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TO: Advisory Committee on Nuclear Waste
Nuclear Regulatory Commission

FROM: K.B. Krauskopf
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SUBJECT: Review of DOE Study Plan on Water Movement Tests

DOE proposes to estimate rates of water movement in the vadose zone at Yucca Mountain from measurements of the radioactive chlorine isotope, $^{36}Cl$, in samples of tuff taken at many levels in a projected shaft 450 m deep. This is a promising method of determining ages of very old water, but it has not yet been widely used and so far as I know has never been applied to a situation like that at Yucca Mountain. In places where it has been tried, reported results have often been less than clearcut. I think it is worth trying at Yucca Mountain, but only with two provisos: (1) that it not be relied on as the only way to estimate rates of water movement, but used in combination with other methods, and (2) that the possibility of ambiguous results be clearly recognized.

Reasons for possible ambiguity in the results can be suggested by considering possible scenarios:

(1) The samples could show a regular increase of age downward, say to 450,000 years at the base of the shaft. This would be convincing evidence that water has been percolating downward at a uniform rate of 1 mm/yr, and would go far toward proving that the site is well qualified for repository construction.

(2) Samples near the bottom could show a higher ratio of $^{36}Cl/Cl$ than those at the top. This would mean that water carrying fallout from the Pacific bomb tests has moved 450 m downward in 30-odd years, and would probably be regarded as disqualifying the site. It could still be argued that rapid movement was proved at only a single location, but this would hardly be convincing to skeptics.

(3) The ratio $^{36}Cl/Cl$ could remain constant within the limits of measurement all the way down. Because a decrease would be detectable only if the water was more than 30,000 years old, this result could mean either that water was moving very rapidly downward, or that the bottom water had required 30,000 years for the descent, or anywhere in between. The site would be neither qualified nor disqualified.

(4) Most probably the measured ages will increase downward but irregularly, even possibly with reversals. This could be interpreted in many ways: water could have moved downward in temporally widely spaced pulses, the path of water movement could have changed over time, the amount of pristine chlorine contributed to the samples from the various tuff layers could be different, and so on. Slow movement in general would be indicated, but proof of the site's qualification would be open to argument.

Thus it seems to me that scenario (1) would help greatly in qualifying the site, scenario (2) would probably disqualify it, and the more likely scenarios (3) and (4) would only add fuel to current arguments.

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The sketch on page 3, reproduced from Montazer and Wilson (1984), shows the many possible complications in water movement thru tilted and faulted layers of tuff. The many places where old water could be retained for long periods, and where younger water could mix with it or move under it, are evident from the indicated flow paths. The possibilities seem so numerous and so unpredictable that one can fairly ask whether the $^{36}Cl$ method, or any method of determining water ages on isolated samples, can give an interpretable picture of water movement. The flow paths on the diagram, of course, are only conjectural, based on general rules of groundwater movement and the properties of the different tuff layers; it is possible that actual movement for the most part follows simpler downward paths, so that water ages might have more obvious meaning. It seems to me that this possibility is great enough so that DOE's proposed measurements should be tried.

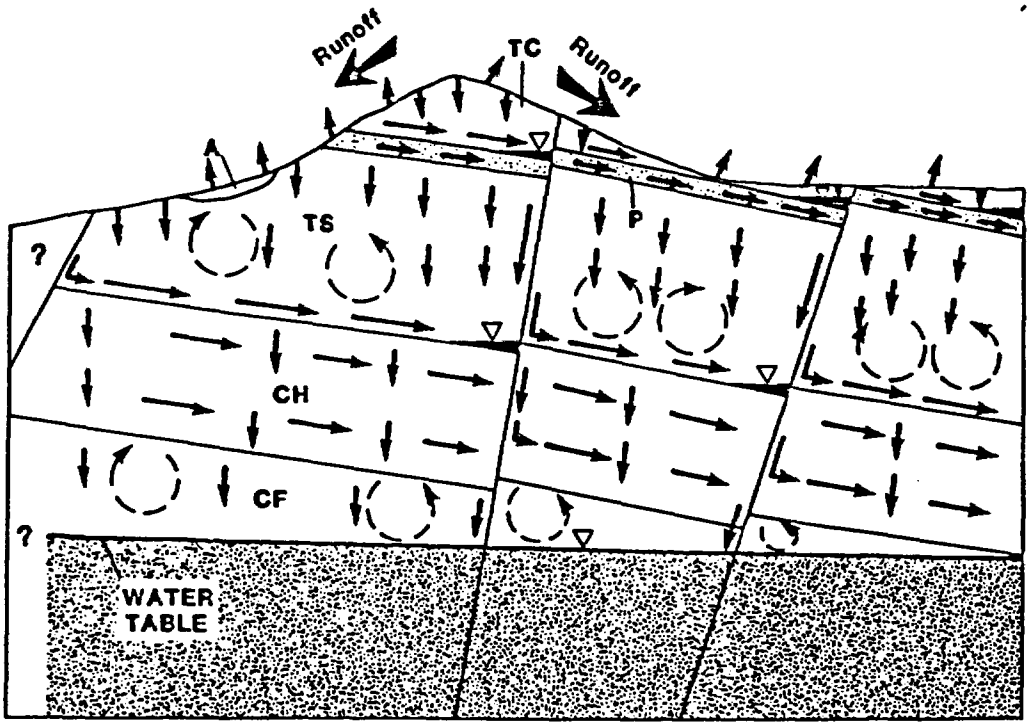
The Study Plan is well presented. Its authors evidently have the necessary technical background and an easy familiarity with the pertinent literature. They have devised a plan of action that will not be easy to carry out but that should be feasible, and they seem aware of the many things that can go wrong. A few minor points in their description may be worth a comment.

1. Possible changes in the stable chlorine isotopes, $^{35}Cl$ and $^{37}Cl$, are mentioned as a means of distinguishing meteoric chlorine from rock chlorine (pages 3, 4, and 10). The only reference I know to any separation of these isotopes in nature is the one cited on page 3 (Desaulniers et al. 1986). This one describes a large body of nearly static groundwater, in which very slight changes in the 35/37 ratio are measured and ascribed to long-continued diffusion. I don't see how this can have any application to the very different situation at Yucca Mountain. Seems to me that looking for changes in the stable isotopes is futile.

2. Bromine is to be added as a tracer to the water used for washing the shaft, to make possible an estimate of the chlorine that might be added to the samples from the wash water. In preparing the samples for analysis the bromine will be dissolved from the powdered tuff along with the chloride and will be precipitated as AgBr together with the AgCl. Will the presence of Br have any effect on the mass-spectrographic analysis of Cl? I doubt it, but maybe this should be mentioned.

3. On page 9 in the third paragraph is a statement that some samples at a depth of a few meters "may be collected independently of the shaft mining operations." I would be happier if the sentence said "<u>will</u> be collected." Seems to me that such samples should be collected and run thru the analytical procedure well before the shaft is started, both to check on details of the procedure and to ensure that the source term for meteoric chloride is well established.

4. Seems to me the first paragraph on page 11 needs clarification. I read it to say that decay data may give an apparent age resulting from mixing of chloride from more than one pulse of water movement, that such an age would be of no use in estimating rates of movement, but that it might be useful in calculating travel times for the movement of pertechnetate ion. Seems to me that ages for some of the samples will almost inevitably represent mixing of chloride ions from many pulses. But I should think they might still give useful information about water movement as well as predicting the possible migration of $TcO_4^-$. Have I missed something in the logic?

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EXPLANATION

| | |
|---|---|
| A | ALLUVIUM |
| TC | TIVA CANYON WELDED UNIT |
| P | PAINTBRUSH NONWELDED UNIT |
| TS | TOPOPAH SPRING WELDED UNIT |
| CH | CALICO HILLS NONWELDED UNIT |
| CF | CRATER FLAT UNIT |
| → | DIRECTION OF LIQUID FLOW |
| ⇢ | DIRECTION OF VAPOR MOVEMENT |
| ▽ | PERCHED WATER |

Figure 14.--Generalized section across Yucca Mountain showing flow regime under baseline conditions. Lengths of solid arrows show relative magnitude of fluxes.