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APPLICATION OF A GEOTHERMAL COMPUTER FILE SYSTEM TO CHEMICAL GEOTHERMOMETERS

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Authors

Phillips, S.L.
Swanson, J.R.

Publication Date

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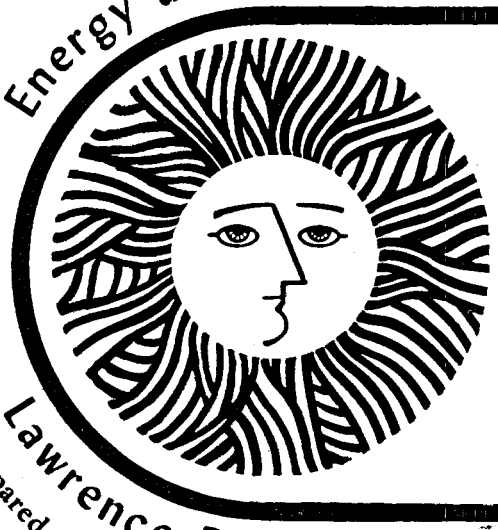
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Presented at the
32nd ACS Southwest Regional Meeting,
Fort Worth, Texas
December 1-3, 1976

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Energy and Environment Division



Lawrence Berkeley Laboratory University of California/Berkeley

Application Of A Geothermal Computer File System To Chemical Geothermometers

Sidney L. Phillips, LBL and
James R. Swanson,
Office of Resource Analysis,
U.S. Geological Survey
Reston, Va 22092

MASTER

January 1977

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LBL-5915

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Presented at the 32nd ACS Southwest Regional Meeting,
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APPLICATION OF A GEOTHERMAL COMPUTER FILE SYSTEM TO CHEMICAL GEOTHERMOMETERS

by

Sidney L. Phillips
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

and

James R. Swanson
Office of Resource Analysis
U.S. Geological Survey
Reston, VA 22092

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In the field of geothermal chemistry there is a distinction between "pure" and "applied" research which frequently hinders progress in these two aspects of the field. We speak of pure research as that mainly in academic or government institutions, whereas applied research is an industrial function.

In order that each group may function effectively to contribute its share to the health and welfare of the United States, there must be a coordination of their activities. Frequent and fruitful contacts with new developments will forestall slippage by industry into expensive and time-wasting empiricism. On the other hand, the results of pure research are of academic interest only, until applied to areas which affect our lifestyle in an important manner, for example, the development of new domestic energy resources. Only an effective and fruitful two-way flow of information between chemists engaged in pure and applied research will prevent our slide into an industrial dark age.

Despite the close and cordial relations that frequently exist among workers in these two fields, there is still a large gap between their activities. This gap is especially noticeable in long established industries, which have grown up entirely on an empirical basis, and in which the possibilities for the application of basic science are just beginning to be realized. But even in those industries which employ many persons of scientific training for the development and control of their processes, there is still much conservatism and a tendency to crystallize too soon and too firmly their methods of operation. The need to close this information gap is obvious.

The National Geothermal Information Resource (GRID) and the geothermal resource file (GEOTHERM) are sponsored by the U.S. Energy and Development Administration and U.S. Geological Survey with the objective to collect, organize, and disseminate data on the major areas of geothermal exploration and assessment. The aim of GRID and GEOTHERM in this joint effort is mainly to collect and disseminate on a continuing basis site-dependent numerical data on geothermal fields, brines, and surface waters for electrical and non-electrical resource assessment.

GRID searches the world literature on a continuing basis, retrieves and indexes publications relevant to geothermal science, extracts the numerical data or information, and critically evaluates the information and data. Primary emphasis is placed on coverage of the numerical data needed to understand geothermal energy and to utilize its resources. See Figure 1. GEOTHERM is a site-dependent file of worldwide information needed to evaluate areas for their geothermal resource potential. It includes information on fields and wells, for example geology, well temperature, and chemical analyses. See Figure 1. While the larger work of the two data bases covers the field of geothermal energy, this paper is limited to data used to develop the chemical geothermometers which are used to infer the temperature of a subsurface geothermal hot water resource by chemical analysis of surface waters. Table 1 illustrates two important uses for subsurface temperature data:

<u>Inferred Reservoir Temperature Needed To:</u>

(1) Calculate Reservoir Heat Content, Q:

Q = (Reservoir Volume) x (Specific Heat) x (Temperature)

(2) Assess for Use

Electrical ($T > 180^{\circ}C$)

Other (e.g., District Heating, Process Heat)

Figure 1

National Geothermal Information Resource (GRID)

-ERDA Information Analysis Center

-Computerized Data Storage/Retrieval (BDMS)

-Files contain

- o Basis (Transferable) Numerical Data
- o Site-Dependent Numerical Data
- o Selected Bibliography

Office of Resource Assessment (GEOTHERM)

-USGS Site-Dependent Resource Information

-Computerized Data Storage/Retrieval (GIPSY)

-Files contain

- o Geothermal Fields
- o Geothermal Wells
- o Chemical Analyses

As shown in Table 1, typical uses of the inferred hot water reservoir temperature at depth,which is calculated from chemical analyses of the surface thermal springs, include computation of the reservoir heat content from the product of the reservoir volume, specific heat, and the inferred temperature at depth. Another example of the use of the temperature is in assessing the hot brine reservoir for use either in electrical power production where the preferred temperature should exceed about 180°C and for non-electrical uses, for example in district heating or in processing heat. The basis for chemical geothermometers used to infer subsurface temperatures includes the following five assumptions:

Basis for Chemical Geothermometers

1. Temperature-dependent chemical reaction within the hot water reservoir.
2. Equilibrium for the chemical reaction is attained in the reservoir.
3. The concentration of measured constituents does not change, as water flows from the reservoir to the surface where it is sampled and analyzed.
4. The chemical reaction is not concentration limited in the measured constituent.
5. The reservoir hot water is adequately mixed, so there are no concentration gradients within the reservoir.

There are a number of chemical geothermometers. Typical geothermometers include the following:

Typical Geothermometers

1. Silica-based on quartz solubility
2. Na/K ratio: $K^+ + Na - feldspar = Na^+ + K - feldspar$

$$Keq = \left(\frac{Na^+}{K^+} \right) \left(\frac{K - feldspar}{Na - feldspar} \right) = K(T)$$

3. Other (e.g., Mg, $Cl/(HCO_3 + CO_3)$, Cl/F).

As an example, the silica solubility in water over the range of temperatures 25 to 300°C follows mainly a logrithmic expression. The silica concentration in geothermal waters is estimated by analyzing the surface thermal water for silica content, and then relating the silica content to the temperature at depth, assuming that silica has not precipitated and that the hot water has not been diluted or the concentration otherwise changed in silica from the time fluid flows from the brine reservoir to sampling at the surface.

In summary, chemical geothermometers such as the silica geothermometer have been found useful in inferring the temperature of a hot water geothermal resource at depth by chemical analysis of the silica content in surface thermal springs. The following section describes application of a computer file system to the collection, extraction, and utilization of chemical analysis data for chemical geothermometers.

Computer File System

The GRID documentation file, GEODOC, is a computer-based file which contains descriptive cataloging and indexing rules for all GRID documents. This file (along with other GRID files) is managed by the Berkeley Data Base Management System (BDMS). Each record in the GEODOC file contains descriptive cataloging, abstracting, and indexing information corresponding to a single document. The information within a given record is subdivided into computer retrievable "data elements"; for example, see Figure 2.

Figure 7

BOOK	COLLECT	DRAWING	FILM	MAP	PHONO.	J ART.	PATENT	REPORT	COMPUT
B	C	D	F	G	H	J	P	R	T

Type of Record

/

ANAL	MONOGR	SERIAL	COLL
A	M	S	C

Biblio. Level

/

CONF	DICT	N DATA	THESIS	STAND	BIBLIOG	PR.REPT.	ABSTRACT
K	L	N	U	W	Z	Y	E

Literary Indicator

NATIONAL GEOTHERMAL INFORMATION RESOURCE

GENERAL FORM

GRID WORKSHEET

☐ OF ☐

SHORT CODE (SC)	
DES. CAT. SOURCE (DCSO)	
DOCUMENT TYPE (TY)	

PERMITTED BIBLIOGRAPHIC LEVEL: A or M

BIBLIOGRAPHIC LEVEL (BL)	
PRIMARY TITLE (PT)	
PRIMARY SUBTITLE (PS)	
TITLE AUGMENTATION (TA)	
LANGUAGE (L)	
ORIGINAL TITLE (OT)	
ORIGINAL SUBTITLE (OS)	
EDITION (ED)	
AUTHOR (AU)	
AUTHOR NOTE (AN)	
AUTHOR AFFILIATION (AA)	
AFFILIATION CODE (AC)	
CORPORATE ENTRY (CE)	
CORPORATE CODE (CC)	
ACADEMIC DEGREE (DG)	

The GRID descriptive cataloging rules are standardized and modeled after those of the International Nuclear Information System (INIS) of the International Atomic Energy Agency. The data elements have been chosen to correspond as closely as possible to those used by INIS to facilitate both U.S. and worldwide information exchange with other data bases using INIS rules.

The GRID records are permanently stored on magnetic tape; temporary storage on disc files is also utilized when faster access than provided by tape is desired. Multiple copies of the data are stored on back-up tapes to provide for possible computer system crashes or failure of the storage medium, e.g., breakage of the magnetic tape.

We have found that a computerized data base has numerous advantages in the manipulation of large amounts of data. For example, selective retrieval and editing of bibliographic citations is made trivial through the use of BDMS, and several of the data element keys (indexes) can be searched for a specific topic, e.g., Author, thus facilitating the generation of various quick indexes to the stored records.

Essentially all the records have a category called "Descriptors" which contain key words to describe the data content. This enables one to retrieve all the records that deal with a particular property; for example, one may retrieve all the records that deal with chemical geothermometers. At the present time, searches are allowed on only one descriptor at a time; later we expect to have the capability of performing a Boolean search. This will permit a file search with a string of operations, e.g., to find all the stored citations that deal with geothermometers and silica solutions. All "Descriptors" used are taken from a thesaurus of controlled items.

Figure 3 is an example of application of the computer file system to chemical geothermometers. It shows a typical printout in a user-type format which contains three records dealing with chemical geothermometers. This form of the GRID bibliographic compilation includes the data elements, title, author, reference to the literature, and is annotated by addition of descriptors from a control thesaurus of geothermal terms. All of the data elements, including the descriptors, are machine searchable and can be used for generating indexes to provide quick access to desired information.

Figure 4 shows a printout of a machine-generated index covering subjects such as geopressured systems and geothermal activity. Each record contains the author short code and the record number. The author short code contains the last name of the first named author of the article; the two digits are the last two digits of the year in which the paper was published. The record number refers to the information shown in Figure 3. Figure 5 illustrates an index based on descriptors, for example temperature measurement, temperature surveys, and Texas. Besides the descriptor, which is an annotation covering the information content of the record, is given the journal title (e.g., Journal of Geophysical Research) and the record number which refers to the paper. Figure 6 is an index dealing with geothermometry; if one is interested in all the stored literature dealing with chemical geothermometers, one can obtain a printout by keying the appropriate computer commands. In this printout you have the title of the paper and the record number for quick referral.

Figure 7 is an alphabetical index based on all the authors of the papers which are listed in our geothermometer computer file; it includes not only the author but the title of the paper and the record number. In

5E

FOURNIER 74
EXPLORATION/GEOCHEMISTRY

TITLE- GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-PART 1, BASIC ASSUMPTIONS.

AUTHOR- FOURNIER, R.O.;WHITE, D.E.;TRUESDELL, A.H. [GEOLOGICAL SURVEY, MENLO PARK, CALIF. (USA)].

REFERENCE- J. RES. U. S. GEOL. SURV., V. 2 (3), P. 259-262(1974).

DESCRIPTORS- GEOCHEMICAL SURVEYS; SURFACE TEMPERATURES; SUBSURFACE TEMPERATURES; WATER ANALYSIS; CONVECTION; ASSUMPTIONS; SOLUBILITIES; EQUILIBRIUM; EXPERIMENTAL PROCEDURES; GEOTHERMOMETRY; SOLUBILITIES; TEMPERATURE DEPENDENCE.

5G

FOURNIER 74B
EXPLORATION/GEOCHEMISTRY

TITLE- GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-PART 2, ESTIMATION OF TEMPERATURE AND FRACTION OF HOT WATER MIXED WITH COLD WATER.

AUTHOR- FOURNIER, R.O.;TRUESDELL, A.H. [GEOLOGICAL SURVEY, MENLO PARK, CALIF. (USA)].

REFERENCE- J. RES. U. S. GEOL. SURV., V. 2 (3), P. 263-270(1974).

DESCRIPTORS- RESERVOIR TEMPERATURES; WATER MIXING; EQUILIBRIUM; GEOTHERMOMETRY; MIXING MODELS.

6C

FOURNIER 74C
EXPLORATION/GEOCHEMISTRY

TITLE- GEOCHEMISTRY APPLIED TO EXPLORATION FOR GEOTHERMAL ENERGY.

AUTHOR- FOURNIER, R.O.;TRUESDELL, A.H. [GEOLOGICAL

ZABLOCKI 76 ;

RECORD NUMBER 208

GRILLOT 74;

RECORD NUMBER 250

GEOPHYSICS

RUBIN 74 ;

RECORD NUMBER 78

WILLIAMS 74 ;

RECORD NUMBER 337

GEOPRESSURED SYSTEMS

HAMMOND 75;

RECORD NUMBER 35

RINEHART 75 ;

RECORD NUMBER 44

WARD 75 ;

RECORD NUMBER 99

REX 74 ;

RECORD NUMBER 43

MAGARA 75 ;

RECORD NUMBER 166

AUD 75 ;

RECORD NUMBER 221

MAGARA 74 ;

RECORD NUMBER 167

GEOTHERMOMETRY

ARNORSSON 75 ;

RECORD NUMBER 119

GEOTHERMAL ACTIVITY

LYON 74 ;

RECORD NUMBER 285

GEOTHERMAL BRINES

SPOONER 74;

RECORD NUMBER 88

GEOTHERMAL DRILLING

WITHAM 76 ;

RECORD NUMBER 339

GEOTHERMAL ENERGY

PIRSON 75 ;

RECORD NUMBER 194

GEOTHERMAL ENERGY CONVERSION

PALMER 75 ;

RECORD NUMBER 346

GEOTHERMAL EXPLORATION

MEIDAV 75 ;

RECORD NUMBER 11

BARR 75 ;

RECORD NUMBER 20

LACHENBRUCH 76 ;

RECORD NUMBER 163

GEOTHERMAL FIELD

NATHENSON 74 ;

RECORD NUMBER 41

GEOPHYS. J. R. ASTRON. SOC. ;
RECORD NUMBER 325

GEOL. SOC. AM. BULL.;
RECORD NUMBER 329

EARTH PLANET. SCI. LETT. ;
RECORD NUMBER 306

GEOPHYS. J. R. ASTRON. SOC. ;
RECORD NUMBER 336

TEMPERATURE LOGGING

AM. ASSOC. PET. GEOL. BULL. ;
RECORD NUMBER 317

TEMPERATURE MEASUREMENT

ONSEN KOGAKKAI-SHI ;
RECORD NUMBER 67

RAZVED. PROMYSL GEOFIZ ;
RECORD NUMBER 176

NONE
RECORD NUMBER 179

NONE
RECORD NUMBER 186

NONE
RECORD NUMBER 200

NONE
RECORD NUMBER 211

NONE
RECORD NUMBER 177

TEMPERATURE MEASUREMENTS

J. PHYS. E. ;
RECORD NUMBER 236

TEMPERATURE SURVEYS

J. GEOPHYS. RES. ;
RECORD NUMBER 164

GEOPHYS. RES. BULL. ;
RECORD NUMBER 253

GEOPHYS. J. R. ASTRON. SOC. ;
RECORD NUMBER 271

TEMPERATURES

J. GEOPHYS. RES. ;
RECORD NUMBER 168

N. Z. J. GEOL. GEOPHYS. ;
RECORD NUMBER 304

J. GEOPHYS. RES. ;
RECORD NUMBER 308

GEOCHIM. COSMOCHIM. ACTA ;
RECORD NUMBER 89

NONE
RECORD NUMBER 206

TENSILE STRENGTH

J. GEOL. SOC. LONDON;
RECORD NUMBER 275

TEXAS

J. GEOPHYS. RES. ;
RECORD NUMBER 237

OIL GAS J.;
RECORD NUMBER 318

RECORD NUMBER 177

GEOTHERMOMETER

APPLICATION OF THE SILICA GEOTHERMOMETER IN LOW TE
MPERATURE HYDROTHERMAL AREAS IN ICELAND ;

RECORD NUMBER 119

GEOTHERMOMETRY

GEOCHEMISTRY APPLIED TO EXPLORATION FOR GEOTHERMAL
ENERGY ;

RECORD NUMBER 60

RESERVOIR TEMPERATURES OF YELLOWSTONE THERMAL SYST
EMS ;

RECORD NUMBER 95

DIVERSE ORIGINS OF HYDROTHERMAL ORE FLUIDS
;

RECORD NUMBER 101

SULPHUR ISOTOPIC VARIATIONS IN NATURE. II. SULPHUR
ISOTOPE RATIOS OF SULPHIDES FROM THE BROADLANDS G
EOTHERMAL FIELD ;

RECORD NUMBER 130

GEOTHERMAL STUDIES IN REGION OF ISOLATED HOT SPRIN
GS, WESTERN MONTANA ;

RECORD NUMBER 133

ISOTOPIC FRACTIONATION IN SOLIDS ;

RECORD NUMBER 147

LEACH HOT SPRINGS GEOTHERMAL AREA, NEVADA
;

RECORD NUMBER 155

A SYSTEMATIC DEVIATION FROM NA-K-CA GEOTHERMOMETER
BELOW 75 DEGREES C AND ABOVE 10-4 ATM PCO2
;

RECORD NUMBER 156

GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-P
ART 1, BASIC ASSUMPTIONS ;

RECORD NUMBER 58

RADIOLOGICAL CONSIDERATIONS IN DEVELOPMENT OF GEOT
HERMAL RESOURCES IN WESTERN UNITED STATES
;

RECORD NUMBER 69

THE APPLICATION OF THE NA-K-CA GEOTHERMOMETER TO T
HERMAL AREAS OF UTAH AND THE IMPERIAL VALLEY, CALI
FORNIA ;

RECORD NUMBER 90

IMPERIAL VALLEY INVESTIGATIONS-UTILIZATION OF THE
SODIUM-POTASSIUM-CALCIUM GEOTHERMAL EXPLORATION TE
CHNIQUE IN THE IMPERIAL VALLEY AREA, CALIFORNIA
;

RECORD NUMBER 137

THE CHEMICAL COMPOSITION AND ESTIMATED MINIMUM THE
RMAL RESERVOIR TEMPERATURES OF THE PRINCIPAL HOT S
PRINGS OF NORTHERN AND CENTRAL NEVADA ;

RECORD NUMBER 141

GEOTHERMAL SYSTEMS OF NORTHERN NEVADA ;

RECORD NUMBER 66

GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-P
ART 2, ESTIMATION OF TEMPERATURE AND FRACTION OF H
OT WATER MIXED WITH COLD WATER;

RECORD NUMBER 59

PRELIMINARY STUDIES OF SOME GEOTHERMAL AREAS IN IN
DIA ;

RECORD NUMBER 63

the case shown here, for example, under Fournier, R.O., one sees that there are four publications within the time span covered by the computer file.

Figure 8 is a computer-generated index based on the author's affiliation; it includes the author's affiliation, for example, California University, Berkeley, Lawrence Berkeley Laboratory; the author's name, and a reference to the various record numbers under the author's name. In Figure 9, there is illustrated an index based on the journal title, for example, Journal of Physical Research, and again the various authors; in this particular case, all the authors in an article, for example, Lachenbach and Sass as the co-authors of a paper with Sorey and Lewis, and the record number of the citation.

Figure 10 is a printout of data from the GEOTHERM file. In this example, chemical analysis records were selected, formatted, and the data used as input to an accessory program which uses the common chemical geothermometer to calculate the inferred reservoir temperatures.

SUMMARY AND CONCLUSIONS

A computer-based information system has been established with the objective to collect and disseminate worldwide geothermal data. The larger system based on the GRID and GEOTHERM files contains data needed to evaluate important aspects of geothermal utilization, for example, electric power potential, scaling and corrosion effects, and modeling. In this paper, as an example, data in the files was applied to chemical geothermometers. The information system has the capability to retrieve data quickly and will be useful to geothermal specialists, for example in evaluating proposals and assessing reports.

UENCY AND TEMPERATURE DEPENDENCE (FIRST RESULTS)
;

RECORD NUMBER 247

FORSYTHE, G.T.
GEOTHERMAL RESISTIVITY INVESTIGATIONS IN NEW MEXIC
O ;

RECORD NUMBER 264

FOSTER, S.E.
HEAT-FLOW NEAR A NORTH ATLANTIC FRACTURE ZONE
;

RECORD NUMBER 248

FOURNIER, R.O.
GEOCHEMISTRY APPLIED TO EXPLORATION FOR GEOTHERMAL
ENERGY ;

RECORD NUMBER 60

GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-P
ART 1, BASIC ASSUMPTIONS ;

RECORD NUMBER 58

GEOCHEMICAL INDICATORS OF SUBSURFACE TEMPERATURE-P
ART 2, ESTIMATION OF TEMPERATURE AND FRACTION OF H
OT WATER MIXED WITH COLD WATER;

RECORD NUMBER 59

PHYSICAL RESULTS OF RESEARCH DRILLING IN THERMAL A
REAS OF YELLOWSTONE NATIONAL PARK, WYOMING
;

RECORD NUMBER 206

FRANK, D.
INCREASED HEAT EMISSION FROM MOUNT BAKER, WASHINGT
ON ;

RECORD NUMBER 10

RECURRENT GEOTHERMALLY INDUCED DEBRIS AVALANCHES O
N BOULDER GLACIER, MOUNT BAKER, WASHINGTON
;

RECORD NUMBER 4

RECURRENT GEOTHERMALLY INDUCED DEBRIS AVALANCES ON
BOULDER GLACIER, MOUNT BAKER, WASHINGTON
;

RECORD NUMBER 172

FREIDLINE, R.O.
YELLOWSTONE HOT SPOT-NEW MAGNETIC AND SEISMIC EVID
ENCE ;

RECORD NUMBER 322

FRIEDLINE, R.
MARYSVILLE, MONTANA, GEOTHERMAL PROJECT. PART II.
GEOLOGICAL AND GEOPHYSICAL EXPLORATION AT MARYSVIL
LE GEOTHERMAL AREA--1973 RESULTS ;

RECORD NUMBER 227

FRIEDMAN, J.

FRIEDMAN, J.D.
RECURRENT GEOTHERMALLY INDUCED DEBRIS AVALANCHES O
N BOULDER GLACIER, MOUNT BAKER, WASHINGTON
;

RECORD NUMBER 4

RECURRENT GEOTHERMALLY INDUCED DEBRIS AVALANCES ON

BALDI, P. ; FERRARA, G.C. ;
MASSEL, L.; PIERETTI, G. ;
RECORD NUMBER 120

FALCONBRIDGE NICKEL MINES LTD., VANCOUVER, B.C. (CANADA)
BANC, R.B.; WILKINSON, N.M. ;
RECORD NUMBER 121

FLORIDA UNIV., GAINESVILLE (USA). DEPT. OF CIVIL ENGINEERING
RUBIN, H.I. ; CHRISTIANSEN, B.A.
;
RECORD NUMBER 78

FLORIDA UNIV., GAINESVILLE (USA). DEPT. OF GEOLOGY
SMITH, D.L. ;
RECORD NUMBER 321

FORAMINES, S.A.
URBAIN, C.;
RECORD NUMBER 203

GEOLOGICAL SURVEY, ALBUQUERQUE, N.MEX. (USA)
TRAINER, F.W. ;
RECORD NUMBER 94

GEOLOGICAL SURVEY, ALBUQUERQUE, N.M. (USA)

GEOLOGICAL SURVEY, ANCHORAGE, ALASKA (USA)
BARNES, I.; MILLER, T.P. ;
RECORD NUMBER 122
MILLER, T.P. ; BARNES, I.;
PATTON, W.W., JR. ;
RECORD NUMBER 150

GEOLOGICAL SURVEY, CARSON CITY, NEV. (USA)
OLMSTEAD, F.H. ; VAN DENBURGH, A.S.
;
RECORD NUMBER 155

GEOLOGICAL SURVEY, DENVER, COLO. (USA)
RYE, R.O. ; OHMETO, H.C. ;
RECORD NUMBER 79
HOOVER, D.B. ; FRISCHKNECHT, F.C.
; TIPPENS, C.L. ;
RECORD NUMBER 110
MC CARTHY, J.H., JR.;
RECORD NUMBER 145
ANDERSON, L.A. ; JOHNSON, G.R.
;
RECORD NUMBER 214
ZOHDY, A.A.R. ; ROY, A. ;
RECORD NUMBER 340
FRANK, D. ; POST, A. ; FRIEDMAN,
J.D. ;
RECORD NUMBER 4
MUFFLER, L.J.P. ; WILLIAMS, D.L.
;
RECORD NUMBER 40
STANLEY, W.C. ; JACKSON, D.B.
; ZOHDY, A.A.R. ;
RECORD NUMBER 114
KANE, M.F.; MABEY, D.R. ;

IL'IN, V.A. ; CLEYNIK, B.I.
;
RECORD NUMBER 261

INT. GEOL. REV.
MARINOV, N.A. ; TOLSTIKHIN, N.I.
; SHKAPSKAYA, S.G. ;
RECORD NUMBER 144

J. GEOCHEM. EXPLOR.
MC CARTHY, J.H., JR.;
RECORD NUMBER 145
BANC, R.B.; WILKINSON, N.M. ;
RECORD NUMBER 121

J. GEOL. SOC. LONDON
LAJTAI, E.Z. ; LAJTAI, V.N.
;
RECORD NUMBER 275
SIBSON, R.H. ; MOORE, J.M.
; RANKIN, A.H. ;
RECORD NUMBER 319

J. GEOPHS. RES.
SOREY, M.L. ; LEWIS, R.E.
;
RECORD NUMBER 161

J. GEOPHYS. RES

J. GEOPHYS. RES.
HOOVER, D.B. ; FRISCHKNECHT, F.C.
; TIPPENS, C.L. ;
RECORD NUMBER 110
IYER, H.M.; HITCHCOCK, T. ;
RECORD NUMBER 111
STEEPLES, D.W. ; PITT, A.M.;
RECORD NUMBER 116
MARINER, R.H. ; WILLEY, L.M.
;
RECORD NUMBER 143
LACHENBRUCH, A.H. ; SOREY, M.L.
; SASS, J.H.; LEWIS, R.E.
;
RECORD NUMBER 164
MERCER, J.W. ; PINDER, G.F.
; DONALDSON, I.G. ;
RECORD NUMBER 168
ANDERSON, L.A. ; JOHNSON, G.R.
;
RECORD NUMBER 214
BIRCH, F.S. ;
RECORD NUMBER 224
BIRL, P. ; TOKSOZ, M.N. ;
SLEEP, N.H. ;
RECORD NUMBER 225
DECKER, E.R. ; SMITHSON, S.B.
;
RECORD NUMBER 237
GRINGARTEN, A.C. ; WITHERSPOON, P.A.
; OHNISHI, Y. ;
RECORD NUMBER 251

GEOTHERMAL FIELD	COUNTY	SAMPLE TYPE	SOLUTE ANALYSIS				TEMPERATURE (C)					
							GEOCHEMICAL					MEASURED
			NA	K	CA	SIO2	NA-K-CA 1/3	NA-K-CA 4/3	SIO2 AD	SIO2 COND	SIO2 CHAL	
ALASKA												
BAILEY HOT SPRINGS		SURFACE			13.0	142.0			150	158	132	85
BARANOF HOT SPRINGS		SURFACE	51.0	1.2	2.5	70.0	111	68	117	119	88	51
BELL ISLAND HOT SPRINGS		SURFACE			4.6	105.0			135	140	112	72
CHENA		SURFACE	110.0	3.3	1.3	85.0	137	129	125	129	99	57
CIRCLE		SURFACE	230.0	9.8	20.8	95.0	143	108	130	135	106	54
EAST COLD BAY		SURFACE	780.0	34.0	229.0	68.0	144	110	115	117	86	54
FISH BAY AREA		SURFACE			13.0	110.0			137	143	115	47
GEYSER BIGHT		SURFACE	441.0	33.0	.1	303.0	236	493	192	210	194	100
GODDARD HOT SPRINGS		SURFACE	1500.0	61.0	380.0	120.0	147	129	141	148	121	67
GRANITE MOUNTAIN (SWEEPST		SURFACE	51.0	1.3	2.0	75.0	116	75	120	122	92	49
HOONIAH HOT SPRINGS (WHIT		SURFACE			85.0	98.0			132	136	108	44
HOT SPRINGS BAY, AKUTAN I		SURFACE	288.0	21.0	9.9	128.0	179	167	145	152	125	83
HOT SPRINGS COVE, UMNAK I		SURFACE	603.0	33.0	163.0	88.0	153	115	127	131	101	89
KANUTI		SURFACE	111.0	3.7	2.7		136	114				66
LITTLE MELOZITNA		SURFACE				80.0			122	126	96	
MANLEY HOT SPRINGS (BAKER		SURFACE	130.0	4.5	4.0	65.0	137	113	113	115	84	56
MELOZI HOT SPRINGS (MELOZ		SURFACE			11.0	78.0			121	124	94	55
NEAR NORTH END TENAKEE IN		SURFACE	137.0	4.1	21.0	119.0	120	72	141	147	120	82
OKMOK CALDERA, UMNAK ISLA		SURFACE	53.0	5.6	18.0	59.0	164	75	109	110	79	22
PILGRIM HOT SPRING		SURFACE	1450.0	61.0	530.0	100.0	146	120	133	138	109	55
SERPENTINE SPRINGS (ARCTI		SURFACE	800.0	41.0	75.0	90.0	161	151	128	132	103	77
SHAKES SPRINGS (CHIEF SHA		SURFACE	87.0	9.2	13.0	108.0	175	105	136	142	114	52
SOUTH		SURFACE	83.0	2.1	5.9	65.0	115	72	113	115	84	
TENAKEE HOT SPRINGS		SURFACE	190.0	3.3	28.0	60.0	101	63	110	111	80	42
TOLOVANA		SURFACE	321.0	23.0	82.0	75.0	162	110	120	122	92	60
ARIZONA												
CLIFTON HOT SPRINGS	GREENLEE	SURFACE	1500.0	82.0	430.0	55.0	160	139	106	107	75	39
GILLARD HOT SPRINGS	GREENLEE	SURFACE	450.0	14.0	22.0	95.0	138	130	130	135	106	82
HOT SPRING N. OF CLIFTON	GREENLEE	SURFACE	2600.0	170.0	740.0	100.0	174	165	133	138	109	59
CALIFORNIA												
AETNA SPRINGS	NAPA	SURFACE	352.0	6.0	22.0	96.0	110	94	131	135	107	21
ARROWHEAD HOT SPRINGS ARE	SAN BERNARDINO	SURFACE	255.0	12.0	27.0	90.0	147	111	128	132	103	
BAKER SODA SPRING	LAKE	SURFACE	2630.0	189.0	69.0	81.0	202	271	123	126	96	24
BIG BEND HOT SPRINGS	SHASTA	SURFACE	565.0	20.0	88.0	73.0	137	110	118	121	90	82
CALISTOGA	NAPA	SURFACE	193.0	8.8	4.5	139.0	155	144	149	157	131	98
COOKS SPRINGS	COLUSA	SURFACE	710.0	50.0	21.0	91.0	187	204	128	132	103	
COSO HOT SPRINGS	INYO	SURFACE	1630.0	244.0	74.0	150.0	238	275	153	161	136	
CRABTREE HOT SPRINGS	LAKE	SURFACE	1650.0	34.0	50.0	154.0	133	167	154	163	138	40
DEADSHOT SPRING	COLUSA	SURFACE	2190.0	199.0	167.0	97.0	203	228	131	136	107	
FALES HOT SPRINGS	MONO	SURFACE	550.0	31.0	42.0	118.0	164	150	141	147	120	59
FOUTS SPRING (CHAMPAGNE)	COLUSA	SURFACE	13.0	1.4	135.0	68.0	128	4	115	117	86	
FOUTS SPRING (REDEYE)	COLUSA	SURFACE	3800.0	56.0	104.0	125.0	125	182	143	150	124	17
GROVERS HOT SPRINGS	ALPINE	SURFACE	423.0	11.0	34.0	96.0	126	108	131	135	107	

GEOTHERMAL FIELD	COUNTY	SAMPLE TYPE	SOLUTE ANALYSIS				TEMPERATURE (C)					
							GEOCHEMICAL					MEA-
			NA	K	CA	SIO2	NA-K-CA 1/3	NA-K-CA 4/3	SIO2 AD	SIO2 COND	SIO2 CHAL	SURED
HUNT HOT SPRINGS	SHASTA	SURFACE	300.0	6.5	53.0	49.0	111	75	102	101	69	58
KELLY HOT SPRING	MODOC	SURFACE	231.0	6.4	29.0	127.0	122	85	144	151	125	95
LONG VALLEY	MONO	SURFACE	390.0	45.0	.9	340.0	238	344	200	219	205	94
LOS GUILICOS WARM SPRINGS	SONOMA	SURFACE	104.0	13.0	19.0	86.0	184	111	126	129	100	29
MARK WEST SPRINGS	SONOMA	SURFACE	29.0	3.9	31.0	105.0	161	48	135	140	112	30
MERCEY HOT SPRINGS	FRESNO	SURFACE	830.0	7.1	43.0	75.0	91	94	120	122	92	46
MORGAN SPRINGS	TEHAMA	SURFACE	1398.0	196.0	79.0	233.0	229	251	177	191	171	
NAPA ROCK SODA SPRINGS (P	NAPA	SURFACE	136.0	5.6	22.0	111.0	133	81	138	143	116	26
NAPA SODA SPRINGS (JACKSO	NAPA	SURFACE	49.0	9.6	82.0	126.0	182	60	144	151	124	
ONE SHOT MINING CO.	NAPA	SURFACE	604.0	34.0	218.0	95.0	152	108	130	135	106	22
ORNBAUM SPRINGS	MENDOCINO	SURFACE	15.0	1.3	117.0	81.0	122	3	123	126	96	16
ORRS HOT SPRINGS	MENDOCINO	SURFACE	140.0	1.3	4.8	61.0	86	67	111	112	81	40
PILGER ESTATES HOT SPRING	RIVERSIDE	SURFACE	888.0	33.0	107.0	79.0	145	132	122	125	95	82
POINT ARENA HOT SPRINGS	MENDOCINO	SURFACE	105.0	.4	.9	53.0	63	62	105	105	73	44
SALT SPRING	GLENN	SURFACE	9400.0	90.0	115.0	140.0	123	222	149	157	131	25
SALT SPRING	SHASTA	SURFACE	3030.0	12.0	1180.0	55.0	62	55	106	107	75	20
SARATOGA SPRINGS	LAKE	SURFACE	224.0	7.9	280.0	99.0	116	46	132	137	109	16
SEIGLER SPRINGS (INCLUDIN	LAKE	SURFACE	162.0	20.0	30.0	170.0	188	122	159	169	146	52
SESPE HOT SPRINGS	VENTURA	SURFACE	320.0	16.0	23.0	92.0	155	130	129	133	104	90
SKAGGS HOT SPRINGS	SONOMA	SURFACE	945.0	29.0	14.0	124.0	152	194	143	150	123	55
SODA SPRING	LAKE	SURFACE	1310.0	60.0	153.0	120.0	158	154	141	148	121	17
SULFUR BANK HOT SPRINGS (	LAKE	SURFACE	1340.0	44.0	26.0	203.0	156	201	169	181	159	99
SURPRISE VALLEY	MODOC	SURFACE	343.0	16.3	11.0	182.0	159	154	163	174	151	86
TRAVERTINE HOT SPRINGS (M	MONO	SURFACE	1109.0	35.0	60.0	89.0	145	155	127	131	102	
TUSCAN SPRINGS (LICK SPRI	TEHAMA	SURFACE	4080.0	51.0	22.0	99.0	112	258	132	137	109	30
VICHY SPRINGS (DOOLINS UK	MENDOCINO	SURFACE	924.0	30.0	49.0	91.0	145	151	128	132	103	29
WALTER SPRINGS (WALTERS M	NAPA	SURFACE	232.0	5.6	28.0	94.0	116	81	130	134	105	
WARNER HOT SPRINGS	SAN DIEGO	SURFACE	97.0	1.0	.4	107.0	100	111	136	141	113	
WENDEL - AMEDEE	LASSEN	SURFACE	227.0	6.8	16.0	96.0	129	101	131	135	107	
WILBUR HOT SPRINGS AREA	COLUSA	SURFACE	8500.0	440.0	2.8	200.0	240	781	168	180	158	53
COLORADO												
AVALANCHE SPRINGS	PITKIN	SURFACE	337.0	90.0	382.8	98.0	223	124	132	136	108	53
CEROLLA HOT SPRINGS (POWD	GUNNISON	SURFACE	267.2	74.7	133.3	79.5	233	144	122	125	95	45
COTTONWOOD SPRINGS	CHAFFEE	SURFACE	108.0	2.6	5.6	55.0	117	83	106	107	75	57
GLENWOOD SPRINGS	GARFIELD	SURFACE	7585.5	477.5	853.1	99.6	190	242	133	137	109	41
IDAHO SPRINGS	CLEAR CREEK	SURFACE	500.0	77.0	138.0	58.0	207	154	109	109	78	50
MINERAL HOT SPRINGS (CHAM	SAGUACHE	SURFACE	140.0	14.0	56.0	51.0	168	91	103	103	71	63
MT. PRINCETON SPRINGS	CHAFFEE	SURFACE	57.0	1.7	10.0	61.0	113	52	111	112	81	54
ORVIS HOT SPRING (RIDGWAY	OURAY	SURFACE	374.0	102.0	274.1	57.5	230	141	108	109	77	57
PAGOSA AREA	ARCHULETA	WELL	607.0	260.0	230.2	160.2	277	204	156	166	141	60
PONCHA HOT SPRINGS	CHAFFEE	SURFACE	200.0	8.6	16.0	86.0	143	108	126	129	100	66
ROUTT HOT SPRING	ROUTT	SURFACE	162.2	11.1	7.5	88.4	168	137	127	131	102	64
STEAMBOAT SPRINGS	ROUTT	SURFACE	2047.0	155.0	113.0	84.8	195	227	125	129	99	24
WAGON WHEEL GAP	MINERAL	SURFACE	462.0	46.0	65.0	86.0	188	152	126	129	100	57
WAUNITA HOT SPRINGS	GUNNISON	SURFACE	154.6	2.5	5.4	85.7	106	87	126	129	100	70

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TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720