LEGIBILITY NOTICE

LA-UR--90-1066

DE90 008969

Received by OSTI

APR 05 1990

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: THE INTERNATIONAL STRIPA PROJECT: TECHNOLOGY TRANSFER FROM COOPERATION IN SCIENTIFIC AND TECHNOLOGICAL RESEARCH ON NUCLEAR WASTE DISPOSAL

AUTHOR(S): R. A. Levich, E. S. Patera, P. M. Ferrigan, and P. L. Wilkey

SUBMITTED TO: American Nuclear Society International Conference on High-Level Nuclear Waste, April 8-12, 1990, Las Vegas, Nevada
(To be published in Proceedings)

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

MASTER

FORM NO 836 R4

THE INTERNATIONAL STRIPA PROJECT: TECHNOLOGY TRANSFER
FROM COOPERATION IN SCIENTIFIC AND TECHNOLOGICAL RESEARCH
ON NUCLEAR WASTE DISPOSAL

ROBERT A. LEVICH
U.S. Department of Energy (DOE)
Yucca Mountain Project Office
101 Convention Center Drive
Phase II, Suite 200
Las Vegas, NV 89109
(702) 794-7946

P. MICHAEL FERRIGAN
U.S. Department of Energy (DOE)
Repository Technology Program
9800 South Cass Avenue
Argonne, IL 60439
(708) 972-2021

EDWARD S. PATERA
Los Alamos National Laboratory
P.O. Box 1663, MS-J514
Los Alamos, NM 87545
(505) 665-3465

PATRICK L. WILKEY
CER Corporation
c/o U.S. Department of Energy
9800 South Cass Avenue
Argonne, Illinois, 60439
(708) 972-3115

INTRODUCTION

The Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA) sponsors the International Stripa Project. The Stripa Project is open to participation by all OECD member nations and nine nations have participated in the project over its duration. The objectives of the Stripa Project are: (1) to develop techniques for characterizing sites located deep in rock formations that are potentially suitable for the geologic disposal of high-level radioactive wastes; and (2) to evaluate particular engineering design considerations that could enhance the long-term safety of a high-level radioactive waste repository in a geologic medium.

The purpose of this paper is to briefly summarize the research conducted at Stripa and discuss the ways in which the technology developed for the Stripa Project has been and will be transferred to the United States Civilian Radioactive Waste Management Program's Yucca Mountain Project.

The in situ experiments of both the OECD Stripa Project and the earlier Swedish-American Cooperative were located in the Stripa Mine in central Sweden (figure 1). The Stripa Mine was an iron mine which operated between the mid-fifteenth century and 1976. Adjacent to the ore body is a small granitic intrusive rock body in which most of the experiments have been conducted. The research conducted for both the Swedish-American Cooperative and the

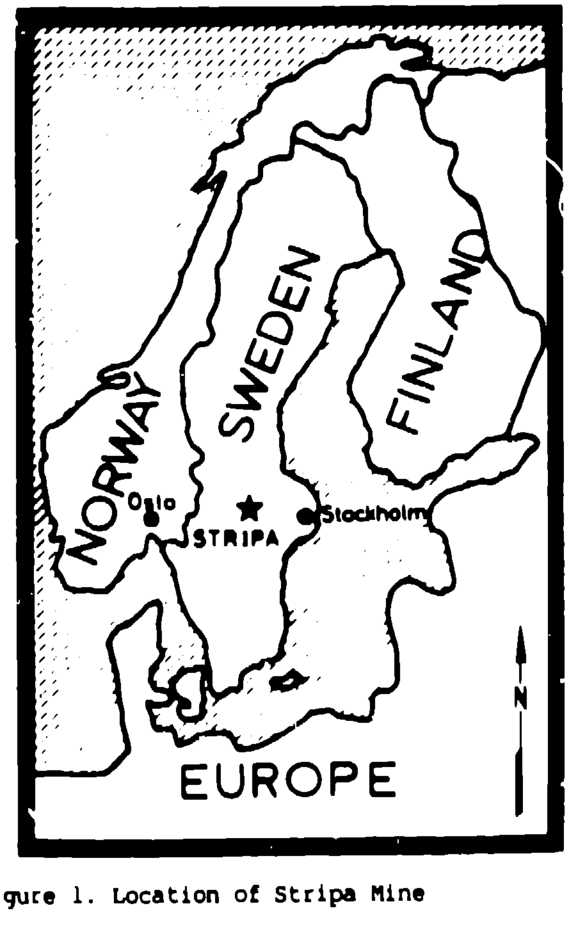

Figure 1. Location of Stripa Mine

International Stripa Project have great potential for application to the Yucca Mountain Project in the areas of site characterization and design of engineered barriers.

SWEDISH-AMERICAN COOPERATIVE PROJECT

In 1976 Sweden began research on waste disposal at the Stripa Mine, and in 1977 was joined by the U.S. DOE. The Swedish American Cooperative Project (SAC) was conducted in the Stripa mine between 1977 and 1980. Most of the SAC tests were performed at the 360 m level in granitic rock (figure 2). The tests were full scale and time scale heater tests, hydrological studies, and in situ stress measurements.

The results of the full scale heater tests indicated very good correlation with model predictions. Rock expansion from high heat loads was accommodated by existing fractures in the rock mass as demonstrated by fracture closing and a decrease in water inflow from the surrounding rock mass to the heater emplacements. In the time scale heater tests, short term results were extrapolated in time by using the law of heat conduction to compress the time scale by a factor of 10:1 and by compressing linear scales (distance power) by the ratio of the linear distance to the square root of the product of time and the thermal diffusion in the host rock. Analysis of the modeling showed good correlation except where fractures introduced non-linear behavior.

A large-scale hydrologic macropermeability experiment (ventilation test) was performed to determine the representative equivalent volume for measuring permeability in the fractured rock mass. All water that entered the drift was evaporated and collected outside by using constant temperature circulating air in the sealed off drift. Results indicated that a high degree of hydrologic communication exists within the fracture system at the Stripa mine. In situ stress measurements showed a good correlation between hydraulic fracturing and four different overcoring methods.

OECD/NEA STRIPA PROJECT

The International Stripa Project was established in 1980 under the auspices of the OECD/NEA. The project is managed by Swensk Karnbranslehantering AB (SKB)—the Swedish Nuclear Fuel and Waste Management company under direction of the Stripa Joint Technical Committee (JTC). The Stripa JTC is composed of representatives from each participating OECD/NEA country. The purpose of the Stripa Project has been twofold: (1) develop techniques to investigate sites in underground rock formations which may be potentially suitable for the disposal of radioactive wastes, and (2) examine engineering design phenomena (in particular, sealing) associated with enhancing the long term safety of a repository for high level nuclear waste.

The International Stripa Project was scheduled in three phases: Phase 1 (1980-1984), Phase 2 (1983-1986), and the current Phase 3 (1986-1991). The individual experiments in each of the three phases are summarized below.

STRIPA PHASE 1

Phase 1 of the Stripa Project was begun in 1980 and completed in 1985 with multinational participation by seven nations: Canada, Finland, France, Japan, Sweden, Switzerland, and the United States. It consisted of research in three main areas:

1. Hydrological investigations consisting of single hole and multiple hole tests (interference tests) to design and test methods for geologic, hydrologic, hydrochemical, and geophysical tests in boreholes to determine hydrologic characteristics and interactions among fractures in the rock mass; and hydrochemical studies to investigate the geochemistry of deep groundwaters.
2. In situ single fracture migration studies to investigate extension of laboratory experiments on sorption and retardation of radionuclides.
3. The buffer mass test to investigate the suitability and predicted functions of bentonite-based buffers under simulated repository conditions.

The hydrological testing, carried out in both horizontal and vertical boreholes provided information on favorable conditions for performing each test and an evaluation of their comparable reliability. The hydraulic test program demonstrated that it is possible to carry out hydraulic site investigations deep underground in order to define the detailed layout of a repository. Promising test methods were performed in Phase 2.

A very extensive hydrogeochemical testing program indicated the existence of available working methods and methods with strong developmental potential to determine residence times. The investigations at Stripa indicated deep local groundwaters may have very long residence times suitable for radioactive waste disposal. The

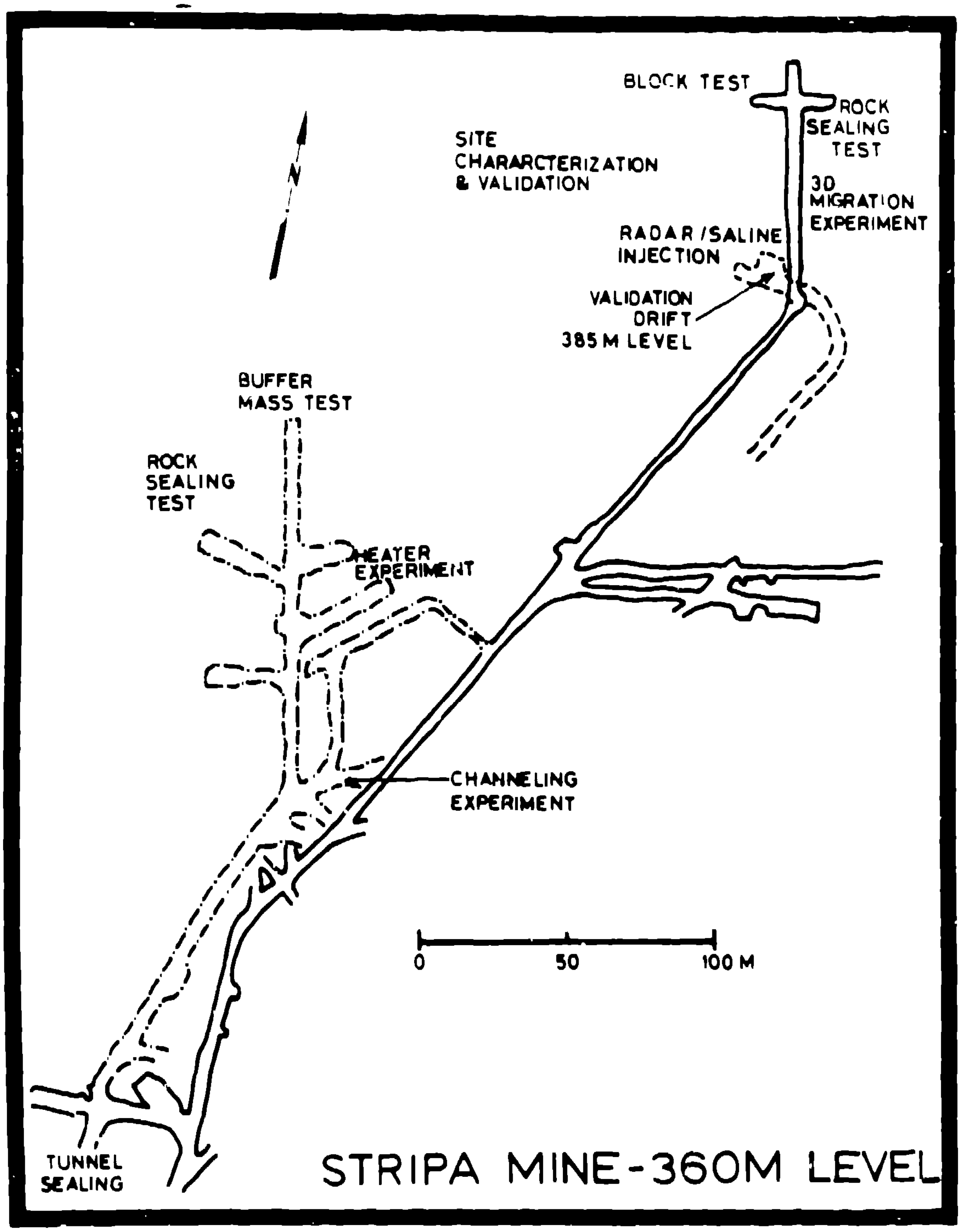

Figure 2. Location of Research Experiments on Level 360 of Stripa Mine

perturbations of an underground environment due to subsurface mining, drilling, and thermal loads can however result in rapid infiltration of shallow groundwater.

The sorption results from the single fracture migration studies indicated a fit for a variety of analytical models. Results also indicated a fracture cannot be realistically treated as two planar parallel surfaces with a constant separation distance. Preferential flow directions (channeling) could not be determined from the experimental results. Further research is needed to understand processes involved in nuclide migration so realistic assessment of waste repositories can be performed.

The buffer mass test served as a practical demonstration of the preparation, handling, and placement of soil-type backfills. The feasibility was verified for concepts based on the use of smectite-rich clays as overpacks for moderately hot canisters and smectite mixtures as tunnel backfill. The available models of buffer behavior were validated and can be used to predict repository configuration using bentonite and related mixtures.

STRIPA PHASE 2

Stripa Phase 2 started in 1983 and ended in 1987. Nine nations participated in this second phase: Canada, Finland, France, Japan, Spain, Sweden, Switzerland, the United Kingdom, and the United States. Research was conducted in five areas:

1. Crosshole techniques to detect and characterize fracture zones by borehole radar and borehole seismic methods.

2. A three dimensional migration experiment to understand and quantify the transport processes of flow porosity, longitudinal and transverse dispersion, channeling, and the validation and/or modification of models.

3. Borehole, shaft, and tunnel plugging tests to determine whether Na-bentonite is practical to seal boreholes, shafts, and tunnels in repositories.

4. Hydrogeological characterization of the Stripa site to develop a statistical characterization of fracture system geometry, determine the range and nature of fracture permeabilities, determine the effective and total fracture porosity distributions from field and laboratory data, and determine the three dimensional configuration of the groundwater flow system at Stripa.

5. Hydrochemical characterization of the Stripa groundwaters to determine geochemical origin and evolution of deep groundwaters at Stripa and identify processes and mechanisms of water-rock interactions.

The crosshole investigations led to several major conclusions. The radar techniques were proven to be much more effective than expected. Penetrations were up to 150m compared to early estimates of about 30-50m. The seismic techniques were proven useful in an initial site characterization program to locate major fracture zones wider than 20m. However, it remained necessary to solve problems with the source to develop a clearer signal which will allow better resolution. Tomography software was developed for processing crosshole data.

The three dimensional migration experiment concluded that very careful planning and design are required prior to performing complex experiments. The test showed a very uneven distribution of water in the large rock mass. Tracer arrival was spread over a very broad range of times. One question raised by both this experiment and the single fracture experiment is the validity of hydraulic testing using present interpretation methods to obtain flow porosity in fractured rock. The observed fracture openings used to determine the water volume residing in the fracture is considerably larger than that needed to induce the observed pressure drop.

The sealing activities demonstrated that an effective plug of compacted bentonite can be installed in a borehole, drift, or repository shaft. The long term stability based on erodability and chemical stability was also addressed. Results indicated that if certain measures are taken including pregrouting and temperature control (below 100°C), a long term limit is possible on erodability and extended chemical stability during the isolation period.

The hydrogeological and hydrogeochemical characterization of the Stripa mine were, in general, site specific activities. The synthesis of the data to achieve a site model for predicting response of the rock mass however provides a valuable tool to be used in future site characterization activities. Much of these data formed the basis for the site characterization and validation activity during Phase 3.

STRIPA PHASE 3

The third and final phase of the Stripa Project began in 1986 and is scheduled to conclude in 1991. The seven current member nations of the Stripa Project are Canada, Finland, Japan, Sweden, Switzerland, the United Kingdom, and the United States. Phase 3 continues research started during the first two phases, builds on results obtained from the previous studies, and develops new areas of research. The primary activities of the Stripa Phase 3 program are organized in three sub-projects:

1. Site characterization and validation.

2. Improvement of site assessment methods and concepts.

3. Sealing of fractured rock.

Site characterization and validation consists of five successive stages: (1) preliminary site characterization; (2) preliminary predictions; (3) detailed characterization and preliminary validation; (4) detailed predictions; and (5) detailed evaluation.

Improvement of site assessment methods and concepts will enhance the quality of predictions, especially in the area of fracture flow and includes the following activities: (1) development of high resolution and directional borehole radar; (2) improvement of techniques for high resolution borehole seismic testing; (3) development of a three-dimensional network flow model; (4) improvement of understanding of conditions and processes that cause uneven flow (channeling) in a fracture system; and (5) estimation of fracture length and aperture from single fracture packer tests.

Phase 3 research on sealing of fractured rock, which emphasizes the sealing of groundwater flow paths, will be conducted in five consecutive stages: (1) a state-of-the-art survey of fracture sealing materials to establish the range of thermal, thermomechanical, hydrogeological, and geochemical conditions that could effect the sealing capacity of specified materials over time; (2) identification of sealing materials and the design of tests to demonstrate their long-term stability; (3) determination of long-term stability of selected materials; (4) use of field pilot tests to evaluate and demonstrate injection techniques for selected materials; and (5) development of a large scale sealing test.

TECHNOLOGY TRANSFER

Characterization of radioactive waste repository sites in geologic media present challenges and requirements far beyond standard geotechnical practices. These challenges include the development of new concepts, approaches, methods, instruments, and techniques. Research at Stripa has served as a locus to develop, test, and model these new ideas. It has presented a central locale and theme for applied geoscientific studies and a forum for developing and improving repository-related research.

METHODS OF TECHNOLOGY TRANSFER

The development and implementation of research programs as part of the Stripa Project involve many different technological aspects. Research at Stripa represents state-of-the-art investigations and includes development of instruments and techniques for studies related to high-level waste repositories. Scientists and engineers from OECD/NEA participant nations have access to this research through a variety of technology transfer initiatives.

Personnel Involvement

Personnel from U.S. DOE and contractors within the U.S. program have been and continue to be involved in both the planning and implementation of the experimental programs as well as their evaluation and analysis. The direct involvement of U.S. personnel in the Stripa Project constitutes the best form of technology transfer. Three levels of involvement are defined.

1. U.S. personnel can become principle investigators for research funded by the Stripa Project. Each participant nation is solicited to submit proposals to the Project for evaluation. Successful proposals are accepted based on the likelihood of accomplishing the overall objectives of the Stripa Project.

2. Each participant nation is represented on the various committees, subgroups, and task forces. The highest level group is the Joint Technical Committee (JTC). Each member nation is entitled to representation on the JTC based roughly on the shares it contributes to the Stripa Project. The JTC functions as the "Board of Directors" of the Stripa Project and is responsible for setting the objectives and goals of the Project and providing the management (SKB) with the guidance it needs to carry out the tasks. During Phase 1 and Phase 2, the Project had two technical subgroups (TSG) that provided advice and consultation to the management and the JTC on the technical scopes of work within the project. Each nation is entitled to send two technical representatives to each technical subgroup, and can also send up to two observers to TSG meetings for the purposes of advising their representatives and transferring the knowledge gained during these meetings back to their respective national programs. Only one technical

subgroup was established for Phase 3 because of the highly integrated nature of this phase of the project. However, early in Phase 3 it became clear that two technical areas needed special attention to define the technical requirements to accomplish the overall objective. Therefore, two task forces were established: (1) a Task Force on Sealing Materials; and (2) a Task Force on Fracture Flow Modeling. Task forces are different from the TSG in that they are established for the benefit of the involved principal investigators. Each nation was asked to appoint a technical representative to each task force. In addition, other experts have been invited to work on the Project through the task forces. For example, two U.S. representatives have developed a thermodynamic data base and calculational schemes for cement based sealants under the Sealing Materials Task Force. Two other U.S. representatives are developing Discrete Fracture Flow Models for the Stripa Project through the Task Force on Fracture Flow Modeling. This work is helpful to the U.S. program because it allows the U.S. personnel an opportunity to exercise their capabilities on a field experiment designed expressly for the purpose of making predictions of water flow and radionuclide transport and validating those models before similar predictions are made within the U.S. program.

3. The Stripa Project Agreement also permits member nations to send technical experts to Stripa to work alongside the principal investigators on selected aspects of the Project as approved by the JTC and the Stripa Management. The duration of these visits may be several months.

Property, Patents, and Intellectual Property Rights

The participating nations own the property that is purchased and constructed by the Project. Each nation can use for its own benefit any of the apparatuses used by or built for the Stripa Project. For example, the United States program can use and evaluate the borehole radar instrument developed at Stripa to characterize Yucca Mountain, providing there are no scheduling conflicts. In addition, each nation has patent rights and can construct any instrument developed by the Project. These rights also extend to intellectual property including computer codes, as provided by the Stripa Project Agreement.

Symposia/Workshops

The Stripa Project sponsors technical symposia and workshops on many aspects of the program. Three major international symposia have served as forums to present and discuss Stripa research with scientists and technical managers from around the world. A series of technical workshops have shared advances, methods, and techniques with scientific investigators from member nations. Topics have included sealing, site characterization methods, geophysical instrumentation, and the summary and progress of development of exploration and interpretation methodologies.

International Cooperative Work

Participation by U.S. principal investigators in the experimental programs alongside other internationally recognized experts at Stripa aids the U.S. program in obtaining and refining the current state-of-the-art technology for planning and implementing domestic activities.

Direct Use

Procedures and techniques developed and implemented in the Stripa Project can be directly transferred to the U.S. waste disposal program.

Publications

The Stripa Project has to date published more than 75 technical reports which describe and summarize the procedures and results from the scientific investigations. Copies of these reports are disseminated to interested parties within the U.S. program.

PLANS FOR INCORPORATING STRIPA TECHNOLOGIES

To date the Yucca Mountain Project has not fully taken advantage of the technologies being developed and refined at Stripa. The reasons are multiple and include the former structure of the U.S. program and the evolving relationship between the International technical programs and those scientists responsible for the development of domestic technical investigations.

For the past year steps have been under way for further incorporating Stripa-developed technologies into the U.S. program. These steps are expanding and accelerating and include:

1. Broader dissemination of Stripa publications. For the past year Stripa reports have been sent routinely to all Yucca Mountain Project participants, and back issues will be provided during 1990.

2. During 1989, for the first time, Yucca Mountain Project scientists routinely attended Stripa symposia and workshops. This will continue and expand in 1990 and

thereafter.

3. Scientists long associated with the Stripa Project from Lawrence Berkeley Laboratory and U.S. private contractors, have been incorporated into the Yucca Mountain Project and are integrating Stripa-developed technologies into the Nevada program.

4. A number of revised bilateral exchanges were begun in 1989 and will expand in 1990 between Principal Investigators from the Yucca Mountain Project and International colleagues familiar with the Stripa-developed technologies.

5. Stripa technologies already introduced or in the process of being introduced into the Yucca Mountain Project include borehole radar, seismic crosshole tomography, tracer/migration testing techniques, fracture flow modeling, channeling studies, sealing, and site characterization and validation techniques.

CONCLUSION

The bilateral and multinational-sponsored research studies at Stripa have advanced the state-of-the-art technologies of characterizing the geotechnical, hydrologic, and geochemical properties of a rock mass, and the performance of engineered barriers.

Stripa and similar international research projects provide national programs with locales to make mistakes and learn from them. It is important to remember that not all research studies at Stripa have proved successful, but that is the nature of and "raison d'etre" for research. Many of the topics studied at Stripa including fracture flow modeling, channeling studies, sealing and grouting, and geophysical and integrated characterization techniques are both at the cutting edge of scientific research and of vital importance to understanding and characterizing a potential repository site. The knowledge, techniques, and instruments obtained from the Stripa Project can be incorporated into the U.S. program for use in repository characterization and development.

Thus, technology transfer from Stripa has been and is being performed through: (1) technical symposia and workshops at which the principal investigators explain their work; (2) publication of technical reports, copies of which are disseminated to domestic investigators; and (3) the participation of U.S. personnel in the activities.

Technology transfer will continue throughout the completion of Phase 3 and shall enhance repository-related research well into the future; and thus, radioactive waste programs from the United States and other participant nations will continue to benefit from Stripa activities into the 1990s.

REFERENCES

1. SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY (SKB), Executive Summary of Phase 1, Stripa Project Report 86-04, OECD/NEA (1986).

2. SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY (SKB), Executive Summary of Phase 2, Stripa Project Report 89-01, OECD/NEA (1989).

3. SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY (SKB), Program for the Stripa Project Phase 3, 1986-1991, Stripa Project Report 87-09, OECD/NEA (1987).