Geological research and nuclear waste management

Department of the Environment

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One day's electricity in every week is now generated in nuclear power stations, and this is increasing. The fuel used is uranium, a mildly radioactive metal in its natural state. One pound of uranium is equal in electricity output to over 10 tons of coal, but the waste products from burning it amount to about ¼ oz. However, being strongly radioactive they need special treatment.

Radioactive Waste

When uranium is used in a nuclear power station it produces new radioactive materials—fission products and actinides. The best-known actinide is plutonium.

After removal from a power station, the used fuel is taken by special transport to Windscale where the remaining uranium and practically all the plutonium are recovered and purified for further use in new fuel.

The residue has no value and is at present stored safely as a liquid in special tanks at Windscale designed to keep the liquid cool (the radioactivity of the fission products generates heat).

Turning the Liquid Waste into Glass

To make storage even safer than at present and to facilitate eventual disposal, the liquid will, from the late 1980s, be solidified into steel-clad blocks of special glass. The nuclear output of 5,000 megawatts from Britain's present nuclear reactors would lead to the production of 30–40 blocks a year of the size presently considered (about ten feet long and two feet in diameter).

With the passage of time, the radioactivity of the fission products in the glass will fall and after about 1,000 years the radioactivity of the glassified waste will be almost entirely due to the actinides. It will be similar to that of some radioactive minerals which occur naturally on the Earth's crust.

These glass blocks could if necessary be stored indefinitely on the surface becoming progressively less radioactive as time passed but it is prudent to consider how they could be safely disposed elsewhere.

Disposal Options under Consideration

The Royal Commission on Environmental Pollution considered nuclear power and the environment and in their Sixth Report, published in 1976, they concluded that there are two reasonable options for the permanent disposal of these wastes: to geological formations on land and below the ocean bed. They recommended a substantial and vigorous UK research effort on both options. These recommendations were accepted by the then Government in May 1977 (Cmnd 6820) and a third option, disposal on the ocean floor, was also identified as meriting detailed technical assessment. No commitment has been made to any of the three options at this stage.

Their comparative merits will be assessed when the research programmes have proceeded further (probably during the 1990s). The Government also accepted a number of other recommendations of the Royal Commission on Environmental Pollution, including giving the Secretary of State for the Environment and his colleagues in Scotland and Wales responsibility for policy on the management of civil radioactive wastes, thus making it independent of those responsible for promoting nuclear power.

Research

As part of its new responsibilities the Department of the Environment on behalf also of the Scottish and Welsh Offices, is sponsoring research into radioactive waste disposal. The Natural Environment Research Council have agreed to undertake much of the research recommended by the Royal Commission, and their Institute of Geological Sciences, an internationally respected independent national institute, is assessing the suitability of geological formations underground to accept the wastes safely. The UK, with other Common Market countries, has already started a coordinated study of the three most promising types of rock formation. Within this programme, Britain and France are studying granite and other crystalline hard rocks. Belgium and Italy are studying clay, and West Germany and Holland are studying salt. Since the UK has an interest in all such formations the future national programme will be investigating examples of them to find out whether any are geologically suitable for safe disposal. The twelve types provisionally selected and their distribution in fifteen areas are shown and described in the figure and its key (reproduced from *Nature,* 4 October 1979). Assessments of the characteristics and of the geology are already well under way, and work is programmed for each of the areas.
The geological assessments are expected to take about ten years. They would require drilling a number of exploratory boreholes a few hundred feet deep at selected places in each area. Planning permission is required before the drilling can start and is being sought as suitable sites are identified. Subsequently the holes would be used for investigating the properties of the rock to estimate water flow, consequences of climatic change and effects of heat and earthquakes. One or two temporary buildings may be erected at each site for the use of visiting scientists but no other obtrusive structures would be involved. Radioactive waste will not be used in any part of this research programme.

Possible forms of a Repository

When all the evidence from the various areas has been collated it will be considered along with the results from the complementary programme of research into disposal on or under the ocean bed. Decisions will then be taken on the best location or locations for

much more detailed studies aimed at providing experimental disposal repositories. Further planning permission and full discussion of all the implications would be needed before any more detailed exploratory work on land can be undertaken.
If a site is eventually selected for the development underground of an experimental repository its detailed form will depend on the outcome of the research programme. However, it is likely to be on the following lines:

The main part of the installation would be below ground. Beneath the ground, galleries would be made from which shafts would be sunk to depths of at least 1,000 feet below the surface. The glass blocks would be brought from Windscale to the site in containers tested to safety standards at least as stringent as those that have been used for many years to transport used fuel, which is much more radioactive. Safety regulations would be equally strict.
When the repository becomes fully operational, the steel-clad blocks would be placed in the shafts and sealed so that they would become, in effect, part of the rock structure itself. Alternative layers of blocks and filling material may be built up in the shafts to not less than 1,000 feet below the surface, and all the shafts would then be filled in.

When work at the repository is finished, all the excavations would be filled in and the surface capped and sealed. The land could then be restored to its original use.

Environmental Safeguards
Operations at a disposal site, which would be monitored and controlled by the regulatory authorities, would not be expected to give rise to any radioactive releases for thousands of years. Thereafter, any conceivable increase in direct radiation to the public would be an insignificant fraction of the background radiation that has always formed part of our natural environment.

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Map showing the distribution of rocks thought to meet the selection criteria and of those areas which have been selected for feasibility studies. Crystalline igneous and metamorphic rocks are stippled, argillaceous rocks are shown with horizontal lines and evaporites with vertical lines. The crystalline rocks include the postulated subsurface outcrops of the granites of northern and south-western England. No rock types meeting the criteria occur in the Shetland Islands.

Areas for further study

Crystalline rocks

1. Caledonian granites intruded into (1A) Lower Palaeozoic sediments or (1B) volcanic rocks. The Loch Doon Granite (Intrusion 1A) is a zoned body with an outer unit of biotite tonalite merging progressively into a central unit of biotite granite. It is intruded into Ordovician sediments of various types, predominantly greywackes, but with significant developments of black shales and cherts and has a sharp contact with an extensive thermal aureole. The Cheviot Granite (Intrusion 1B) varies in composition from a pyroxene granite to a pyroxene-free granophyre, is intruded into andesite lavas and has a faulted brecciated contact.

2. Caledonian granite forcefully intruded into Pre-Cambrian metamorphic rocks. The Ossian Granite is a coarse hornblende-biotite tonalite varying to granodiorite towards the outer part. A number of SW-NE trending fractures cross the granite which is intruded into metamorphosed sediments belonging mainly to the Pre-Cambrian Moine Supergroup. No thermal aureole is developed but the intrusion margin is generally intimately welded to the country rock by the development of contact migmatites.

3. Caledonian granite permissively intruded into Pre-Cambrian metamorphic rocks. The Etive Complex is a ring complex composed of 4 successive granite intrusions emplaced as a result of progressive cauldron subsidences. The innermost unit known as the Starav Granite is a quartz adamellite which has a simple, near-vertical contact and is free of dykes.

4. Granitic complex in the core of a regional migmatite zone. The Strath Halladale Granite occupies the core of an injection complex within metasediments of the Moine Supergroup. The injected material is dominantly biotite grantite of variable grain size which occurs as veins or concordant sheets within the psammitic host.

5. Caledonian basic intrusive. The Morven/Cabrach Intrusion is mainly composed of norites with associated gabbros and diorites. It is steepsided with steeper dips on the west than on the east, implying an increase in width at depth. Much of the intrusion is extensively altered with pyroxene replaced by amphibole.

6. Non-migmatised Pre-cambrian Moine Metasediments. The rocks of the Moine Supergroup consist of thick metamorphosed arenaceous and argillaceous sediments with some intermediate types. The area around Inveroykell is being considered within a region of massive to flaggy quartzo-feldspathic psammi of intermediate metamorphic grade and relative lack of structural complexity.

7. Pre-Cambrian Lewisian basement rocks. The Lewisian includes relics of several orogenic cycles covering a time span of at least 2,800 my to the latest reworking at 1,600 my. The major sub-division is into two time-based complexes, the older Scourian and the younger Laxfordian. The Laxfordian rocks are dominantly grey quartzo-feldspathic and biotite hornblende gneisses with intrusive sheets and veins of granite and pegmatite. The gneisses have undergone thorough re-working resulting in rock units that are relatively homogeneous compared with much of the rest of the Lewisian basement and appear the most suitable as a disposal medium. Such rocks occur in North West Scotland, between Loch Laxford and Cape Wrath and in the Outer Isles, but so far no specific research area has been identified.

Argillaceous and evaporite formations

8. A series of gently folded Ordovician and Silurian rocks in North Wales dominated by argillaceous types totalling some 4,000 m in thickness. The rocks are well exposed at the surface and dip consistently to the south-east at an angle of about 45°.

9. A sequence of turbiditic mudstones with interbedded siltstones and limestones of Lower Carboniferous age. The rocks occur within a fault bonded trough known as the Widmerpool Gulf and a minimum thickness of 1,000 m of argillaceous rocks is available. These rocks constitute a good example of the effective compromise desirable in argillaceous rocks — a thick formation that has been dewatered and developed a mature clay mineralogy by deep burial, without the attendant development of structural complexity.

10. A mudstone dominated sequence of Triassic rocks attaining thicknesses just in excess of 500 m in the central part of the Worcester Basin. These occur within the evaporite-free part of the major depositional basin with a cover of up to 500 m of mainly argillaceous rocks of Jurassic age.

11. A series of Silurian mudstones and greywackes in Southern Cumbria with an overall thickness of around 5,000 m. These rocks are folded on both a large and small scale and are cleaved to a lesser or greater extent depending on lithological variations.

12. Hybrid evaporite/mudstone sequences within Permo-Triassic sediments developed in the Cheshire (12A), Somerset (12B) and Wessex Basins (12C). These are all major depositional basins where the rocks of interest are in excess of 600 m in thickness and are generally overlain by other argillaceous formations. In all these areas examination of the cyclicity of the hybrid sequence from the point of view of waste containment is a particularly important aspect.