

Lawrence Berkeley National Laboratory

LBL Publications

Title

Geothermal Reservoir Engineering Management Program Vol 2 No 4

Permalink

<https://escholarship.org/uc/item/0xz832wr>

Author

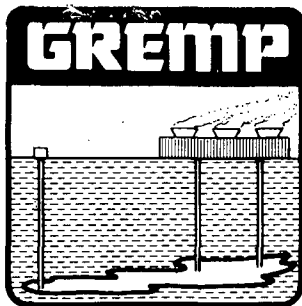
Lawrence Berkeley National Laboratory

Publication Date

1979-12-01

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.



NEWS from

Geothermal Reservoir Engineering Management Program

Sponsored by

U.S. DEPARTMENT OF ENERGY - DIVISION OF GEOTHERMAL ENERGY

RECEIVED
 JAN 28 1980
 Ref. Lib.
 E.B.L. LIBRARY

Vol. II, No. 4
 Nov./Dec., 1979/700

This is the sixth edition of *News from GREMP*. This edition is an update and features the specific achievements of five contracts now in progress. Copies of the *News from GREMP* are being sent to individuals who requested the publication by returning the coupon, attached to Vol. I, No. 1 and 2, and Vol. II, No. 1, 2, and 3. For your convenience the coupon is being repeated again in this edition.

PROJECT HIGHLIGHTS

1. SIMPLIFIED ANALYTICAL TECHNIQUES TO INTERPRET TWO-PHASE FLOW

Principal Investigator: Pete Taylor (Intercomp)

Objectives: Develop two-phase flow analytical techniques to interpret temperature, pressure, and mass flow rate at the well head.

Progress: Under Task 2, test data for geothermal wells were gathered which would be suitable for matching by means of numerical simulation. The effort resulted in obtaining the following:

- very good quality data for five different flow tests on Hawaiian well HGP-A;
- incomplete but usable data for a two-rate test on well M-21A in Cerro Prieto (SPE-6887);
- incomplete data on several interference tests in Cerro Prieto;
- miscellaneous data on Baca field.

Efforts to obtain suitable well test data from Wairakei and Italy were unsuccessful.

Much progress was made in simulating two-phase well tests (Task 3). A successful match of the test on well M-21A revealed that the permeability-thickness product is an order of magnitude larger than calculated by others who used analytical techniques. Simulations of the tests on well HGP-A have not yet resulted in a satisfactory match.

The validity of existing (single-phase) analytical techniques for well test analysis was investigated using Cerro Prieto data and simulation (Task 4). The results are generally poor, both for wellhead and bottomhole data, and no significant improvements in analysis techniques have been found to date. Similar work is presently under way using the Hawaiian data.

References:

Jesus-Rivera, R., and Ramey, H. J., Application of two-rate flow tests for the determination of geothermal reservoir parameters, paper SPE-6887.

2. PETROLOGICAL AND GEOCHEMICAL STUDY OF SAMPLE FROM GEOTHERMAL RESERVOIRS

Principal Investigator: Wilfred Elders (University of California, Riverside)

Objectives: Provide an analysis of reservoir heating at the Cerro Prieto geothermal field by using isotope geochemistry, geothermometry and hydrothermal mineral variations in well cores and cuttings.

Progress: More than forty wells in the Cerro Prieto geothermal system have been analyzed as to water-rock interaction. Subsurface mineral zones diagnostic of temperatures of up to 340° C aid in correlation between wells. Fluid inclusion studies on vein minerals indicate repeated fracturing and temperature shifts of more than 100° C.

Detailed $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values in calcites show consistent patterns of subsurface flow and temperature. Silicate $\delta^{18}\text{O}$, vitrinite reflectance and surface emanation studies are also under way.

Differences in the abundance of hydrothermal minerals, particularly epidote and calcite, appear to indicate differences in fluid flow.

As the accompanying photograph shows, the role of hydrothermally deposited clay and zeolite minerals on permeability can be significant. (Figure 1.)

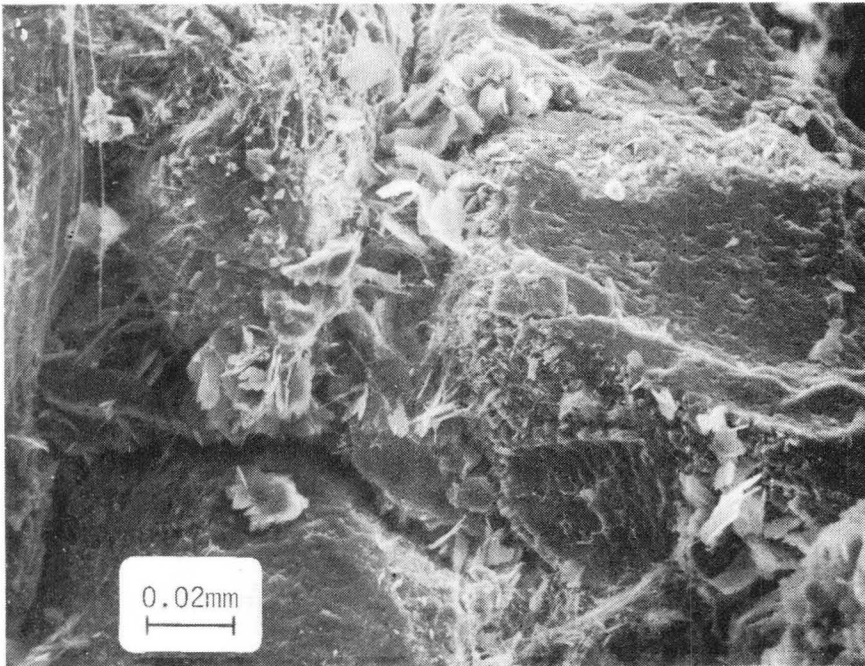


Fig. 1

A scanning electron microphotograph; 500X magnification of a core chip from 2720 in depth at Cerro Prieto. Note the delicate clay and zeolite crystals partially filling the pore space between the original deltaic quartz and feldspar sand grains.

XBB 799-12511

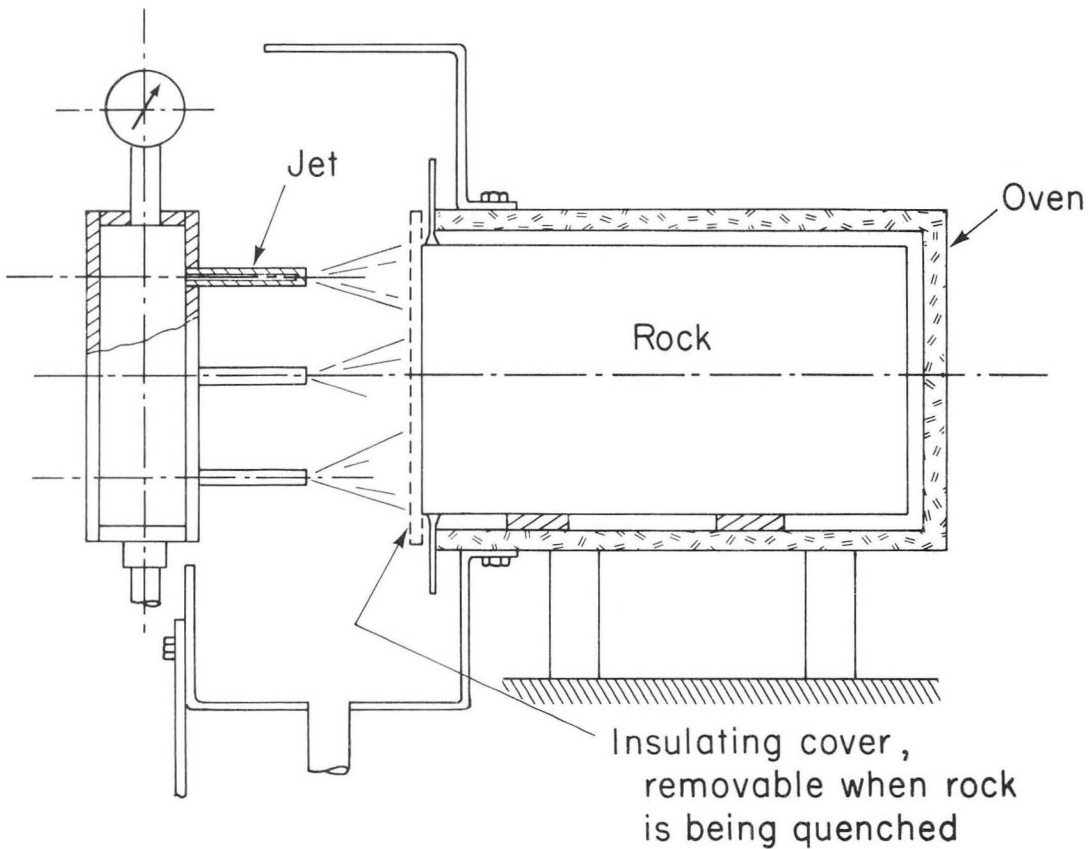


Fig. 2

Schematic Diagram of the Apparatus for the Thermal Fracturing Experiment

XBL 7911-13462

3. MODELING, TRACER AND ANALYTICAL STUDIES OF GEOTHERMAL RESOURCES

Principal Investigator: Henry J. Ramey, Jr., and Paul Kruger (Stanford University)

Objective: Develop techniques for assessing geothermal reservoirs through better interpretation of physical models, mathematical analysis and experiments to obtain wellhead and reservoir data.

Progress: Significant progress has been made in all the four main areas; i.e., energy extraction, bench scale flow experiments, radon tracer techniques, and well test analysis.

Energy extraction experiments concern the efficiency with which the in-place heat and fluids can be produced in the most economical manner. The large reservoir model was used to study basic non-isothermal processes such as in-place boiling, cold water sweep, and steam drive. Overall energy extraction efficiency does not seem to be affected much for the ranges of porosity and permeability considered for the first experiment. Computed and experimental results were presented for cold water sweep studies. Steam drive was not found to be an effective process to extract energy. A five inch rock cube was heated up to 400°F and then was quenched at the front face by multiple jets (Figure 2). No cracking was observed on the quenched surface and a plot of temperature versus distance from the quenched face is presented at various time intervals.

Bench scale experiments were used to examine the properties of flow through porous media at elevated temperatures and pressures. Three models were used in all. One model is used to study the effect of temperature on absolute permeability, a second model to measure steam water relative permeability, and a third model to determine the mechanisms of vapor pressure lowering in porous media. Results are presented for all the cases.

Radon flow transients were completed in vapor dominated reservoirs at The Geysers, California, and Serrazzano, Italy, and in liquid dominated reservoirs at Pohoiki, Hawaii and Cerro Prieto, Mexico. Studies were also initiated at Mammoth Lake, California; Raft River, Idaho; Wairakei, New Zealand and Los Azufres, Mexico.

Numerous aspects of well test analysis were studied. These include: earth tide effects; pressure transient analysis of multilayered systems; interference testing with storage and skin effects; determination of steam water relative permeability from well head data; well test analysis for wells produced at constant pressure; the parallelepiped model; slug test DST analysis and pressure transient behavior in naturally fractured reservoirs.

Reference:

Ramey, H. J., Jr., and Kruger, Paul, Stimulation and reservoir engineering of geothermal resources, *Second Annual Report*, SGP-TR-35, Stanford University, September, 1979.

4. DATA COMPILATION AND ANALYSIS FROM ITALIAN GEOTHERMAL FIELDS

Principal Investigator: Dr. Frank G. Miller (Stanford University)

Objectives: Analyze Serrazzano, Travale-Radicondoli, and Bagnore reservoirs of Larderello geothermal field to understand the physics of the system.

Original scope of work, under the cooperative agreement between ERDA (now DOE) and ENEL, contained eight projects. Three projects of this agreement are being investigated by Stanford University.

Progress: The efforts were focussed on Tasks 3.9 (basic studies of vapor-dominated reservoirs) and 3.10 (transient pressure analysis for geothermal wells) of the DOE-ENEL agreement.

Under 3.9, effects of non-condensable gases on geothermal wells were investigated. Because of difficulties with field data this work has not yet been completed. An analytic study of the Gabbro reservoir was carried out, which will be presented at the Stanford Geothermal Workshop, December 1979. In this work, past production history has been matched, and reserves were computed. They exceed previous estimates.

New methodology was developed under Task 3.10, in order to analyze the behavior of well Travale 22. A computer program was written and applied to analyze the long time pressure response of a well producing dry steam from a two-phase reservoir. A good match was obtained, which made it possible to determine several important reservoir parameters. Further work was performed on developing "influence functions" for geothermal wells, which would greatly facilitate the analysis of tests with variable flow rates.

References:

Cinco-Ley, H., Brigham, W. E., Economides, M., Miller, F. G., Ramey, H. J., Barelli, A., and Manetti, G., A parallelepiped model to analyze the pressure behavior of geothermal steam wells penetrating vertical fractures, paper SPE-8231, presented at the 54th Annual Fall Technical Conference and Exhibition of the SPE, Las Vegas, September, 1979.

5. RESERVOIR TRACER TECHNOLOGY IN GEOTHERMAL OPERATIONS

Principal Investigators: Otto J. Vetter and Karl Zinnow (Vetter Research)

Objectives: The applicability of tracers to determine the movement of fluids in geothermal reservoirs is to be evaluated. The scope of work is limited to theoretical evaluations and complex laboratory measurements.

Progress: The stability of tracers with favorable properties are being tested in the laboratory under conditions which are designed to closely resemble actual geothermal conditions. Adsorption properties will be measured, also under closely simulated conditions, both in static mode and with the tracer solution flowing through rock material.

All pertinent tracer stability and tracer/rock or tracer/fluid interactions are being studied in the laboratory. The project will study the pertinent aspects of the tracer behavior under simulated geothermal reservoir conditions. The final product of this work will be a compilation of tracers which can be used directly for a large number of field applications.

In preparation for selecting candidates for laboratory experiments, the properties of radioisotopes as found in the literature are being scrutinized. Use of the following isotopes has been reported:

H^3 , C^{14} , Na^{24} , P^{32} , S^{35} , Ca^{45} , Cr^{51} , Co^{57} , Fe^{59} , Co^{60} , Se^{75} , Br^{82} ,
 Rb^{86} , Sr^{90} , Zr^{95} , In^{114} , Sb^{124} , I^{131} , Cs^{134} , Ir^{192} , Tl^{204} .

Selection criteria are :

- 1) Known performance in tracer studies in laboratory tests and field applications,
- 2) Isotope properties such as half-life and decay type, energies and intensities, and
- 3) Chemical nature and behavior, whether to use simple or complex ions, cations or anions, ions which are part of the rock-brine system or not, and consideration of their stability in aqueous solutions, under different pH-conditions.

Under the present program, a detailed data base will be generated from comprehensive experiments, more computer modeling and field tests.

FUTURE MEETINGS OF INTEREST TO RESERVOIR ENGINEERING

Title	Place	Date	Contact
Fracture Hydrology Modeling Workshop	Lawrence Berkeley Laboratory	Feb. 19-20, 1980	W. J. Schwarz (415) 486-4706
Third Invitational Well Testing Symposium (Subject: Well testing in Low Permeability Environments)	Lawrence Berkeley Laboratory	March 26-28, 1980	W. J. Schwarz (415) 486-4706
Computer Code Workshop	Lawrence Berkeley Laboratory	June 17-19, 1980	W. J. Schwarz (415) 486-4706
Italian/American Meeting on Geothermal Resources Assessment and Reservoir Engineering (ENEL/DOE)	Lawrence Berkeley Laboratory	October 20-22, 1980	R. C. Schroeder W. J. Schwarz (415) 486-4706
Field trip to The Geysers, California	From Lawrence Berkeley Laboratory	October 23, 1980	W. J. Schwarz (415) 486-4706
Third Symposium on the Cerro Prieto Geothermal Field	San Francisco	March 24-26, 1981	W. J. Schwarz (415) 486-4706
Field trip to The Geysers, California	From San Francisco	March 27, 1981	W. J. Schwarz (415) 486-4706

Note: *News from GREMP* will be sent to those who ask to be put on the mailing list. If you are not receiving *News from GREMP* or if you know of someone who would be interested, please fill out and return the coupon.

PUBLICATIONS AND DOCUMENTS

The following publications may be obtained from the GREMP Program office at LBL.

- o GREMP-1 (LBL-8664)
Annotated Research Bibliography for Geothermal Reservoir Engineering.
(R. Harrison and G. Randall, TerraTek, Inc.)
- o GREMP-2 (LBL-8669)
Summary of Reservoir Engineering Data, Wairakei Geothermal Field, New Zealand. (D. Riney, Systems, Science and Software)
- o GREMP-3 (LBL-8784)
Modeling Heat and Mass Transfer at the Mesa Geothermal Anomaly, Imperial Valley, California
(D. R. Kassoy and K. P. Goyal, University of Colorado)
- o GREMP-4 (LBL-9088)
Water/rock interactions in the Cerro Prieto geothermal field, Baja California, Mexico.
(W. A. Elders, J. R. Hoagland, E. R. Olson, S. D. McDowell, and P. Collier, UC-Riverside), due January 1980
- o GREMP-5 (LBL-9089)
Scale Inhibitor Tests at East Mesa
(O. Vetter, Vetter Research)
- o GREMP-6 (LBL-9090)
An Appraisal of Measurement Methods for Geothermal Well System Parameters
(M. Lamers, Measurement Analysis Corporation)
- o GREMP-7 (LBL-9248)
Evaluation of Potential Geothermal Well Head Flow Sampling and Calorimetry Methods (W. C. Cliff, W. J. Apley, and J. M. Creer, Battelle Pacific Northwest Laboratory)
- o Proceedings, Invitational Well Testing Symposium (LBL-7027)
- o Proceedings, 2nd Invitational Well Testing Symposium (LBL-8883)
- o News from GREMP, Vol. I, No. 1 (Aug. 1, 1978) No. 2 (Nov. 3, 1978);
Vol. II, No. 1 (Feb. 1, 1979), No. 2, (May 1, 1979), No. 3 (Aug. 31, 1979).
- o Subsidence Series, #1 (GSRMP-1, LBL-8615)
Environmental Economic Effects of Subsidence (C. K. Vaughan and R. C. Harding, EDAW/ESA)
- o Subsidence Series, #2, (GSRMP-2, LBL 8669)
Instruments for Subsurface Monitoring of Geothermal Subsidence
(J. E. O'Rourke and B. B. Ranson, Woodward Clyde Consultants),
due January 1980

- o Subsidence Series #3 (GSRMP-3, LBL-8617)
Guideline Manual for Surface Monitoring of Geothermal Areas
(C. J. Van Til, Woodward Clyde Consultants)

- o Subsidence Series, #4 (GSRMP-4, LBL-8618)
Areas of Ground Subsidence due to Geofluid Withdrawal (P. Grimmud,
B. L. Turner, and P. A. Frammer, Systems Control, Inc.)

- o Subsidence Series #5 (GSRMP-5, LBL 9093)
State-of-the-Art Review of Geothermal Reservoir Modeling (G. F. Pinder,
Princeton University for Golder Associates), due January 1980

- o News from Subsidence, Vol. I., No. 1 (Feb. 1, 1979), No. 2 (June 1, 1979)

I wish to be on the mailing list.

GREMP

I do not wish to be on the mailing list at this time.

Name: _____ Phone: () _____

Affiliation: _____

Address: _____

City

State

Zip

Please clip and return to L. Di Fraia or W.J. Schwarz, Bldg. 90/1012F, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720.

For further information contact:

Werner J. Schwarz
Lawrence Berkeley Laboratory
Building 90 Room 1070
One Cyclotron Road
University of California
Berkeley, California 94720
(415) 486- 4706
FTS 451- 4706