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**GEOHERMAL RESERVOIR ASSESSMENT AND  
CONFIRMATION PROGRAM FOR DIRECT  
HEAT APPLICATION**

**ANNUAL REPORT  
JUNE 26, 1977 - DECEMBER 31, 1978**

**RICHARD H. PEARL**

**December 1978**

**Colorado Geological Survey  
Department of Natural Resources  
1313 Sherman, Denver, Colorado 80203**



**IDAHO OPERATIONS OFFICE**



**IDAHO NATIONAL ENGINEERING LABORATORY**

**DEPARTMENT OF ENERGY**

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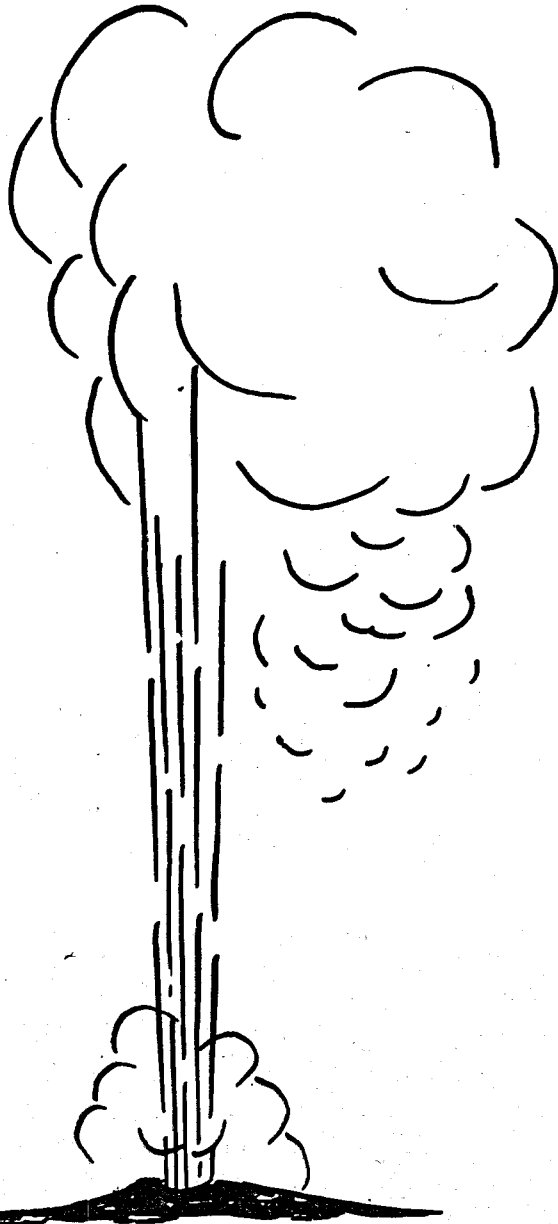
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PREPARED FOR THE DEPARTMENT OF ENERGY  
DIVISION OF GEOTHERMAL ENERGY AND IDAHO OPERATIONS OFFICE  
UNDER CONTRACT NO. EG-77-07-1678

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**GEOHERMAL RESERVOIR ASSESSMENT AND CONFIRMATION PROGRAM FOR  
DIRECT HEAT APPLICATIONS**

**RICHARD HOWARD PEARL**

**PROJECT DESCRIPTION**

This is a reservoir confirmation program leading to the stimulation of the low and moderate temperature geothermal reservoirs in Colorado for direct heat applications. The program includes assessment and confirmation studies of individual reservoirs having a marked potential for direct heat application development.

The Colorado Geological Survey is responsible for preparation of a preliminary report summarizing the known distribution and quality of the geothermal reservoirs that appear suitable for direct heat applications. This is accomplished through a synthesis of available geological, geochemical, geophysical, and hydrological data. Data obtained through this effort will be provided to the U.S. Geological Survey for incorporation into the GEOTHERM data base.

**INTRODUCTION**

1. This report covers the period from the start of the contract, June 27, 1977, to December 31, 1978.
2. The project was originally set up to run from June 27, 1977 to June 26, 1978. On March 21, 1978, the contract was amended to run from Jan 1, 1978 to December 31, 1978.
3. The original budget of \$154,130.36 was also amended on March 21, 1978 to be \$251,456.45.

**PROJECT PERSONNEL**

1. Personnel working on the project full time
  - a. Richard H. Pearl, Principal Investigator, and Chief of the Ground-Water Investigation Section, Colorado Geological Survey.
  - b. Michael Galloway, Project Chief, Ground-water Geologist, Colorado Geological Survey
  - c. Jay D. Dick, Geothermal Geologist, Colorado Geological Survey. Hired July 1, 1977, terminated April 1, 1978
2. Personnel working part time on project
  - a. Doris Sweetman, Secretary
  - b. Cheryl Brchan, Draftsperson
  - c. Mark Persichetti, Draftsperson
  - d. Becky Andrews, Word Processor operator
  - e. Tish Mihara, Word Processor operator
  - f. James Barrett, Geologist
  - g. Pat Mangnall, Intern

## CONTRACTS ENTERED INTO

1. Dr. William Atkinson: Mineralogical examination and report of drill cuttings and diamond drill core from Pagosa Springs well.
2. Cryogenics Research Co., Inc.: Design and fabrication of a deep well temperature logger.
3. Denver Research Institute: Assessment and reports on environmental consequences of drilling and testing of exploratory geothermal wells in Pagosa Springs and Glenwood Springs, Colorado.
4. Geophysics Fund, Inc.: Geophysical investigation of Pagosa Springs and Glenwood Springs areas.
5. Geophysics Fund, Inc.: Drilling of six temperature gradient and heat-flow holes at Pagosa Springs.
6. GO Wireline Services, Inc.: Borehole geophysical logging of exploratory and production wells at Pagosa Springs.
7. James Drilling Co., Drilling and testing of exploratory and production wells at Pagosa Springs
8. Ruwart Leasing, Inc.: Lease of one Chevrolet LUV pickup truck
9. Schlaphoff and Associates: Development of computer software programs.

## SCHEDULE OF EVENTS

1. June 27, 1977. Project started
2. July 1977. Entered into a contract with Geophysics Fund, Inc., for geophysical evaluation of Pagosa Springs and Glenwood Springs areas. Various electrical surveys as well as "Vibroiseis" and soil mercury surveys were run during late summer and fall of 1977. Interpretation of electrical surveys data delineated the areal extent of a supposed thermal reservoir in the Pagosa Springs area. Due to cultural effects the results of the surveys ran in the Glenwood Springs area were inconclusive.
3. August 1977. Entered into a contract with Cryogenics Research Co., Inc. to design and fabricate an automated down hole temperature logger and probe. This equipment was delivered during Oct. 1977 and has been used extensively by this office since that time.
4. August 1977. Entered into a contract with Schlaphoff and Associates to develop a computer software program.
5. August 1977. Entered into a contract with Denver Research Institute to evaluate and prepare a report on the environmental consequences of the drilling and production testing of exploratory geothermal wells in Pagosa Springs and Glenwood Springs. The Pagosa Springs report was accepted by USDOE/DGE and this office in February 1978. Limited copies of the report were printed and are

available at no charge from this office.

The Glenwood Springs report was accepted by this office in September 1978, and will be forwarded to the Washington office of USDOE/DGE in the near future. Due to change in project plans, in that the planned well will not be drilled in the near future at Glenwood Springs, we do not plan to publish this report unless requested to do so by DOE/DGE.

6. September 1977. Michael Galloway started work as Project Chief.

7. January 1978. Met with Drs. Michael Wright, Duncan Foley of the University of Utah Research Institute, and George Berry and Paul Grim of N.O.A.A., Boulder, about the Colorado project and any information that we might be able to furnish them for the forthcoming U.S.G.S. Circular 790. Periodic meetings have been held with George Berry and Paul Grim since then concerning this publication. Requested information and material have been supplied to them.

8. Fall of 1977 and Winter of 1977-78. Field and office geologic and hydrogeologic appraisals were made of the Pagosa Springs and Glenwood Springs area by Michael Galloway, Project Chief, and Jay Dick, Geologist.

9. From initiation of project, contacts were established and maintained with local officials in Archuleta County and Pagosa Springs about the possibility of drilling a well or wells in or adjacent to the city of Pagosa Springs and the possible uses any thermal waters developed might be put to.

10. October 1977. Entered into a contract with Geophysics Fund, Inc., for drilling of six heat-flow holes in and adjacent to Pagosa Springs. Interpretation of data from these holes confirmed the location of the thermal reservoir as determined by geophysics. The highest gradient (130°C/km) was measured in the immediate vicinity of the Big Spring with values decreasing in all directions away from the spring.

11. October 1977. Entered into a contract with Ruwart Leasing, Inc. to lease one LUV Chevrolet mini-pickup truck.

12. November 1977. Met with DOE/DGE officials at the Idaho Falls, Idaho office to discuss future plans and actions of the project.

13. January 1978. As required by Colorado Statute, application was filed with the Colorado Oil and Gas Conservation Commission for required approval to drill and production test a well, or wells, at Pagosa Springs. A hearing on this application was held before the Oil and Gas Commission on March 20, 1978 and the permit was approved, with minor amendments.

14. January 1978. A permit application, to dispose of any thermal waters produced during drill and testing phases of wells to be drilled at Pagosa Springs, was filed with the Water Quality Control Commission, Colorado Dept. of Health. Permit was issued in late March.

15. January 1978. Permit application was filed with Air Quality Control Commission, Colorado Dept. of Health, to cover any possible violation of air quality standards during drilling and testing of the Pagosa Springs wells. No permit was required.



16. March and June 1978. At request of Dr. Jack Salisbury, Richard H. Pearl, Principal Investigator, participated in the Rocky Mountain Basin and Range Commercialization planning meetings in Salt Lake City, Utah.

17. April 1978. After competitive bids were requested and received, a contract was entered into with James Drilling Co., Arvada, Colorado, for the drilling of one production well and up to two observation wells at Pagosa Springs, Colorado.

18. May 1978. Michael Galloway, Project Chief, met with Mr. Roger Stoker, EG&G, Idaho Falls, in Salt Lake City, Utah, to discuss problems associated with drilling of geothermal wells.

19. June 1978. Entered into a contract with GO Wireline Services for borehole geophysical logging of wells at Pagosa Springs.

20. June-September 1978. Drilling of wells at Pagosa Springs. Drilling plans called for one observation well up to 2,000 feet deep, one observation well up to 400 feet deep, and one production-type well up to 2,000 feet deep to be drilled. Drilling problems and escalating drilling costs necessitated that only one observation well and the production type well be drilled. The observation well was drilled to a depth of approximately 700 feet and the production well to a depth of 1,483 feet. A report describing the drilling of these wells was submitted to DOE/DGE Idaho Falls during the fall of 1978. A copy of that report is attached. See also paragraph #26 below.

21 July 1978. Richard Pearl presented a paper on the Pagosa Springs drilling program at the annual meeting of the Geothermal Resources Councils annual meeting in Hilo, Hawaii. A copy of this paper is attached.

22 Winter of 1977-78. Data was received from the U.S. Geological Survey regarding the GEOTHERM file. This office has been working with the U.S.G.S. on this file ever since then. During the summer of 1978, Ms. Pat Mangnall coded and sent to the U.S.G.S. data concerning 127+ thermal wells and springs in Colorado. A printout of that data has been returned to this office for editing.

23. Summer-Fall 1978. A report assessing the Hydrothermal Resource Potential of Colorado was prepared. A copy of the report was sent to DOE/DGE, Idaho Falls, for review and comments. When the report is returned, a final report will be prepared and submitted to DOE/DGE, Idaho Falls.

24. October 1978. Proposal for ongoing work submitted to DOE/DGE, Idaho Falls, Idaho.

25. Nov. 1978. Michael Galloway and Richard Pearl met with officials of DOE/DGE in the Idaho Falls office to discuss progress of the project and future project plans.

26. Fall 1978 and winter 1978-79. Michael Galloway is preparing a detailed report about the Pagosa Springs project. It is anticipated that this report will be completed during late winter or early spring 1979. Copies will be mailed to DOE/DGE, Idaho Falls, when completed.

27. December 1978, Entered into a contract with Dr. William Atkinson,

Boulder, Colorado, for a mineralogical and fluid inclusion examination of the drill cuttings and diamond drill core from the Pagosa Springs well. Dr. Atkinson's report will be made part of Michael Galloway's final project report.

28. December 27 1978. Project continuing.

## BRIEF REPORT OF DRILLING ACTIVITIES, PAGOSA SPRINGS, COLORADO

by

Michael Galloway

The drilling of observation well 0-1 started June 10, 1978. Boulders up to 2 feet in diameter, hot water flowing at 500 GPM, and equipment problems complicated much of the early drilling. Once into the Dakota Sandstone, the upper flow was cased to allow the use of an air-hammer bit at least through the slow drilling Dakota Sandstone. However, water was encountered almost immediately, requiring the use of an additional compressor and a booster. From 670 to 700 feet a severe caving zone was encountered, causing drilling to be stopped. The hole diameter was too small to case this zone and still be able to continue to 2000 feet. Instead of abandoning 0-1 entirely, it was used as the shallow observation well, with the number changed to 0-2.

Because of increased costs and technical problems derived from hole conditions, the slim deep observation well had to be eliminated from the program. Work then began on P-1, the large diameter production well.

The drilling of P-1 started July 29, 1978. A 22-inch culvert was used to alleviate the problem of boulders in the first 12 feet of the hole, allowing fairly rapid drilling through the Mancos Shale. It was planned to drill to 400 feet and set surface casing to shut off as much of the shallow flow as possible. Unfortunately, a fault or fracture zone was encountered at 255 feet, resulting in a flow of 1500-2000 GPM at 144°F. The spring level dropped nearly 3 feet and all hot wells which were being used at the time stopped flowing. Casing was run in an attempt to stop this flow as soon as possible. As with 0-2, cementing was complicated by the high flows and pressures at shallow depths. Cement overruns were typically 200-400%.

Drilling continued until the caving zone in the Morrison Formation was encountered, at which time another string of casing was run and cemented. This casing was difficult to install because of a few hard shoulders in the lower Dakota Sandstone.

Drilling proceeded fairly rapidly to the top of the Precambrian at 1,371 feet. An air-hammer bit was used until water was encountered, making drilling difficult at that depth with the available air (number of compressors). A rotary rock bit was then used to 1,475 feet and 8 feet of core was recovered from 1,475-1,483 feet.

Temperature gradients taken before and after the coring indicate isothermal conditions from about 500 feet to 1,483 feet. It was decided to terminate the drilling program because of the isothermal conditions, high costs due to hole conditions, and cold weather which required the use of existing hot wells, eliminating any possibility of thorough testing.

### Summary

The hottest water, at 255 feet, was 151°F, but fluctuated between 112-120°F in the lower part of the hole. Total flow is about 5,000-6,000 GPM. Water samples were collected at various depths and are being analyzed for standard constituents, tritium,  $O^{18}$ , deuterium, and various radioactive species. Rock

samples, including the core, are being examined by a University of Colorado mineralogist. Geophysical and drilling logs are being examined by CGS. In a few weeks, a temperature gradient will be measured under shut-in conditions, and a deepening and/or testing program will be planned for next summer.