INEL-96/00185

CONF-960912--43

UNCERTAINTIES IN REPOSITORY MODELING

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ABSTRACT

The distant future is very difficult to predict. Unfortunately, our regulators are being encouraged to extend the regulatory period from the standard 10,000 years to 1 million years. Such overconfidence is not justified due to uncertainties in dating, calibration, and modeling.

I. INTRODUCTION

In repository studies, scientists have been wrestling with the difficult issues of predicting events and conditions 10,000 years into the future. Now, the recommendation has been made to extend this prediction out to one million years. Three major problems with analyses one million years in the future are uncertainties in geological dating, dating calibration, and modeling uncertainties.

Source	Date (years)
American Indian Legend	few thousand
Stratigraphic controls	low thousands to a few million
K-Ar	10,000
K-Ar	1.2 ± 0.2 million
K-Ar	117 ± 3 million
Rb-Sr Isochron	1.34 ± 0.04 billion
Pb-Pb Isochron	2.6 ± 0.21 billion

Table 1: Dates for Volcano on Grand Canyon Rim

II. GEOLOGICAL DATING UNCERTAINTIES

Frequently, geologic events are assigned dates for which uncertainties are presumed to be very small in spite of great variability between methods. For example, Table 1 is an illustration of the variability of geological dating for the basaltic rocks of the Uinkaret Plateau on the lip of the Grand Canyon.

The variation between methods used in Table 1 is quite large, but the uncertainty assigned to each method (e.g., instrument uncertainty) is quite small. For instance, the K-Ar uncertainty is 3% to 17%. But these small uncertainties are misleading for another reason: One experimenter in a radiometric dating lab privately stated that 50% of the K/Ar results are discarded (and never reported) in order to preserve the apparent accuracy of the method. (When this experimenter was encouraged to document his experience, he refused for fear of being blackballed from the industry). This was qualitatively confirmed by McDougall: "The criterion for exclusion of a datum was that the calculated age differed by more than twice its error (2σ) from that of the plateau."[1] And, what else should be expected but small uncertainties when the uncertainties are calculated after the outliers are discarded, based upon the expected uncertainties?

A geologist can look at these dates and pick the "right" method because he "knows the approximate date." And that approximate date is based upon similar selection processes elsewhere, ad infinitum. For the most part, their conclusions tend to cluster, and they have standardized reasonings for throwing out any dates that don't conform to their expectations.[2] But, subjectivity and circular reasoning are involved in this approach, and disagreements do arise. This may work well amongst peers, but such circular

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reasoning and subjectivity will be very easy to attack in the licensing process.

III. DATING CALIBRATION

In any scientific field, an instrument is not accepted unless it is periodically calibrated against a known. Radiocarbon dating is fairly well accepted because it can be calibrated against known historical dates. Yet, great disparity exists between this "calibrated" dating technique and other dating techniques (see Table 2).

Potassium Argon (KAr) dating was tested on 22 volcanic rocks from various parts of the world, known to have crystallized in the last 200 years, yielding crystallization ages ranging from 100 million to 10 billion years.[3] The explanation for this discrepancy is occluded argon that did not get released from the molten lava (so the "clock" was not reset). Yet, in spite of this calibration failure for KAr dating, great confidence is placed in it even when we have nothing to calibrate it against.

The obvious rejoinder is, KAr dating is not valid in the ranges of historical time (4,000 B.C. to present) or radiocarbon dating (50,000 B.C. to present). Then, the following questions must be addressed:

1) Since KAr dating can err a billion years either way, how do we know which is correct? For example, one reference[4] noted that ages varied considerably throughout the entire pillow of lava, and recommended that the age in the center was most accurate because it had more time to outgas the argon. How do we know it had enough cooling time to completely reset the clock?

2) If radiocarbon dating cannot apply to such ancient dates (Table 2), why does it give a readable date, rather than "below detectable limits"?

3) Granted that it is impossible to calibrate KAr against knowns, why does it behave so poorly when calibrated against other dating methods that are also uncalibrated (Table 1)?

IV. MODELING UNCERTAINTIES

The primary driver in determining the peak dose to the biosphere from a repository is the timing and severity of the next ice age. This is based upon the number and intervals of past ice ages. This is very controversial.

Over 60 theories have been proposed to explain the Ice Age, all with serious difficulties.[5] The most popular ice age theory maintains the earth has gone through 15-30 ice ages, driven by Milankovitch cycles (major peaks in the high-latitude summer insolation). However, such cycles have more "misses" than "hits," with the "hits" showing stimulus to warming 4,000 to 7,000 years after other records show results of warming in sea level variations.[6] This leads to the conclusion "Pleistocene climate phenomena are aperiodic and therefore that their timing is probably unpredictable."[7]

Object Dated	C-14 Date (years)	Date (Dating Technique)
Australopithicus - Ethiopia	15,500	1 to 2 million (KAr)
Zinjanthropus - Kenya	10,000	2 million (KAr)
Saber-toothed Tiger	28,000	100,000 to 1 million (geologic chart)
Natural Gas	34,000	50 million (geologic chart)
Coal	1,680	100 million (geologic chart)
Note: These C-14 dates are based upon several issues of Radiocarbon Journal		

Table 2: Dating Techniques Fail to Calibrate to Radiocarbon Standard

Not surprisingly, estimates of the number of ice ages the earth has experienced vary with the choice of theory. The Alpine Model, based upon research done in the Swiss Alps, claiming four ice ages, was the predominant model for over 60 years, during which time all data throughout the world supported it. Then the Milankovitch model, originally displaced by the Alpine Theory, came back in, and again, all data throughout the world supported it! This tendency of data to adapt to the latest theory is called the Reinforcement Syndrome, and is frequently observed.[8, 9]

Most of the evidence on dry land points to a single ice age.[10, 11] Multi-Ice-Age proponents forgive the data by claiming that the last ice age acted as an eraser to remove previous evidence. So, they resorted to oxygen isotope evidence on the sea floor to validate the Milankovitch Model. Problems with this are the requirements that the sediment be undisturbed by erosion or sea-bottom life, and to know the surface temperature within a few degrees, and the residence time for sea-bottom waters.[12, 13]

Further complicating the issue is the evidence for a single ice age. A spot of land in southwest Wisconsin, and another in northeast Montana, have never been glaciated, though surrounded by ice sheet in the ice age of 10,000 years ago.[14, 15] How did all the other ice ages miss these spots as well? The probability of this oddity occurring once is far greater than it repeatedly occurring 15 to 30 times. The giant woolly mammoths and 33 other large mammals became extinct in the ice age of 10,000 years ago (two to five times the number of extinctions in all previous "ice ages").[16] How did they survive all the other ice ages? No consensus has been reached on this question.

V. OVERCONFIDENCE

Overconfidence can destroy the credibility of any scientific tool. This was demonstrated in the PRA industry when a 10^{-6}/year cutoff was selected as a design goal for nuclear reactors. For years PRA analysts tried to stretch their art to meet this incredible goal, and the Advisory Committee on Reactor Safeguards exposed their weaknesses. Eventually, approved reactor PRAs admitted to accident frequencies as high as 10^{-3}/year.[17]

When the National Academy of Sciences (NAS) recommended extension of the previous 10,000-year repository mission time to one million years, part of their justification for going so far into the future was "reasonable geologic stability."[18]

Other experts do not share the NAS's confidence:

> "For high level waste, the shortest timescales specified are 10,000 years, and modeling performance over such timescales causes skepticism among both lay and technical people."[19]

> "...geological conditions are not easily determined, and even if they were known, we could not predict future geological events with any certainty."[20]

The geologists are confident that the earth will have "reasonable geologic stability" for the next 1 million years, but they can't speak for uncertainties in other scientific fields for that length of time. In addition, they are running the risk that any expert is subject to:

> "It is difficult for experts to put uncertainties in their specific fields in perspective."[21]

> "It is therefore most important to be wary of our over-confidence, for this over-confidence is at its greatest in our own area of expertise -- in short, just where it can do the most damage."[22]

VI. OBVIOUS UNCERTAINTIES

The NAS[18] cited uncertainty in human intrusion scenarios and future population distributions and lifestyles as sufficient reason to exclude such input from the regulatory arena. I would like to add one more uncertainty:

According to the Encyclopedia Britannica, the boundary between historic/prehistoric times occurred between 5,000 and 6,000 years ago. Since then, man has progressed from a creature that was dominated by his environment into a being that can destroy his environment. Given a similar change in man's technology and effect on the environment for the next 5,000 years, how can we predict groundwater flow paths, human/environment interactions and individual doses? Extrapolating further, multiply these projected changes by two for a 10,000-year repository horizon, or by 200 for a million-year horizon. For example, people of the future may be living in multi-story underground apartment complexes in the vicinity of the repository. What doses will these apartment dwellers experience?

Recommendations:

I would like to make the following recommendations:

1. Great uncertainty exists between various models (e.g., for ice ages), and radiometric dating methods. For the most part, these uncertainties have had little discussion in the open literature. Part of the reason for this is because these uncertainties never before had any impact on public policy. Now they do.

2. Geologists seem to be comfortable with the uncertainties one million years hence. But, they have completely different backgrounds, training and terminology from the PRA (Probabilistic Risk Assessment) analysts. I would encourage the regulators to give time for the PRA analysts to enter the dialogue assessing the uncertainties: Having been burned once, the PRA analysts are one mistake wiser (in the area of being over-confident about the uncertainties of a predictive technique) and, as a result, perhaps a little more humble.

3. Performance assessment has two functions -- "licensing... characterized by a robust bounding analysis of the system," and "research and development guidance." The two purposes should not be mixed up. Trying to regulate in the uncertain areas that need further R&D work will only discredit the analysis, or drive it underground.

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Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management (EM)
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223