INTRODUCTION

Disposal of high-level and/or long-lived radioactive waste in engineered facilities, or repositories, located underground in suitable geological formations, is being widely investigated world-wide as a long-term management solution. This is in order to protect humans and the environment, both now and in the future. From a quantitative point of view, a repository is said to be safe if it meets the relevant safety standards, such as internationally recommended or specified by the responsible national regulatory authorities. In recent years the scope of the safety assessment has broadened to include the collation of a broader range of evidence and arguments that complement and support the reliability of the results of quantitative analyses. The broader term "post-closure safety case", or simply "safety case",[1] is used to refer to these studies. It has also become evident that repository development will involve a number of step-by-step stages, punctuated by interdependent decision making on whether and how to move from one stage to the subsequent one. These decisions require a clear and traceable presentation of robust technical arguments that will help to give confidence in the feasibility and safety of a proposed concept. The depth of understanding and technical information available to support decisions will increase from step to step. The safety case is a key input to support a decision to move to the next stage in repository development. It reflects the state of understanding and the results of the research and development (R&D) undertaken at a certain stage, and supports decisions concerning future R&D efforts.

Potential geological host formations (and the geological environments in which they lie) for deep repositories are chosen in particular for their long-term stability, for their ability to accommodate the waste disposal facility, for their ability to prevent or attenuate potential releases of radioactivity and for their buffering capacity with respect to external and internal perturbations. Natural hazards are also considered in the choice of a site for a potential disposal facility. It is recognised that no natural system is in equilibrium and, thus, the concept of "geosphere stability" does not imply that steady-state conditions prevail over very long periods of time. The concept of geosphere stability does imply, however, that the changes that occur in the geological system do so to an extent and at such a rate that their effects are unlikely to compromise the short- or long-term safety of the disposal system.

Site characterisation and evaluation are important for determining the suitability of a site and the long-term safety of geological repositories of long-lived radioactive waste. Several previous NEA workshops have already taken place on the subject of "geosphere stability". The first of these was held in Helsinki in September 1991 on "Long-term observation of the geological environment" and dealt, in particular, with the needs and techniques for such long-term observations.[2] The workshop concluded that such long-term observation programmes are an integral part of site qualification and confirmation for deep repositories, with the view to building confidence in geological performance

1 "The safety case is an integration of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in the safety, of the geological disposal facility" [see NEA, (2004), *Post-closure Safety Case for Geological Repositories – Nature and Purpose*].

2 NEA (1993), *Long-term Observation of the Geological Environment – Needs and Techniques*. Proceedings of an NEA Workshop, Helsinki, Finland, 9-11 September 1991. OECD/NEA, Paris.

models. The second workshop was held in Paris in 1994,[3] and was entitled the "Characterisation of long-term geological changes for disposal sites". This workshop noted that scientific information concerning long-term geological evolution is needed for several purposes, such as the design of disposal systems, safety assessments, confidence building and siting programmes. The results of these workshops provided the basis and context for the present project on geosphere stability.

Since the early 1990s, through various initiatives, national safety assessments have been compared and safety cases have evolved towards providing an important basis for decision making related to geological disposal. That evolution was made possible by an increasing depth of understanding of both technical and non-technical issues, informed in part by extensive additional site characterisation data.

With regards to the long timescales involved in the concept of geological disposal, the relevance to disposal systems of various natural processes and events depends on the time frame to be considered. As highlighted in a previous NEA workshop,[4] the main concern is on the features, events and processes over a period of about one million years – the order of magnitude of the time needed for radioactivity to decay to levels comparable to uranium ores is about a few hundred thousand years. Repositories are typically sited in stable geological environments in which the key characteristics that provide safety are unlikely to change significantly in the course of time. However, over long enough timescales, even the most stable geological environments are subject to perturbing events and changes. Arguments for safety can be developed to build confidence in the overall safety case and an acknowledgement of the limits of predictability of the system will be important for credibility.

With respect to the stability of the geosphere, it is necessary to develop arguments for the reliance that can be placed on key safety functions. This applies, in particular, to the maintenance of the long-term containment capability of the geosphere and/or the maintenance of favourable mechanical or chemical conditions in and around the engineered barrier system. In building an overall safety case, it is therefore important to assess:

- the features, events and processes that could affect the evolution of the geosphere;
- the long-term stability of the favourable conditions displayed by the host formation; and
- the buffering capacity of the formation vis-à-vis perturbations.

The key issue is to evaluate the resilience of the main safety functions of the geosphere (often relying upon flow and transport properties) to natural perturbations. Thus phenomenological evidence of the persistence of those functions in past episodes of climatic changes, seismic activity, diagenetic evolution, burial/uplift, etc. should enhance confidence in geosphere stability.

To provide national waste management organisations and the scientific community at large with an overview on the subject of geosphere stability, the NEA Integration Group for the Safety Case (IGSC) proposed a series of workshop dealing with this issue for various host rock types (i.e. crystalline rocks, argillaceous media and evaporites). The first workshop of the series (and thus the third to consider the subject of geosphere stability, taking into account those in the 1990s) dealt with argillaceous formations. It was hosted by GRS (Gesellschaft für Anlagen und Reaktorsicherheit)

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3. NEA (1996), *Characterisation of Long-term Geological Changes for Disposal Sites*. Proceedings of an NEA Workshop, Paris, France, 19-21 September 1994. OECD/NEA, Paris.

4. NEA (2002), *The Handling of Timescales in Assessing Post-closure Safety of Deep Geological Repositories,* Workshop Proceedings, Paris, 16-18 April 2001.

in Braunschweig, Germany, on 9-11 December 2003; and was organised under the auspices of the IGSC Working Group on the Characterisation, the Understanding and the Performance of Argillaceous Rocks as Repository Host Formations (referred to as the "Clay Club").[5]

The present workshop dealing with crystalline rocks thus represents the extension of the project to address another potential host rock type. Like the earlier workshop on clays, this workshop sought the views of the Earth Science community on the scientific and operational bases for the assessment of geosphere stability. Due to the multidisciplinary aspect of the IGSC initiative, the workshop brought together scientists from a variety of organisations, mainly from national waste management organisations, but also from academic institutions, consultants and regulatory authorities.

5 *Stability and Buffering Capacity of the Geosphere for Long-term Isolation of Radioactive Waste: Application to Argillaceous Media, "Clay Club"* Workshop Proceedings (Braunschweig, Germany, 9-11 December 2003), OECD, Paris, 2005.

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