**Subject: comments for use**
**Date:** Thu, 20 Apr 2000 12:22:49 -0600
**From:** "denis l norton" <denis@ruralnetwork.net>
**To:** "Jeff Hulen" <jhulen@egi.utah.edu>

Jeff:

Follows some brief comments that I view as progress on the task to identify prospective geothermal resources in the Western US, and to help guide the evaluation of these resources through the use of geochemical transport methods and geologically reasonable senarios. I include
1) Medicine Lake
2) Dixie Valley
3) Salton Sea

I suggest appending to the Medicine Lake or to the whole thing the expose Prescription for Reconstructing the Natural History of Prospective Geothermal Systems or something like that, the doc i e-mailed to you but seem to have lost on this end, IF you cant find it I can regen it, ELSE IF you find it please forward copy to me. Thanks.

1) Medicine Lake Volcano

The following comments are based on a reconnaisance overview of the Medicine Lake region last fall and initial compilation of data this winter with the goal to reconstruct the magma-hydrothermal history of the region. The objective of this reconstruction is to help delineate the history and present distribution of potential geothermal resources. Although information on the distribution of magma/hot plutonic rocks at depth is sparse, we are assembling an ensemble of geologic models that best approximate the situation as known to date.

The Medicine Lake region is a constructive volcanic edifice comprized of a series of protrusive domes and andesitic flows that were intruded through the Miocene Modoc Plateau rocks. The domes outcrop over a 250 sq mi area that has resulted in the accretion of 2500 ft thickness volcanic pile that slopes about 10 degrees to the North and South of Big Glass Mountain.

The aerial distribution of these modern and historic protusive centers is evident on aerial photographs of the region. Their eruptive centers define source loci of the extrusive volcanics and provide a first-order approximation to the distribution of magma sources at depth. A map of these sources is in progress and will form a basis for reconstructing the distribution of magma/hot plutonic rocks beneath the volcanic edifice. Eroded analogs to this system will help guide the reconstruction.

Further constraints can likely be provided by data sets from exploration activity in the area if these are provided to us.

This work follows the general prescription for analysis of magma-hydrothermal systems as derived from our previous work:

Jeff append here the presciption.

2) Dixie Valley

Dixie Valley geothermal system is set in a Basin and Range geologic environment similar to the Safford Basin in Arizona. Studies of the latter in 1981, included approximate modeling of the deep recharge of fluids from the surrounding mountain massifs into the basin, reactions with extensive beds of anhydrite, heat production from the conversion of anhydrite to gypsum, and effluent flows to the thermal spring systems along the valley.

The general program of analysis evaluated the various heat sources and the consequent affect of them on fluid isotopic and bulk chemical compositions. Field analyses of thermal spring fluids were then used to evaluate the most likely fluid flow patterns and heat sources. This combined use of chemical and thermal transport processes, geologic reasoning and field data sets was quite effective in delineating the nature of the Safford Basin hydrothermal system.

The Dixie Valley hydrothermal system enjoys a wealth of diverse data. These data are ripe for analysis using the methods mentioned above. Toward this goal preliminary information was assembled during the last month to begin the stages of construction of a reasonable ensemble of fluid flow and thermal computations that will ultimately provide a working dynamic model of the Dixie Valley resource.

3) Salton Sea

Thoughts on the Salton Rift geothermal systems

General Geology

The Salton Sea structural basin and its extension into the Sea of Cortez reflects a young tectonic rift in the North American continent. The hydrothermal-magma history of this region is undoubtedly similar to other continental rift settings that have been exposed by erosion or are presently active around the world today.

The style of volcanism in the early stages of continental rifts is dominated by gabbroic magmas and their associated hydrothermal carapaces. Because the magmatic portion of the activity tends to be deep in these regions early in the opening of the rift, the predominate forms of intrusive are dikes and sill like bodies whose thermal mass is usually small with regards to the extent of hydrothermal activity.

Concommitant sedimentation into the rift valleys that form early in the rift tectonics generates a thick sequence of alternating detrital and closed basin muds and evaporite deposits. This sequence has an intrinsicly strong ansiotropic permeability; high permeability sands and gravels, and low permeability mudstones and interbedded evaporites. This setting is interfingered with alluvial fan and landslide deposits from the basin margins, and may include local basalt flows that rise along the rift margins.

The stratified permeability provides a strong insulator over any subsurface intrusive bodies and consequently leads to complex patterns of hydrothermal activity and perplexing data sets from traditional heat flow measurements and electrical resistivity surveys.

Some analogies

There are many modern day equivalent geologic provinces to the Salton-Sea of Cortez Rift. The Red Sea rift is probably the most studied in terms of volcanism, heat flow, hydrocarbon fractionation and accumulation of metal rich sediments in deep basins of the sea. However, identification of causitive magmas in that rift setting has also been unproductive.

Examples of ancient rift settings are also numerous, my favorite are the outcrops left from the early opening of the North Atlantic rift system, on the eastern shores of Greenland. Here a granitic gneiss basement was rift apart, followed by an infilling of sediments, then effusive basaltic volcanism covered the region, followed closely by a sequence of gabbroic intrusives, laccoliths, dikes, and sills. The sediment accumulation was only a few hundred meters thick and does not appear to have included evaporitic deposits.

Magma-hydrothermal processes in rift basins

The diversity of the basin rocks that host intrusives and hydrothermal activity in rift settings, their entrainment of saline fluids, and frequent intrusion of small magma bodies into the basin requires that programs whose goal it is to delimit potential energy resources in the region must rely on the fundamentals of hydrothermal processes and their interactions.

First, we must recognize that the traditional empircal geothermometers based on solute properties of fluids are bound to fail at temperatures greater than $200-250^oC$, Bird and Norton, 1981. However, extensive data sets are now available that permit analysis of systems in this temperature range and greater. The methods for this analysis rely on quantitative knowledge of the mineralogic composition of alteration events and consequent analysis in the context of modern geochemistry, for example see Bird and Norton, 1981.

Extension of the analysis by Bird and Norton, 1981, in in the context of tools developed specifically for estimation of fossil and modern permeabilities in hydrothermal systems, Norton, 1984 and 1988 and

Villas, and Norton, 1979, would be a fundamental new approach to analysis of the S-SoC Rift systems.

An additional tack that could provide short term results would be to reinterpret data sets on electrical resistivity in the rift in the context of the work on resistivity in hydrothermal systems by Moskowitz and Norton, 1977. The simple interpretation of resistivities in terms of not only conductive metallic sulfides and salty fluids but also in terms of the extreme variability of electrical resistivity in hydrothermal fluids in the 100-450oC range could contribute new perspectives in exploration.

References

Norton, D., and Villas, R. N., 1977, Irreversible mass transfer between circulating hydrothermal fluids and the Mayflower stock: Econ Geol v. 72, p. 1471--1504.

Bird, D. K., and Norton, D., 1981, Theoretical prediction of phase relations among aqueous solutions and minerals in the Salton Sea geothermal system: Geochim et Cosmo Chem Acta v. 45, p. 1479--1493.

Norton, D., 1986, Metasomatism and permeability: American Journal of Science,
v. 288, p. 604-618.

Moskowitz, B., and Norton, D., 1977, A preliminary analysis of intrinsic fluid and rock resistivity in active hydrothermal systems: Journal of Geophysical Research, v. 82, p. 5787--5795.

Norton, D., 1984, A theory of hydrothermal systems: Annual Review of Earth Planetary Sciences, v. 12, p. 155--177.

(Jeff: I think 75000yr is our extreme error, 100000 yr from zircon, etc....... it is actually quite remarkable to be within a few 100K years!!!!)