APPENDIX 5

INTRAVAL (88)4

DRAFT

INTRAVAL DRAFT TEST CASE

RADIONUCLIDE MIGRATION IN THE WEATHERED ZONE OF THE KOONGARRA URANIUM DEPOSIT

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1 INTRODUCTION

A Pilot Group Identification

At the INTRAVAL Coordinating Group meeting in Stockholm in October 1987, Peter Duerden was appointed as the Pilot Group Leader, with Cezary Golian of ANSTO as a member.

B Experimental Location

The Alligator Rivers region of the Northern Territory of Australia is located about 200 km east of Darwin, with the Koongarra uranium ore deposit being approximately 25 km south of Jabiru, the principal town. There are regular airline services from Darwin to Jabiru and sealed highways link Darwin with Jabiru, and Jabiru with Koongarra excepting the last 10 km.

C Objectives

The objective of the modelling is to deduce the timescale and the rate of the uranium mobilisation which resulted in the redistribution of the ore body along the general groundwater flow direction.

Weathering of the upper 30m deep zone of the geological stratum preceded the mobilisation event, but it has been suggested that deposited material present in surface run-off waters may have minimised surface erosion in the ore zone. Transport in the weathered zone is considered to be through porous rock as well as by fast groundwater flow through fractures.

It is anticipated that hydrodynamic modelling of a natural analogue system such as Koongarra, with the inherent lack of control over experimental conditions and insufficient knowledge of the initial conditions prevailing, will be enhanced by further modelling aproaches such as multi-phase, geochemical, and open-system concepts.

D/E Theories Tested and Validation Aspects

The mass uranium redistribution from the primary deposit area to the extended fan-like area of the secondary deposit is visually impressive proof of radionuclide transport in the porous rock, and the shape of the secondary deposit appears to be linked to present day groundwater flow patterns.

Up to now the mobility of uranium-238, uranium-235 and uranium-234 have been included in models based upon hydrodynamic flow and open system concepts. A large data base for concentration and activity ratios of these radioisotopes and others such as thorium-230 and radium-226 is available.

Rock may be considered as a single phase medium when modelling retardation processes, sorption and leaching mechanisms, and relevant radiochemical data is available. However, an alternative aproach would be based upon the assumption that the rock can be treated as a multi-phase medium, and there is experimental evidence which supports this idea of radionuclide fractionation between amorphous iron, crystalline iron and clay/quartz phases.

It would appear that

i) the uranium of the amorphous, but not of the crystalline iron, is directly accessible to groundwater;

ii) on the geological timescale, exchange occurs between the amorphous and crystalline iron;

iii) the bulk of the uranium and thorium is associated with the iron phases, whereas an excess of radium accumulates in the clay/quartz phase; and

iv) the recoil effect leads to an accumulation of the daughter element in the clay/quartz.

In the Koongarra ore body the activity ratios of these fractions increase in magnitude from the ferrihydrite/ amorphous /Fe through crystalline Fe-goethite to be largest in the clay/quartz phase.

The effect of colloid transport may also need to be considered. Preliminary results indicate the relative insignificance of uranium colloid transport in comparison to that in groundwater. However radionuclides insoluble in groundwater such as thorium were found to be present in colloid and fine particulate material even though the effects of the sampling methods have to be closely examined.

F Background Information

Given in the general background document.

2 EXPERIMENTAL DESIGN

A Parameters Measured

A large number of hydrogeological, hydrochemical, geological, mineralogical and radiochemical parameters are available, and are listed in Section 6 of the Background Description.

B Spatial and Temporal Scales

The spatial scale of the 'experiment' is determined by the size of the secondary dispersion fan of which the economic uranium zone is about 80 m long, about 25 m deep and 45 m wide.

The temporal scale is to be estimated through modelling, but maybe expected to range from hydrogeological to geological timescales.

C Experimental Set-up

The initial hydrological and geological experiments were carried out during preliminary mining exploration work.

The radiochemical experiments are divided between laboratory and field experiment investigations of rock and water samples. A detailed description of these is given in the general description.

D Sampling Strategy

A large number of groups have been involved in the various experimental measurement programs and where possible duplicate measurements have been made.

E Interdependence Between Data Sets

i) The data originating from rock and from groundwater are completely independent.

ii) A section of the groundwater data may have arisen from water sampled at a specific collection time. However the individual analyses are carried out separately with a range of measurement techniques. In addition the groundwater data base consists of analyses obtained during repeat sampling programs and these measurements are completely independent. A number of the groundwater samples were collected by baling, whilst the others are the result of pumping. The latter have until now been collected without using packers; it is possible that some mixing of aquifers was possible with some groundwater coming from deep aquifers. All future pumped samples will be collected from packed-off zones.

iii) An extensive rock, two-dimensional data set is available from the 6109 N section through the ore deposit (See Figure 1). Parallel sections of the orebody can provide the modeller with independent data to test the modelling.

F Biases Present

Although every effort is made to keep the samples in as near as possible to in situ conditions, it is possible that some are disturbed in transit to the laboratory. The most recent core material was drilled in 1978. It is possible that some modification has taken place during storage in the core shed.

G Complementary Experiments

Fission products and transuranic elements production and migration, colloidal transport. Details are presented in the general Koongarra description.

3 CURRENT STATUS AND EXPERIMENTAL SCHEDULE

See the general description.

4 EXPERIMENTAL RESULTS

A/B/C Raw Data/Processed Data/Data Storage

The data are available either in raw or processed form in numerous mining, hydrological, geological, environmental reports as well as in radiochemical papers.

The data is generally in tabular form. A computerised data base 'MICROMINE' is being installed, and will provide all available information with full spatial graphic facilities.

Access to the data base will be either via floppy disk transfer or direct via computer mail.

5 PREVIOUS MODELLING

As stated in general document.

6 EXPECTATIONS FROM INTRAVAL

A Experimentalists' View

Features of the Koongarra orebody that favour modelling.

The main orebody at the Koongarra deposit features well-defined areas of primary and secondary uranium mineralisation. The primary orebody has been extensively altered by percolating, oxidising groundwaters but shows little evidence of uranium transport, with the possible exception of very localised effects. Radium on the other hand appears to have been extensively mobilised within the primary orebody.

Mobilisation of uranium appears to have occurred only in the 30 m deep weathered zone. This consists of a previous upward extension of the deposit, from which uranium has been leached and a horizontal, tongue-like extension of dispersed uranium. This tongue transforms from an up-flow region of secondary mineralisation to more widely dispersed, unmineralised uranium in the down-flow extremities.

Several features of the Koongarra orebody may be favourable towards mathematical modelling. These are as follows -

(a) There are well-defined zones of leaching and deposition within the weathered zone. These have arisen from lateral flow of meteoric groundwater which is greatly influenced by the proximity of the nearby sandstone escarpment. Lateral movement of uranium from its original location appears to have dominated over downward movement.

(b) Since the position of the pre-erosioned orebody is well known and the uranium was concentrated within a fairly narrow zone, mathematical modelling can assume a reasonably specific location for the original uranium at time zero (i.e. at the onset of erosion).

(c) Uranium transport appears to have been confined almost entirely to the 30 m deep weathered zone. This enables the modeller to make quite general assumptions regarding the geochemical properties of the host medium. Although it obviously cannot be considered homogeneous, the dominant minerals (i.e. iron oxides, kaolinite, quartz and chlorite) occur widely, varying mainly in their relative proportions.

(d) Secondary uranium mineralisation is not found in the majority of samples from the weathered zone. From the modelling point of view, the short-term distribution of uranium can be considered in terms of an accessible phase, in isotopic equilibrium with the groundwater, and an inaccessible component consisting mainly of uranium incorporated within iron oxides.

(e) The migration of uranium in the weathered zone is not influenced by redox processes, since uranium is confined almost entirely to the +6 oxidation state in this region. Modelling of uranium transport can therefore be simplified by discounting the effect of a redox barrier on uranium solubility.

(f) A considerable amount of data is already available on the relative distributions of ^{238}U, ^{234}U, ^{230}Th and ^{226}Ra from a two-dimensional, vertical cross-section of the deposit running roughly parallel to the direction of groundwater flow. The data supports previous estimates of the direction of groundwater flow and resulting uranium movement.

B Modellers' View

The Koongarra ore deposit should prove to be an interesting, and relevant site for field tests and modelling. Because of the inherent problems associated with modelling natural analogues, such as the very limited control or knowledge of experiment conditions, it is important to use a diversified approach and to obtain a large number of modelling predictions from which hopefully some consistent conclusions can be drawn.

In particular,

i) Different modelling approaches can help to arrive at a possible timescale for the process of the formation of the secondary deposit. Results so far have not been entirely consistent, but the introduction of a variety of modelling concepts may produce a more reliable picture. The difficulties incurred in the selection of initial and boundary conditions may also be clarified.

ii) Geochemical modelling being carried out within the ARAP may provide assistance in establishing submodels for such components as the source terms, radionuclide retardation, radionuclide sink terms and mass transfer among mineral phases. Geochemical modelling could also be used to identify sources of colloids in the groundwater field.

iii) The Koongarra site is located in a subtropical area and is influenced by distinctive wet and dry seasons. It would be interesting to include in the models the variations in groundwater recharge and eventual flow rates, together with any consequent chemistry changes in the groundwater.

7 INFORMATION EXCHANGE

Experimental questions should be addressed to:

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8 POSSIBILITIES FOR FUTURE EXPERIMENTS AND DATA COLLECTION

An extensive experimental program is planned within the Alligator Rivers Analogue Project and details of the objectives and proposed work is given in the general background description.

9 OUTPUT FORMAT

The format in Appendix 8 of the First Meeting of the INTRAVAL Coordinating Group will be used.

10 REFERENCES

Detailed lists of references are included in the general background description for all aspects of the experimental and modelling programs. A list of general references is given below.

Snelling, A.A., 1980. A Geochemical Study of the Koongarra Uranium Deposit, Northern Territory, Australia. PhD Thesis, University of Sydney, Australia.

Radionuclide Migration Around Uranium Ore Bodies - Analogue of Radioactive Waste Repositories. United States Nuclear Regulatory Commission Contract NRC-04-81-172.

Annual Report 1981-82, AAEC/C29.
Annual Report 1982-83, AAEC/C40, NUREG/CR-3941.
Annual Report 1983-84, AAEC/C45.
Annual Report 1984-85, AAEC/C55, NUREG/CR-5040.
Annual Report 1985-86, in press.

Golian, C. and Duerden, P., 1987. Application of open system modelling to studies of secondary mineralization (Koongarra) and rock matrix diffusion (Krakemala). Proceedings of CEC Symposium on Natural Analogues in Radioactive Waste Disposal, Brussels, 28-30 April. EUR11037.

Duerden, P., Golian, C., Hardy, C.J., Nightingale, T. and Payne, T., 1987. Alligator Rivers Analogue Project - review of research and its implications for model validation, ibid.

Ivanovich, M., Duerden, P., Payne, T., Nightingale, T., Longworth, G., Wilkins, M.A., Edghill, R.B., Cockayne, D.J. and Davey, B.G., 1987. Natural Analogue Study of the Distribution of Uranium Series Radionuclides between the Colloid and Solute Phases in the Hydrogeological System of the Koongarra Uranium Deposit, NT, Australia, ibid.

Airey, P.L., 1987. Applicability of natural analogue studies to the Long-term Prediction of the Far-field Migration at repository sites, ibid.

Curtis, D., 1987. The geochemistry of natural technetium and plutonium, ibid.

Fabryka-Martin, J.T., Roman, D., Airey, P.L., Elmore, D. and Kubik, P.W., 1987. Redistribution of natural iodine-129 among mineral phases and ground water in the Koongarra uranium ore deposit, N.T., Australia, ibid.

11. DATA

A Hydrogeology

1 Climatological data, including rainfall and temperature.

2 Surface water measurements, including stream flow.

3 Location, elevation, geologic logs, casing and perforation details of all test holes and wells.

4 Map, showing test holes and wells, as well as land-surface contours.

5 Aquifer test results including water-level drawdowns, discharge measurements, and water quality of discharge.

6 Periodic water-level measurements which show seasonal fluctuations and regional gradients.

7 Results of geophysical surveys and back-hoe pits which show thickness of upper deposits.

8 Results of early packer tests in upper part of the bedrock. Resistivity traverses.

B Hydrochemistry

1 pH, Eh, D.O., conductivity, temperature.

2 Cations - F, Mg, Na, Al, Si, S, K, Ca, Ti, Mn, Fe.

3 Anions - HCO_3^-, SO_4, Cl, PO_4.

4 Trace Metals - Cd, Cr, Cu, Pb, Mn, Mo, Ni, Zn.

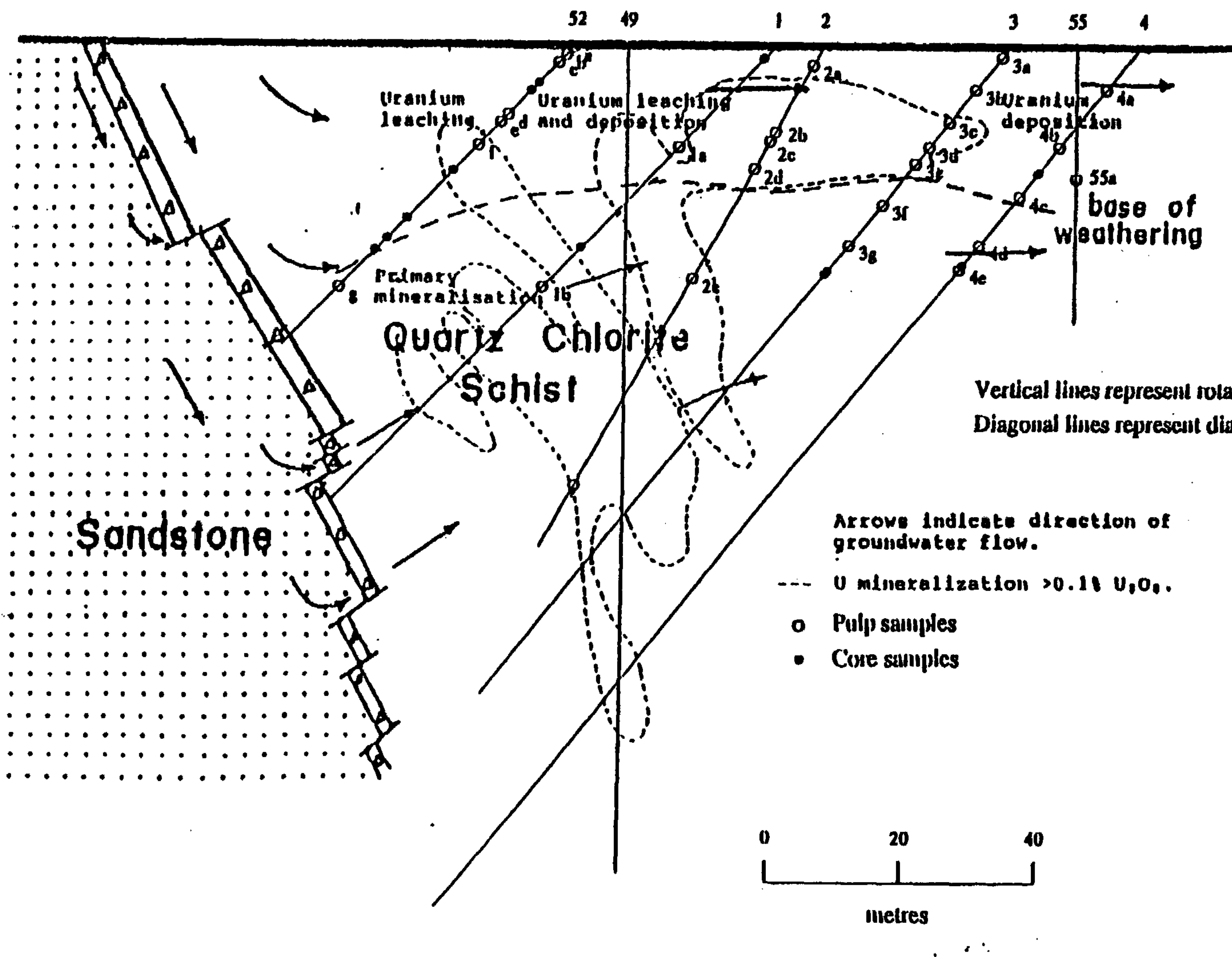
5 Isotopic - ^{14}C, $\delta^{13}C$, Ra, Rn, ^{3}H, $^{36}Cl/Cl$, Th, U.

C <u>Geology, Mineralogy, Radiochemical</u>

An edited tabulation of rock data presently available is included with this test description, where Figure 1 indicates the position of the drill cores in the uranium deposit. Tables 8 and 9 provide an example of the data available from sequential extraction experiments; further results are available on request with a complete description of the procedure and its relevance to a multi-phase treatment.

The MICROMINE exploration and mining software package will at a later date provide graphic log sheet displays with histograms of uranium grades or contoured displays showing profiles of the uranium dispersion fan. Drill core records relevant to the modelling task will also be supplied on request.

FIGURE 1 Cross section of Koongarra uranium deposit
(drill holes and sample locations are shown)



CHARTER FOR THE

VALIDATION OVERSIGHT AND INTEGRATION COMMITTEE

BACKGROUND:

At the first INTRAVAL Coordinating Meeting, the Secretariat approved a motion by Dr. Norman Eisenberg, US DOE to establish a working group to formulate a Validation Oversight and Integration Committee (VOIC). The need for this committee is based upon issues reported in the INTRAVAL ad hoc report, and a critique of that report and the INTRAVAL Project Proposal presented by Dr. Shlomo P. Neuman, University of Arizona, earlier at the meeting. The Vice-Chairman was requested to chair a Working Group to develop ideas and plans to implement the motion, and to report to the Coordinating Group on their specific recommendations. This Charter serves that role.

The INTRAVAL Project has selected a set of experiments (including laboratory and field experiments, and natural analogs) which include a range of media types, flow and transport processes, spatial and time scales, and various environmental conditions associated with radioactive waste disposal in geologic media. Included within these experimental studies are various performance issues and models which are the topic of these selected validation studies. However, there is presently no effort within the INTRAVAL Project which deals specifically with an overall synthesis and integration of these validation studies. This integration effort would build upon the experiences and knowledge gained from the individual INTRAVAL test cases. This proposed effort would enable the INTRAVAL Project to advance the knowledge of validation in a more comprehensive manner than if the test cases were considered separately.

It is this need for a specially designed effort dealing with the integration of these broad validation issues that is the motivation for the formation of the Validation Oversight and Integration Committee (VOIC).

As the INTRAVAL Project's progress is reviewed by the VOIC, and these broad validation issues are identified, the VOIC could also serve an oversight function by advising the INTRAVAL Coordinating Group of needed modifications and additions.

PURPOSE:

The purpose of the Validation Oversight and Integration Committee is to provide a means for the INTRAVAL Project to investigate the broad issues related to demonstrating the validity of theories and models used in the performance assessment of repositories, and to provide for a continuing technical oversight which will allow for ongoing adjustments and improvements to the selected test cases.

OBJECTIVES:

The objectives of the Validation Oversight and Integration Committee (VOIC) are to:

(1) examine the broad validation issues associated with demonstrating the validity of theories and models used in the performance assessment of repositories through a synthesis and integration of the experiences and knowledge gained from each of the INTRAVAL test cases, and review of other appropriate research studies outside of INTRAVAL.

(2) provide a technical oversight function through recommendations (based on the VOIC's synthesis and integration efforts of validation issues, reviews of non-INTRAVAL research studies, and ongoing reviews of the INTRAVAL test cases) to the INTRAVAL Coordinating Group.

MEMBERSHIP:

Composition - A list of proposed VOIC members will be submitted to the INTRAVAL Coordinating Group that will consist of 6-8 recognized experts in the field of ground-water flow and transport studies with both experimental and modeling experience.

Support - The committee could request through the Secretariat, assistance from the individual Project teams to provide the committee with required information and additional expertise. Financial support for members of the VOIC will follow the INTRAVAL Agreement, and will therefore be the responsibility of the individual organizations who are sponsoring the VOIC members.

IMPLEMENTATION:

The Validation Oversight and Integration Committee will interface with the INTRAVAL Coordinating Group and project teams through the Secretariat in an attempt to synthesize and integrate:

- the results from the efforts by the project teams on various INTRAVAL test cases,
- the accomplishments resulting from the INTRAVAL Workshops and Coordinating Group Meetings, and
- the independent research and review efforts of the VOIC

into a unified scientific approach for model validation. The VOIC will seek information and experiences both inside and outside of the nuclear waste community (e.g., USEPA, NASA, USDOD, NATO and other governmental agencies and international organizations which have had to deal with the subject of validation) to assist in development of this unified scientific approach to model validation.

The VOIC will gather the needed knowledge for their integration and synthesis efforts, and also provide continuing independent reviews and evaluations of the INTRAVAL project by: (1) attending the INTRAVAL Workshops and Coordinating Group meetings: (2) interacting with the various project teams; (3) reviewing the various project team reports; and (4) covering separate meetings preferably at the conclusion of the INTRAVAL workshops. Other mechanisms for providing for a rigorous peer review of the INTRAVAL Project and its results will also be considered by VOIC.

The VOIC will provide feedback, when appropriate, to the project teams and Coordinating Group through presentations at the INTRAVAL workshops and Coordinating Group meetings as well as through VOIC reports.

A list of potential tasks which the VOIC might undertake are:

- review the INTRAVAL Ad Hoc report, and other available information (e.g., GEOVAL papers) to determine the outstanding questions with regard to validation of radionuclide transport models;

- review the nine test cases to identify the primary hypotheses, models and theories being tested, so as to identify any missing relevant theories and models and suggest which ones could provide credible alternatives to the ones being tested:

- integrate the various test cases into a framework covering the range of theories, media, processes, and scales being considered;

- recommend modifications to existing test cases or development of new test cases to address omissions in the validation framework;

- investigate both the specific issues related to demonstrating the applicability of the chosen models to actual experiments and the broader issues related to integrating these diverse studies into a coherent program for validation of ground-water flow and radionuclide transport models.

It would also be desirable if VOIC would examine the following issues:

- the basic steps for a validation approach including the role of comparisons to experiments,

- an approach for dealing with the different spatial and temporal scales,

- the role of an iterative approach involving calibration and validation steps,

- an approach for dealing with the differences between modeling scale and measurement scale,

- the relationship between model purpose and quality of model agreement with experimental data in a model validation effort.

It should be noted that these lists of tasks and issues are presented only to portray the general topics the VOIC may wish to explore. Since VOIC is meant to be as independent and unbiased as possible, VOIC should establish a detailed action plan and specific topics utilizing the guidance provided in this Charter.

SCHEDULE:

The proposed schedule for formulating the Validation Oversight and Integration Committee is as follows:

January 1988	- Circulate first draft of the VOIC Charter to the Working Group
March 1988	- Transmit the finalized VOIC Charter to the Secretariat
March 1988	- Circulate VOIC Charter to Coordinating Group members and to formulate committee membership and chairmanship for presentation at the 2nd INTRAVAL Coordinating Group Meeting
April 1988	- Report to the INTRAVAL Coordinating Group on the VOIC Charter
May 1988	- Following approval, organize VOIC convocational meeting and establish an action plan