GEOTHERMAL EXPLORATION METHODS AND RESULTS - INLAND STATES

James C. Maxwell

Los Alamos Scientific Laboratory (LASL)
Los Alamos, NM 87545

ABSTRACT

The Los Alamos Scientific Laboratory (LASL) geothermal exploration sequence includes: (a) review of AAPG/USGS gradient maps, (b) literature search, (c) consideration of potential markets, (d) groundwater silica geothermometry, (e) analysis of bottom-hole temperatures, (f) heat flow measurement of available wells, and (g) drilling of new test holes. This procedure has located anomalies near Syracuse, NY (36°C/km, 56°C silica max.), near Buffalo, NY (36°C/km, 65°C silica max.), southeast Ohio, western and southwestern Nebraska, and three new warm springs in Arkansas. Other investigations have found high heat generation (14-25 HGU) in the White Mountain batholith NH (170°C calculated at 6 km depth), uparching of the Adirondac Dome, NY, and potentially economic electricity from hot brines in southwest Arkansas.

INTRODUCTION

To encourage the use of geothermal energy in the eastern United States, the Department of Energy, through LASL, is evaluating the geothermal potential of several states between the Rocky Mountains and the Atlantic Coastal Plain. LASL has developed a general pattern for geothermal exploration in these states, and is pursuing this pattern in several states as funds permit. We are also pursuing some departures from the general pattern where special geologic or economic conditions have been found.

METHODS

The LASL approach to eastern states geothermal exploration is based initially on the AAPG geothermal gradient maps (1974, 1976) and on published geologic literature. States which have no local concentrations of gradients higher than 35°C/km and no surface expression of local geothermal phenomena are given relatively low priority for study. Literature about states with above average gradients is searched to find available heat flow measurements and possible geologic causes of high gradients or high heat flow. Concurrently, plans are made to conduct geochemical sampling of spring and well water. LASL experience to date has been that the silica concentrations give more reliable or consistent estimates of temperatures at depth than do the sodium-potassium-calcium ratios. Results of the literature and well data survey, with some consideration of proximity to potential users, have been used to determine which prospects will receive geothermometry and heat flow studies. Present plans are to complete these studies over several areas before selecting a few sites for geophysical studies and test drilling. Most of the above work is being done under contracts supervised by the LASL Geological Applications Group.

RESULTS

Under the general plan outlined above, work is in progress in New York, Ohio, Nebraska, and Arkansas. In New York, a group headed by Dennis Hodge at State University of New York, Buffalo, and assisted by Chan Swanberg and Paul Morgan of New Mexico State University, has completed literature and data surveys. Two anomalous areas, the Cayuga anomaly 50 km southwest of Syracuse and the East Aurora anomaly southeast of Buffalo, have temperature gradients exceeding 36°C/km. Silica geothermometry of ground waters from these areas indicates a maximum temperature of 56°C at the Cayuga anomaly and 60°C at the East Aurora anomaly. Both anomalies are associated with gravity lows which may be caused by granitic plutons in the underlying basement. Radioactivity in the plutons could cause the geothermal anomalies. Bottom hole temperatures available from several thousand oil wells are being reevaluated to improve the state gradient map. Temperature logging of selected wells in the anomalous areas is in progress.

In Ohio, a group headed by Yoram Eckstein, from Kent State University, is working on literature and data searches. They have located at least 15 wells suitable for heat flow measurements. Thermal conductivity measurements have been completed on 44 core samples from four of these wells. Samples from these and other well cores are to be analyzed at Los Alamos Scientific Laboratory to determine their uranium, thorium, and potassium-40 content, to enable calculation of heat generation and heat flow. No well-defined anomalies have yet been identified although gradients in southeastern Ohio are generally higher than elsewhere in the state.

The work in Nebraska is being done jointly by William Gosnold of the University of Nebraska-Omaha and personnel of the Hydrology Section of the Nebraska Conservation and Survey Division. Fifteen or twenty holes less than 100 m deep are to be temperature logged to determine gradients. In a large area in western Nebraska, deep aquifers on the east flank of the Denver-Julesberg basin contain anomalously warm water, and in southeastern Nebraska, where the Nemaha ridge brings Precambrian basement rock to within 200 m of the surface, gradients exceed 25°C/km. Too little information is available yet for even an evaluation of Nebraska's geothermal potential.

One of the largest surface expressions of geothermal heat in the eastern states was first visited by white men in the early 1500's, at what is now Hot Springs, Arkansas. Although the surface geology of the area has been mapped, nothing is known of the deeper structures because of the concern that drilling would disrupt the spring flow. One other small area of warm springs at Caddo Gap, approximately 55 km southwest of Hot Springs, is currently undeveloped although it has been known for many years. Recently, by analysis of available geologic maps, the author has located three small previously unreported warm springs near Hot Springs, on folded structures similar to the one at Hot Springs. Interpretation of the complex folded structures which control geothermal spring flow in the Ouachitas must avail future drilling. Ground water sampling of a few springs and wells throughout the Ouachita Mountains, for silica geothermometry, is to be done this year. Re-evaluation of bottom hole temperatures from oil wells in southern Arkansas and new gas wells being drilled in northern Arkansas hopefully will be done when funds become available.

OTHER STUDIES

One of four local studies done independently of the general exploration plan was completed in New Hampshire where the Conway granite is known to contain very high percentages of uranium and thorium. A hole was drilled 915 m deep near Conway, with core recovered from most of the hole. Sections from these cores have been analyzed to determine the distribution of the radioelements. Although the granite produces 14 to 25 heat generation units, its temperature is low because it is not covered by any insulating blanket of low conductivity rock. A gravity survey completed for LASL by P. H. Osberg and associates of the University of Maine indicates that the batholith is a horizontal tabular body 3 to 5 km thick and 30 to 40 km in diameter.

A circular topographic anomaly near Blue Mountain Lake in east central New York was studied by Yngvar Isaachsen of the State University of New York-Albany. Detailed photo interpretation and reconnaissance field mapping showed no evidence of volcanism or other geothermal activity, although the site remains a possible target for natural gas exploration because of possible doming of the Paleozoic sedimentary rocks.

Isaachsen also completed a releveling traverse across the southern Adirondack dome which showed that the dome is currently rising, with the maximum rate of uplift near the center of the dome. He speculates that the uplift may be caused by a local mantle increase in temperature or a tectonic upwarp of the mantle, bringing higher temperature rock closer to the surface.

Investigation of another unusual geothermal energy source is being pursued in southwestern Arkansas by the Arkansas Power and Light Company (AP&L). In that area, several chemical companies pump brine at 62°C from a very permeable limestone at depths of 2400 to 3000 m. After bromine is extracted, the brines at approximately 63°C are wasted to disposal wells. AP&L has received support from DOE to build a binary phase heat exchanger, turbine, and generator to produce electricity from these moderate temperature brines. The economic viability of the project depends upon the success of the experimental heat exchanger and the price asked by the chemical companies for use of the waste brines.

CONCLUSIONS

Thus, it is apparent that sources of low- to moderate-temperature geothermal energy occur widely throughout the eastern United States. Exploration for and evaluation of these sources has not yet progressed as far as for the higher temperature sources of the west. Modest funding and manpower devoted to this work is beginning to provide the data necessary to evaluate some of these eastern prospects. As the technology to utilize low temperature sources become available, these sources will make an increasing contribution to America's energy base.

ACKNOWLEDGEMENTS

The author thanks Gerry Brophy of DOE, and A. William Laughlin of LASL, who have provided continuing encouragement and direction for this work, the several contractors who have provided the results reported above, and the many private landowners and state officials who have assisted with this program.

SELECTED BIBLIOGRAPHY

Anon., 1974, Preliminary geothermal gradient maps of the United States and Canada: Am. Assoc. Petroleum Geologists, 12 sheets.

Kinney, D. M., 1976, Geothermal gradient map of North America: Am. Assoc. Petroleum Geologists and U. S. Geological Survey.

Osberg, P. H., Wetteraner, R., Rivers, M., Bothner, W. A. Creasy, J. W., 1978, Feasibility study of the Conway Granite as a geothermal energy source: University of Maine at Orono.

Roy, R. J., Blackwell, D. D., and Birch, J., 1968, Heat flow in the United States: J. Geophys. Res., V. 73, p. 5207-5221.