OKLO/OBSIDIAN/ANCIENT GLASSES: APPLICATIONS TO NUCLEAR WASTE PUBLIC INFORMATION PROGRAMS

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ABSTRACT

Natural analogs such as the Oklo natural nuclear reactor and archaeological data from ancient, man-made glasses can be helpful in making a more interesting presentation on nuclear waste disposal. The extent to which natural analogs and archaeological data can also be used as benchmarks for our current understanding of processes over long periods of time is sometimes overlooked. The potential pitfalls of using natural analogs and archaeological evidence in a presentation in nuclear waste disposal, as well as the benefits, must be carefully considered.

Numerous surveys have shown that nuclear waste disposal remains a major issue in the public debate on the future of nuclear power[1]. It is not surprising that waste disposal often arises as an issue in the public information programs presented by the Westinghouse Water Reactor Divisions. We have found that natural analogs such as the Oklo natural nuclear reactor and archaeological data from ancient, man-made glasses can be helpful in two major ways. In the first place, they can make a presentation more interesting and provide a counterpoint to the often presented conceptual designs and theoretical safety studies. In the second place, Oklo/Obsidian/Ancient Glasses can provide a time perspective. The 600 years for the significant fission products to decay to very low levels or the 1000 years referenced in the EPA and NRC proposed regulations are time spans that might as well be millions of years as far as the general public is concerned. This is especially true in the United States where the educational system seems not to provide much historical perspective - even for those citizens normally considered "educated".

My purpose is not only to show how natural analogs and ancient glass artifacts can be used, but also to show how care must be taken that they are not misused. The misuse of natural analogs and archaeological data through a lack of understanding of their place in the larger waste management picture can, I believe, be damaging to credibility in the long run. The following are separate discussions of the Oklo phenomenon, obsidian, and ancient glasses.

THE OKLO PHENOMENON

The Oklo natural nuclear reactor was discovered by French scientists in 1972 [2]. Two billion years ago normal uranium was composed of 3% uranium-235, versus 0.7% today.

In what in modern times is Gabon, West Africa, water entered a rich uranium deposit about 1.8 billion years ago and 13 reactor zones, typically about one meter wide by three meters long, went critical and sustained a chain reaction on-and-off for about 300,000 years [3]. It has been estimated that 12 MT of uranium-235 fissioned and the plutonium and fission products produced equalled the inventory of those elements in 1-2% of the spent fuel inventory of the entire United States in 1980. Data from mineral studies indicate that during operation the temperatures were in the range of 450 degrees °C to 600 degrees, the pressure at an estimated depth of 3-5 km [4] was about one kilobar, (approximately 10 atmospheres) and the thermal loading has been calculated to be about 50 W/meters-squared, which is two to five times the loadings proposed for nuclear waste repositories [4].

It is a significant, but not the only, lesson to be learned from the Oklo phenomenon that a number of the elements produced by the Oklo reactors, such as the plutonium, have remainded relatively immobile for about two billion years [5]. Also, recent research suggests that even some of the more mobile elements, such as technicium-99, appear to have been retained by the surrounding geologic media a few tens of meters from the reactor zones [6]. The retention of these nuclides is all the more significant given in the fact that there is evidence for flowing water during the history of the Oklo formation.

Critics of nuclear energy will sometimes charge that Oklo is not exactly like the sites being studied for nuclear waste repositories, that Oklo didn't have mine shafts to be sealed, or that Oklo is a fluke because we haven't found lots of other such events. These questions miss the point that the main importance of the Oklo studies is the validation of much of our understanding of the geochemical processes involved. The work of Brookins [7, 8,] shows remarkable agreement between what we would have expected to have happened at Oklo and what seems to have really occurred two billion years ago. Of course, our understanding will never be perfect. For example, there is now some question as to the mechanism for the retention of the technicium-99 [9]. However, the safety studies

* The views expressed in this paper are those of the author and not necessarily those of Westinghouse Electric Corporation.

done over the last decade [10] indicate that we do not have a need for this unattainable perfect understanding.

OBSIDIAN

Obsidian is a naturally occurring volcanic glass which has been used to make simple tools for thousands of years. There have been extensive studies about the rate at which obsidian is altered by water to form hydration layers with the goal of using the information for archaeological dating [11]. Friedman and Trembour believe that the archaeological evidence shows that the hydration thickness is proportional to the square root of time; that each successive unit of hydration thickness takes longer to form. The formula in this case is that X (the hydration layer thickness squared) equals a constant (k) times time (t). Using this approach, typical constants are in the range of 1 to 20 microns squared per 1000 years [12]. They have found this relationship to hold with samples as old as 200,000 years B.P. (before present). Ericson, however, believes that there is evidence that the hydration rate is directly proportional to time (X=kt); that is, each unit of hydration thickness forms as quickly as the last [13].

From a waste management point of view, it is important to keep in mind that most of this data is from samples obtained in the upper few meters of soil and not 1/2 mile below the surface in a deep geological environment. Even so, the fact is that hydration layers of 10 to 20 microns are typical for samples 10-15,000 years old and 25 microns are only a thousandth of an inch. However, there are other problems in using obsidian as an example, aside from the scientific disagreement on rates of hydration.

As Ewing pointed out in his 1978 paper, obsidian cannot be directly related to the borosilicate nuclear waste glasses now proposed by DOE, because the chemical composition of the obsidian is different with a much higher percentage of silica [14]. However, obsidian can be used as a benchmark to check the accelerated tests which are used to rank different waste forms. For example, some of the tests used distilled water, which is fairly rare in nature.

Even with the disagreement on specific mechanisms, the data on obsidian demonstrate the importance of temperature as a parameter and the availability of water to form the layer. Work by P. B. Adams, Corning Glass [15], W. Ross, Battelle Pacific Laboratories [16], and S. N. Darkhanis, University of Western Ontario [17], would seem to indicate that at temperatures below 100 degrees centigrade the borosilicate glass proposed by DOE for nuclear waste disposal is about a factor of 5-10 less resistant to corrosion than obsidian. In summary, obsidian can provide a useful benchmark in waste disposal programs but the disagreements about reaction rates means that conclusions drawn from a study of obsidian data must be limited and used with great care.

ANCIENT GLASS

In about 2500 B.C., we find the earliest evidence of man-made glass objects [18]. There are a number of glass objects which have been preserved for thousands of years. I like to include such objects in a waste management presentation not only to give historical perspective but also because they are beautiful to look at. Samples of ancient glass, which is usually similar in composition to modern soda-lime glass, have been found preserved in environments as varied as the dry deserts of Egypt to 1000-year-old glass from the bottom of the Aegean Sea near Turkey [19]. I was recently asked after a presentation at the Hutchins Institute in Santa Barbara, California if I was implying that all glass artifacts have survived for thousands of years. My answer was emphatically negative. Depending on factors such as glass composition, weather cycles, and pH of the environment, some glass objects would not survive or, if they did, be badly corroded. My first point is that these glass objects were designed primarily to be decorative and the fact that any significant number have survived to fill a number of museums is some indication of the durability of glass. My second, and perhaps more important, point is that we can learn about the behavior of glass over long periods of time by studying these glass artifacts. For example, the effect of too much potassium can be seen in the deterioration of Medieval stained glass windows which were made from a glass containing too much (about 20%) potassium [20].

While the composition of the borosilicate glass produced for use as a nuclear waste solid form is somewhat different from the composition of ancient glasses and generally more durable than even good soda-lime glass, a few principles about the durability of glass in nature can be developed from the available data on ancient glasses [21, 22].

- Glass seems to hold up better in a stable environment, either wet or dry, than in a cyclic environment (e.g., freeze-thaw).
- Based on the above, it is likely that the long-term, stable environment one-half mile beneath the surface of the earth should be conducive to preservation of the glass matrix.
- High concentration (greater than 10%) of the alkalines (such as potassium) are generally detrimental to the durability of glass.

The situation regarding canister materials is less promising from an archaeological perspective. For one thing, the corrosion of metal artifacts is even more variable than that for glass and so, therefore, limits drawing conclusions from the available data. There is also a limit on the materials to be studied. Iron tools have survived since Roman times and iron is being considered as a canister material [23]. The data on other candidate materials is quite limited. I do not think you can expect to find archaeological data on stainless steel or titanium alloys--unless you are a believer in the theories about Earth being visited by ancient astronauts.

SUMMARY AND CONCLUSIONS

Natural analogs and archaeological data are not a substitute for the rest of the waste management research program such as laboratory studies, in-situ testing, and geologic field studies. However, natural analogs and archaeological data can be used to improve our understanding of the one variable which cannot really be controlled in the laboratory--time.

The Oklo phenomenon, obsidian, and ancient glasses can be used to present effective public imformation programs regarding nuclear waste disposal when coupled to information on the large-scale research, such as the tests in basalt in Washington and in granite in Nevada. These concrete examples thus complement the presentation of the numerous safety study results for nuclear waste disposal which show that nuclear wastes can be disposed of safely without posing a significant threat to these or future generations [10].

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