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Geothermal Energy

RESOURCE STATUS AND ASSESSMENT

1
(ETDE/JP-mf–96713460)
Fiscal 1992 geothermal development promotion survey. Report on the demonstration test on small- and medium scale geothermal binary power generation systems. New Energy and Industrial Technology Development Organization, Tokyo (Japan). Mar 1994. 615p. (In Japanese). Order Number DE96713460. Source: OSTI; NTIS; Available from New Energy and Industrial Technology Development Organization, Sunshine 60, 30F 1-1, 3-chome, Higashi-Ikebukuro, Toshima-ku, Tokyo, Japan.

An investigational study was conducted to practically apply small- and medium-scale geothermal binary power generation systems which make an effective use of low- and medium-temperature geothermal resources. When synthesizing the fiscal 1992 results and the results of the conventional surveys, the amount of the usable resource from 63 geothermal wells of 100-500 kW scale is 12597 kW in total output nationwide, which equal to 32.1% of the total resource amount. Wells of over 500 kW scale are 12 in number and generate output of 11251 kW, which are 28.9% of the total resource amount. Geothermal water exhausted from the 100 kW power generation is 125 tons/h, and 76°C in temperature, which equal to 8.3 Gcal/h in total heat quantity. It can fully respond to various demand from remote islands, resorts, etc. For an effective use of geothermal water containing energy, the isopentane binary method is more suitable than the flash steam power generation method. From a study on economical efficiency under constant preconditions, obtained is a durable year average sending-end power generation cost of 25.71 yen/kWh. Personnel cost occupies more than 50% of the cost. An investigational study was also made on the development of a system which can be introduced as a practical system of the demonstration test for the development of small- and medium-scale geothermal binary power generation. 19 figs., 28 tabs.

GEOLOGY AND HYDROLOGY OF GEOTHERMAL SYSTEMS

2
(ETDE/JP-mf–96713454)
Report on fiscal 1992 geothermal development promotion survey data processing. No.38 Mt. Aso west area (secondary). New Energy and Industrial Technology Development Organization, Tokyo (Japan). Mar 1994. 1361p. (In Japanese). Sponsored by New Energy and Industrial Technology Development Organization, Tokyo (Japan). Order Number DE96713454. Source: OSTI; NTIS; Available from New Energy and Industrial Technology Development Organization, Sunshine 60, 30F 1-1, 3-chome, Higashi-Ikebukuro, Toshima-ku, Tokyo, Japan.

Results of the fiscal 1992 survey of the status of geothermal resource existing in the Mt. Aso west area were comprehensively discussed and analyzed. The surface soil in the west area consists of pre-Aso volcanic rocks of the middle of the Pleistocene Epoch, and volcanic products from Mt. Aso which was active during the middle of the Pleistocene Epoch through the Holocene Epoch. The basement rocks outside the caldera are strata alteration of sand stone and mud stone. In the case of the west area of Mt. Aso, it is necessary to think that formation of geothermal manifestation seen in Yunotani and Tarutama does not relate to activity of new-period central crater knolls, but relates to heat sources located in the shallow area. The alteration zone is classified into silicification, kaolinite, smectite, halloysite, and non-alteration zones. In the Yunotani area, meteoric water which permeated underground from the central crater knolls is heated by volcanic heat sources to be neutral-alkalescent deep geothermal water, which forms deep geothermal reservoirs at approximately 220-290°C. Steam and gas derived from deep geothermal reservoirs rise along the fracture and form steam-dominant reservoirs. 133 refs., 345 figs., 293 tabs.

3
(LA-UR–95-3408)
Using seismic tomography to characterize fracture systems induced by hydraulic fracturing. Fehler, M.; Rutledge, J. Los Alamos National Lab., NM (United States). [1995]. 8p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-36. (CONF-9511148–1: SEGJ/SEG international symposium on geotomography, Tokyo (Japan), 8-10 Nov 1995). Order Number DE96002461. Source: OSTI; NTIS; GPO Dep.

Microearthquakes induced by hydraulic fracturing have been studied by many investigators to characterize fracture systems created by the fracturing process and to better understand the locations of energy resources in the earth's subsurface. The pattern of the locations often contains a great deal of information about the fracture system stimulated during the hydraulic fracturing. Seismic tomography has found applications in many areas for characterizing the subsurface of the earth. It is well known that fractures in rock influence both the P and S velocities of the rock. The influence of the fractures is a function of the geometry of the fractures, the apertures and number of fractures, and the presence of fluids in the fractures. In addition, the temporal evolution of the created fracture system can be inferred from the temporal changes in seismic velocity and the pattern of microearthquake locations. Seismic tomography has been used to infer the spatial location of a fracture system in a reservoir that was created by hydraulic fracturing.

4
(PB–95-272332/XAB)
Effects of well discharges on hydraulic heads in and spring discharges from the geothermal aquifer system

in the Bruneau Area, Owyhee County, Southwestern Idaho. Water resources investigation. Berenbrock, C. Geological Survey, Boise, ID (United States). Water Resources Div. 1993. 65p. (USGS/WRIR–93-4001). Source: NTIS Prices: PC A04/MF A01.

Demand for ground water in the 600-square-mile Bruneau study area has also increased since 1954 because of the agricultural development. Declining flow at Indian Bathtub spring is adversely affecting a unique species of snail that inhabits the spring. The purpose of the third phase of the study, described in this report is to determine the cause or causes of declining flow at Indian Bathtub Spring. The third phase, completed in 1992, included (1) evaluating all available information about the regional geothermal aquifer system; (2) describing the geohydrology of the Bruneau study area, including ground-water recharge, discharge, movement, and hydraulic head; and (4) determining the effects of discharge from wells on hydraulic heads and spring flows in the study area.

5

Heat transfer from a hot rock to water flowing through a crack. Ogino, Fumimaru (Kyoto Univ. (Japan). Dept. of Chemical Engineering); Mukai, Kei; Kamata, Masahiro. *Heat Transfer - Japanese Research;* 23(7): 658-668 (Oct 1995).

Heat transfer between a fluid flowing in a slit and particles packed in it and that between the fluid and the slit wall are important for the extraction off heat from hot dry rocks. Mass-transfer coefficients, instead of the heat-transfer coefficients, on the packed particles in the slit and on the slit wall were measured by making use of the electrochemical method. The results indicate that the mass-transfer coefficient on the particles increases with decreasing void fraction and approaches that in a usual packed bed. The mass-transfer coefficient at the wall increases also with decreasing void fraction. New empirical equations for the mass-transfer coefficients on the packed particles in the slit and on the slit wall are presented.

6

Effect of non-uniform boundary temperatures on thermal instability in a porous medium with internal heat source. Parthiban, C. (Anna Univ., Madras (India). Dept. of Mathematics); Patil, P.R. *International Communications in Heat and Mass Transfer;* 22(5): 683-692 (Sep-Oct 1995).

The effect of horizontal temperature gradients due to non-uniform heating of the boundaries on the onset of convection in a fluid saturating a porous medium with uniformly distributed internal heat sources is studied using Galerkin method. The results reveal that (1) convection sets in via stationary longitudinal modes, (2) the presence of internal heat sources promotes the onset of convection, its effect being more at higher horizontal gradients, (3) stationary transverse modes are not possible in a system with internal heat sources, (4) transverse oscillatory modes are possible only for small magnitudes of the internal heat source parameter η, (5) the critical Rayleigh number increases with horizontal gradients.

7

Geologic background of the geothermal areas in Kenya distributed along the East African great rift valley. Yamasaki, T. (Kyushu University, Fukuoka (Japan)). *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 43-63 (15 Jun 1995). (In Japanese).

This paper describes the wide area geology of the East African Great Rift Valley in order to understand the geothermal sources in Kenya. The East African Great Rift Valley with a total length of about 7,000 km runs from the Dead Sea, via the Red Sea, crossing east African countries in the north to south direction, and to the Indian Ocean. The Great Rift Valley in Kenya accompanies a number of step faults with throws ranging from 1,000 m to 2,000 m. The width of Great Rift Valley is constant, that ranges from 50 km to 100 km. The savannah and semidesert are widely distributed in the bottom of the Great Rift Valley. Active Quaternary volcanoes distributing within the Great Rift Valley have a close relation to the geothermal resources. The formation of the Great Rift Valley consists of three stages of uplift, formation of fissures, and volcanic activity. Geologic systems directly relating to the Great Rift Valley in Kenya are summarized. The Great Rift Valley in Kenya is covered by the Quaternary Volcanoes and their effusions in the almost all regions. The volcanic stratigraphy and underground structure of individual geothermal zones distributing in the Great Rift Valley are described. 41 refs., 19 figs., 3 tabs.

8

Development of deep-seated geothermal reservoir bringing the quaternary granite into focus in the Kakkonda geothermal field, Northeast Japan. Kato, O. (JMC Geothermal Engineering Co., Ltd., Iwate (Japan)); Sato, K. *Shigen Chishitsu (Mining Geology (Tokyo, 1992));* 45(251): 131-144 (10 Jun 1995). (In Japanese).

This paper was concerned to summary of geothermal reservoir in the Kakkonda field and development of the deep-seated geothermal reservoir. The Kakkonda geothermal field was clarified that a geothermal reservoir showing different characteristics was divided by a boundary where temperature is rapidly increasing in depth about 1500m. The shallow reservoir lower than depth about 1500m has characteristics of temperature from 230 to 260°C, a rather good permeability and thermal water with weak alkalinity having PH degree of 8. On other side, the deep reservoir deeper than depth about 1500m has characteristics of temperature more than 300°C, a bad permeability and thermal water with acidity having PH degree of 3.2 to 5.1. All of producing wells had been belong to shallow reservoir in the Kakkonda geothermal field until 1988. However, deep-seated reservoir has been developed since 1989. As a result, granite was reached in depth about 2778m, granitic magma was intruded at speed over 100 t/h. Recently, steam with speed of 350 t/h was obtained from four deep producing wells successfully dug. 26 refs., 15 figs.

9

Mapping the fluid flow of the Mariana Mounds ridge flank hydrothermal system: Pore water chemical tracers. Wheat, C.G. (Univ. of Hawaii, Honolulu, HI (United States)); McDuff, R.E. *Journal of Geophysical Research;* 100(B5): 8115-8131 (10 May 1995).

The authors present a conceptual model of fluid circulation in a ridge flank hydrothermal system, the Mariana Mounds. The model is based on chemical data from pore waters extracted from piston cores and from push cores collected by deep-sea research vessel Alvin in small, meter-sized mounds situated on a local topographic high. These mounds are located within a region of heat flow exceeding that calculated from a conductive model and are zones of strong pore water upflow. The authors have interpreted the

chemical data with time-dependent transport-reaction models to estimate pore water velocities. In the mounds themselves pore water velocities reach several meters per year to kilometers per year. Within about 100 m from these zones of focused upflow velocities decrease to several centimeters per year up to tens of centimeters per year. A large area of low heat flow surrounds these heat flow and topographic highs, with upwelling pore water velocities less than 2 cm/yr. In some nearby cores, downwelling of bottom seawater is evident but at speeds less than 2 cm/yr. Downwelling through the sediments appears to be a minor source of seawater recharge to the basaltic basement. The authors conclude that the principal source of seawater recharge to basement is where basement outcrops exist, most likely a scarpt about 2-4 km to the east and southeast of the study area. 71 refs., 14 figs., 3 tabs.

10
New vents in the Goshogake hot springs, Akita prefecture. Sasaki, N. (Kagawa University, Kagawa (Japan). Faculty of Education). *Onsen Kagaku (Journal of the Balneological Society of Japan);* 44(4): 227-235 (31 Dec 1994). (In Japanese).

At the end of 1989, new vents were formed in the north neighborhood (30 m away) of the Oname vent in the Goshogake Hot Springs, Akita Prefecture. The shape and chemical composition of the vents were observed from the formation so as to watch the transition. This paper arranged and reported the obtained result, and simultaneously considered the formation mechanism. The thermal water is a gas type and is close to that of the Oname vent in chemical composition. However, the thermal heat is similar to the Konyazigoku vent in that it contains a large quantity of black mud. Three years after new vents are formed, the size of the vents gradually became larger than in the first year, but the amount at the vents slightly decreased. As in the first year, the black mud did not gush after the second year. For the chemical composition of the thermal water, the concentration of $SO4^{2-}$, ΣFe, and SiO2 is gradually increasing, and PH is decreasing. The neighboring Oname and Motome vents are significantly influenced by the formation of the new vents. Namely, a decrease in temperature, a decrease in the concentration of anion, and a rise in PH are observed. 8 refs., 13 figs., 4 tabs.

11
Self-propping and fluid flow in slightly offset joints at high effective pressures. Durham, W.B. (Lawrence Livermore National Lab., CA (United States)); Bonner, B.P. *Journal of Geophysical Research;* 99(B5): 9391-9399 (10 May 1994).

The authors have made laboratory measurements of joint closure and permeability of both well- and poorly mated, laboratory-produced joints in Westerly granite under joint normal stresses to 160 MPa, appropriate to midcrustal depths. They have also made detailed topographic measurements of the joint surfaces, both before and after pressure testing. The purpose of the study was to characterize and understand the hydraulic behavior of joints under conditions where fluid migration under natural settings is known to occur but where physical conditions, namely high lithostatic load, suggest that the presence of open, fluid-conducting joints might be improbable. Normal stress was applied by hydrostatic confinement of cylindrical samples, each containing a single axial tensile fracture. Experiments were performed at room temperature under conditions designed to minimize chemical effects of dissolution or precipitation. The authors found that while a mated joint can be completely closed by the application of high normal stresses, the same joint laterally offset by 0.53 mm remains open and many orders of magnitude more hydraulically conductive than the mated joint even at highest stresses. Detailed topographic observations are consistent with self-propping of the offset joint. Permanent damage to the surfaces of the offset joint is not widespread but occurs at isolated locales covering about 10% of the surface. Damage is confined to regions of negative (convex upward) curvature, such as summits and the edges of plateaus. Approximately 20% of the joint surface is in wall-to-wall contact at 160 MPa, and the flow tortuosity thus induced is probably the cause of the breakdown of the parallel plate approximation for fluid flow in the offset joint. 38 refs., 7 figs., 1 tab.

12
Petrophysical rock modeling. Fedenczuk, L.L. (Gambit Consulting Ltd. (Canada)); Wyvill, B. *Canadian Well Logging Society Journal;* 18: 107-120 (Oct 1992). Sponsored by Natural Sciences and Engineering Research Council of Canada, Ottawa, ON (Canada).

A method of visualizing a realistic 3D representation of the petrophysical rock structures was described.. An 'octree' data structure was used to represent rock models of arbitrary precision. Random packing and tube models allowed the calculation of the permeability of rocks. The percolation theory and network models constituted another approach to modeling, but these models did not account for the actual distribution of the pore size. A more realistic approach was suggested to involve the measurement of the size of pores from thin sections which can be photographed for analysis of the image, either manually or by automatic digitizing systems. The model used a three dimensional joint distribution function of the rock space. The reconstruction of the porous media gave a network of empty/solid cubes where the porosity distribution corresponded to the actual rock. The system allowed to build both 3D images of rock models, and 2D images (cross sections). The model considered: (1) the volume associated with pore/grain size distributions; (2) a statistical representation of these parameters by random sampling; (3) a computer data structure allowing description of rock information; and (4) a computer system producing the information in a form that allowed visualization of the models. Results showed that the images developed closely reflected real images, and that the minor differences observed were dependent on the octree depth and light of the scene. 30 refs.

GEOTHERMAL EXPLORATION AND EXPLORATION TECHNOLOGY

Refer also to citation(s) 33

13
(NEDO-P--9404)
Study on development and introduction of new geothermal exploration techniques. New Energy and Industrial Technology Development Organization, Tokyo (Japan). Mar 1995. 495p. (In Japanese). Sponsored by New Energy and

Industrial Technology Development Organization, Tokyo (Japan). Order Number DE96713450. Source: OSTI; NTIS; Available from New Energy and Industrial Technology Development Organization, Sunshine 60, 30F 1-1, 3-chome, Higashi-Ikebukuro, Toshima-ku, Tokyo, Japan.

In relation to the exploration of geothermal resource, conducted is a survey of the trend and the present status of exploration techniques, and from the survey the development and introduction of new exploration techniques are discussed. As for the trend survey of exploration techniques, in addition to the existing geothermal exploration techniques, the survey is made on the exploration techniques being studied and applied in university researches and in studies on civil engineering, radioactive waste, oil and volcanoes. The survey is conducted in terms of enhancement of deep exploration capabilities by elastic waves and electromagnetic waves, fracture hydraulic characteristic exploration, exploration of reservoirs at the stage of control, construction of geothermal reservoir images, etc. As to the survey of the present status, a questionnaire survey is carried out on exploration made by geothermal-related enterprises, problems of exploration techniques, ideas about new exploration methods, etc. From these, it is pointed out that for new exploration, it is needed to change exploration from the static characteristic exploration of reservoirs mostly made so far to the dynamic characteristic exploration such as the reservoir variable characteristic exploration and the fracture hydraulic characteristic exploration. Therefore, it is pointed out how important the reservoir imaging integrating these is. 214 refs., 45 figs., 17 tabs.

14

Into the hot rocks. *Energy Economist;* (167): 10-13 (Sep 1995).

This article focuses on the global exploitation of geothermal energy. Topic discussed include the difficulty posed by competition with natural gas, the major US geothermal energy producers, the Coso project in California, tax exemptions for Phillipino geothermal developers, and global geothermal power growth projections. (UK)

15

Nationwide geothermal resources exploration project (third stage). Investigation of exploration methods for the new type geothermal resources. Hisatani, K. (New Energy and Industrial Technology Development Organization, Tokyo, (Japan)); Narita, N.; Muraoka, H. *Chinetsu Gijutsu;* 20(1,2): 35-49 (28 Jul 1995). (In Japanese).

The purpose of the nationwide geothermal resources exploration project promoted by NEDO is to grasp the distribution condition of geothermal resources in Japan, and to propagate the rational geothermal development. This paper describes the results of investigation of exploration methods for the new type geothermal resources at the third stage of the project. In this study, the hot dry rock, magma, deep-seated geothermal resource, and medium/high temperature hot water are treated. The aero-electromagnetic and aeromagnetic survey and the remote sensing survey have been conducted. For the aeromagnetic survey, it was found that the high magnetic region corresponds with the distribution of Quaternary volcanic rocks and shallow intrusive bodies, while, that the low magnetic region corresponds with the distribution of geothermal alteration zones. It was shown that the aero-electromagnetic survey plays a role of the ground resistivity survey. Furthermore, for the remote sensing survey using an environmental survey satellite and an aircraft, it was illustrated that the zoning of geothermal alteration zones and the distribution of surface temperature can be grasped in high accuracy through the practical application of optical sensor with high surface resolution and high spectral resolution. 5 refs., 7 figs., 8 tabs.

16

Monitoring of geothermal reservoirs by electrical prospecting. Fluid Flow Tomography (FFT) method. Ushijima, K. (Kyushu University, Fukuoka (Japan). Faculty of Engineering); Mizunaga, H.; Tanaka, T.; Hashimoto, K.; Kaieda, H. *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 1-17 (15 Jun 1995). (In Japanese).

Introduced herein is an electrical prospecting method (named Fluid Flow Tomography) enabling the real-time visualization of fluid-flow behavior in reservoirs. This method is a four dimensional prospecting method capable, aided by a fluid serving as a shadow-forming agent, of a continuous monitoring of the spatiotemporal changes in the ground surface potential distribution and capable of visualizing the distribution of fractures deep in the ground (and capable of probing for targets moving with the passage of time). A pulsating current is applied across a pit casing pipe and a remote current electrode, and the potential difference between the reference potential electrode and the measured potential electrode positioned on the ground surface is instantly measured, and the obtained value is subjected to data processing for the elimination of the spontaneous and charged potentials from the obtained value. The spatiotemporal distribution of the penetrating current-flow directions and velocities is determined using the time change of spontaneous potentials, and the changes in the apparent specific resistance are determined using the time change in the spontaneous potentials. Further, from the expansion of the penetrating fluid-flows, the spatial distribution of the penetration rates is obtained. From the time series data of the charged potentials distribution, the dimensions of the penetrating fluid-flow, the scope of the distribution of the fluid-flows, the anisotropy of the soil layers, and the gap rate, are determined. This method is suitable for use in the investigation of reduction wells, production wells, and power generation using high temperature rock mass. 43 refs., 16 figs.

17

Development of exploration method using electromagnetic wave. Array CSMT method. Yoneda, Y. (New Energy and Industrial Technology Development Organization, Tokyo, (Japan)). *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 78-85 (15 Jun 1995). (In Japanese).

This paper introduces the development situation of array-type CSMT (controlled source magnetotelluric) method, developed measuring equipment, and software for analysis in the project of development of fracture type reservoir prospecting, promoted by NEDO. Application purpose of the array-type CSMT method is to clarify the resistivity structure with a high accuracy and in a high density. The prospecting system developed is composed of the measuring equipment of magnetotelluric data and the software for data processing and analysis. The measuring equipment is composed of a receiver for measurement by artificial signals and measurement by natural signals, transmitter, array-type multiple point

simultaneous measuring cable, booster, and signal conditioner. For the measurement of array-type CSMT, sixteen potential electrodes are embedded in the ground at an interval of 50 m along a traverse line. As a consequence of application tests in the Sumikawa district, Akita Prefecture, it was confirmed that the array-type CSMT method is effective for geothermal prospecting. 7 refs., 8 figs., 1 tab.

18

Annual report on geothermal energy development in Japan, 1994. *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 110-113 (15 Jun 1995). (In Japanese).

Japan's geothermal exploitation in fiscal 1994 is summarized. The utilization rate of geothermal power stations is 72.3% on the average. When the planned geothermal power stations go into operation, the total geothermal power output of Japan will exceed 500MW. There is a total of seven geothermal exploitation research areas, new and running. For the furtherance of efforts for exploitation, subsidiaries are issued. The technologies the Agency of Industrial Science and Technology is propelling forward for geothermal exploitation are mentioned below. Among the geothermal prospecting efforts aiming at the detection of geothermal reservoirs, there are the development of methods for prospecting fracture type reservoirs using seismic and electromagnetic waves, investigation of geothermal resources using research wells as deep as 4000 meters, and verification experiments for the high precision reflection method and VSP. Among the efforts under way in relation to excavation and energy collection, there are the development of systems for grasping real-time underground data and the development of enduring excavators. Investigations are under way, aiming at the utilization of unused thermal resources, for the development of binary cycle power plants utilizing medium and high temperature water or high temperature rock masses. 1 fig., 5 tabs.

19

Study on the prospecting of anisotropic layers by using the splitting of S-waves. Gonda, K. (Kyoto University, Kyoto (Japan). Faculty of Engineering); Watanabe, T.; Sassa, K. *Butsuri Tanko (Geophysical Exploration);* 48(3): 149-160 (Jun 1995). (In Japanese).

S-waves split into two polarized waves which have different velocities in anisotropic media caused by aligned cracks. Splitting S-waves contains more information such as the orientation of polarization and the phase delay in addition to the velocity, the amplitude and the waveform of S-waves. Therefore we can estimate the orientation of cracks and the crack density by observing splitting S-waves. At first, we developed a numerical modeling method which can simulate the particle motion excited by the incidence of wave. The stress-strain relation of anisotropic media is early introduced in the modeling. Thus we can calculate the splitting S-waves propagated through the anisotropic layer. We observed the characteristics of S-wave splitting by changing parameters describing the property of anisotropic layer. Next, we analyzed the splitting S-waves by using the rotation transform proposed by Afford (1986). The property of the anisotropic layers is obtained accurately not only in case of the single anisotropic layer but in case of many anisotropic layers. 15 refs., 17 figs., 4 tabs.

20

Efficient calculation of potential distributions for three-dimensional resistivity method by the boundary element method. Okamoto, Y. (Chiba Institute of Technology, Chiba (Japan)); Noguchi, K.; Teramachi, Y.; Akabane, H.; Agu, M. *Butsuri Tanko (Geophysical Exploration);* 48(3): 176-185 (Jun 1995). (In Japanese).

The boundary element method (BEM) has been used to calculate potential distributions in the DC resistivity prospecting problem over three-dimensional structures assuming piecewise homogeneity. The BEM used conventionally is designated the 'indirect method' where the piecewise homogeneous model is equivalently replaced with an infinite homogeneous model with secondary sources distributed over the boundaries. In this paper, we propose an efficient technique based on the 'direct method' in which equations that relate potentials and their normal derivatives on boundaries are constructed independently for each compartment. Accuracy in calculating potential distributions is evaluated by comparing numerical and analytical results in a buried sphere model. 18 refs., 7 figs.

21

Groundwater measurement for energy development. Characteristics and exploration of geothermal resources (1) exploration of developing point. Hanano, M.; Doi, N.; Yoshida, Y. *Chikasui Gakkaishi (Journal of Groundwater Hydrology);* 37(2): 105-124 (31 May 1995). (In Japanese).

In the geothermal resources intended for the geothermal power generation, there are two types in roughly division, which are 'the convection type geothermal resources' acting heat transport in reservoirs with natural convection developed mainly in the reservoirs and 'the hot-dry-rock type geothermal resources' mainly acting heat conduction. Out of them, the hot water prominence type geothermal resources is the most common one used for the actual geothermal power generation at present in Japan or in the world. In the exploration of the geothermal resources, there is regional difference which has regionally different adopted and effective techniques. The geothermal resources consists in natural convection system developing under the ground. Therefore, it is the first step of the geothermal exploration to detect the place where such natural convection system develops. In this paper, on the exploration of the natural convection system, that is, the exploration at a developed place, the exploration of whole structure of the natural convection system developed under grounds and its rising basin is introduced based on some examples. 61 refs., 18 figs., 1 tab.

22

Groundwater measurement for energy development. Characteristics and exploration of geothermal resources (2) exploration of well drilling target. Hanano, M.; Doi, N.; Yoshida, Y. *Chikasui Gakkaishi (Journal of Groundwater Hydrology);* 37(2): 125-134 (31 May 1995). (In Japanese).

The geothermal fluids can not always be obtained from all well drilled into the geothermal reservoirs. It depends upon whether the well situates on a crack to be a path of the fluids or not. In general, in and around of the common geothermal wells, the fluid can be considered to move radially to the wells. Therefore, though fluid flow speed is lower at a distant place from the wells, it becomes higher as the distance is shorter. As a result, crack propagation rate arounding the wells effects greatly on the fluid flow

resistance. Then, on a stage of drilling geothermal wells, exploration of the crack capable to produce the fluids becomes necessary. For the exploration of such aim in a geothermal zone, physical surveys or exploration based on geologic survey results of a well are often used. In this paper, this exploration is introduced centering cases to examine a recent drilling target at Kakkonda geothermal zone, Iwate prefecture. 40 refs., 26 figs.

23
Visit to ground-surface three-dimensional seismic prospecting data collecting site in Europe. *Sekiyu No Kaihatsu To Bichiku;* 28(2): 53-78 (Apr 1995). (In Japanese).

Visits were made to ground-surface three-dimensional seismic prospecting data collecting sites in Europe. What was learnt is outlined below. The area subjected to the Vienna ground-surface three-dimensional seismic prospecting site is located in the suburbs of Vienna, at the northern part of the Vienna basin. The area is divided into two regions, one for dynamite-aided prospecting and the other for vibroseis-aided prospecting. The data collecting pattern is a brick wall pattern. Only 500g or 1kg of dynamite is exploded at a 15m depth for quake generation. In the shot record, the surface wave prevailed and no reflection was recognized. The prospecting cost is 1.3-million dollars per month. The ground-surface three-dimensional seismic prospecting in the vicinity of Bremen aims at the gas field region. The sources of quake are dynamite and vibroseis. The investigating cost is approximately 1.2-billion yen. The data collecting pattern is a line pattern. Dynamite 500g in weight is exploded at 10-20m for the generation of quake. The prospecting here is larger in scale than that in the suburbs of Vienna, and is accomplished very quickly. The higher efficiency comes from the use of new prospecting equipment and the pre-loading of explosives into the quake generating pit. 20 figs., 2 tabs.

24
Application of CDP stacking to cross-well reflection data. Consideration by numerical simulation and experimental scale model. Rokugawa, S. (The University of Tokyo, Tokyo (Japan). Faculty of Engineering); Matsushima, J. *Butsuri Tanko (Geophysical Exploration);* 48(2): 84-98 (Apr 1995). (In Japanese).

A test was conducted wherein the CDP stacking method using seismic reflection was applied aiming to grasp the cross-well structure and physical properties. Numerical experiments were made and experimental models were used for the examination of this method. A cross-well reflection wave travelling time formula was derived, and velocities were analyzed in compliance with the prescribed procedure. Its application to various kinds of models was examined. Using a cross-well horizontal structure model, the structure of a spot near the middle between the wells, where the stacking density is relatively high, was reproduced. The impact of velocity contrast and thickness were examined in numerical experiments, and it was found that the impact was great when the velocity contrast was high and thickness was small. In case of a fault structure model, a fault structure was reproduced when the influence of diffraction waves was removed by migration processing. In case of an abnormal velocity point structure model, an abnormal velocity point was reproduced by migration processing. Efforts were made to apply this technique to the data from model experiments, when it was found that S-S reflection wave imaging was possible in addition to P-P reflection wave imaging. The imaging of P-S conversion waves having a different radiation pattern was not carried out. 10 refs., 23 tabs.

25
Prospecting for small inclined jacking pipe by the electromagnetic method. Kusumi, H. (Kansai University, Osaka (Japan). Faculty of Engineering); Tanaka, H.; Kagami, K. *Butsuri Tanko (Geophysical Exploration);* 48(2): 99-106 (Apr 1995). (In Japanese).

This article studies how to measure the angle of inclination of a small-diameter jacking pipe that has become inclined in the ground. This is a method based on the theoretical analysis of the magnetic field produced by a circular oscillation coil installed on the jacking pipe. It is possible to theoretically derive the X, Y, and Z components of the magnetic field produced by the circular coil. Experiments were conducted using an experimental model. It has been found that the value obtained by measuring the angle of inclination of the experimental jacking pipe is different when its head is different in depth, which demands some correction. Then the real direction of the pipe is examined, and it has been found that, in case the coil is installed inside a vinyl pipe, there is approximation between the measured value and the real value when correction is made using a value R ($T' \approx RT$ stands when the depth is within a prescribed range, wherein T' is the measured angle of inclination and T is the real angle of inclination) theoretically obtained from the pipe head depth. The above equation does not stand because of the influence of the secondary magnetic field when the coil is installed inside an iron pipe, but when the coil is installed outside the metal pipe where the influence is weaker, the measured value after correction approximates the real value. 3 refs., 11 figs., 3 tabs.

26
Fixed source, moving source and generalized Doppler effects. Yoshioka, O. (Railway Technical Research Institute, Tokyo (Japan)). *Butsuri Tanko (Geophysical Exploration);* 48(2): 107-128 (Apr 1995). (In Japanese).

A theoretical examination was made of a moving vibration source using a framework theory centered model with a view to applying the result to the vibration of structures due to running railway cars. The following have been found. Suppose that the vibromotive force of the moving vibration source is the sum of a constant component and a variable component, the average energy at the observation spot is represented by the sum of the contributions of the said two components. The problem of a moving vibration source is after all the problem of a fixed vibration source. There is a great difference between a moving vibration source and a fixed vibration source, however, that the equation 'response equals transmission function times vibromotive force' does not stand in the moving vibration source. When a moving vibration source positioned on a half-infinite platform is considered, it is understood that the solution to Lamb's problem may be translated into a solution to the problem of a moving vibration source. A case wherein vibration is within a finite range may be discussed taking reference to its relation with Ben-Menahem's factor involving a seismic hypocenter. A response of a constant vibromotive force is attended with resonance attributable to the transonic phenomenon in case attenuation is small in the medium. The response of a

moving vibromotive force shows Doppler effects in case attenuation is small, but it will be attended with waveform deformation when attenuation grows larger. 23 refs., 4 figs.

27
Synthetic fluid inclusion logging for temperature measurement and fluid sampling in geothermal wells at higher than 350°C. Sasada, M. (Geological Survey of Japan, Tsukuba, Ibaraki (Japan)); Sawaki, T. *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(1): 1-13 (15 Mar 1995). (In Japanese).

The synthetic fluid inclusion logging system is a system to be able to sample a liquid in situ in wells, together with executing a temperature measurement at a high temperature environment. The fluid inclusion is made by healing the cracks in a host mineral such as a quartz. The synthetic fluid inclusion logging is a technology applied what the fluid inclusion can be prepared by a crack healing, and moreover a temperature measurement technology applicable even at a temperature exceeding 350°C and a fluid sampling technology. A temperature inside wells is searched for from a measurement value of the homogenization temperature for a synthetic fluid inclusion made through healing the cracks of quartz in a solution added by a silica, and from a measurement value of a pressure in the capillary tube. At a temperature range exceeding 350°C, so as to raise a measurement accuracy, a capsule, in which a NaCl solution with a high critical point is put in, can be used. The liquid sampling in the wells is performed by hanging down a container attached with a rupture disc to a target depth. 33 refs., 9 figs.

28
Methods of determining induced fracture orientation : Ferrier Field application. Parker, D.L. (Amerada Hess Canada Ltd. (Canada)); Hefferman, P.D. *Canadian Well Logging Society Journal;* 18: 7-20 (Oct 1992).

Three methods of determining the direction of an induced hydraulic fracture in a well in the Ferrier Field in S.W. Alberta were evaluated. The first two methods (i.e. Oriented Borehole Breakout and Strain Relaxation) infer the fracture direction based on rock deformation or failure properties. The third method, called Electrical Borehole Images of Hydraulically Induced Fracture, measures the electrical properties of an actual induced fracture. The first method, which uses oriented calipers, was found to be the least expensive; the second, requiring an oriented core and uses strain gauge analysis, the most difficult operationally; the third, which requires the injection of drilling mud and uses the Formation MicroScanner (FMS), was found to be the most effective. The results show that: (1) oriented calipers (first method) are not centered in the breakout direction due to cable torque; (2) the accuracy of the strain relaxation method is limited by the ability to properly the core; and (3) the FMS technique (third method) is the most accurate method of determining the direction of an induced fracture. 15 refs., 8 figs., 2 tabs.

29
Analysis of dipmeter logs : Part 1 - Evolution of dipmeter tools. Crain, E.R. (Spectrum 2000 Mindware Ltd, Calgary, AB (Canada)). *Canadian Well Logging Society Journal;* 18: 23-74 (Oct 1992).

This paper is an extract from the 'Dipmeter Theory and Data Processing' chapter of The Log Analysis Handbook - volume 2, published by Pennwell Books.

The evolution of dipmeter tools, dipmeter calculation methods and dipmeter data presentation methods were discussed. The first anisotropy dipmeter appeared in 1933 and was supplanted by the SP dipmeter in 1943. In 1969, modern high resolution dipmeters were introduced, and in 1975 computer processing was developed to validate the results. In 1986, the 'ultimate' dipmeter was introduced, called the Formation MicroScanner (FMS), which is still in use. The computation of dipmeter data has been handled in three general ways: manual processing, combination of manual and computer processing, and total computer processing. It was considered essential that these computations take into account correlation closure error and the correlation planetary error.. Dip can also be determined by clustering, pooling and the use of fan plots. Three methods to calculate stratigraphic high resolution dips were also reviewed: mean squares (MSD) dips, continuous side-by-side (CSB) dips, and local derivative (LOC) dips. 31 figs.

30
Application of the fracture height log to deep sandstone reservoirs, Alberta, Canada. Boyd, Doug (Western Atlas - Core Laboratories (Canada)). *Canadian Well Logging Society Journal;* 18: 75-103 (Oct 1992).

Theory and case examples of the application of fracture height logs were presented. The frac pressure fracture height model was explained.. The mechanical behaviour of earth materials was shown to depend on confining pressure, temperature, time, pore pressure, anisotropy, ductility and lithology. The dynamic Poisson's ratio was calculated from shear wave and compressional wave velocities. This ratio is applied with overburden pressure and rock pore pressure to determine continuous rock stress profiles. Five case examples of using the frac pressure fracture height model were presented. These examples showed that: (1) an empirical correlation between dynamic Poisson's ratio, pore pressure, and micro/mini frac data improved minimum horizontal stress prediction in an area of tectonic stress; and (2) the relative magnitude of stress barriers to hydraulic fracture height extension were correctly identified by the frac pressure fracture height model. 28 figs., 44 refs., 1 tab.

31
An apparatus for seismic surveying and an method of synchronizing systems for seismic surveying. Helgerud, P.; Bragstad, H. To Geco A/S, Stavanger (Norway). Norwegian Patent 176860/B/. 27 Feb 1995. Filed date 30 Jun 1992. Norwegian Patent Application 922584/A/. Int. Cl. H04L 7/00; G01V 1/26. 17p. (In Norwegian). Source: Available from Styret for det industrielle rettsvern, N-0033 Oslo, Norway.

The invention relates to the synchronization of systems for seismic surveys. The systems are composed of subsystems and may be land-based or marine. The survey system is supplied with an absolute time standard and a time code based on the absolute time standard being generated in the survey system. There is further provided at least one programmable event generator in the survey system and this is synchronized with the absolute time standard. The time for a specific event is predetermined on the basis of given parameters and supplied with the time code which corresponds to this time. The time for a determined event is then supplied to the subsystems which are also provided with the absolute time standard. The event can thereby be executed in one or

more of the subsystems on the basis of the supplied absolute time standard and synchronization is obtained with the desired accuracy. It is thus possible to synchronize shot times in a seismic signal generating system, and synchronize the shot recording time and sampling times in a seismic data recording system. It is also possible to determine the exact time of actually occurring events in a system for seismic surveys. 5 figs.

ECONOMIC, INDUSTRIAL, AND BUSINESS ASPECTS

Refer also to citation(s) 38

32
Cost modelling of electricity-producing hot dry rock (HDR) geothermal systems in the United Kingdom. Doherty, P. (Sunderland Univ. (United Kingdom)); Harrison, R. 420p. European Commission, Luxembourg (Belgium) (1995). Contract EN3G-0090.

Price ECU 46.50.

A detailed and comprehensive cost model for Hot Dry Rock (HDR) electricity producing systems has been developed in this study. The model takes account of the major aspects of the HDR system, parameterized in terms of the main physical and cost parameters of the resource and the utilization system. A doublet configuration is assumed, and the conceptual HDR system which is defined in the study is based upon the UK Department of Energy (DEn) HDR geothermal R and D programme. The model has been used to calculate the costs of HDR electricity for a UK defined base case which represents a consensus view of what might be achieved in Cornwall in the long term. At 14.2 p/kWh (1988 costs) this cost appears to be unacceptably high. A wide-ranging sensitivity study has also been carried out on the main resource, geometrical, and operational parameters of the HDR system centred around the UK base case. The sensitivity study shows the most important parameters to be thermal gradient and depth. The geometrical arrangement and the shape of the reservoir constitute major uncertainties in HDR systems. Their effect on temperature has a major influence on system performance, and therefore a range of theoretically possible geometries have been studied and the importance of geometrical effects on HDR electricity costs assessed. The most cost effective HDR arrangement in terms of optimized volumes and flow rates has been investigated for a world-wide range of thermal settings. The main conclusions from this study suggests that for HDR electricity to be economic, thermal gradients of 55°C/km and above, well depths of 5 km or less, and production fluid temperatures of 210°C and above are required. (UK)

GEOTHERMAL POWER PLANTS

33
Development of geothermal hot water power generation plant. Development of the binary cycle generating plant (development of measurement while drilling (MWD) system for geothermal wells). Sato, Y. (New Energy and Industrial Technology Development Organization, Tokyo, (Japan)). *Chinetsu Gijutsu;* 20(1,2): 50-57 (28 Jul 1995). (In Japanese).

In order to acquire the real-time information of well bottom during the drilling of geothermal wells, NEDO has developed a measurement while drilling (MWD) system. The MWD system is composed of a sensor and an analysis system. The sensor consists of a well bottom apparatus and a ground apparatus, and the analysis system consists of a drilling trace control support system and a well evaluation support system. The development items of the well bottom apparatus in FY 1994 include the mud pulse generator, well bottom signal processor, inclination information sensor, design of unified sonde and anti-vibration, vibration measurement, incidental apparatus outside the sonde, heat-proof confirmation test for electronic parts, and test apparatus. The development items of the ground apparatus include the experimental analysis program, automatic discrimination program for S/N ratio degradation recovery, and calculation of simulation. The development items of the analysis system consist of the drilling trace planning system, drilling trace display system, drilling trace prediction system, and temperature analysis system. Results of these development items are demonstrated. 3 figs., 3 tabs.

34
Generation by heated rock. Technology for hot dry rock geothermal power. Hori, Y. (Central Research Inst. of Electric Power Industry, Tokyo (Japan)). *Doboku Gakkai-Shi (Journal of the Japan Society of Civil Engineers);* 8(7): 10-13 (15 Jun 1995). (In Japanese).

Japan is one of the most distinguished volcanic country in the world and about 8% of the active volcanos of the world are distributed in Japan. This kind of a large quantity and natural energy resource near us are used as hot springs in the whole country and as for electricity in 10 geothermal power stations. In future, if this enormous underground geothermal energy could be utilized safely and economically by using new power generation system like hot dry rock geothermal power generation (HDR), it may contribute a little to the 21st century's energy problem of Japan. Central Research Inst. of Electric Power Industry has installed 'Okachi HDR testing ground' in Okachi-machi of Akita Ken, and is carrying out experiments since 1989. Hot dry rock geothermal power generation is a method in which water is injected to the hot dry rock and the thermal energy is recovered that the natural rock bed is used as a boiler. However, development of many new technologies is necessary to bring this system in practical use. 9 refs., 5 figs., 1 tab.

35
Scaling protection technology for Sumikawa 50MW geothermal steam turbine. Amagasa, S. (Tohoku Electric Power Co. Inc., Sendai (Japan)); Saito, S.; Yoshida, K.; Sakanashi, H. *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 18-42 (15 Jun 1995). (In Japanese).

A newly developed technology for scale prevention that can be accomplished within a steam turbine is introduced, and the result of a test conducted actually in a 50MW geothermal steam turbine is reported. The deposition of scales on the nozzle and their adhesion thereto were investigated, to reveal the substances constituting the scales and the spots of their deposition on the back and front sides of the nozzle. Scale adhesion preventing techniques were

studied on the basis of the mechanism of their deposition and adhesion, to result in what are stated below. The lowering of nozzle surface metal temperature so as to inhibit the drain on the said surface from re-evaporation and condensation leads to the prevention of scales composed mainly of NaCl and SiO2. For lowering the temperature of the nozzle surface metal, a design was contrived wherein a coolant passage was provided in the nozzle piece for cooling water from outside to flow through. The scale preventing nozzle was tested alone, the nozzle provided with two cooling water apertures intercommunicating each other via a U shape pipe. Further, a test was conducted wherein the scale preventing nozzle was actually used as the nozzle for a 50MW turbine. The two tests demonstrate that this technology is effective in preventing the adhesion of scales. 3 refs., 34 figs., 14 tabs.

36
Outline of Puna geothermal power station, Hawaii. Miyazaki, S. (Japan Metals and Chemicals Co. Ltd., Tokyo (Japan)). *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 86-88 (15 Jun 1995). (In Japanese).

Puna Geothermal Power Station generates electric power of 25,000 kW by ten power generation units which combine back pressure steam turbine and binary turbine. In the Puna Geothermal Power Station, steam is supplied from two production wells. The power generation unit called combined cycle geothermal power generation unit is composed of a back pressure steam turbine and a binary power generation module. In the binary power generation module, a heat exchanger, binary turbine, generator, control system, and pipes are integrated. High pressure and efficient power generation is conducted by supplying high pressure steam separated by the separator into the back pressure steam turbine. Heat of low pressure steam exhausted from the back pressure steam turbine can be also utilized effectively by the binary turbine. Isopentane is used as a medium of the binary power generation. Since all amount of hot water, condensed water, and non-condensable gas are reduced to the underground, there is little environmental pollution. 6 figs.

37
Utilization of geothermal energy in Kazuno, Akita. Sato, T. (Kazuno City Office, Akita (Japan)). *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 104-109 (15 Jun 1995). (In Japanese).

Onuma Geothermal Power Station of Mitsubishi Materials Co. started its operation in 1974 as third geothermal power station in Japan, and has been stably operated for more than twenty years. In Onuma Geothermal Power Station, 400 t of hot water, whose temperature is 96 centigrade, flows out per hour in addition to steam for power generation. Since 1980 Kazuno-City has conducted the demonstration survey in order to utilize the hot water effectively, contribute to the regional promotion, and accelerate the development of geothermal energy. It has been planned that the source hot water of Onuma Geothermal Power Station is heat exchanged by the river water, to produce 150 t of hot water, whose temperature is 70 centigrade, and to supply for heating, hot water supply, and green house vegetation. The source hot water from the Onuma Geothermal Power Station is introduced to the tank coil type heat exchanger. The source hot water from the heat exchanger is reduced to the underground through a reducing well. The geothermal energy obtained is utilized for the warm water swimming pool, heating, hot water supply, and snow melting. Finally, problems of geothermal utilization are provided. 11 figs., 1 tab.

38
Groundwater & ground-coupled heat pump systems. Rafferty, K. *Geo-Heat Center Quarterly Bulletin;* 15(3): 9-11 (Mar 1994).

This is the first in a series of articles which will inform Bulletin readers about future research work to be conducted at the Geo-Heat Center. It's purpose is to introduce the issues involved and outline the direction the research will take. In an upcoming research task, the Geo-Heat Center will be comparing some cost and performance aspects of different ground-source (geothermal) heat pump systems for commercial applications. Over a range of system sizes (50 to 500 tons), the work will examine capital cost and pumping energy requirements of the ground source portion of ground-coupled and groundwater systems. Due to the different factors influencing the cost of these two approaches, it is likely that for a given project one design will be substantially less costly than the other.

GEOTHERMAL ENGINEERING

39
(NEDO-P--9356)
Report for joint study on inhibiting scale deposition caused by brines from geothermal power plant. New Energy and Industrial Technology Development Organization, Tokyo (Japan). Mar 1994. 69p. (In Japanese). Sponsored by New Energy and Industrial Technology Development Organization, Tokyo (Japan). Order Number DE96713469. Source: OSTI; NTIS; Available from New Energy and Industrial Technology Development Organization, Sunshine 60, 30F 1-1, 3-chome, Higashi-Ikebukuro, Toshima-ku, Tokyo, Japan.

In the demonstration survey of geothermal hot water supply business at the request of the Ministry of International Trade and Industry (MITI) to the New Energy Foundation (NEF), the 'technology to inhibit the silica scale deposition by pH adjustment' was developed in Shizukuishi Area, Iwate Prefecture, and Kazuno City, Akita Prefecture. Through the visit to Indonesian and Philippine geothermal development-related organizations in the ASEAN countries during February 7 through 19, 1994, investigation was made on the possibility of cooperative research with the local organization to execute the geothermal development. This research aims at demonstrating that the above technology developed is effective also in developing the overseas geothermal hot water which is different in properties from that of Japan. Both countries are desirous of executing the cooperative research. Particularly, the Philippines strongly desire the cooperative research to be widely expanded for the inhibition of silica scale deposition. It was stated that, in case of executing the present cooperative research, its counterparts were to be the State Electric Company (PLN) and Philippine Electric Company/Philippine National Oil Company (NPC/PNOC) on the side of Indonesia and the Philippines, respectively. From now on, the program will be planned to start the present cooperative research with conducting the demonstration test. 9 figs., 13 tabs.

40
(NEDO-P--9456)
Investigation report on feasibility of developing a silica scale deposition inhibiting technology jointly with other countries. 2. New Energy and Industrial Technology Development Organization, Tokyo (Japan). Mar 1995. 61p. (In Japanese). Sponsored by New Energy and Industrial Technology Development Organization, Tokyo (Japan). Order Number DE96713475. Source: OSTI; NTIS; Available from New Energy and Industrial Technology Development Organization, Sunshine 60, 30F 1-1, 3-chome, Higashi-Ikebukuro, Toshima-ku, Tokyo, Japan.

This paper reports a joint research and development with Indonesia and Philippines on a silica scale deposition inhibiting technology. Subsequent from the investigations by visits from Japan in the previous year, fiscal 1994 had responsible persons invited from both countries to introduce research and development works in Japan and discuss the possibility of implementing more specific joint researches. The responsible persons from both countries have made investigation tours through the geothermal experiment areas in Shizukuishi in Iwate Prefecture, Kazuno in Akita Prefecture, and Odake-Hacchobara in Kyushu. They recognized the importance of the operations for inhibiting silica scale deposition, and left for their own countries with strong desire to apply the technology to the geothermal fields in their home countries. Requests were given to both countries to compare hot water and geological conditions in their countries with those in Japan and pick up suitable research locations from which verification data required by Japan can be obtained. Philippines proposed suitable locations. As a result of discussing the design, fabrication, and installation in both countries of machines being operated in Japan, Philippines presented a positive proposition on annual plans and expense including the expenses to be shared by both countries. 12 figs., 2 tabs.

41
Crack propagation models for rock fracture in a geothermal energy reservoir. Fitt, A.D. (Univ. of Southampton (United Kingdom). Faculty of Mathematical Studies); Please, C.P.; Kelly, A.D. *SIAM Journal of Applied Mathematics;* 55(6): 1592-1608 (Dec 1995).

The propagation of a one-dimensional, fluid-filled crack in a hot dry rock geothermal energy reservoir (HDRGER) is discussed. In previous studies a number of different relationships between the normal stress on the crack, the fluid pressure, and the crack height (so-called crack laws) have been used, as have different "flow laws" to determine the relationship between flow rate and crack geometry. Here it is shown that the choice of submodel may have profound implications for the mathematical structure of the problem. In particular, two crack laws (a linear law and a hyperbolic law) are considered as well as two flow laws (a cubic law and a linear law). The model contains a dimensionless parameter that measures the relative importance of stresses due to local deformation of asperities and the long-range deformation of the crack surface. The case is considered where the former is the dominant mechanism. A perturbation analysis is performed, and it is found that for some combinations of laws a strained-coordinate analysis is required, while for others a matched asymptotic approach is needed. In the latter case the problem may be reduced to that of solving a linear, nonhomogeneous singular integrodifferential equation to determine the behavior in the boundary layer. This problem is solved, and some conclusions are drawn regarding the relevance of various laws to flow in HDRGERs.

42
Practical aspects of well test analysis under composite reservoir situation. Ambastha, A. K. *Journal of Canadian Petroleum Technology;* 34(5): 41-46 (May 1995).

Well test analysis using a radial composite model was studied. A two- region, radial composite reservoir model was assumed to be composed of two regions of different properties. Well test analysis based on this model showed that it can be used to obtain estimates of discontinuity radius, reservoir properties, and skin factors corresponding to both regions. Problems related to data misinterpretation which can lead to misinterpretation of reservoir characteristics and skin factors were examined. A detailed analysis of a sample well test was presented as an aid to interpreting tests from composite reservoir situations. 28 refs., 8 figs.

43
The study of the solid phase granulation in the drilling fluid on the damage rate of near-borehole zone. Falkowicz, S. (Instytut Gornictwa Naftowego i Gazownictwa, Cracow (Poland)). *Nafta-Gaz;* 51(5): 199-203 (May 1995). (In Polish).

The paper presents the phenomena proceeding in the time of the reservoir rocks drilling and the contacting with the drilling fluid. The aim of presented study is the explanation of the influence of the size and the quantity of solid phase particles in the drilling fluids used now or the damage range and rate of the drilled rocks permeability. (author). 6 refs., 2 figs., 3 tabs.

44
Evaluation on ground pressure at hot dry rock experimental fields. Oikawa, T. (National Institute for Resources and Environment, Tsukuba (Japan)). *NIRE Nyusu (National Institute for Resources and Environment);* 5(3): 1-4 (Mar 1995). (In Japanese).

This paper describes the result of applying the differential strain curve analysis (DSCA) in hot dry rock experimental fields. The analysis was intended of evaluating the ground pressure necessary for developing hot dry rock geothermal energy. The DSCA is a method to obtain ground pressure information by extracting information on cracks that develop when the force applied onto rocks is released. In this case, the developed cracks grew larger along the face perpendicular to the force releasing face and according to the size of the force. If the cracks are blocked by applying the ambient pressure onto the collected samples, the deformation behavior of the rocks may be regarded as a deformation behavior of matrix that does not contain cracks. The DSCA derives the ground pressure based on the ambient pressure/strain line charts. The experiment described in this paper performed an analysis under an assumption that the difference in gradients in the line charts is proportional to the strain generated by the released force. Measurements were made on eight kinds of rock cores collected during the excavation. The gradient values converge as the ambient pressure was increased, and into a certain value at 90 MPa or higher. The blocking of the cracks was considered finished at this time, at which the ground pressure was determined. Consistency was verified in the result relating to

directions of the main stress and the ground pressure condition in the reservoir bed. 6 figs., 1 tab.

45
Application of the chemical monitoring of drilling fluids to hydrogeology. Aquilina, L. (Bureau de Recherches Geologiques et Minieres (BRGM), 45 - Orleans (France)); Brach, M.; Fouillac, C.; Sureau, J.F.; Criaud, A.; Baubron, J.C.; Pinault, J.L.; Boulegue, J.; Bariac, T.; Vuataz, F.D., et al. *Hydrogeologie;* (4): 37-45 (1994). (In French).

During the last ten years, BRGM has carried out five experiments to chemically monitor drilling fluids. It has therefore developed a methodology adapted specifically to this type of work and an important experience in the interpretation of the results. The results of these scientific investigations could find hydrogeological applications by using the simplest and lightest parts of monitoring, especially gases and physico-chemical parameters logging. The purpose of this paper is to describe the evolution of the techniques employed and the principal results acquired during the period over which the work was carried out. (O.L.). 24 refs., 4 figs., 3 tabs.

DIRECT ENERGY UTILIZATION

Refer also to citation(s) 37

46
(DOE/ID/13040--T29)
Geothermal direct-heat utilization assistance. Quarterly project progress report, July 1995--September 1995. Lienau, P. Oregon Inst. of Tech., Klamath Falls, OR (United States). Geo-Heat Center. 1995. 20p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract FG07-90ID13040. Order Number DE96002994. Source: OSTI; NTIS; GPO Dep.

The report summarizes geothermal technical assistance, R&D and technology transfer activities of the Geo-Heat Center at Oregon Institute of Technology for the fourth quarter of FY-95. It describes 80 contacts with parties during this period related to technical assistance with geothermal direct heat projects. Areas dealt with include geothermal heat pumps, space heating, greenhouses, aquaculture, equipment and resources. Research activities are summarized on low-temperature resource assessment, geothermal energy cost evaluation and marketing strategy for geothermal district heating. Outreach activities include the publication of a geothermal direct use Bulletin, dissemination of information, geothermal library, technical papers and seminars, and progress monitor reports on geothermal resources and utilization.

47
Geothermal energy: A modern power plant in Iceland. Svartsengi - energy out of the cleft in the Atlantic Ocean. Hug-Fleck, C. *Energie;* 47(4): 20-23 (Apr 1995). (In German).

In the far south-western part of Iceland, a very modern geothermal power plant provides 20,000 people with electric power and thermal energy. A wonderful side effect is the "Blue Lagoon", a wide and shallow basin with highly mineralised excess water. 100,000 guests visit the lagoon every year, either for fun of for healing purposes. (orig.)

GEOTHERMAL DATA AND THEORY

48
Numerical simulation of hydrothermal alteration. Takeno, N. (Geological Survey of Japan, Tsukuba (Japan)). *Chinetsu (Journal of the Japan Geothermal Energy Association);* 32(2): 64-77 (15 Jun 1995). (In Japanese).

This paper describes the numerical geochemistry simulation based on the chemical equilibrium. When the chemical species composition is discussed in the high temperature environments like geothermal regions, pH should be treated as an unknown, as well. Calculations, by which the chemical species composition is estimated and the degree of saturation is determined, are significant to judge the stability of minerals in the interaction between rocks and water. Through the numerical simulation of interaction between water and rocks, the change of chemical composition of hot water in response to the dissolution of rocks and the change of crystallized minerals can be examined. For the dissolution reaction model, kinetics of the chemical reaction should be taken into account. Function forms are explained, which express reaction rates. Among the parameters, the dissolution reaction rate constant and the reaction surface area are important. Equation systems for the numerical geochemistry simulation are solved numerically by using a computer. Finally, several examples of numerical geochemistry simulation are introduced. 39 refs., 5 figs., 2 tabs.

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Laboratory characterization of fluid flow parameters in a porous rock containing a discrete fracture. Rasmussen, T.C. (Univ. of Georgia, Athens, GA (United States)). *Geophysical Research Letters;* 22(11): 1401-1404 (1 Jun 1995). Contract NRC-04-90-053.

A porous block of volcanic tuff with an embedded fracture was used to perform laboratory-scale water and gas flow experiments for the purpose of obtaining unsaturated fractured rock characterization parameters. Rock matrix properties included porosity, hydraulic diffusivity and the gas-phase diffusion coefficient. Fracture properties included apertures, transmissivity, hydraulic conductivity, and air-entry pressure. Gas tracer experiments using argon and helium are presented for estimating fracture hydraulic conductivity, fracture apertures and rock matrix porosities. 4 refs., 3 figs., 1 tab.

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Laboratory investigation of matrix imbibition from a flowing fracture. Tidwell, V.C. (Sandia National Labs., Albuquerque, NM (United States)); Glass, R.J.; Peplinksi, W. *Geophysical Research Letters;* 22(11): 1405-1408 (1 Jun 1995). DOE Contract AC04-94AL85000.

Predicting fluid flow and transport behavior in unsaturated, fractured rock is greatly simplified where matrix imbibition can be modeled as a linear function of the square root of time ($t^{1/2}$); however, such treatment implicity assumes homogeneous matrix properties. To investigate matrix heterogeneity effects, the authors perform a simple experiment in which x-ray imaging is used to measure the imbibition of

water from a flowing fracture into a slab of volcanic tuff. Experimental results show matrix imbibition to follow a linear $t^{1/2}$ relationship even though the saturated hydraulic conductivity of the tuff varies by over four orders of magnitude. 13 refs., 4 figs.

MISCELLANEOUS

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Problems in energy technology development. Fukiwake, M. (Agency of Industrial Science and Technology, Tokyo (Japan)). *Chinetsu Gijutsu;* 20(1,2): 3-5 (28 Jul 1995). (In Japanese).

This paper describes the problems of geothermal technology development and energy technology development in the New Sunshine Project. Geothermal energy is purely domestic energy without exhaustion, is friendly energy to global environment with less emission of carbon dioxide, has accumulated accomplishments as energy for power generation, and can be utilized as heat sources for regional heating, green house vegetation, culture, wood drying, snow melting of roads, etc. Geothermal energy is one of the prospective renewable energy. For the practical utilization of geothermal energy, a large risk of its development has been pointed out. For the problems of energy technology development, it is proposed that a data base of technology development information should be constructed. It is also pointed out that an efficiency of research and development should be improved. Furthermore, it is affirmed that the propagation of research and development results should be promoted. Economical and social significance of introduction and propagation of new energy is provided.