Nationale Genossenschaft
für die Lagerung
radioaktiver Abfälle

Société coopérative nationale
pour l'entreposage
de déchets radioactifs

Società cooperativa nazionale
per l'immagazzinamento di
scorie radioattive

NAGRA

TECHNISCHER BERICHT 81-09

Stripa Project

ANNUAL REPORT 1980

April 1981

Geschäftsstelle Parkstrasse 23 CH-5401 Baden Telephon 056/22 01 82

Nationale Genossenschaft für die Lagerung radioaktiver Abfälle
Société coopérative nationale pour l'entreposage de déchets radioactifs
Società cooperativa nazionale per l'immagazzinamento di scorie radioattive
NAGRA

TECHNISCHER BERICHT 81-09

Stripa Project

ANNUAL REPORT 1980

April 1981

Geschäftsstelle Parkstrasse 23 CH-5401 Baden Telephon 056/22 01 82

Das Stripa-Projekt ist ein Projekt der Nuklearagentur der OECD. Unter internationaler Beteiligung werden von 1980-84 Forschungsarbeiten in einem unterirdischen Felslabor in Schweden durchgeführt. Diese sollen die Kenntnisse auf folgenden Gebieten erweitern:

- hydrogeologische und geochemische Messungen in Bohrlöchern
- Ausbreitung des Grundwassers und Transport von Radionukliden durch Klüfte im Gestein
- Chemische Zusammensetzung des Grundwassers in grosser Tiefe
- Verhalten von Materialien, welche zur Abdichtung von Endlagern eingesetzt werden sollen

Seitens der Schweiz beteiligt sich die Nagra an diesen Untersuchungen.

The Stripa Project is organized as an autonomous project of the Nuclear Energy Agency of the OECD. In the period from 1980-84 an international cooperative programme of investigations is being carried out in an underground rock laboratory in Sweden. The aim of the work is to improve our knowledge in the following areas:

- hydrogeological and geochemical measurement methods in boreholes
- flow of groundwater and transport of radionuclides in fissured rock
- geochemistry of groundwater at great depths
- behaviour of backfill material in a real geological environment

Switzerland is represented in the Stripa Project by Nagra.

Le projet Stripa est un projet autonome de l'Agence pour l'Energie Nucléaire de l'OCDE. Il s'agit d'un programme de recherche avec participation internationale qui sera effectué entre 1980 et 1984 dans un laboratoire souterrain en Suède. Le but de ces travaux est d'améliorer et d'étendre les connaissances dans les domaines suivants:

- mesures hydrogéologiques et géochimiques dans les trous de forage
- écoulement des eaux souterraines et transport des radionucléides dans les roches fracturées
- chimie des eaux souterraines à grande profondeur
- comportement dans un environnement réel des matériaux de bourrage pour dépôts de déchets radioactifs

La Suisse est représentée dans le projet Stripa par la Cédra.

STRIPA PROJECT 81-02

ANNUAL REPORT
1980

TECHNICAL REPORT

An OECD/NEA International project managed by:
SWEDISH NUCLEAR FUEL SUPPLY CO/DIVISION KBS

STRIPA PROJECT

SKBF KBS

Mailing address: **SKBF/KBS**
Box 5864 S-102 48 Stockholm Telephone: 08-67 95 40

S T R I P A   P R O J E C T

ANNUAL REPORT 1980

This annual report is prepared by the Project Manager in accordance with Article 2, Paragraph 8 of the draft Stripa Project Agreement with the aim to inform the OECD Nuclear Energy Agency Committee on Radioactive Waste Management and its Coordinating Group on Radioactive Waste Disposal into Geologic Formations as well as the Participants in the Project about the general progress of work during 1980.

Stockholm, April 1981

Hans Carlsson

PREFACE

During 1977-1980 a series of investigations in the field of radioactive waste storage were conducted in the abandoned Stripa mine, located in Central Sweden. The main part of the investigations were performed by Lawrence Berkeley Laboratory (LBL), University of California sponsored by the US Department of Energy (DOE) in cooperation with the Swedish Nuclear Fuel Supply Company (SKBF) through Division Nuclear Fuel Safety (KBS). The aim of these experiments was to develop techniques for determining regional rock mechanic, hydrologic and geophysic parameters at potential waste repository sites. In addition, the generated data increased the knowledge of the suitability of crystalline rock for terminal storage of radioactive material.

The LBL-KBS project aroused great interest in several countries. A new international cooperative project - the Stripa Project - again in the field of nuclear waste management, has therefore been established as an autonomous OECD/NEA project. The management of the Stripa project has been entrusted to KBS. Technical input and contribution of funds are given by the following countries:

Participant	Sponsored by
Canada	Atomic Energy of Canada Ltd (AECL)
Finland	Teollisuuden Voima Oy (TVO); Ministry of Trade and Industry; Imatra Power Company
France	Commissariat à l'Energie Atomique (CEA)

Participant	Sponsored by
Japan	Power Reactor and Nuclear Fuel Development Corporation (PNC)
Sweden	Swedish Nuclear Fuel Supply Company (SKBF)
Switzerland	Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (NAGRA)
United States	Department of Energy (DOE)

A list of previous reports published from the Stripa Project is attached at the end of this report.

TABLE OF CONTENTS

1 BACKGROUND

In 1976 a cooperative program in the management of nuclear waste storage was initiated between US Department of Energy (DOE) and the Swedish Nuclear Fuel Supply Co (SKBF). The abandoned Stripa mine, located in central Sweden, was converted into a test facility, Figure 1. Experimental drifts, with a total length of about 400 meters, were excavated into a granite formation. A series of investigations were carried out by the division KBS within SKBF and Lawrence Berkeley Laboratory (LBL), University of California, sponsored by DOE. The investigations included:

- Full scale heater experiments
- Time-scaled heater experiment
- Assessment of fracture hydrology

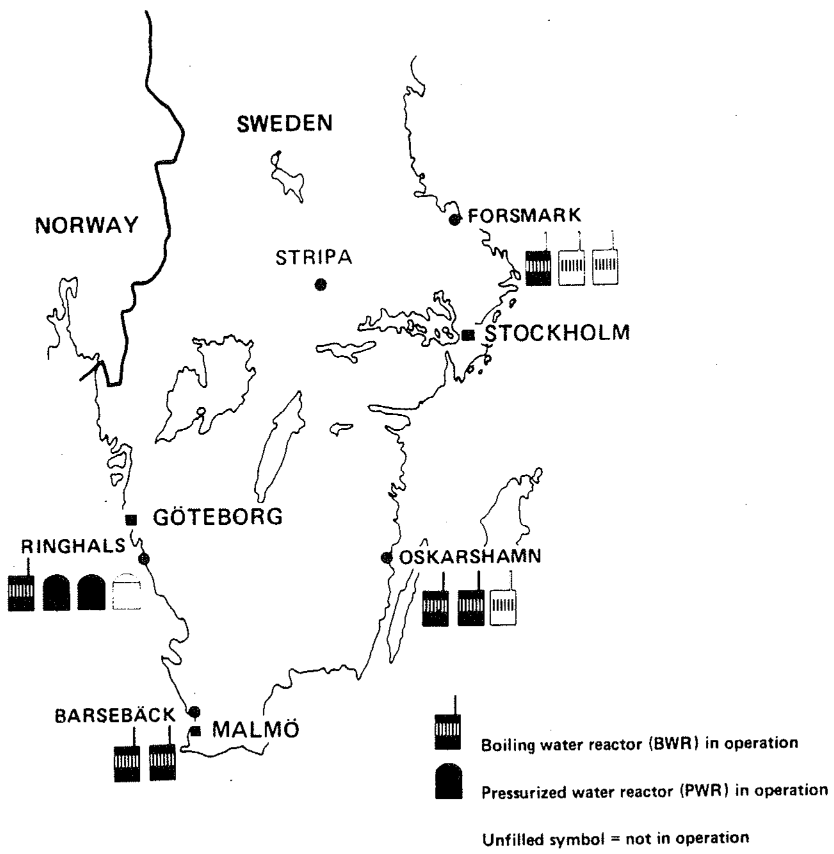

Figure 1. Location of the Stripa Mine

Several supporting investigations were carried out in conjunction with the above-mentioned main tasks:

- Geophysical measurements
- Stress measurements
- Permeability experiments

The results from these experiments are published in a special series of reports, see Appendix 1. The results have also been presented at several conferences and symposia.

In September 1978 an OECD/NEA symposium on "In Situ Heating Experiments in Geological Formations" was held in Ludvika, a town close to Stripa. Consideration was given to possibly expand the cooperation at the Stripa mine in 1980 when the joint Swedish/US project should be terminated. It was the general opinion that the facility provided an unique experimental possibility for investigations related to final disposal of long-lived radioactive waste in crystalline rocks. The discussion in Ludvika was followed by negotiations between OECD/NEA and potential participants in the continued program. A meeting was arranged in Paris, June 11-12, 1979 where potential members met and discussed different topics that should constitute the new international project. The main interest was given to the following subjects:

- engineered barriers tests
- migration experiments
- hydrogeological and geophysical investigations in boreholes

The discussions were continued in conjunction with the "International Symposium on the Underground Disposal of Radioactive Wastes" in Otaniemi near Helsinki, Finland, July 2-6, 1979. The symposium was jointly organized by IAEA and OECD/NEA.

A clear interest to participate in the continued cooperative investigations in Stripa was at this date declared by Canada, Finland, Switzerland, Sweden and the United States. Representatives from these countries met in Stockholm, November 5-6, 1979, to constitute the steering committee of the project.

2 ORGANIZATION

A Stripa Joint Technical Committee (JTC) was established at the meeting in Stockholm November 5-6, 1979. The committee agreed to act as an OECD/NEA restricted group and it was decided that the Stripa Project should be classified as an autonomous OECD/NEA project.

The organization plan for the Stripa Project is shown in Figure 2. The Swedish SKBF/KBS organization, in charge of the operation of the Stripa Mine is acting as the host organization for the project. Experimental programs are recommended by the participating countries and reviewed by Technical Subgroups (TSGs). The Technical Subgroups cover the fields of hydrology and chemical transport, rock mechanics and engineered barriers. The TSGs consist of members from the participating countries and each task is assigned to a principal investigator.

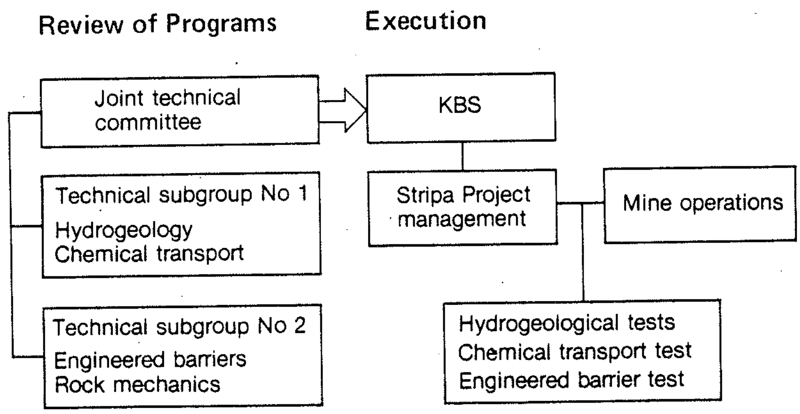

Figure 2. Organization plan for the Stripa Project

Supervision of the experimental program is entrusted to the Joint Technical Committee (JTC) composed of representatives of participating countries that are providing financial support to the project. Full and associate membership in the Stripa Project will be contingent on commitment of 7.2 and 0.65 MSEK respectively per year unless otherwise agreed by the committee. The project is planned to last four years.

The members of the Joint Technical Committee and in the Technical Subgroups are listed in Appendix II.

3 PROGRESS OF THE PROPOSED PROGRAM 1980

The first meeting with the Technical Subgroups was held in Stockholm and Stripa, March 3-5, 1980. The following proposals were submitted.

- "Hydrogeological investigations in boreholes" proposed by L Carlsson and T Olsson, Geological Survey of Sweden (SGU)

- "Geological studies in conjunction with the Stripa Project" proposed by H Wollenberg, Lawrence Berkeley Laboratory (LBL), University of California, USA

- "Migration experiments in fissured granite and compacted bentonite" proposed by I Neretnieks, Royal Institute of Technology, (KTH), Sweden

- "In Situ Stress Measurements at the Stripa Mine" proposed by T Doe, Lawrence Berkeley Laboratory (LBL), University of California, USA

- "Rock Mass Pressure Test" proposed by O Stephansson, University of Luleå, Sweden

- "Buffer Mass Test" proposed by R Pusch, University of Luleå, Sweden

After having reviewed and commented on the proposals, all but the "Geological studies in conjunction with the Stripa Project" were recommended for approval by JTC. However, due to lack of funding, the following priority was made up by the JTC when they met in Stockholm and Stripa April 22-24, 1980.

1 Buffer Mass Test (with modifications)

2 Hydrogeology investigations in boreholes (with modifications)

3 Preparatory migration studies in fissured granite

The start of the project was set to May 1, 1980 and it will continue to May 1, 1984. The budget, including an estimated annual inflation of 10% over the four year period, is about 50 MSEK.

A separate meeting with TSG-2 was held in conjunction with the Rockstore 80 meeting in Stockholm, June 26-27, 1980. The objective of the meeting was to finalize the selection of the site for the Buffer Mass Test and to review the modifications as accomplished by Roland Pusch based on the recommendations from the meeting of the TSG on March 3-5, 1980.

An informal meeting was also held in Boston November 1980 during the Materials Research Society Meeting, by a few members of the TSG-2 for the purpose of reviewing the program of the Buffer Mass Test.

Full unanimity about the final language of the Stripa Project Agreement was not reached at the end of 1980. This fact, however, did not delay the progress of the Project, as the Participants on a case-by-case basis authorized the Managing Participants to proceed as planned.

4 SUMMARY OF DEFINED PROGRAMS

Below a summary is given of the defined programs within the Stripa Project. For further information, see /1/.

4.1 Hydrogeological and Geochemical Investigations in Boreholes

The purpose of these investigations is to design and test methods and instruments for geologic and hydraulic studies in horizontal and deep vertical boreholes. Additional information on the hydraulic characteristics of the granite and on interactions between fractures will also be gained from these experiments. Another project goal is the increased knowledge of the chemical conditions in groundwater at great depth.

The investigation is divided into two phases, each self-contained but based on the results and instrumentational development of the preceding phase. Only the first phase has so far been funded.

Phase 1. Investigations of individual vertical and horizontal boreholes and associated problems.

A Methods, techniques and instrumentation will be developed to measure hydraulic properties and conditions at depth in nearly horizontal boreholes in fractured, granitic rocks and other similar rocks. These methods will then be tested and compared.

B Basic quantitative information will be gathered on the hydrogeologic conditions at depth in fractured, granitic rock. This information will be valuable to the field of waste management, and will also contribute to evaluations of current and future investigations at the Stripa Mine.

C Borehole samples from 1400 m below the surface will be used to analyze the geochemistry of groundwater in the deeper sections of fractured granitic rock.

D The analysis and interpretation of these data will form the basis for continued development of methods to characterize near- and far-field conditions in fractured rock of low hydraulic conductivity at repository depths. Planning of these additional studies will be an integral part of the original project.

If additional funding is made available the following is proposed.

Phase 2. Investigations of the hydraulic interconnection between different horizontal boreholes, and associated problems.

A Methods and instruments will be developed to establish the hydraulic properties of existing fracture zones and hydraulic interconnections between boreholes along existing fractures or fracture zones.

4.2 Migration Test

The bedrock itself is one of the most important barriers to radionuclide release from a final repository. The radionuclides will migrate with water flowing in the fissures of the bedrock. Their movements will be retarded by sorption on the fissure surfaces, and possibly by migrating into microfissures in the rock matrix.

In the proposed experiment various tracers representing all the important types of radionuclides will be introduced through a single fissure in granite into the naturally flowing water. The natural flow system at Stripa is well suited for this type of experiment, as the hydraulic gradient and flow rate are many orders of magnitude larger than in a natural system. Consequently, a time scaling of two or three orders of magnitude is automatically achieved.

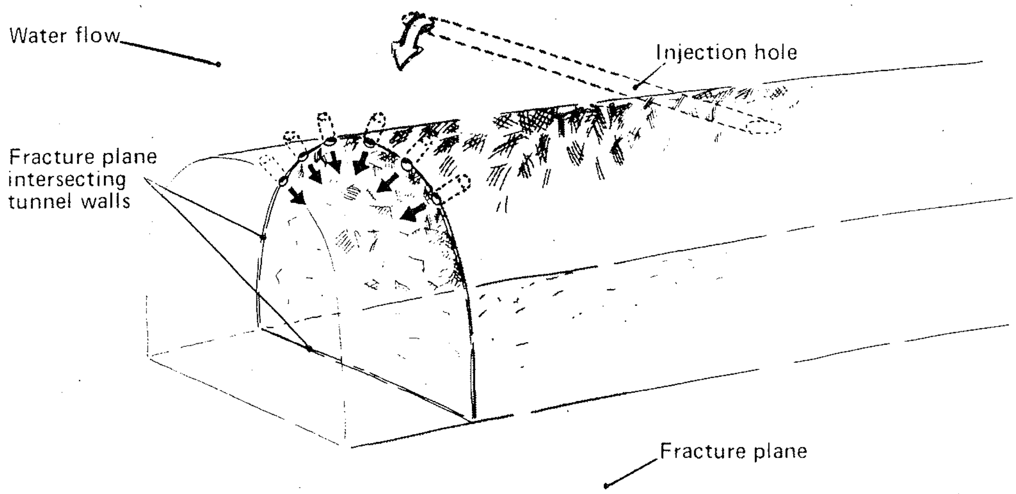

Figure 3. Schematic layout of the migration experiment in a single fissure.

The fissure will be excavated after the runs with the sorbing tracers have been completed and the concentration of the tracers at the surface has been analyzed. The experiment will show how well sorption data from the laboratory can be used to predict radionuclide migration in the field. It will also provide data on longitudinal and transverese dispersion in a single fracture. A schematic layout of the test is shown in Figure 3.

A first phase of the test regarding development of equipment and a pilot test was funded during 1980.

4.3 Buffer Mass Test

According to the KBS plan, canisters of high-level waste will be stored in shallow, vertical boreholes in the floor of horizontal tunnels approximately 500 m below the surface.

The annulus between the canisters and the boreholes will consist of a highly compacted clay. After deposion of the canisters, the entire tunnel will be sealed off with a mixture of clay and sand. The suggested buffer material-bentonite clay, has a very low permeability and a high swelling capacity when absorbing water. Fractures caused by swelling would be filled with bentonite, which would detain any potential leakage of radioactive nuclides to the groundwater.

Although theoretical analysis and various laboratory tests seem to yield similar results on the expected properties of the buffer materials in situ, it is still necessary to test the behavior of the integrated system of heat-producing objects, buffer materials, rock, and groundwater in a representative crystalline rock mass. The objective of the test is to verify the barrier function of highly compacted bentonite and mixtures of bentonite and sand under real conditions.

Electric heaters, simulating the heat generations from nuclear waste canisters, will be placed in storage holes drilled in the floor of a drift. The annulus between the heater and the borehole wall will consist of highly compacted bentonite, and the innermost part of the tunnel will be filled with a mixture of bentonite and sand, as specified in the KBS plan. An on-site computer will monitor temperatures, water uptake, and pressures in the highly compacted bentonite and in the bentonite/sand mixture. A schematic drawing of the test site is shown in Figure 4.

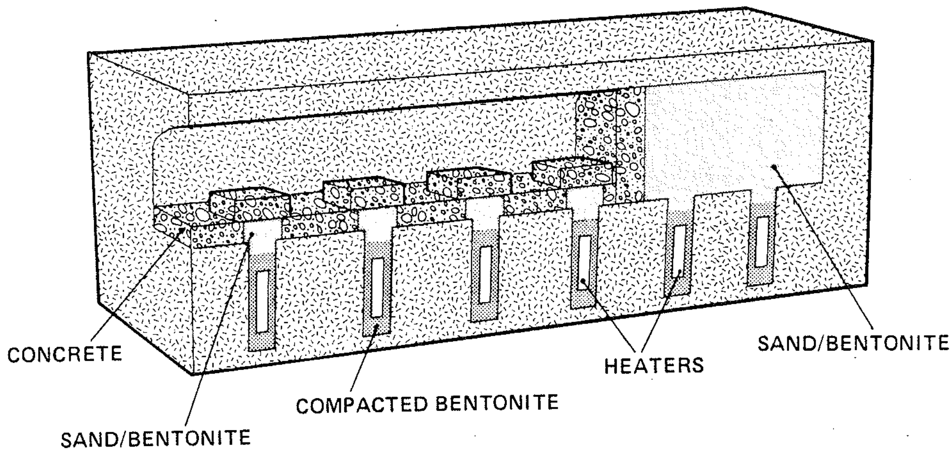

Figure 4. Schematic layout of the Buffer Mass Test

5 PROGRESS OF THE DEFINED PROGRAM

5.1 Management

The work for having an agreement signed between the participating countries continued with increased effort. Acceptance from all countries on the draft agreement were not received by KBS at the end of this reporting period. However, authorization for KBS to make the necessary commitments have been received from the participants and the project is well underway and no serious delays are reported.

Japan (PNC) has decided to join the project with a full membership, whereas Canada has, for internal budgetary reasons, withdrawn from the project. However, together with France, United Kingdom and West Germany they have expressed interest in associate membership. An associate member pays a lower share of the cost but has on the other hand no influence on the decisions.

Table 1 shows the budget for the project and the accumulated costs through December 1980. The total accumulated cost for the project is well within the estimations. A detailed information of the financial situation is given in quarterly reports.

A brochure about the Stripa Project and about the Stripa test site in general has been prepared and sent to the participants for distribution. A movie showing the main activities in Stripa is also in progress.

Table 5.1 Budget and accumulated cost for the project (MSEK)

Programs	Budget Jan 1, 1980	Accumulated cost Jan 1, 1980
Project management	3.1	0.43
Stripa generally (mine rent etc)	14.0	0.98
Hydrogeological investigations	6.5	0.61
Migration studies (preparatory study)	0.5	0.77
Buffer mass test	15.0	0.16
Total	39.1	2.95

5.2 Hydrogeological Investigations in Boreholes

The test site at the 360 m level in Stripa has been excavated and the instrument shed has been constructed.

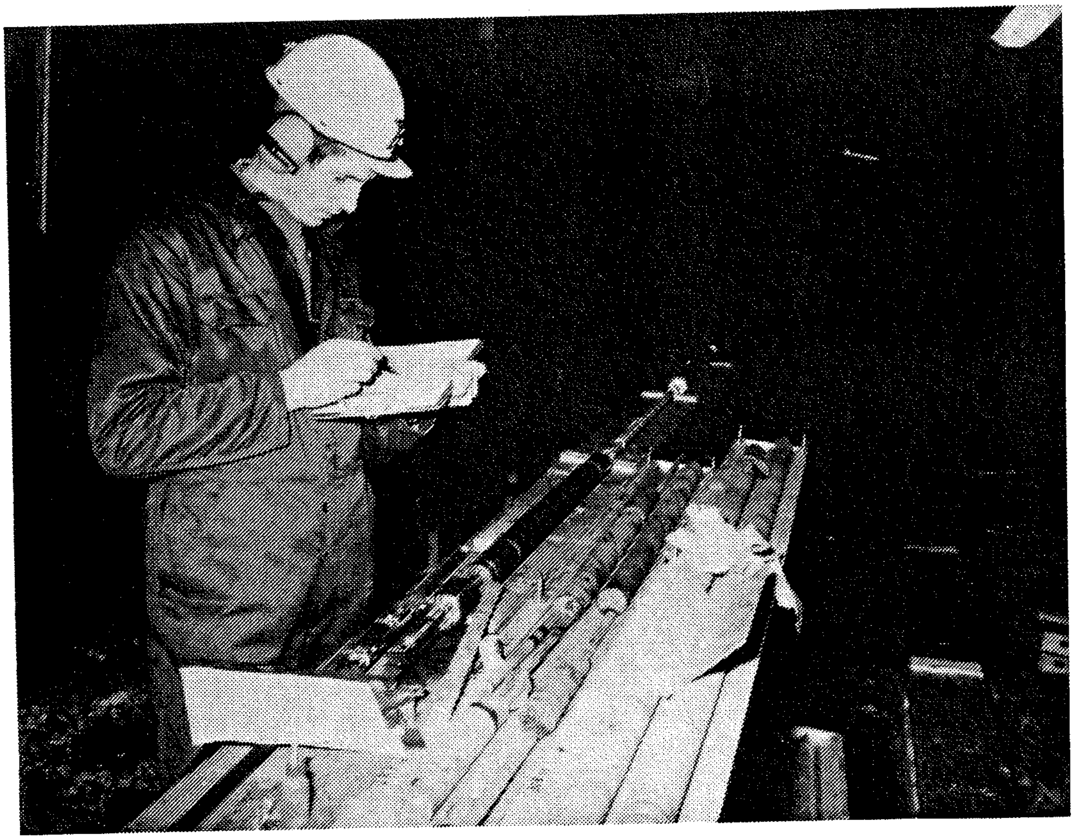

Figure 5. Logging of the core from the vertical borehole

During the reported time period the drilling down to the first break at 150 m was completed. The drilling was carried out without any tracer added to the drilling-water. The rock down to the first stop is exclusively made up by a homogeneous granite with only few fractures. Mean fracture frequency is about 2.4 fractures per m, but most of the fractures are sealed by Chlorite and in addition also Calcite and Quartz occur. The frequency of opened fractures is about 1.5 fractures per m. The core logging indicates that the water in to the borehole only takes place at four levels of the 150 m.

After the drilling was interrupted at 150 m the water flow from the borehole was monitored to be about 6 ml/min (0.006 l/m), of which the major quantity probably originates from the 51.5 - 53.5, 55.5 - 57.5 and 66 - 71.5 m levels. It is estimated that the flow is too low to allow any extensive water sampling for hydrogeochemical purposes.

Rock stress measurements, using a modified Leeman triaxial overcoring technique, were performed at the 150 m level by the Swedish State Power Board. The equipment for the hydraulic testing has been manufactured and tested individually. Testing of the complete system is scheduled for January 1981. The data acquisition system is in operation and is found to function properly.

On December 5, a meeting was held between the principal investigators and an expert group of hydrogeochemists from different countries. The members of the advisory group proposed by P Fritz, University of Waterloo, Canada are:

J Andrews	UK
B Eriksson	Sweden - chairman
P Fritz	Canada
H Loosli	Switzerland
K Nordstrom	USA
B Payne	Austria (IAEA)

During the meeting the group decided that groundwater samples should be analysed with respect to the constituents listed in Table 5.2. For the analysing procedure different laboratories are involved as given also in Table 5.2. The sampling procedure for the vertical borehole should be divided into three different phases, sampling during drilling, sampling under pressurized conditions and sampling under free flowing conditions.

The members of the group of hydrogeochemists were asked to leave their comments and the reason for the chosen analyses, the quality and detection limit required and how the hydrogeochemistry will gain the subject of nuclear waste disposal. These comments should be given as soon as possible in order to complete final program for hydrogeochemistry during January 1981.

Table 5.2. Constituents to be analysed on water samples and laboraotires to carry out the analyses

Constituents	Laboratories
Major, minor and trace elements	SGU, USGS
U, Th, Ra	University of Bath
Gases	University of Bath
Oxygen 18	IAEA
Deuterium	IAEA
Tritium	Inst f Radiohydrometrie
Helium 3	Inst f Radiohydrometrie
Chloride 36	(Fritz invest.)
Carbon 13, 14	(Fritz invest.)
U, Th on rock samples	Univ. of Bath, SGU

5.3 Migration in a Single Fissure - Preparatory Study

A suitable fissure was found close to the LBL-KBS test area at the 350 m level. Drilling and preparation of the site was completed as well as manufacturing and testing of the equipment. The experimental site is shown in Figure 6.

Circulation of fluorescein in the fissure was initiated. The test was speeded up by increasing the injection pressure above the natural pressure in the fissure. The pressure in the injection hole was then allowed to decrease to stability. After cleaning the hole with anoxid water Rhodamine Wt was circulated for seven days. Anoxid water was again used for cleaning the hole and preparations for injection of fluorescein and Rhodamine Wt simultaneously started.

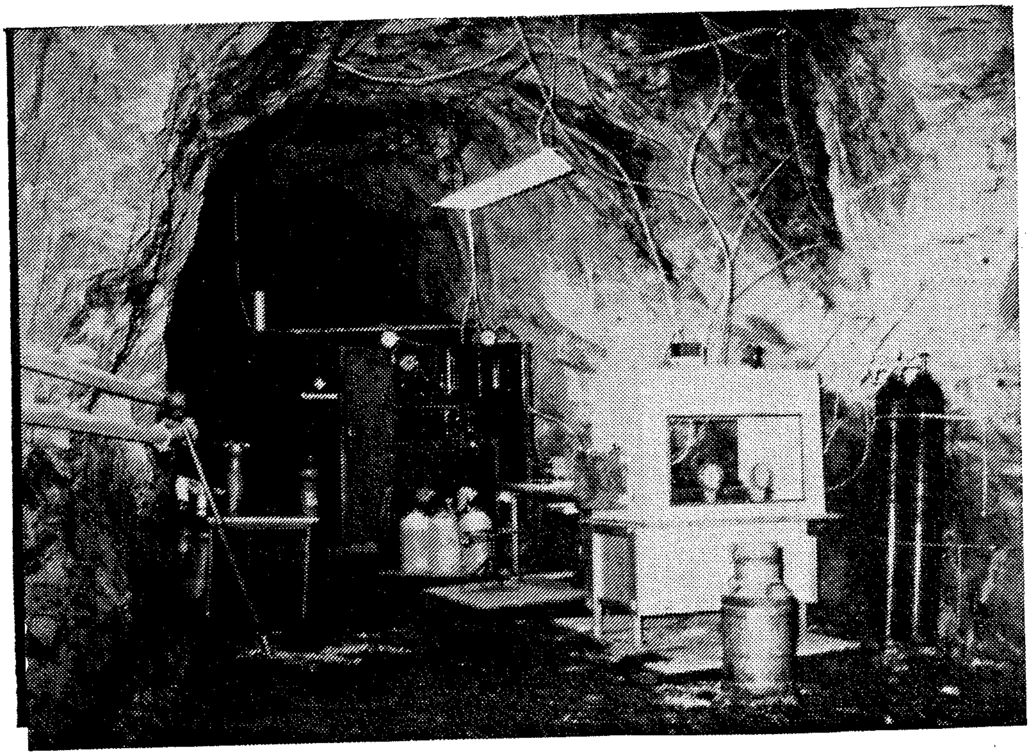

Figure 6. The test site for the preparatory migration study.

The time needed for fluorescein to reach the sampling holes was less than 24 hours and water from three of the sampling holes contained tracers with a dilution factor varying from 25 to 400. Rhodamine Wt that was circulated for seven days was not found in the sampling holes.

5.4 Buffer Mass Test

After having revised the original program of December 1979 as a result of the TSG-meetings in April and June 1980 preparations for the accomplishment of the test started. It was desided to use the so called ventilation drift, previously used by LBL for the macro-permeability experiment, for the buffer mass test. The existing instrumentation for continuous water pressure changes in the surrounding rock could thus be used. Early in the year, a pilot deposition hole with a diameter of 760 mm and a depth of 3 m was drilled, Figure 7.

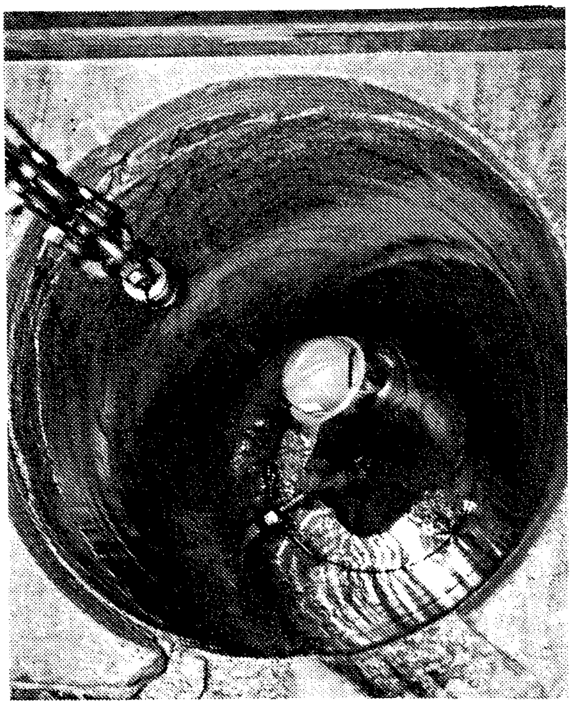

Figure 7. A pilot deposition hole for the Buffer Mass Test was drilled early in the year.

The design of the heaters and auxiliary equipment started and by the end of the year the first heater was constructed. Testing of the heater under simulated in situ conditions will be performed early next year. The length of the heater is 3.1 m, the diameter 0.4 m and the power output will be 600 W.

The data acquisition system has been designed and ordered. The detailed analysis, interpretation etc will be made at the University of Luleå computer centre.

Great care was taken in the choice of suitable gauges to avoid the risk of deterioration or breakdown of the sensors as well as of the cables. Thus, steel-mantled SIS 2343 thermocouples and Gloetzl cells for temperature and pressure measurements were chosen.

Moisture sensors of an improved type have been developed and tested under relevant conditions in swelling pressure oedometers. The experiments were designed not only to test if the gauges can sustain high swelling pressures (> 1 MPa), but also to yield an average calibration of the new version.

The materials for the backfill of the drift and the boxing-outs have been delivered and are now stockpiled in Stripa. The intended sand-bentonite mixture has been successfully used in a pilot grouting test. In this test the mechanical durability of the thermocouples and moisture sensors was also documented.

Twelve pilot inspection holes have been bored to obtain a structural (hydrological) mapping of the tunnel floor for the choice of heater hole sites. One of the holes will be located in virtually dry rock and this gives a good opportunity to observe water migration and possible drying effects in very dense rock. The rest of the holes will probably have considerable access to flowing groundwater. The first 76 cm diameter heater hole was also bored in mid-December to approximately 2 m depth without special difficulties.

The office and computer localities in the main office building have been rebuilt and are presently being furnitured.

The preparation of preliminary prognoses with reference to the expected development of temperature fields and rate of moisture uptake started in November. This activity will be intensified when the results from the heater hole borings (water inflow measurements and core mapping) become available. Also, the results from previous laboratory tests (funded by KBS) on backfill materials are required as a basis, and these results are presently being analyzed.

The various activities and responsibilities in the management of the BMT are organized as shown in Figure 8.

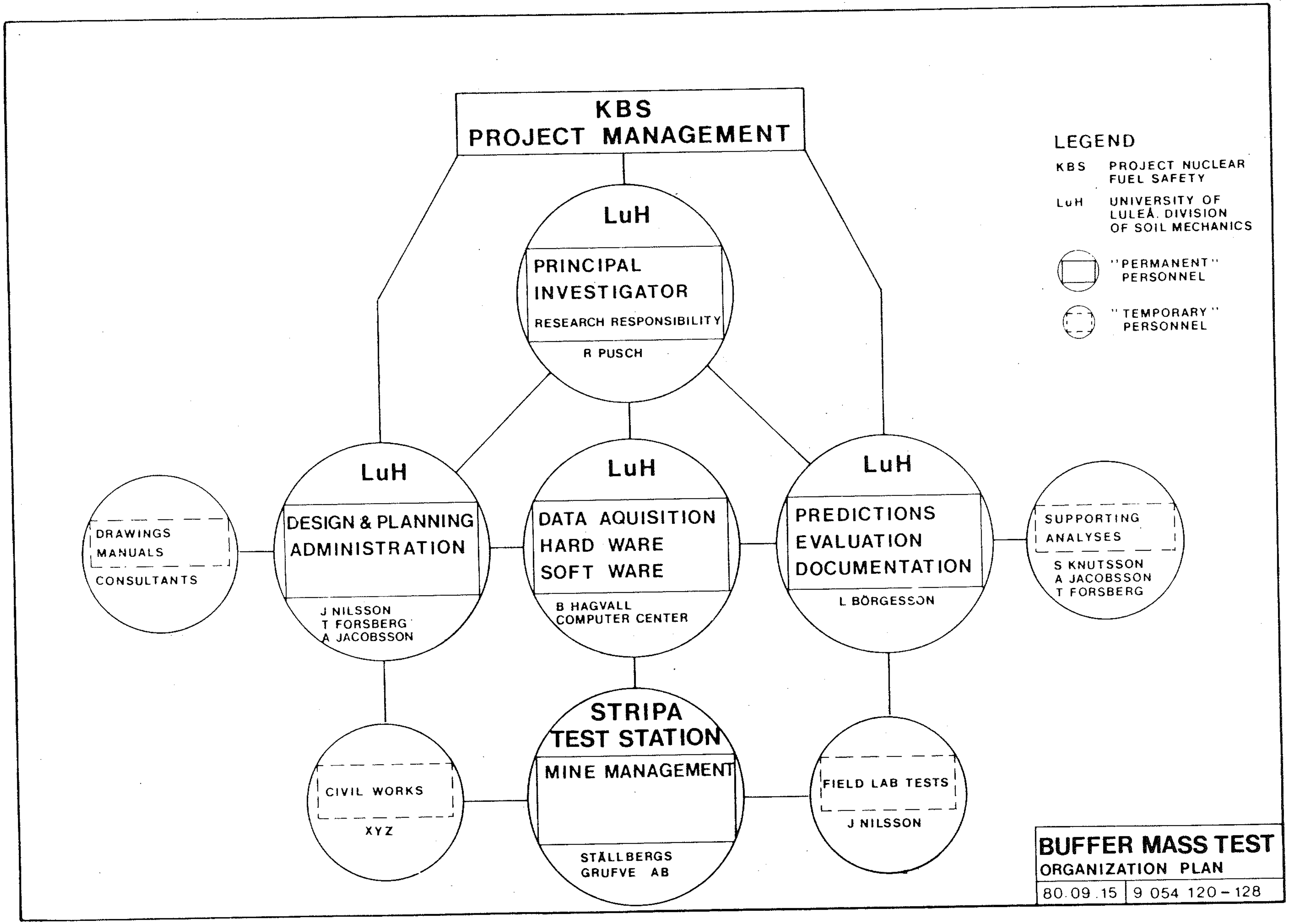

Figure 8. Organization plan for the Buffer Mass Test.

REFERENCES

/1/ "Summary of defined programs" by L. Carlsson, T. Olsson, I. Neretnieks and R. Pusch. Stripa Project, Technical report 81-01, SKBF/KBS, Stockholm, Nov. 1980.

APPENDIX I

The list of reports given below is documenting the results of the Swedish-American cooperative research program in which the cooperating scientists explore the geological, geophysical, hydrological, geochemical, and structural effects anticipated from the use of a large crystalline rock mass as a geologic repository for nuclear waste. This program has been sponsored by the Swedish Nuclear Power Utilities through the Swedish Nuclear Fuel Supply Company (SKBF), and the U.S. Department of Energy (DOE) through the Lawrence Berkeley Laboratory.

The principal investigators are L.B. Nilsson and O. Degerman for SKBF, and N.G.W. Cook, P.A. Witherspoon, and J.E. Gale for LBL. Other participants will appear as authors of the individual reports.

Previous technical reports in this series are listed below:

1. Swedish-American Cooperative Program on Radioactive Waste Storage in Mined Caverns by P.A. Witherspoon and O. Degerman. (LBL-7049, SAC-01).

2. Large Scale Permeability Test of the Granite in the Stripa Mine and Thermal Conductivity Test by Lars Lundström and Håkan Stille. (LBL-7052, SAC-02).

3. The Mechanical Properties of the Stripa Granite by Graham Swan (LBL-7074, SAC-03).

4. Stress Measurements in the Stripa Granite by Hans Carlsson (LBL-7078, SAC-04).

5. Borehole Drilling and Related Activities at the Stripa Mine by P.J. Kurfurst, T.Hugo-Persson, and G. Rudolph (LBL-7080, SAC-05).

6. A Pilot Heater Test in the Stripa Granite by Hans Carlsson (LBL-7086, SAC-06).

7. An Analysis of Measured Values for the State of Stress in the Earth's Crust by Dennis B. Jamison and Neville G.W. Cook (LBL-7071, SAC-07).

8. Mining Methods Used in the Underground Tunnels and Test Rooms at Stripa by B. Andersson and P.A. Halén (LBL-7081, SAC-08)

9. Theoretical Temperature Fields for the Stripa Heater Project by T. Chan, Neville G.W Cook, and C.F. Tsang (LBL-7082, SAC-09).

10. <u>Mechanical and Thermal Design Considerations for Radioactive Waste Repositories in Hard Rock. Part I: An Appraisal of Hard Rock for Potential Underground Repositories of Radioactive Waste by N.G.W. Cook; Part II: In Situ Heating Experiments in Hard Rock: Their Objectives and Design</u> by N.G.W. Cook and P.A. Witherspoon (LBL-7073, SAC-10).

11. <u>Full-Scale and Time-Scale Heating Experiments at Stripa: Preliminary Results</u> by N.G.W. Cook and M. Hood (LBL-7072; SAC-11).

12. <u>Geochemistry and Isotope Hydrology of Groundwaters in the Stripa Granite: Results and Preliminary Interpretation</u> by P. Fritz, Barker, and J.E. Gale (LBL-8285, SAC-12).

13. <u>Electrical Heaters for Thermo-Mechanical Tests at the Stripa Mine</u> by R.H. Burleigh, E.P. Binnall, A.O. DuBois, D.O. Norgren, and A.R. Ortiz (LBL-7063, SAC-13).

14. <u>Data Acquisition, Handling and Display for the Heater Experiments at Stripa</u> by Maurice B.McEvoy (LBL-7062 ,SAC-14).

15. <u>An Approach to the Fracture Hydrology at Stripa: Preliminary Results</u> by J.E. Gale and P.A. Witherspoon (LBL-7079, SAC-15).

16. <u>Preliminary Report on Geophysical and Mechanical Borehole Measurements at Stripa</u> by P.Nelson, B. Paulsson, R.Rachiele, L. Andersson, T. Schrauf, W. Hustrulid, O. Duran, and K.A. Magnusson (LBL-8280, SAC-16).

17. <u>Observations of a Potential Size-Effect in Experimental Determination of the Hydraulic Properties of Fractures</u> by P.A. Witherspoon, C.H. Amick, J.E, Gale, and K. Iwai (LBL-8571, SAC-17).

18. <u>Rock Mass Characterization for Storage in Nuclear Waste in Granite</u> by P.A. Witherspoon, P.Nelson, T. Doe, R. Thorpe, B. Paulsson, J.E. Gale, and C. Forster (LBL-8570, SAC-18).

19. <u>Fracture Detection in Crystalline Rock Using Ultrasonic Shear Waves</u> by K.H. Waters, S.P. Palmer, and W.F. Farrell (LBL-7051, SAC-19).

20. <u>Characterization of Discontinuities in the Stripa Granite --Time Scale Heater Experiment</u> by R. Thorpe (LBL-7083,SAC-20).

21. <u>Geology and Fracture System at Stripa</u> by A, Olkiewicz, J.E. Gale, R. Thorpe, and B. Paulsson (LBL-8907, SAC-21).

22. <u>Calculated Thermally Induced Displacements and Stresses for Heater Experiments at Stripa</u> by T. Chan and N.G.W.Cook (LBL-7061, SAC-22).

23. <u>Validity of Cubic Law for Fluid Flow in a Deformable Rock Fracture</u> by P.A. Witherspoon, J.Wang, K. Iwai and J.E. Gale (LBL-9557, SAC-23).

24. <u>Determination of In-Situ Thermal Properties of Stripa Granite from Temperature Measurements in the Full-Scale Heater Experiments: Methods and Primary Results</u> by J.Jeffry, T.Chan, N.G.W. Cook and P.A.Witherspoon (LBL-8424, SAC-24).

25. <u>Instrumentation Evaluation, Calibration and Installation for Heater Tests Simulating Nuclear Waste in Crystalline Rock, Sweden</u> by T. Schrauf, H.Pratt, E. Simonson, W. Hustrulid, P.Nelson, A. DuBois, E.Binnall, and R. Haught (LBL-8313, SAC-25).

26. <u>Part I: Some Results from a Field Investigation of Thermo-Mechanical Loading of a Rock Mass when Heater Canisters are Emplaced in the Rock</u> by M.Hood. <u>Part II: The Application of Field Data from Heater Experiments Conducted at Stripa, Sweden for Repository Design</u> by M.Hood, H. Carlsson, and P.H. Nelson (LBL-9392, SAC-26).

27. <u>Progress with Field Investigations at Stripa</u> by P.A. Witherspoon, N.G.W. Cook, and J.E. Gale (LBL-10559, SAC-27).

28. <u>A Laboratory Assessment of the Use of Borehole Pressure Transients to Measure the Permeability of Fractured Rock Masses</u> by C. Forster and J.E. Gale (LBL-8674, SAC-28).

29. <u>Thermal and Thermomechanical Data from In Situ Experiments at Stripa, Sweden</u> by T.Chan, O. Wan, C. Weaver, K. Ang, J.Braley and M. McEvoy (LBL-11477, SAC-29).

List of participants in the Joint Technical Committee (JTC)

Per-Eric Ahlström	Sweden	
Rudi Beck	Switzerland	- observer
Glenn Boyer	USA	
Hans Carlsson	Sweden	- project manager
Paul Gnirk	USA	- observer
Hans Issler	Switzerland	
Tohru Murano	Japan	
Lars B Nilsson	Sweden	- chairman
Richard Robinson	USA	
Veijo Ryhänen	Finland	
Harald Åhagen	Sweden	- secretary

List of participants in the Technical Subgroups (TSGs)

TSG-1

Rudi Beck	Switzerland	- chairman
Otto Brotzen	Sweden	
George Cowan	USA	
Reijo Gardemeister	Finland	
Ingmar Grenthe	Sweden	
Olli Heinonen	Finland	
Anders Hult	Sweden	- secretary
Andi Nold	Switzerland	
Paul Witherspoon	USA	

TSG-2

Anders Bergström	Sweden	- secretary
Paul Gnirk	USA	- chairman
Sven Hansbo	Sweden	
Pekka Holopaininen	Finland	
Sumio Masuda	Japan	
K Thirumalai	USA	
Raymond Véya	Switzerland	

STRIPA PROJECT - PREVIOUS PUBLISHED REPORTS

TR 81-01 "Summary of defined programs"
L Carlsson and T Olsson
Geological Survey of Sweden, Uppsala, Sweden
I Neretnieks
Royal Institute of Technology, Stockholm, Sweden
R Pusch
University of Luleå, Luleå, Sweden