GL01904

UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

September 18, 1987

Mr. Joe Iovenitti
Thermal Power Company
601 California Street
San Francisco, CA 94108

Dear Joe:

Herewith is a marked-up copy of your draft report on CTGH-1. In general, I believe the report is a good one and does not require substantial modification. The one thing I would like to see added is a breakdown of costs, as noted on page 7. This would help others in determining their own costs for coreholes in similar terrain.

I would like to personally compliment you and Thermal on the way you have conducted this project. Your promptness and thoroughness of documentation at each stage will contribute to the lasting scientific value of the project. We will look forward to collaborating with you as we continue to collect research data.

Sincerely,

Phillip M. Wright

pmw:kr

cc: Sue Prestwich

PMW -
I have a copy
for my files -
HR

THERMAL POWER COMPANY

Project Title: Cascade Geothermal Drilling

CLACKAMAS 5000-FOOT THERMAL GRADIENT HOLE

Cooperative Agreement No. DE-FC07-851D12614

PROJECT DATA COLLECTION PLAN

Submitted by:

Thermal Power Company
3333 Mendocino Avenue, Suite 120
Santa Rosa, California 95401

Joe Iovenitti

J. L. Iovenittti
Senior Geologist
for Participant

Approved by:

U. S. DOE, Idaho Operations Office
785 DOE Place
Idaho Falls, Idaho 83402

Susan Prestwich
DOE Project Officer

TABLE OF CONTENTS

FIGURES

APPENDICES

PROJECT DATA COLLECTION PLAN

The Clackamas 5000-Foot Thermal Gradient Hole (CTGH-1) Data Collection Plan is described herein for all data collected during the drilling and coring operation, and after borehole completion. Complete lithologic, hydraulic head, and lost circulation data will be recorded on-site by two drillsite geologists. Additionally, formation liquid sampling, as well as, geophysical borehole logging will take place. The Data Collection Plan has been formulated to maximize high quality geotechnical data retrieval for the drillsite operation. This program will assist the characterization and comprehension of the geothermal setting of the High Cascades.

Data Collection During Drilling and Coring

Drillsite Geologists

Two wellsite geologists, each working 12 hours per day, will be utilized in the estimated 60-day drilling and coring operation (see Thermal Power Company Proposed Drilling Plan). Their responsibilities described in Appendix 1 are complete drillsite geotechnical data collection. The two geologists are Mr. D. Goodwin and Ms A. McDannel. Their respective resumes are given in Appendix 2. Additionally, Mr. A. Waibel of Columbia Geoscience would have intermittent involvement in the drillsite work due to his knowledge of the surface and subsurface geology of the area.

Rock Sampling

Rock sampling, one of the primary objectives of this operation, will be accomplished by diamond coring from approximately 500' to total depth. A 2.50" core will be recovered from the intended coring with a HQ (3.85" OD) size corehead. If hole conditions necessitate borehole size reduction to a NQ (3.03") hole, a 1.88" core will then be retrieved. Drill cuttings will also be obtained from at least, the upper 500 feet of this hole and whenever else possible.

Fluid Sampling/Measurements

Daily measurements of the hydraulic head in the borehole will be obtained as allowed during the drilling and coring operation. Lost circulation data will be collected. The drillsite geologist is responsible for logging these data (Appendix 1).

If artesian flow is encountered, a short-term test (less than 1 day) will be conducted at total depth to obtain samples of formation water and to record flowing wellhead temperature and pressure. Depending on hole conditions, a flow test may also be conducted prior to reaching total depth. If no artesian flow is encountered, a flow test will be attempted at total depth or some other interval as dictated by hole conditions, analysis and interpretation of drillsite geotechnical data. Potential methods for initiating flow are swabbing, bailing and/or airlifting. The technique(s) utilized will depend on existing hole conditions.

The flow test set-up is shown in Figure 1. A 2" pipeline will be used to flow fluids from the borehole to a Baker tank. The drilling sump will be a back-up to the Baker tank, if necessary and feasible. Fluids will be sampled at Point A, Figure 1. Temperature and pressure measurements will be made at the wellhead. An estimate of flow rate will be made by fluid level differences within the Baker tank.

DOE will be responsible for supplying collection bottles, sample collection procedures, and chemical analysis of the liquid samples. Selected on-site analysis (i.e., pH, specific conductance and temperature) and sample collection will be conducted by Thermal Power Company personnel. Each sample collected will consist of at least two liters. A total of seven samples will be collected for each discrete, one-day flow test, at the following time intervals after flow initiation: 15, 30, 60, 120, 300, 600 and 1440 minutes (assuming a 24-hour flow period). Not all these samples collected, need be analyzed nor retained. This decision will be made by the TPC Senior Geologist in conjunction with DOE.

Geophysical Borehole Logging

Temperature, resistivity, caliper, self-potential, sonic velocity, density, and natural gamma will be run in the drillhole up to, but not exceeding, three separate occasions. These time periods are referred to as the shallow, intermediate and deep logging runs. Respectively, these runs would be conducted prior to setting surface casing at 500 feet*, prior to setting intermediate casing (depth dictated by actual hole conditions), and at total depth (5000').

Open hole logs (SP, caliper, resistivity and sonic) will be run approximately 50 feet into the cored hole. Temperature logs will be run from the surface to total depth. Gamma and density logs will only be run about 100 feet into the cored hole. The latter will allow for cross-calibration between runs. Tool calibration would be conducted by the geophysical borehole logging contractor prior to the actual field operation as well as performing field calibrations both before and after the executed logging runs.

Two potential contractors are currently being evaluated: Colorado Well Logging, Inc. and Dresser Atlas. Depending on final contractor selection, supplemental logs may be run in this Program. These are fluid resistance and guard resistivity, and a compensated neutron log, respectively.

The Thermal Power Company Senior Geologist associated with this project will be directing and observing all logging operations. A comprehensive logging report will be prepared for each logging operation.

*It was indicated in the TPC/DOE contractual agreement for CTGH-1 that the sonic velocity log would be run at 500 feet. However, running this log is both cost-prohibitive and marginal value at best at this shallow depth. An agreement was reached by TPC, DOE and its geotechnical consultant UURI for the program change as described above.

Maximum Temperature Reading

Three maximum recording thermometers will be run at 100-foot intervals**. As the bottomhole temperature attains 125°F and 175°F, the recording intervals will be decreased to every 50 feet and 30 feet, respectively. These data will be collected by the drillsite geologist and reported on the mud log (Appendix 1).

Daily Drilling Report

A drilling and coring report will be completed every day. A sample form is presented in Appendix 3.

Mud Log

A "mud" log (Appendix 1, Form 4) will be maintained during the drilling operation. This log will provide the following principal data, summarized at a vertical scale of 1" = 100":

1. geologic field description of core (including lithology, alteration mineralogy and fracture geometry assuming a vertical hole);

2. graph of penetration rate versus depth;

3. graph of measured water level versus depth;

4. lost circulation zones (including time/date, depth, total amount of fluid loss and rate of fluid loss);

5. casing profile; and

6. appropriate comments (i.e., bit type, bit change, etc.) as they related to enhanced interpretation of the borehole data.

Deviation Survey

The borehole deviation will be surveyed at total depth and prior to setting any 4-1/2" casing.

Data Collection After Borehole Completion

Temperature Surveys

Two temperature surveys are planned to be conducted one week and one month after the CTGH-1 has been completed. These surveys will be run from surface to total depth. Pruett Wireline Industries, Inc. of Bakersfield, California, will provide this service.

**It was indicated in the TPC/DOE contractual agreement for CTGH-1 that maximum recording thermometers will be run at every core recovery. This intended procedure would prove to be unnecessarily time consuming. An agreement was reached between TPC and DOE and its geotechnical consultant UURI, for the program change as described above.

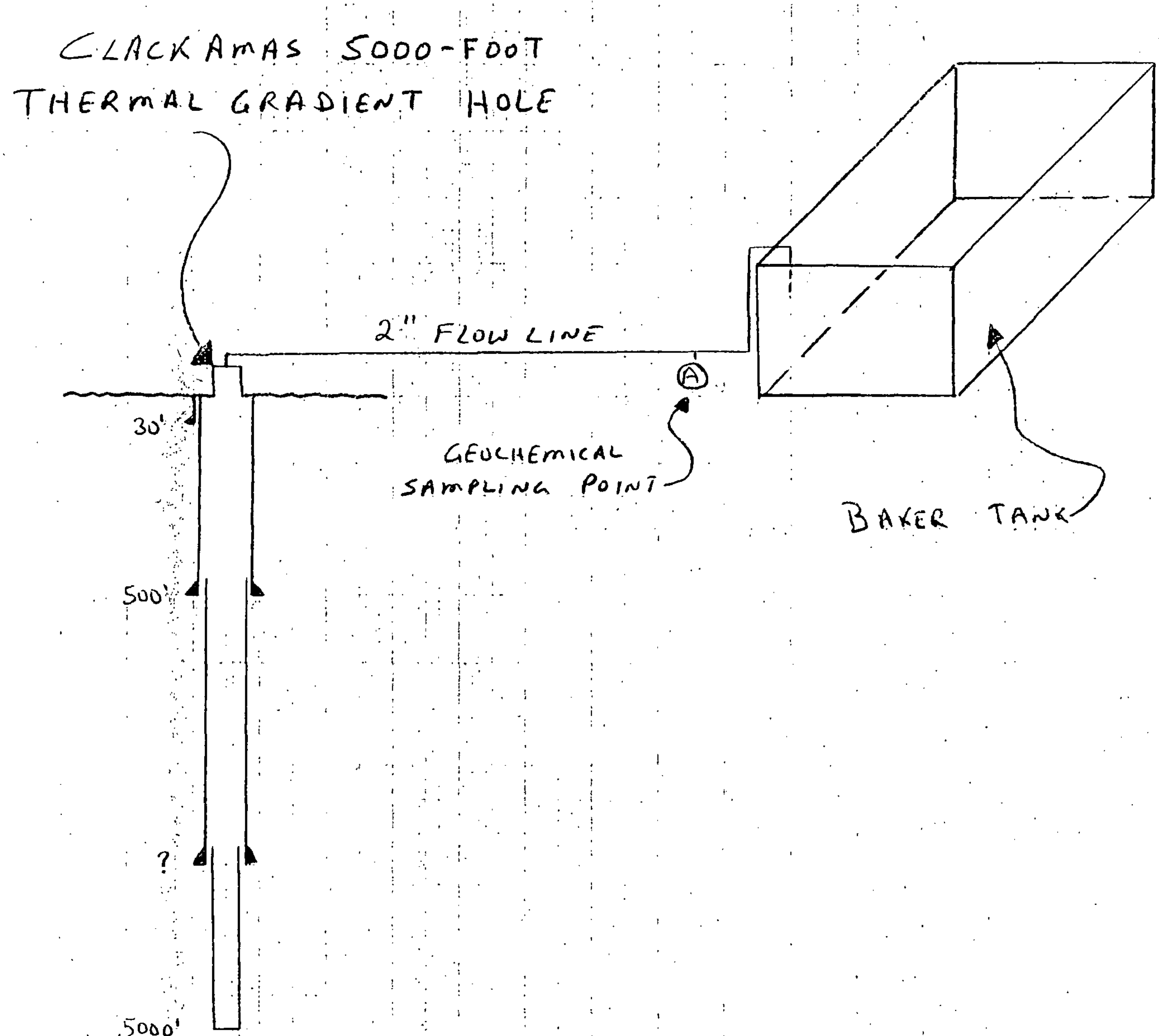


FIGURE 1: SCHEMATIC OF CTGH-1 FLOW TEST

APPENDIX 1: DUTIES OF A DRILLSITE GEOLOGIST

The primary responsibilities of the drillsite geologist is to complete an accurate, continuous (24 hours per day), geotechnical compilation in accordance with the Project Data Collection Program, to observe and to record all other pertinent data, to promptly report critical borehole observations, and to provide the Thermal Power Company Drilling Supervisor with the required geotechnical data support to effectively drill and/or core the hole. These activities will be supervised on a daily contact basis by the Senior Geologist of Thermal Power Company. The drillsite geologist duties follow.

1. Notify Thermal Power Company (contacts below) daily of all activities related to data collection from the borehole. Reports to Mr. Waibel of Columbia Geoscience will be provided as requested by Thermal Power Company.

Principal Contact:		Joe Iovenitti Senior Geologist	707/576-7232
Secondary Contact:	1.	Jeff Hebein Senior Geologist	707/576-1398
	2.	W. L. (Bill) D'Olier Vice President-Geothermal Exploration	707/576-7040

2. Collecting, washing, labelling and boxing of all rock samples as described below. Procedures follow directly from DOE policy with minor modification by Thermal Power Company.

   Drill Cuttings: Will be collected whenever available at 10-foot intervals. Each sample will weight approximately one kilogram. Samples will be collected at the end of a flow line with a bucket acting as a screening device. Drilling cuttings will be washed of drilling mud as needed. Sample will be placed in a bag labelled with the Hole name, Prospect name, State, Section, Township and Range, and drilling depth interval. Two sets of one kilogram each will be collected at each sample interval.

   Core: The core will be transferred from a core barrel to a core trough where it will be washed. Care will be taken to ensure that all pieces of core remain in their original orientation and sequence. All core pieces with length equal to or greater than core diameter will be marked with an arrow pointing downhole using a permanent felt tip marker. Core will be transferred from the core trough to core box.

   When the core is placed in the core box, a wooden block labelled with the bottom depth of the core run will be placed at the end of the core from the run. If a core run did not directly follow the previous core run because of some non-coring operation, a wooden block labelled with the beginning depth of the core run will be placed at the top of the run such at the beginning and ending depth of each will be indicated. All core will be placed in core boxes following a uniform system: with the box orientation label on the left, the box will be filled from upper left to lower right (Figure A1-1). The label on each core box will be completely filled out using care to ensure that lettering is easily legible, as large as practical and done with an appropriate permanent marker. The drillsite geologist will be responsible for marking orientation arrows on the core, placing the depth labelled blocks at the top and bottom of each core run, and labelling core boxes.

3. Provide detailed geologic descriptions as described below of all cuttings at 20-foot intervals. Core will be described at a scale of one inch is equal to five feet (1" = 5'). Form sheets 1 and 2, respectively, are to be utilized.

   Geologic Description: For both drill cuttings and core consist of complete lithologic, alteration mineralogic, and structural (e.g., fractures, joints and fracture) descriptions. Where appropriate, rock units will be identified along with their upper and lower contacts. Core size, bit type, drilling fluid and lost circulation material will be noted insofar as it affects sample conditions.

4. Maintain the core recovery log (Form 3).

5. Maintain a temperature log both for drilling fluid temperature in/out and MRT readings.

6. Maintain a depth penetration log.

7. Maintain measured hydraulic head log which will be recorded daily.

8. Maintain a lost circulation log which includes time, depth, amount and rate.

9. Summarize all field drilling data (above) onto a "mud" log (Form 4) at a maximum scale of 1" = 100'.

10. Collect fluid samples, record wellhead temperature and pressure, and measure pH, temperature and specific conductance of recovered samples as appropriate.

11. Observe geophysical well logging operation with Thermal Power Company Senior Geologist.

12. Coordinate and discuss geotechnical data collection program with Thermal Power Company Drilling Supervisor, as appropriate.

Diamond Shamrock
Thermal Power Company

CUTTING DESCRIPTION

HOLE ______________ GEOLOGIST (S) ______________

FIELD ______________ BASIS ______________

DEPTH INTERVAL	LITHOLOGIC DESCRIPTION

Form 1

Diamond Shamrock
Thermal Power Company

CORE DESCRIPTION
40 FOOT INTERVAL

HOLE ____________ GEOLOGIST(S) ____________
FIELD ____________ BASIS ____________

DEPTH INTERVAL	DESCRIPTION

Form 2

Diamond Shamrock
Thermal Power Company

PAGE ____ of ____

CORE RECOVERY LOG

HOLE ______________________ FIELD ______________________ GEOLOGIST(S) ______________________

____

DEPTH INTERVAL CORED (ft)	RUN / BOX NUMBER	CORE BARREL MEASUREMENT	AMOUNT RECOVERED (%)	COMMENTS

Form 3

Diamond Shamrock
Thermal Power Company

HOLE ______ SPUD DATE ______ COMPLETION DATE ______ TOTAL DEPTH ______
FIELD ______ COUNTY ______ STATE ______ TOTAL VERTICAL DEPTH ______
LOCATION ______ ELEVATION ______ ☐ KB of ___ ☐ GL BOTTOM HOLE LOCATION ______
CONTRACTOR / RIG ______ GEOLOGIST (S) ______

CASING PROFILE	LITHOLOGY	DEPTH	DRILLING TYPE ______	TEMPERATURE	PENETRATION RATE	WATER LEVEL (Measured)	LOST CIRCULATION ZONES	LITHOLOGIC DESCRIPTION	COMMENTS

Form 4

Appendix 2: Drillsite Geologist Resumes

ANGELA K. McDANNEL

44 N. W. 27th
Corvallis, OR 97330
(503) 758-5101

OBJECTIVE	Career as a geologist in geothermal exploration/production		
EDUCATION	Oregon State University	M. S., Geology, in progress	
	Oregon State University	B. S., Geology, March, 1980 overall GPA 3.4, major 3.5	
	Georgia State University	B. S., Urban Studies, June, 1973 overall GPA 3.2	

EXPERIENCE AND EMPLOYMENT

6/85--10/85
6/84--11/84
6/83--10/83
Union Geothermal Division, Union Oil Company of California, 2099 Range Ave., Santa Rosa, CA 95401, (707) 542-9543. During the 1983 and 1984 field seasons, I was Union's on site geologist for exploration wells drilled in northern California and Oregon. My responsibilities included making decisions regarding drilling technique and procedure, keeping accurate records of drilling progress, well temperature, lithology and alteration mineralogy. My most recent assignment was in the Santa Rosa office where my work focused on structural and stratigraphic analyses of two geothermal prospects.

6/82---8/82
The 1982 field season was dedicated to field work which provided a foundation for my thesis project. This work included mapping numerous Pliocene and Pleistocene lava and pyroclastic flows, epiclastic sedimentary rocks, and structure in sixty square miles of volcanic terrane within the Deschutes Basin of central Oregon.

3/81---9/81
9/80--11/80
Freeport Exploration Inc., Mt. City Star Route, Elko, NV 89801, (704) 738-9221
During these field seasons I worked with Freeport Gold's Jerritt Canyon Project exploring for satellite ore bodies of fine-grained gold. My responsibilities included: geologic field mapping, geochemical sampling, logging drill chips, and writing reports of field work and drilling results.

4/80---8/80
Freeport Exploration Inc., 50 W. Liberty, Reno, NV 98505 (704) 323-2251
As an assistant geologist working in precious metal exploration, I engaged in reconnaissance scale mapping and geochemical sampling throughout northern Nevada.

ACTIVITIES AND INTERESTS

member, Geological Society of America
member, Oregon Academy of Science
Leisure activities: climbing Cascade peaks, hiking, bicycling, ballet.

REFERENCES

John M. Bodel, Geologist, Union Geothermal, 2099 Range Ave., Santa Rosa, CA 95406, (707) 542-9543

Edward M. Taylor, Associate Professor, Oregon State University, Corvallis, OR 97331, (503) 754-2484

William H. Taubeneck, Professor Emeritus, Oregon State University, Corvallis OR 97331, (503) 754-2484

DOUGLAS GOODWIN
232-1/2 Holtby Road
Bakersfield, CA 93304
(805)322-9534

EMPLOYMENT OBJECTIVE	Seeking an opportunity for resource exploration and development with a dynamic, growing organization
SUMMARY	Eight year's practical experience in the exploration and development of mineral and geothermal resources using state-of-the-art geology, geochemistry and geophysics

EXPERIENCE

Geologist — Bakersfield, CA

11/84 - 11/85 Santa Fe Geothermal, Inc., Exploration Dept.
11/80 - 11/84 Occidental Geothermal, Inc. Exploration Dept.

Responsible for prospect generation, resource characterization and evaluation, SW U.S. Developed and supervised phased regional and prospect geothermal exploration programs consisting of geology, geochemistry, and geophysics leading to reservoir testing.

Field Geologist — Billings, MT

8/77 - 9/80 Johns-Manville Corp., Mining Division, Exploration Department

Explored for/delineated reserves of platinum, uranium, asbestos, diatomite, and perlite at prospects/mines in U.S., Mexico, Canada, and Sudan. Responsible for prospecting, claimstaking, gridding, geologic mapping, core logging, performing geochemical and geophysical surveys, surveying, drilling supervision, coring, blasting, logistics, construction. Reported results of research, field work and prospect/mine evaluations.

EDUCATION

1/76 - 6/77 University of California, Santa Cruz
1/75 - 3/75 B. S. Earth Science 12/77 General College Honors

9/75 - 12/75 University of California, Los Angeles
9/72 - 12/74

AFFILIATIONS	Geothermal Resources Council	1981-1985
	Northwest Mining Association	1978-1980
REFERENCES	Available upon Request	

REFERENCES

Dr. Robert A. Crewdson
General Manager
Sierra Scientific Services
2446 Hasti Acres Drive
Bakersfield, CA 93309
(805) 831-5121

Mr. John F. Arestad
Exploration Manager/Senior Geophysicist
Santa Fe Geothermal, Inc.
3333 Lee Parkway
Dallas, Texas 75219-5199
(214) 521-3151 ext. 732

Dr. Robert W. Potter
Senior Geochemist
Santa Fe Geothermal, Inc.
3333 Lee Parkway
Dallas, Texas 75219-5199
(214) 521-3151 ext. 684

Dr. Stan J. Todd
Johns-Manville Sales Corporation
Exploration Department
1826 Grand Avenue, Suite #1
Billings, Montana 59102
(406) 656-1531

Mr. Graeme R. Driver
Geothermal Energy New Zealand Ltd.
P. O. Box 37-231
3 Broadway
New Market
Auckland 1, New Zealand

Appendix 3:   Daily Drilling Report Form

THERMAL POWER COMPANY

CSG
" CSG. ____
" CSG. ____
" CSG. ____
LINER ____
TIE-BACK ____

WELL NO.____ AFE NO.____
REPORT NO.____ DATE ____
TOTAL RIG DAYS ____ TIME FROM SPUD ____
DEPTH @ 2400 HRS. ____ FOOTAGE DRLD. ____
HRS. DRILLED ____ HRS. TRIPPED ____ HRS. REPAIR ____ RIG NO.____
HRS. OTHER ____ COOLING TOWER IN USE. YES ☐ NO ☐
MUD WT.____ VIS.____ W.L.____ CK.____ PH____ CHL____ YP____
P.V.____ GELS____ % SAND____ % SOLIDS____ % LOST CIRC. MTL.____
GALVONIC PROBE____ CORRATOR____ SULPHIDE____ OXY.____ AIR-H_2O RATIO __/__
FORM. DRLD.____ FLOW LINE TEMP.____°F. SUCTION TEMP.____°F.
MAX. TEMP.____°F. DEVIATION SURVEYS: ____

BIT #	SIZE	MAKE	TYPE	SER. NO.	JETS	IN	OUT	FT.	HRS.	WT.	RPM	COND
												T B G
												T B G
												T B G

PUMP	LINER	STROKE	SPM	GPM	PSI	TOTAL GPM	NOZZLE VEL.	ANNULUS VEL.

AIR COMP. NO____ CFM____ PSI____ TEMP. °F____ CHEM.____ RATIO__/__ RATE____
DRILLING ASSEMBLY, TOTAL LENGTH AND DESCRIPTION:____

TOTAL STRING WT. ____ TOTAL PICKUP WT. ____ ROTARY TORQUE (HIGH AVERAGE LOW) ____ ____ ____
STEAM ENTRIES, DEPTH, LBS.____

REMARKS FOR 24 HOUR PERIOD:

OPERATION @ 0600 HOURS FOLLOWING DAY:

INOPERATIVE EQUIP'T. EXPLAIN ____

COSTS

TANGIBLES
- CASING ____
- VALVES ____
- FLANGES ____
- OTHER ____

INTANGIBLE
- LOCATION ____
- RIG MOVES ____
- RIG ____
- ABATEMENT ____
- BITS ____
- DRILL EQUIP. MAIN. ____
- DRILL. EQUIP. RENTAL ____
- FUEL, WATER POWER ____
- MUD ____
- SUPERVISION & LABOR ____
- CEMENT SERVICES ____
- TRANSPORTATION ____
- LOGGING SERVICES ____
- FISHING & DIRECTIONAL ____
- OTHER ____

DAILY TOTAL ____
FORWARD ____
ACCU. TOTAL ____
AFE ____

United States Department of the Interior

GEOLOGICAL SURVEY

copy to Davey for Sample library – orig Geo

Octobe

Mike Wright
University of Utah Research Institute
Earth Science Laboratory
391 Chipeta Way, Suite C
Salt Lake City, UT 84108

Dear Mike:

Thanks for letting me sample the CTGH-1 and GEO N-3 drill cores. I began at the bottom of the GEO N-3 drill core and only looked at the lower half of the core because the little hydrothermal alteration present does not appear to extend much above 2700' depth in the core. My hand-lens inspections found only calcite, siderite, pyrite, clay-smectite?, some iron oxide staining, and perhaps a little fumarolic alteration. The CTGH-1 drill core is equally as dull from a hydrothermal alteration viewpoint and contains only a few zeolite minerals, silica, and clay.

I gave lists of the samples collected from each drill core to Davey; however, the CTGH-1 list was not in numerical order, so am enclosing a more useful sample list for that drill core. I will send reports of the distribution of secondary minerals in the two drill cores as soon as they are available.

Once again, thank you very much for your cooperation in letting me sample the two drill cores. I hope no problems occurred with DOE because of my early start.

Just out of curiosity, did you find space for the 6 truckloads(!) of drill core expected the week following my departure?

Sincerely,

Keith E. Bargar

Keith E. Bargar

CTGH-1 samples
collected by Keith Bargar

535	1646	2259.75	2902.5	3569.5	4355.5	4538
552	1658.5	2265	2909	3584.5	4364	4545.5
557.5	1680, 1681.5	2295	2912.5	3601	4386.7	4546
567	1710.5	2303.5	2925.5	3605.5	4389.6	4565
585.25	1725	2317.5	2941	3606.75	4391	4573
623	1744.5	2321	2951	3613.75	4393.5	4581.5
633.5	1826.5	2348.5	2954.5	3626.25	4398.2	4589.4
654.5	1825	2361.5	2974.5	3633	4399.3	4591.7
714	1831	2368.9	2981	3665.5	4401	4592
801	1847.5	2388.8	3008	3707.5	4404.6	4596
817.5	1852	2393	3013	3717	4406	4610
825.5	1872.5	2397	3027.5	3740	4408.9	4620
882	1880.5	2416.5	3041.5	3757	4423.5	4624
921	1933.5	2449	3062.5	3797.3	4431	4629
983.75	1947	2485.25	3100.5	3812.5	4431.5	4629.4
1001.5	1952.5	2507	3112	3828	4432	4631.2
1010	2041.5	2515	3135.75	3835	4441.5	4651
1049	2067	2585	3140	3859.5	4452	4655.[illegible]
1067.5	2070	2592.25	3148.75	3884	4455.5	4661.2[illegible]
1081.25	2079.25	2605	3161.5	3905.75	4456	4677
1114.5	2083.5	2608	3175.5	3920.5	4457	4681.9
1152	2090.5	2661.75	3182.5	3928.5	4460	4682.[illegible]
1186	2111.5	2665	3196.5	3944	4469	4693.5
1197.5	2114	2693	3210	3965.75	4483	4696.2[illegible]
1209	2124.5	2704.5	3237	3995	4497.6	4707.2[illegible]
1243.5	2137	2712.5	3236.5	4016.5	4501	4710
1251.75	2147.5	2723	3248	4017.5	4501.5	4713
1273.75	2148.5	2736.5	3264.5	4049.75	4503	4720
1300.75	2149.75	2745	3325	4081.5	4504.5	4723
1321	2153.5	2761.5	3329.25	4106.5	4505	4732
1349.5	2157.25	2768.5	3348	4114	4505.8	4754.5
1361.5	2164.75	2783.75	3372.75	4134	4507.8	4777
1376	2168.25	2787.5	3407	4153	4514	4779
1384	2175.5	2803	3423.25	4179.5	4517.75	4786.9
1424	2183.75	2808.5	3450	4193.75	4518.8	4790.6
1436	2184.75	2819	3456	4206.25	4521.5	4792
1442	2192.5	2825	3481	4241	4523.9	
1495	2215	2835	3483	4263.5	4531.8	
1534	2224	2843.5	3518	4300.5	4533	
1576.5	2242.5	2863	3544.5	4301.5	4534	
1614.5	2244	2895	3560	4322.75	4536	

CLACKAMAS THERMAL POWER HOLE

Drilling History

The Clackamas hole is located in the western part of the high Cascade graben, Sec. 28, T8S, R8E, near Detroit, Oregon. The hole was spuded on June 7 and completed on September 7, 1986. Out of 80 days of operation, 59 days were spent actually drilling, and 21 days involved setting casing and rigging up BOP, technical problems, logging the hole and rigging down. During August, drilling was suspended for 13 days due to forest fire danger.

In general, the drilling of the Clackamas thermal gradient hole progressed smoothly and coring averaged 80 feet per day with excellent core recovery. Two significant lost time problems occurred. The first was test failure of the BOP due to a faulty flange. This problem cost 3 days of operation and may have been avoided by pre-assembly and test of the BOP by the supplier, prior to delivery to the drill site.

The second problem was parting of the HX drilling pipe. This probably was caused by a combination of metal fatigue and drag or torque forces in the drill string. Quality inspections of the drill pipe connections during trips out of the hole may have prevented the failure. In any drilling operation, failure of pipe connections is always a possibility however. Of the five down days resulting from the HX rod failure, about 3 were lost to waiting on the NX rods to be transported to the site. These 3 days of down time could have been prevented by having NX rods on site beforehand as a precaution. However, this would have incurred additional mobilization cost unnecessarily if the NX had not been needed.

Continual total drilling fluid loss while coring greatly increased the cost of the mud program and may have contributed to problems such as sanding-in the core barrel and parting of the HX rods due to poor hole cleaning. Only minor efforts were made to regain circulation. Lost circulation is a typical problem when drilling volcanic rocks, especially basalt flows. Core drills have very limited ability to control lost circulation because of their small mud system and low pump rate. The most limiting factor is the close tolerance of the coring system does not allow use of coarse matting LCM materials while drilling. However, the cost of the large volumes of LCM and mud, and rig time that would be required to try to cure lost circulation, could equal the cost of continual mud loss without ensuring success.

A brief summary of the events, problems and cost of each segment of the Clackamas hole is given in Appendix I, and a daily list of depth and events during drilling is given in Appendix II. Figures provided by Thermal Power Company of casing completion and the casing head assembly are provided in Appendix III.

APPENDIX I

CTGH-1 Drilling History - Summary

June 7 - 13	Tricone drill to 517', set 35 of 10 3/8" conductor in 12 1/4" hole. Set 519' of 7" K-55 BT & C, 26 lb. casing in 8 3/4" hole and cemented with 181 cu. ft. of cement mix (see Daily Activities). Main problems were getting conductor set into the 40' of glacial boulders in till, some lost circulation in the basalts, which was overcome, and the 7" casing hung up some in the basalt flows. The 8 3/4" bit cut 482' of hole. Costs to this point was $49,390, including mobilization. Drilling cost averaged about $60 per ft., but costs and drilling time were controlled more by hole problems and setting casing than penetration rate.
June 14-19	Nippling up BOP and rig up for coring. The first test of the BOP failed due to a flange leak, requiring a new flange. Costs for this phase of the project were $19,030, equipment not included.
June 20- Aug 18	Cored 4283 feet to a depth of 4800'. Circulation was lost at 540' and never regained while drilling with HX rods to 4203', although LCM efforts brought the water level to within 20' of the surface. Most of the time the static water level was at a depth of about 70'. Core recovery was virtually 100% for the entire hole. Penetration averaged 80'/day during the 54 days of actual drilling. the cost for this section of the hole was $316,843 total, or $74/ft. Six HX core bits cut an average of 600' each, although individual performance was highly variable. For example one bit cut 1385', but the first bit run cut only 61 ft. and was not used for the average above. The short 61' run is probably due to non-lithology factors such as driller's error, junk in the hole after drilling out the casing shoe or a defective bit. Note, also that the first NX bit run cut only 23' due to milling out the HX bit left in the hole. The second NX bit cut 574' to T.D. A total of 9 core bits were used. While drilling the main section of the hole, 10 non-drilling days resulted from technical or equipment problems. These problems were core barrel jammed in defective rods or sanded in,

parted wireline, and the drill pipe broke or twisted off twice. The first time the rods broke while drilling at a depth of 527 feet with a 6" tricone bit. Drill pipe failure was probably due to a combination of stresses from the 6" bit and the HX rods "wipping" around in the 7" casing. After the bit and lost drill pipe were fished out, 4.5" core guide casing was set to 527 feet. Once the casing was in place coring continued to 4203 feet with only minor problems.

The second twist off of the HX drill pipe occurred at a depth of 4203 and may have been caused by general metal fatigue and friction drag in the hole. It was decided at this time that it would be best to switch to NX drill pipe, rather than attempt fishing out the HX. Six days were lost waiting on the NX drill pipe to arrive and retrieving the HX core barrel.

The final T.D. of the hole was determined by the U.S. Forest Service shutting down all operations in the area due to extreme fire danger. After the shut down was over, the hole was conditioned for logging, then geophysical logs were run. Then the drilling company rigged down and moved off site. The discouraging results of a temperature survey run on August 27th (Table II), nine days after drilling ceased, let to the decision not to drill any deeper. All of the HX drill pipe was left in the hole.

APPENDIX II

Daily Drilling Activities

Thermal Power CTGH-1

Date Day/Mo.	Drilled/ Depth	Activity
7 June	35′	12 1/4" bit - Spud, used air hammer 12-35′ in boulders. 10 3/4 conductor hung up at 12′
8 June	35′	Moved rig 6′-12 1/4 bit to 35′, conductor hung up at 28′- 54 vis mud
9 June	-0-	Clean hole to 35′, set 35′ 10 3/8" conductor and cemented with 32 sacks cement, 3% CaCl
10 June	185-220	8 3/4" bit, 6" D.C. Drilled to 220′, deviation 1/2^{o} at 160"
11 June	200-420	61 vis mud, 9.2 wt; 400-410 L.C. 50% 1000 gal.
12 June	97-517	70 vis, 8.8 wt. Lost 60 bbl at 425′, Geophy log 517-35′
13 June	-0-	Problems setting 7" casing to 488′ 127 ft^3 G cement 1:1 perlite + 40% silica flour, plus 32 ft^3 tail slurry. Good returns
14 June	0-517	Top job cement 4 bbl class G 1:1 perlite, cut off 7" casing, dug cellar
15 June	0-517	Nipple up casing head and BOP
16 June	0-517	Nipple up BOP, test, found leak, ordered new flange
17 June	-0-	Still working on 8 5/8" X 6" flange
18 June	-0-	Install new flange, tested BOP and approved
19 June	0-517	Rig up and align core rig.
20 June	10-529	6" tricone bit, drilled out cement, lost bit and 4.5" joint on bottom

Date	Drilled/ Depth	Activity
21 June	0-527	Pulled fish out with Bowen overshot, set 4.5" core guide casing with 11 stabilizer
22 June	70-597	Started coring with 3.937", HX rods, lost circulation at 530', bit cut 61'.
23 June	97-694	Coring with no fluid returns, -30 GPM mud in. 45 vis
24 June	80-774	Coring, no fluid returns, tried LCM but no results
25 June	85-859	Replaced bit at 859' it cut 271'
26 June	59-918	Coring, run in hole with new bit, mud 45 vis
27 June	44-962	POH to grease rods, then sanded in core barrel and POH
28 June	121-1083	Coring, no fluid returns, greased rods
29 June	162-1245	100% core recovery, no fluid returns
30 June	71-1316	Replaced bit (412'cut) at 1271' depth
1 July	137-1453	Coring, no fluid returns, 100 % core, water level in hole 45'
2 July	137-1590	Coring
3 July	100-1690	Coring
4 July	75-1765	Coring
5 July	10-1775	POH, replaced bit, RIH, 560-963 interval partially blocked
6 July	53-1828	POH to service coring assembly, bridge at 660' when re-entering hole
7 July	89-1917	Coring
8 July	81-1998	Coring
9 July	85-2083	Coring
10 July	98-2181	100% core recovery, no fluid returns

11 July	105-2286	Coring, mud is 45 vis
Date	Drilled/ Depth	Activity
12 July	50-2336	Wireline parted, POH, fix line, RIH with new bit
13 July	32-2368	Washed from 1000'-2336
14 July	98-2466	Coring
15 July	69-2535	Core barrel jammed in rods at 500', POH bad joint of core tubing, bridge at 1776'
16 July	59-2594	Core barrel jammed in rods again, at 400' bad joint of tubing
17 July	114-2708	Coring
18 July	101-2809	100% core recovery, no fluid returns
19 July	103-2912	Coring
20 July	68-2980	Coring
21 July	89-3069	Coring
22 July	104-3173	Coring, water level 80' in hole
23 July	96-3269	Coring
24 July	86-3355	Coring
25 July	106-3461	Coring
26 July	101-3562	Coring, water level up to 70'
27 July	79-3641	Coring
28 July	80-3721	Coring
29 July	2-3723	POH put on new bit, core barrel latch and reamer shell
30 July	88-3811	Coring
31 July	90-3901	Coring with HX bit
1 Aug	81-3982	Coring
2 Aug	80-4062	Coring
3 Aug	81-4143	Coring

Date	Drilled/ Depth	Activity
4 Aug	60-4203	Coring, HX drilling rods broke in the hole at 823'
5 Aug	0-4203	Waiting on NX rods
6 Aug	-0-	Waiting on NX rods
7 Aug	-0-	Nx Rods arrived, RIH to locate break at 823'
8 Aug	0-4203	Ran latching assembly on NCC rods to pull HX core barrel, POH without core barrel
9 Aug	0-4203	Modified latching assembly, RIH, POH with core barrel
10 Aug	23-4226	Milled through lost HX bit with new NX bit, cored 23' then POH for new bit
11 Aug	53-4279'	Coring with NX bit
12 Aug	92-4371	Coring
13 Aug	79-4450	Coring, torque increase at 4405'
14 Aug	80-4530	Coring
15 Aug	90-4620	Coring
16 Aug	80-4700	Coring
17 Aug	60-4760	Coring-Temp. survey, recover and repair broken wireline
18 Aug	40-4800 TD	Shut down by Forest Service due to dry forest condition
27 Aug	-0-	Temperature-pressure survey ran
2 Sept	-0-	Crew moved on site and run NX rods to bottom
3 Sept	-0-	Condition hole for loggers
4 Sept	-0-	Geophysical logs run
5 Sept	-0-	Completed logging, shipped core to UURI

Date	Drilled/ Depth	Activity
6 Sept	-0-	Rigging down
7 Sept	4800 TD	Finished rigging down. Drilling costs to date: $438,718

APPENDIX III

Well Completion Diagrams

CLACKAMAS CTGH-1 CORE LOG

Location: Marion Co., Oregon
T85,R8E, Sec. 28
Drilled July-Sept., 1986

Well Head Elevation: 3840 feet
Logged by: Sibbett, UURI, Nov., 86
Page: 1 of 18

GEOLOGIC DESCRIPTIONS

Box #	Bottom Depth Of Box	Fractures (90^o=vert.)	Unit Interval (feet)	Lithology Description
1	527-536	74^o,88^o,5^o	527-550	Olivine Basalt 2% 2mm Xls Ol, Plag. Xenomor, light gray, 1% < 2mm vesicles, myrolitic cavities
2	544	mod. to few 45-90^o		Basalt con. 3-5% diktytaxitic cavities, med. xl. text Vesicular flow base starts at 549'
3	552	irregular fract. few 25^o, breccia	550-580	Basalt viscular 1/2-2 cm, grayish-red, 10% $\leq$ 1 mm anh. pheno Plag. & ol., glommupheric, matrix fine grain.
4	562	no sign. alt. pk-brn clay	558-580	Diktytaxitic cavities. Flow breccia, vesicular.
5	579			Med-gray, flow breccia, vesicular
6	588	few 75^o	580-610	Basalt, ves. first 8', < 0.5 cm ves. Med-dark gray nonporph. Fine grain xenomorphic.
7	595.5	mod. 80-90^o		Dense flow, vert. joints, few plag. pheno.
8	606.5	mod. 80-90^o		Vesicular base starts at 603
9	620	few 80-90^o	610-646	Basalt, vesicular top to 618', 1-2 cm ves., Dark gray fine grain. 2% 1mm plag. xls.
10	629	minor fault 60^o	625-628	Flow bands horizontal, 624.5 flow base breccia starts to 628. Slicken side, minor clay, fault & flow breccia above.
11	639	few 90-85^o		1/2 cm 15% vesicles, pink clay wash-in on fract.
12	648	few 65^o		near horiz. flow-band bubble plan. Flow breccia
13	658	few 65^o & 90^o	646-661	Basalt flow, dark gray, fine, 1/2 cm ves., 25% vesicular top to 653' Xenomorphic, 2% 1 mm plag.
14	675	few 85^o-90^o	661-683	Basalt flow, & breccia, vesicular 25%, fine grain dk gray-grayish-brn. 1-3 mm ves. clay matrix in brec.
15	693	mod. 80-90^o, few 65'	683-711	Basalt flow, v. fine grain, med-dk gray, dusky brn-grayish brn, flow-top breccia 686, $\leq$ 1 mm ves.
16	701	mod. 60-70^o 90^o		2% 1mm plag. pheno, anh, few 1-5 mm ves. fractures spaced 2-6 cm
17	710	few 55-60^o and 90^o		White clay on vert. fract. 0.5 ft. flow breccia base recovered.
18	733	few 70^o	711-795	Basalt Flow, ves., fine grain. Grayish red upper flow breccia, gray below 730'
19	743	mod. 80-90^o		Brnish-dk gray, < 1 mm ves. abundant. minor clay on fractures spaced 3-6 cm.
20	750	few 60^o		V. fine grain, med. gray, clay coat on fractures.
21	760	2 fractures, 30^o & 65^o		Same as above
22	770	45^o & 70^o		Xenomorphic, non-porphyritic.
23	785	few 65^o	774-	Flow contact, vesicular basalt above & below.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
24	800	minor clay in ves.	795-815.2	Basalt Flow, vesicular top, dark gray, diktytaxitic 2% 1 mm anh plag. pheno. yel-brn clay on fractures
25	809	few 80° & 60°		Fault breccia at 811', flow breccia 814-815.2'
26	817.5	mod. strong 70-90°	815.2-846	Lithic Tuff, yel-gray to pale yel-brn ash
27	826.5	crush-zone		Light gray to reddish-brn clast., non-welded weak compaction. Lithic-Lapilli tuff.
28	838	few 80°		Blocks to 15 cm. dia., water lain (?) ash 3 cm thick at 837. Andesitic? blocks in lapilli tuff
29	848.5	broke up	846-1114	Andesite? lava-flow, gradual contact 840-846 fine grain, dk grnish-gray.
30	863	strong 10°		non-porphy, clay coating on flow fract. 2-3 cm sp. flow foliation dipping 10°
31	883.5	mod.-strong 10° flow joints 80°		Andesite (cont.) dk-grn-gray-fine grain. bimodel xls. 20% 1 mm plag. & pyrox/Ol, mag.
32	883.5	65° 4 cm sp. strong 0-20°		black 1 mm min. on fract. Mn.Ox?
33	892	mod. 10° & 30°		as above, fractures 3-6 cm spac.
34	903.5	mod. spec. 10-30° few 80°		pink-grayish orange clay on 80-90' fract.
35	913	mod. 10-30° & 90°		as above
36	918.5	10-30°		Andesite Flow continued from 846', fine grained
37	928	90° fract.		as above, clay on 90° fractures, MnOx on 10-30° fract.
38	937.5	10-30° strong few 60°		Andesite continued
39	949	strong 0-20°, 90o		some clay cement breccia, slickesides-20° dip. increased clay on all fractures
40	960	strong 0-20°, 90°		Minor hem. stain on fract. gray-orange clay in fractures. Andesite cont.
41	964.5	mod. 0-70°		as above, bi-model andesite < 1 mm plag. xls, in an aphanitic matrix, very uniform texture
42	974	few 0-20° few 90°		clay infill on vert. fract., minor hem. coat on fract.
43	984	mod. 10-30° few 80°		as above, 2-20 cm fracture spacing
44	992.5	mod. 10-30° few 80°		clay on 80° fract.
45	1000.5	strong 10-30° few 70°		minor breccia zone at 1,000', clay filled fracture spacing 1-3 cm
46	1010.5	mod. 0-20°		as above

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
47	1021	mod. 0-10° few 80-90°		clay filling vertial fract.-clay had drying cracks
48	1030	mod. 0-10° mod.70-80°		as above
49	1039	strong 65° 0-10° few 90°		1038-39 breccia, clay filled
50	1049	mod. 0-20° few 55°		as above, fracture spacing 5-20 cm
51	1057.5	mod. 10-20° 60°, few 80°		clay on high angle fractures
52	1057.5-1066.5	strong 70-80° few 10°, 60°		Andesite Flow continued from 846', dark-grn-gray, fine grained, 20% 1 mm xls plag. & pyrox fracture spacing 2-3 cm
53	1075	Strong 80°		as above, fracture spacing 1 cm
54	1082.5	Mod. 75-90° Few 30°		Andesite(?) poss. dacite continued.
55	1091.5	Mod. 40-60° few 90°		clay on fractures
56	1101	few 80-90°		clay on fractures
57	1110	Few 80-90° few 60°		Conformable lower contact with underlying pyro-clastic. 1109-1114 basal flow breccia
58	1119	V. few 90° Minor slip 1115'	1114-1137.5	Lahar(?) volcanoclastic deposit, crude bedding. Carbon in top 1.5', mix. vol. clasts in tuff-sand-clay matrix
59	1130.5			Gray-brns to pale red near base -- base contact conformible, pebbles to 20 cm blocks, upper contact dips 15° lower contact 20°
60	1139		1137.5-1243.5	Dacile (?) Porphyritic 10% 1-3 mm anhedral feld. plag? pyx, bio, matrix is grnish-black, aphanitic, even text, minor ves. upper 6'
61	1149	Few 75-90°		porphyritic 10% 1-3 mm pheno. plag, prox bio. grn-black matrix, clay on fract. is pale-brn w/ red flakes, clay filled breccia 1143-1145
62	1158	Few 50-60° & 80° & 30°		Clay coating on fract. < 1 mm to 3 mm, tuffac. banded clay washed into fractures.
63	1167	Few 90-80° & 60°		minor slip surface on clay joint 1160'
64	1177	Few 90°		Dacite cont. joints clay coated
65	1186	Mod. 70° 90° few 55°		pink clay in joints, washed in.
66	1196	Mod. 50-60° few 80° & 40°		color grades to dark-olive gray. 40° flow-parting with clay & mica on fractures
67	1205	Few 50° & 30° flow parting		few andesitic? xenoliths. 2 cm.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
68	1215	few 90-80° & 30°		dark brn coating-MnOx? on 30° fractures
69	1223.5	mod. 20° few 90°		dacite continued, 4-8 cm fracture spacing
70	1232.5	few 20°, 70°		basal flow breccia starts at 1230', greenish-blk blocks with ash & minor clay filling breccia, vesicular, red oxidized matrix
71	1242			ves. in blocks increase, blocks red-oxidized also. minor pale-brn clay injected. Prob. flow emplacement fault at base.
72	1251.5	fault 1244'	1243.5-1587	Volcano-clastic-2% porphy, pale-brn, Dacitic dome. ~~lapilli to block~~ size brn andesitic? clasts 2% xls.
73	1261	v. few 70°		pale red baked upper contact to 1251, pale brn clasts in a light brn to pink tuffac. clay matrix, clast suported
74	1270.5			pink to brn laminated swelling clay infills between clasts.
75	1280	few 70°		probable rubble flow or dome spree apron.
76	1288	few 40°		volcano clastic or flow breccia continued, core breaks around clasts
77	1297.5	few 70°		Dacitic (?) flow or dome with upper breccia 1243-1292'
78	1306.5	few 70°		change to flow banded & sheared 70o to vertical.
79	1315.5	mod 90°		vertical flow banded, probably a dome- or thick flow
80	1325.5	mod 70°		dark grnish-gray, some flow brecciation continued,
81	1335	mod 50-60°		clay along fractures
82	1344	mod 70° few 30°		as above
83	1352.5	mod 90° & 70° few 30°		
84	1362	mod 90° to 50° few 0-20°		Dacitic Dome or Flow continued from 1243'
85	1370	prod 0-30° few 80°		
86	1379	mod 10-30° & 55-70°		2% 1 mm plag. pheno's., fracture spacing 3-7 cm
87	1387.5	mod. 80-90°, 10°		as above, fracture spacing 1-5 cm
88	1395	mod 80-90°, 10°		fracture density increased
89	1404	mod 60-70° & 80°, few 20°		as above
90	1412	strong 30-40° 80°, few		Dacite or poss. Andesite continued.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
91	1420	strong 80°, 10-20		Andesitic-Dacite Dome, continued 2% 1 mm pheno, in a dk grnish-gray matrix
92	1428	strong 0-20° & 80°		pink clay wash-in along fractures, 1-5 cm spacing
93	1438	mod 30°, 60°, 80°		Viscosity as indicated by thick flow breccias suggest dacite
94	1447	80-90° & 10-20°		flow shear appears to be about 10° dip
95	1456	mod 90° few 5°		gray-pink clay up to cm thick in vert. fract.
96	1466	mod 80° & 10°		dacite continued
97	1475.5	few 80° 10, 60°		flow shear planes about 10° dip
98	1485	strong 10o 80-90°		dacite continued
99	1494.5	mod 50°, 90°, 10°		2 cm thick clay wash-in on vertical fractures
100	1503	mod 80°, 60°, 10°		white mineral, plag? along flow shear planes
101	1512	mod 80 & 10°, few 60°		dacite continued from 1243'
102	1521.5	few 10°		fracts. along flow shears
103	1530	mod 10° & 75°		dacite continued
104	1539	mod 80° 10° & 30°		dacite continued
105	1548	few 20° & 50°		dacite continued
106	1557	few fract. 60°, 20°, & 90°		dacite continued
107	1565	80-90° & 55°		fracturing moderate to strong frequency
108	1574	few 30° & 70°	1570-1587'	basal flow breccia
109	1583	few 50° & 90°		basal flow breccia
110	1592	few 40° 75-90°	1587-1629	Lahar? Volcanoclastic, lapilli & few blocks in an ash & clay matrix, non-sorted, dark-med gray
111	1601	few 55°		2' beds of ash, 40 cm blocks. Andesite to basaltic clasts, also few pumice clasts
112	1610.5	no fract		some clasts are fairly rounded-smoothed surfaces, few clast irregular to angular, no alteration
113	1621	none		4 cm thick laminated bed at 1620.5
114	1630	few zone		broke up with 80-90° fractures 1626-1629

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
115	1639	few 50°	1629-1673.5	Basalt flow, viscular, to 1648, 2% 2 mm plag xl., upper flow breccia 1624-1644 in filled with ash & clay from lahar
116	1648	V. few 70°		brown and white clay layers half filling vesicles, basalt med-gray, fill surfaces 4° off normal to core
117	1656.5	few 50° 90°, 20°		brownish-gray, flow-shear planes dip 20°, with clay & ves. along planes
118	1666	mod. 20° 90°-70°		clay in-filling along fractures. Basal flow breccia starts at 1666.5
119	1675.5	minor faults 50-60°	1673.5-1694	Lahar or Volcanoclastic 10 cm clasts in banded clay and ash matrix, mostly clast supported
120	1684.5	mod 60-90° & 20°		clay slicken surfaces on fracture, probably minor movement. Most is gray brns & reds, mod-reddish-brn. matrix supported clay zone with gray lapilli
121	1693.5	none		Vol. Breccia-Volcanoclastics continued. dk gray dacitic blocks with pale red-gray ash-lapilli matrix
122	1704	few 55-60°	1694-1784	Basalt or Andesite-olive-black, fine grain. Pink clay-ash in-filling, non-porphyritic, plag, pyroxene-ol.?
123	1711	mod. 60° 32°, 90°		top flow breccia to 1702' breaking along flow shear planes
124	1721	mod. 70-90°, 20°		pale green clay coating or hem. on fractures
125	1728.5	strong 80°, 45°		few 2 mm vesicles
126	1737.7	mod 90°-70°		MnOx & clay on fract.
127	1745.5	mod-strong 55°, 90o		strong MnOx coat on high angle fract. minor hem. stain on 55° fract.
128	1755	mod. 50-60°		MnOx & blue-grn clay coat on 2-15 cm spaced fract.
129	1764.5	strong 50-60°		rock type & alt. continued, fracture spacing 1-5 cm
130	1779.5	mod 45-60°		fracture spacing 2-9 cm
131	1788.5	few 70-90°	1784-1798	Intra-flow breccias and cinders, red, non-vesicular
132	1798	few 60° 10°		clay matrix in-filling flow breccias
133	1807.5	few 70-80°	1798-1820	Basalt Flow, med-dk gray, 25% 1-3 cm vesicles filled with blk-waxy clay, non-porphy
134	1817	mod 90-70°, 60° 10°		grn-blk clay & poss chlor on fract. minor flow breccia at base, but also slicken surface in clay alt. tuff
135	1825	mod 70° 45 & 90°	1820-1826.5	Lapilli Tuff, clay alt. waxy, cracking clays, lapilli alt. also, mod. reddish brn. to orange. mod. sorting
136	1834.5	few 70°	1826.5-1969	Basalt Flow, vesicular, black, non-porphy, upper flow breccia to 1836 in-filled with ol-brn ash

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
137	1845	few 75°		vesicles & fractures filled with black-waxy clay
138	1854	few 90-70°		curving irregular fractures
139	1963	none		Basalt Flow cont. color varies to dk. olive grn, basal flow breccia starts 1857'
140	1872	none		flow breccia-gray to gray-red
141	1882	few 90-80°, 60° & 20°		as above, dark gray
142	1891	few 50°		flow shear planes at 50°
143	1900	V. few 70°		flow shear 10-20°
144	1909	few 70-80°		flow shear 20°, brnish blk clay on fractures
145	1919	mod 70°-80°		basalt flow continued
146	1928	mod 75° 30°, 90°		
147	1937	mod 65° 30°, 90°		basalt flow continued
148	1946.5	strong 50-70°		rock crushed, abundant black-waxy clay on fract.
149	1956	strong		dark gray basalt continued, strong fractures
150	1964.6	V. few 50°		Basalt continued
151	1974	few 80°, 70 & 30°	1969-1970.5	Lapilli tuff red, clay alt, compact, slicken surfaces
152	1984	few 55-70°	1970.5-2037	Basalt flow vesicular top w/flow breccia, dark gray, nonporphy, clay & chlor. alt. along fract.
153	1992	mod 80-90°		few olivene pheno. 1-2 mm, partly alt., rock is grayish black
154	2001	breccia fault		rock is strongly crushed & recemented by clay & chlorite, poss. zeo.
155	2010	strong 60-70°		fractures of all angles, brecciated and cemented
156	2019	brecciated		breccia
157	2030			basal flow breccia, also crushed. red basal oxidized zone 2035-2037
158	2039.5	few 65° & 80°	2037-2240	Basalt flows greenish-blk, vesicular, non-porphy strongly chloritized, ves. & fract. filled with white clay
159	2049	mod 60°, 45°, 80°		flow-breccia to 2039', poss. zeo. in vesicle, chloritized
160	2057	few 45°		grnish, blk chloritized, white lined vesicles
161	2067	few 50-75°		Basalt Flows cont. white xl. min. in ves. and fract., prob. zeo. cubic xls. and few euh. qtz xls.
162	2076	few 20°, 65°		zeolite in vesicles and fractures
163	2085	few 80° 90°, 55°		fract. healed with chlor & zeo.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
164	2095	V. few 75°		vesicles continue thru entire flow
165	2105	V. few 65°		as above
166	2114	few 65°		as above
167	2124	few 90° 75°		as above-few zones alt. to red-brn
168	2133	few 65-80°		vesicle filling level 4° off normal to core axis, abundant 0.5 to 2 cm vesicles, zeo. lined
169	2142	few 40°		fewer vesicles
170	2151.5	few 65°		grnish-blk grading to dk red-brn
171	2161	few 90° 10° & 70°		dark red brn., dark yellowish-orange zeo, on 90° fract.
172	2170	few 90-85°		as above. about 1/2 grnish black
173	2179.5	few 60°		as above, grnish black
174	2189	few 65°		some breccia healed with chlorite. Intra-flow ash clay alt., compact at 2184'
175	2198	few 90°		fault zone?-crush breccia recemented by chlorite, clay slicken side & open space zeo. on vertical fract.
176	2208	none		totally chloritized, rock crushed and chlr. cemented, vesicles with zeo. & clay amygdules in some clasts
177	2218	few 65-50°, 40°		as above, grnish-black, zeolite and chlorite
178	2228	few 60°		chlr, zeo. alt., color grades to dk-red-brn
179	2231	few 30°, 60°		intra flow ash, brn-clay alt. compacted at 2240. Basalt grades back to grn. black
180	2247	few 65° 85°	2240-2318	Basaltic flow Breccia & Ash, vesicular upper flow breccia, zeo. amygdules, clay in-filling
181	2257	fault 40-60°		grn-black blocks, brn to olive-brn clay matrix, minor movement
182	2265	few 60-70°		red brn to gray flow breccia, chlor.-clay alt. some tectonic crushing
183	2273	few 70-80°		as above
184	2284	few 50-60°		basaltic? flow breccia cont.
185	2292.5	90-70°		extensive clay alt., chloritized, zeo. in fract.
186	2301.5	strong-50-90°		as above
187	2310.5	few 90° 50-60°		basaltic flow breccia and ash. cont.
188	2319	few 35°	2318-2419	Lahar(?) w/minor ash & vol. breccia zones. Grnish-blk. to red. ol. brn. chlor, clay alteration
189	2327.5	few 40°		mixed vol. litho. in clasts
190	2337.5	few 10° 45°		increased gray-red ash
191	2348	few 50° & 20°		dk gray brn to red Lahar/vol. breccia
192	2358	irregular		mixed vol. clasts types, andesitic, hornblendes,

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
193	2366	few 20-30°		chlorite and clay alt. continued
194	2374.5	strong 90°, 20-30°		core broke up - Lahar cont.
195	2383.5	mod 80°, 30°		poss. lithic rich pyroclastic flows, slip on fractures
196	2393	mod 20-30, 70-90°		as above
197	2402.5	few 90° 45°, 70°		chloritized as above. poss. lava flow or dike 2400-2412
198	2411	strong		as above, fractures of all angles
199	2420	few 50°		grn-black to red, Vol. breccia-Lahar
200	2430	mod 20° 30-50°	2419-2448	Andesitic Breccia, dk-grn-gray to gray-red. Uncertain as to brecciation pre-dates emplacement or post dates chloritization. strong chlr.
201	2440	strong 50-75°		clast-matrix ratio variable
202	2449	strong 50° few 80°		minor movement on these fract. surfaces
203	2458	mod-strong 68-70°, 25-45°	2448-2454	Crystal Ash Flow Tuff, clay alt. 15% 1-2 mm plag xls., compact, abund. bio., brn
204	2467.5	few 70° & 75°	2454-2546	Andesite Flow, 15% 1-2 mm plag. xls. alt to chlor, clay, minor calcite. flow is brecciated
205	2466.5	few 70°, 50°		brec. mostly flow emplacement, gray-red-brn to grn-black
206	2486	V. few irreg.		flow grades to dk grnish-gray, w/hornb./bio 1-3 mm and motled appearance, magnetite still present
207	2495	few 80° 20°		strong chloritization, fractures zeolite filled
208	2504	few 70-80°		chor. veinlets along crush surfaces, zeolite
209	2512.4	few 25°, 90°		rock is more crushed, extensive tectonic breccia and chlr. matrix
210	2512.5	few 80°		as above
211	2533	strong 75-80°		Andesite flow continued dark grn-gray, 15% porphy-strong, chloritized, clay? grn schist?
212	2543	V. few		basal flow breccia with red matrix ash 2535-2546
213	2552.5	V. few 50°	2546-2586	Andesite? flow, 15% 1-2 mm pyx xls. pyx. are little alt hem. coating, dark gray
214	2561.5	V. few 20-50°		Upper flow top breccia 2546-2553, poss. port. alt. pyx to hornb.
215	2570	mod. 80°		minor zeo. along 80° fract. Much less chlor. alt.
216	2579	strong 70-90° few 20°		pale grn. clay along fractures

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
217	2589	few 45° 75-80°	2586-2602.5	Lithic-lapilli tuff red to pale grnish-gray, 60% lapilli sand to 3 cm size mixed vol. litho
218	2598	few 45° & 65°		few V. pale grn. fiamme, compacted strong chloritization of matrix, mod. clay alt.
219	2606	none		Lapilli reduced to 30%, more fiamme.
			2602.5-2657	Crystal Lithic Tuff. grayish-blk, 10% 2 mm plag.
220	2615	1 fract 25%		< cm lapilli 5% mix vol. litho, black-fiamme, vol. brecc. at top of unit 2602-2604
221	2624.5	V. few 40°		tuff appears little altered
222	2633.75	none		Vitric ash
223	2643	none		compact, pumice flattened, but not strongly welded obsidian lapilli, matrix unaltered
224	2652.5	none		minor clay & chlorite alt. near base 2656'- tuff lightens to brnish-gray below 2654
225	2662	none	2657-2694	Olivine Basalt, ves. near top 10% 1-2 mm olivine 3% plag, amygdules of zeo? 12 flow breccia on top
226	2671	few irreg.		black to brnish-gray, minor chlor. alt, zeo. filled fract.
227	2680	few 50°		
228	2690			> cm size open space lift in breccia, zeo. cement & coat. basal flow breccia starts 2684', soft, white zeo.
229	2699	none	2694-2713	Lahar, mixed vol. lapilli to blocks in a clay + sand matrix, dk red-brn to olive black
230	2708.5	few irreg.		mixed colors & non-to porphy. clasts
231	2717.5	few 45° w/sliken	2713-2719	Lapilli ash 1-3 mm clasts, well sort. yel-brn to dk yel.-brn, 3 cm clast near base
232	2727	none	2719-2726	Lahar or volcanoclastic, light gray blocks-lapilli in an olive-black matrix, clasts are rounded, non-sort
233	2736.5	none	2726-2842	Andesite Flow, 5% 2 mm pyrox, 2% plag. blk-red-pale brn-to gray black, hem clay alt.
234	2745	few 80°		zeo. on fract. minor alt.
235	2754.5	few 80°		pale grn clay or celadonite on fract.
236	2765.5	mod. 70-90°		black MnOx(?) coat and waxy clay on fract. chlor. alt. increases
237	2775	mod. 70-90°, few 30°		clay & chlor. on fractures, andesite or poss. basalt cont.
238	2784.5	mod 70-90°, few 30°		minor movement on high angle joints, chlor-+ zeo. cement fractures
239	2794	mod 70-30o, few 90°		crush and chlor. alt.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
240	2804	mod. 70-80°		clay on joints as above
241	2814	mod. 70-90°, 40°		Andesite Flow-cont. grnish-black, 5% 2 mm prox., 2% plag. strong chlor. alt.
242	2823	mod. 80-90°, 50-60°		chlor. on fract.
243	2832	mod. 60° few 45°		Andesite flow continued
244	2842	few 60-75°		color changes to gray-red in basal flow breccia at 2837
245	2851.6	few-mod. 80-90°	2842-2935	Volcano-clastic or Lahar Mixed litho. of lapilli to blocks, non-sort., fine matrix of ash to clay, red-olive blk
246	2861	irreg. breaks		zeolite filling fractures
247	2870	few 70°		brown clay alt. matrix, minor stricken surfaces
248	2880	few 10°	2877-2879	Well sorted lapilli zone-dk brn to yel-brn clay alt. ash-cinders?, 75° sip surfaces
249	2889	60°-45°	2885-2891	Lapilli-clay alt, compact, few slip surfaces
250	2899	75°,90° & 45°		as above, yel-brn & pale grn.
251	2909	few 75°		Lapilli cinders, minor ash, few blocks
252	2918	few 80°		grn, dk-gray & dk red lapilli few light gray, grnish gray to brn.
253	2928	few 80°		olive black
254	2937	few 45° 70 & 90°	2935-2952	Ash or tuff, trace plag. xls., dk. gray to gray-red
255	2945	few 75°		rare lapilli in ash, few slip surfaces
256	2955	few 65-90°	2952-2966	Volcanoclastic lapilli pyroclastic, mix litho, dark grnish gray, slip surfaces on clay
257	2964	strong 90-60°		few blocks & thin sand bed. clay alt. matrix. Basal contact is a fault
258	2973.5	mod. 45° 80-90°	2966-4800 TD	Olivine Basalt flows. fine grain few mm xls. olivine, grnish blk to blk. mod. chlor-alt., 2% mm plag. xls.
259	2983	mod. 65°		upper contact is a minor fault at 2966'
260	2992	minor-irreg.		flow breccia, small irreg. vesicles, minor zeo.
261	3001	few 65°		multi-colored flow breccia, mono-litho, zeo. and clay alt.
262	3010	few 45°		vesicular, 1-3 mm, irreg.
263	3018.6	irreg.		as above
264	3028	none		dunite zenoliths?
265	3037.5	few 80°		Basalt Flows continued, light blue clay alt.
266	3047.5	few 60°		as above
267	2057	few 90°		as above, flow breccia-cinders
268	3066.5	strong 90°, 70°, 50°		more solid flow rock, white, blue & grn coating on fract.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
269	3076	few 80°		flow breccia, vesicular
270	3085	few 50°		vesicular, vesicles open, coated w/blue clay
271	3084	none		continued dk gray-brnish gray, vesicular, irregular vesicles, 2% plag.
272	3103	none		as above, clay coating vesicles
273	3113	few 60-90°		med gray - as above
274	3123	strong 50-90°		open fractures, clay and chlorite
275	3131	mod 60		as above
276	3140.5	few 60-70°		open irreg. ves. flow breccia-cinders
277	3150	mod. 70-90°		chalcedony coating on open fract.-space
278	3159.5	mod. 90-70°		
279	3168.5	mod. 60-70°		as above, open irreg. ves.
280	3177.5	few 10° & 70°		as above
281	3187	few 70-80°, 100		chlor. on fract.
282	3196	few 80°, 40°		some open breccia at 3196'
283	3205.5	few 45° 65°		as above
284	3214.5	few 50-40°		clay in filling breccia & fract. chlor-alt.
285	3223.5	few irreg.		vesicular, as above
286	3233	few 30°		as above
287	3242	irreg. breaks		vesicular
288	3252	few 80° 30°		Basalt Flows continued from 2966'
289	3261	few 90° & 60-70°		as above
290	3270	few 90-80° & 60°		as above
291	3279.5	few 70°		as above
292	3289	few 60°		
293	3299	few 90°		flow centers & breccia, mod. chlor. alt. in flow breccia
294	3308	few 25° & 90°		
295	3318	V. few 65°		as above, clay and zeolite along fract. cont.
296	3328	85° few		vesicular flow breccia, minor chalcedony

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
297	3337	few 80°, 60°		as above
298	3346	mod-strong 90°, 10°, 60°		as above, flow center
299	3355	mod. 80-90°, 55°, few 10°		
300	3364	few irreg.		as above, flow breccia
301	3373.5	55° few		Basalt-Andesite Flows continued, dark red-gray to grnish black, 3% 1-2 mm plag. xls.
302	3383	mod. 90° 60-75°, 10°		chlor. on fract. about 2/3 flow breccias & 1/3 solid flow center, Flow brec. consolidated. 2 mm irreg. vesicles
303	3392	mod. 80-90°, few 20-30°		chlor. on fractures
304	3401	mod. 70-90°, few 30°	3396-3421	flow breccia vesicular, dk olive grn
305	3411	none		fract. joints not present in flow breccia flow breccia cont.
306	3421	none		vesicular flow breccia, grn-gray shades
307	3430	mod. fract. 55°, 90° 20°	3421-3434'	flow center, open space 2nd minerals chlor-white zeo., poss. clay blue-grn Basalt Flows continued from 2966'
308	3440	mod. 80° 10-20°		flow breccia starts 3434, vesicular
309	3439.5	few 80° 20°, 45°		flow breccia to 3444 then flow center
310	3458.5	few 90-80°, 45° 10°		flow-breccia 3 feet thick
311	3468	one 90° 2-20°		all flow breccia
312	3477	irreg.		dk-gray-grn to grnish black. Vesicular flow breccia, consolidated
313	3487	mod. 70-75°, 30°		grn. chelcedony? on fractures, flow center
314	3497	few 75-90°		flow breccia, empty vesicles
315	3507	few 80°		as above
316	3517	irreg. 50°		as above
317	3526	mod. 75-80°, few 45°		flow center

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
318	3535	mod. 80, 70°, few 10°		flow center to 3531 then flow breccia chlor. on fract.
319	3544.5	strong 60-70°		flow breccia zeo. along fract. & coat open space breccia
320	3553.5	mod. 70° irreg.		flow breccia, vesicular
321	3563	few 30°		vesicular flow breccia, as above
322	3572.5	2-55°		as above
323	3582	few 65-90°		clear to pale grn. zeolite on fractures
324	3592	V. few 57°		flow breccia-open vesicles
325	3601.5	V. few 70°		as above
326	3611.5	mod. 35°, 45°, 90°		Basalt Flows continued from 2966'. 5' thick flow center vesicular
327	3620	few 45° 75°		4' flow center - 6 flow breccias
328	3629	V. few 10-20° & 50°		calcite coating on one fracture
329	3638.5	V. few fract. 55° & 20°		matrix of flow breccia strong alt. to chlor or celadonite?
330	3648.5	V. few 80°		as above
331	3658	irreg. breaks		Basalt-Andesite? Flows continued, dk-gray, brn, gray-grn. 3% 1-2 mm plag. vesicular 2 mm, vesicles -1/2 filled w/zeo.
332	3669.5	irreg. break		flow breccia as above
333	3677	none		zeo. & clay as above
334	3687			as above
335	3696			as above
336	3706	none		at 3703, 3 cm vesicle-zeo. coat, amygdules of chalcedony, celadonite
337	3715	none		qtz & celadonite amygdules
338	3723.5	few 8° & 50°		as above
339	3733	mod. 75°, 40°		flow breccia
340	3242.5	V. few 60°		as above
341	3751.5	irreg.		as above
342	3760.5	few 90, 70°		as above
343	3770	few 70° 80°		ves. 2/3 filled. as amygdules

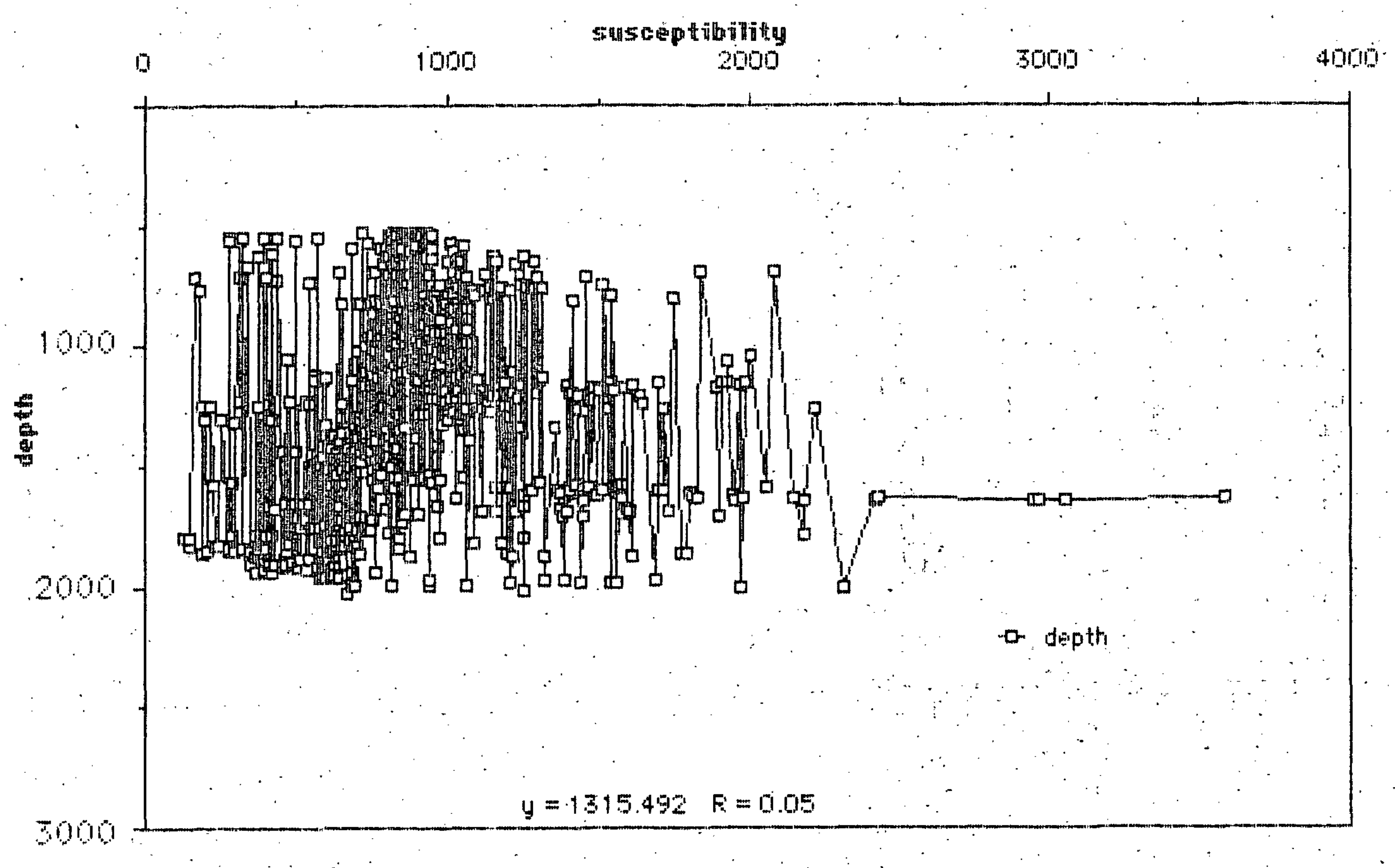
Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
344	3779	few 90-60 irreg.		flow breccia as above
345	3788	irreg.		as above
346	3797	few 90-80, 65°		as above
347	3805.5	mod. 80°, 60, 30°		Basalt Flows continued from 2966' qtz. filled 7 flow center amygdules
348	3815	none		flow breccia-as above
349	3824	few mod. 45°, 90°		as above
350	3833	few 75-80°		as above
351	3842	few 65°		as above flow breccia, qtz amygdules
352	3852	few 65o		vesicular, few celadonite filled, some open
353	3861	strong 75-80°, few 30°, 60°		chlor & qtz along fract.
354	3871	few 80-90°		as above, flow breccia
355	3880	few 80-90°		most vesicles empty
356	3889	none		flow breccia
357	3998	few 65° 80°, 90°		as above
358	3907	mod. 65-75°		celadonite amygdules but most ves. empty, flow breccia as above & qtz amygdules
359	3916	none		as above, breccia
360	3924.5	mod. 80-90°, few 75°'		flow center. 8' thick
361	3434	none		Basalt-Andesite flows cont. 2 mm vesicular, 5-10% 3% 1-2 mm plag. xls, grnish-blk, to dk gray
362	3943.5	none		flow breccia cont.
363	3953	few irreg. 75°		as above
364	3962	few 20-25°		as above
365	3972.5	few 90° & 70°-80°		fract. qtz rock more crushed below 3970', qtz cemented
366	3982	strong 50-90°		chlorite & qtz cement
367	3991.5	few 20-30°		Basalt Flows continued from 2966', qtz amgydules
368	4000	mod. 90° 55-65°		as above
369	4009.5	few 70°		as above

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
370	4019	mod. 80-90°		fract. in flow center, qtz in celadonite-chlor on fract.
371	4028	strong 70-90° 50°		qtz. vein/fract. fill increasing flow center
372	4037	few 70°		flow breccia, less qtz
373	4047	few 75°		as above, less qtz
374	4055.5	strong 70-80° 55°		flow center
375	4065	strong 70-80° few 55°		flow center as above
376	4074.5	mod. 80° & 20°		as above, center to breccia at 4069'
377	4084	strong 90°, few 65°		as above, flow center 4089-4103
378	4094	strong 80° & 70°		flow breccia to 4099
379	4102	strong 90°, 70-80°		as above, flow center 4089-4103
380	4112	few 60° & 80°		as above, flow breccia
381	4121	none		as above
382	4030.5	few 50°		as above
383	4140	none		celadonite amygdules
384	4149.5	none		as above
385	4158.5			as above, flow breccia
386	4168			flow breccia
387	4177.5			as above
388	4186	mod. fract. 70-80° & 50°		as above, Basalt Flows
389	4195	few 40°		chlor. on fract., qtz. amygdules
390	4206	mod. 85-90°, few 45°		as above
391	4216	few 25 & 70°		Basalt flows & breccia-cont. from 2966' 2 mm vesicular-5 10%, 3% plag. 1-2 mm, grnish-black vesicles to 1 cm
392	4226	strong 90°, 50° 75°		
393	4235	mod. 90° 35-30°		as above
394	4245	trace py.		qtz. & celadonite amygdules, zeo.

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
395	4255	no fract.		as above, breccia
396	4284.5	strong 75-80° 25°		flow center
397	4274	mod. 80-90°, few 20°		flow breccia
398	4283.5	few 65-70°, 30°		most ves. open/unfilled
399	4293	mod. 90° few 85°		as above
400	4301.5	few 85-90°, few < 10°		as above
401	4311	few 60° 45°		as above-flow center, upper part vesiclar
402	4321	few 50, 90°		as above, center-breccia-ves. top
403	4330	few 90° 40°		as above
404	4339.5	strong 90°-80° 10°		Basalt Flows and intra Flow Breccias continued from 2699'
405	4349	few 90°		flow breccia
406	4359	few 80° 50°		as above
407	4368	none		as above
408	4377	few 70-90°, 25°		thin qtz coat on fract.
409	4387.5	mod. 90° 50°		flow center, as above
410	4397	few 55° & 25°		as above, flow center to 4391 breccia
411	4406.5	mod. 40° 80°		as above, flow center
412	4415	mod.		crushed rock with fractures at all angles
413	4423.5	strong 30° & 60°		as above
414	4433	mod. 30° & 60°		minor fault 30°, flow center over breccia
415	4442	irreg.		as above, ves. breccia
416	4451.5	few 55°		basalt cont.
417	4461	v. few 60°		qtz. amygdules
418	4471	few irreg.		as above

Box #	Bottom Depth Of Box	Fractures (90°=vert.)	Unit Interval (feet)	Lithology Description
419	4480.5	few 90°		as above
420	4489.5	mod. 10°, 30o, 80°		flow center

Box 421 to 453, Interval 4536-4800 T.D. Basalt Flows and breccia continued from 2966′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2000
3000
4000
depth
1000
2000
3000
depth
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