The Need For Geothermal Research

Exploration and Reservoir Sustainability are Crucial to Geothermal Industry Survival

Editor's Note: **The following is an article edited from an Industry Keynote Presentation by Dick Benoit, Oxbow Power Services, Inc. (Reno, NV) at the U.S. Department of Energy Geothermal Program Review on March 25.**

Geothermal research is an especially broad and fascinating topic. No individual is capable of being on top of all its various aspects. Those of us who work in the relatively small geothermal resource industry are fortunate that this diversity of potential research topics makes life interesting.

This presentation is confined to geothermal resource issues and research needs, but this by no means implies that above-ground hardware is not worthy of research. For example, a method to add a second flash cycle to existing single-flash plants would be a significant accomplishment. This may not be out of the question as preliminary testing of a new silica inhibitor is showing promising results.

In larger industries there is a relatively clear division of labor between researchers and those working to discover or routinely produce a product. In the gold industry, for example, I know a number of geologists who have worked more than ten years, but haven't performed any work that I would call research or published significant papers. Sure, they create geologic maps, look at cuttings and use some standard geochemical techniques, but at the end of the day they have not increased the fundamental understanding of their resource. They have simply utilized tools that others have developed. The same can be said for most geologists in the oil and gas industry, where research and development, and exploration and production, are clearly separate departments.

In the much smaller geothermal industry we are fortunate that things are different. Virtually all of the resource people who have managed to remain employed or at least involved in this industry can legitimately claim to have participated in true research that has increased our fundamental knowledge about the character and extraction of geothermal resources. I would even say that in many cases research activities have led to employment longevity in the industry. For more than two


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decades, research personnel or collaboration with bona fide researchers has been required for companies to successfully develop projects and survive. Furthermore, 25 years has been plenty of time to weed out individuals and companies that could not technically advance.

Let's take a light-hearted look back over the past quarter century at some examples of where we are in our understanding of geothermal resources—and how far we've come as a result of research:

- In 1974, most geothermists were unaware that temperatures could get colder with depth near geothermal systems. We now recognize that this happens all the time in the vicinity of active geothermal systems, and have turned this common feature into a viable exploration tool.
- During the late 1970s, one company was still evaluating geothermal wells with drill stem tests. Another company drilled eight identical wells in one prospect, and its small-diameter casing program never evolved or improved. The management of another company decreed no logs could be run in flowing wells. These three cases show the hazards of company management by people with no background in geothermal research. All three companies are no longer directly involved in the geothermal industry.
- During the 1970s, we focused research on fancy logging tools and worried about things like M-N crossplots. But seldom is a neutron log even run in the industry now. It took an embarrassingly long time to get a reliable hot-hole pressure, temperature and spinner tool (PTS) in routine use.
- Prospects were abandoned by companies because of concern about carbonate scaling in production wells.
- We actually thought that hot dry rock would be a commercial and competitive source of electricity before the end of the century.

The list goes on and on, but despite this history we have survived and greatly improved our skills through research. For many this survival amounts to half a lifetime of work. Yet even as things change, they remain the same—some old, unsolved problems from the 1970s continue to haunt us.

I'll focus on two areas crucial to the survival of the industry: exploration and reservoir sustainability. Exploration is not currently the most pressing problem facing the domestic industry, but U.S. operators working overseas—especially in Indonesia—are having a sporting time of exploration right now. Conversely, reservoir sustainability is not yet a concern for U.S. operators overseas, but is currently the main resource concern in the United States. Sustainability is becoming a concern in the older geothermal fields of the Philippines, and in several years it will become a big issue in Indonesia.

Exploration

In 1974, I started exploring for 1,000-megawatt reservoirs for Phillips Petroleum Co. in the Basin and Range Province of the western United States, looking for something resembling The Geysers geothermal field in Northern California. Never mind that it was 1976 before I ever set foot in The Geysers. The beauty of that geothermal field was that holes could be drilled on a grid, and the productivity of wells could be predicted by how close a well was to a certain temperature-gradient contour. The Geysers also had the advantage of having many cubic miles of fractured rock. (I am still waiting to read the details on how this fracture network was created.) By the late-1970s, it became apparent to everyone that The Geysers was a freak of Nature and not an appropriate model for most geothermal reservoirs.

The Geysers experience cut both ways, as those working outside that geothermal field did not find a similar resource, and those inside The Geysers didn't do so well exploring other areas within the United States. For about 15 years we have known that the fundamental challenge in geothermal exploration is to locate a crack (or even several fractures) with an aperture of a few centimeters to a few meters, at depths of 1,000 to 4,000 meters. Our progress appears to have been minimal, judging by the number of unsuccessful hot dry wells or second legs required to make a successful well. This holds true even in the mid-1990s. Research is needed to develop methods for determining when to attempt a redrill and to develop stimulation methods, so we can improve the productivity of dry or marginal wells.

It's not overly pessimistic to state that we will never come up with a black box that can be used on the surface to unequivocally detect a few cracks at a depth of 2,000 meters. It is far more realistic to expect that our advances are going to evolve from an improved, basic geological understanding of geothermal reservoirs.

I know I am not the only one involved in geothermal exploration who believes that the crude and simple cartoons we presently call conceptual models of geothermal systems are inadequate to truly portray the resource. A site-specific understanding of an individual resource is a slow learning process that comes from the integration of literally thousands of bits of data that may not be related to each other or to a geothermal system. Only research and publicized experience and case histories will help us advance in this arena.

Corporate accountants cry that it takes too long and costs too much for an experienced geothermist to spend the man-years necessary to obtain the detailed understanding required to predict where the edge of a reservoir might be or where injection might be most effective. It is not fair to expect that a rookie in the industry would be up to this task. This process can never be turned into a cookbook or a quick consulting job. The best we can realistically hope for in the next decade is that new tools and better understanding—combined with thoughtful analysis—will tilt the odds of making successful decisions a couple of more percentage points in our favor.

The domestic geothermal industry now is crying that low-cost natural gas is making us uncompetitive power producers and making it impossible to obtain power sales contracts. But our relatively low success rate in finding fractures is also a significant factor. At Nevada's Dixie Valley, which is probably the most straightforward Basin and Range geothermal area, I cannot promise even a 50-percent chance of success on an initial wildcat well. The potential upfront cost of a $2 million to $3 million dry hole tends to ruin the economics of thin deals.

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As drilling stories gradually trickle out of Indonesia, it is becoming clear that there are a wide variety of resources and that locating quality fractures in many of them is as difficult as it is in the United States. I have not yet done any exploration overseas, but I can see that exploration in volcanic arc environments presents new challenges that domestic geologists in the geothermal industry have not faced before. One is simply getting reliable PTS logs. In fact, supplying reliable memory tools to remote projects appears to be one of the most important short-term things that can be done to help overseas explorers.

Spending some research dollars on foreign projects will provide some important results and even modify the way we view our domestic reservoirs. Given enough experience in Indonesia, for example, we might ferret out the key to finding reservoirs that could be developed in the Cascade Range of the northwestern United States.

It is obvious that for exploration, we have a very difficult and fundamental problem to address. We have made progress in the past two decades — even if painfully slow—and we will make progress in coming years. But it is not going to be quick or easy, and we will not come up with a magic method that takes the place of careful and detailed analysis of local geology. Research will provide us with better high-temperature logging tools, but interpretation of these logs will still require knowing analysis.

Reservoir Sustainability

In the United States, industry efforts are now focused on reservoir sustainability. Even if the immediate objective of management is to meet a rolling average or to maintain an 80-percent to 90-percent capacity factor, the ultimate goal is reservoir sustainability.

There are two tools available to replace depleted production: makeup wells and injection. For very understandable reasons, makeup drilling always seems to be the first tactic employed. By the time a power plant is on-line, the company's technical staff have demonstrated some kind of acceptable success rate, and management has become comfortable with production well drilling—even if the accountants are experiencing heartburn. Any geologist with any time in the industry knows enough to leave a few spots open for infill wells, so there are usually some easy targets for the first couple of makeup wells, which are generally successful.

As production starts, an injection strategy is in place (for better or worse) that is largely untested and unproven. Everyone is rightfully nervous about the injection program, and with a few cost overruns in production drilling, efforts are made to cut injection-side costs. Seldom, if ever, has a well been targeted and drilled specifically as a long-term injector prior to the start of power plant construction. Most injection wells in service today were drilled as producers, and for various reasons later condemned to injection.

Would some of our projects be performing better if injection was given its due importance at the beginning of a project? Recent research has given us the ability to detect chemical tracers in the few parts-per-trillion range, offering no excuse to operators for not being on top of their injection programs.

Injection is really the only management tool we have for getting the most out of a reservoir once a power plant is sized and built. We have no control over reservoir temperature, heat stored in place, fracture surface area, the amount of water in place, porosity, permeability or a number of other factors.

But even though we have a long way to go in truly understanding injection, we do control the amount of water we inject and most importantly, where this water is injected. There is no generally agreed upon "best" strategy for injecting, but continued research on reservoir stimulation should ultimately provide a method for "experimenting" with the location and flow rates of injection wells before we actually have to return a drop of fluid to a reservoir.

Beyond injection of produced fluids we get into the up-and-coming era of injection augmentation, where water from outside a geothermal resource is injected into a reservoir to support pressure and mine heat. Certainly, efforts at The Geysers in capturing water for injection have been the overall technical success in this field for the past 15 years. However, even with injection augmentation at The Geysers, a much smaller percentage of fluid is returned to the reservoir relative to production than at any liquid-dominated resource.

Water conservation has been mimicked by other operators of liquid-dominated reservoirs, at least in the United States. Some foreign operators, however, are not following the water conservation crowd and are paying a very high price in lost megawatts and shortened reservoir life.

We are now aware of the limits of even a perfect injection program that focuses solely on returning reservoir fluids. Again, the leader in large-scale injection augmentation is The Geysers, with the Lake County pipeline that is now nearly completed. This project really is a true quantum leap from smaller, existing water capture schemes. The next step in the evolution of injection augmentation will be to do the same thing in a "controlled manner," with a liquid-dominated reservoir.

By controlled manner, I refer to instances where injection outside a reservoir has led to excessive natural augmentation and rapid cooling of production wells. In this case, chemical interaction between reservoir and augmentation fluids is more of a concern because there is a potential for massive amounts of solids to precipitate. Research in chemical modeling may provide predictions where and how solids are likely to form. The ideal reservoir for this next test will be one in which pressure—not temperature—is the limiting factor.

A successful injection augmentation program will share some of the characteristics of a successful injection program. In other words, the sooner that augmentation can be instituted, the more effective it should be because it will have a longer time to more efficiently mine the heat.

New Blood Needed

Many in the industry are aware that there is a major research effort underway at Dixie Valley covering many topics. That research covers both exploration and sustainability, with the ultimate goal of gaining a more complete understanding of a relatively simple reservoir along a normal fault. The key questions to be answered are why do some areas contain abundant fractures; why are others impermeable; and how can we best locate and most efficiently utilize these fractures.

What is not well known about current efforts along these lines in Dixie Valley is that it has introduced a number of new researchers to the geothermal industry. It is hoped that their interaction in meetings other than those sponsored by the Geothermal Resources Council, Stanford University and the U.S. Department of Energy will breathe some new energy into geothermal research about our fundamental problems. Over the years, it is no secret that geothermal industry technical leaders—particularly in geosciences—have probably become a little too focused on routine problems of survivability. There is a lot of experience and geothermal wisdom in this group, but much of its talent seems focused on narrowly defined, specific topics with day-to-day urgency.

Over the past several years, geothermal literature has contained remarkably little in the way of serious discussion on fracturing in rocks or along faults and sustainability of reservoirs. Inside the industry we seem to be nibbling around the edges of these topics. A major research focus on these problems with some new thinkers could help the industry in many ways.

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Conclusions

Throughout the world, all industries are on a treadmill to improve their products, lower their costs and gain market share. Like it or not, the geothermal industry is being swept along with that tide, and must improve its performance or end up as a mere curiosity on a few remote islands. Ten years from now, the corporate players and others involved in producing geothermal energy will either be new to the industry or those who have maintained an active role in research.

Everyone in the geothermal industry must support and encourage research to help keep geothermal energy cost-competitive with alternative sources. Research is more effective when everyone participates, and those efforts will be more efficient if various companies take the initiative to coordinate and share at least some of their results. Those who don't will not have a long-term future in the geothermal exploration and development industry.

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