (non-heat generating). As an illustration, Figure 2 presents the dominant radionuclides in spent fuel and in high level waste [1].

Objectives of Deep Geological Disposal

2.2 The main issue with respect to the disposal of highly active wastes is how to cope with the very long term radiological risk associated with the presence of long-lived radionuclides in spent fuel, high level waste from reprocessing and other alpha bearing waste, and the high radiotoxicity of some of these radionuclides. Therefore the objective of disposal is to isolate waste from the biosphere for as long as necessary without unacceptable burdens on future generations: i.e. until radioactivity levels have decayed and that the eventual return of radioactivity to man and the environment, as a result either of natural processes or of man's activities, can present no significant radiological risks.

The Concept of Deep Underground Disposal

2.3 As one of the possible alternative solutions to the isolation of long-lived waste from the biosphere, the concept of deep underground disposal has the following features:

1) Waste emplacement deep underground in sufficiently stable and impermeable rock can ensure that waste will remain undisturbed and isolated for extremely long time scales;

2) The safety of deep underground "geologic" disposal relies on multi-barrier systems and repositories characterised by a high degree of reliability and predictability. Long-term performance of geologic repositories can be assessed using the most advanced scientific techniques and methodologies;

3) Geologic disposal is an entirely passive system with no requirement for continuing human involvement for its safety, and particularly no long-term need for surveillance and monitoring of the site. The geologic barrier is the key element of the system;

4) Burden on future generations will be minimal if any, both from the point of view of potential migration of radionuclides through the geosphere with time up to the biosphere due to natural processes, and from the point of view of potential intrusion by man, the likelihood of which depending to some extent on the depth of the repository.

2.4 In addition to the above positive features of the geological disposal concept is the fact that there is a relative abundance of suitable geological formations and also there exist through the International Commission on Radiological Protection (ICRP) a highly suitable basis for judging the acceptability of disposal.

2.5 From the above it can be seen that two important features have to be taken into account when designing a system for the disposal of radioactive wastes i.e. heat generation and the toxic potentital of the waste. The former is illustrated in Table 1 which gives the thermal power of spent fuel and high level waste [2]. The latter can be derived from a summation of the comparative level of radioactivity of each radionuclide relative to the limit on its annual level of intake by ingestion recommended by the ICRP. Figure 3 gives a graphical representation of the radiotoxicity calculated in this way for high level radioactive waste compared with the risk potential of an equivalent amount of Uranium ore [3]. From this rough guide, it can be seen

that, for high level waste, the period of concern extends to about 10-100,000 years, a period of time far longer than normal institutional control periods.

FIGURE 1

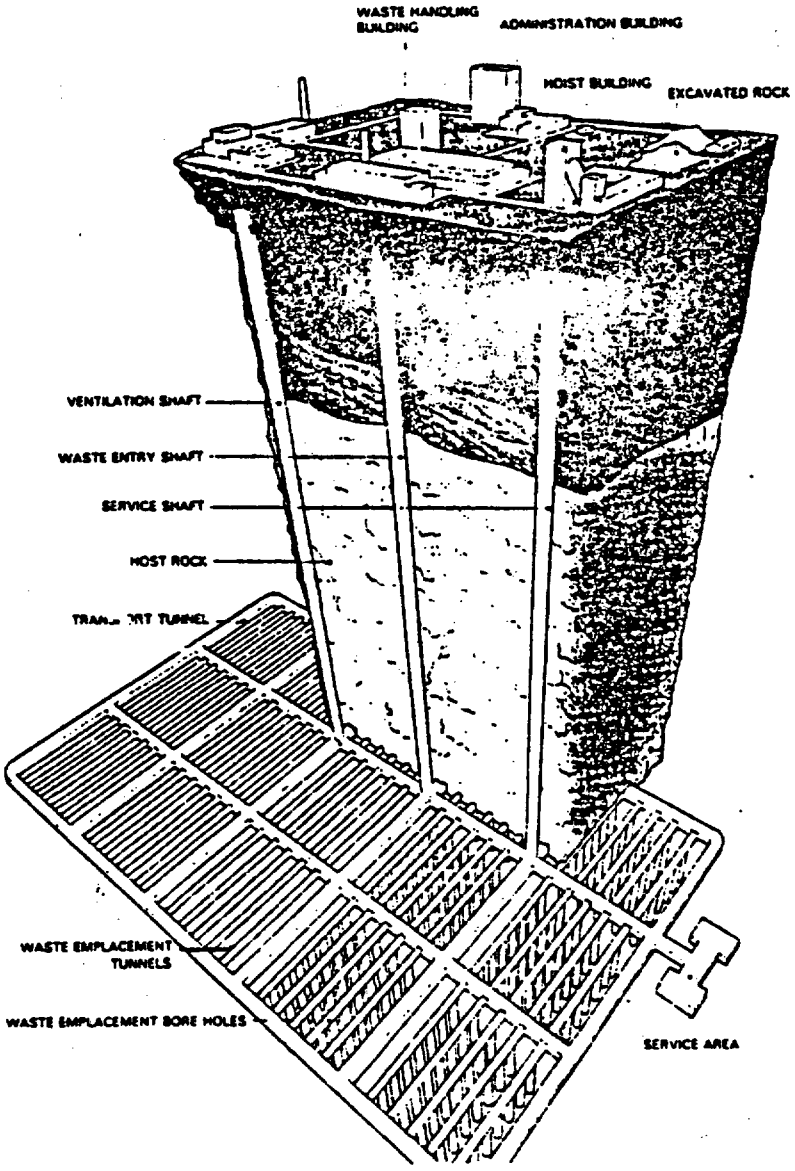


FIGURE 2 DOMINATING RADIONUCLIDE INVENTORY IN SPENT FUEL AND IN HIGH LEVEL REPROCESSING WASTE
(Assumes PWR fuel with a burnup of 33 GW.day/tonne, reprocessed after 5 years cooling)

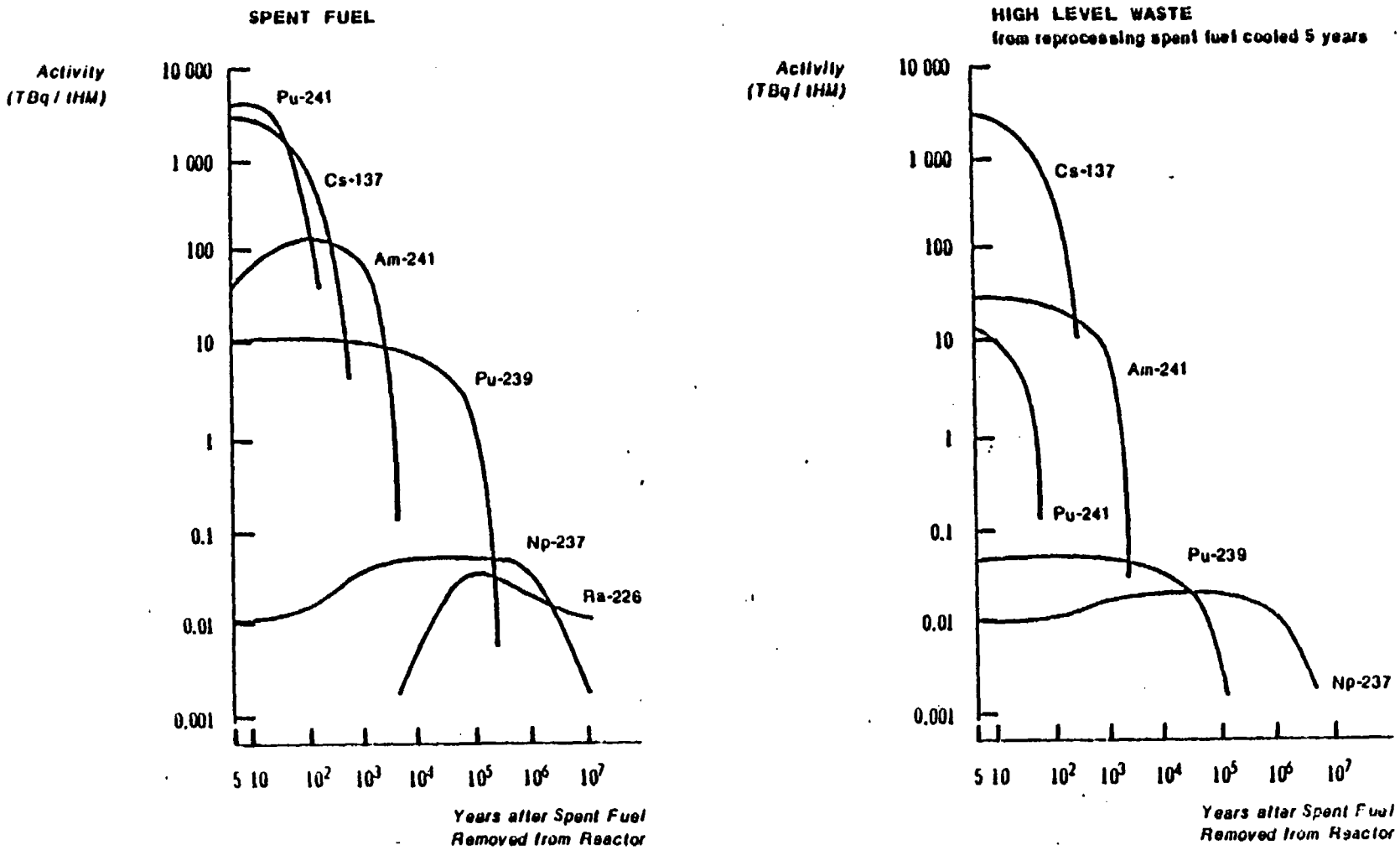


FIGURE 3

TYPICAL TOXIC POTENTIAL OF VITRIFIED HIGH-LEVEL WASTE FROM REPROCESSING ONE TONNE OF LWR FUEL AS A FUNCTION OF TIME COMPARED WITH THE TOXIC POTENTIAL OF AN EQUIVALENT AMOUNT OF A 0.17 % URANIUM ORE [3]

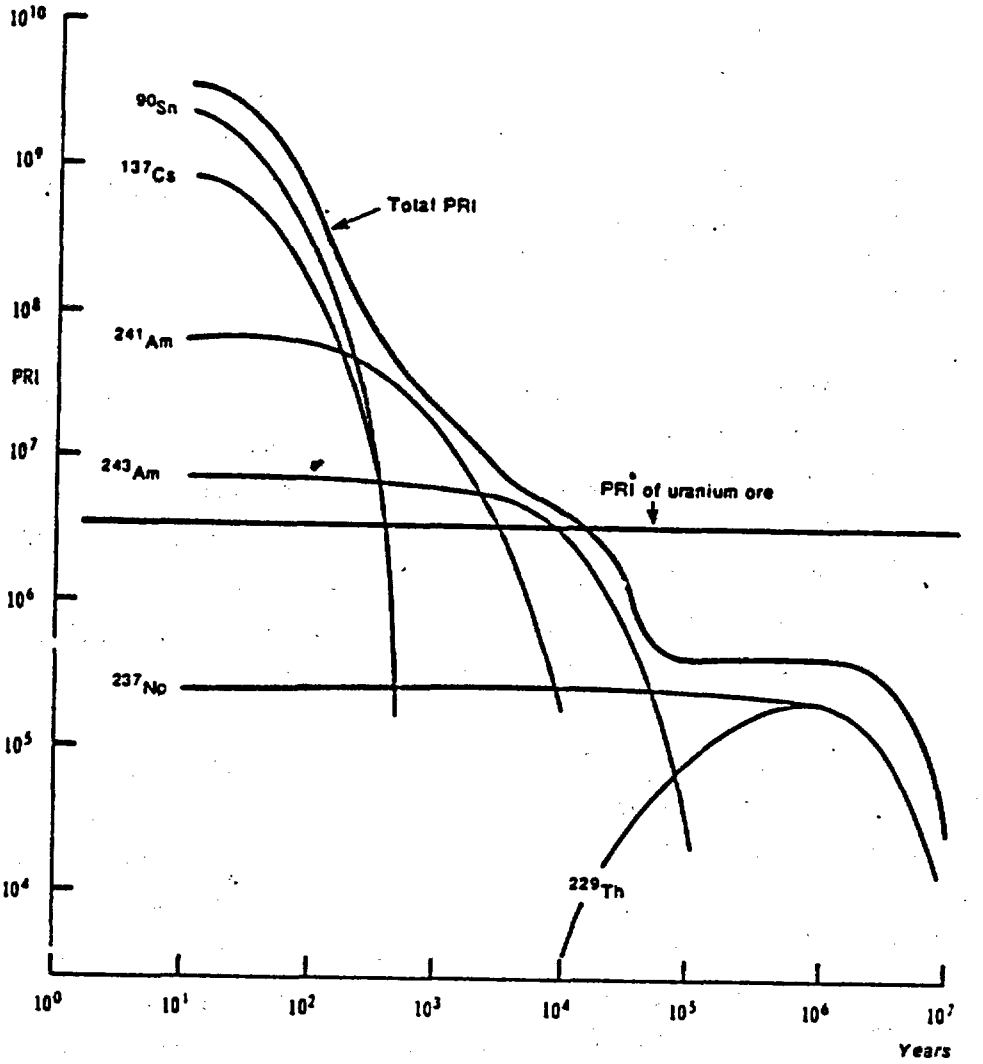


TABLE 1

THERMAL POWER OF SPENT FUEL AND HIGH LEVEL WASTE
AS A FUNCTION OF TIME *
Watts/tHM of original fuel elements

Time from Reactor Discharge (Years)	Spent Fuel	High Level Waste
10	1 290	1 120
100	284	134
1 000	49.4	6.8
10 000	13.5	0.6
100 000	1.0	0.10
1 000 000	0.3	0.102.3

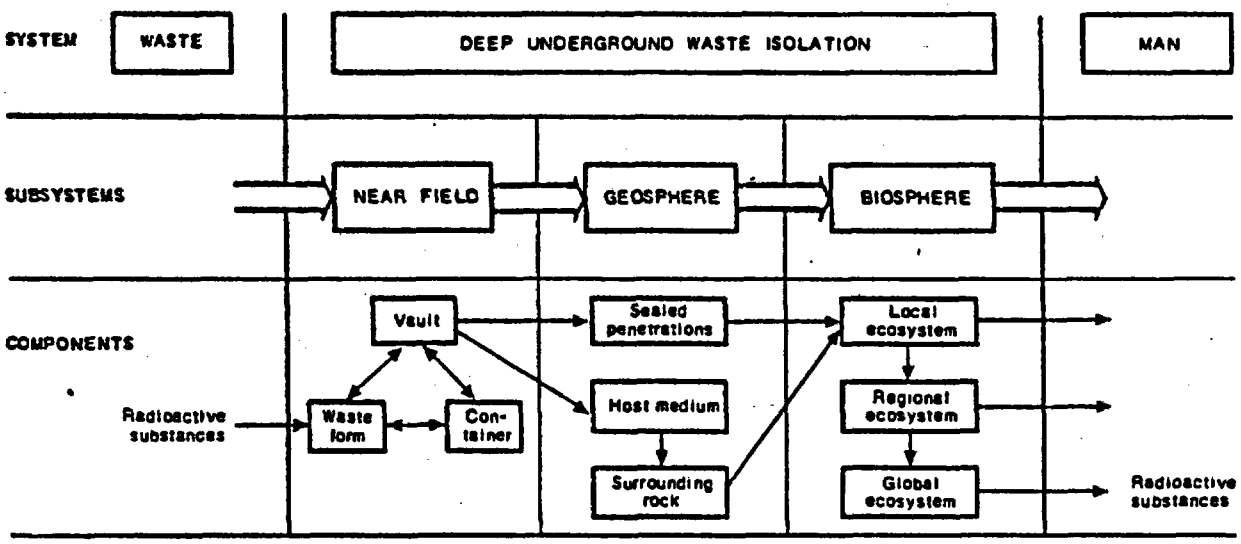
* Data illustrated are for a PWR with a fuel burn-up of 33 GW day/tonne and subsequent reprocessing after 5 years
Source: Reference 6.

2.6 It is these two features that has led to the concept of the disposal of heat-generating and alpha-bearing wastes into deep geological formations being widely recognised as the primary method of disposal [eg. 3 - 8]. Such a disposal system would provide more than adequate shielding against radiation, as well as absorb and disperse heat and provide long term isolation irrespective of human involvement. A deep underground location also decreases the likelihood of inadvertent intrusion by man.

2.7 The "deep geological disposal" concept consists of a number of barriers to the release of radioactivity, a general breakdown of which is illustrated in Figure 4. This multi-barrier approach relies upon three main elements: the near-field, the geosphere and the biosphere. The near-field constitutes an engineered emplacement and containment system, the geosphere comprises one or a sequence of geological formations selected so as to provide adequate isolation or containment of any degradation products from the radioactive waste, while the biosphere represents the accessible environment for man. The latter, while not being a barrier as such, utilises dilution and dispersion as its contribution to the effectiveness of the disposal system.

FIGURE 4

THE GENERAL BREAKDOWN OF THE ISOLATION SYSTEM



3. PREFERRED GEOLOGICAL ENVIRONMENTS

3.1 A number of geological media are being investigated in NEA Member countries as part of procedures leading to a choice of host formation or to an actual site. The choice of rock types largely depends on their availability within each country. Table 2 gives examples of the countries studying each main rock type:

TABLE 2

Main Candidate Geological Most Media for Deep Repository

Rock Type	Countries
Clays	Belgium, France, Italy, United Kingdom
Crystalline rocks	Canada, Finland, France, Japan, Sweden, Switzerland, United Kingdom, United States
Salt/anhydrite	Denmark, France, Federal Republic of Germany Netherlands, Switzerland, United Kingdom United States
Basalt	United States
Tuffs	Japan, United States
Schists	France

- Clay Formations

3.2 The undoubted suitability of clay or similar argillaceous formations as hosts for deep repositories stems from: (i) deposits can be extensive in area and many hundreds of metres thick; (ii) an inherent impermeability (eg. 10^{-13} m/sec) provides a very effective barrier to groundwater movement; (iii) clay particles (by definition less than 0.1 mm in size) provide a large surface area which, combined with their ion exchange capacity, makes them excellent sites for sorption of radionuclides; (iv) the plastic nature of

some clays means that no fractures exist for short-cutting groundwater movement, that boreholes and tunnels tend to seal and that the effects of any tectonic movements may be minimal.

- Crystalline Rocks

3.3 Crystalline rocks such as granitic plutons or gneissic metamorphic formations, are often termed 'hard rocks' due to their inherent stability, structural strength and resistance to erosion. They are usually massive and very compact which makes them highly impermeable. The only significant groundwater flow takes place through fractures in the rock mass. The degree of fracturing can be very variable. Typically, a crystalline rock mass would contain minor joints and fractures separated from each other by distances of several centimetres to a few metres; although isolated zones can be found with no open fractures for several hundreds of metres. Radioactive waste placed deep within a crystalline rock repository is very unlikely to be disturbed by climatic or geological events or by human intrusion. The only significant pathway by which radionuclides could return to man's environment is through dissolution in groundwater and migration associated with groundwater flow. A typical bulk permeability for a crystalline rock mass would be 10^{-9} m/sec, low enough to give very slow travel times. In addition, research has shown that diffusion into stagnant areas and closed fissures means in reality the effective flow velocities are much slower.

- Salt Formations

3.4 Extensive salt deposits are found in Europe and North America as either statified or "bedded" salt or as more localised salt dome formations; the latter being formed due to diapirism of the former. Both types of deposit are very stable; they are often extensive in area and depth and can be easily mined; they have a negligible permeability; they have a low water content (usually less than 0.1% by volume); they have an inherent plasticity which increases with temperature and allows lithostatic pressure to reseal boreholes and heat fractures; and they have a high thermal conductivity which gives them the ability to accommodate the high heat load associated with high-level waste.

- Other Rock Types

3.5 Several countries have investigated other rock types as potential hosts for a repository. Basalt, a fine grained, dark volcanic rock, is being considered in the United States where bedded basalt flows of several hundreds metres in thickness are found. These rocks exhibit much the same characteristics as granite rock. The United States is also considering welded tuff as a host rock. This comprises volcanic ash welded under high temperatures associated with a particular type of volcanism. The welded tuffs possess features of crystalline rock in that they are usually hard and possess fractures but the migration behaviour is more akin to that possessed by clay. In addition, several countries, including Switzerland, are considering anhydrite as a possible host rock. This rock type is very similar in character to rock salt but with a more diverse mineralogy.

4. CONCEPT FEASIBILITY AND SAFETY

4.1 Decisions on the implementation of the geological disposal concept in NEA Member countries will rely heavily on two factors. First, the demonstration of concept feasibility and, to a lesser extent, cost effectiveness and, second, on the level of confidence in predictions of the long term safety. It is these two areas which are currently the subject of a major research effort in NEA Member countries.

4.2 Two recent NEA reports [7, 8] outlined what must be demonstrated to establish confidence in our ability to manage high level waste safety. These included the need to show that:

- Repository designs are feasible in engineering terms;

- Repository operations, backfilling, and closure can be achieved in the manner envisaged in the design without compromising the long-term integrity of the repository;

- Stress fields are sufficiently understood and predictions of distortions below ground can be made to allow stable structures to

be created for emplacement; prediction of the impacts of any changes in the zone affected by the repository that will occur after closure can be estimated;

- All significant mechanisms by which radionuclides might return to man can be identified and analysed, and are amenable to predictive modelling;

- Mathematical modelling of repository behaviour and radionuclide transport is feasible, and the results are sufficiently reliable for confidence in their validity;

- The data needed by the models can be acquired, and are sufficiently reliable for their purpose;

- The results of safety assessments for the operating and post-closure periods are consistent with long-term safety objectives;

- All safety objectives can be achieved without imposing an unacceptable economic burden on implementing agencies and governments.

4.3 It can be seen from this list that demonstration of feasibility is closely associated with factors that can only be considered in situ on a host rock or site specific basis. These include:

- detailed site investigations to obtain an adequate understanding of the local geology and hydrology for design and construction and as data for detailed safety assessments;

- developing safe handling, transport and emplacement techniques adapted to each type of host rock and disposal concept;

- developing techniques for plugging boreholes and shafts and sealing excavations; and

- conducting specific model validation experiments in support of safety assessments.

4.4 It is this need for site or host rock specific activities that several NEA Member countries have developed specially designed test facilities, or underground research laboratories (URLs). Such in situ facilities are essential in order to build up a body of knowledge and data about rock formations with very low permeability.

5. UNDERGROUND RESEARCH AND INVESTIGATION FACILITIES

5.1 In situ experiments and investigations carried out at likely repository depths can help increase our confidence in a proposed disposal solution in three main ways:

(i) by comparing site specific observations with numerical model predictions to test our ability to predict specific phenomena (validation);

(ii) by testing components of repository design, construction, operation and closure (demonstration); and

(iii) by providing testing facilities to develop specific site investigation techniques as well as experience in using a combination of techniques (instrumentation).

5.2 Even though generic studies of the safety of radioactive disposal systems indicate that the solutions are safe when judged against all reasonable criteria, further work is necessary to improve the component models in order to make these more realistic i.e. progressing from using pessimistic to more realistic assumptions of the behaviour of a disposal system. Heavy reliance is placed on predictive mathematical models to represent the various parts of the disposal system i.e. the vault, geosphere and biosphere, in assessing the radiological consequences of disposal. Such models in turn have to be based on observations made in the laboratory or <u>in situ</u> in order that confidence can be placed on the results. The interaction between modelling and observations is iterative in that detailed process models will be developed based on observations carried out in the laboratory or field. Such models should then be validated by first predicting the performance of a

specific phenomena and then comparing this with laboratory or field observations. The detailed models, where necessary, are used to develop simpler models which can be used to model complete disposal systems.

5.3 In addition, further effort has been devoted, where possible, to demonstrating concept feasibility by carrying out full or part-scale testing of particular components of the disposal system. This is particularly the case for the vault or near-field environment which includes a large proportion of engineering design involving civil engineering and geotechnical evaluations.

5.4 A further aspect of concept feasibility and assessment is the development of techniques to carry-out field investigations both on a regional and small scale i.e. at the site of a disposal facility. As most potential sites are situated in formerly unproductive geologies of low economic interest then little effort was devoted to methods for measuring those aspects of interest to site investigations. Where previous studies have been carried out these do not often provide in an acceptable form or depth. Hence, new techniques have had to be developed to gather data necessary for site evaluation and safety assessments.

5.5 An overview of the current status of R&D at underground research laboratories and investigations at potential sites is given in Table 3. This indicates the widespread acceptance of the benefits of developing in situ facilities among OECD Member countries by either establishing a test facility at a generic site or on sites that are potentially suitable as disposal facilities.

Current Status of R&D on Deep Geological Disposal in OECD Member Countries

ROCK TYPE	COUNTRY	GENERIC STUDIES	SURVEY OF SITES	SURFACE INVESTIGATIONS	TEST BOREHOLES	TEST FACILITIES AT DEPTH AT DEPTH: ACCESS SHAFT OR TUNNEL SUNK	TEST FACILITY (1)	LOCATION	IN SITU STUDIES AT POTENTIAL SITES	LOCATION
Crystalline Rocks										
Granite	Finland	x	x	x	x					
	Canada	x	x	x	x	x	x	Whiteshell		
	France	x	x	x	x		x	Fanay-Augères	x	Neuvy-Bouin (1)
	Japan	x	x				x	Kasama		
	Spain	x	x	x	x		x	IPES (1)		
	Sweden	x	x	x	x		x	Stripa		
	Switzerland	x	x	x	x	x	x	Grimsel Pass		
	UK	x	x	x	x					
	USA	x	x	x	x	x	x	Climax		
Schist	France	x	x	x	x				x	Montrevel (1)
Gabbro	Sweden		x	x	x					
	Canada	x		x	x					
Diabase	Japan			x	x					
Basalt	USA	x		x	x		x	NSTF Hanford	x	Hanford (1)
Tuff	USA	x	x	x	x			NTS	x	Yucca Mountain (1)
	Japan	x	x							
Evaporites										
Salt Diapirs	Denmark	x	x	x	x					
	France	x	x	x	x				x	Segré (1)
	F.R. Germany	x	x	x	x	x		Gorleben	x	Gorleben
	F.R. Germany	x	x	x	x		x	Asse II		
	Netherlands	x	x	x	x					
	USA	x	x	x	x		x	Avery Islands		
Bedded Salt	Spain	x	x							
	USA	x	x	x	x		x	Lyons	x	Deaf Smith County (1)
	USA	x	x	x		x	x	WIPP	x	WIPP
Anhydrite	Switzerland	x	x	x	x		x	Felsenau		
	USA	x	x							
Other Sedimentary Rocks										
Clay	Belgium	x	x	x	x	x	x	Mol	x	Mol
	France	x	x	x	x				x	Montcornet Sissonne (1)
	Italy	x	x	x			x			
	Switzerland	x								
	UK	x	x	x	x					
Shale	USA	x			x					
	Japan	x	x							
	Spain	x		x	x					
Other										
Mixed Marine Sed. Sequence	F.R. Germany			x	x		x	Konrad (2)	x	Konrad

Notes:

(1) Proposed location
(2) Low and intermediate waste only

6. IN SITU R&D ACTIVITIES

6.1 Model Validation

6.1.1 Model validation experiments are necessary in order to improve confidence in predictions made using numerical models and to reduce uncertainties in the results. The normal approach adopted is to (a) develop a conceptual model of a specific part of the disposal system, eg. the behaviour of the backfill material; (b) extract from existing literature the necessary input parameters; (c) make predictions; (d) compare these with laboratory or field observations; (e) if these agree it is therefore valid and can be used as part of the overall system performance assessment; if not, the predictive models should be improved and, then, compared with laboratory or field observations until the model can be said to be satisfactorily validated. Figure 5 illustrates this iterative model validation process.

FIGURE 5

ITERATIVE APPROACH TO MODEL VALIDATION

6.1.2 The types of phenomena that can be treated in this way are numerous, although a major difficulty exists in conducting validation experiments on processes involving long time scales. In situ experiments are in particular valuable in addressing coupled effects such as thermal-mechanical-chemical-hydraulic phenomena or the following specific areas of study:

Waste form degradation
Corrosion of Canister and overpacks

Behaviour of backfilling and sealing materials
Radiation effects on host medium
Thermal effects on host medium
Chemical and mineralogical changes/reactions
Mechanical effects
Hydrological changes

6.2 Demonstrations of Engineering Feasibility

6.2.1 Engineering demonstrations of construction, operation and closure of deep repositories have been carried out, or are planned, at a number of in situ research facilities. The aim of each of these activities is to clearly demonstrate that specific technologies exist to implement a chosen disposal concept at a specific disposal site or in a particular host rock and also, to optimise all the components of a disposal system. Examples of these include carrying out actual emplacement of waste in a test site to demonstrate operational capabilities; observing the behaviour of backfill and sealing materials; and testing various excavation methods for shafts, tunnels and underground openings to examine the response of the rock mass to excavations so as to minimise rock damage and not hinder the containment provided by the host rock.

6.3 Improving Site Characterisation Methods and Procedures

6.3.1 It is necessary to carry out a detailed characterisation of any proposed site for a deep disposal facility in order to develop site specific designs and performance assessment models and to confirm that no significant geological features remain undetected. The geological, hydrological, geochemical and geomechanical features exhibited by candidate sites that are relevant to design and safety analyses often require the development of specific site investigation techniques. For example, they should, where possible, be non-destructive and so remote techniques such as seismic, radar and hydraulic methods have had to be or are in the process of being specifically adapted for characterisation of potential disposal sites.

7. NATIONAL AND INTERNATIONAL IN SITU RESEARCH AND INVESTIGATION PROGRAMMES

7.1 INTRODUCTION

7.1.1 The following sections provide broad overviews of in situ research, demonstration and investigation programmes in OECD Member countries. These illustrate the widespread acceptance of the integral role played by in situ facilities in demonstrating the feasibility and safety of proposed disposal solutions as well as confirming the suitability of potential disposal sites.

7.2 BELGIUM

7.2.1 The underground laboratory constructed on the site of the belgian nuclear research establishment (SCK/CEN) at Mol, Belgium has been the starting point of an extensive in situ research programme in deep clay [9, 10, 11, 12, 13]. Specific in situ investigations in the field of corrosion behaviour of various structural materials and waste forms are being carried out in representative conditions. Important contributions have been brought to conducting assessments of the hydrology of the clay body and the adjacent layers, the geotechnical aspects of building galleries in clay and radionuclide migration in clay.

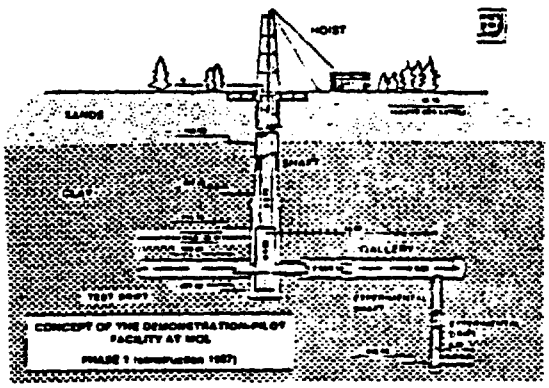
7.2.2 The result of all these investigations are very encouraging and the decision was taken to extend the underground laboratory towards a pilot size demonstration facility. The H(igh) A(ctivity) D(isposal) E(xperimental S(ite) project will be developed within the framework of the european atomic energy community's cost sharing research programme on radioactive waste management and disposal.

7.2.3 For reasons of technical convenience the HADES project has been split into two phases

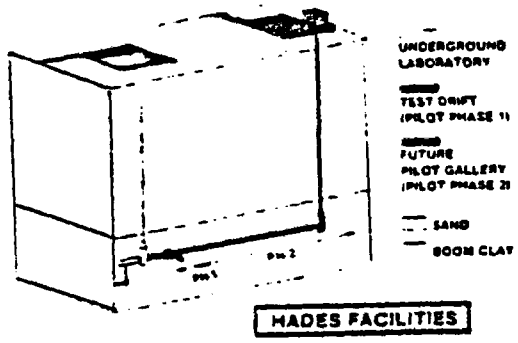
- in first phase (1986-1992) includes the upscaling of construction capability in non-frozen clay coupled to pilot size experiments on heat transfer, radiolysis and gamma source handling;

- in a second phase (1988-1994) includes the construction of a second shaft with connection tunnels to the existing laboratory. This phase will be started after approval by the National Waste Management authority (NIRAS-ONDRAF).

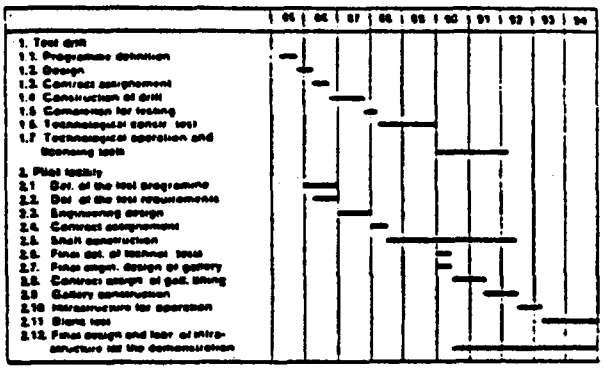
7.2.4 The full scale underground demonstration gallery will allow to perform mock-up tests on real scale first and retrievable disposal of different waste forms at a later stage.



CONCEPT OF THE DEMONSTRATION TEST DRIFT AS IT WILL BE CONSTRUCTED IN THE VICINITY OF THE UNDERGROUND LABORATORY



SCHEMATIC VIEW OF THE HADES FACILITY AS IT IS PLANNED TO BE CONSTRUCTED AND OPERATED IN THE NEXT 10 YEARS



TIME SCHEDULE OF THE HADES FACILITY CONSTRUCTION

7.3 CANADA

7.3.1 In April 1981, the Canadian government approved a 10-year generic research and development program, the Canadian Nuclear Fuel Waste Management Program (CNFWMP), with the following objectives:

(1) to assess the environmental and safety aspects of the concept of isolating immobilised fuel waste by deep underground disposal in plutonic rock;

(2) to develop the technology for storage, transportation, immobilisation and disposal to the extent necessary; to provide data for the concept assessment; to design facilities; to specify operating processes and procedures; and to demonstrate that practical technology is available for implementation of the concept;

(3) to establish the requirements, equipment and procedures for the site-characterisation and site-selection processes for the next phase of nuclear fuel waste management; and

(4) to develop the basis for public acceptance and support through scientific and regulatory review, and public information, interaction and participation

7.3.2 Atomic Energy of Canada Limited (AECL) was assigned responsibility for developing technologies for the immobilisation and safe disposal of nuclear

fuel waste. The disposal concept being studied by AECL is a multiple-barrier system comprising a low-solubility waste form, a corrosion-resistant container, low-permeability clay-based buffer and backfill, and a stable geosphere that separates the emplaced waste from the biosphere. Research and development activities are in progress in all areas of the conceived disposal system to develop methods for establishing the radionuclide isolation capabilities of each barrier and to assess the performance of the entire multiple-barrier system.

7.3.3 One focus of geoscience research is the Underground Research Laboratory (URL) located east of Lac du Bonnet, Manitoba on a portion of a large granitic pluton, the Lac du Bonnet batholith (see Figure 2). The URL is a unique geotechnical research facility because it is being constructed in a previously undisturbed portion of the pluton that was well characterised before construction began, and most of the shaft and all potential testing areas are below the water table. The URL provides a representative geological environment in which to carry out a wide variety of geoscience research and development programs [14].

Background to URL Project

7.3.4 The general objectives of the URL programme can be summarised as:

(1) to assess airborne, surface and borehole survey techniques for characterisation of the subsurface geological and hydrogeological environment in plutonic rock,

(2) to assess the changes in physical and chemical conditiions in the rock mass and groundwater caused by excavation of the URL, and

(3) to perform experiments relevant to assessing the performance of the disposal system being considered in Canada for nuclear fuel waste disposal.

7.3.5 The project comprises experimental and development activities and generally progresses from site evaluatiion, through facility development and characterisation, to the post-development or operating-phase experiments.

These phases have been implemented or are planned on the following schedule:

Site Evaluation and Monitoring:	1980 to 2000
- Site Evaluation:	1980 to 1984
- Site Monitoring:	1984 to 2000
Facilities Development and Characterisation:.....	1982 to 1989
- Surface Facilities Development:	1982 to 1986
- Shaft Excavation to 255 m:	1984 to 1985
- 240 Level Development and Characterisation:	1985 to 1986
- Characterisation and Grouting of Fracture Zone No. 2: .	1986 to 1987
- Shaft Excavation to 455 m:	1987 to 1988
- 440 Level Development and Characterisation:	1988 to 1989
Operating Phase Experiments:	1989 to 2000

[DIAGRAMS OF CANADIAN URL FACILITY AND TESTS]

7.4 FEDERAL REPUBLIC OF GERMANY

7.4.1 The radioactive waste disposal concept in the Federal Republic of Germany is based on the use of three sites with different history and geology for different purposes [15]. In brief characteristics and status of development can be stated as follows:

Gorleben site

7.4.2 The salt dome of Gorleben is being proved for its suitability for LLW, ILW and HLW waste disposal by in situ investigations. After an extensive drilling campaign and a hydrogeological survey the two exploration shafts are presently being sunk. After completion a comprehensive underground site investigation programme will be executed.

Konrad mine

7.4.3 After completion of a feasibility study including geological, hydrogeological, rock mechanical and seismic research work a site confirmation programme was initiated in 1982. This work has been terminated in July 1986 and the complete plan for the proposed repository for non heat generating waste has been submitted to the licencing authority. A positive decision is expected in 1988.

Asse mine

7.4.4 The Asse mine is the only pilot radioactive waste repository and underground research facility in the Federal Republic. In this former salt mine basic research work was and still is being performed on the characteristics and the behaviour or rock salt in response to the disposal of all kinds of radioactive waste, in particular of high level waste. The data measured so far were fed into model calculations for a high level waste repository to be built in a fresh salt dome. The techniques developed together with the underground disposal of low and intermediate level waste have been integrated into the Gorleben concept. Today the Asse mine is being used for advanced in situ tests on sensitive subjects of geological disposal, especially on the inter-relation of waste and rock salt and its consequences for the long term safety of the repository. In addition, advanced technologies for waste disposal as well as for construction, operation, backfilling and sealing of a repository are being developed and demonstrated.

In the Federal Republic of Germany all R&D-work regarding radioactive waste disposal in salt formations is being performed in the Asse mine. Since for any commercial repository only proved technologies can be licensed, there is a definite need for an in situ testing site like Asse, a national laboratory available to all R&D-institutions working in this field. The R&D-projects are being financed by the Federal Minister for Research and Technology (BMFT). Some are being performed under contract with and with contributions by the CEC. A bilateral agreement between the BMFT and DOE (Department of Energy/USA) provides for some joint in site tests in the Asse.

[Diagrams of GORLEBEN, KONRAD and ASSE]

7.5 FINLAND

7.5.1 In-situ research and investigations in Finland have been carried out at two potential sites for medium and low level waste disposal and on one site where the testing methods were experimented for high level waste disposal [16].

7.5.2 Repositories for low and medium level waste (reactor waste) disposal will be built 1988-1992 and brought into operation in 1992. The site for high level waste disposal will be selected by the year 2000. The site will be investigated and the facility designed 2000-2010, the repository will be constructed 2010-2020 and operational by 2020. The site will be sealed around 2050-2060.

7.5.3 The power plant sites of Olkiluoto and Hästholmen have been considered as potential sites for low and intermediate waste disposal. No other sites are presently being considered and all investigations are done on the two sites. The site investigations on the two sites began 1980. At Olkiluoto the waste will be bitumenised and disposed in steel drums in 45 m high silos at the depth of 100 metres (Figure 1). In Hästholmen the waste will be cast in concrete cubes and placed in caverns at the depth of 120 metres.

Site Investigation Methods

7.5.4 Numerous boreholes have been drilled on the power plant sites to investigate the geology and to conduct various tests in the boreholes and in the rock between the holes. Most of the holes are vertical. Most of the holes have been cored with 56 or 66 mm core barrels. A few holes have been drilled using percussion drilling. During drilling various kinds of measurements have been done including: drilling rate and energy consumption; consumption of flushing water; and pressure of flushing water. Drill cores have been carefully logged and documented. Rock types and joint minerals have been studied in thin sections and using X-ray methods.

7.5.5 After drilling the borehole has been logged and the following measurements have been done: water sample analyses; temperature logs; caliper logs; and inclination measurements. Simultaneously with borehole surveys or in parallel with them, geophysical borehole surveys have been

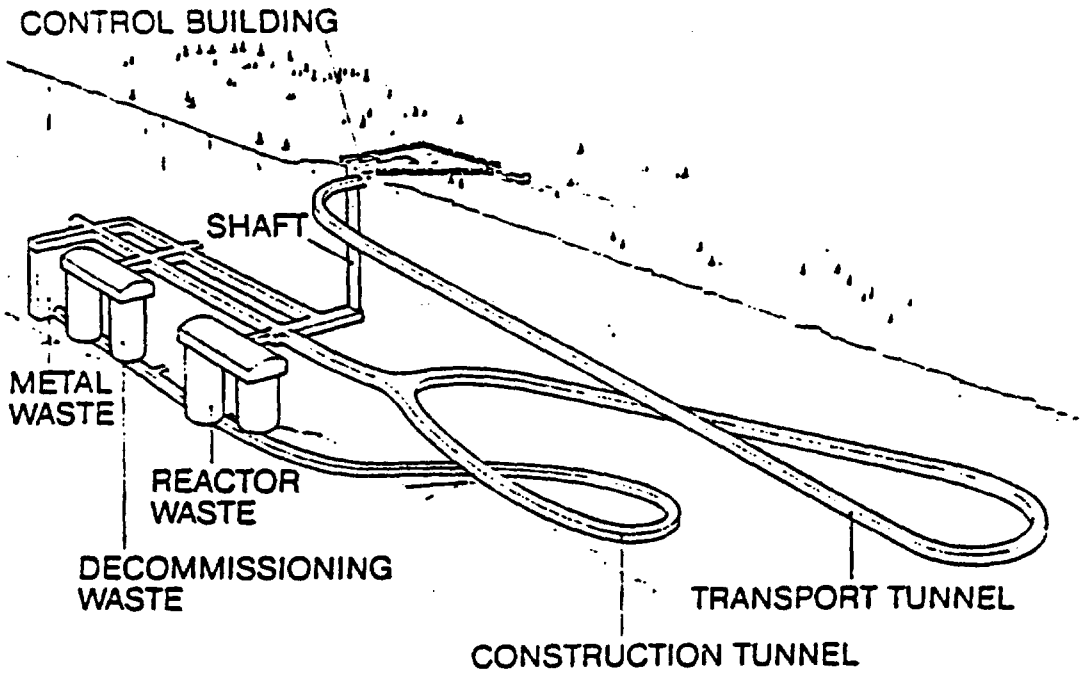


Figure 1: Disposal rooms for reactor waste at Olkiluoto/TVO.

carried out, including: resistivity surveys; sonic logs; seismic measurements (VPS); and radiometric surveys. In addition, cross hole seismic surveys have been conducted between holes up to 200 metres apart. Equipment and interpretation algorithms are under constant development.

7.5.6 The main part of the research and investigations for nuclear waste disposal in Finland to date have concerned reactor waste disposal which require the rock to be investigated at depths 0 to 200 metres. It is believed that the same methods can be applied in the near future in locating and investigating potential sites for high level waste which require the rock to be investigated at depths 0 to 1000 metres.

7.5.7 There are no plans in Finland to establish an underground research laboratory for nuclear waste disposal research. The repositories for reactor waste which will be built by 1992 will be instrumented and monitored during

the construction and operation stages and used as research laboratories to test and develop methods also for the high level waste disposal research and investigations.

7.6 FRANCE

7.6.1 The National Agency for Radioactive Waste Management (ANDRA) is, within the CEA, responsible of the disposal at shallow depth for LLW and of the geologic disposal of HLW and transuranic waste [17]. In addition, studies on the characteristics of the host rocks, especially granite formations, are being carried out by the Institute of Protection and Nuclear Safety (IPSN) of the CEA for assessing the safety of such a disposal.

Site selection

7.6.2 Considering the broad variety of possible host rocks in France, it has been decided to investigate the possibility of creating an underground repository in different rock types: sedimentary rock such as clay or salt and hard rock such as granite or schists. All of them show some advantages and it has been proven in different countries that a safe repository can be constructed in each type. But for all of them, the remaining task is to provide site-specific demonstrations either of technical feasibility and stability during the operational period or of the tightness of the backfilling and/or the surrounding geosphere over a long period of time. In every case, even if all these demonstrations were made, the whole system remains to be optimised.

7.6.3 The possibility of having suitable sites in several host rocks provides an interesting flexibility for the final choice. The first step of the site selection process described in the National Program was to compile a national inventory of the possible sites, based on criteria among which the most important were: long-term stability, and favorable hydrogeologic sites with very low permeability and good physico-chemical properties such as nuclide retention. The national inventory was completed at the end of 1983. About 30

zones covering the four main typical geologic settings: clay, outcropping granite, schists, and salt, were identified as possible locations for a future repository. In some cases a combination of layers of the different materials improves the isolation capacity of the site.

7.6.4 Among the 30 zones, a preselection has been made of the most attractive ones on which further investigations have to be carried out. The second step will be to start field investigations to confirm the choice of the preselected sites and to meet the Government's requirement that a candidate location be nominated for the Underground Site Validation Laboratory (USVL) by the end of 1989. The kind of work to be performed naturally depends on the type of geologic formations, but in every case it will need geophysical measurements from the surface and several deep drillings with core recovery. This second phase should start in early 1987 on four to five zones covering all the different typical kinds of host rock.

7.6.5 After a candidate site has been selected, construction of the Underground Site Validation Laboratory will start. The laboratory will be the main tool to complete the site selection process by validating the site. Validation means that, with the data collected during this phase, it will be possible to demonstrate the technical feasibility and the economics of the repository, and to prepare a preliminary safety impact report to show that the future repository's consequences for the environment are acceptable.

7.6.6 To achieve this, it is necessary to explore in depth the whole volume of rock involved in the repository construction and to carry out in-situ experiments to confirm thermal and mechanical behaviour of the host rock and to evaluate and model the isolation capability of the whole system of barriers, including backfilling material and the different layers of the geosphere. Construction of the USVL will probably spread over two years and its implementation will last between two and three years. If the program proceeds normally, site evaluation will be obtained before the end of 1994.

Generic In Situ Studies In Crystalline Formations

7.6.7 Within the R&D programme of the CEA, IPSN takes charge of safety studies relating to the disposal of radioactive waste [18]. IPSN studies of radioactive waste disposal in crystalline rocks began with the first five

years plan of the CEC (1976-1980). At the time IPSN had started up an intensive programme of research on geologic crystalline formations. That programme included the inventory of the granitic massifs potentially favorable for the disposal of HLW, and detailed studies on geology, geophysics and hydrogeology and some related studies (particularly modelling). Three granitic massifs were studied in detail:

- two, located in Brittany, formed the subject of thorough investigations on geophysic, petrography, tectonic and hydrogeology.

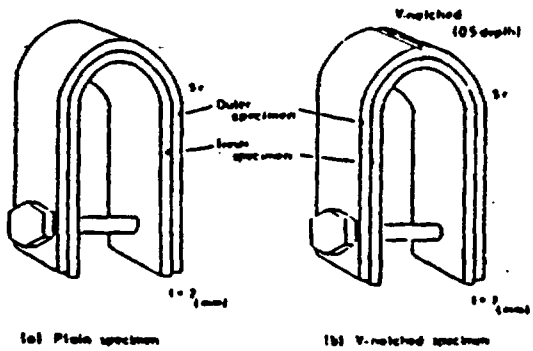
- the deep borehole were carried out in the Auriat Massif, located in Limousin. One is 1003,4 deep and the other bored at 10 meters is 500 m deep.

7.6.8 The 1000 m borehole was the subject of numerous investigations regarding petrography of granite, mode of fracturing, permeability at different depth, geotechnic and thermal properties, thermal flux, chemical composition of the waters, detailed analysis of the fractures, etc. Some tests with tracers were also carried out.

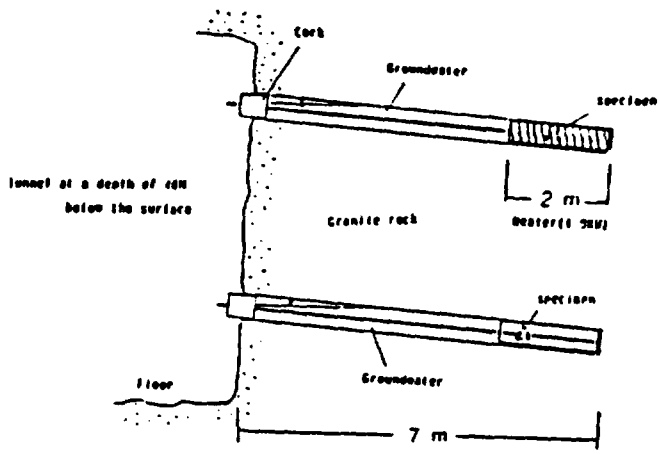
7.7 JAPAN

7.7.1 In-situ experiments have been carried out in Japan since 1978 in several kinds of crystalline rock such as granite, diabase, propylite and shalstein by Japan Atomic Energy Research Institute (JAERI) using a gallery of an old metal mine [19]. The purpose of this research and development work was to examine experimental techniques in order to develop site assessment methodologies for the disposal of radioactive waste. In-situ experiments in fractured granite were started in 1983 at a new test site as part of a three-year programme. An important part of the safety assessment of the geological disposal of high level waste is the effect of heat from radioactive decay on the surrounding host rock. Migration of radionuclides released from a repository is also one of the most important factors to be considered when carrying out safety analyses of a repository for radioactive waste in a wet geological formation. At the Granit mine in Kasama, two heater tests, a migration test using a fracture zone and several corrosion tests using ten kinds of metal for canister materials were performed in an experimental room excavated for exclusive use of these experiments, i.e.

JAPAN IN SITU R&D



SCHEMATIC DIAGRAM OF DOUBLE U-BEND TYPE SPECIMEN



CROSS-SECTION VIEW OF CORROSION TEST

- Heater test

  1) small scale heater test in a no fractured part
  2) canister scale heater test in a fractured part

- Migration test

  migratioin of bromine in a fracture zone

- Corrosion test

  Stress corrosion cracking (SCC) test for 10 kinds of metal

- Validation test of safety assessment methodology with deep boreholes

FUTURE PLAN

7.7.2 The effects of thermal loading on the fractured granite will be quantitatively analysed. Large scale migration tests will be performed for the purpose of development and validation of a migration model using sorbing tracers as well as non-sorbing ones. Stress corrosion cracking tests will be carried out under deeper geological conditions.

7.8 SWEDEN

7.8.1 There are two major in-situ research, demonstration and investigation programmes carried out and planned in Sweden in support of R&D into the disposal of spent fuel [20]. There are the long established International Stripa Project and a recently initiated Underground Research Laboratory Project.

STRIPA PROJECT

7.8.2 The Stripa Project is a joint in-situ research project undertaken by a number of Member countries of the Organisation for Economic Co-operation and

Development (OECD) and is carried out under the auspices of the OECD Nuclear Energy Agency (NEA). It was established in 1980 to develop techniques to fully investigate sites located deep underground in granite rock formations that are potentially suitable for the disposal of heat generating radioactive wastes, and also to examine particular engineering design phenomena associated with enhancing the long term safety of a high level radioactive waste repository.

7.8.3 The research work carried out within the project is concentrated on the Stipa Mine, an old abandoned iron ore mine located in the central of Sweden. Adjacent to the ore excavations is a granitic intrusion which is accessible at about 350 metres below the ground level. Several drifts have been excavated at this level in order for the specific experiments to be carried out.

7.8.4 The Stripa Project has been divided into three phases. Phase 1 was carried out from 1980 to 1985 and Phase 2 began in 1983 and is due to be completed in 1987. Phase 3 started as of 1st September 1986 and should be finalised by 1991.

Phase 1 of the Project

7.8.5 Phase 1 of the Stripa Project was started in 1980 and completed in 1985. The experiments in Phase 1 were grouped under the following headings:

- Hydrogeological and hydrogeochemical investigations
- Migration in a single fracture
- The Buffer mass test

Stripa Phase 2

7.8.6 Phase 2 began in 1983 and is due to be completed in 1987. The research is carried out under four main headings:

- Hydrogeological investigations of the Stripa granite and migration of nuclides within single and multiple fracture systems

- The hydrogeochemistry of groundwaters at the Stripa Mine

- The detection and characterisation of fracture zones in granite

- The behaviour of bentonite clay as a backfilling and sealing material under field conditions

7.8.7 The experience gained from Phase 1 was also used in the development of Phase 2 of the project and in the planning of Phase 3. Both of these phases build on the findings of Phase 2 by continuing the broad areas of work and initiating new activities aimed at developing techniques and procedures for evaluating the performance and engineering development of a radioactive waste repository located in granitic rock.

Stripa Phase 3

7.8.8 The Phase 3 of the Stripa Project started as of 1st September 1986 and is expected to continue until 1991. The research activities in the third phase of the Stripa Project will be carried out under two headings:

- Fracture Flow and Nuclide Transport
- Groundwater Flow Path Sealing

<u>Fracture Flow and Nuclide Transport</u>

The main objectives are:

- To predict groundwater flow and nuclide transport in a specific unexplored volume of the Stripa granite and make a comparison with data from field measurements. The comparison will be made by means of an integrated approach with existing site characterisation tools and methods, particularly those developed under Phases 1 and 2

- To continue the development of site assessment methods and strategies and, where found appropriate, apply them in later stages of the integrated site characterisation exercise outlined above.

Groundwater Flow Path Sealing

7.8.9 The principal objectives are:

- To identify, select and evaluate sealing substances which promise to possess long-term chemical and mechanical stability; and

- To demonstrate in a pilot test as well as in a full scale field test by use of suitable methods and techniques, the effectiveness of such substances for the long-term sealing of groundwater flow paths in the Stripa granite.

7.8.10 The Phase 3 Programme continues and builds on the work carried out under Phases 1 and 2 and also develops new areas of research. An unexplored volume of granite (about 125 m x 125 m x 50 m), will be studied for which a combined deterministic/statistical flow model will be developed and compared with data from field measurements. This modelling approach will be used because previous investigations have shown that an equivalent porous media model is considered inappropriate for similar volumes of fissured crystalline granitic rock. If successful, this will significantly enhance the confidence in the application of predictive mathematical models to site specific conditions.

7.8.11 The ultimate product of the Phase 3 programme will be the availability of the tools and know how to assess a potential radoactive waste disposal site. Techniques will have been developed to carry out non-destructive site investigations which will have been fully evaluated under rigorously controlled in situ conditions, together with sealing methods designed to optimise the isolation potential of a repository established within crystalline granitic rock.

UNDERGROUND RESEARCH LABORATORY

7.8.12 In as much as research activities at Stripa will be wound up in early 1990s, it has been deemed to be of very high priority to build an underground research laboratory where research can be pursued at a high scientific level to broaden the available body of knowledge. The research laboratory should be

sited in an environment that is geologically and geohydrologically unaffected by previous activities. This will provide an opportunity for many scientific experiments of vital interest for a safety analysis with good precision.

7.8.13 The underground research laboratory is also planned for other purposes than purely geoscientific studies. In preparation for the submittal of a siting application, integrated tests, pilot plants and in-situ tests may be necessary during the latter half of the 1990s. Such experiments can be conducted in the underground research laboratory. The goals of the underground research laboratory are to:

- demonstrate that the factors that control the safety of a final repository are understood and can be quantified or delimited

- validate models and assumptions included in the safety analysis.

7.8.14 The principal activities during the period 1987-2010 are planned to be:

- Detailed investigation of the natural barrier (the rock) in bedrock of a final repository character. This includes development of methodology, collection of data and validation of models for groundwater movements and radionuclide transport.

- Pilot in-situ tests for analysis of performance interaction between the repository's engineered and natural barriers.

- Development of appropriate methods for execution and quality assurance of repository construction.

- Demonstration of system, technology and quality assurance.

7.9 SWITZERLAND

7.9.1 In 1985 NAGRA presented to the Swiss Government a detailed report on the feasibility and safety of the final disposal of nuclear waste in

geological formations in Switzerland [21]. In essence the concept is based on two repositories,namely a type C for high-level waste and a type B for low- and intermediate-level waste. The type C repository is a system of mined tunnels (dia. 2.20 m - 3.50 m) at a depth of around 1200 m in the crystalline basement of northern Switzerland. Such a repository should be operational by the year 2020. For the type B repository a mined cavern-system with access through a horizontal tunnel in an alpine formation of marl, gneiss or anhydrite is envisaged. Scheduled start-up time is at the end of this century.

7.9.2 In situ investigations by NAGRA in Switzerland are governed by the above disposal concept. They have been or will be carried out in the following steps.

7.9.3 NAGRA commissioned in June 1984 a test site in crystalline rock at the Grimselpass in central Switzerland. The first 5-year plan of investigations at the Grimsel Test Site (GTS) is being carried out by Nagra in partnership with two German research institutes viz. the Federal Institute for Geoscience and Natural Resources, Hannover (BRG) and the Research Centre for Environmental Sciences, in Munich/Braunschweig (GSF). The main objectives of the investigations at the GTS are:

- to check the applicability of existing research results to the geological conditions in Switzerland

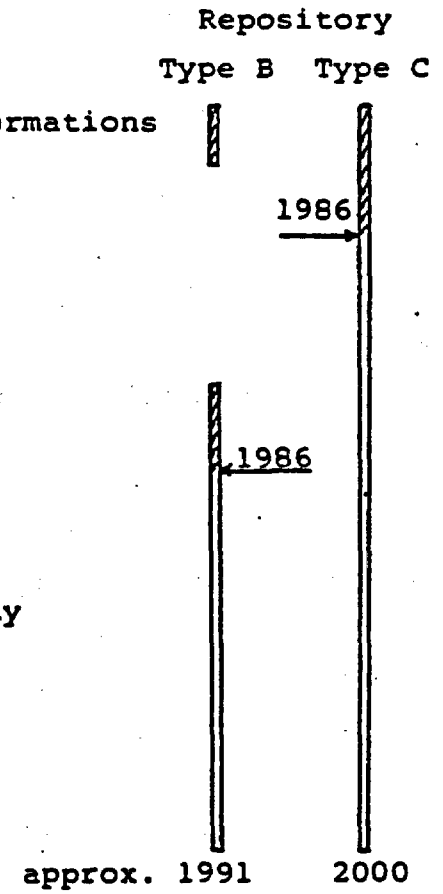
- to carry out specific experiments based upon the Nagra repository concepts

- to build up know-how in the planning, execution and interpretation of underground tests in various experimental fields

- to acquire practical experience in the development, testing and use of test apparatus and measuring methodology.

Fig. 1 and 2 show the layout of the GTS
with the location of the various tests included
in the current five year program.

THE GRIMSEL TEST SITE (GTS)



- **Select potentially suitable geological formations**
  Regional investigations based on existing data
- **Confirm region(s) and formation(s)**
  Seismic investigations, deep drilling
  Standard methods for data acquisition, but special evaluation
- **Select several possible specific sites**
  Additional seismic tests and deep drillings incl. tests in existing underground excavations
  Mostly standard methods, some special tests
- **Select 1 - 2 sites and confirm suitability**
  First, special methods from existing or pilot shafts/galleries
  Next construct access shaft/gallery plus test caverns
  Special methodology, tailored to geological and geometrical characteristics of host rock formation

7.10 UNITED KINGDOM

7.10.1 The last decade in Britain has seen increased interest in the geological disposal of radioactive waste. There have been a number of programmes sponsored by different agencies, all charged with the responsibility of proving the feasibility of disposing of radioactive waste. Since it maintains the national archive and has a long term interest in improved understanding of the geological environment of the UK, the British Geological Survey has been involved in all the programmes [22]. These programmes have ranged from high level to low level waste, from granites to clays and from landfill-style facilities to deep repositories.

7.10.2 Each programme has been associated with some form of in-situ research. This has generally consisted of several boreholes coupled with geological and geophysical surveying. The boreholes have been tested to determine the properties commonly of interest in studies associated with radioactive waste (ie hydrogeological and geochemical parameters). In the earlier

investigations the borehole tests tended to use single boreholes whereas more recently a cross-hole configuration has become more favoured. Another trend in the field investigations has been the desire to integrate the testing with the surveying and to try to interpret more precisely the results from remote sensing methods.

7.10.3 British in-situ research has certain characteristics. Firstly there is a wide range of experience in different rock types. Secondly, because progress towards a repository has not been rapid on any individual programme, studies have been more concerned with the broad issues of a safety case rather than the more specific problems of site investigation. Thirdly, the lack of an underground facility in Britain has discouraged in-situ work on rock mechanics aspects and tended to inhibit integrated studies. Lastly the geochemical and natural analogue work has influenced the studies concerning time scales and the ability to validate models.

7.10.4 In some ways the current work with which the B.G.S. is involved shows that British in-situ research is changing and improving to meet the needs of actual site investigation and site specific safety assessment. Hence the B.G.S. is involved in seven field-based studies at present involving work on:

1. At the Harwell "research site" related to the methods of measuring parameters for safety assessment;

2. combining hydrogeological and geophysical measurements in the Crosshole Programme of Stripa Project Phase II;

3. natural analogues both in the UK and elsewhere;

4. the migration of radionuclides in a shallow glacial sequence;

5. a geochemistry research programme linked to the four shallow sites beginning to be investigated by NIREX;

6. an integrated site characterisation and model validation programme within Stripa Phase III.

POSSIBLE STATEMENT ON UK NIREX [23] & UK DOE WORK

7.11 UNITED STATES

DEFENCE PROGRAMME

7.11.1 The Experimental Program for the Waste Isolation Pilot Plant (WIPP) has been developed by the Department of Energy (DOE) to address those technical issues that concern the safe disposal of Defense Transuranic (TRU) Wastes and Defense High Level Wastes (DHLW) in underground storage rooms [24]. This program involves technology development through laboratory and theoretical studies and in situ testing done in representative waste storage room configurations for both the ambient (for TRU) and heated (for DHLW) conditions. The technology development studies, since 1975, have been investigating phenomena associated with radioactive waste emplacement in a rock salt environment and have produced response models and predictive techniques using available laboratory and theoretical data. The in situ testing program at the WIPP has been developed to evaluate these models and predictive techniques through full-size experiments in the actual host rock. The first portion of the in situ tests (underway since 1984) are without radioactive materials and use electric heaters to simulate heat-generating waste where applicable. The second portion of the in situ testing programme, scheduled for the early 1990s, will include the use of actual radioactive wastes and other radioactive sources.

7.11.2 The in situ testing programme includes analyses and evaluations of data obtained from in situ measurements that provide an understanding of the actual behaviour of salt surrounding full-size storage rooms while undergoing creep closure due to overburden stresses and thermal loadings from waste containers. Data analyses and evaluations also pertain to tests that are designed to measure TRU and DHLW container performance, materials interface interactions, and engineered barriers and seals performance in an actual salt environment. These tests are expected to provide a better understanding of the phenomena, provide in situ data to validate models and theoretical studies, and demonstrate the behaviour of the salt, waste packages, and engineered barriers and seals in an actual underground salt environment. An underground layout of the in situ tests at WIPP is illustrated in Figure

NUCLEAR REGULATORY COMMISSION

7.11.3 Before submitting a license application for a civil radioactive waste repository, the DOE is required by the Nuclear Waste Policy Act of 1982 and by 10 CFR Part 60 to conduct a programme of site characterisation [25]. In situ testing is an important element of site characterisation. These tests are to be performed from the exploratory shaft(s) and underground openings on surrounding rock and on other materials and components such as the waste package, engineered backfill, linings, and seals. The conditions under which these in situ tests are to be run should represent, as closely as possible, the realistic repository environment (for example, temperature and stresses). The tests performed under such conditions would provide data to assess the suitability of a particular site and a particular geologic medium to host high-level nuclear waste and realistic input parameters for the design of a geologic repository.

7.11.4 In situ tests can only be conducted for a limited duration compared with the long time span during which the repository must function to isolate the waste. Analytical, experimental, and numerical models must be used to make predictions far into the future; however, models have their own limitations on applicability and are sensitive to the quality of data used as input. Some of the uncertainties in the prediction process can be reduced by conducting appropriate in situ tests on a representative volume of rock and by using appropriate models to account for possible inherent spatial variations of physical, hydraulic, and chemical properties within the rock formation. By comparing in situ test data with modeling results, models can be validated, thereby reducing some uncertainties in the prediction process.

NRC Technical Positions on In Situ Testing

7.11.5 The NRC staff technical positions on in situ testing during site characterisation are:

(i) Before submitting a license application, DOE should perform a necessary and sufficient variety and amount of in situ testing to support, if the facts so warrant, a staff position that the requirements for issuance of a construction authorisation (10 CFR Part 60.31) have been met.

(ii) The in situ testing program should be developed with two major objectives: (a) characterisation of host rock and in situ measurement of its properties prior to construction and waste emplacement; and (b) determination of response characteristics of the host rock and engineered components to construction and waste emplacement.

(iii) DOE should present its site specific and design specific in situ test plans in the Site Characterisation Plan (SCP).

(iv) Before developing the in situ test plan, DOE should develop a rationale for in situ testing and present this rationale with the test plan in the SCP. The overall goal of the rationale should be to ensure that all important parameters are identified and ranked according to their relative importance in supporting 10 CFR Part 60 licensing findings.

(v) For successful site characterisation, DOE should integrate the data from surface borehole testing and laboratory testing on small-scale samples with the in situ test results.

7.11.6 This technical position is general and covers in situ testing for all potential repository sites and designs. It was developed and presented to the Department of Energy in an effort to provide ongoing pre-licensing guidance.

DEPARTMENT OF ENERGY

7.11.7 In accordance with the requirements specified in the Nuclear Waste Policy Act of 1982, the Department of Energy (DOE) is developing site characterisation plans for the three potential sites for the first repository [26]. Those sites are the Hanford site in the state of Washington, the Yucca Mountain site in Nevada and the Deaf Smith County site in Texas. As part of the site characterisation plans, the DOE will describe the methodology used to identify the information needed from the characterisation studies and the tests necessary to obtain that information.

7.11.8 The methodology used in developing the site characterisation plans was to first identify a common set of issues that must be resolved to demonstrate compliance with applicable Federal regulations and to support site selection and licensing. The next phase was to develop "issue resolution strategies"

for each of the issues. Since the issues are derived from applicable Federal regulations, the information needed to resolve them will be the basis for planning of the work that need to be done to demonstrate compliance with the regulatory requirements. The issue resolution strategy provides a step-wise procedure for identifying and planning the work needed to support resolution of the issues. Because the rock types and conditions at each of the candidate sites are different, the issue resolution strategies and the related site characterisation plans will differ from site to site.

7.11.9 As part of the issue resolution strategy, DOE utilises a process called "performance allocation". Performance allocation entails deciding which items within a geologic repository will be relied upon in resolving a particular issue. The function an item must perform and the processes that affect the performance are identified for each item. Using performance allocation, a testing programme can be developed which obtains the information necessary to demonstrate that an item will perform its particular function as expected. Once the appropriate information needs are identified, DOE can identify what underground tests should be conducted.

7.11.10 The in situ tests currently being considered for site characterisation at each of the three candidate sites are grouped under three broad categories: 1) basic geologic characterisation tests; 2) hydrologic characterisation tests; and 3) near-field and thermally perturbed tests. The objective and/or rationale for performing a test is based on the performance allocation process.

7.11.11 Of the 47 tests currently defined, only 14 (30%) of the tests will be conducted at all three sites. As mentioned above, this is due to differences in the characteristics of the site (i.e., rock type, in situ conditions, etc.) or differences in the design of the test facility. For example, the perched water test for the Nevada Nuclear Waste Investigations project (NNWSI) and the brine migration test for the Salt Repository Project Office (SRPO) are not planned at the other sites due to the site specific nature of the phenomenon being investigated. The design of the shafts to the exploratory shaft facility at the Basalt Waste Isolation Project (BWIP) prevents the mapping of the shaft walls. The shaft will be blind drilled and the shaft liner installed while the drilling mud is still in the shaft, preventing direct access to the shaft wall.

7.11.12 As part of the site characterisation plan, detailed test plans and procedures are being written for the test at each site. In addition, quality assurance procedures are required to insure the test data is accurate, reliable, and traceable. The test plans and procedures will be reviewed by several groups of peers to insure the tests are appropriate and comprehensive. The tests may change based on peer review recommendations or to reflect modifications in the information needs and strategies chosen to resolve the various issues.

7.12 COMMISSION OF THE EUROPEAN COMMUNITIES

7.12.1 On-site investigations, either for site characterisation or for generic purposes, has formed a major part of the research activities in the CEC programmes for a considerable time [27]. The works at Auriat and Fanay-Augères (France), Altnabreac and Troon (UK), Mol (Belgium), Asse and Konrad (FRG), as well as the numerous Italian sites including Pasquasia (Sicily) are now well known. The investigations described below are a logical follow up of this effort and are carried out within the third Community R&D programme on radioactive waste management and storage (1985-1989) as well as the radioactive waste programme of the Joint Research Centre of the European Communities.

<u>Underground pilot facilities</u>

7.12.2 The salient feature of this programme is the participation of the CEC in the construction and operation of underground demonstration facilities, in which simulated or real waste forms will eventually, in a retrievable manner, be emplaced and monitored. At present, these include the HAW project in the Asse salt mine (GSF, FRG), the HADES project in the Boom clay at Mol (CEN/SCK, B) and the ATLAS project in a medium to be specified in France (ANDRA, F). Preliminary contacts are now going on between the Commission and the Spanish ENRESA concerning a demonstration facility in granite (the IPES project).

7.12.3 The co-operation includes, among other things, participation of scientists of other Member states in the above-mentioned projects, especially

by means of temporary secondment of personnel, and the completion of the programmes with their own specific activities, according to modalities specified on a case-by-case basis. The significant participations of the ECN (NL) in the HAW project and ANDRA (F) in the HADES project are examples of this.

Site characterisation and improvement of techniques

7.12.4 The main effort at Community level is directed towards the detection and characterisation of fractures in geological media. A joint project puts together the efforts of the BGS (UK), University of Exeter (UK) and ISMES (I) for the detection of faults in clays using respectively hydrological techniques, gas emanation measurements and geophysical methods. The BRGM (F) pursues the development of an electromagnetic borehole probe for fracture location in granite; this is complemented by the improvement of geochemical downhole probes (CEA-IPSN, F). Finally, the GSF (FRG) and the ECN (NL) are realising a new deep, dry-drilled exploratory borehole with large diameter in the Asse salt mine.

Rock Mechanics

7.12.5 This item is now recognised as being of basic importance for geological disposal. The behaviour of the rock mass and its response when subjected to excavation, heat output and gamma-radiation from wastes, will be a major item of research for all the demonstration facilities listed above.

7.12.6 Additional specific research is carried out mainly at the Fanay-Augères underground laboratory, where a scaled thermo-hydro-mechanical test is being prepared by the CEA-IPSN (F). The long-term stability of clay, either at ambient or elevated temperature, is being studies at the Mol site by a co-operative programme involving the CEC/SCK (B), ANDRA (F) and its sub-contractors.

7.12.7 As regards salt, a specific effort was made concerning the validation of rock mechanics computer codes via the Community project COSA. In this project, the behaviour of a salt cube sampled from the Asse mine and submitted to mechanical and thermal loading was predicted by ten European computer teams working independently under the co-ordination of the firm ATKINS (UK). The

exercise was viewed as a useful step towards the quality assurance of the codes. A subsequent phase will consider the retrospective calculation of an in situ heating experiment in salt.

Backfilling and Sealing

7.12.8 Major contributions are expected from the demonstration facilities, both for buffer and backfill materials. Supporting research will be carried out as regards sealing of in situ boreholes and fractures in the Fanay-Augères mine (CEA-IPSN, F), the in situ thermal testing of a clay-based buffer material at reduced scale (CEA-DRDD, F) and the behaviour of large, old, backfilled rooms in the Asse salt mine (GSF, FRG). The influence of heat on compaction of crushed salt is also being investigated by a heating test in a French potash mine co-ordinated by ANDRA (F). Backfilling tests will also be carried out concerning the deep borehole disposal concept in clay, as supported by ENEA (I) and ISMES (I), to be carried out on an Italian site.

Migration of radionuclides in the geosphere

7.12.9 The MIRAGE II project is continuing previous efforts on radionuclide migration in the geosphere and is now concentrating on five areas: near-field studies with a view to source term, modelling behaviour of actinides and fission products in natural aquifer systems, in situ migration studies and techniques, natural analogues and vevelopment of geosphere migration calculation tools.

Amongst the actions undertaken in the framework of this project, the intercomparison exercises realised under the auspices of the COCO Club could be mentioned as an example focusing on the role of complexes (humic acids) from specific sites (Fanay-Augèes, Mol, Gorleben) on radionuclide migration and on the characterisation and sampling of colloids from natural groundwater of reference sites. In situ migration tests are being prepared at Drigg (BGS, UK) and at Mol in the existing laboratory in clay (CEN/SCK); the boreholes at the ISPRA site are the subject of the FARM project by JRC-ISPRA.

Sites such as the Lock Lomond (UK) and the Langenberg (F) are natural analogues for radionuclide migration respectively in sediments and hard rock. These works now fall within the broader scope of the CEC Natural Analogue Working Group initiated last year by the Commission.

7.13 OECD NUCLEAR ENERGY AGENCY

7.13.1 Disposal into deep geological formations was always a priority area and, in 1975, the RWMC established the Coordinating Group on Geological Disposal (CGGD) to provide advice and develop joint initiatives in this area. At the annual meeting of the group, following a review of geological disposal activities in Member countries and those sponsored by the NEA, topical issues were addressed in order to provide recommendations and make arrangements for workshops or consultant meetings. The work of the CGGD culminated in 1984 with the publication, jointly with the CEC, of a report entitled 'Geological Disposal of Radioactive Waste - An overview' [6]. One of the mian conlusions of the reports was that, on the basis of available information, early disposal of either high level waste or spent fuel is technically feasible, and that future research should concentrate on imporving the understanding of specific aspects rather than establishing the viability of any particular concept. It further recommended that early engineering demonstrations of disposal so as to further generate public confidence and understanding. Such findings were to play a major role in formulating the future programme of the RWMC."

7.13.2 The most recent review of the programme of work of the RWMC was carried out towards the end of 1984. As a result it was agreed to focus on two areas of major importance i.e. performance assessments and in situ research and investigations. It was considered extremely beneficial ot have an exchange of views at an international level on both topics and two new advisory groups were established replacing the CGGD which had played a pionneering role in initiating actual cooperation, suh as Stripa and ISIRS. Each group would provide advice for the RWMC, help coordinate the various activities in each area and recommend new initiatives where appropriate. The following text describes the main activities of the RWMC in these two key areas.

Advisory Group on In Situ Research and Investigations for Geological Disposal (ISAG)

7.13.3 The In Situ Advisory Group met for the first time on 28-29 October 1986 with the following draft terms of reference:

i) improve information exchange between different field projects and between field projects and performance assessments;

ii) keep close contact with the Performance Assessment Advisory Group on matters of mutual interest (e.g. validation, uncertainties and data acquisition);

iii) identify problems of mutual concern and seek ways that these may be overcome, e.g. by recommending and holding topical workshops;

iv) identify initiatives for cooperation; and

v) advise the RWMC on matters of interest and/or concern.

7.13.4 In fulfilling the terms of reference the ISAG will place the emphasis on improving <u>information exchange among field projects located in every candidate host rock formation</u> i.e. clay, salt, granite, tuff and basalt and also between those working in situ and those carrying out performance assessments. In particular, this 'club' embraces activities associated with:

i) in situ experimentation at various underground laboratories, eg. Stripa (Sweden), Grimsel (Switzerland), URL (Canada), Mol (Belgium), etc.;

ii) the investigation or potential disposal sites: Forsmark (Sweden), US Field Projects, Konrad (FRG), etc.;

iii) the engineering and laboratory studies in support of i) and ii);

iv) improving information exchange between scientists working in i), ii) and iii) and those carrying out performance assessments.

7.13.5 At the first meeting representatives from Belgium, Canada, Finland, France, FRG, Japan, Sweden, Switzerland, United Kingdom, USA and CEC were present. Participation in the group is entirely voluntary and therefore no budget is required. While progress on non-technical issues will be reviewed periodically within ISAG, the group will however act as a specialist club where <u>technical issues</u> on <u>all types</u> of geological media will be discussed. At

its first meeting, ISAG agreed to improve interaction between those in charge of in situ experiments and modellers, notably for the purpose of site characterisation, and proposed the organisation of two workshops in 1987 on excavation response and on backfilling and sealing materials and techniques respectively. ISAG does not therefore cover the more policy-oriented discussions which would be the objective of a crystalline repository programme directors group.

The NEA International Stripa Project

7.13.6 The International Stripa Project started in 1980 on the strength of the results achieved under the Swedish American Cooperative Programme which began in 1977. Three phases of research have been agreed: Phase 1, 1980-85; Phase 2, 1983-87; and Phase 3, 1986-91. Research is carried out in a former iron ore mine located in central Sweden in granite bedrock some 360-400 metres below ground [see Section 7.8].

7.13.7 The International Stripa Project is one of the prime examples of cooperation in the area of radioactive waste management. By combining the resources of several nations it has been possible to carry-out costly field research so that tools and methodologies now exist for the characterisation of granite host rocks on which to base judgements on safety and in designing repository systems. Also large scale demonstration experiments have been carried out so as to enhance confidence in repository design concepts.

NEA Performance Assessment Advisory Group (PAAG)

7.13.8 The objective of PAAG is to provide an international forum to consider post-closure performance assessments for the safe disposal of all radioactive waste types with the emphasis on the long term, in order to help build confidence within the technical community.

In meeting this objective, the group would:

i) exchange information and experience to further the development of performance assessment methodologies, and avoid duplication of effort;

ii) identify initiatives for co-operation on the development and use of performance assessment methodologies, in particular in the areas of model development, data acquisition and regulatory requirements.

iii) advise the RWMC on scientific and technical aspects of performance assessments by periodic reports to the Committee on the current state-of-the-art, and

iv) Assist the RWMC in the co-ordination of existing and new activities of NEA in the area of performance assessments, including peer reviews on request.

7.13.9 The following technical areas are covered by the group. Model development - including verification, validation and code development and exchange. Data acquisition - including data base development, assessment of uncertainty in data and data from site investigation, and co-ordination with in situ research and laboratory studies. Regulatory needs - including the development of performance objectives and criteria. PAAG will play a major role in the future in advising the RWMC on matters relating to the most substantial part of its programme. Improvement of performance assessment methodologies and confidence building are key words for the future activities of PAAG which will result in both general and topical reports.

NEA International Sorption Information Retrieval System

7.13.10 The International Sorption Information Retrieval System (ISIRS), a data base for the storage and manipulation of information related to the sorption of radioelements from solution onto geologic materials, was initially created in July 1981, with the support of 11 Member countries, for a period of two years. During this period, the data base management software was developed by Pacific Northwest Laboratories (PNL) in the United States, acting on behalf of the Operating Agent - the US Department of Energy. Following this initial stage, the Participating countries agreed in 1983 that the data base and computer software be transfered from PNL to the NEA Data Bank at Saclay and that the Technical Committee of ISIRS should undertake to evaluate the performance of the System over the next two years. Subsequently, the RWMC accepted a recommendation of the Technical Committee that ISIRS be continued

for two more years (July 1985 - June 1987) as a service to interested countries, within the framework of the NEA.

7.13.11 The objective of ISIRS is to advance the understanding and prediction of the migration of radionuclides through geologic media in support of safety assessments for radioactive waste disposal. Its scope covers:

i) the development and preparation of an expanded data base for the continued operation of ISIRS;

ii) the testing and updating of this data base as well as the system's maintenance and upgrading of a number of operational features of ISIRS;

iii) the retrieval of data from ISIRS in response to requests from Participants.

NEA Chemical Thermodynamic Data Base (THERM)

7.13.12 The development of an international chemical thermodynamic data base is a recent activity of the NEA carried out jointly between the NEA Data Bank and the Division of Radiation Protection and Waste Management of NEA. It was initiated to account for the increasing need of such data which are going to constitute an essential tool for the next generation of geochemical codes used in safety analyses for nuclear waste repositories. The main difference with ISIRS is that while K_d values are essentially empirical and are supposed to represent a number of physical and chemical phenomena acting together in specific circumstances, thermodynamic data are fundamental values which can be used in any specific or generic situation. The development of this data base involves not only a compilation of all relevant published thermodynamic data, but also a detailed critical review and, finally, the selection of a 'best data set' which will be recommended. Each review is being performed by a group of four to five internationally acknowledged experts in chemical thermodynamics. Each expert team has at least one member who is CODATA liaison, to assure compatibility with the CODATA tables. The first 10 elements to be reviewed are: Uranium, neptunium, plutonium, americium, technetium, cesium, strontium, radium, iodine and lead. The thermodynamic data being compiled and reviewed for each species include:

$\Delta_f G°$	the standard Gibbs free energy of formation	$(kJ.mol^{-1})$
$\Delta_f H°$	the standard enthalpy of formation	$(kJ.mol^{-1})$
S°	the standard entropy of formation	$(J.mol^{-1}K.^{-1})$
Cp	the standard heat capacity (at constant pressure)	$(J.mol^{-1}K.^{-1})$

together with uncertainties and, if available, the temperatude functions. Emphasis is placed on data for 298.15° K, 10^5 Pa and zero ionic strength.

7.13.13 In addition, an interface program is being developed which makes it possible to extract specific d[illegible] from the thermodynamic data base and to convert them into a form in which they are readable by geochemical modelling codes, such as PHREEQE, MINEQL and EQ3/6, all of which can be used geochemical reaction path computer codes. The data could also be made available in a form compatible with other computer codes if there is any demand from users.

7.13.14 This relatively new activity is at present funded within the regular budget of the NEA Data Bank and of the NEA Secretariat. Proposals now under discussion could involve the combination of ISIRS and THERM. There is actually a strong support for THERM, and this activity is expected to continue and even expand in the next few years, within a broadly NEA framework where computer-related activities in support of system performance assessments are going to be integrated and also cover modelling codes.

NEA Probabilistic Systems Assessment Code User Group

7.13.15 The PSAC User Group was established by the RWMC in early 1985 following a request from the United Kingdom in order to help coordinate the development of probabilistic assessment codes for radioactive waste management applications such as SYVAC. It provides an international forum for:

i) exchanging information and experience;
ii) comparing and verifying codes;
iii) peer reviews;
iv) carrying out joint code development activities; and
v) discussing topical technical issues.

7.13.16 Only those Member countries actively developing probabilistic systems assessment codes are invited to take part in the User Group.

Currently, the 15 Group members are drawn from organisations in Belgium, Canada, the Federal Republic of Germany, Finland, Japan, Sweden, Switzerland, the United Kingdom and the United States, as well as the Joint Research Centre of the CEC.

7.13.17 The main emphasis is placed on code exchange and intercomparison as well as discussion of specific technical issues. No budget is involved although substantial resources are required within Participating countries in order to perform computer calculations, intercomparisons, etc. This is also an expanding NEA activity, conducted in cooperation with the NEA Data Bank.

HYDROCOIN

7.13.18 The NEA is participating in the Secretariat of the Swedish initiated HYDROCOIN exercise. The purpose of the study is to obtain improved knowledge of the influence of various strategies for groundwater flow modelling for the safety assessment of final repositories for nuclear waste. To this end calculations are made with different mathematical models used by a number of organisations. The study is intended to address:

a) the impact on the groundwater flow calculations of different solutions algorithms;

b) the capabilities of different models to describe field measurements; and

c) the impact on the groundwater flow calculations of incorporating various physical phenomena.

The project has fourteen participating organisations, including the Swedish Nuclear Power Inspectorate (SKI) as managing participant and OECD/NEA as a member of the project Secretariat. It began in 1984 and is due to be completed in 1987.

8 REFERENCES

[1] Nuclear Spent Fuel Management - Experience and options; A report by an OECD/NEA Expert Group, OECD/NEA, Paris 1986.

[2] H. Hamstra and Y. Van der Freer, "New ICRP norms and underground disposal of radioactive waste", Energie Spectrum, 81, 4, ECN, The Netherlands 1981 (in Dutch).

[3] "Objective, concepts and strategies for the management of radioactive waste arising from nuclear power programmes; report of an NEA group of experts", OECD/NEA, Paris 1977.

[4] Disposal of radioactive waste - An overview of the principles involved, OECD/NEA, Paris 1982.

[5] "Geological disposal of radioactive waste, research in the OECD area", OECD/NEA, Paris 1982.

[6] "Geological disposal of radioactive wastes: An overview of the current status of understanding and development", OECD/NEA and CEC, Paris 1984.

[7] Long-term management of high-level radioactive wastes - the meaning of a demonstration, OECD/NEA, Paris 1983.

[8] The Management of high-level radioactive waste - A survey of demonstration activities, OECD/NEA, Paris 1985.

[9]) In Situ Research and demonstration plans in the Hades Project (Mol, Belgium)

[10] The Hades Demonstration Project for Radwaste Disposal in Deep Clay. L.H. Baetsle - A.Bonne - P. Dejonghe

[11] Compatibilityof Candidate Overpack Materials with Deep Argillaceous HLW Disposal Environments. H.A.W. Tas - W. Debruyn - J. Dresselaers

[12] IN Situ Testing of Nuclear Waste Forms in an Underground Laboratory in Clay. P. Van Iseghem - W. Timmermans

[13] Disposal of Radwaste in Clay: the Experience gained in Belgium. A. Bonne - B. Neerdael

[14] Atomic Energy of Canada Limited's Underground Research Laboratory for Nuclear Waste Management. Gary R. Simmons

[15] The Asse Mine - The German R&D and Testing Site for Radioactive Waste Disposal

[16] In Situ Research in Finland. Paavo Vuorela

[17] Point des recherches et expérimentation In Situ - Stockage en profondeur. Mme André-Jehan

[18] Note sur les Etudes effectuées dans le laboratoire souterrain de Fanay Augères. A. Barbreau

[19] In Situ (Experiments in fractured granite, M. Kumata, H. Kimura, K. Shimooka, A. Nakagoshi, S. Muraoka & H. Nakamura, JAERI 1986.

[20] In Situ Research, Demonstrations and Investigations for the Disposal of Radioactive Waste in Sweden. B. Stillborg

[21] In Situ Investigations in Connection with the Swiss Concept for Radioactive Waste Disposal. R.W. Lieb - P. Zuidema

[22] In Situ Research on Radioactive Waste Disposal - The British Geological Survey Connection. J.H. Black

[23] In Situ Research for UK Nirex. P.J. Bourke

[24] The Integrated In Situ Testing Program for the Waste Isolation Pilot Plant (WIPP). Rudolph V. Matalucci

[25] Overview of the United States Department of Energy's Site Characterisation Tests in the Exploratory Shaft Facilities at three Candidate Repository Sites. C.F. Voss

[26] Generic Technical Position on In Situ Testing during Site Characterisation for High-Level Nuclear Waste Repositories. Mysore S. Nataraja

[27] Overview of the CEC Actions in the Field of In Situ Research and Investigations for Continental Geological Disposal. P. Venet - B. Côme

ANNEX 1

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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

IN SITU ADVISORY GROUP (ISAG)

Improving Communication and Interaction Between In-Situ Research and Investigations and Modelling - Questionnaire

1. Following a recommendation made at the first meeting of the NEA Advisory Group on In Situ Research and Investigations for Geological Disposal (ISAG) a consultant group(*) was convened by the Secretariat to, among other things, consider ways of increasing communication and interaction between in situ researchers and investigators and those developing performance assessment models. The consultants considered a background paper on the need for effort in this area and possible solutions. The document was largely based on comments received from several members of ISAG and the findings of an NEA workshop on system performance assessment in October 1985 when the links between laboratory/field observations and modelling activities were considered. The consultants agreed that this is currently one of the most important areas that could benefit from discussion at an international level. However, they considered that any initiatives should be based on a thorough review of available information and as wide a range of views as possible, not only from those carrying out in situ research and investigations but also from those developing and using performance assessment models. It was therefore agreed that the Secretariat prepare a questionnaire which would be used to gather the necessary information and views. The questionnaire would be given a high priority and consequently would be distributed to the NEA Radioactive Waste Management Committee as well as to ISAG and PAAG and others as appropriate.

2. The findings of the consultant group were discussed at the meeting of the NEA Performance Assessment Advisory Group in March. The importance of increasing interaction and communication was endorsed by PAAG and it was agreed that close links between ISAG and PAAG should be maintained in developing the questionnaire and in considering the results.

(*) Members of the Consultant Group were:
Dr. Bonne (Chairman), Ms. André-Jehan (ANDRA), Mr. Bourke (AERE), Dr. Brewitz (GSF), Dr. Weidman and Dr. Zuidema (NAGRA), Dr. Simmons (AECL)

The following timetable is suggested:

(i)	15th May	Draft questionnaire sent to ISAG consultant group and several PAAG members for comments
(ii)	29th May	Deadline for completion of draft questionnaire distribution of draft questionnaire to ISAG
(iii)	23rd-25th June	Discussion of draft questionnaire at ISAG meeting in Paris
(iv)	10th July	Questionnaire sent to RMWC for distribution to ISAG and PAAG members and others as appropriate
(v)	1st October	Deadline for receipt of completed questionnaires
(vi)	end October	Meeting of ISAG/PAAG Consultant Group to consider the results and prepare recommendations.

3. The first draft of the questionnaire is attached for the comments and approval of ISAG prior to its distribution to the RWMC, PAAG, etc.

Draft 18.5.1987

ANNEX I

QUESTIONNAIRE ON THE INTERACTION BETWEEN EXPERIMENTS AND MODELLING

Background

This questionnaire has been formulated in order to ascertain the most pressing issues currently arising from the various R&D programmes in OECD Member countries devoted to selecting, assessing and developing sites for the disposal of radioactive wastes. The information will be used as the basis for planning initiatives at an internatioinal level as the first step to increase communication between those working on the development of predictive mathematical models for performance assessments and those carrying out in situ research and investigations. The objective is to compile comprehensive information and comments on the status of modelling and experimentation for concept feasibility and safety assessments so as to assess the need and scope for initiatives at an international level to increase the communication and interaction between those working in these areas.

This is an initiative taken by the NEA In Situ Advisory Group (ISAG) in co-operation with the NEA Performance Assessment Advisory Group (PAAG). Its scope is not limited to any particular host geology or disposal concept, though separate questionnaires are requested for each i.e. Argillaceous, Salt/Anhydrite and Crystalline rocks and Low level, Intermediate, or High level/spent fuel concepts.

The questionnaire is designed to complement a similar one on scenarios that has been distributed by PAAG. It is intended that a joint ISAG/PAAG meeting of consultants meet in the Autumn to consider the responses and prepare recommendations on the way forward.

1. GENERAL INFORMATION

Name .....

Organisation .....

Address .....

.....

Tel. ..... Telex ..... Telefax .....

Concept: LLW ILW HLW Spent fuel

Host Rock: Clay Salt Anydrite Crystalline Other

2. GENERAL QUESTIONS

2.1 Have you carried out comprehensive performance assessments? If so, give key references.

2.2 Do you carry out in situ experiments for concept feasibility, demonstration, model validation etc? If so, list key references.

2.3 How is communication/interaction between modelling and in situ/laboratory investigations carried out?

3. SPECIFIC QUESTIONS TO MODELLERS

3.1 List the most important release scenarios, phenomena, processes being considered for concept assessment:

SCENARIO	Brief description of groundwater pathways, radionuclide release and migration exposure to biosphere. Is it well understood? i.e. well, moderately well, not at all	Do you have a model?		Do you have data?	
		Yes/No	Level of confidence 1 = low 5 = high	Yes/No	Level of confidence 1 - 5

3.2 With regard to the most important scenario(s), list those geological, hydrological, physical, chemical, geotechnical parameters that are most critical to conducting performance assessments.

(a) Vault/Near Field

Parameter	Category eg. phys/chem	Source of data eg. lab, field, expert opinion etc.

(b) Geosphere/Far Field

Parameter	Category eg. phys/chem	Source of data eg. lab, field, expert opinion etc.

(c) Biosphere

Parameter	Category eg. phys/chem	Source of data eg. lab, field, expert opinion etc.

4. FUTURE NEEDS

4.1 Will parameter variations (i.e. using a distribution of values) and/or laboratory field tests be sufficient to give confidence in the data base i.e. do you need specific: (a) in situ tests; (b) laboratory experiments or (c) can you reliably use existing data?

4.2 Are there any processes, phenomena or parameters of major importance not sufficiently covered by current research/investigations and should be investigated in the future?

5. SPECIFIC QUESTIONS TO EXPERIMENTERS

5.1 List the most important tests carried out in support of the development and proof of concept (i.e. feasibility/safety):

System Component	Tests	Purpose of Test
Vault		
Waste form		
Waste package		
Backfill & Sealing		
Near field effects		
Geological barrier		
Accessible environment/ biosphere		

5.2 Which of these test are not adequate for validation of research/ assessment models?

5.3 Comment on the extent to which the research models and data derived from the tests are applicable, with simplification, to overall assessments. How has this transfer of information been done? Where is more effort required?

6 COMMENTS ON FUTURE NEEDS

6.1 Comments/suggestions on ways to improve communication/interaction between experimenters and modellers and where it is most needed.

6.2 Comment on How Interaction Between Modelling and Experiments is taken into account when setting research priorities. How are research priorities established e.g. ad hoc, using sensitivity analysis, inertia! etc.

7. REFERENCES (list under section numbers).

ORGANISATION FOR ECONOMIC
CO-OPERATION AND DEVELOPMENT

NUCLEAR ENERGY AGENCY

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412.2

Natarajan PEB MJB Golson
JCB Cordone

RADIOACTIVE WASTE MANAGEMENT COMMITTEE

Advisory Group on In Situ Research and Investigations
for Geological Disposal of Radioactive Waste (ISAG)

Proposed NEA Workshop on Excavation Response
Draft Information Note

1. The attached document is the draft Information Note for an NEA/ISAG workshop on "Excavation Responses in Deep Radioactive Waste Repositories - Implications for Engineering Design and Safety Performance", which is now proposed for 26th-28th April 1988 in Winnipeg, Canada and will be hosted by Atomic Energy of Canada Limited. AECL have offered to host the Workshop and provide a one-day visit to the Canadian URL facility which will include demonstrations of small scale excavation response testing.

2. The Information Note is presented for review and comments of ISAG. It was prepared by the Secretariat based on discussions within the ISAG consultant group meeting in February. At that meeting it was agreed that a range of host rock types would be considered as opposed to holding a series of small workshops as this was more in keeping with the aims of ISAG. The preliminary programme is fairly straightforward as outlined and your assistance and comments are sought, in particular, in the following ways:

[redacted]

5161

[redacted]

[redacted]

3. Taking into account the above, the group is invited to review the draft Information Note and agree to its distribution to prospective participants via the RWMC and ISAG.

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WORKSHOP ON EXCAVATION RESPONSES IN DEEP RADIOACTIVE WASTE REPOSITORIES - IMPLICATIONS FOR ENGINEERING DESIGN AND SAFETY PERFORMANCE

WINNIPEG
26th-28th April 1988

DRAFT INFORMATION NOTE

Organised by the
OECD NUCLEAR ENERGY AGENCY

In Cooperation with
ATOMIC ENERGY OF CANADA LIMITED

WORKSHOP ON EXCAVATION RESPONSES IN DEEP RADIOACTIVE WASTE REPOSITORIES - IMPLICATIONS FOR ENGINEERING DESIGN AND SAFETY PERFORMANCE

I. Background

At the first meeting of the NEA In Situ Advisory Group (ISAG) a review of current needs in the area of in situ research and investigations was carried out which led to two topics being highlighted as meriting urgent discussion at an international level. The first topic concerns the potential responses that may be induced from using different types of excavation techniques during the construction of an underground repository for radioactive wastes; in particular, how such responses may impinge upon the safety performance of a repository and affect the engineering design. Secondly, there is a need to review the materials and methods available for backfilling and sealing repositories located in different geological media. The latter was seen as being consequent to a workshop on excavation responses. ISAG therefore recommended to the NEA Radioactive Waste Management Committee that, as a first step, ISAG should organise a workshop on excavation responses. This Information Note outlines the objectives and preliminary programme for the workshop, which will be held on 26th-28th April 1988 in Winnipeg and hosted by the Atomic Energy of Canada Limited.

II The Need to Study Excavation Response

Of the numerous components of the multi-barrier concept for the deep disposal of radioactive waste the boundary between the "engineered vault", containing waste form, canister, backfill and sealing material and the host geological environment (geosphere) is conceptually one of the least well understood components of the system. When considering the engineering design and performance of a repository, residual stresses, potential creep or subsidence, induced fractures leading to increased potential for groundwater flow, are phenomena requiring analysis, in order to answer the following key questions: to what extent do excavation responses impinge on the performance, in terms of safety, of a repository? Also, what phenomena associated with excavating a repository should be taken into account when preparing final designs? These questions apply in varying degrees to all deep disposal

concepts; the answers are by no means simple, even though much is already known from experience gained from tunnelling and mining operations. Recently, there has been considerable effort devoted to research into excavation responses. Geotechnical and rock mechanical investigations are part of each in situ research programmes. A mine-by experiment has been carried out at the Climax Mine in Nevada and one is currently being planned at the Canadian URL to assess the ability to model rock mass response to excavations and to assess rock-mass damage caused by different excavation techniques. Other studies, for example at the Konrad Mine in the FRG, examine stability following excavation using the room-and-pillar method. In salt and clay formations creep is particularly important, especially that induced following the introduction of heat. This has been the subject of detailed studies at several facilities including Mol, WIPP and Asse.

Several topics can be highlighted that merit specific attention in a workshop, including (i) the overall context in which excavation response is viewed as a phenomenum to be accounted for in the design of a repository, both from the engineering and safety aspects; (ii) the type of in situ tests and measurements carried out, and (iii) the mathematical models that have been developed. The validation of the latter is particularly important.

It is these broad areas that will be addressed in the workshop not only in general terms but also on host rock specific basis i.e. crystalline, argillaceous and salt formations.

III. OBJECTIVES OF THE WORKSHOP

The objective of the workshop will be to review the potential responses caused by the excavation of an underground repository for radioactive wastes on (i) the engineering design and (ii) the safety performance; and to prepare recommendations on ways of accounting for the effects caused in developing repositories located in argillaceous, crystalline and salt rock formations. It is intended that the published proceedings of the workshop take the form of a state-of-the-art report on the treatment of excavation responses in developing deep respoitories; including recommendations on design, validation and instrumentation needs. Particular emphasis will be placed on theoretical

analysis and modelling, in situ measurement techniques, excavation techniques and methods available to reduce excavation responses. In addition, specific recommendations on topics to be addressed in the follow-up workshop on backfilling and sealing materials and methods will be sought. In meeting the objective it is intended that a thorough exchange of views take place among scientists working on different host rock types. It may also provide a forum for discourse between those carrying out in situ laboratory measurements and those preparing predictive models on excavation response effects.

III AUDIENCE

The workshop will be of interest to those carrying out R&D into excavation effects for radioactive waste management purposes. It may also be of interest to those directly responsible for the orientation of R&D concerning geotechnical investigation at underground facilities as the relative importance of excavation responses for engineering design studies and performance assessments will be an integral part of the workshop. The level of presentations will reflect the state-of-the-art in this area but will not be overly theoretical in nature and will emphasize the practical consequences of excavations responses in terms of in situ testing and mathematical modelling needs.

IV. FORMAT

The workshop will allow considerable time for discussion following each paper. It has been decided that there will be 5 sessions. In the opening session on overview of current experience will be provided by using invited speakers. Sessions II-IV will each be opened by an invited speaker followed by short 10-15 minutes presentations from participants; the aim being to generate discussion on approaches presented. The final session will be plenary involving short summary statements by the session Chairman followed by discussion aimed at preparing a set of recommendations on the research development and modelling needs relating to excavation effects. It is also intended that the invited papers be available for review prior to the workshop. The following provisional programme is proposed:

NEA WORKSHOP ON EXCAVATION EFFECTS

PROVISIONAL PROGRAMME

Day 1 - Tuesday, 26th April

10.00 OPENING OF THE WORKSHOP

Session I: OVERVIEW OF RESEARCH AT UNDERGROUND LABORATORIES ON EXCAVATION RESPONSES AND ASSOCIATED ACTIVITIES

CHAIRMAN: Dr. K. Dormuth, AECL Canada

1.	Aims and objectives of the workshop	NEA Secretariat
2.	Accounting for excavation responses in developing an underground repository in clay formations - engineering design concepts, the types of effects found due to excavations in clay, the phenomena involved, their importance for performance assessments. Experiments carried out or planned	A. Bonne, SCK/CEN Belgium
3.	Accounting for excavation responses in developing an underground respository in crystalline rock - Engineering design concepts, the types of effects found due to excavations in granite, the phenomena involved and their importance for performance assessments. Experiments carried out or planned.	G. Simmons, AECL Canada

	4.	Accounting for excavation responses in developing an underground respository in evaporite formations	K. Kuhn, GSF FRG
		- Engineering design concepts, the types of effects arising due to excavation in evaporite formations such as salt and anhydrite, the phenomena involved, heat effects, convergence effects. Experiments carried out or planned	
		Discussion	
13.00	Lunch		

Session II: EXCAVATION EFFECTS IN CLAY

CHAIRMAN: Dr. R.H. Heremans, NIRAS/ONDRAF, Belgium

14.30	5.	Key-note paper: Excavation response studies at the Mol facility in Belgium - results from experiments carried out and those planned	B. Neerdael, SCK/CEN Belgium
	6.	Contributions from participants on excavation effects in clay.	
		Invited and contributed papers on:	
		(i) Excavation response testing and instrumentation in clay	
		(ii) Predicting excavation response - model development and validation against field measurements	
		(iii) Implications of repository design and safety performance	
		Discussion	

17.30 End of first day

Day 2: Wednesday 27th April

Session III EXCAVATION EFFECTS IN CRYSTALLINE ROCK

(a) Overview of studies

CHAIRMAN: Dr. R.A. Robinson, US DOE

9.30 7. Key-note paper: Excavation responses in developing an underground repository in crystalline rock in Switzerland — Switzerland

- results from experiments carried out and those planned

8. Contribution from participants on excavation effects in granite

Invited and contributed papers on:

(i) Excavation response testing and instrumentation in crystalline rock

(ii) Predicting excavation response
- model development and validation against field measurements

(iii) Implications of repository design and safety performance

Discussion

12.30 Lunch

Session III: (b) Specific Geotechnical Studies

CHAIRMAN: A. Barbreau (IPSN, France)

	9.	Key-note paper: Geotechnical studies of excavation responses in granite rock - results from experiments carried out and those planned	Sweden
	10.	Contributions from participants on excavation effects in granite Invited and contributed papers on: (i) Excavation response testing and instrumentation in evaporite (ii) Predicting excavation response - model development and validation against field measurements (iii) Implications of repository design and safety performance	
	Discussion		
17.30	End of second day		

Day 3: Thursday 28th April

Session IV: EXCAVATION EFFECTS IN SALT

CHAIRMAN: L. Tyler (SNL, USA)

9.30	11.	Key-note paper: Excavation effects in developing an underground repository in salt formations - results from experiments carried out and those planned	Netherlands or FRG

12. Contributions from participants on excavation effects in evaporites

Invited and contributed papers on:

(i) Excavation response testing and instrumentation in evaporites

(ii) Predicting excavation response in evaporites
- model development and validation against field measurements

(iii) Implications of repository design and safety performance

Discussion

12.30 Lunch

Session V: PLENARY SESSION

CHAIRMAN: Dr. K. Dormuth, AECL Canada

13. Presentations by session chairman giving summaries of topics considered in each session and recommendations

14. Discussion of recommendations to be made to ISAG on (a) future needs in the area of excavation effects and (b) topics to be addressed at the follow-up workshop on backfilling and sealing

17.30 END OF WORKSHOP

V. ORGANISATION OF THE WORKSHOP

The workshop will comprise a mix of invited and contributed papers. Nevertheless an abstract for each contributed paper will have to be agreed by the Secretariat by 1st February 1988 at the latest in order to prepare the final programme for each session. Geotechnical, hydrological, thermal, mathematical modelling and coupled processes will be examined and prospective authors are invited to submit abstracts via their respective RWMC or ISAG member.

VI. PARTICIPATION IN THE MEETING

The meeting is open to specialists from all NEA Member countries, but the number will be restricted. Participants must be nominated by the corresponding member of the Radioactive Waste Management Committee or the In Situ Advisory Group. They should be specialists in the subject area defined by the scope of the workshop, and should work in relevant research, operational or regulatory activities, and should be qualified to contribute actively to discussions. The number of participants nominated from each country should be consistent with a total participation of about 50 experts. Nominations should reach the NEA Secretariat before 1st February 1988.

VII. SECRETARIAT

All correspondence concerning participation and the programme of the meeting should be addressed to:

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VIII. REPORT OF THE WORKSHOP

A report of the workshop and recommendations for further study will be presented to the NEA In Situ Advisory Group and the Radioactive Waste Management Committee at their next meetings in mid 1988. Full proceedings of the workshop will be published by the NEA.

IX. WORKING LANGUAGES

The working languages of the workshop will be English and French.

X. LOCAL ARRANGEMENTS

The workshop will take place at the OECD, Château de la Muette, 2, rue André Pascal, Paris 16ème. It will begin at 10.00 a.m. on the first day, Wednesday 18th November and is expected to finish at 17.30 on Friday 20th November. Participants are expected to make their own arrangements for hotel accommodation and travel.