CONCLUSIONS AND RECOMMENDATIONS

The third AMIGO workshop focused on the application and integration of geoscience arguments in the safety case and in design, and addressed the qualitative and quantitative use of geoscientific information in these areas.

A main outcome was to highlight some specific examples of how geoscientific evidence and arguments are increasingly being incorporated in safety assessments and in safety cases. This has been achieved by:

- The integration of wide-ranging geoscientific information in a geosynthesis.

  A geosynthesis (or site descriptive model) integrates the various and complementary types of data from field investigations and associated laboratory studies in a single, coherent, logical and defensible description of a site. It not only provides specialised information and data such as groundwater flow rates, geosphere sorption parameters and data on rock stress needed to support safety assessment and engineering studies, but also provides complementary evidence (e.g. for intrinsically favourable properties of a site, including its long-term stability) to support the safety case.

- The establishment of effective communication between the geoscientists and safety assessors.

  Effective communication is essential to promote completeness in the information included in a geosynthesis, to ensure consistency between information of different types, and to identify all relevant uncertainties.

  A range of project tools and methods is available to support the integration of geoscientific information in geosyntheses and in safety cases. For example, multidisciplinary integration groups are increasingly used to foster dialogue between disciplines. However, some geoscientific evidence has not yet been effectively integrated (e.g. diagenetic evidence from sites) and natural analogues could still be better used to communicate the favourable qualities of a site to stakeholders.

Examples were also given of how the safety concept and repository design are adapted to site-specific conditions, guided, for example, by safety-related and other criteria on the properties of a rock block that make it suitable for tunnel construction or waste emplacement. There is thus a strong link between safety concept and associated repository design on the one hand, and site characterisation on the other.

All programmes adopt an iterative approach to safety studies and analysis, design development and the acquisition of geoscientific knowledge. The workshop provided several examples of geoscientific issues identified as priority areas for future studies based on the results of previous safety assessments, the compilation of safety cases and the review of these activities.

The working groups addressed issues in more detail than was possible in the plenary sessions. Their observations and recommendations should not necessarily be taken as consensus statements

from the workshop, since they were not broadly discussed outside the working groups, but they raise issues that deserve attention. Indeed, many of the recommendations represent widely accepted views that have already been documented in other national and international projects. Some key observations of the working groups include:

- Site investigation clearly provides fundamental data underpinning safety assessments and safety cases. It supports the development of conceptual models, provides data to derive parameter values, and is used to define relevant processes and scenarios. It also provides evidence and arguments for the intrinsically favourable properties of a site that can be used in the wider context of a safety case. The types of data that are available and the uncertainties associated with the data have clear implications for the scope and level of detail achieved in a safety assessment. The priorities and issues in safety assessment and in repository programmes overall can, therefore, be expected to evolve as a programme (including site characterisation aspects) progresses.
- Information from site investigations, and uncertainties related to the geosphere, can also strongly affect the design of a disposal system, and there are many examples in which this has happened. In adapting a design to the characteristics of a site, care should be taken to ensure that a change made to solve one problem does not introduce other, more serious problems or uncertainties.
- The data needs for safety assessment (both operational and post-closure) are a major driver for focussing site characterisation programmes – a practical necessity, since manpower and financial resources are not infinite. Furthermore, the results from safety assessments can influence site characterisation and related R&D programmes. However, site characterisation usually goes beyond the needs of safety assessment alone, in order to support a high degree of qualitative site understanding, which is another important component of the safety case.
- Repository design can also have significant implications for site characterisation – for example, because specific data may be required to confirm the stability of geochemical conditions that are potentially affected by design choices, or to avoid potentially disruptive features that could otherwise affect the ability of the engineered barriers to fulfil their requisite safety functions.
- In the course of site investigation, care should be taken in extrapolating the results of short-term experiments to infer information about slow processes, since these may not be well-suited to providing information on processes operating over safety-relevant timescales. Long-term experiments are needed to elucidate some slow processes, such as mass transport in diffusion-dominated systems.
- Simplification and abstraction of processes governing the evolution and performance of a repository are usually a necessary part of safety assessment model development but must be clearly justified and agreed. Site characterisation can make an important contribution to an iterative process in which models are progressively refined throughout repository planning and implementation, as additional information becomes available.
- In terms of dealing with uncertainties affecting safety assessment models (related not only to site characterisation data and geosphere understanding, but also to other aspects of the repository programme), both probabilistic and deterministic approaches have a role. There are advantages and disadvantages to each, and the choice or balance between the two often reflects national regulatory guidance and preferences. The important thing is to develop an overall approach that demonstrates understanding of the repository system and the relative influences of various uncertainties on that behaviour.

- The results from detailed safety assessment models generally become more subject to uncertainties at longer times in the future. In terms of the geosphere, it may be advantageous to divide repository evolution into discrete time frames over which different processes can act, different types of uncertainty may be important and different probabilities may be applied to the occurrence of key events.
- Arguments other than those based on the calculation of dose or risk may be used to illustrate safety are being developed in several national programmes, including those based on the features of a site that intrinsically favour safety, such as long ground-water travel times, slow migration of naturally occurring radionuclides in the environment, and the geochemical stability of the host rock. Such arguments are applicable over various time frames, but may be particularly valuable for the far future, as the some of the assumptions on which the models used for dose and risk evaluations are based become increasingly questionable.
- One of the complexities of the geosphere, particularly in the case of fractured hard rocks, is its spatial heterogeneity, which is a challenge for safety assessments. In most situations, it would be computationally infeasible to represent the full extent of spatial heterogeneity; fortunately, this is not necessary. Spatial heterogeneity needs to be represented only to the extent that it is important in understanding the performance of the disposal system. The performance of some concepts can, however, be sensitive to spatial heterogeneity. In such cases improvements in the techniques for characterising heterogeneous features may be valuable to support the development of safety cases.
- Certain observations made at a repository site or at another location (a "site analogue") that closely resemble a site in its important properties can be used to understand the present situation and history of a site, and also to indicate that processes that will or may happen during the evolution of a repository. Such observations are an increasingly important element of safety cases.
- Nevertheless, the degree to which information from natural analogues (particularly "process analogues") has been integrated in safety cases remains limited. These analogues are viewed by some as still under-utilised with respect to their potential to communicate safety cases to wider (including non-technical) audiences. On the other hand, arguments based on natural analogues are not always simple and readily accessible to such audiences. Furthermore, as well as analogues that provide clear support for safety assessment hypotheses and the safety case, there may be other "negative analogues" that need to be explained in order that they do not undermine safety case arguments.
- Proper documentation, justification, and cross-referencing are needed to provide data traceability. Information needs to be organised in quality-assured databases. Strategies are particularly needed for maintaining records of data and for qualifying external data, as well as for anticipating and adapting to evolving information technologies. Regarding old records and data, it may, in certain situations, be less expensive to redo a measurement than to update the old information. It was also noted that data storage methods become outmoded (e.g. computer cards, floppy disks), and there is a need to invest resources to ensure that "old," but still relevant, data are stored in a form that can be accessed.

The questions to the working groups and the conclusions of AMIGO-3 overlap to a large extent with those of previous workshops in the AMIGO and earlier GEOTRAP series. In particular, all the workshops have indicated the need for multi-disciplinary integration in order to plan site investigations, synthesis geological information and use this information in safety cases. AMIGO-3, however, has provided practical and encouraging examples of progress in achieving integration in practice in several national programmes. These include the increasing use of integration groups to

identify and address gaps in knowledge and understanding and the development of project tools and methods to support integration, such as the phenomenological analysis of repository situations (PARS/APSS) developed by Andra and the safety function approach applied by SKB,

A recurring theme in the papers, presentations and discussions at AMIGO-3 was the use of safety functions, “safety statements” or similar concepts to organise geoscientific information according to its safety relevance and to prioritise R&D and site characterisation work to address potential weaknesses in safety cases. The “language” of safety functions can provide a valuable tool for communicating between safety assessors, geoscientists and also stakeholders. The Andra safety functions and associated indicators are, for example, developed collaboratively by designers, safety assessors and scientists and the ONDRAF/NIRAS safety statements were developed collaboratively by safety assessors and geoscientists. It was, however, cautioned that the primary aim of R&D and site characterisation work remains to understand the site and its evolution in the presence of a repository, and this work should not be unduly biased by concepts of what the function of the geosphere in a safety case should be.