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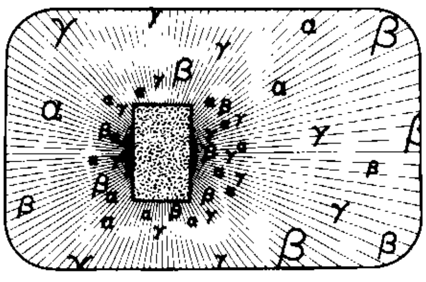

Science and Technology: Bridging the Frontiers

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AAAS Annual Meeting, January 3-8, 1981
Close to 4000 participants gathered in the spacious ballrooms of the Sheraton Centre and the Royal York Hotel (Toronto) to learn how science and technology managed to bridge their frontiers. Nearly every major aspect of the sciences was represented in the 170 symposia that were run in 20 concurrent sessions over six days.

Typically, a symposium would last one half day and would consist of 4 to 5 papers. The presentations were normally followed by a discussion period between a panel of speakers and the audience. The discussions were occasionally lively, especially when speakers holding opposite views had been invited. Most papers were well presented and of sufficient scope to be interesting to audiences that try to identify links between sciences and are concerned with the question of how sciences relate to socio-economic problems. Many of these problems are new, in addition to being complex, leaving room for many different opinions. Very often seemingly technically-viable solutions to accommodate environmental problems, for example, are far from being viable politically or socio-economically, leading to mutual distrust between technologists and the public. Nowhere is the distrust more evident than in dealing with the question of safe and permanent disposal of nuclear waste.

I am reporting on symposia that were concerned with long-term nuclear waste disposal, as well the symposium on problem of anthropogenic carbon dioxide accumulation in the atmosphere. Except for a short comment at the end, the views expressed here are those of the speakers.

Radioactive Waste: Technically and Politically Viable Solutions
Radioactive waste cannot be destroyed. Some of it is long lived, therefore dangerous to future generations. For example, the half life of plutonium-239 is 24,000 years and technicium-99 is 210,000 years. These are often considered the two most toxic and dangerous radionuclides. The most pressing technical problem is therefore how to retain the waste within the storage facility. Interim storage for the next 50 years seems to be in hand. For example, the irradiated fuel rods of the CANDU reactors are stored in water at the reactor sites. A long-term repository for these is projected to be in engineered vaults in crystalline rocks. Liquid high-level nuclear waste from other reactor types or from military waste is stored in tanks. Methods are being investigated to convert this waste to low-solubility solids. The most intensely studied method of solidification is within borosilicate glass. Crystalline mineral-like ceramics and cement-based forms are also being investigated. These solids, harbouring the high-level nuclear waste, are the initial barriers in a multibarrier system of permanent disposal.

In all disposal schemes, the multiple barrier concept is anticipated to be suitable for the design of the nuclear waste disposal in geologic formations. The initial barrier such as waste solidification and encapsulation is man made and is considered to have a finite limit of confidence of about 1000 years. The physics and chemistry of the nuclides is reasonably well understood in the man-made materials and the investigators are optimistic that a technical solution is available for the disposal of the high-level nuclear waste for this period of time.

By far less confident are those who investigate the natural media through which nuclides may migrate. The required accuracy of data bases and requirement for completeness of the predictive models are stringent. In almost every case more detailed investigations point out the hopelessly insufficient data base. Hydrogeology of deep rock formations is a good example, where at present there is a considerable uncertainty regarding the flow patterns and geochemistry of ground water. The deep sea clays, which have conceptually favorable nuclide retention properties, are considerably more complex in terms of *in situ* geochemistry and depositional history than expected. It seems that some degree of uncertainty must be accepted in order to be able to proceed in defining the multibarrier system.

Speakers with both technical and nontechnical backgrounds agreed that regardless of how technically feasible the disposal of nuclear waste might be, it should not take place without local acceptance. To gain acceptance, equity of risk in radioactive waste management must be demonstrated. The "not in my back yard" position held by many could be confronted with positions based on principles of fairness, recognizing that, for example, burden should be borne by beneficiaries, or, imposition of harm should be shared. It is obvious that more visible institutions are needed that will ensure fairness in sharing risks arising from the nuclear waste disposal sites. Remoteness of disposal sites is an asset and this is one of the reasons why the disposal of nuclear waste in the seabed in gaining serious attention as an alternative.

During the discussion period of this symposium, the gist of questions dealt with the low credibility of scientists who appraise the technical feasibility of waste

disposal. Scientists are creating the impression of being on the side of the establishment that is trying to impose on the public the inconvenience of having dangerous waste nearby.

This is a problem of linguistics, according to the panel. Scientists cannot proclaim absolute safety and remain honest. Every single problem cannot be solved; there are probabilities of mishaps and miscalculations. The probability concept is often misunderstood; the public must be educated through participation in meetings where the technical aspects of waste disposal are being explained. So far these meetings have not been successful, mainly because of the seemingly one-sided representation (the establishment's). The Swedish adverserial scientific discussion on environmental problems apparently has been successful in gaining public acceptance. Here scientists, known to hold opposite views, are presenting their cases in a paper, which is then widely distributed. According to S.N. Lundine (U.S. House of Representatives), in Sweden more serious attention is paid to public education than in the U.S.A., where the press often prefer excitement rather than education.

The Problem of Nuclear Proliferation

Nuclear proliferation is a fact. A horizontal proliferation, in which the number of countries in the world where potentially a nuclear bomb could be exploded, is steadily increasing. For example, Spain could become a nuclear power. Israel and South Africa could explode a bomb now. In a vertical proliferation, the nuclear arsenal is increased by a nuclear power. The two major nuclear powers maintain that they need to improve their present system because of security. It is argued that unless vertical proliferation is stopped, horizontal proliferation will not stop. Non-proliferation treaties have a limited effect; for example, potential proliferators such as Argentina and Pakistan are not members of the Partial Test Ban Treaty.

How is proliferation possible? All sources of nuclear power are inherently aiding the development of the bomb. Burnt out fuel and high-level nuclear waste from the reprocessing of nuclear fuel contain fissionable materials, such as plutonium, that can be used to make an atomic bomb. The extraction of these materials from the waste is becoming progressively simpler. These preparations are indistinguishable from building a nuclear arsenal, and it was argued that nuclear power provides a cover-up for the manufacture of weapons.

"Materials to make a bomb would not be available commercially in a non-nuclear world" argued Armory Lovins from Friends of the Earth, San Francisco. Apparently, we do not keep a very good track of our fissionable fuel; and with a large number of reactors available, bombs could be made quickly, if needed. These could be delivered with a railway car or a fishing boat and if not exploded, then at least available for nuclear blackmail.

However, a non-nuclear world is not possible, we have gone too far, there is too much fissionable material already on hand. The danger of proliferation is real and must be faced.

There is no technical answer for curbing proliferation. Nuclear proliferation is based on political motivations; for example, Pakistan's concern for national security makes them potential proliferators. India is afraid of China, who is afraid of Russia. Both seem to be more secure with a bomb.

A runaway nuclear proliferation could be controlled with strict commercial practices, where Canada could play an important role. Canada sells many billions of dollars worth of uranium that is needed by many countries. By setting a good example and exercising influence in the nuclear marketplace, Canada could minimize the risks arising from nuclear commerce.

Planning for Uncertainty: Climate Change and the Study of Impacts

This symposium dealt with the possible impacts of the steady increase of CO_2 in the atmosphere as a result of burning fossil fuels. The global anthropogenic change in the atmosphere has a parallel to the possible effect of nuclear waste in harboring the seeds of a major environmental disaster.

More CO_2in the atmosphere traps more heat from the sun, causing a rise in temperature. This was predicted by Arrhenius as early as 1904. The net effect of the atmospheric warming is difficult to predict because of the complex feedback systems. At the present, we are undergoing a cooling trend, despite the atmospheric increase in CO_2. This may be a climatic change or one of the frequent fluctuations that does not lead to a consistent trend. It does not have an accepted explanation; however, if it were not for the increased CO_2, the average temperature of the world would have been lower by 0.3° C.

We know that we are adding excess CO_2 to the atmosphere and that it is unlikely we will stop this process for at least the next few decades, therefore, we must be prepared for the consequences. Because we are not certain of the effects, we must consider several possibilities.

One of the possibilities is to reduce anthropogenic CO_2 release. We could burn less fossil fuel, increase biomass by planting forests, develop plants that grow under adverse conditions, e.g. in saline water (holophytes). The biosphere is the most effective CO_2 sink, although only when new growth is occurring, therefore a temporary help.

Atmospheric warming may produce indirect effects, such as a change in precipitation. There seems to be agreement that due to atmospheric warming and decreased temperature gradients, the general circulation of air masses will be weakened and that dry areas will become drier. The largest changes will be felt in the polar regions. Decreased amounts of snow will decrease spring runoffs, which is important for moisture in Canada's prairie soils, where there is very little room for delay in cultivation, because of the short growing season. With a slight increase in temperature, the U.S. corn belt would move to the north towards Canada where the extent of arable land is smaller, therefore, total output will be decreased

The climatic change caused by the increase in the atmospheric CO_2 will impose stress on populations. There are many factors that determine the response towards a disaster. The spirit of pioneers helps. At the beginning of this century, Canada and the U.S. were "can do" societies that were able to cope with many calamities. Now we tend to fall "flat on our faces" (Lester B. Lave) when facing a disaster. The poor and uneducated societies will feel the stress more. Societies with large research and development programs in combination with large and fluid capital stock can adapt more easily to changes.

CO_2-Induced Climate Change and the Dynamics of Antaratic Ice

This symposium was concerned with the possible effects that a warmer ocean could have on the Antarctic ice sheet due to increased atmospheric CO_2. Different views on its present-day stability were discussed.

Antarctic ice reaches the coast through drainage basins, and the flow of the ice towards the sea is controlled by grounded ice shelves. Most of the West Antarctic ice sheet is grounded below the sea level and is considered to be unstable. At present, it is buttressed by the relatively stable East Antarctic ice sheet and the less stable Ronne and Ross ice shelves. Therefore, the dynamics of the Ross ice shelf are critical to the behavior of the West Antarctic ice sheet.

During the last glacial maximum, the Ross ice shelf was grounded up to the continental margin. Since 20,000 y BP to approximately 7000 y BP, the grounding line of the ice shelf has been retreating to its present position. A continuous retreat of the grounding line could cause a collapse of the West Antarctic ice sheet, and the volume of water added to the oceans would cause a six to eight metre rise in the global sea level.

Will increased atmospheric CO_2 advance this process? This question is difficult to answer because of the many uncertainties. There seems to be a consensus that increased CO_2 will have very little direct effect on the Antarctic ice sheet. The dynamics are more influenced by the position of the grounding lines of the ice shelves, which in turn are sensitive to the temperature of water and sea level along the continental margin.

Predicitions for the behaviour of the ice in Antarctica depends on computer modeling, which can give ambiguous results, if the baseline data is insufficient or poorly understood. The sparcity of basic data and the disagreement in the interpretation of this data was illustrated by arguments during the discussion period. For example, a question was raised pertaining to the stability of the Ross ice shelf due to tide cracks between the fast ice and the floating ice, which moves up and down with the changing tides. Because of this decoupling, there is a possibility that the buttressing effect of the fast ice is not great. An opposing view maintained that a heeling process takes place where cracks are being filled with freezing water from the sea below.

Comment

Usually scientists communicate new concepts and ideas to other scientists. The problem is that the lay public receives the news of scientific advances second hand and often outdated. In many cases, the public does not immediately grasp the significance of these new advances.

In the AAAS meetings, science news is tailored for the public and delivered by specialists. The significance is achieved by bringing together isolated advances to contribute to a problem or concern of a large scope. As a geologist with a concern for the environment, I find the discussions on nuclear waste and anthropogenic CO_2 accumulation in the atmosphere timely, although answers or solutions to these long-term, man-made problems seem to be still out of sight. These are new frontiers of science that demand new kinds of answers for new kinds of questions.

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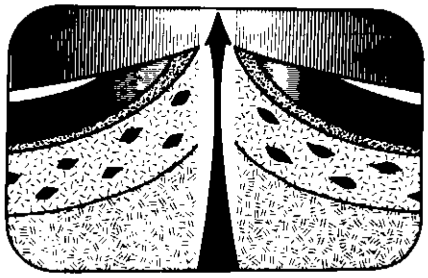

The Generation of the Oceanic Lithosphere

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AGU Chapman Conference, Airlie House, Virginia, April 6-10, 1981

With the abundance of geochemical data for deep sea basalts, the discovery of hydrothermal activity on the sea-floor and the arrival on the scene of high resolution geophysical and sonar techniques, this conference marked a milestone in the understanding of the oceanic lithosphere, and provided a platform for the formulation and diffusion of research objectives for the 1980s. Of particular interest was the possibility of geochemists and petrologists reaching a consensus with the geophysicists on models of magma generation and eruption, and hydrothermal activity at a ridge axis. This possibility was enhanced both by the idyllic setting of the Airlie House Conference Center in the Virginia countryside and by the format of the conference which allowed an equal number of oral and poster presentations; the latter were particularly effective in aiding the exchange of ideas since these sessions did not overlap with the oral presentations as is often the case in larger meetings. A total of 150 participants from nine countries presented 100 papers during the five day conference.

The introductory sessions dealt with the general nature of the crust and upper mantle at ridge axes. Talwani and Orcutt presented seismic models that demonstrated a narrow axial zone with the lithosphere rapidly attaining its maximum thickness. Their presentations were complemented by Lewis who presented gravity data from the Rose area which lead to the intriguing conclusion that a region of positive density contrast exists below the ridge axis; this provided some stimulus for the MgO-rich parental basalt proponents, who envisaged a column of dunite underlying the ridge axis! It is clear that we still have much to learn from gravity structure. A new perspective to the understanding of the upper mantle was given by the magnetotelluric data of Filloux. These data demonstrated a zone of conductive anistropy for the NE Pacific at 100 to 150 km which may represent a zone of partial melting; this technique, as yet in the development stage, has great potential for oceanic crust and upper mantle studies. These techniques represent one of the few tools for deep sounding and perhaps for answering the vital question as to the ultimate depth of ridge sources.

The petrological data for the oceanic crust led to a series of arguments concerning the presence of normal crust. Thompson introduced a series of papers on the Kane Fracture zone which has been classified as normal oceanic crust due to the lack of high iron or alkaline basalts. Dick argued from the phase mineralogy of oceanic peridotites that the oceanic mantle and deep oceanic crust are remarkably heterogeneous but distinct from most ophiolite assemblages; the latter, he argued, reflect island-arc or back-arc material. This led to a series of interventions related to the probability that the sample of the deep oceanic crust is biased since more than 90% of the samples are from fracture zones.

The isotopic and geochemical presentations broached the problem of oceanic mantle heterogeneity. The isotopic arguments of Zindler and Anderson stressed the problem of Pb-isotopic heterogeneity; both presentations invoked a crustal component to explain the anomalous values, leading to the speculation that "wet spots" rather than "hot spots" control oceanic island volcanism. Machado presented Nd-isotopic data indicating small-scale, long-lived heterogeneity in the oceanic mantle, and questioned the contention that the oceanic mantle is well mixed. Although the papers were well presented and provocative, the discussions were tempered due to the absence of certain European and West Coast U.S.A. geochemists. However, all the models invoking mantle heterogeneity were questioned by O'Hara, who, in his own style, explained geochemical variations by mixing and contamination by assimilation in high level magma chambers. Using major elements, Langmuir showed the mantle to be undepleted and homogeneous. However, the large variations that exist in the FeO content for oceanic basalts of similar MgO content were ascribed to variable geoth-