A-1 DRILL SITE SELECTION

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DATA ANALYSIS AND DRILLING SITE SELECTION

for

ORE-IDA PROPERTY

ONTARIO, OREGON

including

geological, geophysical and hydrochemical

factors

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CONCLUSIONS

1. The seismic and hydrogeochemical studies conducted for phase 1 of the Field Experiment have encouraged the decision to proceed to the drilling phase. No negative factors evolved from the studies and data analysis.

2. Additional subsurface geological data from deep drill holes near Ontario, in both the Snake River depression and the adjacent borderland, confirm that rocks of the Idaho Group, an insulator, occur to a depth in excess of 1.5 km (5,000 feet). The Ontario area probably is located on an intradepression graben, within which the Idaho Group rocks may be as much as 1.9 km (6,200 feet) thick.

3. The Columbia River Group basalt flows, with interbedded sands and tuffs, underlie the Idaho Group. The basalts are about 1 km (3,300 feet) thick and are fractured in zones of tectonic stress, such as along the boundary of the Snake River depression. Permeability afforded by interflow scoria, volcanic rubble and vertical cooling joints will be interconnected further and enhanced by high-angle fractures.

4. A seismic reflection survey at Ontario identified a reflector horizon at a depth of 1.9 km (6,200 feet), which serves as an effective seismic basement. Its rough surface suggests fault displacement and/or topographic relief from erosion. Velocity characteristics of the reflector suggest it is basalt.

5. Data from the seismic survey are interpreted to suggest throughgoing west-northwest-striking faults with minor displacement in the Idaho Group, probably extending into the underlying Columbia River basalts. The faults have been projected geometrically to the depth where temperatures greater than 150°C are forecast, below 2.2 km (7,000 feet).

6. Gravity surveys suggest northwest-trending structures in the Ontario area but cannot be used to locate specific faults.

7. An aeromagnetic survey indicates structures of northerly and northwesterly trends in the vicinity of Ontario; however, these could not be identified on the basis of known geology nor were magnetic gradients coincident with faults indicated by the seismic survey.

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8. Hydrochemistry of a limited number of water wells in the Ontario area suggests some leakage from a deep-seated aquifer. Total dissolved solids, chloride and sulfate concentrations are unusually high for waters of the area. Some of these high concentrations are in wells close to the faults indicated by the seismic survey.

9. The general northwest trend of heat flow anomalies in the Snake River depression and bordering structural elements support the indications that northwesterly faults occur at Ontario. However, Ontario is not associated with any of the narrow zones of high heat flow that appear to represent major faults.

10. It is possible to select a primary and a secondary site for drilling the initial exploratory production holes, based on the above, and especially on the evidence of one near-certain and one possible fault zone illuminated by the seismic survey.

11. The primary site is located at the southeast of Ontario. It is within an area limited by the freeway (I-80 N) to the east-southeast, the Treasure Valley Community College to the west-southwest, 9th Avenue on the south and 7th Avenue on the north. It would be about 1.7 km (1.1 miles) from the Ore-Ida plant and the planned heat-exchanger facilities.

12. The secondary site is located at the northeast of Ontario. It is on the Ore-Ida property, between the freeway and the Snake River. It is adjacent to the settlement lagoons, about where the Field Experiment Proposal initially recommended that drilling sites be selected.

13. The primary site is chosen to take advantage of the projection at depth of the near-certain fault and therefore is more favorable technically, as this enhances the probability of drilling into rocks with high permeability in the potential thermal zone. The fault would possibly provide a channel along which temperature isotherms would be raised surfaceward. These two factors might permit a shallower hole with a shorter length of completion zone necessary to produce thermal fluid.

14. The primary site should be drilled to make the all-important first test of the resource. The secondary site could then be drilled to delineate field extent and/or for reinjection objectives. Should the secondary site prove to contain sufficient producible fluid at temperatures above 150°C, the roles of the two holes could be switched, so that a less expensive pipe can be constructed to carry waste fluids to a southern reinjection site.

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RECOMMENDATIONS

1. Do no further geological, geophysical and/or geochemical surveys. This includes temperature-gradient and seismic surveys.

2. Investigate rights of way from the primary site to the Ore-Ida property for movement of fluids to heat exchangers and waste disposal areas.

3. Procure land positions at the primary site by purchase, option to purchase and/or lease. Be certain that these carry all subsurface mineral and water rights, including disposal rights, plus full rights to surface occupancy and land use.

4. Determine availability of temporary disposal sites for geothermal wastes for period of reservoir testing (before disposal well is completed).

5. Proceed to the well-design phase of the Field Experiment.

6. Prepare specifications for all drilling, completion and testing operations for the primary site and, with necessary modifications, for the secondary site.

7. Solicit bids from selected drilling contractors to drill the first hole at the primary site.

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INTRODUCTION

Preface

Phase I of the Field Experiment, Food Processing Industry, Geothermal Energy, by Ore-Ida, under contract No. ET-78-C-07-1725 with DOE, provides that a seismic survey, data analysis and decision where to drill the first well will be accomplished and reported. GeothermEx, Inc., by letter contract from CH2M-Hill, was appointed sub-subcontractor to perform data analysis and reporting tasks for phase 1.

The seismic survey was planned during May and June of 1978 and a sub-subcontract was signed between CH2M-Hill and Geotechniques, Inc. (GTI), Boise, Idaho, on 29 June 1978. Geotechniques agreed to provide the qualified team and equipment to collect the field data, process the data and report to GeothermEx and CH2M-Hill the results of the seismic survey. The GTI report is a separate appendix to this data analysis. The information and interpretations from the GTI report have been used for GeothermEx's applications to site selection. Additionally, GeothermEx used the services of an associated seismologist, independent of GTI, to evaluate the field procedures of GTI, the field data records, the data printout sections from the data analytical laboratory, and the interpretations of GTI. GeothermEx's seismologist independently interpreted the data laboratory's sections and drew interpretive maps.

GeothermEx solicitied additional geophysical data from other sources. Dr. Couch, Geophysics Group, Oregon State University, was contracted to provide a Total Field Magnetic Anomaly Map of the vicinity of Ontario, Oregon, from data obtained during 1976 for other programs, but not previously processed and contoured. The result was a map, scale 1:62,500, with contour interval of 10 gammas, extending for a minimum radius of 3.5 miles from Ontario.

Private sources provided additional gravity maps of the Ontario area. These are residual gravity contour maps, scale 1:48,000, with contour interval of 0.5 milligals. In addition, the public Bouguer gravity maps of southwestern Idaho and eastern Oregon, scales 1:500,000 and 1:250,000, respectively, were synthesized into a single map, scale 1:250,000, to include the Ontario area. Previously, the Ontario area was at the margins of both maps. A gravity map of Weiser, Idaho, scale 1:125,000, was also studied.

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GeothermEx sent a field geochemist to Ontario to canvass the availability of wells for water sampling. Very few wells were available and most of these were shallow. Thirteen samples were collected from wells and springs that included those available in and near Ontario and a few at Weiser, Idaho. These samples were analyzed by a commercial laboratory, and the results are discussed herein.

The surface and subsurface geology of the Ontario area were described by the Technical Proposal, Volume 1, in response to PON EG-77-N-03-1553. For the data analysis, additional information was developed by acquiring access to new and private public lithologic and electric logs from deep drill holes. This information has been used to clarify the description in the Technical Proposal and to construct geologic cross sections in the form of fence diagrams.

Compilations of these data and synthesis of the interpretations have led to redefinition of the potential resource and location of an optimum drilling site and recommendation of actions toward obtaining land position and permits to drill.

Scope and Purpose of Report

This report is submitted as a concise presentation of the facts and interpretations developed by the activities described in the Preface. The report has as its objective providing the prime contractor, subcontractor and DOE with documentation of the results of the data analysis. With these results and interpretations, DOE and the prime contractor are to reach mutual agreement on whether to proceed to the drilling phases and at what location the initial well should be drilled.

DATA ANALYSIS

Drill Hole Stratigraphy and Structure

The original *Description of the Resource* from the Technical Proposal, Volume I, has been modified and supplemented by information obtained during the past few months. Therefore, it is resubmitted herein as the vehicle for reporting the new data and interpretations.

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The Snake River geomorphic province is a topographic and structural depression in the crust that extends from about 32 km (20 miles) northwest of Ontario in east-central Oregon, eastward across Idaho to Yellowstone Park in Wyoming. The western part of the depression is referred to as the Snake River Basin. The boundary of the depression eastward, northward and westward of Ontario is shown on the accompanying Generalized Geologic Map (plate 1). Lithologic and electrical logs from drill holes on different sides of the boundary of the depression make it clear that a significant structural discontinuity occurs at its margin. There appear to be about 1.8 km (6,000 feet) of relief on the top of the Miocene Columbia River Group between Weiser and Ontario.

The Snake River Plain formed as a crustal rift or compound graben beginning in late Oligocene or Miocene time; crustal extension continued episodically at least into the Pleistocene epoch. Volcanism has taken place almost continuously during that time, within the plain and at the margins of the uplands to the northwest and south.

Regional seismic surveys indicate that compared to the thin-crusted Basin and Range province, the Snake River Plain exhibits a totally thicker crust. However, the upper or granitic layer appears to be absent or quite thin and patchy beneath the plain. The crust in the region therefore consists of a thin, hot intermediate layer on top of a thick, hot lower crust. We may infer that the granitic layer has been altered, remelted, or is absent because of rifting and has been replaced by upward-moving mantle differentiate. This is typical of flood basalt and crustal rift areas. This provides the model for a region of significantly higher heat flow than normal and the support for presence of hot water systems.

Thousands of meters (thousands of feet) of fluviatile and lacustrine sediments and volcanic rocks have been deposited in the depression during Holocene to Miocene time. There are more than 4 km (12,500 feet) of Tertiary and Quaternary bedded sedimentary and volcanic rocks in the deeper parts of the basin and at least 2.5 km (8,000 feet) of these rocks in the basin near Ontario. These rocks decrease in thickness to the northeast, west and northwest of Ontario. Composition of the Tertiary and Quaternary bedded rocks ranges upward in Chevron Highland No. 1, S. 24, T. 6 N., R. 5 W., from rhyolites and andesites to andesitic tuffs, basalts, basaltic to rhyolitic tuffs, sandy and silty tuffs, sandstones, siltstones, claystones, clays, silts and gravels. The Highland No. 1 drill hole is 3.8 km (12,000 feet) deep and represents one of the thickest Tertiary and Quaternary sections in the depression. In the vicinity

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of Ontario, no other drill holes have penetrated rocks below 1.6 km (5,200 feet). It is expected that the total Tertiary and Quaternary rocks at Ontario may not be as thick as at the Highland No. 1 location, but post-Miocene faulting may have produced a thicker Pliocene Idaho Group section at Ontario.

The surface geology in the vicinity of the Ontario property of Ore-Ida is relatively simple. Quaternary alluvium and terrace deposits crop out over a radius of about 6.5 km (4 miles) around Ontario, and the alluvium is even more extensive where the Snake and Malheur Rivers join, to the south. The alluvium and terrace deposits do not display evidence of recent faulting, except through extrapolation from the linearity of some stream channels, as may be observed on the topographic map (plate II). The alluvial material is not likely to support features in which evidence of faulting is preserved.

Bounding the Quaternary deposits are rocks of the Idaho Group, which are Pliocene in age. These rocks crop out in a broad belt for more than 20 km (15 miles) in all directions from Ontario. The Idaho Group appears to lap over the structural boundaries of the Snake River depression but becomes much thinner beyond the depression. This abrupt thinning is evident in Chrestesen No. A-1, S. 29, T. 11 N., R. 3 W.

The Idaho Group has been divided into formations by some authors. The formation names do not extend with consistency across the Oregon-Idaho boundary, for rock units which are obviously lithologically and stratigraphically similar. In fact, equivalent units have been given different names when they have been deposited in adjacent basins separately by minor highlands.

In eastern Oregon the stratigraphic succession within the Idaho Group is, from youngest to oldest, "Coarse-grained Basalt," Chalk Butte Sediments and Basalt Flows, Grassy Mountain Basalt, Grassy Mountain Sediments, and Kern Basin Formation. In Idaho the group includes the Black Mesa Gravel, Bruneau Formation, Chalk Hills Formation, Banbury Basalt, and Poison Creek Formation. The group may total more than 2 km (6,300 feet) in thickness in interior grabens within the main Snake River depression but may be less than 1.2 km (4,000 feet) thick at interior horsts. It appears from well logs and also is reported from the active seismic surveys conducted for this project (Appendix 1) that the Ontario area is a local graben with Idaho Group rocks more than 2 km (6,300 feet) thick. Southward, well logs indicate that a horst occurs, trending northwesterly, and Idaho Group rocks may be thinner than at Ontario. Private

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seismic records support this conclusion (Applegate, personal communication, 1978).

Within the Idaho Group, the principal lithologies are tuffaceous claystone, tuffaceous sandstone, sandstone, shale, siltstone, basalt and some interbedded conglomerates. In some areas, the basalt flows may comprise a formation nearly 300 m (1,000 feet) thick, which has been called the Grassy Mountain Basalt, but the seismic data obtained at Ontario did not indicate significant basalt flows within the first 2 km (6,300 feet) below surface. A reflector horizon identified by the seismic survey at about 250 m (800 feet) depth which was probably basalt was neither thick nor continuous. We may conclude that the Grassy Mountain Basalt will not be a factor influencing the geothermal resource at Ontario. The reservoir rock at depths where the temperature is sufficiently high for production interest will be Miocene basalts of the Columbia River Group.

Initially, it was calculated that the Columbia River Basalt (equivalent southwestward is the Owyhee Basalt) would be encountered at a depth of less than 1.7 km (5,500 feet) below surface at Ontario. The seismic survey identified seismic basement, a strong reflector horizon, at about 2 km (6,200 to 6,300 feet) depth. It is probable that this seismic basement is the Columbia Basalt.

The seismic survey sections do not penetrate the reflector horizon to determine thickness of the basalt or nature of the materials underlying the basalt. The survey did suggest that the reflector horizon had significant relief. The relief may be either structural or erosional. The tectonic history of the area suggests that the relief is structural.

Total thickness of the Columbia River Basalt flows at Ontario is not known. A recently drilled well 12 miles northeast of Ontario, outside of the Snake River depression, intercepted about 1.9 km (6,000 feet) of basalt flows, below about 100 m (300 feet) of Idaho Group sedimentary rocks, with only minor interbedded tuffs and volcaniclastic rocks interbedded with the basalts. This same thickness has been measured in surface outcrops north of Weiser. Southward from Ontario, in the logs of deep drill holes, there has been a less thick section of the basalt observed. At the James No. 1 well site, S. 27, T. 4 N., R. 1 W., the basalts are less than 1 km (3,000 feet) thick. The basalts are also less than 1 km (3,000 feet) thick in the subsurface at the Highland No. 1 drill hole.

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The Columbia River Group characteristically is split into two series of flows by tuffs and lacustrine sediments with varying thickness. The pyroclastic and sedimentary rocks have been named the Payette Formation (stratigraphic equivalent of the Sucker Creek Formation). Ontario was at the approximate center of the location of Miocene Lake Payette, and the Payette Formation name may be preferable to Sucker Creek in this area. The tuffs and lacustrine rocks are as much as 700 m (2,200 feet) thick. Another 1 km (3,000+ feet) of basalt flows may occur below the Payette Formation. In the James and Highland holes, there are at least 1 km (3,000 feet) of shale, silt, tuff and interbedded basalt flows below the thick section of flow-on-flow basalts which mark the upper part of the Columbia River Group. Southward and eastward into Idaho, felsites become more frequent. A silicic volcanic assemblage in that area originates in a magmatic regime with different composition.

The stratigraphic column presented by Corcoran and Newton (1963) may be applied to the Ontario area. It is compatible with the drill hole records and sections supplied by these authors as well as the column constructed by Warner (1977). A stratigraphic column after Corcoran and Newton is shown in figure 1. The geologic cross sections (fence diagrams) of plate III also are after Newton and Corcoran, with the added stratigraphic information from recent drill hole logs and the seismic data from Applegate (1978).

Seismic Reflection Survey

The greatest effort and budget for collection of additional data for site selection was directed toward an active seismic survey. It was thought possible that a seismic reflection survey would inform us of two critical factors about the potential resource area. These were depth to the principal reservoir formation and degree of fracturing present in the reservoir rocks. This information could only be expected from a survey run under ideal conditions, but interbedded volcaniclastic and volcanic flow rocks do not provide ideal geologic conditions for response to seismic profiling. Nevertheless, the survey has provided valuable information.

The survey was sufficiently important that an expert seismologist was used in addition to the well-qualified seismic contractor to make independent evaluations of the field procedures, data laboratory analyses and interpretation. We therefore had the advantage from the outset of

FIGURE 1. STRATIGRAPHY AT ONTARIO

Formation	Principal Lithology	Thickness at Ontario	Age
Quaternary Alluvium and terrace deposits	Gravel, sand, silt	0-100+ meters	Pleistocene and Holocene
Snake River Quaternary eruptives	Basalt flows	Absent	
Idaho Group, may include			Pliocene
Chalk Butte Fm./Chalk Hills Fm.	Tuffaceous claystone, tuffaceous siltstone	1,200+ meters	
Grassy Mountain Basalt/ Banbury Basalt	Dense basalt	300 meters Absent?	
Grassy Mountain sediments/ Kern Basin Fm.	Tuffaceous sediments, tuffs	100± meters Absent?	
Deer Butte Fm./Poison Creek Fm.	Tuffaceous sediments	100± meters Absent?	
Silicic Volcanics	Rhyolite flows, welded tuffs	Absent	
Columbia River Basalt/ Owyhee Basalt	Basalts	1,000± meters	Miocene
Payette Fm./Sucker Creek Fm.	Tuffs, lacustrine sediments	To 700± meters	
Columbia River Basalt (lower series)	Basalts	1,000± meters	
Idaho Batholith	Granitic, intrusions	Absent?	Pennsylvanian to Cretaceous
Paleozoic-Mesozoic Rocks	Metasediments, intrusions	Basement	

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having confirmation of many results of the survey as well as discussion and some resolution of contested interpretations.

We can make two valuable assumptions as a result of the survey. It is suggested that the first continuous basalt is that of the principal target reservoir, at a depth of about 1.9 km (6,200 feet). This conclusion is based upon agreement by the seismologists that the seismic "basement" is at that depth. This would appear to be the Columbia River Basalt Group, from analysis of the known lithologies of their region and their reaction to seismic reflection and their seismic velocities. Since anticipated basalts were not observed at depths between 1.2 and 1.9 km (4,000 and 6,200 feet), we may even assume that it is possible to project the gradient of 85°C/km from the surface to about 1.9 km, rather than to 1.2 km (4,000 feet) as in the Field Experiment Technical Proposal. This would increase the projected temperature from about 150°C to about 175°C at a depth of 1.9 km (6,200 feet), in the event there is no significant increase of rock thermal conductivity between 1.2 km and 1.9 km (4,000 and 6,200 feet). This provides additional optimism for successful completion of the field experiment.

There may be discontinuous basalts in the section above the Columbia River Group, but they would not have a net effect equal to 300 m (1,000 feet) of continuous "Grassy Mountain Basalt." The tuffaceous rocks with minor interbedded flow basalts of the Idaho Group would then consitute a low conductivity insulator for 1.9 km (6,200 feet) over the reservoir rocks.

There is some difference of opinion between the seismologists about the number and precise location and direction and dip of some faults in the Ontario area, but they agree that faults occur. In some instances there is agreement about the precise location, direction and dip. It was not previously known that there were any major fractures or faults in the vicinity of the Ore-Ida property and leased areas. The seismic data in some instances are so strong as to leave no doubt that faults occur, albeit with minor displacement. Where data is poor and/or there is disagreement between seismologists about interpretation of the data, there still may be large fractures and joint systems with little displacement. Plate IV provides a synthesis of the conclusions from the seismic survey interpretations.

The presence of faults and fractures is still considered important to the evaluation of the geothermal resource at Ontario. Open fracture systems would provide increased permeability and would transfer

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heated fluids closer to the surface. The reservoir rock is likely to be flow-on-flow basalt of the Columbia River Group. There are minor interbeds of sand and tuff in the basalt. Primary porosity in the basalts is restricted to shrinkage joints and interflow scoria and basalt rubble/loose soil zones. An individual basalt flow more than 30 m (100 feet) thick may have nearly zero permeability in its interior. It has been observed that yields are highly variable in areas where wells are producing from this unit.

Basalt flows in the Columbia River Group which have been stressed by active tectonic environments may develop closely spaced, nearly vertical open joint systems. Joints are evident in the electrical logs of wells drilled in the basalt near the active margin of the Snake River depression. The effect of fractures and major fault systems would be to increase effective porosity and permeability within individual basalt flows and also to connect the highly permeable interflow zones. Therefore, it would be advantageous to site a hole where it is known that the hole would intersect a major fracture at the projected depth of production-temperature fluid. The added permeability may be the difference between a single well which can and cannot produce 800 gallons per minute from an interval between 2.2 km (7,000 feet) depth and 2.4 km (7,500 feet) in an otherwise unfractured basalt. In an internally jointed basalt, the major fracture could reduce by several hundred meters (nearly 1,000 feet) the completion zone necessary for production. At depths below 2.2 km (7,000 feet) the cost difference may be $200,000. It is therefore of considerable advantage to locate the hole where a major, steeply dipping fracture may be projected, from geometry interpreted from the seismic data, to intersect the top portion of the reservoir.

It is also well known from study of geothermal reservoirs in many different lithologies that a major fracture system will tend to bow the isotherms surfaceward. In other words, the fracture is a permeable conduit for thermal fluids. Under pressure from the potentiometry of the hydraulic system, the thermal fluids will rise along the fault. Under some conditions, the fluids may even reach the surface as a thermal spring. Therefore, a drill site which is located so that the hole intercepts a fracture system may encounter fluids warm enough for production higher in the section than a site where the drill hole encounters normal hydraulic conditions. Again, this may lead to reduction of costs in the event a shallower hole than programmed is possible.

The detailed results of the seismic reflection survey are described in Appendix 1 of this report. This represents the final report which the seismic contractor submitted. A separate commentary about the data reported by the processing laboratory is provided as Appendix 2. The commentary uses the same reference numbers to faults and sections for convenience, although the commentator may disagree with the actual existence of the faults.

Wherever there is reasonable doubt about existence of faults after synthesis of the two interpretations of the seismic data, it appears preferable to assess the potential drill site locations as if the fault does not exist. This is decidedly a conservative view. The faults which are controversial probably do exist in some form of fracture or joint system. However, it is critical that their geometry be accurately known before these structures can be projected to the depth of the target reservoir at the place where production temperatures are reached, in order for them to be useful. This cannot be done with the existing data for some proposed faults.

Suggestions have been made that additional information should be sought by running additional seismic lines to cover the area where results were poor. There is no guarantee that new efforts will produce better data. In fact it is almost assured that a new survey would have to employ larger explosive charges buried at greater depths to have a good chance of better data recovery. Such a survey would probably cost upwards of $10,000 per line 1.6 km (1 mile). It would be difficult to obtain environmental agency approvals and permits from land owners for the deep drilling and large explosive charges. Additional seismic surveys are therefore not recommended.

Based on the interpretations of the seismologists who have reviewed the seismic data, two preferred locations for the proposed drill holes are recommended. The first location, in order of preference, is at the southeast part of Ontario, in the SE4, SW4 Sec. 10, T. 18 S., R. 47 E. A location north of the center of the section should intersect the best known fault at a depth below 2.2 km (7,000 feet). Precise location of the drill hole may be accomplished to obtain the best combination of all factors: land control, pipeline alignment, and geology.

The second location is at the Ore-Ida property, in the vicinity of the NE4, Sec. 3, T. 18 S., R. 47 E. The imprecisely known subsurface positions of the northerly faults makes precise location of the secondary drill hole on the basis of geology impossible. It would be logical to select the location based upon construction considerations. The location proposed in the Field Experiment proposal, close to the settlement ponds, is acceptable.

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It should be emphasized that except for the seismic data, coupled to suggestions of geochemistry and geomorphology, the subsurface geology is quite the same in both the southern and northern drill site recommended locations. Little displacement on the faults is suggested. The seismic data, as interpreted by consensus of seismologists, give weighty technical support to the southern drill site as the "best first shot." Poor data from the northern seismic lines had led to disagreement between the seismologists. This cannot be considered to make the interpretations of the existence, locations and dip of the northern faults any better than ambiguous. It would be providential to intersect a fault at the depth of the potential production horizon, but we could not rely upon geometric solutions.

Gravity Survey

The assembled gravity information used for the Technical Proposal for the Field Experiment showed that the Snake River Basin is characterized by a strong northwesterly grain in western Idaho and parts of eastern Oregon (plate V). The very marked en echelon west-northwesterly trending anomalies in the western Snake River depression persist into Oregon, where they are marked in the vicinity of Willow Creek, 25 km (15 miles) west of Ontario. However, the anomalies near the axis of the Snake River depression in Idaho, such as near Caldwell, are positive (gravity highs), while that at Willow Creek is negative (gravity low).

Ontario is very nearly on the trace of the axes of the positive gravity anomalies, between the high centered near Caldwell and the low at Willow Creek. At Ontario, the gravity picture is complex and unclear. Ontario is situated on a nearly featureless shelf between the Caldwell high and Willow Creek low. A slight negative anomaly at Ontario is probably explained by the deep sediments with relatively low density at the junction of the Snake and Malheur Rivers. Little more can be observed on the small scale, 5-gamma contour interval map.

Private sources have permitted the use of a 30-year-old gravity survey of the Ontario area. This survey mas made with 800-m (.5-mile) station intervals and a residual contour map was produced at scale of 1:48,000 and contour interval of 0.5 milligals. A portion of the map is shown as plate VI. The residual contour map is marked by a group of nearly circular to rectangular gravity anomalies with amplitudes between 2 and 6 milligals. The largest of these is a high anomaly at Malheur Butte. A corresponding low occurs about 1.6 km (1 mile) west of the

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Ontario airway beacon. The Ore-Ida property is on a northerly trending gradient with a slope of about 1 milligal per 1.5 km (1 mile).

The potential geothermal resource area at Ontario is located at a gently negative anomaly, sloping toward positive gravity features to the east, southeast and southwest. This is dissimilar to the potential resources areas at Weiser and Grandview, Idaho, and Vale, Oregon, which are located near positive anomalies. Moreover, the Ontario area is not associated with a known major structure, while the others are.

The lows and highs near Ontario are separated by gradients along which may be projected several northwest and west-northwest trending lines. Northeasterly trends and a northerly trend also may be observed. The reason for the distribution and shape of anomalies is not clear. They may be explained by differing depths to the basalt of the Columbia River Group, to a discontinuous younger basalt or other dense rock or to differing composition, degrees of compaction and thickness of the deep sedimentary rocks.

The gradients may mark the approximate location of discontinuities or faults. The shallow portions of faults determined by the seismic survey do not appear to be supported by gravity gradients, but there is one northwest-trending gradient about 2.5 km (1.5 miles) south of the airport, which may mark displacement of basement on the faults indicated by the seismic survey. The gravity map is not sufficiently detailed nor are stations sufficiently close to be compatible in the seismic map especially if there is very little displacement on the faults.

The regional gravity map was rationalized in the field experiment proposal as a northwesterly grain imparted by the large tectonic feature of the basin and by internal components of the basin--fracture zones and changes from high to low density rocks.

Northwest-trending, discontinuous, subparallel faults with individual faults to 20 km (12 miles) in length mark the northern and southern boundaries of the Snake River Plain. No clear evidence exists for the presence of right-lateral strike slip faults, as suggested by Lawrence (1976), or northeast-trending structures in the Snake River Plain. Gravity maps suggest that there are intragraben or intrarift faults, horsts and small grabens, oriented northwesterly. A mechanical model is an extensional couple, which would produce northwest-trending normal faults, north-northwest-trending shear fractures with normal movement and weakly developed northeast-trending fractures.

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Aeromagnetic Survey

The Total Field Magnetic Anomaly Map (plate VII) produced for this project from the data banks by the Geophysics Group at Oregon State University in 1978 has several interesting features. Significant area-wide trends as well as local features are observed in the 430 square km (130 square miles) within the map boundaries.

A very steep regional gradient appears with magnetic highs to the east. There is a decline from as much as 300 gammas in the east to zero (0) gammas in the west.

Within this overview, there is a linear magnetic high which runs northward from the western side of Ontario for about 14 km (9 miles). Closure on this feature is about 40 gammas within 2.6 km (1.7 miles) distance to the east and west. It is not possible to rationalize this magnetic anomaly from the observed geology. It may reflect a buried fault, with west side up, bringing volcanic rocks surfaceward.

Two negative magnetic features occur on the map, centered about 4 km (2.5 miles) east and 14 km (9 miles) north of Ontario (center). The anomaly just east of Ontario coincides with the deep sediments at the confluence of the Malheur and Snake Rivers. It has a diameter of 6 km (3.5 miles) of closure, with relief of about 20 gammas. The second negative feature extends northward, off the mapped area. It has closure of about 10 gammas. The two features can be connected by a northerly oriented axial line. The trace of the axis would approximately coincide with the course of the Snake River.

There is no apparent reason from surface geology for the steep magnetic high east of Ontario. Some single lines of equal magnetic intensity near the northeast boundary of the magnetic low just east of Ontario trend northwesterly, but this is very tenuous support of northwesterly trending structures. The intense gradient 12 km (7 miles) northeast of Ontario, trending northwest, may indicate fault control near the margins of the Snake River depression, but Riens Estate No. 1, in S. 9, T. 8 N., R. 3 W., shows that the Idaho Group sediments are 1.4 km (4,800 feet) thick 22 km (14 miles) east of Ontario.

We may classically assume that the linear to circular high magnetic anomalies in the Ontario area signify relative thinning of nonmagnetic sections of sedimentary rocks, positions of Quaternary basaltic eruptive centers and diabasic intrusive masses. Intense gradients bordering magnetic highs and lows may indicate fault control. It is

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difficult to assign these classical conditions to any of the magnetic anomalies at Ontario.

Hydrogeochemical Survey

A hydrogeochemical survey of the area produced some interesting, if slightly ambiguous, results. Samples were obtained from 10 wells in the Ontario and Payette areas and 2 wells/springs at Weiser.

The wells in the Ontario and Payette areas had SiO_2 concentrations between 41 and 73 mg/l. This cannot be considered indicative of a thermal reservoir leaking toward the surface, even if we credited cold water mixing.

At least 3 wells at Ontario and 1 well at Payette had waters with anomalously high chloride (Cl). The wells at Ontario (0-I-3, 0-I-5, 0-I-8), in Sections 7, 4 and 10, T. 18 S., R. 47 E., are wells with high total dissolved solids (TDS). These wells also have high sulfate (SO_4) concentrations. All of these wells are within less than 1 km (0.6 miles) north and south of the 1.9 km (6,200 feet) depth projection of the most prominent fault located by the seismic survey. It must be stated that other wells might also have high TDS, Cl and SO_4 concentrations but that the sampling represents too small a statistical group. However, we must also consider that the chemistry of these wells indicates leaking from a thermal reservoir. If so, the favorable feature is that the thermal reservoir or reservoirs exist. The unfavorable feature is that the leakage may mean that the rocks of the Idaho Group have a less insulative character than attributed to them. If the Idaho Group is more conductive than lithology indicates, then the temperature gradient may be less than the 85°C/km anticipated. The geochemical information is not adequate to change the original gradient projections.

The hydrochemical data accompanies this report as Appendix 3 and is shown on the topographic map, plate II.

It is of interest to compare the general chemistry of the waters sampled at Ontario with the thermal waters at Weiser. At Ontario the low TDS well waters (equal to or less than 500 mg/l TDS) are confined to two holes, 0-I-6, with TDS of 308 mg/l, and 0-I-4, with TDS of 330 mg/l. Both are within less than 0.5 km (0.3 mile) of the Snake River. These are Na-Ca-HCO_3 waters at 0-I-6 and Ca-Na-HCO_3 waters at 0-I-4.

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At Ontario, waters with high TDS and/or thermal waters are Na-Ca-HCO_3-SO_4 in nature. Ca may occasionally equal Na. This also describes the high TDS and/or thermal waters in the Weiser area. In some of the hot springs at Weiser, SO_4 and Cl may have greater concentrations than HCO_3.

The waters at Ontario have unusually high concentrations of Mg, in the case of most of the wells sampled. Only well O-I-2, south of Payette, has less than 5 mg/l of Mg. By contrast, the great majority of waters sampled in the Weiser area have very low Mg, often less than 1 mg/l. This may be accounted for by the greater amount of fragmental basic volcanic lithologies in the subsurface at Ontario than at Weiser.

There are no strong indications from the geochemistry of waters collected at and near Ontario that a powerful hot water reservoir occurs in the subsurface. This is not surprising and is not a strong negative comment about the potential for producing hot water below electrical generating temperatures. It is reasonable to assume that a hot water reservoir occurs at depth and that water rises from the Columbia River Group flows into the overlying volcaniclastic rocks and heat is broadly dissipated into the thick insulator. No convection cell appears to be formed. In this case, we would expect to see only weak suggestions in the hydrogeochemistry of a thermal system. It was hoped that the geochemical survey would combine with the data developed by the seismic survey and geologic analysis to indicate fracture leakage zones from the deep thermal reservoir. This may be suggested by the chemistry of the waters distributed in wells near the projection of the proposed fault in the southern part of Ontario.

The small amount of chemical data developed do not provide assistance in estimating reservoir base temperature nor in indicating direction, velocity and age of the water in the deep reservoirs.

Heat Flow

A heat-flow analysis has been compiled for the Snake River Plain by Blackwell from temperature-gradient hole information, temperatures measured in stabilized wells, and laboratory measurements of thermal conductivity of recovered rock cores and chips (figure 2). Ontario is within a zone of 2.5 Heat Flow Units (= 2.5 microcalories per square centimer per second). Heat flow is determined by the formula:

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Heat flow (Q) = $k\frac{dt}{dx}$, where

k = rock thermal conductivity, in situ (includes porosity and fluid conductivity corrections)

$\frac{dt}{dx}$ = temperature gradient, degrees C per kilometer (= DT)

With knowledge of any two of the factors, the third may be calculated.

At Ontario, a shallow gradient hole has determined a temperature gradient of between 80° and 90°C/km. Other holes in the area confirm that we can expect this gradient to persist to depths of at least 1.2 km (4,000 feet), before changes from sedimentary rocks with k = 3.2 (average) to volcanic rocks with k = 5.0 to 6.0 probably occur. The effect of higher k would be lower DT. The DT is estimated conservatively to 55°C/km for the zone from below 1.2 km (4,000 feet) to 1.5 km (5,000 feet) and 48°C/km for the zone below 1.5 km (5,000 feet). Using these estimates, a synthetic gradient at Ontario would be:

1. Surface to -1.2 km (-4,000 feet) at 85°C/km = 10° + 104° = 114°C.

2. -1.2 km (-4,000 feet) to -1.5 km (-5,000 feet) at 55°/km = 114° + 17° = 131°C.

3. -1.5 km (-5,000 feet) to -2.2 km (-7,000 feet) at 48°/km = 131° = 29° = 160°C.

Thus, we could anticipate a temperature of 160°C (= 320°F) at a central target depth of 2.1 km (7,000 feet). It is unlikely that the temperature would be less than 150°C (300°F) nor is it likely that the temperature would much exceed about 175°C (350°F) at that depth. In the event that seismic basement at 1.9 km (6,200 feet) is the first major basalt, the sedimentary rock average k = 3.2 may persist to that depth. The effect of this would be to raise the gradient between depths of 1.2 km (4,000 feet) and 1.9 km (6,200 feet). Consequently, the temperature at 1.9 km (6,200 feet) would be about 175°C. Thin, discontinuous basalts high in the section would not alter this estimation, but continuous basalt flows more than 59 m (150 feet) thick conceivably could drain hot water flow and reduce the gradient to nearly isothermal conditions below the basalts.

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There is evidence from the Chevron Highland No. 1 gas and oil wildcat exploration hole in T. 6 N., R. 5 W., S. 24, that the conservative synthetic gradient constructed for Ontario is quite reasonable. The Chevron hole was drilled to a depth of 3,646 m (11,963 feet). An overall average gradient of 61.2°C/km was obtained to a depth of 3,246 m (10,650 feet), based upon temperature measurements of 210°C at that depth. The Chevron hole is located in a zone with average regional heat flow of 2.0 to 2.5 HFU, according to Blackwell, which is less than the average heat flow at Ontario.

Figure 2 clearly shows the parallelism between the northwest-trending structural anomaly of the Snake River depression and the heat flow anomalies. The central axis of the rift zone appears as an anomalously low heat-flow zone. There, the average heat flow is about 1.5 ucal/cm^2/sec. (- 1.5 HFU). The low anomaly may be caused by masking of gradients by thick, young, central basin formations saturated by cold water or may represent real reflections of lateral distance from heat sources. The upper part of the crust may be thinner than normal in the Snake River Basin, providing a high regional gradient.

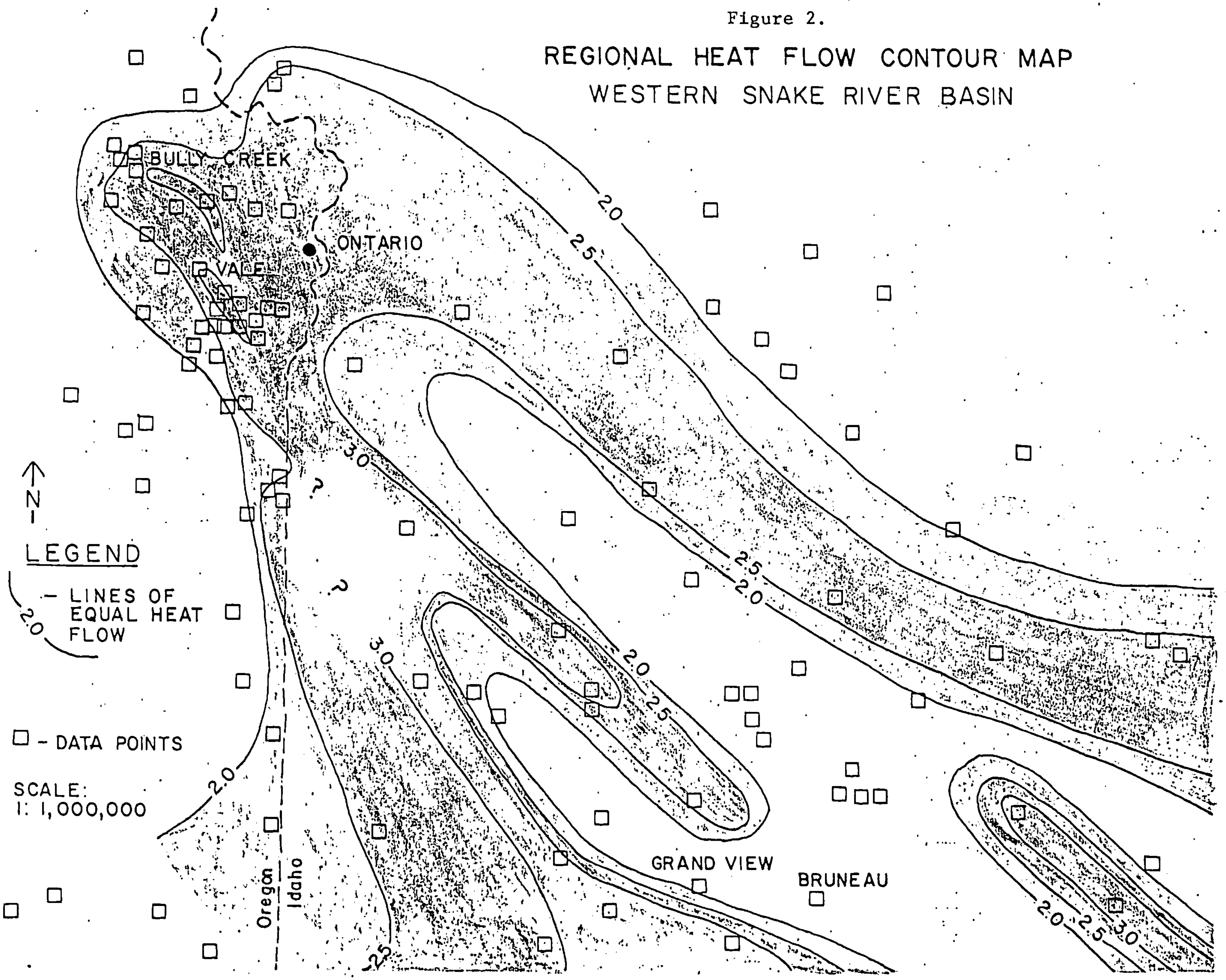
Distributed in an en echelon northwest-trending pattern along and southwest of the regional average 1.5 HFU area are a series of high heat-flow anomalies. In the anomalies, 3 HFU are exceeded. In Oregon, small areas of high heat-flow anomalies are found in the vicinities of Vale and the Bully Creek-Cottonwood Mountain areas west of Ontario. Another is located in Dry Gulch, between Ontario and Jamieson. The anomalies in Oregon are long, narrow features apparently associated with faults. The faults mark the boundaries between basin and horst blocks beyond the main Snake River depression.

There is no specific, clearly founded heat-flow anomaly associated with Ontario, Oregon. Ontario is located in a broad zone of average 2.5 HFU. Some values approaching 3.0 HFU are also found in the zone. The shape of the zone including Ontario is an inverted "u," with the base ending at the Bully Creek and Weiser areas. The zone appears to follow the shape of the western Snake River Basin and indicates, as do geology and other geophysical surveys, that the main basin terminates about 15 miles northwest of Ontario.

POTENTIAL SITES

Two areas have been identified as potential sites for the first exploratory drill hole for the Field Experiment. The objective is a

Figure 2.



REGIONAL HEAT FLOW CONTOUR MAP
WESTERN SNAKE RIVER BASIN
BULLY CREEK
ONTARIO
VALE
GRAND VIEW
BRUNEAU
Oregon
Idaho
N
LEGEND
- LINES OF EQUAL HEAT FLOW
2.0
- DATA POINTS
SCALE:
1: 1,000,000
2.0
2.5
3.0

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production well. Identification of a reinjection well location is a secondary objective. One location is in the southern part of Ontario and one is in the northern part of Ontario. The technical support, from the seismic survey, is considerably stronger for the southern site. Consequently it is referred to as the primary site and the northern site is referred to as the secondary site.

Primary Site

The primary site is an area defined by geometric projection of fault III to a depth of 2.2 km (7,000 feet). This has been done using the limits of dip of the fault plane as 65° and 80° northeastward. The result is a zone about 600 m (1,800 feet) wide from southwest to northeast, as indicated on plate IV.

The area is bounded by the freeway (I-80) on the east and may be extended west-northwestward to the campus of Treasure Valley Community College. The fault zone persists further westward but would be beyond a 3.2-km (2-mile) limit from the Ore-Ida plant site beyond the community college. It is proposed that there is greater geological likelihood that the fault is at an average dip closer to 65° than 80°. Therefore, a site is recommended east of the Union Pacific Railroad lines between the approximate projection eastward of 7th and 9th Avenues. The area least developed, east of 4th Street, is probably most advantageous for communication with the plant site. The area has been indicated on the map (plate IV). In summary, it represents the projected intersection of the fault identified by seismic reflection survey with the potential reservoir formation (Columbia River Group) at a depth where the synthetic gradient indicates that a temperature in excess of 150°C occurs.

Secondary Site

The secondary site is at an area defined by the similar solution by descriptive geometry at the location of possible faults IV and V at a depth of 2.2 km (7,000 feet). Neither, either or both of these faults may in fact exist, according to the views of the seismologists who interpreted the seismic reflection data sections.

Again, the limits of 65° and 80° northeastward dip have been used for the faults. There is an area immediately north and east of the freeway bounded by Flynn Road on the northwest which is the zone between the

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projection of faults IV and V at dips of 65° northeast to 2.2 km (7,000 feet). This zone is about 500 m in width, from southwest to northeast. [redacted] It is indicated on the map (plate III). A site is recommended on the Ore-Ida property which provides best communication with the proposed location of the plant heat exchanger site, the settlement lagoons for waste disposal of fluids during testing, and least problems relative to freeway and environmental considerations.

Summary

The primary site is recommended as the first choice for an exploratory hole entirely for technical reasons. The secondary site is recommended as an alternative because of proximity to the plant, property ownership communications and environmental considerations. It is recommended that the best technical shot be attempted first, inasmuch as the resource must be located and tested before pipeline costs and other factors are pertinent as long as the additional land acquisition, pipeline costs and route environmental constraints are not absolutely prohibitive.

Finally, it is possible to convert the primary site from a production well into a reinjection well site, in the event that the primary site is drilled successfully and followed by a second hole at the secondary site which also produces sufficient amounts of thermal fluid at acceptable temperatures. The reasoning is that the secondary site would be drilled with the intention to be used as a reinjection hole but targeted to the production depth. It would be tested just as the primary site. [redacted] It is assumed that the primary site may be objectionable because of the cost of construction of a pipeline for testing and delivery purposes. A pipeline for exclusively testing and transport of fluid for reinjection purposes would be somewhat less costly.

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BIBLIOGRAPHY

1. Armstrong, L. R., 1975, The Geochronometry of Idaho: Isochron West, No. 14, p. 1-50.

2. Blackwell, D. D., 1975, Reconnaissance Heat Flow and Geothermal Gradient Study in North Central Owyhee County, Idaho: Unpublished document.

3. Bonini, W. E., 1963, Gravity Anomalies in Idaho: Idaho Bur. Mines and Geology Pamphlet 132, p. 10.

4. Bowen, R. G. and Blackwell, U. D. D., 1975, The Cow Hollow Geothermal Anomaly, Malheur County, Oregon: Ore 15 in 37(7):109-121.

5. Corcoran, R. E. and others, 1962, Geology of the Mitchell Butte Quadrangle, Oregon: Oregon Department Geology and Mineral Indus. Geol. Map Series GMS 2.

6. Couch, R. W. and Baker, B., 1977, Geophysical Investigation of the Vale-Owyhee Geothermal Region Malheur County, Oregon: Technical Report No. 2. U.S. Geology Survey, Geothermal Resource Program, p. 13.

7. Couch, R. W., 1977, Analysis of Geophysical data pertaining to the Vale K.G.R.A.: Final Report, U.S. Geol. Survey Geothermal Research Program, p. 52.

8. Gardner, M. C., 1978, Evaluation of The Geothermal Resources Potential of Lands in the Bully Creek Area, Oregon: Unpublished.

9. Hill, D. P., 1963, Gravity and Crustal Structure in the Western Snake River Plain, Idaho: Jour. Geophys. Res., v. 68, no. 20, p. 5807-5820.

10. Hill, D. P. and Pakiser, L. C., 1967, Seismic Refraction Study of Crustal Structure between the Nevada Test Site and Boise, Idaho: Geol. Soc. Amer. Bull., v. 78, no. 6, p. 605-701.

11. Kittleman, L. R. and others, 1967, Geologic Map of the Owyhee Region, Malheur County, Oregon: University of Oregon, Mus. Nat. Hist. Bull., No. 8.

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24. Young, H. W. and Mitchell, J. C., 1973, Geochemistry and Geologic Setting of Selected Thermal Waters: Part 1, Geothermal Investigations in Idaho, Idaho Dept. of Water Admin. Water Info. Bull. no. 30, p. 43.

25. Young, H. W. and Whitehead, R. L., 1975, An Evaluation of Thermal Water in the Weiser Area, Idaho: Part 3, Geothermal Investigation in Idaho, Idaho Dept. of Water Admin. Info. Bull. no. 30, 28 pages.

APPENDIX 1

SEISMIC REFLECTION STUDY

OF THE

ONTARIO, OREGON, AREA

October 1978

James K. Applegate & Paul R. Donaldson

GeoTechniques, Inc.
2887 Snowflake Drive
Boise, Idaho 83706

SEISMIC REFLECTION STUDY OF THE

ONTARIO, OREGON, AREA

Introduction

During the summer of 1978, a high-resolution seismic reflection study was undertaken of the Ontario, Oregon, area. The purpose was to map possible structural controls on the postulated geothermal system. It was anticipated that the geothermal system relies on an insulating blanket model of sediments and volcanics (Applegate and Donaldson, 1977) to provide a significantly higher than normal geothermal gradient. The actual geothermal reservoir would, perhaps, be localized by faulting. This structure should be detected by the seismic reflection study.

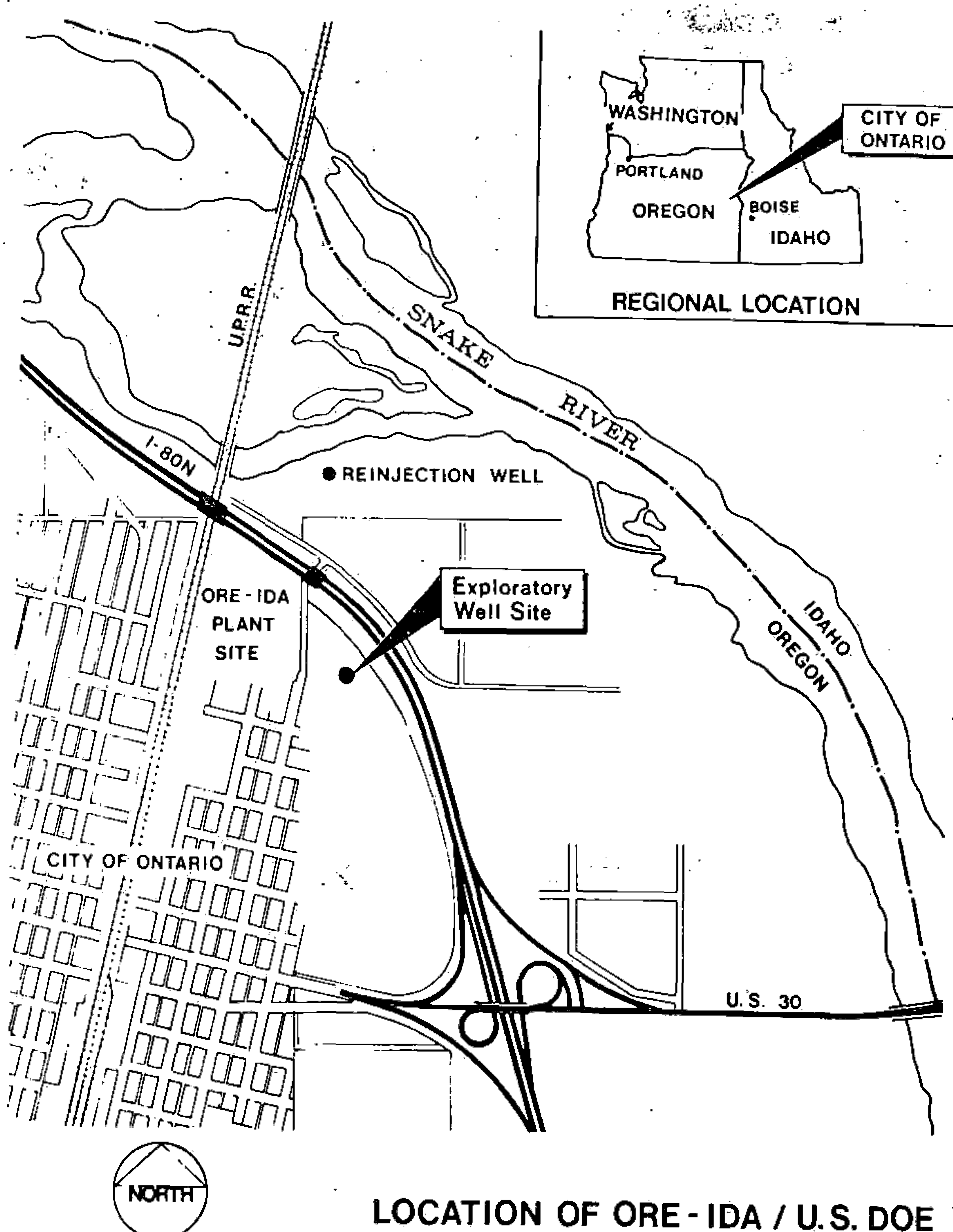
Field Techniques

The high resolution seismic reflection method is a slight modification of standard petroleum exploration techniques. The primary modifications are closer detector spacings and smaller charges resulting in higher frequency data. The closer detector spacings minimize spatial aliasing and allow a more vertical travel path for the seismic energy. Smaller charges yield a higher percentage of high-frequency energy.

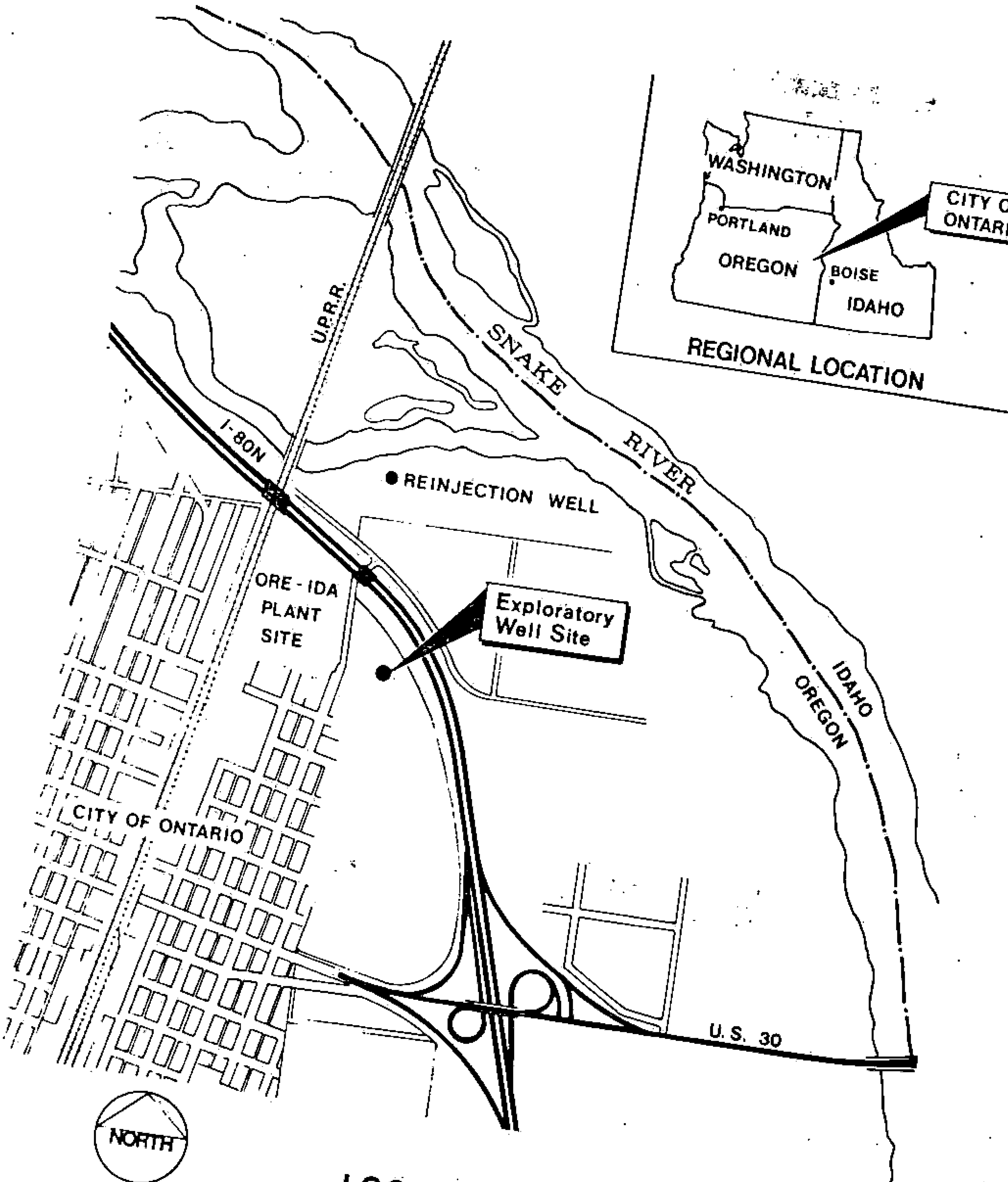
For the Ontario study, a detector spacing of approximately 100 ft was chosen as a compromise to allow the detection of deeper structures while taking advantage of the stacking technique's unique properties, and yet still allowing the mapping of shallow structure. The charge size was kept small to enhance the high frequencies, to attempt to avoid "ringing" of volcanics, and due to logistical constraints.

Two major problems were anticipated and indeed present. These were complex geology--interbedded volcanics and sediments--and logistical problems including utilities and traffic. Every effort was made to design the field techniques and processing techniques to minimize the geological noise, and numerous precautions were taken to minimize the effects of utilities and traffic.

The field equipment utilized was a Quantum Electronics DAS-1 digital recorder. Data were recorded in digital form on magnetic tape with a low-cut filter of 50 hz and an anti-aliasing high-cut filter. The sample interval was 1 ms. The detectors were a single 30-hz geophone per channel. The data were recorded 6-fold. The energy source was from 0.4 to 0.8 lbs of 75% dynamite in 10-ft deep drill holes.



LOCATION OF ORE - IDA / U.S. DOE GEOTHERMAL ENERGY PROJECT



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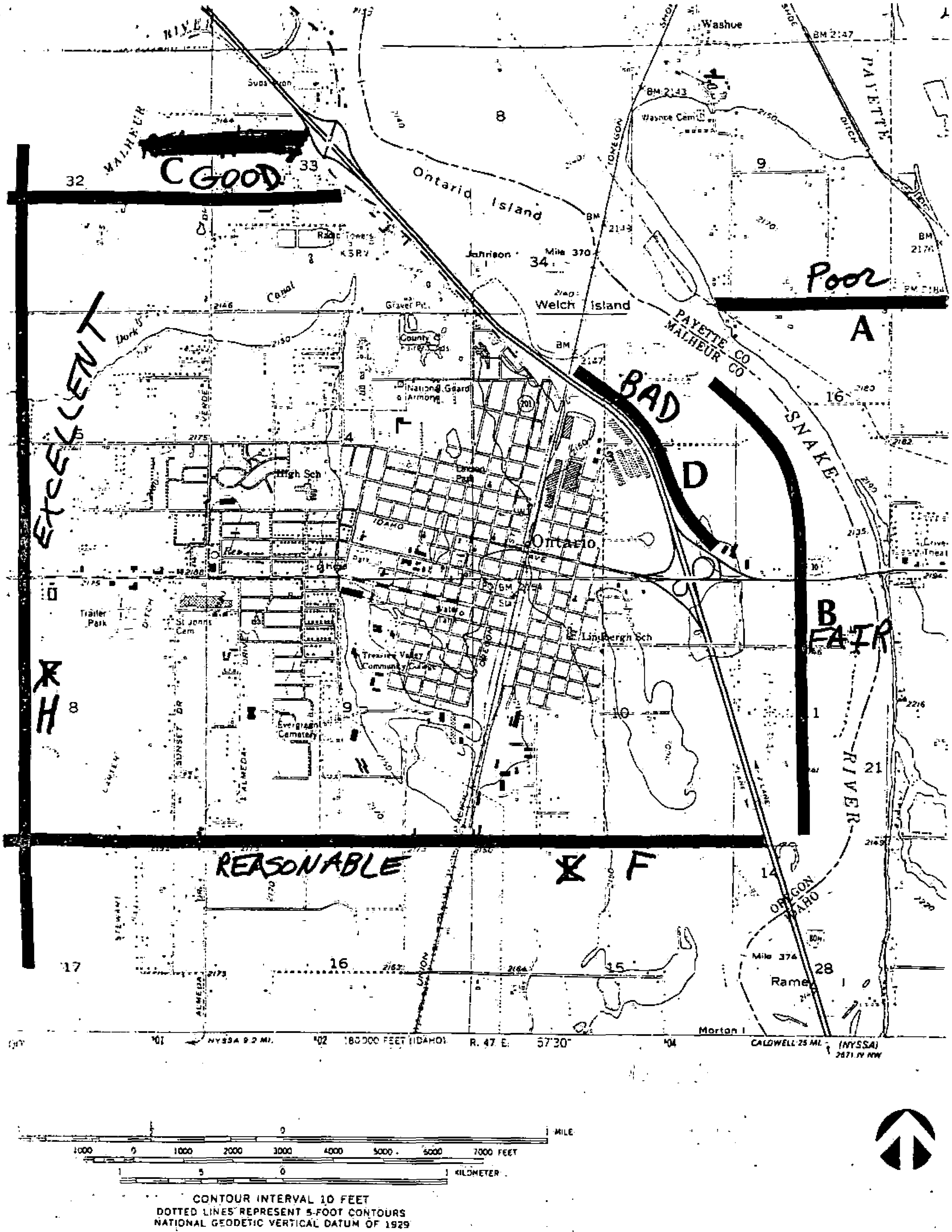

PROPOSED SEISMIC SURVEY LINES

Data Processing

Data processing was subcontracted to Applied Research Concepts, Inc. (ARC), Houston, Texas. The processing sequence began with demultiplexing and reformatting. The data were then sorted into common depth point gathers. Then a number of different processes were applied to enhance the data. Two complete processing runs were made. The output of the first run was utilized in modifying the processing sequence. Static and normal moveout corrections were made to correct the data for elevation variations and also for the geometry of the seismic spread. Other processes included deconvolution. Deconvolution in effect shrinks the seismic wavelet so that the resolution is improved. The data were filtered with a time-variant filter. The purpose of the time-variant filter is to minimize noise that is not part of the seismic signal. Autostatics were also applied to correct for any inadequacies in the regular statics program. Then the data were stacked (6-fold) to enhance the signal-to-noise ratio. The stacking velocities were determined from velocity analyses at approximately every fifteenth shot point.

Interpretation

Six seismic lines were shot to approximate the outline of a box around Ontario. Due to logistic constraints, the corners of the seismic lines were not tied, so it was extremely difficult to map any horizon completely around the box.

Approximately 10.5 miles of seismic data were acquired. The data quality ranges from poor to good. In general the shallow data are good, while the deeper data are of poor quality. Several fault structures were mapped with varying degrees of confidence.

Each of the seismic lines is discussed individually. Fault breaks are graded from A (very good) to D (very poor). These data are then incorporated on a fault map (plate I).

Line A is of little use. The data are generally poor, except for some alignments shallow in the section. On the basis of these poor data, one questionable fault (VII) (grade D) was picked.

Line B is a north-south line. The southern portion of the line is straight while the northern part curves along the river. The data quality is generally fair. Line B has a possible fault (IV) (grade B) at the south end of the section. Another interpretation indicates the anomaly but would rank the fault more questionably. Correlative geomorphologic data are two very parallel and very straight drainages on the east side of the Snake River. Based on this evidence, we believe there is a good possibility that the fault exists. Preliminary data processing showed an additional, parallel feature in the immediate vicinity. However, later processing obscured this feature. The northern part of line B is poor. However, there are some possible fault indications. None appear to be definitive enough to support themselves.

Line C is reasonably good throughout its length and has the best quality data at depth. Three faults of varying quality are indicated on the seismic section. The easternmost fault (VI) was rated B- to C+. However, the amount of offset is very minor and could possibly represent a small roll-over, especially in the shallow section. The middle fault (V) is given an A rating and is indicated by reflection terminations, some possible diffractions, and some roll-over into the fault. The control on this fault appears to extend it clearly into "seismic basement" at a depth of approximately 6,000 ft. The "seismic basement" appears to be massive volcanics, due to similarity with characteristics in other locations where the contractors have worked. The westernmost fault (IV) on line C was given a B rating. Again the throw is minor in the shallow section, but the fault appears to offset "seismic basement." Another interpretation yields significantly different results using the same evidence. However, we feel that our interpretation is compatible with all data indicated.

Line D clearly has the worst data. Only a very few alignments are seen. However, one very poor fault (VI) (grade D) is indicated.

Line F is of reasonable quality throughout. Three significant faults are indicated, and some subsidiary faults are possibly present. Spatially these faults are not well controlled because they cross the line at rather low angles, which tends to smear the contact. The easternmost fault (III) (grade A) is down to the east and is the best controlled fault on the line. Some ambiguity results from the relationship of apparently subsidiary features that appear to feather into the main trace. The two western faults on the line create a relatively broad zone of poor data. The western fault (I) (grade A) is down to the west and is only moderately constrained. An additional west-side down fault (II) may be slightly east of the western fault on line F. This is suggested by data from line H. These two western faults may represent a zone of faulting or merging of the two faults at depth.

Line H is a line of excellent quality data in the shallow section. Three faults are indicated on this line. The southernmost fault (I) (grade A) is down to the south and its location is constrained to a depth of approximately 2,600 ft. The center fault (II) (grade B) is down to the south also and may merge into the southernmost fault at depth. The northern fault (III) (grade A) is down to the north and is reasonably well constrained. The data on this line and on some additional lines suggest that there may be some thin interbedded volcanics in the shallow section (at a depth of about 650 ft on the southern part of line H).

The map (plate I) shows the faults as they are projected to the surface, as well as the most plausible manner of connecting the faults into a regional fault pattern. A number of factors are considered in the procedure of connecting various fault breaks. Some of these are: (1) the character of the faults (throw, dip, and apparent age), (2) the pattern of the fault breaks (direction of throw), and (3) other data on the structural grain of an area. Regional trends of geomorphic expressions and mapped faults with strikes of N55°W to N60°W were observed and incorporated in the analyses.

The southern set of three faults is well constrained. These three faults (I, II, and III) appear to define a prominent horst block with a NW-SE trend. These faults appear to fit well with the regional geologic trends. Displacements for these features are indicated on the map where they were picked. Since the displacement may vary with depth, the depth from which the value is obtained is also indicated.

Faults IV and V are the next ones further north, and the reliability is less due to less control on the features. Fault IV is relatively well defined on line B but differing opinion exists. A second fault cut on B that could correspond to fault V was indicated on the original data processing. However, additional processing obscured this cut and raised some questions on the cut for IV. The cuts on line C are also relatively well defined for both faults IV and V. Again, however, the possibility that these faults exist is questioned by another interpretation. The balance seems to be tipped in favor of their existence by other supporting evidence such as the geomorphic and regional geologic data.

Faults VI and VII are based on questionable data. Fault VI is constrained by a reasonable cut on line C and a very poor cut on line D. Both faults need additional supporting evidence to be interpreted with confidence.

Conclusions

The seismic survey defined several faults. Due to the data quality and geometric constraints, a higher level of confidence is associated with faults I, II, and III than the others. Based on the total data information, however, there is significant evidence to support faults IV and V.

Thus based on seismic evidence, one has two possible targets. One is technically better than the other due to the spatial control on the faulting. Technically the best target is north of fault III. At a slightly lower level of technical confidence is the area north of faults IV and V. Either site offers a viable target for a geothermal well.

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APPENDIX 2

Commentary on:

SEISMIC REFLECTION STUDY

OF THE

ONTARIO, OREGON, AREA

H. Thomas Ise

in association with

GeothermEx, Inc.

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INDIVIDUAL LINE DATA PRINTOUT QUALITY

1. Line "A"

   a. Quite poor data quality, can be faulted amost anywhere, but except for diffractions (?), no *positive* evidence for faulting.

   b. Sum of knowledge approximately zero.

2. Line "B"

   a. Poor to fair variable data; nothing is very clear, but probably there are no faults or shallow (0.2 second) horizon between Shot Points (S.P.'s) 18 and 42, and possibly not from S.P. 42 to 65; vague suggestion of faulting, north (??) side up, around S.P. 75.

   b. Early display strongly suggested an odd-looking down-thrown wedge between two reverse faults on south end of this line, with fault cuts at S.P.'s 7 and 17 @ 0.3 seconds; later playback almost entirely eliminates these fault-cut appearances, although there may still be a north-dipping fault (IV) at S.P. ± (@ 0.3 seconds).

3. Line "C"

   a. Definitely the best quality data we have; early playback was marred by strong multiple reflection around 0.9-1.0 seconds, which masked valid but weaker primary reflections in this zone; "stacking" with proper velocity has nearly eliminated the multiple.

   b. "Basement" shows rather nicely just below 1.6 seconds (6,000 feet), apparently nearly flat-dipping, but possibly broken by block faulting (or rough topography?).

   c. Horizon @ 0.45 seconds (1,300 feet) is not displaced anywhere along line; there is a week spot at S.P. ±, but because weakness is vertical a near-surface cause is suspected. Reflector terminating here would be stratigraphic; other reflectors correlate on character pretty well across weak zone. Good alignment of diffractions may be meaningful or coincidence and suggest a

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fault; no throw can be observed. Abrupt loss of good event at 1.34 seconds may be a fault. [redacted]

4. Line "D"

   a. Poor line, worse than "A." *No* conclusions drawn from this line should carry any weight. The attempt to put a horizon on section is very speculative. (This commentary agrees with Appendix 1, except to discount fault VI.)

5. Line "F"

   a. Poor to good data; variable but generally reliable in shallow part of section.

   b. Most notable features are faults, well defined at S.P. 40 (III), fair @ S.P. 84 ± (I), and poor @ S.P. 63 ± (II). All cuts are at approximately 0.2 seconds. Throw on "III" seems well defined by character of reflectors and location by roll-over and termination of reflectors; at depth it is dependent on diffractions and a few terminations. "I" is not clear because it is in an area of poor data but shows some roll-over and diffractions. "II" is defined shallow by fair roll-over and termination of one reflector, and comes down into a swarm of diffractions.

   c. "Basement" may appear locally around 1.5 seconds on the west end of the line and again under S.P. 90 at the same time (?) and much shallower (1.25 seconds) under S.P. 20. The latter pick is questionable because of its high position (4,200 feet ±).

   d. A good reflector, near 0.1 second on the west end, could be basalt (based on strength and frequency) (?) and is apparently not seen on other lines. It would project (on the dip seen) to the surface about three miles west of the end of the line, about one mile east of Malheur Butte.

6. Line "H"

   a. Fair to good data at shallow depths but very little deep information. There are numerous apparent diffractions.

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b. Faults are prominent features. "III" and "I" are well defined and look remarkably like their counterparts on line "F." "II" is less well defined, but the displacement is indicated by the shallow reflector. Diffractions help define "III" and "I" with depth. Apparent dips are: "III" = 70° ±, "II" = 55° ±, and "I" = 55° ±. These are close to true dips because line "H" is nearly at right angles to the faults.

c. "Basement" may be seen between S.P.'s 82 and 85 at 1.64 seconds (below 6,200 feet). On any of the sections, I cannot relate "basement" apparent faulting with the shallow section, so an unconformity is implied, or at faults which do not persist into the younger beds.

Map 1 is a structure-contour map in two-way vertical time to the shallow reflector horizon. It suggests a very gentle dome under Ontario with broad, very gentle east dips. Another dome is implied at the south end of line "H." The traces of the faults considered probable are shown for this horizon.

Map 2 shows structure contours on the three most probable faults at arbitrary planes below the seismic datum. [redacted]

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APPENDIX 3

GEOCHEMICAL FIELD DATA REPORTS

AND

LABORATORY ANALYTICAL DATA SHEETS

FIELD DATA RECORD - WATER SAMPLE

Source Name: CITY WELL 14

Sample No. ORE-IDA 1

Aliquots: ✓Fu; ✓Fa; Fda; Ru; Ra*

Location: PAYETTE, CENTER AVE AT 21ST ST.

Date: 18 JULY '78 Sampler: MAT

Sample Data:

Temp. 16 °C. °F.

water color/clarity: CLEAR, COLORLESS

where measured: SPIGOT NEAR PUMP AND WELL HEAD: WELL PUMPED 15MIN BEFORE SAMPLE AND FIELD MEASUREMENTS TAKEN.

odor: NONE

Discharge: 225 ~~1pm~~ gal/m

gas: NONE

Well data:

X pumped sample; ____ flowing(artesian)

total depth: 279 ft.

depth to water:

Component	Sample type*	Conc.,ppm	Measured in field	other (when)	Method; comments
Sp.Cond.	R	750 μm	✓		HACH
pH	R	7.5-7.8	✓		
SiO_2					HACH
Cl		100 mg/l	✓		HACH
NH_3		.9	✓		HACH
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

none observed

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: CARPENTER GAS WELL

Sample No. ORE-IDA 2

Aliquots: ✓ Fu; ✓ Fa; Fda;
✓ FuD 1:3 Ru; Ra*

Location: PAYETTE, NEAR BEND IN PAYETTE RIVER

Date: 18 JULY '78 Sampler: MAT

Sample Data:

Temp. 19 °C. °F.

water color/clarity: VERY SLIGHT GREY COLOR - HARD TO TELL BECAUSE OF ORGANIC MATERIAL - ALGAE

where measured: REMOVED ROCKS PLUGGING CASING ~2 ft. IN 1 HR WATER RAISED ~3/4 ft. - SURFACE

odor:

Discharge: <1 lpm

CASING DIA. ~6"

gas: YES - DRILLED FOR GAS WELL IN 1955 BY OMOCO - BUBBLING IS MODERATE - STRONG.

Well data:

_____ pumped sample; _____ flowing (artesian)

total depth:

depth to water:

Component	Sample type*	Conc., ppm	Measured in field	Measured in other (when)	Method; comments
Sp. Cond.	R	2040 µm			HACH
pH	R	~8.0			
SiO_2	--	----			HACH
Cl		450 mg/l			HACH
NH_3		8.0	(DILUTED 1:4)		HACH
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

IN RIVER PLAIN

CONTAMINATED WITH ALGAE

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: FARMERS SUPPLY COOP WELL

Sample No. ORE-IDA 3

Aliquots: ✓ Fu; ✓ Fa; Fda; ✓ FuD 1:4 Ru: Ra*

Location: CROP DUSTING SERVICE, ONTARIO AIRPORT (WEST SIDE OF HANGERS)

Date: 18 JULY '78 Sampler: MAT

Sample Data:

Temp. 17 °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured: SEE NOTE BELOW

odor: NONE

Discharge: 60 gal/min ~~lpm~~

gas: NONE

Well data:

X pumped sample; ____ flowing (artesian)

total depth: 67 ft.

depth to water: 47 ft

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	2500 μm			HACH
pH	R	~7.5			LO-ION PAPER
SiO_2					HACH
Cl		550 mg/l			
NH_3		0.4			HACH
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

NOT POSSIBLE TO TAKE SAMPLE FROM WELL HEAD SO TANK WAS DRAINED AND SAMPLE TAKEN AS WATER WENT INTO TANK. PLASTIC PIPE TO TANK, TANK GALVANIZED.

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: MUNICIPAL WELL #4 Sample No. ORE-IDA 4

Aliquots: ✓ Fu; ✓ Fa; Fda;

Location: WITHIN 50 FT OF SNAKE RIVER Ru; Ra*

Date: 19 JULY '78 Sampler: MAT

Sample Data:

Temp. 17.5 °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured: H_2O LEVEL - WELL STANDING

odor: NONE

Discharge: lpm

gas: NONE

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: 40

depth to water: 14

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	480 μm	✓		HACH
pH	R	7.89			CORNING DIGITAL pH METER #125,
SiO_2					HACH IN WATER TREATMENT PLANT LAB
Cl		100 mg/l	✓		
NH_3		0.2	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

RUST OFF SIDES OF CASING

SNAKE RIVER WATER: 21°C

pH 8.9

TURBIDITY 38.0

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: McDANIEL'S WELL

Sample No. O-I S

Aliquots: ✓ Fu; ✓ Fa; Fda; ✓ FuD 1:3 Ru; Ra*

Location: JUST WEST OF FREEWAY ~ 2 MILES N. OF FREEWAY BRIDGE OVER SNAKE RIVER

Date: 19 JULY '78 Sampler: MAT

Sample Data:

Temp. 14 °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured:

odor: NONE

Discharge: lpm

gas: NONE

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: ~45 ft

depth to water: ~15-18 ft

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	1750 μ m	✓		HACH
pH	R	7.72		IN WATER TREATMENT LAB 10 MIN AFTER SAMPLE TAKEN.	CORNING DIGITAL #125
SiO_2					HACH
Cl		300 mg/l	✓		
NH_3		0.3	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: WELL ON CLARE DICKENS PROPERTY

Sample No. OI-6

Aliquots: ✓Fu; ✓Fa; Fda; Ru; Ra*

Location: N 4873.62 E 504.70, 1 MILE NORTH OF WHERE FREEWAY CROSSES SNAKE RIVER, & 1/4 MI. EAST

Date: 19 JULY '78 Sampler: MAT

Sample Data:

Temp. °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured:

odor: SLIGHTLY ORGANIC

Discharge: lpm

gas: FROM DESCRIPTION BY OWNER, PROBABLY V. SLIGHT METHANE IF WELL LEFT UNPUMPED FOR SOME TIME.

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: 90 ft

depth to water: ~30 ft to 1st AQUIFER
65-70 ft to 2nd AQUIFER

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	450 μm			HACH
pH	R	7.90	TREATMENT LAB, 10 MIN AFTER SAMPLE		CORNING DIG #125
SiO_2					HACH
Cl		100 mg/l			
NH_3		14.7			SUSPECT CONTAMINATION, POSS.
F					LEAK FROM SEPTIC TANK

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: MUNICIPAL WELL
ORE-IDA WELL #5

Sample No. OI - 7

Aliquots: ✓ Fu; ✓ Fa; Fda;
Ru; Ra*

Location: IN FIELD N-NE OF
TAPADERA MOTEL

Date: 20 JULY 78 Sampler: MAT

Sample Data:

Temp. 13 °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured: AT SPIGOT NEAR WELL HEAD

odor: ? FAINT SEWAGE SMELL

Discharge: 450 ~~lpm~~ gal/min

gas: ? POSS. TRACE OF METHANE

Well data:

____pumped sample; ____flowing(artesian)

total depth: 47 ft.

depth to water: 17 ft.

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	470 μm	✓		HACH
pH	R	7.55		✓ TREATMENT LAB 11 MIN AFTER COLLECTION	CORNING DIG. #125
SiO_2					HACH
Cl		62.5 mg/l	✓		
NH_3		1.35	✓		
F					

Other conditions of source (contamination, mineral deposits, geologic setting, sketch, etc.)

BIOCHEMICAL OXYGEN DEMAND = ORGANIC WASTE, PROBABLY FROM CORN & POTATOES. SOME KIND OF GAS IS PRESENT. TWO WELLS SHUT DOWN LAST SUMMER BECAUSE GAS SO BAD.

7 WELLS CLUSTERED, BAD GAS IN TWO, 1A & 4

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: HOLY ROSARY HOSPITAL

Sample No. OI-8

Aliquots: ✓ Fu; ✓ Fa; Fda; ✓ FuD 1:2 Ru; Ra*

Location: 351 SW 9th ST. ONTARIO, ORE.

Date: 20 JULY 78 Sampler: MAT

Sample Data:

Temp. 13.5 °C. °F.

water color/clarity: COLORLESS CLEAR

where measured:

odor: NONE

Discharge: lpm

gas: NONE

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: ~40 FT

depth to water: ~20 FT

Component	Sample type*	Conc., ppm	Measured in field	Measured in other (when)	Method; comments
Sp. Cond.	R	1250 μm	✓		HACH
pH	R	8.05		✓ 15 MIN AFTER SAMPLE	CORNING DIG. # 125
SiO_2					HACH
Cl		125 mg/l	✓		
NH_3		0.4	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: MITCHELL WELL

Sample No. OI-9

Aliquots: ✓ Fu; ✓ Fa; Fda;

✓ FuD 1:2 Ru: Ra*

Location: 626 MALHEUR DRIVE ONTARIO, ORE.

Date: 20 JULY 78 Sampler: MAT

Sample Data:

Temp. 13.8 °C. °F.

water color/clarity: COLORLESS, CLEAR

where measured:

odor: NONE

Discharge: lpm

gas: NONE

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: 110 ft.

depth to water: 65 ft, BETTER AQUIFER AT 70 FT.

Component	Sample type*	Conc., ppm	Measured in field	Measured in other (when)	Method; comments
Sp.Cond.	R	1240 μm	✓		HACH
pH	R	7.60		✓ 45 MIN AFTER SAMP.	CORNING DIGITAL #125
SiO_2					HACH
Cl		162.5	✓		
NH_3		9.4	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

DOMESTIC AND IRRIGATION USE

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: TREASURE VALLEY COMMUNITY COLLEGE IRRIGATATION WELL

Sample No. OI-10

Aliquots: ✓Fu; ✓Fa; Fda; Ru; Ra*

Location: ON E SIDE, SECT. 9, T18S, R47E, ~½ MILE SSE OF TVCC

Date: 20 JULY 78 Sampler: MAT

Sample Data:

water color/clarity: COLORLESS, CLEAR

odor: NONE

gas: NONE

Temp. 14 °C. °F.

where measured:

Discharge: lpm

Well data:

____ pumped sample; ____ flowing (artesian)

total depth: ? ~ 70-80 ft.

depth to water:

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp.Cond.	R	930 μm	✓		HACH
pH	R	7.85		✓ 10 MIN AFTER SAMP.	CORNING DIGITAL #125
SiO_2					HACH
Cl		87.5 mg/l	✓		
NH_3		15.4	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.) PROB. NO CONTAMINATION

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: WEISER HOT SPRING Sample No. OI-11

Aliquots: ✓ Fu; ✓ Fa; Fda;

Location: ~5 MILES NNE OF WEISER

Ru; Ra*

Date: 21 JULY 78 Sampler: MAT

Sample Data:

Temp. 53 °C. °F.

water color/clarity: COLORLESS, SLIGHTLY MURKY, SOME DIRT AND ALGAE CLOUDING H_2O

where measured: AT ORIFICE

odor: YES (?) ORGANIC, SLIGHT SULFUR

Discharge: <5 lpm

gas: YES VERY WEAK & SPORADIC

Well data:

____ pumped sample; ____ flowing (artesian)

total depth:

depth to water:

Component	Sample type*	Conc., ppm	Measured in field	Measured in other (when)	Method; comments
Sp. Cond.	R	670 μm			HACH
pH	R	~10			LO-ION PAPER
SiO_2					HACH
Cl		75 mg/l			
NH_3		0.3			
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

SEEP FROM BANK INTO COLD STREAM

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source ~~Name~~: WEISER HOT SPRING WELL SAMPLE

Sample No. OI - 11A

Aliquots: ✓ Fu; ✓ Fa; Fda; Ru; Ra*

Location: ~5 MI. NNE OF WEISER

Date: 21 JULY 78 Sampler: MAT

Sample Data:

water color/clarity: CLEAR, SOME ALGAE

odor: SLIGHT SULFUR

gas: POSSIBLY - SOME BUBBLES REPORTED WHEN WELL NOT USED FOR A WHILE & THEN TURNED ON.

Temp. 63 °C. °F.

where measured: PUMP TAKES H_2O TO POOL AT ~50-75 gal/min. THERE IS A ½-1 GAL/MIN OVERFLOW AT PIPE JOINT WHERE SAMPLED.

Discharge: lpm

Well data:

____pumped sample; ____flowing(artesian)

total depth: ?? 135 FT.

depth to water:

Component	Sample type*	Conc.,ppm	Measured in field	other(when)	Method; comments
Sp.Cond.	R	700 μm	✓		HACH
pH	R	~11	✓		LO-ION PAPER
SiO_2					HACH
Cl		100 mg/l	✓		
NH_3		0.9	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

FIELD DATA RECORD - WATER SAMPLE

Source Name: ORE-IDA WELL #10

Sample No. OI #12

Aliquots: Fu; Fa; Fda; Ru; Ra*

Location: NE OF FREEWAY ~ 1/8 MI., NE¼ NW¼, SECT 3, T18S, R47E

Date: 21 JULY 78 Sampler: MAT

Sample Data:

water color/clarity: V. SLIGHTLY YELLOW, CLEAR

odor: SLIGHT ORGANIC

gas: NONE OBSERVED

Temp. °C. °F.

where measured:

Discharge: 250 ~~1pm~~ gal/min

Well data:

_____pumped sample; _____flowing (artesian)

total depth: 100 FT.

depth to water: 12 FT IS STATIC LEVEL

Component	Sample type*	Conc., ppm	Measured in field	other (when)	Method; comments
Sp. Cond.	R	1150 µm	✓		HACH
pH	R	6.8 - 7.2	✓		LO-ION PAPER
SiO_2					HACH
Cl		150 mg/l	✓		
NH_3		1.1	✓		
F					

Other conditions of source: (contamination, mineral deposits, geologic setting, sketch, etc.)

* F = filtered; R = unfiltered; u = untreated; a = acidified to pH 2
d = diluted 1:10 with distilled water

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-1 7-18

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SPECIES	mg/L	eq/L
Ca	79.	39-4
Mg	27.	22-4
Na	63.	27-4
K	8.0	20-5
HCO_3	360.	59-4
CO_3		
CO_2(FREE)		
SO_4	81.	17-4
Cl	26.	73-5
TDS	540.	
pH	7.93	
Ec μmhos/cm @25°	811.	
Ec μmhos/CALC	895.	
Ec OBS/CALC	.906	
CATIONS Σ+		9000.
ANIONS Σ-		8320.

SPECIES	mg/L	eq/L
B	0.11	10-6 (a)
SiO_2	49.	81-5 (a)
NH_4		
F	0.29	15-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:
AMTECH American Technical Laboratories, Inc.
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LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: 01-2 7-18

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SPECIES	mg/L	eq/L
Ca	17.	85-5
Mg	2.0	16-5
Na	580.	25-3
K	14.	36-5
HCO_3	1100.	18-3
CO_3		
CO_2(FREE)		
SO_4	8.3	17-5
Cl	220.	62-4
TDS	1558.	
pH	8.31	
Ec µmhos/cm @25°	2410.	
Ec µmhos/CALC	2580.	
Ec OBS/CALC	0.933	
CATIONS Σ+		26600.
ANIONS Σ-		24400.

SPECIES	mg/L	eq/L
B	2.5	23-5 (a)
SiO_2	73.	12-4 (a)
NH_4		
F	0.17	89-7
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.
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LABORATORY NO: 0622-778
DATE OF REPORT: September 1, 1978
IDENTIFICATION: 01-3 7-18

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SPECIES	mg/L	eq/L
Ca	160.	79-4
Mg	80.	66-4
Na	380.	17-3
K	26.	66-5
HCO_3	570.	93-4
CO_3		
CO_2(FREE)		
SO_4	730.	15-3
Cl	250.	71-4
TDS	2076.	
pH	7.95	
Ec μmhos/cm @25°	2820.	3410.(1:10)
Ec μmhos/CALC		3650.
Ec OBS/CALC		.934
CATIONS Σ+		31800.
ANIONS Σ-		31600.

SPECIES	mg/L	eq/L
B	0.51	47-6 (a)
SiO_2	56.	93-5 (a)
NH_4		
F	0.15	79-7
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

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LABORATORY NO: 0622-778
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-4 77-19

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SPECIES	mg/L	eq/L
Ca	42.	21-4
Mg	16.	13-4
Na	39.	17-4
K	7.2	18-5
HCO_3	190.	31-4
CO_3		
CO_2(FREE)		
SO_4	68.	14-4
Cl	24.	68-5
TDS	330.	
pH	7.93	
Ec μmhos/cm @25°	505.	
Ec μmhos/CALC	559.	
Ec OBS/CALC	0.904	
CATIONS Σ+		5300.
ANIONS Σ-		5210.

SPECIES	mg/L	eq/L
B	0.11	10-6 (a)
SiO_2	34.	56-5 (a)
NH_4		
F	0.74	39-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:
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LABORATORY NO: 0622-778
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-5 7-19

GEOTHERMEX
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SPECIES	mg/L	eq/L
Ca	97.	48-4
Mg	50.	41-4
Na	260.	11-3
K	16.	41-5
HCO_3	580.	95-4
CO_3		
CO_2(FREE)		
SO_4	310.	65-4
Cl	140.	39-4
TDS	1273.	
pH	8.02	
Ec µmhos/cm @25°	1890.	2037. (1:3
Ec µmhos/CALC		2218.
Ec OBS/CALC		.918
CATIONS Σ+		20700.
ANIONS Σ-		19900.

SPECIES	mg/L	eq/L
B	0.50	46-6 (a)
SiO_2	47.	78-5 (a)
NH_4		
F	0.98	52-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.
8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-6 7-19

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	27.	13-4
Mg	8.0	66-5
Na	53.	23-4
K	10.	26-5
HCO_3	250.	41-4
CO_3		
CO_2(FREE)		
SO_4	<5.0	<10-5
Cl	13.	37-5
TDS	308.	
pH	7.93	
Ec μmhos/cm @25°	460.	
Ec μmhos/CALC	439.	
Ec OBS/CALC	1.049	
CATIONS Σ+		4520.
ANIONS Σ-		4460.

SPECIES	mg/L	eq/L
B	0.10	93-7 (a)
SiO_2	64.	11-4 (a)
NH_4		
F	0.66	35-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.
8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-7 7-20

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	72.	36-4
Mg	28.	23-4
Na	63.	28-4
K	7.5	19-5
HCO_3	260.	43-4
CO_3		
CO_2(FREE)		
SO_4	150.	31-4
Cl	26.	73-5
TDS	526.	
pH	7.91	
Ec μmhos/cm @25°	794.	939.(1:10)
Ec μmhos/CALC		915.
Ec OBS/CALC		1.03
CATIONS Σ+		8830.
ANIONS Σ-		8120.

SPECIES	mg/L	eq/L
B	0.11	10-6 (a)
SiO_2	41.	68-5 (a)
NH_4		
F	0.88	46-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.
8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-8 7-20

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	85.	42-4
Mg	45.	37-4
Na	150.	65-4
K	16.	41-5
HCO_3	480.	79-4
CO_3		
CO_2(FREE)		
SO_4	220.	46-4
Cl	59.	17-4
TDS	919.	
pH	8.00	
Ec μmhos/cm @25°	1360.	1446.(1:2)
Ec μmhos/CALC		1550.
Ec OBS/CALC		.933
CATIONS Σ+		14900.
ANIONS Σ-		14100.

SPECIES	mg/L	eq/L
B	0.36	33-6 (a)
SiO_2	56.	93-5 (a)
NH_4		
F	0.54	28-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.

8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-9 7-20

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	64.	32-4
Mg	26.	21-4
Na	190.	83-4
K	18.	46-5
HCO_3	500.	82-4
CO_3		
CO_2(FREE)		
SO_4	190.	40-4
Cl	80.	23-4
TDS	905.	
pH	7.95	
Ec μmhos/cm @25°	1364.	1474.(1:2)
Ec μmhos/CALC		1525.
Ec OBS/CALC		.967
CATIONS Σ+		14100.
ANIONS Σ-		14400.

SPECIES	mg/L	eq/L
B	0.37	34-6 (a)
SiO_2	62.	10-4 (a)
NH_4		
F	0.37	19-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:
AMTECH American Technical Laboratories, Inc.
8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: 01-10 7-20

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	38.	19-4
Mg	27.	22-4
Na	120.	52-4
K	16.	41-5
HCO_3	440.	72-4
CO_3		
CO_2(FREE)		
SO_4	78.	16-4
Cl	34.	96-5
TDS	618.	
pH	7.91	
Ec µmhos/cm @25°	980.	
Ec µmhos/CALC	994.	
Ec OBS/CALC	0.985	
CATIONS Σ+		9750.
ANIONS Σ-		9800.

SPECIES	mg/L	eq/L
B	0.24	22-6 (a)
SiO_2	64.	11-4 (a)
NH_4		
F	0.58	31-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:
AMTECH American Technical Laboratories, Inc.

8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: 01-11 7-21

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	24.	12-4
Mg	7.1	58-5
Na	91.	40-4
K	7.0	18-5
HCO_3	150.	25-4
CO_3		
CO_2(FREE)		
SO_4	120.	25-4
Cl	35.	99-5
TDS	456.	
pH	7.93	
Ec μmhos/cm @25°	601.	
Ec μmhos/CALC	663.	
Ec OBS/CALC	0.906	
CATIONS Σ+		5920.
ANIONS Σ-		5950.

SPECIES	mg/L	eq/L
B	1.1	10-5 (a)
SiO_2	86.	14-4 (a)
NH_4		
F	2.2	12-5
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.

8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-11A 7-21

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	2.5	12-5
Mg	0.1	82-7
Na	130.	57-4
K	6.9	18-5
HCO_3	82.	13-4
CO_3	5.7	19-5
CO_2(FREE)		
SO_4	160.	33-4
Cl	49.	14-4
TDS	536.	
pH	8.83	
Ec μmhos/cm @25°	673.	
Ec μmhos/CALC	722.	
Ec OBS/CALC	0.932	
CATIONS Σ+		5960.
ANIONS Σ-		6250.

SPECIES	mg/L	eq/L
B	2.2	20-5 (a)
SiO_2	130.	22-4 (a)
NH_4		
F	3.9	21-5
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.
8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

LABORATORY NO: 0622-78
DATE OF REPORT: September 1, 1978
IDENTIFICATION: OI-12 7-21

GEOTHERMEX
901 MENDOCINO AVE.
BERKELEY, CA. 94707

SPECIES	mg/L	eq/L
Ca	75.	37-4
Mg	30.	25-4
Na	170.	74-4
K	12.	31-5
HCO_3	500.	82-4
CO_3		
CO_2(FREE)		
SO_4	160.	33-4
Cl	41.	12-4
TDS	888.	
pH	7.80	
Ec µmhos/cm @25°	1345.	
Ec µmhos/CALC	1385.	
Ec OBS/CALC	0.971	
CATIONS Σ+		13900.
ANIONS Σ-		12700.

SPECIES	mg/L	eq/L
B	0.40	37-6 (a)
SiO_2	45.	75-5 (a)
NH_4		
F	0.98	52-6
S^{2-}		
Fe^{3+}		
Mn^{2+}		
Rb		
Li		
Sr		
Cs		
Ba		
Hg		

(a) MOLES/L

Analysis by:

AMTECH American Technical Laboratories, Inc.

8909 Complex Drive — Suite F San Diego, California 92123 (714) 560-7717

CONDUCTIVITY

Sample	Ec
Deionized Water (2,3,5,12)	4.57
Deionized Water (8,9)	1.75

CHLORIDE

Sample	mg/ℓ	eq/ℓ
Deionized Water (2,3,5,12)	<0.3	<85-7
Deionized Water (8,9)	<0.3	<85-7