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Front Cover: We are indebted to NASA and Bechtold Satellite Technology Corp. for these space images which form our cover this month.

ARTICLES

GEOTHERMAL EXPLORATION:

STRATEGY AND BUDGETING

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INTRODUCTION

Development "Geysers-type" dry steam geothermal reservoirs is the most economical and environmentally-compatible means of increasing the electrical power generating capacity in the Western United States today. Hot water geothermal reservoirs are currently supplying electrical generating plants in Mexico, Japan and New Zealand, and may well prove the second most economical and environmentally compatible power source.

This article explains the strategy and budgeting for target identification, land acquisition, exploration, and exploratory drilling costs required to make a commercial discovery of geothermal energy.

STRATEGY

The goal of a geothermal exploration program is to find either dry steam (vapor-dominated) or hot water (liquid-dominated) reservoirs of geothermal energy. For commercial use, a reservoir must have an identifiable heat source, a water supply to transport the heat to the surface and sufficient porosity-permeability to facilitate continuing heat transfer at depth.

Initial target identification and the criteria used to nominate targets is the key determinate in formulating a geothermal exploration program. The margins of onshore crustal plate boundaries are the logical places to begin the process of identifying targets. Within the area of these margins a maximum target depth must be established—perhaps 6,000 feet during the early stages of exploration and 10,000 feet as exploration techniques become more sophisticated.

The concepts of crustal plate boundaries and its overt application to geothermal exploration are both relatively new to the industry. "The theory of plate tectonics gives us some direction as where to begin the search for commercial quantities of Earth heat . . . along areas where (these) crustal plates join that the leakage of Earth heat is the most intense. At these places, molten lava may well up as volcanoes. Basins of underground water may become heated, or superheated to steam. Hot springs, geysers and fumaroles may issue at the surface . . . therefore, the recognition of crustal plate boundaries on the continents becomes of major importance in selecting and evaluating geothermal targets." (Koenig, 1974)

While geothermal resources are known to exist elsewhere, the selection of targets in areas of crustal boundaries significantly reduces the geographical prospecting area and establishes a criteria for cataloguing observations during exploration. For instance, an analysis of reported or hypothesized areas of crustal plate boundaries indicates that about one-half of the surface areas in the vicinity of 1109 reported thermal springs in the westernmost states qualifies for target considerations.

It is generally assumed that geothermal energy will be found twenty times more frequently as hot water than as dry steam. This often leads to the implication that dry steam is "rare" and that an exploration strategy must necessarily focus on the discovery of hot water.

The basis for projecting a 20:1 ratio lies partially in similarly proportioned occurrences of surface manifestations of hot springs and venting hot water (geysers) compared to naturally venting dry steam (fumaroles). Geologic evidence suggests, however, that dry steam reservoirs are actually mature liquid-dominated hot water systems and that a number of the hot springs are supplied by ground water aquifiers heated by underlying reservoirs of dry steam.

Dry steam may be more common than generally acknowledged and an exploration strategy along crustal margins should focus on its discovery.

BUDGETING

The experience at The Geysers (dry steam) and Cerro Prieto, Mexico (hot water), can be analyzed to project that successful exploration and field development programs make geothermal energy competitive with other forms of power generation.

Once the strategy has been established a literature search may be initiated to choose specific targets. As target selection progresses, prospect evaluation, land acquisition, and detailed geophysical exploration must

Assuming land acquisition covers roughly 150,000 acres, the 15 targets selected for geophysical exploration lease costs may be budgeted as follows:

Land Status	*Acreage*	*Average Cost Per Acre*	*Total Cost*
Federal KGRA	22,500 15%	$40.00	$900,000
Federal Non-Comp.	90,000 60%	1.00	90,000
Fee Owned	30,000 20%	2.00	60,000
State	7,500 5%	1.00	7,500
Total	150,000 100%	$7.05	$1,057,500

Lease rental expense on the land position will be $172,000 annually. Because some targets will be dropped as exploration proceeds, an amount of $300,000 should be sufficient for second and third year lease rentals.

Management and a small staff's overhead can be maintained for $175,000 per year or $525,000 over a three year period.

Costs for target identification, land acquisition, a progressive exploration program, and drilling four deep test wells when summarized should include:

Budget Category	*Year One*	*Year Two*	*Year Three*	*Total*
Management Expense	175,000	175,000	175,000	525,000
Target Selection/Evaluation	150,000	–	–	150,000
Land Acqs./Rentals	775,000	475,000	125,000	1,375,000
Detailed Geophysics	325,000	650,000	–	975,000
Site Selection	–	100,000	300,000	400,000
Deep Drilling	–	500,000	1,500,000	2,000,000
Contingencies	150,000	200,000	225,000	575,000
Total	$1,575,000	$2,100,000	2,325,000	$6,000,000

Exploration from funds budgeted in this fashion is designed to discover at least commercial geothermal reservoir. The budget represents an investment which will generate a satisfactory return on capital when coupled with developmental funds.

While there are exploratory risks associated with a carefully constructed strategy, an exploration program based on a budget of less than the projected $6 million must be considered totally speculative unless the venture is undertaken in a proven area.

CONCLUSION

The drilling of four deep exploratory wells based on a carefully planned strategy, modest land acquisition costs, and progressive exploration program should lead to at least one commercial discovery of geothermal energy.

A minimum exploration budget of $6 million is required to support an adequate exploration program.

Natural resource companies, large industrial consumers of electricity and utilities who are not active in geothermal energy exploration should initiate projects or join others who are already active. Discoveries of dry steam or hot water will help fulfill present-day as well as future power generating needs in an economically competitive and environmentally compatible fashion.

ABOUT THE AUTHOR

Mr. Barr is presently Chairman and President of the Earth Power Corporation, an applicant for Federal geothermal leases in ten states and co-owner of leases on fee lands in four states. He formerly was associated with a member firm of the New York Stock Exchange, first as a securities analyst and then as the head of syndicate and underwriting departments.

He has served as a Reviewer for the Geothermal Task Force Report for Project Independence, a panelist for the USC Law Center workshop "Geothermal Energy and the Law", and has been a member of the Geothermal Resource Council since its inception. He has been engaged full time in geothermal for the past four years. EARTH POWER is presently co-venturing with AMAX Exploration, Inc., a subsidiary of AMAX, Inc., in three states. The company is headquartered in Tulsa, Oklahoma.

Mr. Barr received his B.A. in Economics from Denison University, Granville, Ohio, in 1966 and has attended New York University Graduate School of Business.