Geothermal Energy Technology

A Current Awareness Bulletin

Geothermal Energy Technology announces on a semimonthly basis the current worldwide information available on the technology required for economic recovery of geothermal energy and its eventual utilization either directly or for production of electric power.

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The subject content of *Geothermal Energy Technology* encompasses:

- RESOURCE STATUS AND ASSESSMENT
- GEOLOGY AND HYDROLOGY OF GEOTHERMAL SYSTEMS
- GEOTHERMAL EXPLORATION
- LEGAL AND INSTITUTIONAL ASPECTS
- ECONOMIC AND FINANCIAL ASPECTS
- ENVIRONMENTAL ASPECTS AND WASTE DISPOSAL
- BY-PRODUCTS
- GEOTHERMAL POWER PLANTS
- GEOTHERMAL ENGINEERING
- DIRECT ENERGY UTILIZATION
- GEOTHERMAL DATA AND THEORY

The summaries in this bulletin and all citations to information on geothermal energy back to January 1967 are available for on-line searching and retrieval using the DOE/RECON system. Citations from June 1976 to the present are available on the Energy Data Base, which may also be searched using the commercial on-line retrieval systems. Retrospective searches can be made on any aspect of geothermal energy, or customized profiles can be developed to provide current information for each user's needs.

Lila B. Smith, Editor

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The citations reference the various kinds of literature: reports, books, conferences, monographs, disserta-

tions, patents, and journal articles. In many cases, individual papers, sections, chapters, etc., from books, conferences, and reports are cataloged separately.

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ABSTRACTS

GEOTHERMAL ENERGY

- 1 (DOE/ET/27155--1) DESIGN FOR AN INFORMATION-MANAGEMENT SYSTEM. (Sonoma State Univ., Rohnert Park, CA (USA). Ruben Salazar Library). 8 Mar 1979. Contract FG03-78ET27155. 26p. NTIS (US Sales Only). Order Number DE82020977.

Portions of document are illegible.

The design of an information management system to assemble, classify, and catalog existing documentation on the development of the Geysers/Calistoga Known Geothermal Resources Area (KGRA) is presented. The study consisted of several components: user need requirements, design of the system, survey of information management systems, and systems analysis and cost proposal. User input concerning information requirements and system characteristics were obtained from interviews (personal and telephone) and a questionnaire. The sample user population expressed a need for the identification and access to relevant information concerning local geothermal development. Furthermore, it was a consensus of opinion that the creation of an information center as a depository for relevant documentation would be useful in meeting information needs. The production of a book catalog utilizing automatic data processing (ADP) and a data base management system (DBMS) approach is proposed. The catalog would contain full bibliographic descriptions for all records as well as abstracts for highly significant documents.

RESOURCE STATUS AND ASSESSMENT

- 2 GEOTHERMAL POWER: SLEEPING GIANT STIRS, BUT WILL REQUIRE YEARS TO WAKEN FULLY. Power; 117: No. 4, 32-34 (Apr 1973).

Although it is true that geothermal activity of one sort or another has been found in scores of countries, the major activity of interest for electric generation appears to concentrate along well-defined lines of volcanic action or rift valleys, where ridge systems in the ocean basin crusts pass under the continental crust. Unfortunately, nearly all these areas are remote from present electric load centers. Criteria for judging geothermal potential include: (1) fluid temperature over 150°F; (2) depth no greater than 10,000 ft, to allow economic drilling; (3) good rock permeability, to let the heat exchange agent flow readily; and (4) water recharge to maintain production.

USA

Refer also to citation(s) 10, 11, 61

- 3 (DOE/ID/12030--T2) EVALUATION OF HYDROTHERMAL RESOURCES OF NORTH DAKOTA. PHASE II. FINAL TECHNICAL REPORT. Harris, K.L.; Howell, F.L.; Winczewski, L.M.; Wartman, B.L.; Umphrey, H.R.; Anderson, S.B. (North Dakota Univ., Grand Forks (USA). Engineering Experiment Station). 1 Jun 1981. Contract FC07-79ID12030. 319p. NTIS, PC A14/MF A01. Order Number DE82020766.

Portions of document are illegible.

This evaluation of the hydrothermal resources of North Dakota is based on existing data on file with the North Dakota Geological Survey (NDGS) and other state and federal agencies, and field and laboratory studies conducted. The principal sources of data used during the Phase II study were WELLFILE, the computer library of oil and gas well data developed during the Phase I study, and WATERCAT, a computer library system of water well data assembled during the Phase II study. A field survey of the shallow geothermal gradients present in selected groundwater observation holes was conducted. Laboratory determinations of the thermal conductivity of core samples is being done to facilitate heat-flow calculations on those hole-of-convenience cased.

- 4 (DOE/ID/12101--5) STATE GEOTHERMAL COMMERCIALIZATION PROGRAMS IN SEVEN ROCKY MOUNTAIN STATES. SEMIANNUAL PROGRESS REPORT, JULY-DECEMBER 1981. Lunis, B.C. (ed.). (EG and G Idaho, Inc., Idaho Falls (USA)). Aug 1982. Contract AC07-76ID01570. 201p. NTIS, PC A10/MF A01. Order Number DE82021076.

Portions of document are illegible.

The activities and findings of the seven state commercialization teams participating in the Rocky Mountain Basin and Range commercialization program are described. The period covered is July through December 1981. Background information is provided, program objectives and the technical approach used are discussed, and the benefits of the program are described. Prospect identification, area development plans, site specific development analyses, time-phased project plans, the aggregated prospective geothermal energy use, and institutional analyses are discussed. Public outreach activities are covered and findings and recommendations are summarized.

- 5 (DOE/NV/10177--2) MULTIPLE-TASK SERVICES FOR THE DEPARTMENT OF ENERGY'S HYDROTHERMAL RESOURCES PROGRAM. FINAL REPORT, NOVEMBER 1980-AUGUST 1982. (Gruy Petroleum Technology,

Inc., Arlington, VA (USA)). Nov 1982. Contract AC08-81NV10177. 19p. NTIS, PC A02/MF A01. Order Number DE82020997.

The assignments under the task to define the geothermal resource potential in the eastern United States consist of the following subtasks: geothermal resource characterization; state-coupled lieson; low-temperature geothermal assessment; user-coupled confirmation drilling program; ASTM geothermal coordination; and topical studies. The technical assistance assignments consist of information dissemination; geothermal reservoir engineering; and technical assistance to geothermal users. Activities under these tasks are summarized. (LS)

- 6 (DOE/SF/10855--82-4) RECONNAISSANCE GEOTHERMAL RESOURCE ASSESSMENT OF 40 SITES IN CALIFORNIA. Leivas, E.; Martin, R.C.; Higgins, C.T.; Bezore, S.P. (California State Dept. of Conservation, Sacramento (USA). Div. of Mines and Geology). 1981. Contract FG03-80SF10855. 251p. (OFR--82-4-SAC). NTIS, PC A12/MF A01. Order Number DE82022220.

Portions of document are illegible.

Results are set forth for a continuing reconnaissance-level assessment of promising geothermal sites scattered through California. The studies involve acquisition of new data based upon field observations, compilation of data from published and unpublished sources, and evaluation of the data to identify areas suitable for more intensive area-specific studies. Forty sites were chosen for reporting on the basis of their relative potential for development as a significant resource. The name and location of each site is given, and after a brief synopsis, the geothermal features, chemistry, geology, and history of the site are reported. Three sites are recommended for more detailed study on the basis of potential for use by a large number of consumers, large volume of water, and the likelihood that the resource underlies a large area. (LEW)

- 7 ENERGY PLANNING IN OREGON: THE IMPLICATIONS FOR GEOTHERMAL ENERGY DEVELOPMENT. Justus, D. Bulletin, Geothermal Resources Council (Davis, California); 10: No. 1, 3-5 (Jan 1981).

A review of Oregon's geothermal energy planning is presented. The Geothermal Task Force report reviews the status of geothermal development in Oregon, estimates the resource potential likely to be on-line by the year 2000, identifies barriers to development, and proposes five basic development strategies which set the parameters for 21 recommendations. A summary listing the elements of the Special Energy Program, which directly addresses development concerns for geothermal energy, is given. The elements include a resource assessment program, a geothermal development fund, state policy support for geothermal development, Geothermal Resource Conservation Act and Geothermal Resource Administration Act, well drilling impacts on district heating systems, modification of the energy facility siting council certification process, revision to the residential renewable resources tax credit program, an energy supply program, utility incentives, and energy and land use planning. (MJF)

- 8 CHRONOLOGICAL HISTORY OF THE TECHNOLOGICAL DEVELOPMENTS FOR RELIABLE ELECTRIC POWER GENERATION AT THE NILAND GEOTHERMAL AREA, IMPERIAL COUNTY, CALIFORNIA. McCabe, B.C. (Magma Power Company, Los Angeles, CA). Bulletin, Geothermal Resources Council (Davis,

California); 10: No. 1, 6-7 (Jan 1981).

The Kent-Imperial No. 1, drilled in 1958 as an exploratory oil and gas well, reached a depth of 3800 ft. The well made an impressive display of hot brine, and as a consequence stimulated the interest of other developers to undertake drilling. In 1972, recognizing the increasing energy shortage, Magma Power Company decided to approach the development of the resource. New Albion Resources Co. and the DOE entered into agreement to jointly fund an experimental test plant known as GLEF. Two important dividends of knowledge resulting from the GLEF operation are that the CO₂ content of the brine through field operation is rapidly exhausted to about the same amount of incondensable gases found in the steam of the Big Geysers Project, and it has proven that the steam produced could be cleaned of any contaminants to about 5 ppm. (MJF)

NON-USA

Refer also to citation(s) 80

GEOLOGY, HYDROLOGY, AND GEOTHERMAL SYSTEMS

USA

Refer also to citation(s) 14, 16

- 9 (DOE/ER/10973--T1) IMPLICATIONS OF FISSION-TRACK ANNEALING FOR GEOTHERMAL MODELS IN THE PACIFIC NORTHWEST. TECHNICAL PROGRESS REPORT. Blackwell, D.D.; Duncan, I.J. (Southern Methodist Univ., Dallas, TX (USA)). 21 May 1982. Contract AC03-81ER10973. 19p. NTIS, PC A02/MF A01. Order Number DE82017169.

A fission-track dating lab has been set up. Samples have been obtained from fossil and active geothermal systems and are in the process of being separated, counted and dated with subsequent modeling planned. The thermal model of horizontal flow in a geothermal aquifer is being prepared. Modeling of magma systems and regional thermal evolution has been confined to studies of the Rio Grande Rift and the deep holes at the Fenton Hill Dry Hot Rock locality at the edge of the Valles caldera. Samples have been obtained from one deep hole in a sedimentary basin, the western Snake River basin in eastern Oregon. These samples are being separated so that the fission-track annealing can be studied. Studies of the systematics of fission-track fading are in progress. Several models have been investigated to explain the existing fission-track fading data, and several annealing experiments are planned. The use of transmission electron microscopy (TEM) for direct observation of fission-track fading has been investigated. (LEW)

- 10 (DOE/ID/12009--T2) GEOTHERMAL-RESOURCE POTENTIAL FOR A PORTION OF THE SAN PEDRO RIVER VALLEY. Hahman, W.R. Sr. (Arizona Bureau of Geology and Mineral Technology, Tucson (USA). Geothermal Group). 1981. Contract FC07-79ID12009. 60p. NTIS, PC A04/MF A01. Order Number DE82021852.

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Three anomalous areas containing shallow-depth warm water have been located in the San Pedro study area: (1) the San Manuel-Mammoth area; (2) the A.C. Gruwell Ranch; (3) Hookers

Hot Springs at the Muleshoe Ranch. The probable explanation for these warm water resources is as follows. The Galiuro Mountains, the remains of a volcanic pile deposited along the axis of a large synform (Rehrig and Heidrick, 1976), are in all probability an area of recharge for the ground water system in the area. The meteoric water falling down upon the Galiuro Mountains percolates downward to great depths through fractures in the volcanic rocks, becomes heated, rises by convection along faults, encounters late Tertiary sedimentary units overlying these faults and migrates laterally through these sediments out into the basin. These warm waters are now near the surface because of erosion of the late Tertiary and Quaternary sedimentary units by the San Pedro River. This type of phenomenon will readily explain the unreasonably high gradients encountered in some of the more shallow wells. This low- to moderate-temperature geothermal resource may be utilized using current heat-pump technology for space heating and cooling, green house operations or in health spas. However, the size and production capabilities of the reservoir has yet to be established.

intact and 30° sawcut cylinders were deformed at confining pressures of 200-1000 bars, pore pressure of 30 bars and temperatures of 150° and 240°C. Thin-section and X-ray analysis revealed that some borehole samples had undergone extensive alteration and recrystallization. Constant strain rate tests of 10^{-4} and 10^{-8} per sec gave a coefficient of friction of 0.68. Due to the highly fractured nature of the rocks taken from the production zone, intact samples were rarely 50% stronger than the frictional strength. This result suggests that the Geysers reservoir can support shear stresses only as large as its frictional shear strength. Velocity of p-waves (6.2 km/sec) was measured on one sample. Acoustic emission and sliding on a sawcut were related to changes in pore pressure. b-values computed from the acoustic emissions generated during fluid injection were typically about 0.55. An unusually high b-value (approximately 1.3) observed during sudden injection of water into the sample may have been related to thermal cracking.

NON-USA

- 11 (DOE/ID/12009--T3) PRELIMINARY ASSESSMENT OF THE GEOTHERMAL RESOURCE POTENTIAL OF THE YUMA AREA, ARIZONA. Stone, C. (Arizona Bureau of Geology and Mineral Technology, Tucson (USA). Geothermal Group). 1981. Contract FC07-79ID12009. 27p. NTIS, PC A03/MF A01. Order Number DE82021571.

Portions of document are illegible.

The Yuma area has had a long and complex tectonic history. The most southwesterly corner of the area presently comprises a small segment of the Salton Trough, a deep sediment-filled structural depression. Known geothermal anomalies in the Salton Trough make the Yuma area a favorable exploration target even though spreading-center heat sources are not expected to occur there. Geological and geophysical investigations reveal that the area is made up of low, rugged northwest-trending mountains separated by deep sediment-filled basins. Relief is a result of both erosional and structural activity. Northwest-trending en-echelon faults bound the range fronts and the basins, and have created several horst blocks (basement highs) that crop out at or near the surface. The Algodones fault is inferred to represent the northeast margin of the Salton Trough and apparently an inactive extension of the San Andreas fault system. Extensive well-pumping and applications of irrigation waters in recent years have created an unnatural state of flux in the hydrologic regime in the Yuma area. Gravity and aeromagnetic anomalies trend strongly northwest through the region as do lineaments derived from Landsat and Skylab photos. Electrical resistivity values in the Bouse Formation are exceptionally low, about 3 ohm-m. Heat flow appears to be normal for the Basin and Range province. Ground-water temperatures indicate zones of rising warm water, with one such warm anomaly confirmed by sparse geothermal-gradient data.

Refer also to citation(s) 22, 24

- 13 MAGMATIC GASES IN WELL FLUIDS AID THE MAPPING OF THE FLOW PATTERN IN A GEOTHERMAL SYSTEM. Armannsson, H.; Gislason, G.; Hauksson, T. (National Energy Authority, Reykjavik, Iceland). *Geochimica et Cosmochimica Acta* ; 46: No. 2, 167-177 (Feb 1982).

Gas composition and silica concentrations of well fluids are used in conjunction with pressure, temperature and enthalpy data to obtain a model of the drilled part of the Krafla geothermal field (Northeast Iceland). A magma chamber is located at 3-8 km depth under the field. Magmatic gases emanate from the chamber and travel via a channel reaching the surface at the Hveragil eruptive fissure. The composition of the gases is apparently modified on the way, in that sulphur, which presumably is in the form of sulphur dioxide to begin with, is removed on the way, and what remains is in the form of hydrogen sulphide at the end. It is suggested that the major removal mechanism is the deposition of pyrite and pyrrhotite during the passage of the gases through the hydrothermal system. The hydrothermal system is divided into a lower part whose temperature exceeds 300°C and whose fluids are to a varying extent affected by the magmatic gases, and an upper part whose temperature is ca 200°C. This upper part is a run-off from the lower part but the magmatic effects have mostly disappeared there.

GEOHERMAL EXPLORATION AND EXPLORATION TECHNOLOGY

Refer also to citation(s) 11, 79

- 12 LABORATORY MEASUREMENTS OF RESERVOIR ROCK FROM THE GEYSERS GEOTHERMAL FIELD, CALIFORNIA. Lockner, D.A.; Summers, R.; Moore, D.; Byerlee, J.D. (U.S. Geological Survey, Menlo Park, CA). *International Journal of Rock Mechanics and Mining Sciences* ; 19: No. 2, 65-80 (Apr 1982).

Rock samples taken from two outcrops, as well as rare cores from three well bores at the Geysers geothermal field, California, were tested at temperatures and pressures similar to those found in the geothermal field. Both

- 14 (DOE/ET/28407--T2) WATER INFORMATION BULLETIN NO. 30: GEOTHERMAL INVESTIGATIONS IN IDAHO. PART 11. GEOLOGICAL, HYDROLOGICAL, GEOCHEMICAL AND GEOPHYSICAL INVESTIGATIONS OF THE NAMPA-CALDWELL AND ADJACENT AREAS, SOUTHWESTERN IDAHO. Mitchell, J.C. (ed.). (Idaho Dept. of Water Resources, Boise (USA)). Dec 1981. Contract AS07-77ET28407. 153p. NTIS, PC A08/MF A01. Order Number DE82020789. Portions of document are illegible.

The area under study included approximately 925 sq km (357 sq mi) of the Nampa-Caldwell portion of Canyon County, an area within the central portion of the western Snake River Plain immediately west of Boise, Idaho. Geologic mapping, hydrologic, geochemical, geophysical, including detailed gravity and aeromagnetic surveys, were run to acquire needed data. In addition, existing magnetotelluric and reflection seismic data were purchased and reinterpreted in light of newly acquired data.

- 15 (DOE/SF/10855--T1) RESOURCE INVESTIGATION OF LOW- AND MODERATE-TEMPERATURE GEOTHERMAL AREAS IN SAN BERNARDINO, CALIFORNIA. PART OF THE THIRD YEAR REPORT, 1980-81, OF THE US DEPARTMENT OF ENERGY-CALIFORNIA STATE-COUPLED PROGRAM FOR RESERVOIR ASSESSMENT AND CONFIRMATION. Youngs, L.G.; Bezore, S.P.; Chapman, R.H.; Chase, G.W. (California State Dept. of Conservation, Sacramento (USA). Div. of Mines and Geology). Aug 1981. Contract FG03-80SF10855. 397p. NTIS, PC A17/MF A01. Order Number DE82020721.

Portions of document are illegible.

Ninety-seven geothermal wells and springs were identified and plotted on a compiled geologic map of the 40-square-mile study area. These wells and springs were concentrated in three distinguishable resource areas: Arrowhead Hot Springs; South San Bernardino; and Harlem Hot Springs - in each of which detailed geophysical, geochemical, and geological surveys were conducted. The Arrowhead Hot Springs geothermal area lies just north of the City of San Bernardino in the San Bernardino Mountains astride a shear zone (offshoot of the San Andreas fault) in pre-Cambrian gneiss and schist. The Harlem Hot Springs geothermal area, on the east side of the City, and the south San Bernardino geothermal area, on the south side, have geothermal reservoirs in Quaternary alluvial material which overlies a moderately deep sedimentary basin bound on the southwest by the San Jacinto fault (a ground water barrier). Geothermometry calculations suggest that the Arrowhead Hot Springs geothermal area, with a maximum reservoir temperature of 142°C, may have the highest maximum reservoir temperature of the three geothermal areas. The maximum temperature recorded by CDMG in the south San Bernardino geothermal area was 56°C from an artesian well, while the maximum temperature recorded in the Harlem Hot Springs geothermal area was 49.5°C at 174 meters (570 feet) in an abandoned water well. The geophysical and geological surveys delineated fault traces in association with all three of the designated geothermal areas.

- 16 (LBL--14132) FINAL REPORT OF THE DEPARTMENT OF ENERGY RESERVOIR DEFINITION REVIEW TEAM FOR THE BACA GEOTHERMAL DEMONSTRATION PROJECT. Goldstein, N.E.; Holman, W.R.; Molloy, M.W. (eds.). (Lawrence Berkeley Lab., CA (USA)). Jun 1982. Contract AC03-76SF00098. 54p. NTIS, PC A04/MF A01. Order Number DE82020611.

The Baca project was terminated due to inability to find sufficient steam production to support the power plant. The following aspects of the project are discussed: regional geology; structure, stratigraphy, and permeability in the Redondo Creek; geophysics; geochemical indicators of reservoir conditions; drilling problems; fracture stimulation experiments; reservoir definition and conceptual model; and prediction of reservoir performance.

GEOPHYSICAL TECHNIQUES AND SURVEYS

Refer also to citation(s) 3, 90

- 17 (BMFT-FB-T--81-111) GEOMAGNETIC AND MAGNETOTELLURIC SOUNDINGS IN THE AREA OF THE CENTRAL EUROPEAN RIFT SYSTEM. FINAL REPORT, JUNE 1980. Richards, M.L.; Schmucker, U.; Steveling, E.; Waterman, J. (Goettingen Univ. (Germany, F.R.)). Aug 1981. 76p. (In several languages). NTIS, PC A05/MF A01.

The conductivity structure connected with the Central European rift system was investigated with regard to geothermal energy sources using methods of geomagnetic depth sounding and magnetotelluric sounding. Sensors, a data acquisition system, and a software package for data handling and data analysis were developed. During a test campaign in the Leinegraben area and two field campaigns in the Rheingraben area, geoelectric and geomagnetic variations in the period range from 6 seconds to 24 hours were registered. At base sites in the Rheingraben and the Black Forest, models of the vertical profile of the electrical conductivity were determined, while at sites in between the lateral conductivity variations were investigated. The perturbation of magnetic field in the region of the Rheingraben is strong and frequency dependent. The higher frequencies (low penetration depths) show the influence of the graben sedimentary structure, filling only the narrow graben area, and strong currents along the center of the graben. The lower frequencies (deeper penetration depths) reflect the deeper, probably broader conductivity structure.

- 18 (DOE/ET/27034--T1) PRELIMINARY GEOTHERMAL INVESTIGATIONS AT MANLEY HOT SPRINGS, ALASKA. East, J. (Alaska Univ., Fairbanks (USA). Geophysical Inst.). Apr 1982. Contract FC07-79ET27034. 85p. (UAG-R--290). NTIS, PC A05/MF A01. Order Number DE82020604.

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Manley Hot Springs is one of several hot springs which form a belt extending from the Seward Peninsula to east-central Alaska. All of the hot springs are low-temperature, water-dominated geothermal systems, having formed as the result of circulation of meteoric water along deep-seated fractures near or within granitic intrusives. Shallow, thermally disturbed ground at Manley Hot Springs constitutes an area of 1.2 km by 0.6 km along the lower slopes of Bean Ridge on the north side of the Tanana Valley. This area includes 32 springs and seeps and one warm (29.1°C) well. The hottest springs range in temperature from 61° to 47°C and are presently utilized for space heating and irrigation. This study was designed to characterize the geothermal system present at Manley Hot Springs and delineate likely sites for geothermal drilling. Several surveys were conducted over a grid system which included shallow ground temperature, helium soil gas, mercury soil and resistivity surveys. In addition, a reconnaissance ground temperature survey and water chemistry sampling program was undertaken. The preliminary results, including some preliminary water chemistry, show that shallow hydrothermal activity can be delineated by many of the surveys. Three localities are targeted as likely geothermal well sites, and a model is proposed for the geothermal system at Manley Hot Springs.

- 19 (DOE/ET/28341--T1) MULTI-SITE MAGNETOTELLURIC MEASUREMENT SYSTEM WITH REAL-TIME DATA ANALYSIS. FINAL TECHNICAL REPORT NO. 210. Becker, J.D.; Bostick, F.X. Jr.; Smith, H.W. (Texas Univ., Austin (USA). Electrical Engineering Research Lab.). Sep 1981. Contract AS05-77ET28341. 189p. NTIS, PC A09/MF A01. Order Number DE82020596. Portions of document are illegible. A magnetotelluric measurement system has been designed to provide a more cost effective electrical method for geothermal and mineral exploration. The theoretical requirements and sensitivities of the magnetotelluric inversion process were specifically addressed in determining system performance requirements. Significantly reduced instrument noise levels provide improved data quality, and simultaneous measurement at up to six locations provides reduced cost per site. Remotely located, battery powered, instrumentation packages return data to a central controlling site through a 2560 baud wire-line or radio link. Each remote package contains preamplifiers, data conditioning filters, and a 12-bit gain ranging A-D converter for frequencies from 0.001 Hz to 8 Hz. Data frequencies above 8 Hz are processed sequentially by a heterodyne receiver to reduce bandwidth to within the limits of the 2560 baud data link. The central data collection site provides overall control for the entire system. The system operator interacts with the system through a CRT terminal, and he receives hard copy from a matrix graphics printer. Data from the remote packages may be recorded in time sequence on a magnetic tape cartridge system, or an optional Hewlett-Packard 21MX minicomputer can be used to perform real-time frequency analysis. The results of this analysis provide feedback to the operator for improved evaluation of system performance and for selection of future measurement sites.
- 20 (DOE/ID/12026--T1) HEAT FLOW, RADIOACTIVITY, GRAVITY, AND GEOTHERMAL RESOURCES IN NORTHERN COLORADO AND SOUTHERN WYOMING. Decker, E.R.; Buelow, K.L. (Wyoming Univ., Laramie (USA). Dept. of Geology and Geophysics). Dec 1981. Contract FC07-79ID12026. 27p. NTIS, PC A03/MF A01. Order Number DE82020751. Portions of document are illegible. The surface heat flow values in the Sierra Madre-Medicine Bow-Laramie Mountains region are in the range 0.6 to 1.5 HFU. When the heat from local bedrock radioactivity is considered, the reduced flux in these mountains is low to normal (0.6 to 1.2 HFU). These data and the low to normal gradients (10 to 25°C/km) in the studied drill holes strongly suggest that the resource potential of the Southern Rockies in Wyoming is low. The geothermal resource potential of the sedimentary basins in Wyoming that border these mountains also appears to be low because preliminary estimates for the flux in these areas are less than or equal to 1.5 HFU and the average gradients in analyzed drill holes are generally less than or equal to 30°C/km. In contrast to southern Wyoming, the high surface and reduced heat flows strongly suggest that the Park areas and other parts of the Southern Rockies in northern Colorado are potentially valuable geothermal resource areas. The narrow northerly borders (less than or equal to 50 km) of these positive anomalies suggest that some of the resources could be shallow, as does the evidence for regional igneous and tectonic activity in the late Cenozoic. The small number of combined heat flow and radioactivity stations precludes detailed site-specific evaluations in these regions, but a few generalizations are made.
- 21 (DOE/ID/12026--T2) HEAT-FLOW STUDIES IN WYOMING, 1979 TO 1981. Decker, E.R.; Heasler, H.P.; Buelow, K.L. (Wyoming Univ., Laramie (USA). Dept. of Geology and Geophysics). Dec 1981. Contract FC07-79ID12026. 44p. NTIS, PC A03/MF A01. Order Number DE82021739. Portions of document are illegible. Thirty heat flow values completed during May 1981 for Wyoming are tabulated and updated maps of heat flow in Wyoming and adjacent areas are presented.
- 22 (EUR--7113-IT) VILLAVERLA 1 WELL. INTERPRETATION OF PRODUCTION TESTS. FINAL REPORT. (AGIP Nucleare, Milan (Italy)). 1981. 53p. (In Italian). European Community Information Service, 2100 M St., N.W., Washington, DC 20037. Portions of document are illegible. A description is given of tests made of the water-pumping productivity of the Villaverla well in the province of Vicenza in limestone at levels of 1500 and 2400 meters at water temperatures of 75°C at 2300 meters for possible geothermal utilization. Tabulated data are given on the water samples taken from the well with respect to water temperature, elevation, water velocity, and other hydrodynamic parameters. The interpretative results indicate that there are very high headwater losses in the well that considerably exceed the losses attributable to aquiferous flow. 28 tables.
- 23 (EUR--7578-DE) SEISMIC STUDIES FOR THE DETERMINATION OF THE CRUSTAL STRUCTURE IN THE REGION OF THE GEOTHERMAL ANOMALY OF TUSCANY. Giese, P.; Wigger, P.; Morelli, C.; Nicolich, R. (Commission of the European Communities, Luxembourg. Directorate-General for Research, Science and Education). 1981. 108p. (In German). Commission of the European Communities, Luxembourg. Within this project the crustal and upper mantle structure in the region of the strongest continental European geothermal anomaly - the western parts of Tuscany and adjacent areas - have been investigated by seismic and magnetotelluric methods. The distribution of the seismic velocities and the electrical resistivity gives hints at anomalous temperatures in the crust and upper mantle and how far their extension is, and by which mechanism the geothermal anomaly is caused. Seismic velocities as well as the electrical resistivity decrease at increasing temperatures. Accordingly this program comprises two parts: 1) the study of the seismic velocity distribution and 2) the study of the electrical resistivity distribution. This report gives information about the results of the seismic measurements.
- 24 GEOTHERMAL GRADIENTS IN THE HINTON AREA OF WEST-CENTRAL ALBERTA. Lam, H.L.; Jones, F.W.; Lambert, C. (Univ. of Alberta, Edmonton, CA). Canadian Journal of Earth Sciences; 19: No. 4, 755-766 (Apr 1982). Temperature data from petroleum exploration well logs of 3360 wells in a region of west-central Alberta are used to estimate thermal gradients. A relatively high geothermal gradient (approx. 36°C/km) of oblong shape located near Hinton is observed. The axis of the anomaly strikes approximately southwest-northeast and passes through the Miette Hot Springs area. It appears that water is heated at depth in the Rocky Mountain disturbed region and travels eastward and toward the surface

along fault planes.

basalt-seawater reaction beneath the east rift zone. (JMT)

- 25 GEOPHYSICAL ASPECTS OF THE ENERGY PROBLEM. Rapolla, A.; Keller, G.V.; Moore, D.J. (eds.). Amsterdam, Netherlands; Elsevier Scientific Publishing Co. (1980). 339p. (CONF-7806198--).

From 2. course on geophysical aspects of the energy problem; Erice, Italy (4 Jun 1978).

Ten of the lectures presented at the course are published in these proceedings. They cover thermodynamic aspects of geothermal energy; geophysical methods in prospecting for geothermal resources; geothermal prospecting for geothermal fields; low enthalpy geothermal fields, with reference to geothermal energy in France; man-made geothermal reservoirs; technical, physical and economic problems in the development and use of petrogeothermal resources; physical and geophysical aspects of solar energy; geochemistry and geology of uranium deposits, earthquakes and security of nuclear plants; and atmospheric and water pollution from power plants. One paper has been individually abstracted.

- 26 HEAT TRANSFER IN GEOTHERMAL SYSTEMS. Cheng, P. (Hawaii, University, Honolulu, HI). Advances in Heat Transfer; 14: 1-105(1978).

Theoretical and experimental investigations of convective heat transfer in geothermal systems are reviewed. The governing equations for such heat transfer in geothermal systems are examined, along with heat transfer in hot-water, water-steam two-phase, and geopressured geothermal systems. Lumped-parameter analyses for predicting averaged reservoir characteristics during production are considered, heat transfer in other geothermal systems (e.g., dry hot rock and magma) is briefly discussed, and investigations of heat transfer in geothermal wellbores are summarized. It is concluded that studies based on the idealization of a geothermal reservoir as a saturation porous medium can provide considerable insight into the physical processes involved.

GEOCHEMICAL TECHNIQUES AND SURVEYS

Refer also to citation(s) 18, 101

- 27 CHEMISTRY AND ISOTOPE RATIOS OF SULFUR IN BASALTS AND VOLCANIC GASES AT KILAUEA VOLCANO, HAWAII. Sakai, H. (Okayama Univ., Misasa, Japan); Casadevall, T.J.; Moore, J.G. Geochimica et Cosmochimica Acta; 46: No. 5, 729-738(May 1982).

Eighteen basalts and some volcanic gases from the submarine and subaerial parts of Kilauea volcano were analyzed for the concentration and isotope ratios of sulfur. The volcanic sulfur gases, predominantly SO_2 , from the 1971 and 1974 fissures in Kilauea Crater have $\delta^{34}\text{S}$ values of 0.8 and 0.9‰, slightly heavier than the total sulfur in the submarine basalts and definitely heavier than the subaerial basalts, in accord with the above model. However, the $\delta^{34}\text{S}$ value of sulfur gases (largely SO_2) from Sulfur Bank is 8.0‰, implying a secondary origin of the sulfur. The $\delta^{34}\text{S}$ values of native sulfur deposits at various sites of Kilauea and Mauna Loa volcanos, sulfate ions of four deep wells and hydrogen sulfide from a geothermal well along the east rift zone are also reported. The high $\delta^{34}\text{S}$ values (+5 to +6‰) found for the hydrogen sulfide might be an indication of hot

- 28 HELIUM ISOTOPES IN GEOTHERMAL SYSTEMS: ICELAND, THE GEYSERS, RAFT RIVER AND STEAMBOAT SPRINGS. Torgersen, T. (Australian National Univ., Canberra, Research School of Earth Sciences); Jenkins, W.J. (Woods Hole Oceanographic Institution, MA (USA)). Geochimica et Cosmochimica Acta; 46: No. 5, 739-748(May 1982).

Helium isotope ratios have been measured in geothermal fluids from Iceland, The Geysers, Raft River, Steamboat Springs and Hawaii. These ratios have been interpreted in terms of the processes which supply He in distinct isotopic ratios and in terms of the processes which can alter the isotopic ratio. Using this interpretational scheme, Iceland is found to be an area of hot-spot magmatic He implying an active volcanic source although the data are suggestive of high-temperature weathering release of crustal He incorporated in the geothermal fluids. By comparison to fumarolic gases from Hawaii and Juan De Fuca and Cayman Trench basaltic glass samples, The Geysers contains MOR type magmatic He again implying an active volcanic source possibly a 'leaky' transform related to the San Andreas Fault System. Raft River contains only crustal He indicating no active volcanic sources. Steamboat Springs He isotope ratios are distinctly less than typical plate margin volcanics but must still have a magmatic source.

- 29 QUICK SEPARATION OF MANGANESE FROM BRINE SOLUTIONS. Grout, G.L.; Webre, C.L.; Beck, J.N. (McNeese State University, Lake Charles, LA (USA). Department of Chemistry). Radiochemical and Radioanalytical Letters; 51: No. 2, 65-71(16 Mar 1982).

Recent chemical analysis of brine water collected from geopressured-geothermal wells have generally shown good agreement between interlaboratory determinations of trace metals except manganese. As a result of this difficulty a radiochemical procedure for manganese was developed using neutron activation analysis. The determination of manganese uses the 2.58 h activity of ^{55}Mn produced from the $^{55}\text{Mn}(n,\gamma)$ reaction. This procedure modifies existing procedures and allows the separation of about 15-20 samples in about two hours. The important steps in the procedure include sequential manganese dioxide precipitations and finally the precipitation of $\text{MnNH}_4\text{PO}_4 \cdot \text{H}_2\text{O}$. Chemical yields were found to range from 40-90% with a final decontamination factor of 10^7 - 10^9 estimated from the γ -ray spectra.

- 30 FLUORAPATITE AND FLUDRITE SOLUBILITY CONTROLS ON GEOTHERMAL WATERS IN YELLOWSTONE NATIONAL PARK. Stauffer, R.E. (Univ. of Wisconsin, Madison). Geochimica et Cosmochimica Acta; 46: No. 3, 465-474(Mar 1982).

Potential solubility controls on phosphorus in Yellowstone National Park geothermal waters were investigated using analytical phosphate estimates the computer program, WATEQF, and adopting the equilibrium constant: $\log K_{25}/\text{sub } \theta / = -61.4$ for fluorapatite ($\text{FAP} = \text{Ca}_5(\text{PO}_4)_3\text{F}$) dissolution. The near-boiling high-Cl geyser and spring effluents are at or near saturation with respect to (with) FAP. The sixteen representative springs in this category had FAP saturation indices ($\text{S.I.} = \log \text{IAP}/K_{25}/\text{sub } \theta /$) ranging from -3.2 to +4.9 and averaging +0.9. The strongly positive indices were all

associated with the highly alkaline conditions resulting from adiabatic cooling in the near surface environment. Hot spring waters indicating extensive dilution (reduced Cl) by meteoric water have lower pH's, and despite PO_4 and Ca concentrations an order of magnitude higher than the geysers, are still frequently undersaturated with FAP. The travertine-depositing "Mixed-water" springs are invariably supersaturated with FAP at ground surface and at or near saturation with hydroxylapatite. Supersaturation may result from kinetic inhibition of apatite crystallization by the elevated Mg^{2+} , HCO_3^- , and lower temperatures in these springs. The phosphates may be residuals of the meteoric dilution water. Separately, if Strubel's temperature-dependent estimates of fluorite (CaF_2) solubility are adopted, the high-Cl geysers and springs on "Geyser Hill" and at Norris are consistently undersaturated with CaF_2 at the 90-100° orifice temperatures. The apparent disequilibrium may reflect fluorite equilibration at the much higher temperatures (<200°C) in the deeper enthalpy reservoirs.

- 31 COMPARISON STUDY FOR DETERMINING DISSOLVED BORON IN NATURAL WATER AND GEOTHERMAL FLUID. Trujillo, P.F.; Gladney, E.; Counce, D.A.; Mroz, E.J.; Perrin, D.R.; Owens, J.W.; Wangen, L.E. (Los Alamos National Lab., NM). Analytical Letters; 15: No. A7, 643-655(1982).

Analytical methods for measuring boron concentrations in geothermal fluid were evaluated. Samples were collected from the Los Alamos Hot Dry Rock Geothermal Energy Project and from natural waters in the vicinity of the project. Three colorimetric techniques, the carmine method and two azomethine H methods, were compared with two plasma emission spectroscopy methods and with thermal neutron capture-gamma spectroscopy. In general, the analytical results from all the methods were comparable and acceptable; however, each method had distinct advantages and disadvantages. 3 tables.

EXPLORATORY DRILLING AND WELL LOGGING

- 32 (DOE/ID/12033--T1) DRILLING REPORT: STATE NURSERY TEST WELL NO. 1. Donovan, J.; Sonderegger, J. (Montana Bureau of Mines and Geology, Butte (USA)). 27 Aug 1982. Contract FC07-791D12033. 12p. NTIS (US Sales Only). Order Number DE82021740. Portions of document are illegible. A geothermal test well was sited and drilled approximately 0.8 miles (1.3 km) east of Broadwater Hot Springs, near Helena, Montana. The site is on the property of the State Nursery, along the north side of Ten Mile Creek. The purpose of the drilling was to test a thermal infrared imagery anomaly and to evaluate whether a source of warm water for space heating of a series of new greenhouses could be developed to replace ones destroyed in the spring 1981 flooding of Ten Mile Creek. The well was drilled to 280 feet total depth, with no success in obtaining hot or even warm water.

- 33 (USGS-OFR--81-1330) VOLCANIC STRATIGRAPHY AND SECONDARY MINERALIZATION OF U.S.G.S. PUCCI GEOTHERMAL TEST WELL, MOUNT HOOD, OREGON. Gannett, M.W.; Bargar, K.E. (Portland State Univ., OR (USA)). Dept. of Earth Sciences; Geological Survey, Menlo Park, CA (USA). 1981. 27p. Geological Survey, Open-File Services Section, P.O. Box 25425, Denver Federal Center, Denver, CO 80225. Portions of document are illegible.

Ninety-one sample splits of drill cuttings from approximately 6.1 m intervals in the 610 m hole that was completed in 1979 were provided for this study. An additional 225 sample splits (3.05 m intervals) from 536 m to the bottom of the drill hole at 1220 m were added to the study following the deepening of the drill hole. Stratigraphic and petrologic observations of the cuttings were made. Scanning electron microscope and x-ray diffractometer examinations were made of alteration minerals. The lithology and secondary mineralization are discussed.

LEGAL AND INSTITUTIONAL ASPECTS

Refer also to citation(s) 7

- 34 (CONF-811249--) CONFERENCE ON LEGAL ASPECTS OF GEOTHERMAL DEVELOPMENT. (Geothermal Resources Council, Davis, CA (USA); American Bar Association, Chicago, IL). 1981. 271p. Geothermal Resources Council, P.O. Box 98, Davis, CA 95617. From Conference on legal aspects of geothermal development; Newport Beach, CA, USA (3 Dec 1981). Portions of document are illegible. Fifteen papers and abstracts are included. Separate abstracts were prepared for six papers and nine abstracts were listed by title.

- 35 (CONF-811249--; pp 48p, Section I) GEOTHERMAL ENERGY AND NATIONAL ENERGY GOALS. Zillman, D.N.; Naumann, S. (Univ. of Utah, Salt Lake City). 1981. Geothermal Resources Council, P.O. Box 98, Davis, CA 95617. From Conference on legal aspects of geothermal development; Newport Beach, CA, USA (3 Dec 1981). The role of law in the production and use of energy resources is discussed. The way the Reagan Administration is changing energy law is examined. How these changes have influenced and are likely to influence the Reagan Administration with regard to geothermal development is explored.

- 36 (CONF-811249--; pp 28p, Section III) UNITIZATION OF GEOTHERMAL RESOURCES: BACK TO BASICS. Hieronymus, E.W. (O'Melveny and Myers, Los Angeles, CA). 1981. Geothermal Resources Council, P.O. Box 98, Davis, CA 95617. From Conference on legal aspects of geothermal development; Newport Beach, CA, USA (3 Dec 1981). Six basic issues in the unitization process are addressed: the land to be included, the parties involved, allocation of costs, allocation of production, decision-making, and lessee's obligations. Both voluntary and compulsory unitization imposed by a government agency are discussed.

- 37 (CONF-811249--; pp 29p, Section IV) WATER LAW AND THE DEVELOPMENT OF GEOTHERMAL RESOURCES. Olpin, O.; Thompson, B.H. (O'Melveny and Myers, Los Angeles, CA). 1981. Geothermal Resources Council, P.O. Box 98, Davis, CA 95617. From Conference on legal aspects of geothermal development; Newport Beach, CA, USA (3 Dec 1981). Western water law is surveyed briefly. The necessity of abiding by state water law in geothermal development is discussed and

compliance problems under state groundwater law are described. Some possible ways out of the conflicts are presented and some recommendations are made for both geothermal developers and for the state.

- 38 (CONF-811249-- , pp 3p, Section V)
FEDERAL LANDS AND GEOTHERMAL RESOURCES
MANAGEMENT PROGRAMS. Conover, R.D. (Dept.
of the Interior, Riverside, CA). 1981.
Geothermal Resources Council, P.O. Box 98,
Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. PUBLIC LANDS;LAND LEASING;CASE
LAW;LAND USE;GEOTHERMAL RESOURCES;MANAGEMENT

- 39 (CONF-811249-- , pp 2p, Section VI)
GEOTHERMAL LEASING FROM PRODUCER'S POINT OF
VIEW. Trower, D. (AMAX Exploration, Inc.,
Golden, CO). 1981. Geothermal Resources
Council, P.O. Box 98, Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. ROYALTIES;LEASING;GEOTHERMAL
FLUIDS;GEOTHERMAL RESOURCES;GRANTS;BY-PRODUCTS;
OWNERSHIP

- 40 (CONF-811249-- , pp 9p, Section VII)
GEOTHERMAL LEASING FROM A LANDOWNER'S POINT OF
VIEW. Byrd, W.N. (Byrd, Sturdevant, and
Krutzsch, Brawley, CA). 1981. Geothermal
Resources Council, P.O. Box 98, Davis, CA
95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. LAND OWNERSHIP;LAND LEASING;
GEOTHERMAL RESOURCES;LEASING;ROYALTIES

- 41 (CONF-811249-- , pp 3p, Section IX) LOCAL
GOVERNMENT PLANNING AND REGULATIONS OF
GEOTHERMAL RESOURCES DEVELOPMENT. Harmon,
J.H. (Imperial County Counsel's Office, El
Centro, CA). 1981. Geothermal Resources
Council, P.O. Box 98, Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. IMPERIAL VALLEY;LAND USE;
GEOTHERMAL RESOURCES;RESOURCE DEVELOPMENT;LAWS;
PUBLIC LANDS;POLLUTION LAWS;PLANNING;LEGAL
ASPECTS

- 42 (CONF-811249-- , pp 3p, Section X)
STRATEGIES FOR A SUCCESSFUL GEOTHERMAL
PERMITTING PROCESS IN LAKE COUNTY. Bridges,
R.L. (Senior Deputy County Counsel, Lakeport,
CA). 1981. Geothermal Resources Council,
P.O. Box 98, Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. GEOTHERMAL RESOURCES;RESOURCE
DEVELOPMENT;PERMITS;ENVIRONMENTAL IMPACTS;
PUBLIC RELATIONS;GEOTHERMAL POWER PLANTS;
GEOTHERMAL EXPLORATION;GEOTHERMAL WELLS

- 43 (CONF-811249-- , pp 10p, Section XI)
PROPOSITION 13: APPRAISAL AND AD VALOREM TAXES
ON GEOTHERMAL RESOURCES IN CALIFORNIA.
Bertholf, H.W. (Harold W. Bertholf and
Associates, Sacramento, CA). 1981.
Geothermal Resources Council, P.O. Box 98,
Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA .
(3 Dec 1981).

Outline only. CALIFORNIA;GEOTHERMAL
RESOURCES;TAXES;TAX LAWS;PROPERTY RIGHTS;
OWNERSHIP;CASE LAW

- 44 (CONF-811249-- , pp 62p, XII) INCOME
TAXATION OF GEOTHERMAL RESOURCES. Maxfield,
P.C. (Univ. of Wyoming, Laramie). 1981.
Geothermal Resources Council, P.O. Box 98,
Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

The state of the federal income tax laws is
outlined as applied to geothermal resources
with particular emphasis on newer developments
such as the Energy Tax Act of 1978.

- 45 (CONF-811249-- , pp 4p, Section XIV) ROLE
OF COUNSEL IN THE SALE AND PURCHASE OF A
PRODUCING GEOTHERMAL PROPERTY: A CASE HISTORY.
Laybourne, E.B. (MacDonald, Helsted and
Laybourne, Los Angeles, CA). 1981.
Geothermal Resources Council, P.O. Box 98,
Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

Outline only. GEOTHERMAL RESOURCES;LEGAL
ASPECTS;SALES;TRADE;RISKS;TAXES

- 46 (CONF-811249-- , pp 31p, Section XV)
CONSTRUCTION AND OPERATION OF GEOTHERMAL
ELECTRIC POWER PLANTS ON LANDS PATENTED UNDER
THE STOCK-RAISING HOMESTEAD ACT OF 1916 OR WHAT
DO YOU DO WITH A BUCKET OF STEAM. Tanke, T.J.
(Knudson, Tanke and Scholz, San Francisco, CA).
1981. Geothermal Resources Council, P.O. Box
98, Davis, CA 95617.

From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).

A problem involved in the Homestead Act is
whether geothermal steam is a mineral reserved
to the government under the Act or a part of
the water rights owned by the homesteaders in
their surface estate. It was ruled that
geothermal steam is a reserved mineral. Since
geothermal steam is not transportable, the
question arises as to whether the reservation
is broad enough to allow power generation
facilities without the consent of the
homesteaders. An argument in favor of mineral
lessee is presented.

- 47 PROPOSED GEOTHERMAL LEGISLATION 1981.
Neville, T.J. (Occidental Geothermal, Inc.,
Bakersfield, CA). Bulletin, Geothermal
Resources Council (Davis, California); 10: No.
1, 8-9(Jan 1981).

The factors deemed most important by
industry for inclusion in new geothermal
legislation are discussed. These factors are:
(1) increased acreage allotments, (2)
redefinition of KGRA's, (3) tax credits for
geothermal exploration and development. The
current legislative acreage allotments of
20,480 acres/state do not permit an active
exploration company to hold sufficient federal
acreage in a given state to satisfy the acreage
needed for more than two projects within the
state (assuming the prospects are on federal
lands). The designation of an area as a KGRA
should be made at the time of filing an
application for a lease instead of at the time
of lease issuance. (MJF)

ECONOMIC AND FINANCIAL ASPECTS

- 48 (CONF-811249-- , pp 28p, Section II)
GEOTHERMAL SALES CONTRACTS. Humphrey, R.L.
(Union Oil Co., Los Angeles, CA); Parr, C.J.
1981. Geothermal Resources Council, P.O. Box
98, Davis, CA 95617.
From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).
Contracts for the sale and purchase of high
temperature geothermal steam for the generation
of electric power are discussed. The following
topics are covered: dedication of the resource;
term; development; subsequent generation
facilities; generating plant siting; production;
pricing methods; indemnification, warranties,
and damages; and relief for failure to perform.
- 49 (CONF-811249-- , pp 1p, Section XIII)
CAPITAL FOR GEOTHERMAL ENERGY DEVELOPMENT.
Worcester, T.E. (Sherman and Howard, Denver,
CO). 1981. Geothermal Resources Council,
P.O. Box 98, Davis, CA 95617.
From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).
Outline only. GEOTHERMAL RESOURCES; RESOURCE
DEVELOPMENT; CAPITAL; PUBLIC UTILITIES; FINANCIAL
INCENTIVES; TAX CREDITS; FINANCING; JOINT VENTURES
- 50 GEOTHERMAL PROGRAMS. Deering, C.L.
(Patton, Boggs and Blow, Washington, DC). pp
4.1-4.5 of Alternative energy: the Federal
role. Ruck, L.E.; Goodwin, L.M. (eds.).
Colorado Springs, CO; Shepard's/McGraw-Hill
(1982).
Title VI of the Energy Security Act of 1980
replaced the unfunded Geothermal Research
Development and Demonstration Act of 1974 to
provide loans and loan guarantees for
exploration and drilling activities and to
finance up to 80% of feasibility studies.
Because these programs were not funded in 1982,
this review of the loan-guarantee program is
limited to the more-important provisions and
refers those interested in application
procedures to the regulations. 29 references.
(DCK)
- 51 ECONOMY OF A GEOTHERMAL POWER PLANT.
Brabant, G.; Moeller, U. pp 49-50 of
Solartechnik - Solararchitektur im Ein- und
Zweifamilienhaus. Praxisorientierte
Beispiele. Steinmetz, E. (ed.). Essen,
Germany, F.R.; Vulkan-Verl. (1980). (In
German)
Two geological conditions apply to all
sources of geothermal energy which are
technically developed today: 1. they are found
in a geothermal anomaly and 2. there are
sufficient amounts of water in an appropriate
depth for an efficient period of utilization.
If geothermal power plants are to supersede
other types of power plants to an extent worth
mentioning another productive method which is
still being developed must be applied: the so-
called 'Hot Dry Rock Method' which can do
without these two highly restrictive conditions
as to the site of the plant.

ENVIRONMENTAL ASPECTS AND WASTE DISPOSAL

Refer also to citation(s) 74

- 52 (CONF-811249-- , pp 1p, Section VIII)
ENVIRONMENTAL PROBLEMS AND GEOTHERMAL
PERMITTING. Windrem, P.F. (Windrem, and
Feeney, Lakeport, CA). 1981. Geothermal
Resources Council, P.O. Box 98, Davis, CA
95617.
From Conference on legal aspects of
geothermal development; Newport Beach, CA, USA
(3 Dec 1981).
Outline only. GEOTHERMAL RESOURCES; RESOURCE
DEVELOPMENT; ENVIRONMENTAL IMPACTS; AIR QUALITY;
NOISE; WATER QUALITY; SEISMICITY; AESTHETICS;
ECOLOGY; LAND USE; ARCHAEOLOGICAL SITES;
REGULATIONS; LEGAL ASPECTS; PERMITS
- 53 (DOE/ET/27146--T15) DAMAGE TO POROUS
MEDIA DUE TO THE DEGRADATION OF FLOCCULANTS.
Vetter, O.J.; Kandarpa, V. (Vetter Research,
Costa Mesa, CA (USA)). 17 Aug 1982.
Contract AC03-78ET27146. 25p. NTIS, PC A02/
MF A01. Order Number DE82021793.
The results of laboratory experiments
involving the flow of two commercial flocculant
solutions through Berea sandstone core plugs at
225°C are summarized. The two flocculants used
are TFL-398 and TFL-362 (commercial flocculants
supplied by Tretolite Division of Petrolite
Corporation). The flow of brine containing
these flocculants through these sandstone cores
resulted in considerable permeability
reductions during the flow experiments even
when used at concentrations of only 5 ppm. The
reduction in permeability is attributed to the
plugging of pore spaces by the degradation
products. The results of these experiments
demonstrated that the use of a flocculant can
cause severe formation damage. It is, therefore
recommended, to always conduct laboratory tests
prior to the use of any specific flocculant for
geothermal applications to avoid any damage to
injection wells.
- 54 (DOE/ET/27146--T16) ENHANCEMENT OF HEAT
PRODUCTION THROUGH SELECTIVE SCALING. Vetter,
O.J.; Kandarpa, V.; Harouaka, A. (Vetter
Research, Costa Mesa, CA (USA)). 16 Aug 1982.
Contract AC03-78ET27146. 51p. NTIS, PC A04/
MF A01. Order Number DE82021792.
Portions of document are illegible.
The heat-depleted brine has to be reinjected
whether it is for technical, economical,
environmental and/or legal purposes. However,
there are many problems related to injectivity
and injectability in a geothermal field. The
major drawback is the dread of an early
breakthrough of the heat depleted brine at the
production wells. It is believed that this
drawback may be overcome through selective
scaling. The results of investigation into the
feasibility of selective scaling are
summarized. Selective scaling is defined here
as the process of intentionally precipitating
large quantities of chemical compounds at
selected locations, such as high permeability
streaks or fractures, for the purpose of
retarding the flow of injection fluids through
these flow channels. Such flow retardation will
increase the residence time of the injected
fluids in the reservoir by a more suitable heat
sweep thereby enhancing the heat extraction
from the geothermal reservoir. Three different
methods of selective scaling are discussed.
These methods are: the injection of a
thermodynamically unstable brine; injection of
a slug of dirty brine or other
thermodynamically unstable brine into selective
locations of the reservoir; and mixing of an
injection brine which is incompatible with a
reservoir brine. The basis of these methods and
their impact on the permeability
characteristics of the reservoir are discussed
through a precipitation model and through

simple flow models. The application of these models are illustrated using Salton Sea brine and Currier 2 brine.

RADIATION MONITORING

- 55 (DOE/EV/10117--T1-Vol.1) IDENTIFICATION OF HAZARDS IN NON-NUCLEAR POWER PLANTS. PHASE I AND PHASE II. SUMMARY REPORT. (NUS Corp., Rockville, MD (USA)). Aug 1979. Contract FG03-78EV10117. 34p. NTIS, PC A03/MF A01. Order Number DE82021526.

Portions of document are illegible.

Work performed in the first step of an evaluation of the public health and safety hazards associated with non-nuclear plants is reported. This study was limited to hazards which could affect the general public outside the plant boundaries. Public health and safety hazards were identified for seven types of power plants: coal-fired conventional boiler, atmospheric fluidized bed boiler, pressurized fluidized bed-combined cycle, oil-fired, oil-fired steam turbine, combined cycle, combustion (gas) turbine, and geothermal. Major plant systems effecting the hazards were identified and are described. Potentially hazardous conditions and events were identified for normal and abnormal plant operating conditions and for accidents at the plant. A classification of each hazard was made which identifies the initiating event, the hazard source, equipment or conditions that increase, monitor or mitigate the hazard. An event tree was developed for each plant which relates the effect on the general public for each hazard and initiating event. A semi-quantitative hazard ranking was developed that provides a method of comparing the hazards and events at different types of plants. Consideration was given to the sensitivity of the hazard ranking to population density, changes in operating mode and technology changes.

- 56 (DOE/EV/10117--T1-Vol.2) IDENTIFICATION OF HAZARDS IN NON-NUCLEAR POWER PLANTS. VOLUME II. PHASE II. Fall, P.W. (NUS Corp., Rockville, MD (USA)). Aug 1979. Contract FG03-78EV10117. 128p. NTIS, PC A07/MF A01. Order Number DE82021584.

Portions of document are illegible.

This study extends the Phase I study to also include a hazards evaluation for two new emerging coal power plant technologies: coal fired atmospheric fluidized bed and pressurized fluidized bed power generating systems. The study also considers the sensitivity of the hazards ranking for all the non-nuclear power plants to the effects of population density, mode of plant operation, technical changes, location and environmental (temperature) effects. Information is provided under the following section headings: background; environmental and public health concerns associated with fluidized-bed combustion power plants; description of a conceptual atmospheric fluidized-bed power plant; pressurized fluidized-bed combustion combined cycle (PFBC) power plant; hazard ranking and risk assessment for non-nuclear power plants; end, hazards sensitivity analysis.

- 57 MEASUREMENT OF ENVIRONMENTAL RELEASES OF RADON FROM THE GEYSERS GEOTHERMAL POWER PLANT. Rich, L.E.; Szalinski, P.A. (PGandE, San Ramon, San Ramon, CA 94583). Transactions of the American Nuclear Society; 39: 81(1981). (CONF-811103--).

From ANS winter meeting; San Francisco, CA, USA (29 Nov 1981).

GEOTHERMAL POWER PLANTS; MEASURING METHODS; NATURAL RADIOACTIVITY; RADON; GEYSERS GEOTHERMAL FIELD; RADIOACTIVE EFFLUENTS; HEALTH HAZARDS;

- 58 THE INFLUENCE OF ROUGH TERRAIN ON POLLUTANT DISPERSION AND TRANSPORT FROM A GEOTHERMAL POWER COMPLEX. Ruff, R.E. (SRI International Corp., Menlo Park, Calif.). pp 122-127 of Symposium on turbulence, diffusion, and air pollution, 4th, Reno, NV, January 15-18, 1979, preprints. Boston, MA; American Meteorological Society (1978).

From 4. symposium on turbulence, diffusion and air pollution; Reno, NV, USA (15 Jan 1979).

A network of eight monitoring stations has been established to measure hydrogen sulfide concentrations in the mountainous terrain surrounding the Geysers geothermal development area. The concentration measurements, together with meteorological observations (temperature and wind speed and direction) have been used to define specific causes of air quality standard violations at each site.

- 59 THE GEYSERS GEOTHERMAL AREA EMISSIONS AND AEROMETRIC DATA BASE AND AIR QUALITY ANALYSIS. Steffen, D.E.; Hidy, G.M.; Wang, L.K.; Berman, E.A. (Environmental Research and Technology, Inc., Westlake Village, Calif.). pp 128-134 of Symposium on turbulence, diffusion, and air pollution, 4th, Reno, NV, January 15-18, 1979, preprints. Boston, MA; American Meteorological Society (1978).

From 4. symposium on turbulence, diffusion and air pollution; Reno, NV, USA (15 Jan 1979).

All available data pertaining to hydrogen sulfide in the California Known Geothermal Resource Area for the period 1976 to 1977 have been collected and analyzed. The observations included ambient H₂S concentrations, wind speed and direction, surface and vertical temperature profiles, precipitation data, and relative humidity in addition to emissions source data such as hourly-average H₂S emission rates, effluent temperature, effluent exit velocity, steam volumetric flow rate and H₂S concentrations, physical release heights and chemical analyses of source samples. The data analysis indicates that the complex terrain in the Geysers-Cob Valley area induces a decoupling of the quasi-gradient flow at the ridge and the wind circulation patterns in the valleys. The airflow in the valleys is mostly influenced by inhomogeneities in surface heating and terrain discontinuities, while winds at the ridge top are apparently driven by meso- or synoptic-scale influences. These phenomena have been related to differences in H₂S levels observed at different monitoring stations.

GEOTHERMAL POWER PLANTS

- 60 STATUS OF THE CERRO PRIETO GEOTHERMAL PROJECT. Espinosa, H.A. (Comision Federal de Electricidad, Mexicali, MX). Bulletin, Geothermal Resources Council (Davis, California); 11: No. 1, 5-7 (Jan 1982).

The status of the Cerro Prieto Geothermal Field is discussed briefly. The project has been divided into three areas. Cerro Prieto I started commercial power production in 1973 with a 37.5 MW unit and its actual installed capacity at present is 180 MW. Steam is separated from the water-steam mixture in centrifugal separators installed at the wellheads where high-pressure steam is produced. The average separation pressure is 8 Kg/cm² ABS. Power is produced by five turbo-generators; units 1 through 4 operate on high-pressure steam and unit 5 operates on medium- and low-pressure steam. Cerro Prieto II will

commence commercial operations in 1983 with 220 MW. The steam will be separated by centrifugal separators at the well head. Each 100 MW generating unit consists of two 55 MW turbines. Cerro Prieto III is scheduled for 1984 with a capacity of 220 MW. Its separation system and power plants will be similar to those of Cerro Prieto II. (MJF)

POWER PLANT SYSTEMS AND COMPONENTS

Refer also to citation(s) 81

61. GEOTHERMAL ENERGY - ITS PAST AND ITS FUTURE AT PG&E. Howe, H.M. (PG&E, San Francisco, CA 94106). Transactions of the American Nuclear Society ; 39: 9(1981). (CONF-811103--).

From ANS winter meeting; San Francisco, CA, USA (29 Nov 1981).

CALIFORNIA;ELECTRIC POWER;GEOTHERMAL ENERGY; GEOTHERMAL POWER PLANTS;GEYSERS GEOTHERMAL FIELD;HOT-WATER SYSTEMS;LICENSING;RESOURCE DEVELOPMENT;SITE SELECTION;VAPOR-DCMINATED SYSTEMS

DESIGN AND OPERATION

62. (DOE/ET/28425--T1) HIGH GEOTHERMAL ENERGY UTILIZATION GEOTHERMAL/FOSSIL HYBRID POWER CYCLE: A PRELIMINARY INVESTIGATION. Grijelva, R.L.; Sanemitsu, S.K. (Burbank City Public Service Dept., CA (USA)). Nov 1978. Contract FG03-77ET28425. 92p. NTIS, PC A05/MF A01. Order Number DE82021365.

Combining geothermal and fossil fuel energy into the so-called hybrid cycle is compared with a state-of-the-art double-flash geothermal power cycle using resources which vary from 429°K (312°F) to 588°K (598°F). It is demonstrated that a hybrid plant can compete thermodynamically with the combined output from both a fossil-fired and a geothermal plant operating separately. Economic comparison of the hybrid and double-flash cycles is outlined, and results are presented that indicate the performance of marginal hydrothermal resources may be improved enough to compete with existing power cycles on a cost basis. It is also concluded that on a site-specific basis a hybrid cycle is capable of complementing double-flash cycles at large-capacity resources, and can operate in a cycling load mode at constant geothermal fluid flow rate.

63. (DOE/ET/28425--T2) CONTINUING SITE-SPECIFIC AND DESIGN ANALYSIS OF HYBRID GEOTHERMAL/FOSSIL POWER PLANTS. Simay, G.L.; Anno, G.H.; Dore, M.A. (Burbank City Public Service Dept., CA (USA); Pacific Sierra Research Corp., Santa Monica, CA (USA)). Jun 1978. Contract FG03-77ET28425. 129p. NTIS, PC A07/MF A01. Order Number DE82021564.

Portions of document are illegible.

A preliminary economic analysis of a hybrid geothermal/coal power plant is given for ten geothermal resource areas: Beowawe (NE), Brady-Hazen (NE), Brawley (CA), Coso (CA), East Mesa (CA), Long Valley (CA), Monroe-Joseph (UT), Niland (CA), Roosevelt (UT), and Surprise Valley (CA). Wasatch-Emergency coal is the principal coal source; Victorville, California, the transmission delivery point. Beowawe, Coso, Monroe-Joseph, and Roosevelt are the most economically favorable sites when compared with an all-coal plant near the source of coal. A subcritical cycle is used in which geothermal energy preheats the boiler feedwater in countercurrent heat exchange. The supercritical cycle is found to offer no appreciable economic advantage over the subcritical cycle. In addition, flashing the geothermal fluid could make economic sense for a high-temperature, high-salinity resource.

64. (DOE/ET/27125--T1) SPERRY LOW-TEMPERATURE GEOTHERMAL CONVERSION SYSTEM. VOLUME I. ORGANIC-WORKING-FLUID PROPERTIES. FINAL REPORT. Carroll, C.; Hules, K.R.; Langley, R.; Toekes, B.; Wilson, D.P. (Sperry Research Center, Sudbury, MA (USA)). 1981. Contract AC03-78ET27125. 135p. (SRC-CR--81-74-Vol.1). NTIS, PC A07/MF A01. Order Number DE82018529.

Portions of document are illegible.

Measurements of the physical properties of R-114 in the compressed liquid and dense gas regions are reported. Included are: experimental studies of the thermodynamic properties of R-114, enthalpy measurement by throttling experiment, engineering model of the thermodynamic properties of R-114, feasibility study to dissociate R-114 with a four-cycle gasoline engine, transport properties of R-114, analytical procedure to determine impurities in R-114, toxicological information on Freons, and a literature search of published properties of R-114, other refrigerants, and other potential working fluids. (LEW)

65. ENHANCEMENT ON VERTICAL FLUTED SURFACES. Michel, J.W. (Oak Ridge National Lab., TN). pp 325-344 of Power condenser heat transfer technology. Computer modeling/design/fouling. Marto, P.J.; Nunn, R.H. (eds.). Washington, DC: Hemisphere Publishing Corp. (1981).

A brief discussion of Professor Ralph L. Webb's paper, The Use of Enhanced Surface Geometries in Condensers, is given with emphasis on the importance of overall cost optimization in the application of heat transfer enhancement. A review of DRNL condensation experiments with enhanced surfaces is presented. The work has centered on optimizing the design variables associated with fluted surfaces on vertical tubes and comparing the tube performance with available enhanced tubes either for vertical or horizontal operation. Data with seven fluids including a hydrocarbon, fluorocarbons, and ammonia condensing on up to 30 different tubes have been obtained. The primary conclusion from this work is that fluted tubes can provide an enhancement in condensation coefficient of a factor of 6 over smooth vertical tubes and a factor of 2 over enhanced commercial tubes either operating vertically or horizontally. These data, together with field test data, have formed the basis for designing a prototype condenser for the 500 kWe East Mesa, California, direct-contact geothermal demonstration plant.

66. APPLICATIONS OF THERMOELECTRICS TO GEOTHERMAL ENERGY CONVERSION. Jayadev, T.S.; Chou, D.J. (Energy Conversion Devices Inc, Troy, Mich). Proceedings, Intersociety Energy Conversion Engineering Conference; 2: 2004-2007(1981). (CONF-810812--).

From IECEC conference; Atlanta, GA, USA (9 Aug 1981).

An analysis of applying thermoelectrics to convert low grade geothermal energy to electricity, including calculations, are presented in this paper using published data on the Raft River Pilot Plant project. It is shown that thermoelectrics offer a simple, reliable and economically viable means of converting low

grade geothermal energy to electricity. 4 refs.

67 COMPONENTS OF GEOTHERMAL POWER PLANTS.

Averbach, Ya.A.; Bonesco, V.A.; Izkovski, A.A.; Kosinov, Yu.P.; Najmanov, O.S. Archiv fuer Energiewirtschaft; 34: No. 9, 719-728 (Sep 1980). (In German).

1. There are no basic problems opposing the design and fabrication of the thermal equipment for geothermal power plants (including equipment for high performance plants), as far as they are based on the use of steam turbines. 2. As steam turbines for geothermal power plants, it is recommended in the medium run to install the LP-parts of standard turbines (also of disassembled ones), that are modernized with respect to optimum operation with hot spring water with a certain state of steam. 3. In the determination of the optimum characteristic data of geothermal power plants the special thermal testing of the boreholes, of the turbines and of the auxiliary equipment plays an important part. These have so far not been performed to a sufficient extent. 4. By means of the given parameters c and psi for two-phase flows boreholes, separators and pipelines can be designed more precisely than in the past, with the different real phase velocities being taken into account.

68 RIPPLED SILICA DEPOSITS IN HEAT EXCHANGER TUBES.

Bott, T.R.; Gudmundsson, J.S. (Birmingham University, Birmingham, England). pp 373-378 of International heat transfer conference, 6th, Toronto, Canada, August 7-11, 1978; general papers. Volume 4. Washington, DC; Hemisphere Publishing Corp. (1978).

From 6. heat transfer conference; Toronto, Canada (7 Aug 1978).

Rippled deposits have been observed during the removal of heat from geothermal water. The effect of the ripples is to produce enhanced heat transfer in the early stages of the fouling process and pressure losses of 170% greater than for equivalent sand grain roughness under similar conditions after 2000 hours.

GEOTHERMAL ENGINEERING

DRILLING TECHNOLOGY AND WELL HARDWARE

Refer also to citation(s) 8, 16, 82

69 (DOE/ET/27026--T3) DRILL PIN FAILURE-

ANALYSIS REPORT. Anliker, D. (Radian Corp., Austin, TX (USA)). Jul 1980. Contract AC02-79ET27026. 15p. NTIS, PC A02/MF A01. Order Number DE82021809.

A cracked drill pin was received from ENEL's Sasso 22 geothermal well with a request for failure analysis. Failure reportedly occurred during temperature measurements inside the drill pipe. This drill pipe had been put into the 4000 meter (13124 ft.) hole for instrument protection about 80 hours before temperature measurements. The temperature measured at the bottom of the hole was 380°C (716°F). The liquid level was at 2000 meters (6562 feet) depth, and the temperature at that depth was 95°C (203°F). Information on the depth where failure of this pin occurred was not given. Numerous drill string failures of this type have been reported at depths greater than 3000 meters (9843 feet) by ENEL. A mixture of 70% river water and 30% condensate from a nearby

geothermal power plant was being used as drilling fluid. The average chemical composition of the power plant wastewater is given. This region of Italy is known as the Boraciferous Region. The average chemistry of the Boraciferous geothermal fluid is given. The failed drill pin was reportedly made of 38 NC B4 steel.

70 (DOE/ET/27146--T14) CHEMICAL DAMAGE DUE TO DRILLING OPERATIONS.

Vetter, D.J.; Kandarpa, V. (Vetter Research, Costa Mesa, CA (USA)). 14 Jul 1982. Contract AC03-78ET27146. 29p. NTIS, PC A03/MF A01. Order Number DE82021795.

The drilling of geothermal wells can result in near wellbore damage of both the injection wells and production wells if proper precautions are not taken. Very little specific information on the chemical causes for drilling damage that can directly be applied to the drilling of a geothermal well in a given situation is available in the literature. As part of the present work, the sparse literature references related to the chemical aspects of drilling damage are reviewed. The various sources of chemically induced drilling damages that are related to drilling operations are summarized. Various means of minimizing these chemical damages during and after the drilling of a geothermal well are suggested also.

71 (SAND--82-1668) INERTIAL NAVIGATION SYSTEM FOR DIRECTIONAL SURVEYING.

Kohler, S.M. (Sandia National Labs., Albuquerque, NM (USA)). Sep 1982. Contract AC04-76DP00789. 31p. NTIS, PC A03/MF A01. Order Number DE83000406.

A wellbore Inertial Navigation System (WINS) was developed and tested. Developed for directional surveying of geothermal, oil, and gas wells, the system uses gyros and accelerometers to obtain survey errors of less than 10 ft (approx. 3 m) in a 10,000-ft (approx. 300-m) well. The tool, which communicates with a computer at the surface, is 4 in. (approx. 10 cm) in diameter and 20 ft (approx. 6.1 m) long. The concept and hardware is based on a system developed by Sandia for flight vehicles.

72 (SAND--82-1954) WELLBORE INERTIAL NAVIGATION SYSTEM (WINS) SOFTWARE DEVELOPMENT AND TEST RESULTS.

Wardlaw, R. Jr. (Sandia National Labs., Albuquerque, NM (USA)). Sep 1982. Contract AC04-76DP00789. 74p. NTIS, PC A04/MF A01. Order Number DE83000405.

Portions of document are illegible.

The structure and operation of the real-time software developed for the Wellbore Inertial Navigation System (WINS) application are described. The procedure and results of a field test held in a 7000-ft well in the Nevada Test Site are discussed. Calibration and instrumentation error compensation are outlined, as are design improvement areas requiring further test and development. Notes on Kalman filtering and complete program listings of the real-time software are included in the Appendices. Reference is made to a companion document which describes the downhole instrumentation package.

FLUID TRANSMISSION

Refer also to citation(s) 67

CORROSION, SCALING, AND MATERIALS DEVELOPMENT

Refer also to citation(s) 53, 54

- 73 (BNL--31737) CATHODIC PROTECTION IN HIGHLY-AGGRESSIVE GEOTHERMAL ENVIRONMENTS. Bandy, R.; van Rooyen, D. (Brookhaven National Lab., Upton, NY (USA)). 1982. Contract AC02-76CH00016. 28p. (CONF-820506--6). NTIS, PC A03/MF A01. Order Number DE82021561.

From International conference on geothermal energy; Florence, Italy (11 May 1982).

Portions of document are illegible.

The feasibility of cathodic protection in highly aggressive geothermal environments has been investigated in the laboratory using both impressed current and sacrificial anode techniques. Artificial brines simulating the hypersaline geothermal brines of the Imperial Valley of California and the less aggressive geothermal fluids found in some other parts of the US were used as test environments. Impressed current tests on carbon steel were conducted under controlled potential, and cathodic protection of carbon steel using zinc sacrificial anodes was studied by monitoring the galvanic current and potential of the couple with a zero resistance ammeter. Weight loss measurements were conducted in all cases to determine the amount of protection achieved. Results show that the weight loss generally follows a semi-logarithmic relationship with the amount of potential shift away from the corrosion potential as a result of the impressed current; significant cathodic protection can be achieved by shifting the potential of the order of only 70 to 80 mV. Under certain controlled cathodic conditions, electrocrystallization has been observed on the carbon steel surface, resulting in a small weight gain. For the carbon steel-zinc couple, the potential gradually drifts towards that of the open circuit potential of zinc, resulting in excellent protection for the steel and a relatively tolerable corrosion rate for zinc.

- 74 (DOE/ET/27146--T13) SCALE FORMATION AT VARIOUS LOCATIONS IN A GEOTHERMAL OPERATION DUE TO INJECTION OF IMPORTED WATERS. Vetter, D.J.; Kandarpe, V. (Vetter Research, Costa Mesa, CA (USA)). 22 Jun 1982. Contract AC03-78ET27146. 96p. NTIS, PC A05/MF A01. Order Number DE82021796.

Portions of document are illegible.

The injection of waters that are not native to a geothermal formation generates various physical and chemical problems. The major chemical problem resulting from such injections is the formation of sulfate scales (particularly CaSO_4 , BaSO_4 and SrSO_4) at various locations starting from the injection well through the production well to the surface facilities of any geothermal operation. One of the ways to prevent this type of scale formation is by reducing the sulfate concentration of the injection waters. The effect of sulfate deionization on scale formation at various locations of the geothermal operations is studied. Some experimental results on the CaSO_4 scale formation in porous media upon heating an injection water with and without addition of scale inhibitors are also given.

- 75 (EGC--2213) EVALUATION OF MATERIALS FOR SYSTEMS USING COOLED, TREATED GEOTHERMAL OR HIGH-SALINE BRINES. Suciu, D.F.; Wikoff, P.M.

(Idaho National Engineering Lab., Idaho Falls (USA)). Sep 1982. Contract AC07-76ID01570. 55p. NTIS, PC A04/MF A01. Order Number DE83000653.

Lack of adequate quantities of clean surface water for use in wet (evaporative) cooling systems indicates the use of high-salinity waste waters, or cooled geothermal brines, for makeup purposes. High-chloride, aerated water represents an extremely corrosive environment. In order to determine metals suitable for use in such an environment, metal coupons were exposed to aerated, treated geothermal brine salted to a chloride concentration of 10,000 and 50,000 ppm (mg/L) for periods of up to 30 days. The exposed coupons were evaluated to determine the general, pitting, and crevice corrosion characteristics of the metals. The metals exhibiting corrosion resistance at 50,000 ppm chloride were then evaluated at 100,000 and 200,000 ppm chloride. Since these were screening tests to select materials for components to be used in a cooling system, with primary emphasis on condenser tubing, several materials were exposed for 4 to 10 months in pilot cooling tower test units with heat transfer for further corrosion evaluation. The results of the screening tests indicate that ferritic stainless steels (29-4-2 and SEA-CURE) exhibit excellent corrosion resistance at all levels of chloride concentration. Copper-nickel alloys (70/30 and Monel 400) exhibited excellent corrosion resistance in the high-saline water. The 70/30 copper-nickel alloy, which showed excellent resistance to general corrosion, exhibited mild pitting in the 30-day tests. This pitting was not apparent, however, after 6 months of exposure in the pilot cooling tower tests. The nickel-base alloys exhibited excellent corrosion resistance, but their high cost prevents their use unless no other material is found feasible. Other materials tested, although unsuitable for condenser tubing material, would be suitable as tube sheet material.

- 76 (SAND--82-7055) EFFECT OF MOLYBDENUM PLUS CHROMIUM ON THE CORROSION OF IRON-, NICKEL-, AND COBALT-BASE ALLOYS IN BASALTIC LAVA AND SIMULATED MAGMATIC GAS AT 1150°C. Ehrlich, S.A.; Douglass, D.L. (California Univ., Los Angeles (USA). School of Engineering and Applied Science). Jun 1982. Contract AC04-76DP00789. 79p. NTIS, PC A05/MF A01. Order Number DE82021127.

Portions of document are illegible.

The compatibility of several binary and ternary alloys in a magma environment was studied. Binary alloys containing molybdenum and ternary alloys containing chromium and molybdenum were exposed to basaltic lava at 1150°C for periods of 24 and 96 hours. A cover gas was used to produce oxygen and sulfur fugacities corresponding to those of the gases dissolved in basaltic melts. Three base metals were used. These included iron, nickel, and cobalt. The primary reactions in binary alloys were found to be sulfidation. Oxide scales with a spinel layer formed on ternary alloys. The synergistic effect of molybdenum and chromium additions in ternary alloys exhibited superior corrosion resistance to binary alloys which formed base-metal sulfides down grain-boundaries. Extensive analyses of the reaction products by scanning electron microscopy, X-ray energy dispersive analysis, electron microprobe analysis, and metallography are presented for each alloy. The products formed are discussed with reference to thermodynamic stability diagrams, and the reaction path concept is used to explain some of the corrosion.

- 77 A REACTION PRODUCT OF ARSENIC-CONTAINING INHIBITORS. Vetter, O.J.; Goldish, E. (Union Oil Co, CA). Society of Petroleum Engineers of A.I.M.E. (American Institute of Mining, Metallurgical and Petroleum Engineers), Paper; No. SPE-4358, 113-122(1973). (CONF-7305137--).

From SPE of AIME oilfield chemistry symposium; Denver, CO, USA (24 May 1973).

Arsenic-containing inhibitors can cause serious plugging if the formation contains H_2S . The arsenic sulfides formed in the formation will enter the well bore by sublimation and cause plugging of the hardware. The arsenic sulfides form a movable scale. The immediate reaction products between H_2S and arsenic are As_2S_3 (oripment) and As_4S_3 (relager). These sulfides can convert to As_4S_3 (dimorphite) which also sublimates and forms a movable scale. There are 2 different modifications of As_4S_3 --an alpha and a beta form, both having distinctively different crystal habits and X-ray diffraction pattern. Each modification can be converted into the other form of crystallization from either CS_2 or pyridine. Aqueous alkali polysulfide solutions are excellent solvents for the arsenic sulfides. However, the arsenic sulfide--alkali polysulfide mixtures are not very stable under some well conditions, and will precipitate metallic arsenic; and, therefore, should not be used in hot wells.

RESERVOIR STIMULATION AND EXTRACTION TECHNOLOGY

Refer also to citation(s) 82

- 78 (DOE/ET/27146--T12) CHEMICAL STIMULATION OF GEOTHERMAL INJECTION WELLS. Vetter, O.J.; Kandarpa, V. (Vetter Research, Costa Mesa, CA (USA)). 23 Jun 1982. Contract AC03-78ET27146. 34p. NTIS, PC A03/MF A01. Order Number DE82021794.

Various types of chemical stimulation methods have been considered. High pH fluids seem to be a logical choice for some wellbore and/or reservoir stimulations. However, forming of secondary deposits and creating of new reservoir damages due to chemical reactions between the rock material and these stimulation fluids make it advisable not to consider any of these high pH fluids in high temperature geothermal reservoirs. Fluids having a neutral pH can be successfully used in chemical stimulation methods only in a very few and rare instances. Low pH fluids, i.e. acids, have by far the best chance to be used for these chemical stimulation jobs. The major part of this report is concerned with acidizing techniques for geothermal injection wells. The acidizing techniques to be used for an experimental and the routine stimulation of injection wells are described. Some recent field experiences and the results of some laboratory work are described.

- 79 (SAND--81-0100) MAGMA ENERGY RESEARCH PROJECT, FY80 ANNUAL PROGRESS REPORT. Colp, J.L. (ed.). (Sandia National Labs., Albuquerque, NM (USA)). Apr 1982. Contract AC04-76DP00789. 109p. NTIS, PC A06/MF A01. Order Number DE82021128.

The technical feasibility of extracting energy from magma bodies is explored. Five aspects of the project are studied: resource location and definition; source tapping; magma characterization; magma/material compatibility; and energy extraction.

- 80 URACH GEOTHERMAL ANOMALY. Kull, U. Naturwissenschaftliche Rundschau ; 34: No. 1, 21-22(Jan 1981). (In German).

West Germany has several regions with geothermal anomalies. Of these the Urach region has the most simple structure, so that this region was selected for exploratory investigations and drills. In the Urach 3 drilling, a temperature of $142^\circ C$ was measured at a final depth of 3334 m. The temperature gradient is irregular. Attempts were made to establish a water circuit, but so far without success.

- 81 GEOTHERMAL ENERGY - EXTRACTING HEAT FROM HOT DRY ROCK MASSES. Nemat-Nasser, S. (Northwestern University, Evanston, Ill.). pp 285-297 of 16th midwestern mechanics conference. Manhattan, KS; Kansas State Univ. (1979).

From 16. midwestern mechanics conference; Manhattan, KS, USA (19 Sep 1979).

In this lecture the exploitation of geothermal energy for commercial use is briefly examined. Attention is focused on the extraction of heat from hot dry rock masses, a concept which has recently been developed and implemented at the Los Alamos Scientific Laboratory, New Mexico. Recent work by the author and his associates on the thermomechanics of fluid flow and heat transfer, and thermally induced tension cracks in rocks, is summarized. Particular attention is paid to the theory of stability of a system of interacting tension cracks, and its application to other fields. New results in this area by the author and coworkers are briefly summarized.

DIRECT ENERGY UTILIZATION

- 82 (DOE/ET/28424--6) DIRECT UTILIZATION OF GEOTHERMAL ENERGY RESOURCES IN FOOD PROCESSING. FINAL REPORT, MAY 17, 1978-MAY 31, 1982. Austin, J.C. (Ore Ida Foods, Inc., Boise, ID (USA)); CH2M Hill, Boise, ID (USA)). May 1982. Contract AC07-78ET28424. 138p. NTIS, PC A07/MF A01. Order Number DE82019753.

Portions of document are illegible.

In early 1978 financial assistance was granted for a project to utilize geothermal energy at Ore-Ida Foods, Inc.'s food processing plant in Ontario, Oregon. Specifically, the project included exploring, testing, and developing the potential geothermal resource; retrofitting the existing gas/oil-fired steam system; utilizing the geothermal resource for food processing, space heating, and hot potable water; and injecting the spent geothermal water back into a disposal well. Based on preliminary investigations which indicated the presence of a local geothermal resource, drilling began in August 1979. Although the anticipated resource temperature of $380^\circ F$ was reached at total well depth (10,054 feet), adequate flow to meet processing requirements could not be obtained. Subsequent well testing and stimulation techniques also failed to produce the necessary flow, and the project was eventually abandoned. However, throughout the duration of the project, all activities were carefully monitored and recorded to ensure the program's value for future evaluation. This report presents a culmination of data collected during the Ore-Ida project.

- 83 (PNL--4422-Vol.1) USER MANUAL FOR GEOCITY: A COMPUTER MODEL FOR COST ANALYSIS OF GEOTHERMAL DISTRICT-HEATING-AND-COOLING

SYSTEMS. VOLUME I. MAIN TEXT. Huber, H.D.; Fassbender, L.L.; Blomster, C.H. (Pacific Northwest Lab., Richland, WA (USA)). Sep 1982. Contract AC06-76RL01830. 223p. NTIS, PC A10/MF A01. Order Number DE82022512.

The purpose of this model is to calculate the costs of residential space heating, space cooling, and sanitary water heating or process heating (cooling) using geothermal energy from a hydrothermal reservoir. The model can calculate geothermal heating and cooling costs for residential developments, a multi-district city, or a point demand such as an industrial factory or commercial building. GEOCITY simulates the complete geothermal heating and cooling system, which consists of two principal parts: the reservoir and fluid transmission system and the distribution system. The reservoir and fluid transmission submodel calculates the life-cycle cost of thermal energy supplied to the distribution system by simulating the technical design and cash flows for the exploration, development, and operation of the reservoir and fluid transmission system. The distribution system submodel calculates the life-cycle cost of heat (chill) delivered by the distribution system to the end-users by simulating the technical design and cash flows for the construction and operation of the distribution system. Geothermal space heating is assumed to be provided by circulating hot water through radiators, convectors, fan-coil units, or other in-house heating systems. Geothermal process heating is provided by directly using the hot water or by circulating it through a process heat exchanger. Geothermal space or process cooling is simulated by circulating hot water through lithium bromide/water absorption chillers located at each building. Retrofit costs for both heating and cooling applications can be input by the user. The life-cycle cost of thermal energy from the reservoir and fluid transmission system to the distribution system and the life-cycle cost of heat (chill) to the end-users are calculated using discounted cash flow analysis.

- 84 (PNL--4422-Vol.2) USER MANUAL FOR GEOCITY: A COMPUTER MODEL FOR COST ANALYSIS OF GEOTHERMAL DISTRICT-HEATING-AND-COOLING SYSTEMS. VOLUME II. APPENDICES. Huber, H.D.; Fassbender, L.L.; Bloomster, C.H. (Pacific Northwest Lab., Richland, WA (USA)). Sep 1982. Contract AC06-76RL01830. 186p. NTIS, PC A09/MF A01. Order Number DE82022511. Portions of document are illegible.

The purpose of this model is to calculate the costs of residential space heating, space cooling, and sanitary water heating or process heating (cooling) using geothermal energy from a hydrothermal reservoir. The model can calculate geothermal heating and cooling costs for residential developments, a multi-district city, or a point demand such as an industrial factory or commercial building. Volume II contains all the appendices, including cost equations and models for the reservoir and fluid transmission system and the distribution system, descriptions of predefined residential district types for the distribution system, key equations for the cooling degree hour methodology, and a listing of the sample case output. Both volumes include the complete table of contents and lists of figures and tables. In addition, both volumes include the indices for the input parameters and subroutines defined in the user manual.

GEOTHERMAL DATA AND THEORY

Refer also to citation(s) 81

- 85 THERMAL CONDITIONS AND RADIOACTIVITY OF THE EARTH. Smyslov, A.A.; Moiseenko, U.I.; Chadovich, I.Z. Leningrad, USSR; Izdatel'stvo Nedra (1979). 192p. (In Russian).

The monograph describes thermal properties and radioactivity of minerals, rocks, structural formations, the lithosphere mantle, and of the earth as a whole. These data are used for evaluating the generation and transfer of heat by various lithosphere components, for determining bathymetric temperatures, and for defining regions of heat accumulation and dispersion. Current data on geothermal conditions of the principal structures of the earth's core and a comparative analysis of the thermal state and the radioactivity of various units of the lithosphere were applied to an interpretation of the energy conditions of geological processes. Finally, the examination and classification of the geothermal conditions made it possible to determine the positions of geothermal deposits in the earth's structure.

PROPERTIES OF AQUEOUS SOLUTIONS

- 86 NATURAL CONVECTION IN POROUS MEDIA AND GEOTHERMAL SYSTEMS. Combarous, M. (Bordeaux I, Universite, Talence, Gironde, France). pp 45-59 of International heat transfer conference, 6th, Toronto, Canada, August 7-11, 1978, general papers. Volume 6 - keynote papers. Washington, DC: Hemisphere Publishing Corp. (1978).

From 6. heat transfer conference; Toronto, Canada (7 Aug 1978).

Experimental and theoretical results concerning the natural and mixed convection in homogeneous and isotropic porous layers saturated with fluid are presented. A description of a sophisticated model used in the analysis of the physical observations on heat transfer is given. Attention is also given to the case where the porous medium is not isotropic. The role of convection in geothermal fields for the case of the usual steam field is discussed considering the overall heat fluxes, temperature distribution, and energy balance. Complimentary information on the influence of free convection in aquifers in natural or artificial situations is given and some aspects of mathematical modeling of real heterogeneous systems are discussed.

PROPERTIES OF MINERALS AND ROCKS

- 87 HEAT CAPACITIES AND ENTROPIES OF Mg_2SiO_4 , Mn_2SiO_4 , AND Co_2SiO_4 BETWEEN 5 AND 380 K. Robie, R.A. (U.S. Geological Survey, Reston, VA); Hemingway, B.S.; Takei, H. American Mineralogist; 67: No. 5-6, 470-482 (May 1982).

The heat capacities of synthetic single crystals of Mg_2SiO_4 (foresterite), Mn_2SiO_4 (tephroite), and Co_2SiO_4 (cobalt olivine), were measured between 5 and 380 K using an adiabatically shielded calorimeter. Mg_2SiO_4 is diamagnetic, and its heat capacity follows a normal sigmoidal curve at low temperatures. Co_2SiO_4 shows a single sharp lambda-type transition at 49.85 ± 0.02 K associated with the antiferromagnetic ordering of the magnetic moments of the Co^{2+} ions into a collinear spin arrangement below 49.8 K. In contrast to Co_2SiO_4 , Mn_2SiO_4 has two transitions in C/sup o//sub p/, a sharp lambda-type transition at 47.38 ± 0.05 K and a smaller "shoulder" in C/sup o//sub p/ centered near 12 K. The upper transition corresponds to the paramagnetic

- (disordered) to collinear antiferromagnetic ordering of the Mn^{2+} moments, whereas the shoulder near 12 K corresponds to the change from the collinear to a canted spin structure. Our calorimetric values for the antiferromagnetic-paramagnetic transition temperature (Neel Temperature) are in excellent agreement with those obtained by powder magnetic susceptibility measurements, 49 ± 2 K and 50 ± 5 K for Co_2SiO_4 and Mn_2SiO_4 respectively. The thermal Debye temperature, $\Theta_{D}/sup C//sub D/$, of Mg_2SiO_4 calculated from our $C//sup o//sub p/$ measurements between 6.3 and 13.8 K is 768 ± 15 K and agrees well with the elastic value $\Theta_{D}/sup E//sub D/$ of 758 K based on the mean sound velocity calculated from the room temperature elastic stiffness constants ($c//sub ij/$) of Graham and Barsch. At 298.15 K (25°C) the molar heat capacities are 118.6, 128.7, and 133.4 J/(mol . K) and the molar entropies are 94.11 ± 0.10 , 155.9 ± 0.4 and 142.6 ± 0.2 J/(mol . K) respectively for Mg_2SiO_4 , Mn_2SiO_4 , and Co_2SiO_4 .
- 88 HEAT CAPACITY AND ENTROPY OF FAYALITE (Fe_2SiO_4) BETWEEN 5.1 AND 383 K: COMPARISON OF CALORIMETRIC AND EQUILIBRIUM VALUES FOR THE QFM BUFFER REACTION. Robie, R.A. (U.S. Geological Survey, Reston, VA); Finch, C.B.; Hemingway, B.S. American Mineralogist; 67: No. 5-6, 463-469 (May 1982).
- The heat capacities of large synthetic crystals of fayalite (Fe_2SiO_4) grown by the Czochralski technique were measured between 5.1 and 381.5 K. The heat capacity exhibits an extremely sharp lambda-transition at 64.88 ± 0.03 K corresponding to the paramagnetic-antiferromagnetic inversion, and a smaller hump centered near 16 K, corresponding to a spin structure change from a collinear to canted antiferromagnetic arrangement. At 298.15 K, $C//sup o//sub p/$ and $S//sup o/$ for fayalite are respectively 131.9 ± 0.1 and 151.0 ± 0.2 J/(mol . K). From a third law analysis of six sets of high-temperature reactions involving fayalite, we obtained $\Delta H//sup o//sub f,298 = 1478.17 \pm 1.30$ and $\Delta G//sup o//sub f,298 = -1378.98 \pm 1.35$ kJ/mol. Using these new data for Fe_2SiO_4 , we calculated the temperature dependence of the equilibrium constant for the reaction $2Fe_3O_4 + 3SiO_2 = 3Fe_2SiO_4 + O_2$; i.e., the quartz-fayalite-magnetite buffer reaction. Our values for $\Delta G//sup o//sub f,T/$ are within 0.70 kJ of those obtained from Hewitt's equation.
- 89 THERMODYNAMICS OF PLAGIOCLASE-MELT EQUILIBRIA IN THE SYSTEM ALBITE-ANORTHITE-DIOPSIDE. Henry, D.J.; Navrotsky, A.; Zimmerman, H.D. (Arizona State Univ., Tempe). Geochimica et Cosmochimica Acta; 46: No. 3, 381-391 (Mar 1982).
- An analysis of thermochemical and phase equilibrium data for high plagioclase solid solutions, glasses, and liquids in the system albite-anorthite-diopside produces an internally consistent model of mixing properties of crystals and melts. The mixing behavior of high temperature plagioclases is described adequately by positive heats of mixing and the aluminum-avoidance entropy model. This model predicts plagioclase exsolution with compositions in the region of Boggild and Huttenlocher intergrowths but provides no evidence for the peristerite gap. Liquids in the region of the plagioclase saturation surface of the system albite-anorthite-diopside are shown to have entropies of mixing significantly less positive than predicted by the "two-lattice" model, which appeared adequate for the pyroxene saturation surface of that system. Along the albite-anorthite binary these deviations are not consistent with aluminum avoidance in the liquid, but can be described by an empirical "regular" excess entropy term which allows a satisfactory calculation of the albite-anorthite binary liquidus loop. The magnitude of this negative excess entropy term can be explained by the assumption of strong Ca-Al charge balance (without restriction of Al-O-Al contacts) which leads to a vanishingly small entropy arising from Na-Ca mixing.
- 90 LABORATORY ELECTRICAL CONDUCTIVITY MEASUREMENTS ON MANTLE RELEVANT MINERALS. Hinze, E. (Mineralogisch-Petrologisches Institut der Universität Bonn, West Germany). Geophysical Surveys; 4: No. 4, 337-352 (Feb 1982).
- The past 20 yrs have documented an increasingly growing interest in the application of electrical properties of rocks in earth science, i.e. in induced polarization, resistivity and electromagnetic methods of mineral and geothermal energy exploration. The influence of environmental conditions and the thermodynamic parameters which may determine the bulk electrical conductivity of, for instance, basaltic rocks are briefly discussed. At present it is not known to what extent these numerous variables determine the electrical conductivity of rocks quantitatively, since all too many laboratory measurements did not account for the required number of variables to define the system. Thus it is difficult to decide whether or not laboratory measurements on rocks have duplicated their in-situ electrical conductivity. One approach is to calculate the bulk conductivity of rocks from conductivities of the constituent minerals, since it is much easier to define the thermodynamic equilibrium conditions for a single phase system. Therefore, laboratory data of the electrical conductivity of minerals, i.e. olivines and pyroxenes, are discussed to some extent particularly in the context of point-defect concentrations as a function of pO_2 and the chemical activities $a//sub i/$ of the binary components of the minerals. The evaluation of a quantitative relationship requires a careful sample characterization. To find a basis for a reasonable interpretation of in-situ resistivity data, the test samples should be selected in regard to those conditions which are believed to exist in the appropriate layer of the earth.
- 91 EFFECT OF CO_2 PRESSURE ON THE RATE OF DECOMPOSITION OF CALCITE. Darroudi, T.; Searcy, A.W. (Lawrence Berkeley Lab., Berkeley, CA). Journal of Physical Chemistry; 85: No. 26, 3971-3974 (24 Dec 1981). Contract W-7405-ENG-48.
- Rates of CO_2 escape from (1011) cleavage surfaces of calcite ($CaCO_3$) single crystals were measured at temperatures from 893 to 1073 K and at CO_2 background pressures, $P//sub CO_2/$, from $<P//sub L/ = 10^{-5}P//sub eq/$ to $4 \times 10^{-2}P//sub eq/$, where $P//sub eq/$ is the equilibrium decomposition pressure and $P//sub L/$ is the CO_2 pressure that produces a flux equal to the flux from a calcite crystal under vacuum. Rates are relatively sensitive to $P//sub CO_2/$ when $P//sub CO_2/ > 10^{-2}P//sub eq/$, but do not obey the parabolic rate law deduced by earlier investigators from data in a limited pressure range. For $P//sub L/ < P//sub CO_2/ < 10^{-2}P//sub eq/$, the decomposition rates are essentially independent of $P//sub CO_2/$, which implies that in this range the apparent activation enthalpy and entropy are unchanged from those measured under vacuum, $\Delta H^* = 209 \pm 12$ kJ (50 ± 3

kcal) and $\Delta S^\circ = 84 \pm 12$ J/deg (20 ± 3 cal/deg). The rate-limiting process in this pressure range is probably condensed-phase diffusion of CO_2 or a surface step for CO_2 prior to desorption.

ROCK-WATER-GAS INTERACTIONS

Refer also to citation(s) 30

- 92 HYDROTHERMAL ALTERATION OF BASALT BY SEAWATER UNDER SEAWATER-DOMINATED CONDITIONS. Seyfried, W.E. Jr. (Univ. of Minnesota, Minneapolis); Mottl, M.J. *Geochimica et Cosmochimica Acta*; 46: No. 6, 985-1002 (Jun 1982).

Fresh mid-ocean ridge basalt glass and diabase have been reacted with seawater at 150-300°C, 500 bar, and water/rock mass ratios of 50, 62, and 125, using experimental apparatus which allowed on-line sampling of solution to monitor reaction progress. These experiments characterize reaction under what we have called "seawater-dominated" conditions of hydrothermal alteration. In an experiment at 300°C, basalt glass undergoing alteration removed nearly all Mg^{2+} from an amount of seawater 50 times its own mass. In the process, the glass was converted entirely to mixed-layer smectite-chlorite, anhydrite, and minor hematite. Removal of Mg from seawater occurred as a $\text{Mg}(\text{OH})_2$ component incorporated into the secondary clay. This produced a precipitous drop in solution pH early in the experiment, accompanied by a dramatic increase in the concentrations of Fe, Mn, and Zn in solution. As Mg removal neared completion and the glass was hydrolyzed, pH rose again and heavy metal concentrations dropped. At water/rock ratios of 62 and 125 and 150-300°C, the mineral assemblage produced was similar to that at a water/rock ratio of 50. Solution chemistry, however, contrasted with the earlier experiment in that Mg concentrations in solution were greater and pH lower. This caused significant leaching of heavy metals. At 300°C nearly all of the Na, Ca, Cu, Zn, and CO_2 and most of the K, Ba, Sr, and Mn were leached from the silicates. H_2S , Al, Si, and possibly Co were also significantly mobilized, whereas V, Cr, and Ni were not. Little or no seawater sulfate was reduced.

- 93 THE SYSTEM ALBITE- H_2O - CO_2 : A MODEL FOR MELTING AND ACTIVITIES OF WATER AT HIGH PRESSURES. Bohlen, S.R. (Univ. of California, Los Angeles); Boettcher, A.L.; Wall, V.J. *American Mineralogist*; 67: No. 5-6, 451-462 (May 1982).

The melting of albite in the presence of H_2O - CO_2 vapor has been determined in piston-cylinder apparatus from 5 to 25 kbar for mole fractions of H_2O in the vapor ($X_{\text{H}_2\text{O}}^{\text{vapor}}$) from 1.0 to 0.0. Albite in the presence of CO_2 -rich vapor melts as much as 150-300°C lower than indicated by previous theoretical and experimental studies. The albite- CO_2 melting curve is indistinguishable from the vapor-absent melting curve up to 15 kbar, but it is significantly lower above 15 kbar as a result of a substantial increase in the solubility of CO_2 in the liquid. Calculated activity coefficients (γ) for water in H_2O - CO_2 vapor in the range 700-1000°C, 5-15 kbar are everywhere greater than unity and increase isothermally and isothermally toward CO_2 -rich compositions. For $X_{\text{H}_2\text{O}}^{\text{vapor}} < 0.3$ calculated $\gamma_{\text{H}_2\text{O}}^{\text{vapor}}$ are significantly greater than those predicted

by the modified Redlich-Kwong equation.

- 94 CALCULATION OF MULTICOMPONENT CHEMICAL EQUILIBRIA AND REACTION PROCESSES IN SYSTEMS INVOLVING MINERALS, GASES AND AN AQUEOUS PHASE. Reed, M.H. (Univ. of Oregon, Eugene). *Geochimica et Cosmochimica Acta*; 46: No. 4, 513-528 (Apr 1982).

The compositional characteristics of many geochemical systems which involve the interaction of natural aqueous solutions with minerals and gases are conveniently described using the following thermodynamic components: Cl^- , $\text{SO}_4^{\text{sup}} = /$, HS^- , $\text{CO}_3^{\text{sup}} = /$, H^+ , Na^+ , K^+ , Ca^{++} , Mg^{++} , Fe^{++} , Zn^{++} , Cu^+ , Al^{+++} , SiO_2 and H_2O . A set of mass balance and mass action equations equal in number to the number of components plus the number of saturated minerals (and gases) is defined for a specified temperature, pressure and bulk composition. The mass balance equations include terms for minerals, gases and the molalities of aqueous complexes and dissociated species. This set of non-linear equations can be solved with the aid of a computer using a Newton-Raphson technique. The calculation takes account of aqueous ion complexing, oxidation-reduction equilibria, activity coefficients, non-unit water activity and solid solutions. The use of H^+ , $\text{SO}_4^{\text{sup}} = /$, HS^- and H_2O as components allows straightforward treatment of processes involving oxidation-reduction, evaporation, boiling and changes of total aqueous H^+ due to hydrolysis, mineral reaction or temperature change. One product of this approach is a technique for calculating pH at high temperature from measurement of pH at room temperature. By linking a series of discrete overall heterogeneous equilibrium calculations in which incremental changes of bulk composition, temperature or pressure are made, dynamic geochemical processes can be modeled. Example calculations for two such processes are given. These are the heating of seawater from 25° to 300°C and the isothermal irreversible reaction of rhyolite with an aqueous solution at 250°C.

- 95 THERMODYNAMIC PROPERTIES OF THE SOLUTIONS (NA, K)Cl- H_2O BETWEEN 400 AND 800 DEGREES C, 1-2 KB: A REVIEW OF THE EXCHANGE EQUILIBRIUM WITH THE SODIUM - POTASSIUM SILICATES. Pascal, M.L.; Roux, J. (*CRSCM, Orleans, France*). *Geochimica et Cosmochimica Acta*; 46: No. 3, 331-337 (Mar 1982).

Several independent determinations of the difference in Gibbs free energy of formation (from the elements at 25°, 1 bar) between NaCl° and KCl° in aqueous solutions (molality > 0.5) are derived from equilibrium data between alkali feldspars, feldspathoids (nepheline-kalsilite), micas (muscovite-paragonite) and hydrothermal (Na, K)Cl- H_2O solutions. These results along with other data from the literature are discussed. The relation: ΔG°_f , $\text{KCl}^\circ - \Delta G^\circ_f$, NaCl° (J) = $-16,500(+/-2,500) - 18(+/-4) \text{ T(K)}$ is proposed from 400 to 800°C and 1 to 2 kbar.

- 96 HIGH PRESSURE DIFFERENTIAL ANALYSIS IN THE SYSTEM CaO - CO_2 - H_2O . van Kester Groos, A.F. (Univ. of Illinois, Chicago). *American Mineralogist*; 67: No. 3-4, 234-237 (Mar 1982).

In the system CaO - CO_2 - H_2O the reaction $\text{CaCO}_3 + \text{Ca}(\text{OH})_2 = \text{L}$ occurs at $632 \pm 2^\circ\text{C}$ at 1 kbar and at $639 \pm 5^\circ\text{C}$ at 9 kbar. These temperatures, which are calibrated against the high-low quartz transition, are 20°C lower than previously reported. The presence of 0.5 wt.% H_2O lowers the reaction temperature about 8°C . In the presence of excess H_2O the reaction

$\text{CaCO}_3 + \text{Ca}(\text{OH})_2 + \text{V} = \text{L}$ takes place at $614 \pm 2^\circ\text{C}$ at 1 kbar and at $575 \pm 5^\circ\text{C}$ at 9 kbar. The enthalpy of reaction is estimated at 38 ± 8 kJ/mole. These data are useful for temperature calibrations of high pressure apparatus.

- 97 AMORPHOUS SILICA SOLUBILITIES IV. BEHAVIOR IN PURE WATER AND AQUEOUS SODIUM CHLORIDE, SODIUM SULFATE, MAGNESIUM CHLORIDE, AND MAGNESIUM SULFATE SOLUTIONS UP TO 350°C . Chen, C.T.A.; Marshall, W.L. (Oak Ridge National Lab., TN). *Geochimica et Cosmochimica Acta* ; 46: No. 2, 279-287 (Feb 1982).

Solubilities of amorphous silica were determined in separate aqueous solutions of sodium chloride, sodium sulfate, magnesium chloride, and magnesium sulfate at temperatures up to 350°C . These salts, of strong interest in hydrothermal oceanography and geothermal energy, generally ranged in concentration from zero to saturation. Solubilities in the sodium chloride solutions followed closely earlier observed decreases in sodium nitrate solutions at high temperatures. Amorphous silica solubilities were depressed most by magnesium chloride, followed by magnesium sulfate, and less by sodium chloride. As the temperature rose the relative decrease in solubility caused by added salt became smaller. Surprisingly, sodium sulfate solutions, showing little effect at 25°C , sharply raised the solubility as the temperature increased to 350°C . Plots of the logarithms of derived activity coefficients against molalities of added salt gave approximately straight lines. These plots allow simple predictions of amorphous silica solubility in single salt solutions.

- 98 AMORPHOUS SILICA SOLUBILITIES V. PREDICTIONS OF SOLUBILITY BEHAVIOR IN AQUEOUS MIXED ELECTROLYTE SOLUTIONS TO 300°C . Marshall, W.L.; Chen, C.T.A. (Oak Ridge National Lab., TN). *Geochimica et Cosmochimica Acta* ; 46: No. 2, 289-291 (Feb 1982).

Solubilities of amorphous silica in several aqueous electrolyte solutions up to 300°C fit the Setchenow equation, $\log (s^0/s) = D \times m$, where s^0 and s are molal solubilities of silica in pure water and salt solution, respectively, m is the molality of salt, and D is a proportionality constant related to the particular salt and temperature. It is now shown that, to a first approximation, the D parameters for various salts at the same temperature are additive. For instance, $D(\text{NaCl}) - D(\text{KCl}) = D(\text{NaNO}_3) - D(\text{KNO}_3)$ or $D(\text{MgSO}_4) = D(\text{MgCl}_2) + D(\text{Na}_2\text{SO}_4) - 2D(\text{NaCl})$. It also follows that $\log (s^0/s) = \sum (\text{sub } i / (D/\text{sub } i / m/\text{sub } i))$. This additivity principle was used to estimate amorphous silica solubilities in mixed $\text{NaCl}-\text{Na}_2\text{SO}_4$, $\text{NaCl}-\text{MgCl}_2$, $\text{NaCl}-\text{MgSO}_4$, $\text{Na}_2\text{SO}_4-\text{MgCl}_2$, $\text{Na}_2\text{SO}_4-\text{MgSO}_4$, and $\text{MgCl}_2-\text{MgSO}_4$ aqueous solutions up to 300°C . The method produces results that agree reasonably well with experimental values and would be useful for predicting silica solubilities, for example, in seawater and its hydrothermal concentrates and in geothermal energy applications.

- 99 SOLUTION MINING METHOD OF SOLUBLE MINERALS OR MINERAL COMPOUNDS FROM DEFINED SUBTERRANEAN MULTIPLE DEPOSITS. Werner, H.H. Canadian Patent 838,477. 7 Apr 1970. Filed date 19 Jul 1968. vp.

By means of hydraulic injection into boreholes, a suitable solvent is laterally distributed along a fractured plane at the base

of a mineral-bearing stratum. The lateral distribution pattern of the solvent is observed and controlled by boreholes. This procedure is repeated until communication is established between the boreholes in the designated area for the creation of an artificial brine field for one stratum or a multiple of strata. The injection of refinery effluent plus a suitable amount of fresh process solvent allows maintaining an appropriate hydraulic flow pressure while the portion equivalent to the fresh process solvent for the refinery consumption is withdrawn. Because the ratio of the retained brine field volume vs. withdrawn saturated solution grows with every cycle, the brinefield fluid attains the prevailing geothermic temperature. Flow conditions can be altered throughout the field to establish a planned dissolution pattern. (39 claims)

- 100 IN SITU LEACHING METHOD. (to Mobil Oil Corp.). Australian Patent 293,942. 25 Sep 1969. Priority date 22 Apr 1965, United States of America (USA), vp.

An in situ leaching process for recovering metallic ions from subsurface mineral deposits (which are capable of combining with ammonia to form metal-ammonia complex ions that are soluble in water) is described. It consists of the following steps: (1) flooding the deposit with water until it is water-wet; (2) displacing at least a portion of the water from the deposit with injected air to increase the permeability to gas of the water-wetted deposit; (3) passing gaseous ammonia into the water-wetted deposit whereby metallic ions capable of combining with ammonia to form complex ions are made soluble in water; and (4) recovering the resulting metal-ammonia complex ions from the deposit by displacement with a waterflood containing sufficient ammonia to preserve the complex ions in solution in such waterflood.

ISOTOPE AND TRACE ELEMENT STUDIES

Refer also to citation(s) 27

- 101 HELIUM ISOTOPES IN GEOTHERMAL SYSTEMS: ICELAND, THE GEYSERS, RAFT RIVER AND STEAMBOAT SPRINGS. Torgersen, T. (Australian National Univ., Canberra); Jenkins, W.J. *Geochimica et Cosmochimica Acta* ; 46: No. 5, 739-748 (May 1982).

Helium isotope ratios have been measured in geothermal fluids from Iceland, The Geysers, Raft River, Steamboat Springs and Hawaii. These ratios have been interpreted in terms of the processes which supply He in distinct isotopic ratios (i.e., magmatic He, approx. 10 R/sub z/; atmospheric He, R/sub a/; and crustal He, -0.1 R/sub a/) and in terms of the processes which can alter the isotopic ratio (Hydrologic mixing, U-Th series alpha production and weathering release of crustal He, magma aging and tritogenic addition of ^3He). Using this interpretational scheme, Iceland is found to be an area of hot-spot magmatic He implying an active volcanic source although the data are suggestive of high-temperature weathering release of crustal He incorporated in the geothermal fluids. By comparison to fumarolic gases from Hawaii and Juan De Fuca and Cayman Trench basaltic glass samples, The Geysers contains MOR type magmatic He again implying an active volcanic source possible a "leaky" transform related to the San Andreas Fault System. Raft River contains only crustal He indicating no active volcanic sources. Steamboat Springs He isotope ratios

are distinctly less than typical plate margin volcanics but must still have a magmatic source. A preliminary assessment of the case for this low ratio is made assuming an "aging" magma source.

102 CARBON-13 EXCHANGE BETWEEN CO_2 AND CH_4 UNDER GEOTHERMAL CONDITIONS. Giggensch, W. F. (International Atomic Energy Agency, Vienna, Austria). *Geochimica et Cosmochimica Acta*; 46: No. 2, 159-165 (Feb 1982).

On the basis of recently reported data on the kinetics of carbon-13 exchange between CO_2 and CH_4 at temperatures above 500°C , first order rate constants $\log k = 11.16 - 10,190/T$

were derived allowing variations in Δ , the difference in the isotopic composition of coexisting CO_2 and CH_4 , to be evaluated as a function of initial composition and cooling rate of the rising geothermal fluid. Observed Δ -values in geothermal discharges are likely to represent frozen in compositions attained after minimum residence times of 20 ka at 400°C or 10 Ma at 300°C . The carbon-13 contents of any biogenic gases are unlikely to have been affected by thermal re-equilibrium at temperatures below 200°C . The chemical equilibrium involving CO_2 and CH_4 can be expected to proceed about a hundred times faster than isotopic equilibration.