AN APPROACH TO GEOTHERMAL DEVELOPMENT

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After about twenty years of geothermal energy development in New Zealand, progress is still hampered by incomplete knowledge. In sane cases, this has led to unnecessary capital expenditure. Lack of accessibility of the medium and its complexity are major obstacles to achieving a better understanding, and the interpretation of field geophysical surveys is often tedious and may be open to ambiguity. There is no substitute for a properly logged drill-hole, with backup studies on the geology and geochemistry encountered, but exploratory drilling is expensive and often difficult to justify to an industry geared to "production psychology."

Most of the advances made in New Zealand have been achieved by compromise. Boreholes intended for production have been used as research holes during the drilling phase. Since production holes may be sited in quite dense clusters, a very detailed picture can be established within a geothermal field. Of course, the drawback to this approach is that few, if any, holes are available for study outside the field. This is an important gap in the geothermal information at the present time; it does not seem possible to determine precisely the volume of hot-water resource available without knowing the vertical temperature gradients at depth between the obviously active geothermal fields.

Where groundwater is abundant, with high water tables, geothermal activity is generally manifest at the surface. Thus the initial location of a resource may not be the main problem. It is necessary to map the resource and to determine how much energy is genuinely recoverable. Here the use of models can be of value, It has been found in New Zealand that the se of the experience gained in the detailed study of one field (Wairakei) can assist in modelling the performance of other fields in early stages of exp oitation. Since all of these fields are within the same volcanic zone, it can be expected that their properties are reasonably similar.

However, the approach is not without pitfalls. Recently it was discovered that the Broadlands geothermal field, which appeared on resistivity studies to have a potential close to that of Wairakei, could perhaps be only partially exploited. During proving tests, the pressure drop encountered was found to correspond to a resource only about one-fifth the size of Wairakei (Grant, 1975). Two possible explanations for this have been considered. First, carbon dioxide levels at Broadlands are much higher than at Wairakei. When the pressure drops around a producing bore, it is possible that carbon dioxide comes out of solution to form a two-phase mixture with very poor transmissibility to water. The second possible explanation is that the poorly productive part of the field is not significantly faulted or fissured so that the bores are located in low-permeability media. If the latter explanation were valid, there would be some prospect for remedial action.

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In another example, the privately owned Kawerau geothermal field, which was thought to be of fairly minor significance, has now been shown to be highly productive from hydrothermally-altered graywacke below the surface volcanics. If this proves to be production from deeper horizons than were previously known, then the Kawerau resource could be upgraded substantially.

Geothermal research involves several disciplines; it can be perilous to neglect the contribution from any one of these. In Fig. 1, an attempt is made to indicate the inter-relationships between the fields which appear to have relevance in New Zealand geothermal research. Each heading is intended to be applicable both on the large (regional) scale and the local (geothermal field) scale.

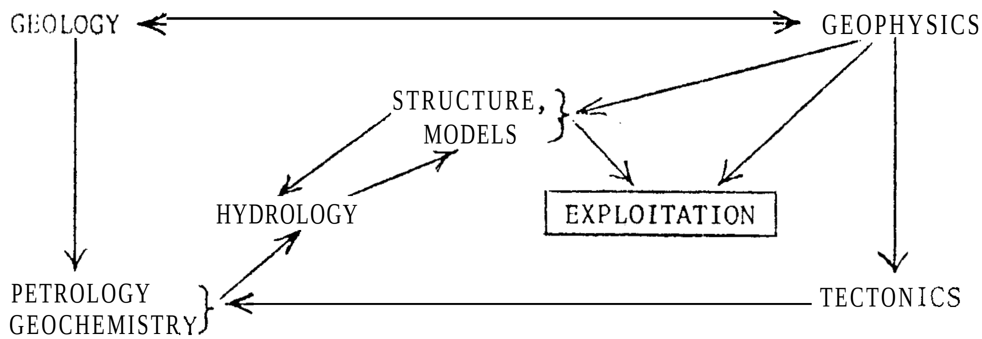

Figure 1. Aspects Relating to Geothermal Development

The large-scale geology and geophysics and associated tectonics are useful in describing the background under which high heat flows occur. Just what mechanisms are involved may have to be inferred from the petrology and geochemistry. This includes extensive use of isotope chemistry and dating methods. The term "hydrology"--here intended 'to embrace all aspects of fluid flow including hydrothermal convection--may be inferred from a knowledge of the field structure, including observed temperature distributions, permeabilities, and chemistry. Models are particularly useful in supplementing the available field knowledge, filling in the gaps by means of hypotheses, and leading to predictions which may be tested. If a model passes such tests, it may become a practical prediction tool. Many of the above aspects aid in the exploitation of a field, and the knowledge gained during exploitation provides essential feedback.

Models of Hydrothermal Systems

Resistivity mapping to a depth of about one-half kilometer has now been carried out by G. F. Risk and W. J. P. Macdonald of New Zealand's Department of Scientific and Industrial Research for a substantial part of the Taupo Volcanic Zone. Ample backup studies indicate that temperature maps would exhibit similar major features.

Unfortunately, detailed results of this quality are not obtainable in three dimensions using presently availab e geophysical methods. One line of models research is aimed at resolving the mechanisms of the groundwater convection problem and establishing real stic values for physical parameters of geothermal fields.

Just one aspect of this effort has been to determine meaningful values of field permeability. It is fairly clear that the large scale permeability of the field, which controls the major groundwater movement, is very low--probably a little less than 10 millidarcies for vertical permeability. Some estimates for horizontal permeability have been significantly higher, but the value obtained from field draw-off studies is about the same as that in the vertical (McNabb, Grant and Robinson, 1975).

Modelling of field behavior under exploitation is of major importance. A successful fit has been achieved in the case of the Wairakei data using the formula

$$q = a + bp + c\, dp/dt \qquad (1)$$

where q is the rate of draw-off, p is the pressure, t is time and a, b and c are coefficients which may be determined from the data. Fig. 2 illustrates a model (due to M. A. Grant) from which Equation (1) may be justified on theoretical grounds.

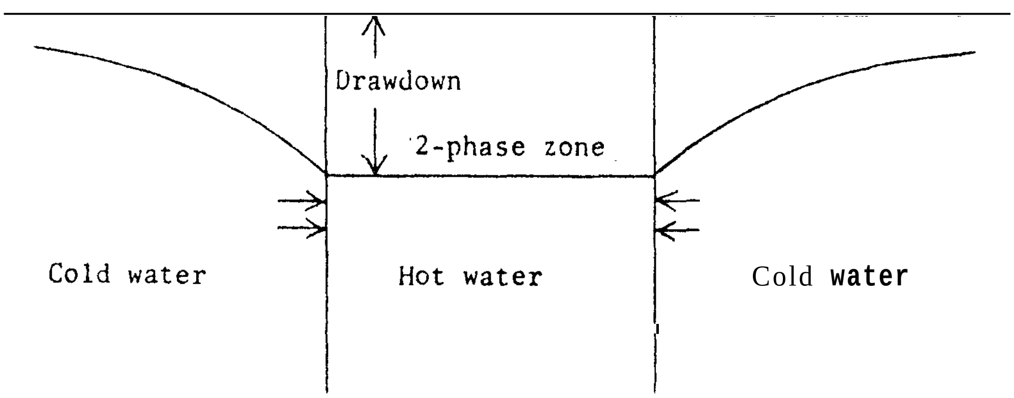

Figure 2. Model of Drawdown in a Hot-Water Geotherma Field (McNabb, Grant and Robinson, 1975)

In Equation (1), the term bp represents inflow from the sides, i.e., contraction of the hot zone, while c dp/dt arises from drawdown of the water surface. The coefficient b depends upon the radius of the field. Since this contracts, b decreases slowly with time, but b may be treated as constant for small times. This indicates that, after draw-off begins, there is a rapid decay of field pressure, which asymptotes to an intermediate value. Further pressure decay is very stow, and is due mainly to contraction.

Equation (1) has been used, in particular, by Donaldson (1975), McNabb (1975), and it has been used for prediction of performance in the Broadlands geothermal field (Grant, 1975).

References

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