Fluid Inclusions: Capabilities And Limitations

NWTRB
Jan. '00
Las Vegas

Fluids Research Laboratory
Virginia Tech
BUBBLES 'R' US
Department of Geological Sciences

Fluid Inclusions

- What are fluid inclusions?
- What can they tell us?
- What can they <u>not</u> tell us?

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What are fluid inclusions?

Minerals form by precipitation of material from a solution. Sometimes, small droplets of the solution are trapped as defects in the growing crystal. These trapped solutions, which usually are only visible under the microscope, are referred to as "fluid inclusions". Also, if a fracture develops in a mineral after it forms, fluid inclusions may form as the fracture "heals" and traps some of the solution in the new mineral filling the fracture.

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Information available from fluid inclusions

- Temperature (minimum)
- Pressure (depth??)
- Fluid Composition (source**)
- Fluid Timing (evolving system)

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Information not available from fluid inclusions

- Absolute age of the inclusion
- Source of the fluid **

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Our ability to analyze fluid inclusions is limited by the size of the inclusions.

10 μm f.l. = 5×10^{-10} grams!!!

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The Question:

What is the probability that heated, ascending fluids will reach the repository horizon in the future?

The past is the key to the future

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Have fluids moved through YM in the past?

What was the temperature of those fluids?
What was the source of the fluids?

When did fluid migration occur at YM?

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Application of F.I. to YM

Information	Confidence level
Temperature Relative age of inclusions	High
Fluid composition Pressure	↓
Depth Source of fluids	↓
Absolute age of inclusions	Low

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February 4, 2000

Dr. Michael Carroll
Nuclear Waste Technical Review Board
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Dear Mike:

I am writing to summarize the conclusions from my presentation at the recent NWTRB meeting held in Las Vegas, NV, January 25-26, 2000. In talking with some of those in attendance, I learned that my presentation painted a somewhat pessimistic picture of the likelihood that fluid inclusions will provide useful information. Hopefully, I can clarify my views here.

First, I want to emphasize that at this point there is absolutely no doubt that fluids with temperatures in excess of present-day temperatures have been present at the repository horizon at some time since the volcanic host rocks were deposited. From my perspective, the only issue that still needs to be resolved concerns the timing of those fluids. If they were present relatively soon after the rocks formed (i.e., approximately 10-12 million years ago) and have not entered the repository horizon since that time, then the probability for future incursions is relatively small. On the other hand, if heated (ascending?) fluids have entered the repository relatively recently (within the past few million years or more recently), and if it can be shown that heated fluids reached the repository horizon episodically since formation of the mountain, then the possibility for this happening again after the repository is filled must be taken into account in all regulatory and engineering design decisions concerning the site.

From a theoretical perspective, the solution to the problem is quite straightforward. All that is required is to find the latest generation of fluid inclusions that have elevated temperatures and determine the absolute age of those inclusions. Finding inclusions that have elevated temperatures is easy as was recently documented in studies by Dublyansky and by the UNLV team. The difficult task is to determine the age of those fluids. My pessimism concerning our ability to do this comes from the fact that *no one has ever been able to obtain direct age dates on fluid inclusions having ages similar to those at Yucca Mountain (<10Ma).* Below I provide some additional background that might help the Board to understand why I am pessimistic about our ability to "date" the high temperature event at Yucca Mountain.

The topic of dating fluid inclusions is one that has interested fluid inclusionists for years. Recently, there have been informative and lively discussions of this topic on the fluid inclusion web site located at:

http://www.geology.wisc.edu/~pbrown/fi.html

Many of my comments below are taken from this web site, and I encourage you and members of the Board to visit the site to view the complete list. Let me state first that no one has yet been successful at dating a *single* fluid inclusion using any available analytical technique. Workers have had moderate success dating older (a few 100 million years) fluids by crushing a sample containing many (thousands to hundreds of thousands) fluid inclusions and dating the released fluids using either Rb/Sr or ^{40}Ar-^{39}Ar techniques. The errors associated with these ages are typically on the order of a few million years and the techniques are not appropriate for the young rocks at Yucca Mountain. The most successful attempts at determining the "ages" of fluids have involved determining the age of the host mineral, and assuming that the contained fluid inclusions are the same age as the host.

Dr. Thomas Pettke, a young geochemist at ETH, Zurich, is in my opinion one of the most knowledgeable workers when it comes to the problems associated with fluid inclusion geochronology. In his email message on the web site, he states that "*Direct dating of fluid inclusions – Although highly desirable, I have many concerns, that this is not really feasible at present, despite the recent, great analytical advances in radiogenic isotope geochemistry.*" Another serious worker in this field, Dr. Andrew Campbell of New Mexico Tech, states that "*I doubt that this technique [^{40}Ar-^{39}Ar] would be worth trying on your samples which you describe as low salinity and 10my old*". This comment is directed to Jean Cline, who asked members of the fluid inclusion listserve for advice on dating the Yucca Mountain mineralization. Another worker, Dr. Martijn Moree from Vrije University, Amsterdam, notes that "*I think those rocks [Yucca Mountain] are too young to date them with either Rb-Sr or Sm-Nd (less than 15 Ma!!!). It will be very hard to date them with any radiogenic method, except for the fi's in the calcite using U-disequilibrium methods,...*"

Given the information presented above, it seems that the only possibility to obtain ages for the high temperature fluids at Yucca Mountain is to date the host mineral containing high temperature fluid inclusions. But, with this technique one must always assume, based on petrographic information, that the host phase and the contained fluid inclusions are the same age. And, at Yucca Mountain the host phase for fluid inclusions is most often calcite (only one or two examples of fluid inclusions in quartz have been found), and young calcite is difficult to date. The more promising approach appears to be to obtain ages on opal and chalcedony that paragenetically bracket calcite containing high temperature fluid inclusions, and use this information to place limits on the age of the calcite (and its contained high temperature fluid inclusions). However, this approach is complicated by the fact that evidence exists for dissolution followed by re-precipitation of calcite, and in some cases calcite appears to have grown around (pre-existing?) opal. Thus, even if ages of opal/chalcedony can be determined, relating this to the age of high temperature fluid inclusions is likely to require various assumptions involving the paragenesis that may be difficult to prove.

I will end this short report by reiterating that fluid inclusion geochronology is one of the more active areas of fluid inclusion research at the present time. And, significant advances are continuously being made as sample size requirements shrink and analytical precision and accuracy improve. Our ability to obtain ages of fluid inclusions is moving forward at a rapid pace. This research effort is likely to be accelerated by the work at Yucca Mountain because determining the age of the youngest hydrothermal event at Yucca Mountain is of more than just scientific interest. The answer has enormous practical and societal implications which, hopefully, will provide the necessary scientific emphasis and resources to allow this problem to be resolved in a timely manner.

Respectfully submitted,

Robert J. Bodnar