GL01681

Extracting Geothermal Energy Can Be Hard

Experience at the Baca geothermal field shows that withdrawing energy from the ground can be tougher than discovering the field

The initially high expectations of the mid-1970's for the rapid development of geothermal energy have been lowered. One reason is continuing uncertainty about the extraction of geothermal energy. Drillers can have a good idea of which areas have concentrations of geothermal energy beneath the surface and still have trouble bringing up enough energy to make a power plant worthwhile. The extraction problem has been highlighted by the recent termination of a federal geothermal demonstration project at the Baca field of the Valles Caldera, New Mexico, the sixth largest geothermal province in the United States. The problem at Baca is not necessarily insoluble, but it is tending to accentuate industry's cautious approach to geothermal exploration.

The Baca geothermal field sits atop the remains of a volcanic eruption 300 times the size of Mount St. Helens that 1.1 million years ago spewed ash over much of the Southwest. One hundred thousand years after the last major volcanic activity, steam, hot water, and gas still seep up through 2000 meters of ash-turned-rock in the Valles Caldera, the 20-kilometer-wide depression left from the cataclysmic eruption. This hydrothermal activity and the results of exploratory drilling in the 1960's encouraged Union Geothermal, a division of Union Oil Company of California, to lease 100,000 acres in 1971 and begin exploratory drilling.

By 1976, initial drilling results at Baca looked good. Five of the 11 wells produced commercially acceptable amounts of hot water and steam. That accounted for about one-third of the energy required for a 50-megawatt power plant. In fact, well tests indicated that the geothermal reservoir penetrated by the wells contains more than 1 trillion liters of hot water. At the time, Union estimated that eight 50-megawatt power plants could withdraw hot water and steam from the reservoir for 30 years. The first plant would require only another ten successful wells to meet its requirement, Union estimated.

In 1977, the Department of Energy (DOE) solicited competitive proposals for industry participation in a geothermal demonstration project; Union thought that Baca was a sound candidate. DOE, relying on its own experts as well as consultants at Lawrence Berkeley Laboratory (LBL) and the U.S. Geological Survey (USGS), agreed that there was little risk that the Baca reservoir could not support the energy requirements of a single power plant. DOE awarded the project to Union and the Public Service Company of New Mexico under a 50:50 government-industry funding arrangement.

To this day, no one doubts that the hot water is down there—the problem is that Union was unable to drill into enough of it soon enough to be sure of supplying even the single plant. Drilling subsequent to the signing of the cooperative agreement produced only two successful wells out of 13 attempts.

Part of the problem was the difficulty of drilling at Baca, according to a team of experts* appointed by DOE to review the experience at Baca. The rock is hard and is riddled by faults and fractures formed by the forces that have been shaping the Valles Caldera for the past million years. As at some other geothermal sites, the hot water flowing through these fractures and the natural voids of the rock is under less pressure than the drilling fluid that cools and cleans the drill bit. If standard drilling techniques were used, this drilling mud would be pushed into the permeable formations and baked into a permanent seal.

The problems that ensued from the rock and the under-pressure conditions were formidable: drill pipe corroded, stuck, or twisted off in the hole; drill-hole sides collapsed; drill-hole casing wore out or collapsed; and drilling fluids disappeared into unmapped permeable rock formations. Union encountered serious problems during three-quarters of its 31 drilling attempts, according to the review team. These problems not only cost money and time but made it more difficult for Union to decipher what it was that they were drilling through, the report says.

Understanding the nooks and crannies of the Baca reservoir proved to be the fatal problem for the demonstration project. Most of this volcanic rock is impermeable. What empty space exists as pores and microfissures is often not connected to other voids, so fluids cannot flow. Geothermal fluids themselves can isolate what permeable zones there are by depositing a mineral seal in the voids. Not all permeable zones even contain fluids. The trick, then, is to predict where in a jumble of fractures, faults, and partially sealed zones of permeability there is hot water that is free to flow into a well. This is a far cry from developing most major oil fields. Once found, a large oil field can be blanketed with a grid of wells, most of which will produce oil.

After failing to find more of these permeable productive zones after initial successes, Union developed a predictive model to guide their drilling. According to the review team, it emphasized the permeability provided by the faults along the edge of a block of rock that had dropped downward to form Redondo Canyon, the site of most of the drilling. Still not much luck. On 1 May 1981, Union formally notified DOE that it could not supply the required steam within a reasonable amount of time.

Failing to find enough naturally permeable production zones in the volcanic rock at Baca, Union suggested and DOE agreed to two alternative approaches. One was the creation of new fractures by hydrofracturing, the pumping of large volumes of fluid under high pressure into a short section of a well. Fractures did form in the two test wells, but apparently they did not intersect the natural, water-filled cracks. The other approach was extremely deep drilling aimed at the nonvolcanic limestone and granite underlying the volcanic rock of the caldera. Two deep wells encountered plenty of heat—temperatures reached as high as 341°C—but they found no flowing fluids and no permeability. In January 1982, the three parties decided to terminate their agreement.

In its postmortem of the Baca project, the review team suggested several ways that the search might have been made more successful. Examining the geological well data, the team concluded that half of the steam or hot water sources that drillers did manage to penetrate are

*The reservoir definition review team consisted of: D. Nielson, University of Utah Research Institute; N. Goldstein, M. Wilt, C.-F. Tsang, and G. S. Bodvarsson, LBL; A. Truesdell, USGS; W. Laughlin, Los Alamos National Laboratory; W. Holman and M. Molloy, DOE; S. Garg and D. Riney, S-Cubed, Inc. The review team's final report, LBL-14132, June 1982, is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. Price code: A04.

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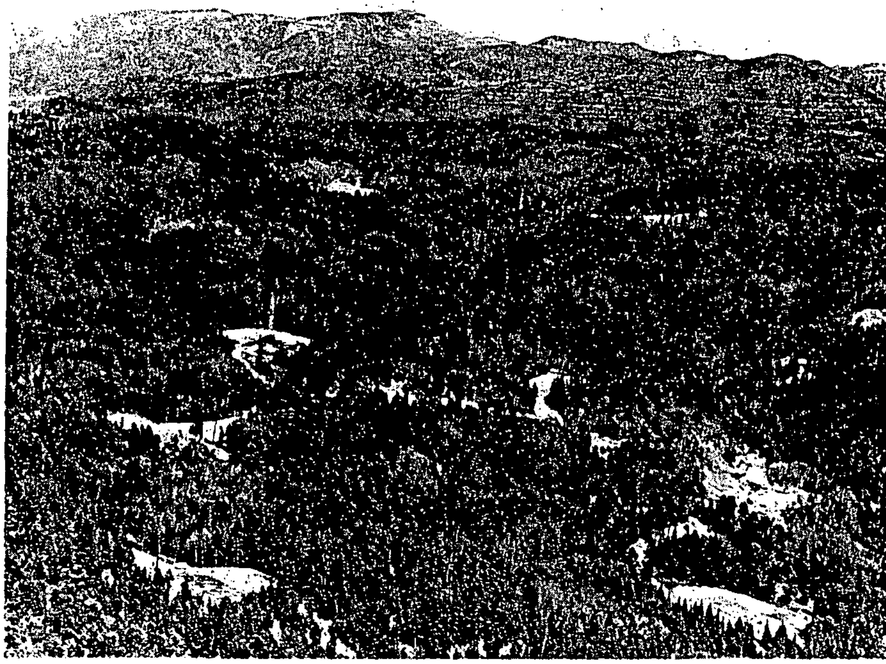
more-or-less flat-lying, permeable layers of volcanic sandstone or ash. Union included neither these zones nor faults that cut across Redondo Canyon in their drilling model, the team contends.

The team's report also noted that geophysical surveys helped locate regions that might contain geothermal reservoirs, but more intensive surveys, which might have more clearly delineated the extent of the reservoir, were not conducted. That such surveys could have been valuable, the report says, is suggested by the coincidence of all of the deep, productive wells with a single, 10-square-kilometer geophysical anomaly. All this, team members emphasize, is seen in hindsight. At the time, the Baca reservoir seemed to be simple and predictable. All that was required, everyone believed, was further drilling.


Union Geothermal

Drill sites at the Baca geothermal field

Union takes issue with these conclusions. The crosscutting faults and permeable strata are there, a spokesman says, but Union geologists do not believe that the positions of such flow paths are predictable enough to guide drilling operations. Likewise, geophysical surveys can be helpful in locating favorable areas, but in the geologically complex Rendondo Canyon area, more geophysical studies would do little to define new drilling targets, the spokesman says.

Even if such technical aids had boosted the drilling success rate at Baca, some researchers doubt that it would have been the productive geothermal field that Union expected. Gudmundur Bodvarsson (a review team member) and his colleagues at LBL have used their own methods to estimate the amount of hot water in the Baca reservoir and the practicality of withdrawing it to produce power.† They agree that there is more than enough hot water there, but ". . . it is questionable that [that portion of] the Baca field can supply enough steam for a 50 MW power plant for 30 years." That conclusion is controversial.

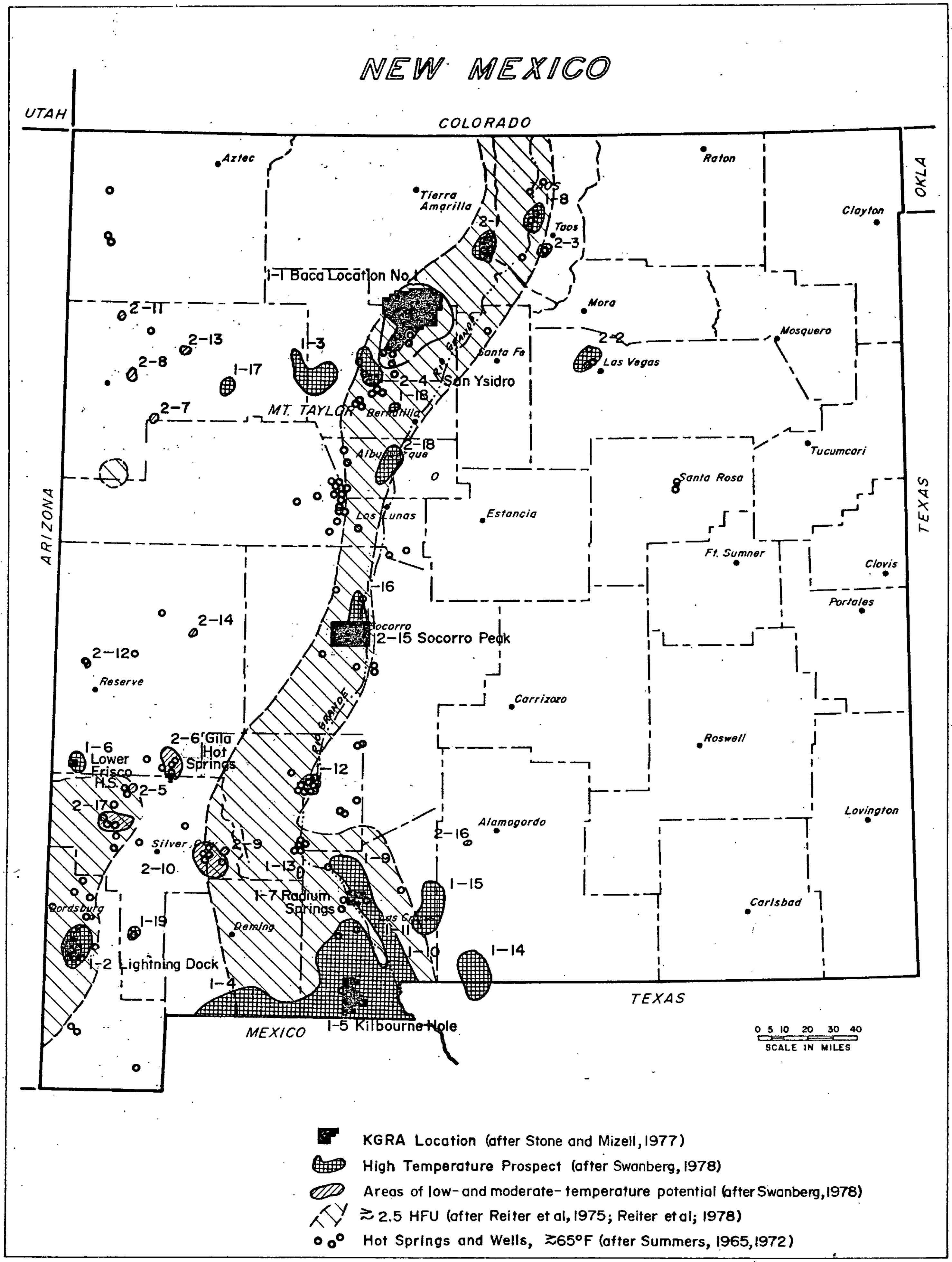
The problem, according to the LBL group, is that the very act of rapidly extracting fluids would cool the rock around the well, reduce the pressure there, and thus decrease the well's output. In the vicinity of a well, the hot water flashes to steam, soaking up thermal energy and cooling the reservoir. The low hydrostatic pressure and low permeability of the reservoir, which restricts the flow of fluids from a distance, promote such boiling. The measure of the ease of flow within a reservoir is called transmissivity. Its value at Baca is ten times smaller than at successfully developed fields such as The Geysers in California, the LBL group notes. Both the Union model for estimating generating capacity and the subsequently developed LBL model take account of transmissivity; Union's allows the entire reservoir to drain freely into a well but restricts resupply from outside the reservoir, while LBL's restricts flow within a subdivided reservoir. But the LBL group believes that their more complicated model is more realistic. That is unlikely to be proven until a geothermal reservoir is modeled both ways and then actually put into power production. A third opinion, as expressed by Roland Horne of Stanford University, is that reservoir modeling in either manner is "extremely problematical in fractured systems," since the models would contain too little information about the reservoir to be useful until it was too late.

All in all, the Baca experience has been a sobering one for those in geothermal exploration. They are unlikely to underestimate again the unpredictability of complexly fractured, volcanic geothermal fields. But geothermal exploration will still be difficult at times. "I don't believe we have adequate tools for assessing and modeling volcanic fractures," says Martin Molloy, a review team member and DOE's Baca project termination manager in Oakland, California. "Our models [of reservoir structure and behavior] are not doing well because of fundamental shortcomings of understanding."

Those shortcomings are showing up at geothermal fields other than Baca. In Iceland, a 30-megawatt plant at Krafla is producing only 15 megawatts for lack of sufficient fluids. Problems of hot but scarce fluids have also plagued development of La Primavera field in Mexico. At Hatchobaru, the reservoir produces sufficient hot fluids, but drillers have not been able to find enough permeable zones to dispose of the waste water. At Kakkonda, reinjected waste water found an unexpected shortcut back to the production wells, decreasing power production until other reinjection wells could be drilled. Even at The Geysers, the United States' premiere geothermal field, success has reportedly been achieved by much trial and error drilling that eventually helped drillers learn how to locate producing zones more easily in the fractured volcanic rock there.

Technical problems may have technical solutions, as the oil and gas industry has often demonstrated. The trend toward initial installation of smaller power production units—10 to 20 megawatts rather than 50 megawatts—is giving drillers more time to deal with the technical problems of geothermal energy extraction. With Baca behind it and budget cuts making themselves felt, DOE has pulled out of all geothermal commercialization projects except one (at Heber in southern California) to concentrate on solving technical problems, including how to understand fractured volcanic systems. In the meantime, Union Geothermal is completing additional testing of the present wells at Baca in preparation for a return to exploration, rather than power production, at Valles Caldera.—RICHARD A. KERR

†G. S. Bodvarsson, S. Vonder Haar, M. Wilt, and C.-F. Tsang, *Water Resources Research*, in press.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High Temperature Prospect (after Swanberg, 1978)
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≳ 2.5 HFU (after Reiter et al, 1975; Reiter et al; 1978)
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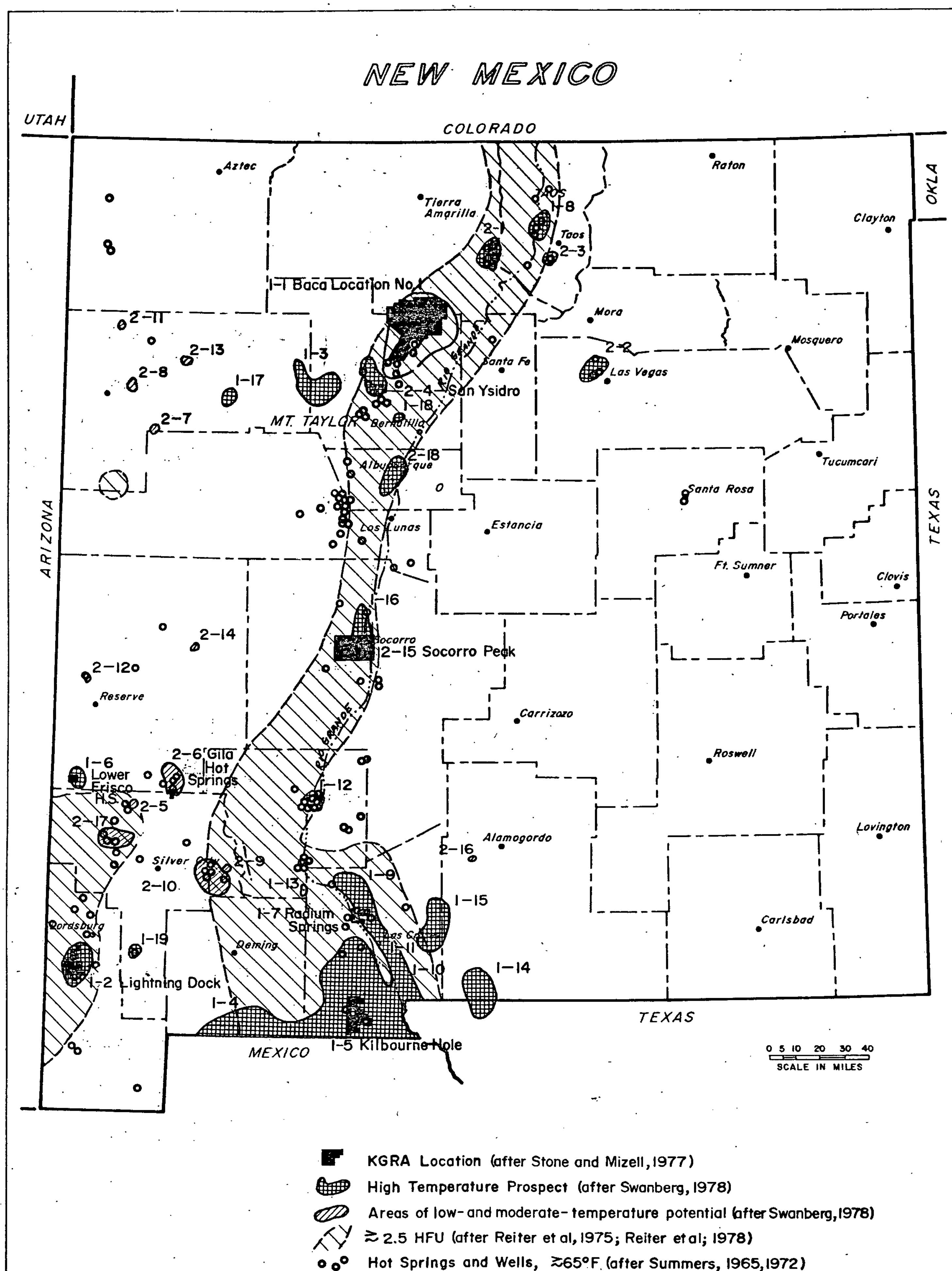
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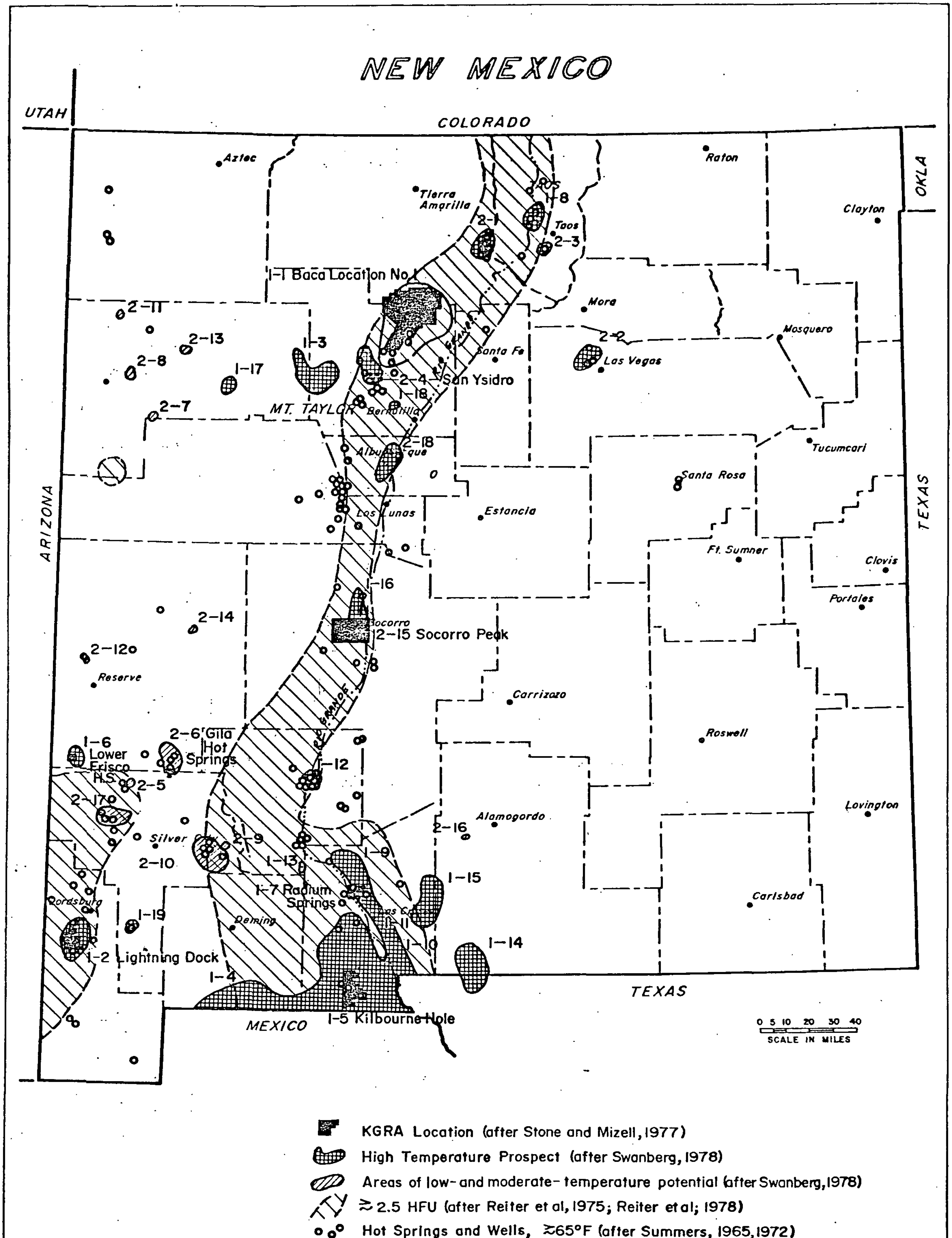
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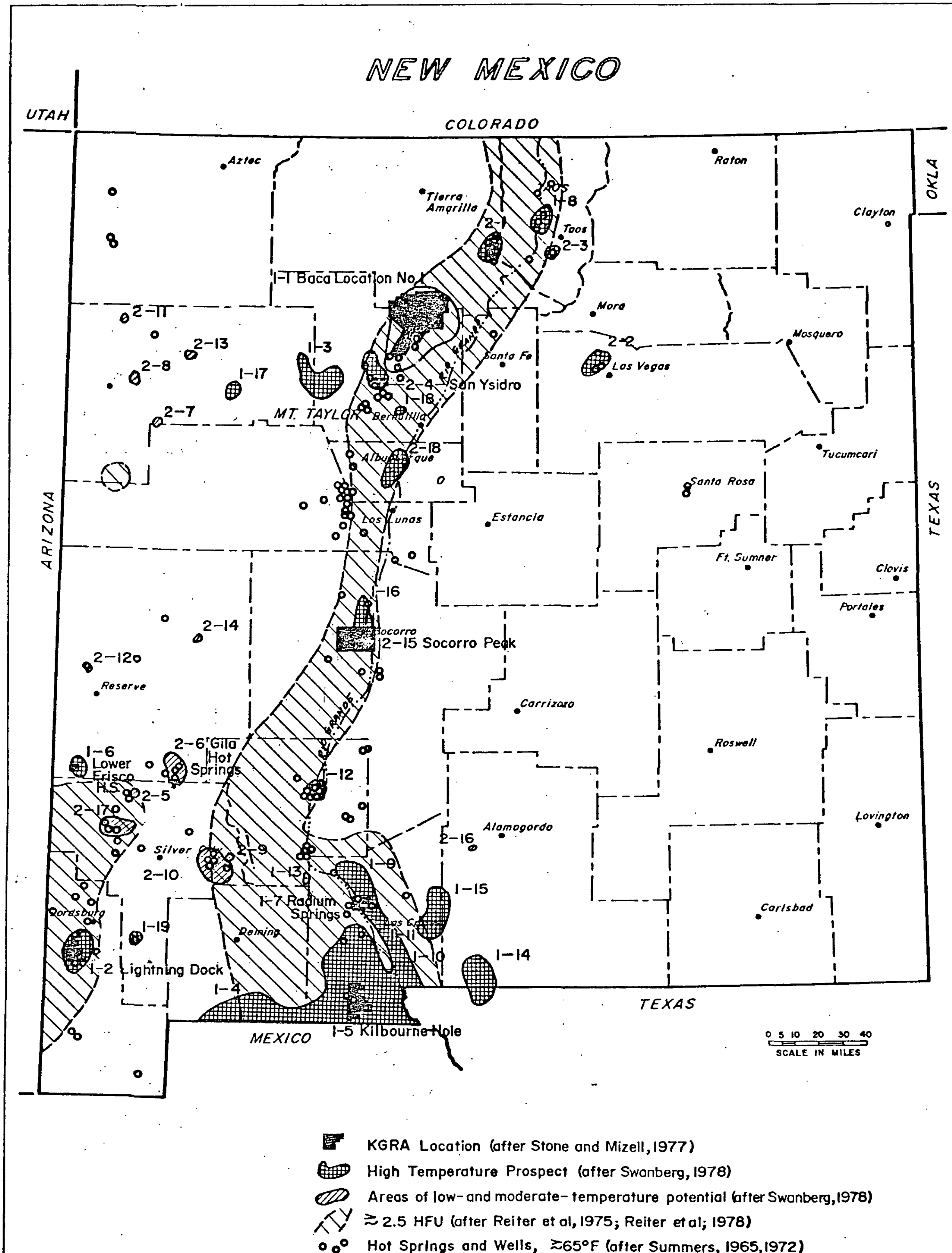
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NEW MEXICO HIGH-TEMPERATURE RESOURCE PROSPECTS

	Map Ref	Lat.	Long	$T_{surface}$ (°C)	T_{SiO_2} (°C)	T_{NaKCa} (°C)	$T_{subsurface}$ (°C)
Areas Sampled:							
Baca Location No. 1 [1]	1-1	35°43°'	106°32'	87	177	234	240
Lightning Dock [1]	1-2	32°08.5'	108°50'	99	160	167	170
Guadalupe Area	1-3	35°30'	107°15'	35	156	177	170
Columbus Area	1-4	31°45'	107°30'	31	135	195	155 [2]
Kilbourne Hole [1]	1-5	31°45'	106°50'	28	133	200	155 [2]
Lower Frisco H.S. [1]	1-6	33°15'	108°47'	49	132	148	150
Radium S. [1]	1-7	32°30'	106°55.5'	53	118	223	130 [2]
Mamby's H.S.	1-8	36°31.6'	105°40.6'	41	116	168	125 [2]
San Diego Mountain	1-9	32°38'	106°58'	warm	105	233	125 [2]
Mesquite-Berino	1-10	32°10.0'	106°40.0'	31	112	175	120 [2]
Las Alturas	1-11	32°15.0'	106°46.0'	43	109	179	120 [2]
Truth or Consequences	1-12	33°08.1'	107°15.2'	45	96	180	100 [2]
Derry Spring	1-13	32°47.6'	107°16.6'	33	83	156	100 [2]
Areas from WATSTORE:							
Southern Tulsarosa Basin	1-14	32°05'	106°05'	71	--	--	150
White Sands (Town)	1-15	32°25'	106°25'	54	114	160	150
North of Socorro	1-16	34°20'	106°50'	41	110	166	150
Prewitt Area	1-17	35°26'	107°53.0'	46	100	200	150
Jemez Reservoir	1-18	106°40'	106°40'	warm	120	150	150
Lordsburg	1-19	32°13.7'	108°30.7'	33	91	151	150

1 KGRA

2 Estimated subsurface temperature in the 150-200°C range if mixing models are applied to the silica data.

NEW MEXICO HIGH-TEMPERATURE RESOURCE PROSPECTS

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1 KGRA

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NEW MEXICO LOW-AND MODERATE TEMPERATURE RESOURCE PROSPECTS

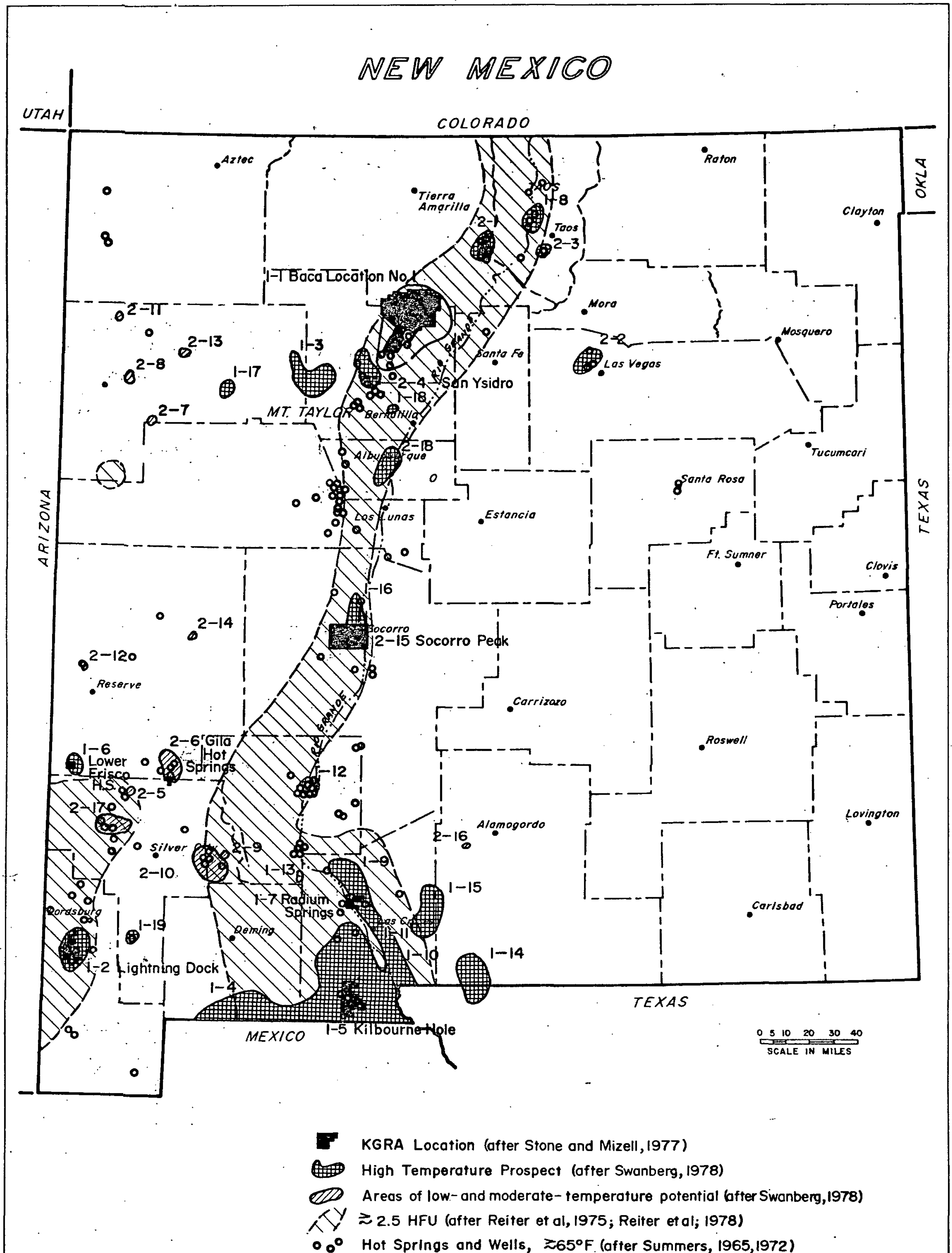
	Map Ref	Lat.	Long	$T_{surface}$ (°c)	T_{SiO2} (°C)	T_{NaKCa} (°C)	$T_{subsurface}$ (°C)
Ojo Caliente	2-1	36°18.3'	106°03.0'	56	122	161	130
Montezuma H.S.	2-2	35°39.2'	105°17.4'	59	122	140	130
Ponce de Leon	2-3	36°19.4'	105°36.5'	34	106	92	105
San Ysidro [1]	2-4	35°35'	106°50'	52	89	160	100
Turkey Creek H.S.	2-5	33°06.5'	108°29.0'	74	117	68	L.T.
Gila H.S. [1]	2-6	33°10'	108°10'	66	129	77	L.T.
Closson	2-7	35°15.5'	108°19.4'	61	95	51	L.T.
Fort Wingate	2-8	35°30'	108°35'	61	--	--	L.T.
Mimbres H.S.	2-9	32°44.9'	107°50.1'	58	107	75	L.T
Faywood H.S.	2-10	32°33.3'	107°59.7'	54	97	78	L.T.
Tohatchi	2-11	35°55.3'	108°34.7'	39	66	82	L.T.
San Francisco H.S.	2-12	33°49.8'	108°47.9'	37	97	52	L.T.
Crown Point	2-13	35°41.6'	108°08.4'	37	60	80	L.T.
E. San Augustin Plain	2-14	34°00.5'	108°05.5'	35	108	53	L.T.
Socorro [1]	2-15	34°05.0'	106°57.0'	34	61	72	L.T.
Garton Well	2-16	32°46.8'	106°09.0'	34	63	100	L.T.
Cliff Area	2-17	32°52.6'	108°35.0'	31	85	53	L.T.
Albuquerque Area	2-18	35°05'	106°45'	30	--	--	L.T.

[1] KGRA.

NEW MEXICO LOW-AND MODERATE TEMPERATURE RESOURCE PROSPECTS

	Map Ref	Lat.	Long	$T_{surface}$ (°c)	T_{SiO2} (°C)	T_{NaKCa} (°C)	$T_{subsurface}$ (°C)
Ojo Caliente	2-1	36°18.3'	106°03.0'	56	122	161	130
Montezuma H.S.	2-2	35°39.2'	105°17.4'	59	122	140	130
Ponce de Leon	2-3	36°19.4'	105°36.5'	34	106	92	105
San Ysidro [1]	2-4	35°35'	106°50'	52	89	160	100
Turkey Creek H.S.	2-5	33°06.5'	108°29.0'	74	117	68	L.T.
Gila H.S. [1]	2-6	33°10'	108°10'	66	129	77	L.T.
Closson	2-7	35°15.5'	108°19.4'	61	95	51	L.T.
Fort Wingate	2-8	35°30'	108°35'	61	--	--	L.T.
Mimbres H.S.	2-9	32°44.9'	107°50.1'	58	107	75	L.T
Faywood H.S.	2-10	32°33.3'	107°59.7'	54	97	78	L.T.
Tohatchi	2-11	35°55.3'	108°34.7'	39	66	82	L.T.
San Francisco H.S.	2-12	33°49.8'	108°47.9'	37	97	52	L.T.
Crown Point	2-13	35°41.6'	108°08.4'	37	60	80	L.T.
E. San Augustin Plain	2-14	34°00.5'	108°05.5'	35	108	53	L.T.
Socorro [1]	2-15	34°05.0'	106°57.0'	34	61	72	L.T.
Garton Well	2-16	32°46.8'	106°09.0'	34	63	100	L.T.
Cliff Area	2-17	32°52.6'	108°35.0'	31	85	53	L.T.
Albuquerque Area	2-18	35°05'	106°45'	30	--	--	L.T.

[1] KGRA.


NEW MEXICO
UTAH
COLORADO
OKLA
ARIZONA
TEXAS
MEXICO
Aztec
Tierra Amarilla
Raton
Clayton
Taos
Mora
Santa Fe
Las Vegas
Mosquero
Bernalillo
Albuquerque
Los Lunas
Estancia
Santa Rosa
Tucumcari
Ft. Sumner
Clovis
Portales
Socorro
Reserve
Carrizozo
Roswell
Alamogordo
Lovington
Silver City
Deming
Lordsburg
Las Cruces
Carlsbad
MT. TAYLOR
1-1 Baca Location No.1
1-2 Lightning Dock
1-3
1-4
1-5 Kilbourne Hole
1-6 Lower Frisco H.S.
1-7 Radium Springs
1-8
1-9
1-10
1-11
1-12
1-13
1-14
1-15
1-16
1-17
1-18
1-19
2-1
2-2
2-3
2-4 San Ysidro
2-5
2-6 Gila Hot Springs
2-7
2-8
2-9
2-10
2-11
2-12
2-13
2-14
2-15 Socorro Peak
2-16
2-17
2-18
0 5 10 20 30 40
SCALE IN MILES
KGRA Location (after Stone and Mizell, 1977)
High Temperature Prospect (after Swanberg, 1978)
Areas of low- and moderate- temperature potential (after Swanberg, 1978)
≳ 2.5 HFU (after Reiter et al, 1975; Reiter et al; 1978)
Hot Springs and Wells, ≳65°F (after Summers, 1965, 1972)

Research Proposal Submitted to
New Mexico Energy Institute - Geothermal

by

University of New Mexico
Department of Geology
Albuquerque, New Mexico 87131

COMPILATION OF GEOSCIENCE DATA RELATING TO DIRECT-HEAT GEOTHERMAL POTENTIAL OF NEW MEXICO

Principal Investigators

Jonathan F. Callender
George R. Jiracek
University of New Mexico

New or renewal proposal: New
Amounted requested: $16,995

Proposed starting date: June 1, 1978
Duration: 4 months

Endorsements:

Principal Investigator
Name Jonathan F. Callender

Signature ______

Title Assoc. Prof. Geology

Telephone (505) 277-4808

Date ______

Principal Investigator
Name George R. Jiracek

Signature ______

Title Assoc. Prof. Geology

Telephone (505) 277-3636

Date ______

Department Head
Name Douglas G. Brookins

Signature ______

Title Professor

Telephone (505) 277-4204

Date ______

Institutional
Admin. Official
Name Edmund B. Kasner

Signature ______

Title Director Res. & Fel. Serv.

Telephone (505) 277-3746

Date ______

This proposal seeks funds for a team of investigators from the University of New Mexico to compile selected geoscience data relating to the direct-heat geothermal potential of New Mexico. Such information is intended for consideration in the final state report and maps to be submitted to NOAA as a portion of phase 1 of DOE-DGE's New Mexico Cooperative Program. In addition, certain data are expected to be included in the USGS computer file GEOTHERM. Our plan is to submit a map on the scale 1:500,000, with appropriate documentation, by September 30, 1978 on each of the following items:

1. Subsurface temperature estimates and source water indications from isotopic geothermometers.
2. Location, extent, and ages of young volcanism and intrusion.
3. Location and nature of geothermal spring deposits.
4. Location of known faults and/or lineaments thought to have a bearing on geothermal resources.
5. Distribution of mineral deposits and/or other geochemical indicators of geothermally deposited elements such as Hg and U prospects.
6. Locations and pertinent results of geoelectric surveys associated with geothermal areas.

Words underlined above are key words for each task for which we have identified the following responsible party in the Geology Department at the University of New Mexico:

1. Isotopic - G. P. Landis
2. Volcanism - A. M. Kudo
3. Spring deposits - J. F. Callender
4. Faults - J. F. Callender

5. Mineral deposits - W. E. Elston

6. Geoelectric - G. R. Jiracek

The responsible UNM parties will seek additional data from appropriate individuals with other groups, e.g. from New Mexico Institute of Mining and Technology, New Mexico Bureau of Mines and Mineral Resources, Los Alamos Scientific Laboratory.

To facilitate the compilation of the important information in each of the aforementioned categories we propose to obtain some new data, in particular, new isotopic measurements and volcanic age dates. Expenses for these analyses are reflected in the proposal budget.

The overall responsibility for the collection and timely presentation of the information will be assumed jointly by Callender and Jiracek. It is understood that all correspondence will be made with C. A. Swanberg, New Mexico State University, who will act as state-wide coordinator for this phase of the DOE-DGE direct-heating program.

PROPOSAL BUDGET

Department of Geology

University of New Mexico

Albuquerque, NM 87131

Budget Category	Requested Funds
A. SENIOR PERSONNEL	
1. Co-investigators (6)	
J.F. Callender	1500
G.P. Landis	1500
W.E. Elston	1000
G.R. Jiracek	1000
A.M. Kudo	1000
L.A. Woodward	1000
Total, Senior Personnel	7000
B. OTHER PERSONNEL	
1. Draftsperson (1) 500 hrs. @ $5/hr.	2500
Total, Salaries and Wages (A + B)	9500
C. FRINGE BENEFITS	
1. 13% of A.	910
2. 15% of B.	375
Total Fringe Benefits	1285
D. MATERIALS AND SUPPLIES	
1. Airphotos, satellite imagery, maps, etc.	300
E. DOMESTIC TRAVEL	
1. Las Cruces Trips (2) 1000 mi @ 20¢/mi	200
F. REPRODUCTION COSTS	
Xerox, etc.	500
G. OTHER EXPENSES	
Volcanic age dates (5) @ 300	1500
H. TOTAL DIRECT COSTS (A through G)	13285
I. TOTAL INDIRECT COSTS	
1. 53% of A.	3710
J. TOTAL COSTS (A through I)	16995

Research Proposal Submitted to
New Mexico Energy Research and Development Program

by

University of New Mexico
Department of Geology
Albuquerque, New Mexico 87131

EVALUATION OF THE GEOTHERMAL RESOURCE IN THE ALBUQUERQUE, NEW MEXICO AREA

Principal Investigator

George R. Jiracek
University of New Mexico

New or renewal proposal: New
Amount Requested: $45,852 UNM
$19,073 NMSU
$64,874

Proposed starting date: July, 1, 1978
Duration: 12 months

Endorsements:

Principal Investigator	Department Head	Institutional Admin. Official
Name George R. Jiracek	Name Douglas G. Brookins	Name Edmund B. Kasner
Signature	Signature	Signature
Title Assoc. Prof. Geology	Title Professor	Title Director Res. & Fel. Serv.
Telephone (505)277-3636	Telephone (505)277-4204	Telephone (505)277-3746
Date	Date	Date

Evaluation of the Geothermal Resource

in the Albuquerque, New Mexico Area

ABSTRACT

The energy future of New Mexico depends heavily on utilization in the Albuquerque area where roughly one-third of the State's population resides. The geothermal potential of the Albuquerque area is documented by high temperatures in nearby water and oil wells, the proximity of young volcanoes, and by high heat flow west of the city. This proposal seeks support to complete the first stage of a plan to evaluate the geothermal potential near Albuquerque by employing current geological, hydrological, and geophysical exploration methods with full use of existing data. We have, for example, secured the availability of several hundred line-miles of reflection seismic data from Shell Oil Company and the possible release of geothermal exploration results obtained by Sunoco Energy Development Company. Our program would work closely with agencies such as the U.S. Geological Survey's Hydrology Branch and Seismology Center in Albuquerque. Our exploration team is composed of investigators from the University of New Mexico, New Mexico State University, and Sandia Laboratories. Although our program is designed to prospect for geothermal occurrences of any magnitude, we are expecting fault controlled targets of a low to medium temperature range. Our program includes geological, hydrological (including geochemistry), seismic, gravity, temperature gradient/heat flow drilling, and electrical resistivity studies. The sequential plan involving these techniques would culminate with a decision to discontinue exploration or in a recommendation for continued evaluation and reservoir assessment.

TABLE OF CONTENTS

INTRODUCTION

The energy future of New Mexico depends heavily on utilization in the Albuquerque area, where roughly one-third of the State's population resides. Albuquerque lies in the Rio Grande rift, which is recognized as one of the major geothermal resource areas in the United States. Although there are no hot springs or similar surface manifestations in the immediate vicinity of the city, the proximity of young volcanoes, abnormal temperatures in nearby water and oil wells, and high heat flow to the west of the city testify to a yet undetermined resource. This proposal documents the basic data pointing to the geothermal potential near Albuquerque and presents a sequential plan to evaluate the prospect. Specifically, we seek support to complete the first stage of this evaluation by employing proven geological, hydrological, and geophysical exploration methods with full use of existing data. The latter information will be, in part, previously unavailable data files released to us by major energy exploration concerns.

Our exploration team is composed of investigators from the University of New Mexico, New Mexico State University, and Sandia Laboratories. In addition, we have secured the assistance of both the U.S. Geological Survey's Hydrology Branch and Seismology Center in Albuquerque. The exploration sequence is aimed at specific site location which, upon positive appraisal, would be recommended for continued follow-up and reservoir assessment. To reach this stage of evaluation we have planned a program of water geochemistry, thermal gradient logging (including drilling 5-10 selected holes), supplemental photogeology, geologic mapping, and geophysical surveying. Geophysical interpretation will rely heavily on gravity, electrical resistivity, and seismic data.

Although our program is designed to prospect for geothermal occurrences of any magnitude, we are expecting targets of a low to medium temperature range. Such reservoirs (<150°C) may not be economical for generation of electricity, but the application of such waters for a variety of heating needs may be ultimately more important. A substitution of geothermal energy for space heating, water heating, cooling, industrial processing, etc. could satisfy a large portion of Albuquerque's projected development. This development is planned to the west of the current urban area into the region considered to be of higher geothermal potential. We must emphasize that as stated in a recent state legislative report (Hatton, 1977), "little is presently known about the practicality of geothermal applications in this (Albuquerque) region". However, "conversion to geothermal space-heating for the numerous state-controlled buildings in the area could, if feasible, save the state large sums of money." The impact of the energy conversion to geothermal fluids would extend well beyond space-heating as can be seen in Figure 1 where a variety of uses and temperature ranges are considered. The use of geothermal energy for most of the applications listed in the figure would represent a more valuable use of New Mexico energy resources. The

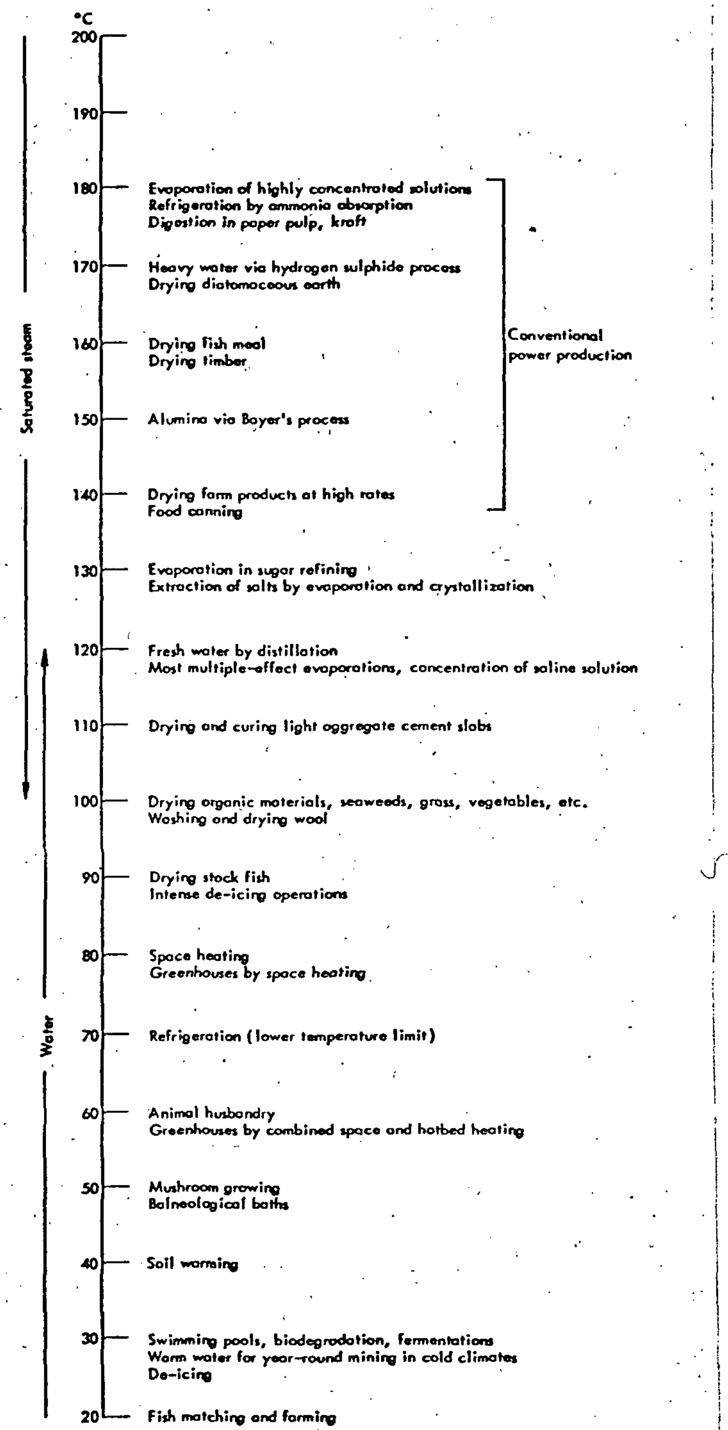


Figure 1. Required temperature (approximate) of geothermal fluids for various applications (from Reistad, 1976).

economical and engineering limitations involved in such applications will be the subject of a recently funded New Mexico Energy Research and Development project for the Albuquerque area (Kauffman and Houghton, 1978). The current proposal represents the first stage in the evaluation of the subsurface resource.

SOME PERTINENT CONSIDERATIONS

Geological

Geologically, Albuquerque lies in the Albuquerque Basin, one of the largest such basins in the Rio Grande valley. The geology of the basin (also called the Albuquerque-Belen Basin) has been recently updated by Kelley (1977). Figure 2 from Hiss and others (1975) includes the major tectonic aspects of the area near Albuquerque. Structural cross-sections included in Figure 3 illustrate the deeply faulted nature of the basin and the bounding uplifts. In the vicinity of Albuquerque the Basin is bounded on the east by the Sandia and Manzano uplifts (Figures 2 and 3). The bounding structures on the west side of the basin are quite different in exposure, magnitude, and style (Kelley, 1977). To the southwest of Albuquerque the structure is the Lucero uplift which merges to the north into the èchelon fault system known as the Puerco fault belt (Figure 2).

Heat flow investigations by Reiter and others (1975) have pointed to a larger geothermal potential on the western side of the Rio Grande rift and this is where young volcanic centers are located near Albuquerque (Figure 2). The Albuquerque volcanoes, forming

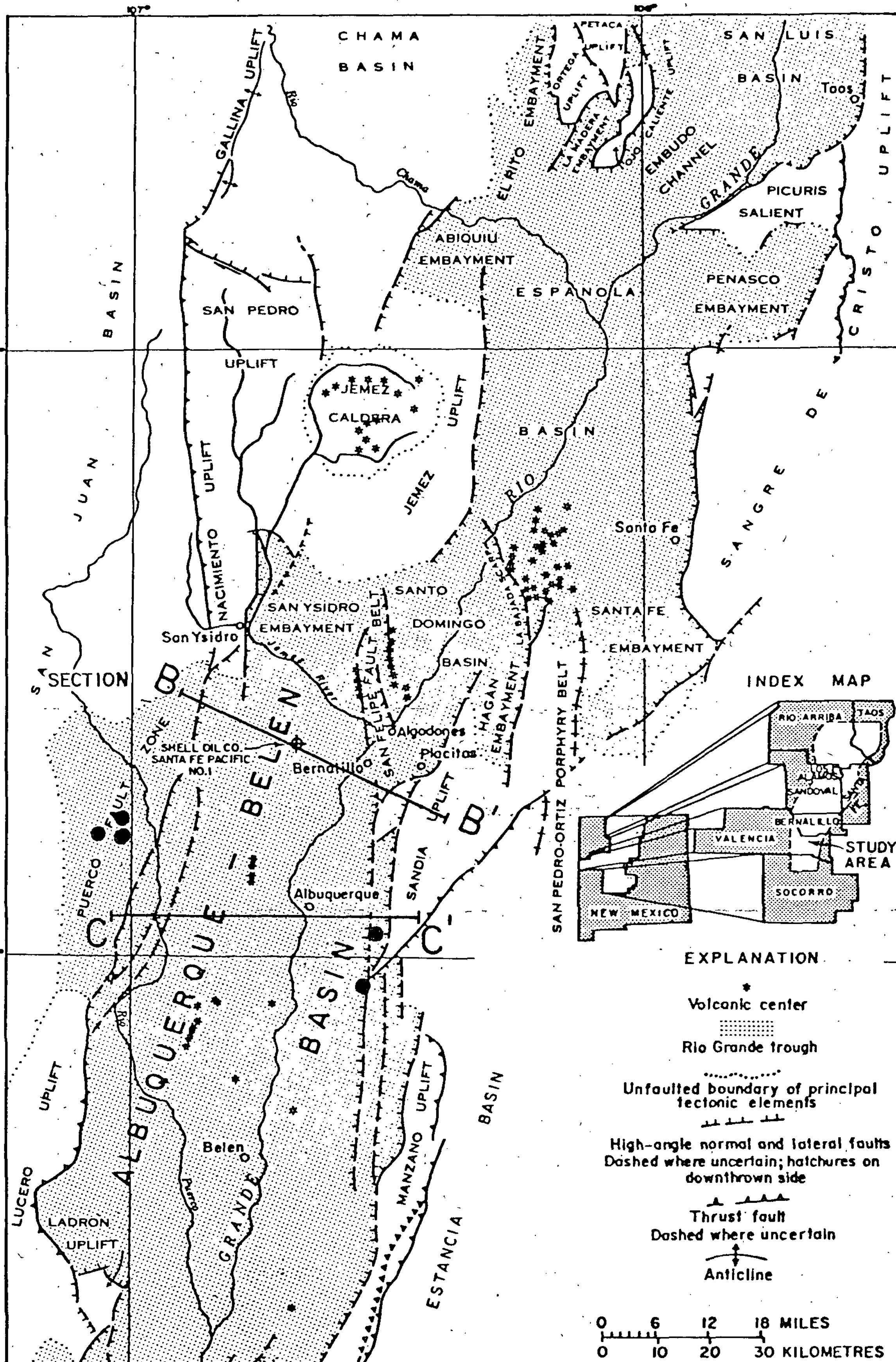


Figure 2. Tectonic diagram of part of the upper Rio Grande area including the Albuquerque-Belen Basin (from Hiss and others, 1975). Heat flow sites from Reiter and others (1975) located by solid circles.

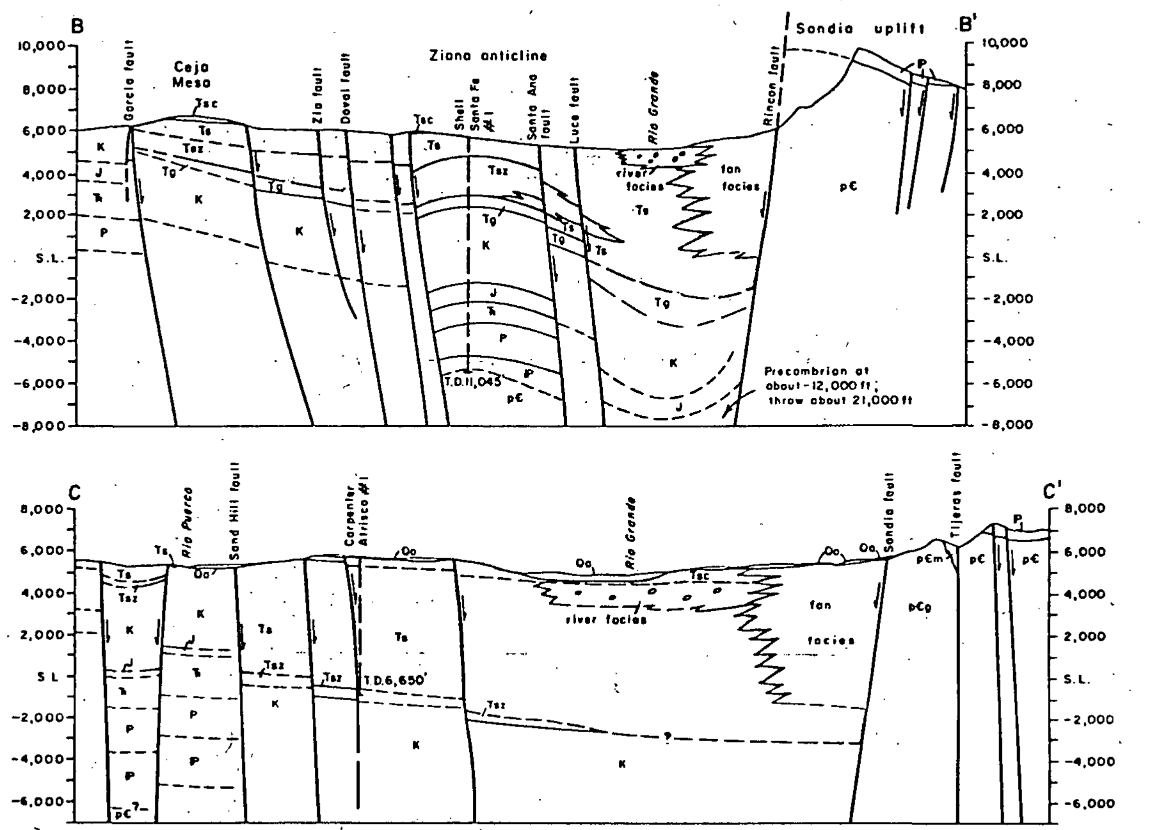


Figure 3. West-east structure sections across Albuquerque basin (from Kelley, 1977). Approximate location of sections sketched in Figure 2.

the city skyline to the west, are fissure-controlled eruptions which have spread several successive basaltic flow units from a near-perfect NS alignment of cones. The last eruptive phase has been dated at 190,000 years ago (Bachman and others, 1975).

From the standpoint of planning our evaluation of the geothermal resource near Albuquerque, Figures 2 and 3 contain the main determining factors. We anticipate any major geothermal occurrence to be associated with 1) deep circulating water along faults or fault zones, or, less likely, 2) waters heated by buried, young intrusives. The latter possibility cannot be completely discounted given the recent volcanism. Our exploration program could detect these types of targets in either a direct (e.g. by thermal anomaly) or indirect (e.g. by gravity anomaly) way.

Hydrological

We propose to collect all pertinent available hydrologic information in the Albuquerque area. An example of such data is presented in Figure 4 which is a water-table elevation map for the area. The contours indicate considerable variation in underground flow directions. For example, near the Shell Oil Co. Santa Fe No. 1 Test Well (also located in Figures 2 and 3) the flow would have a predominant southerly direction (the main Rio Grande drainage). However, to the west of Albuquerque and the volcanoes (Figure 4), the major component of flow would be easterly. Near-surface flow directions are important since ascending geothermal waters would be carried into surrounding aquifers by such movement.

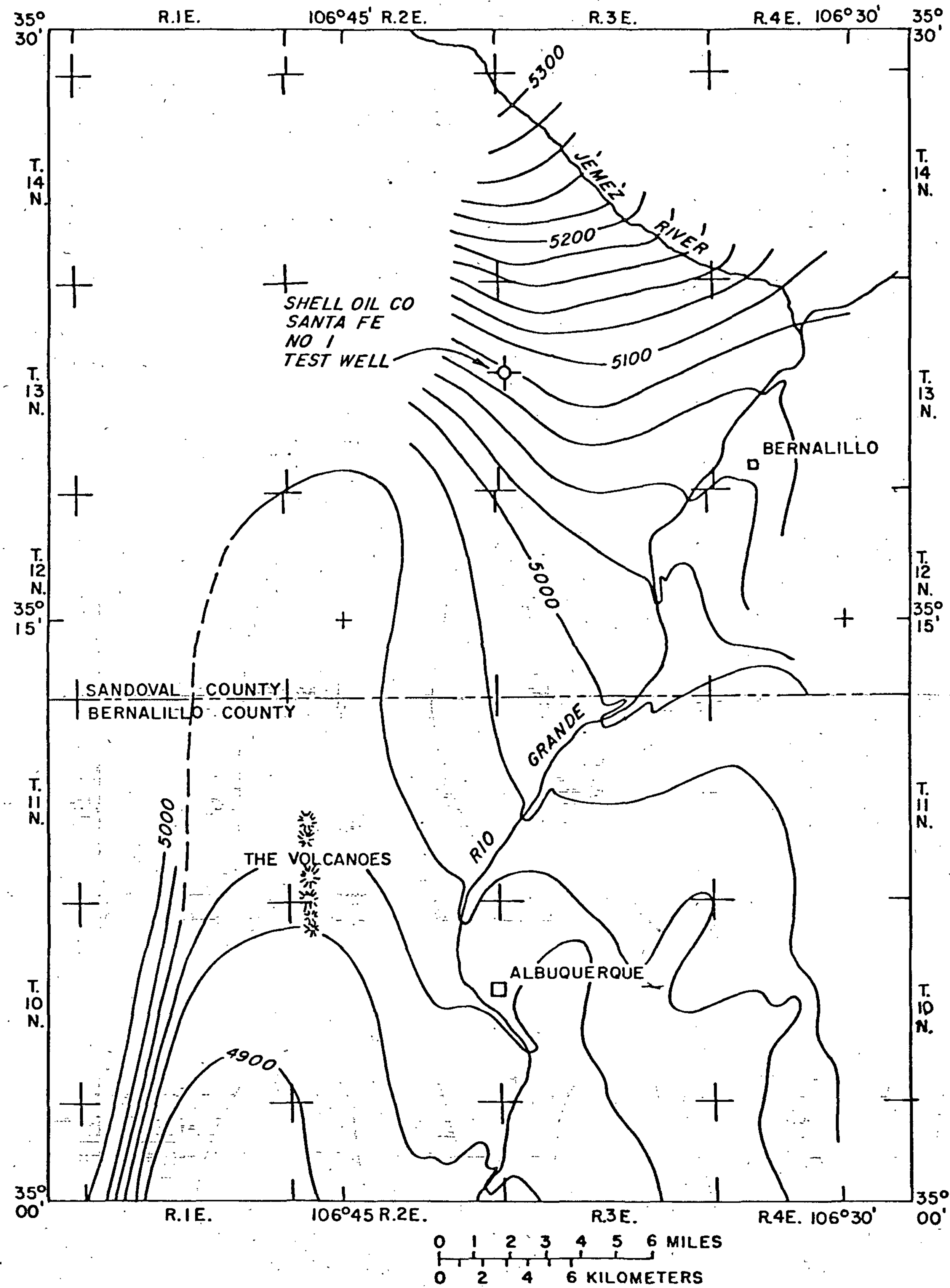


Figure 4. Water-table elevation map in Albuquerque area (after Bjorklund and Maxwell, 1961).

Geophysical

The location of faults or intrusives which would serve as potential geothermal "sources" must combine visible surface indications with geophysical and downhole observations. One geophysical method useful in such structural evaluation is the gravity method. Figure 5 is a portion of the complete Bouguer gravity map open-filed by Cordell and others (1973). Steep gravity gradients mark the bounding fault zones of the basin as is evident east of Albuquerque (Figure 5) in association with the Sandia Uplift (Figures 2 and 3). Similar, though less-pronounced, gravity increase is evident west of Albuquerque connected with the Puerco fault zone. Other smaller features, such as residual patterns south and southwest of the volcanoes (Figure 5) would merit studying for local buried structures. The overall patterns illustrated in Figure 5 (steep gradients marking fault zones and gravity lows in basins) are common to the rift zone. More detailed gravity (<5 mGal contour interval) is necessary to separate the anticipated effects of individual faults or intrusives.

Thermal

To evaluate an area for geothermal potential one must go beyond the indirect evidence such as gravity inferred faults, and place ultimate emphasis on thermal data. Figure 2 includes five heat flow locations in the Albuquerque area published by Reiter and others (1975). The three locations grouped on the west yielded measured heat flow values of 2.3, 3.1, and 2.7 HFU progressing east-to-west. The two

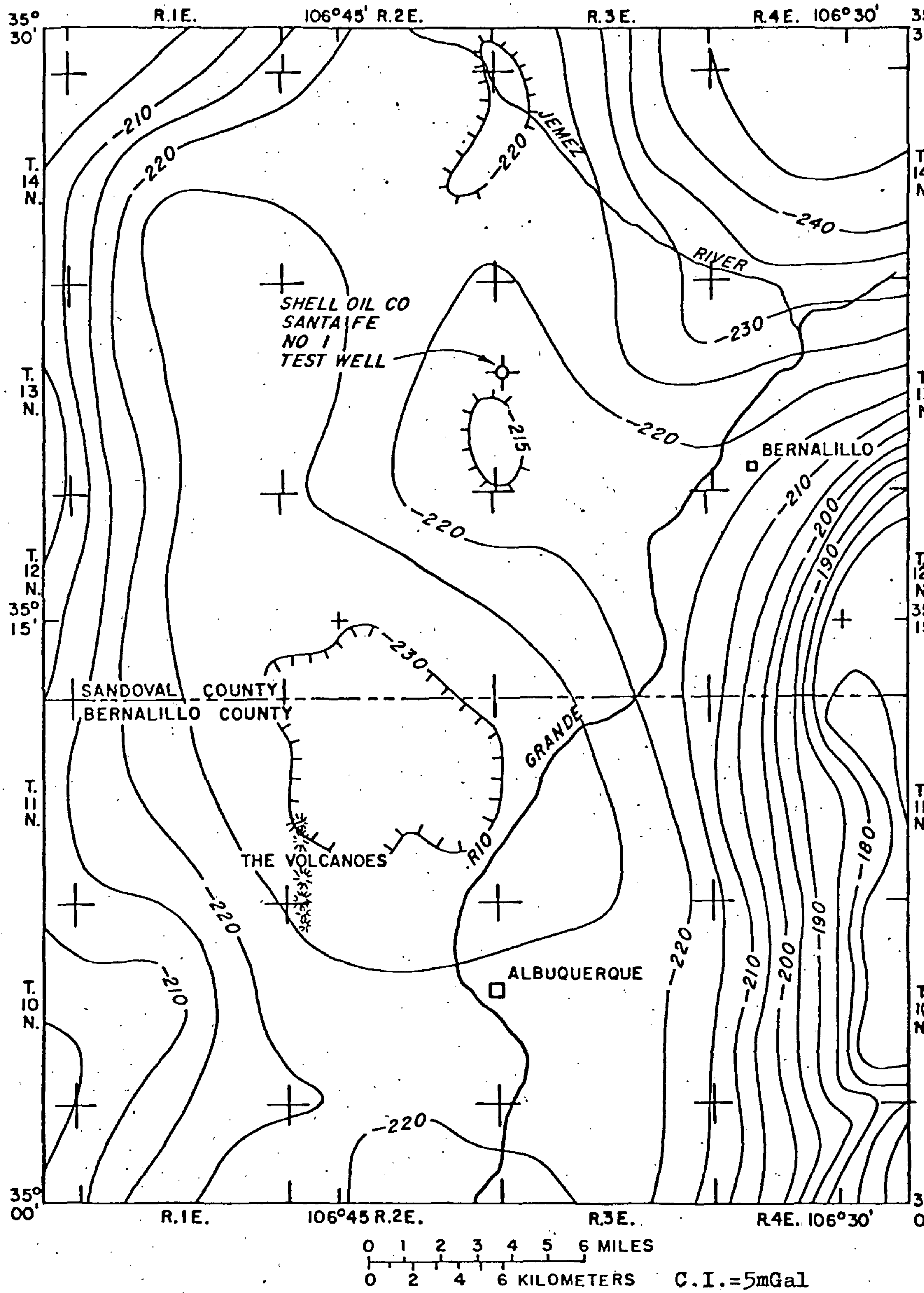


Figure 5. Complete Bouguer anomaly map in Albuquerque area (after Cordell and others, 1973).

sites east of Albuquerque recorded values of 1.1 and 1.2 HFU. These data form an important basis for expecting the geothermal potential to be more significant west of the city rather than east. Thermal gradients measured at the western stations ranged from 31°C/km to over 75°C/km in the upper 200 m of the subsurface.

A cursory scan of deep oil test data near Albuquerque on file with the New Mexico Oil Conservation Commission has resulted in the collection of downhole temperature data presented in Table 1 and Figure 6. Even though the data only represents five test wells, it is clear from Figure 6 and the calculated gradients that an important thermal anomaly may exist very near Albuquerque. Reiter and others (1978) have included the Puerco fault zone and western margins of Albuquerque in their high heat-flow envelope (>2.5 HFU).

EXPECTED GEOTHERMAL TARGETS

As already mentioned, it is anticipated that geothermal occurrences in the Albuquerque area would result from either water ascending along a fault zone or from the presence of a buried heat source such as a very young intrusive. A third, but more unlikely, possibility would be the presence of exothermic reactions such as the conversion of anhydrite to gypsum, a phenomenon that has been proposed for several geothermal areas in Arizona (Swanberg and others, 1977). Anhydrite is known to exist in the sedimentary sequence in the Albuquerque Basin but whether it exists in sufficient volumes so that its exothermic change to gypsum would heat groundwaters to sufficiently high temperatures for geothermal utilization is unknown.

Table 1

SELECTED WELL TEMPERATURE DATA

NEAR ALBUQUERQUE, N.M.

Well	Location	Temperature Data	
		Depth (ft)	Temp (°F)
Shell-Santa Fe #2	T.6N., R.1E., sec.29	14,020	322
Dalies #1	T.7N., R.1E., sec.31	6,091	153
Shell Isleta Central	T.7N., R.2E., sec. 7	16,346	374
Shell-Laguna-Wilson #1	T.9N., R.1W., sec. 8	3,982 10,975	136 245
Shell-Santa Fe #1	T.13N., R.3E., sec.18	7,683 9,375	173,179 212

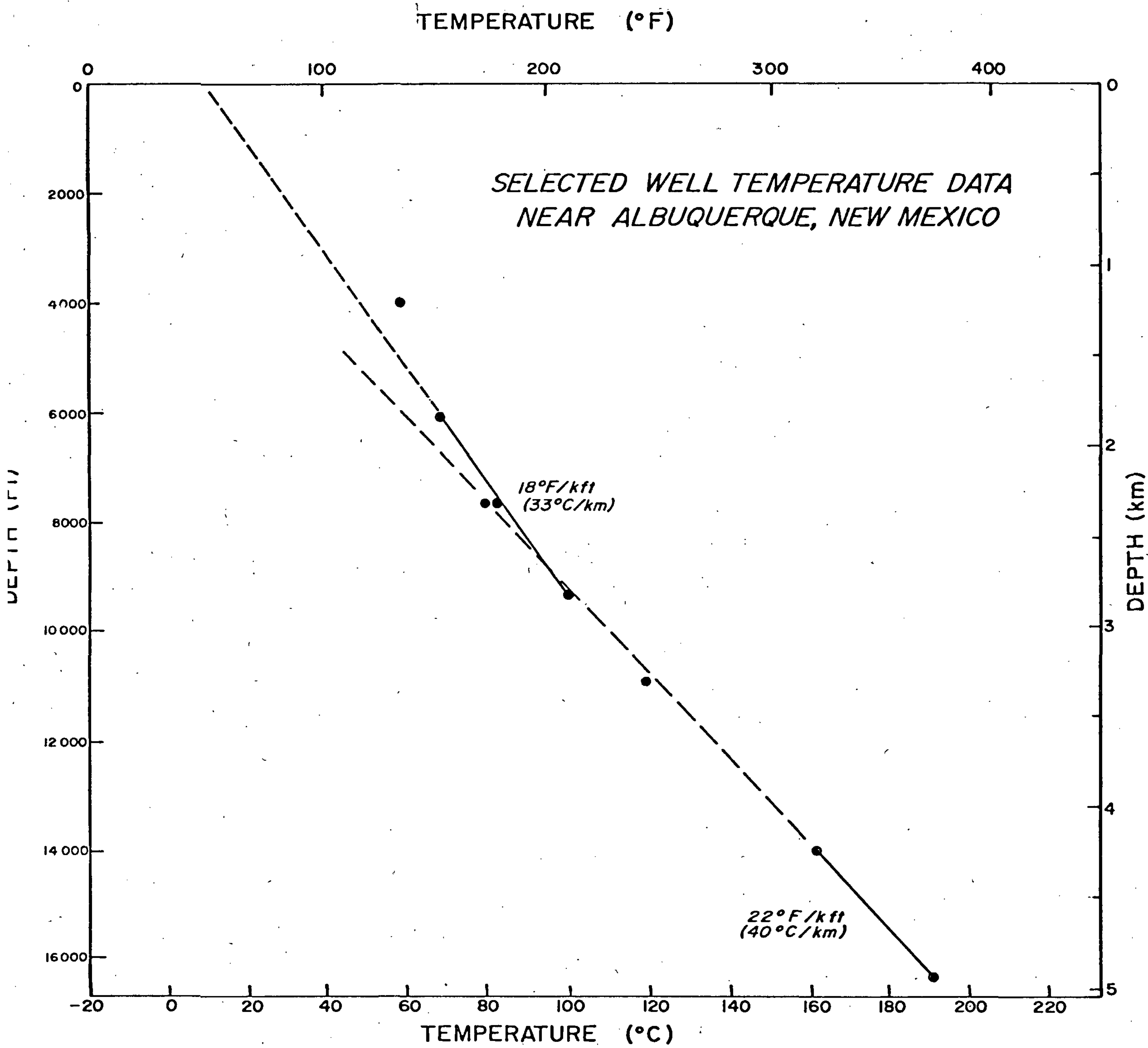


Figure 6. Selected well temperature data and calculated geothermal gradients near Albuquerque.

Although we are not discounting the possibility of a yet unidentified buried intrusive heat source near Albuquerque, it appears likely that a more plausible geothermal target would result from waters ascending along deep fault zones as sketched in Figure 3. Blackwell and Chapman (1977) have suggested that many Basin and Range geothermal areas originate in this manner and have calculated the resulting surface thermal affects. Their models are reproduced in Figure 7 and delineate the magnitude and approximate shape of the surface heat flow anomalies that might be expected. Actually, the heat flow anomaly would be much broader in surface expression than shown in Figure 7 if thermal water is swept into shallow aquifers in a direction normal to the fault plane. Such would be the expected case west of Albuquerque in accordance with the previous discussion of Figure 4.

Some major faults in the Albuquerque area are shown in Figures 2 and 3. An earthquake of magnitude slightly greater than 3 accompanied by surface displacement occurred just west of Albuquerque on January 4, 1971. This and the overall seismicity (Sanford and others, 1972) suggest the possibility that deep geothermal conduits may in fact be active. Further, the sedimentary basin is well in excess of 3 km thick (Figure 3) so that large volumes of geothermal fluids may exist within the basin. Large volumes of water flow have been reported from depths of several thousand feet in wells near Albuquerque, e.g. from the Carpenter Atrisco #1 well shown in Figure 3.

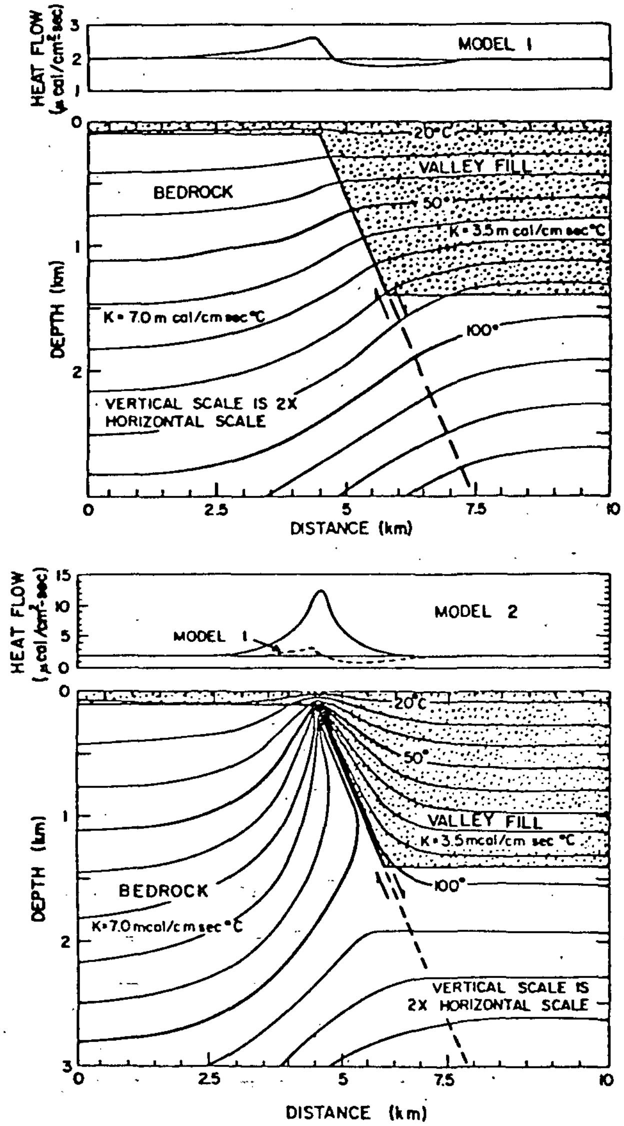


Figure 7. Thermal models for a Basin and Range setting. Model 1: Configuration of isotherms and heat flow pattern across a range bounding fault using typical Basin and Range background heat flow. Model 2: Thermal spring is modeled by hot water circulation along the range bounding fault. A distinctive isotherm and heat flow pattern is seen.

(from Blackwell and Chapman, 1977)

PROPOSED EXPLORATION PROGRAM

General

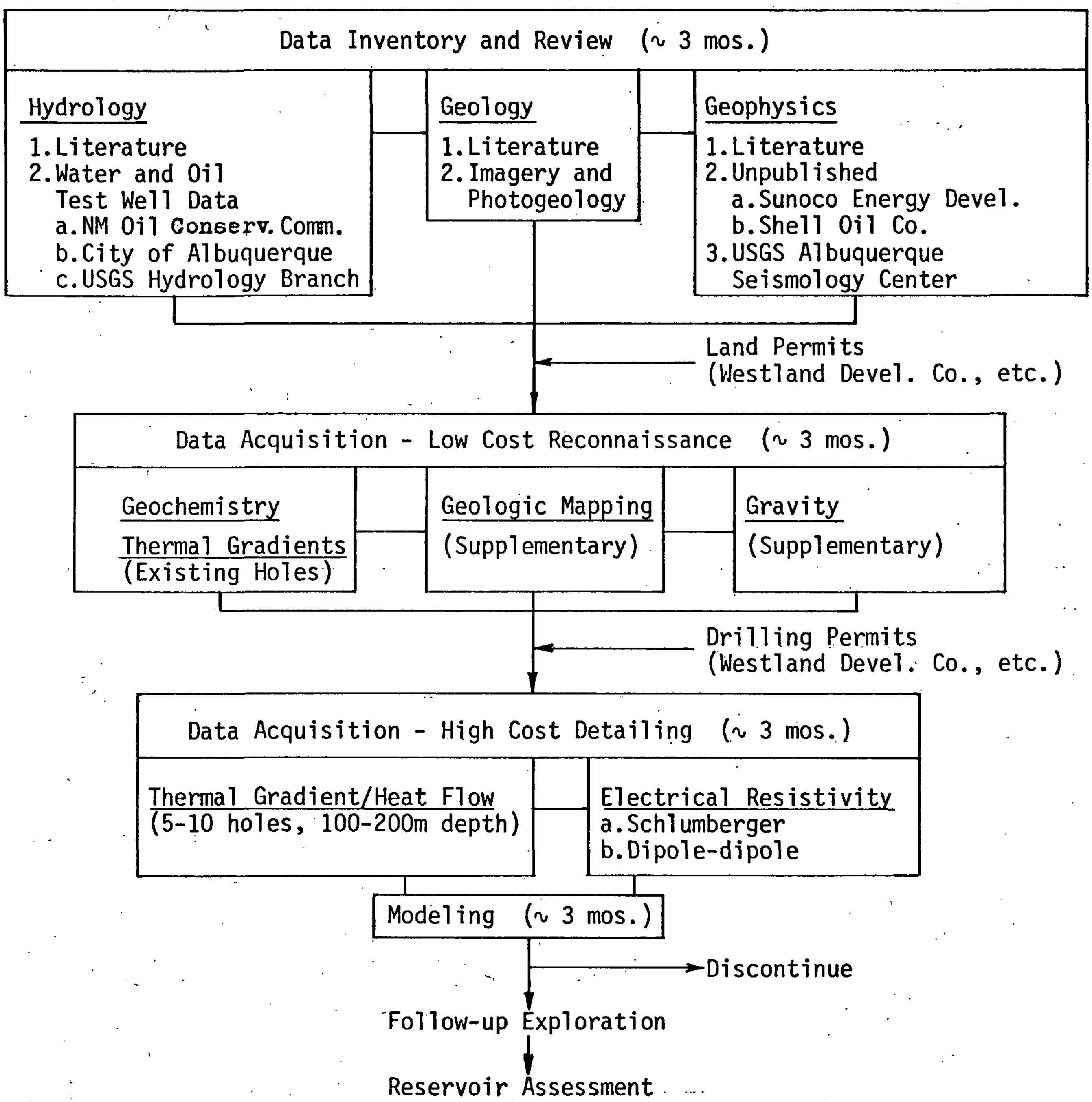
Our proposed exploration program combines the experience of the co-investigators (see vitae p. 27-59) and available results reported by other investigators. Two recent reports by Ward (1977) and Goldstein (1977) were consulted in detail prior to planning the program as outlined in Table 2. This program considers our knowledge to have progressed beyond the reconnaissance phase (2,500 square miles target area) and thus to concentrate on approximately 100 square miles, the exploration detail phase of Goldstein (1977). Actually, we consider our proposed target area to lie intermediate between these approximate values. Goldstein's report (1977), which combines the evaluations of seven geothermal investigators in northern Nevada, lists geologic studies, gravity, active seismic and temperature gradient/heat flow drilling as mandatory to the detail phase of exploration. Our program includes these aspects plus microearthquake analysis and electrical resistivity studies which are considered next in effectiveness (Goldstein, 1977).

Responsibility for each of the areas of investigation are divided as follows:

Investigation	Investigator
Geology, Geologic Mapping, Hydrology	Callender
Geophysics, Gravity, Electrical Resistivity	Jiracek
Seismology	Morgan
Geochemistry	Swanberg
Thermal Gradient/Heat Flow Holes	
Drilling	Wardlaw, Veneruso
Logging	Swanberg, Morgan

Table 2

ALBUQUERQUE AREA
GEOTHERMAL EXPLORATION PROGRAM



The modeling of the combined results for rejection or recommendation for continued evaluation would combine all investigators. Overall responsibility for the proposed project would rest with the principal investigator (Jiracek). Vitae of all investigators listed above are included in p. 27 - 59 of this proposal.

To aid in accomplishing the investigations above we have contacted several agencies and concerns. The U.S. Geological Survey's Hydrology Branch in Albuquerque has agreed to cooperate with our study to the extent of personnel involvement and information exchange (J. McLean, personal communication, May, 1978). Sunoco Energy Development Company are considering releasing to our study the results of their geothermal exploration (gravity, electrical resistivity, seismic ground noise) on the Atrisco Grant (A. Ramo, personal communication, April, 1978). A positive commitment to let us inspect several hundred line-miles of seismic reflection data obtained by Shell Oil Company has been secured (B. Bell, personal communication, April, 1978). Our team of investigators includes a seismologist (Morgan) who would scrutinize these data in Houston, Texas with particular emphasis on the location of deep faults. The U.S. Geological Survey Seismology Center in Albuquerque has agreed to furnish us with local micro-earthquake data collected by their local seismic network. Furthermore, we have obtained verbal permission (written permit to follow) from the Westland Development Company (A. Candelaria, personal communication, April, 1978) to explore and drill on the largest single landholding west of Albuquerque, the 53,000 acre Atrisco Land Grant.

Data Acquisition - Low Cost Reconnaissance

Proposed data acquisition has been divided into low cost reconnaissance and high cost detailing categories. The reconnaissance phase includes some supplementary geologic mapping following a detailed analysis of available multi-band photography and other remote imagery. Much of this data is available at the NASA Technology Application Center in Albuquerque. Detailed gravity, as discussed earlier, is required to investigate individual structures of interest. The extent to which we would occupy new gravity sites depends heavily on the possible availability of the detailed survey done by Sunoco Energy Development. Still, we consider some close-spaced gravity work necessary prior to selecting locations for the high cost data acquisition work (Table 2). The largest effort in the low cost data acquisition phase would be geochemical analyses and in obtaining thermal gradients from existing holes.

The geochemistry portion of the proposed study would consist of an interpretation of existing groundwater chemical data and the collection, analysis, and interpretation of several additional samples in key areas near Albuquerque. The data would be treated in the standard fashion, i.e., qualitative and quantitative geothermometers would be used to detect the presence of geothermal waters and estimate the base temperature of the reservoir from which they originated. Major polluting elements would be noted in order to catalog potential environmental effects.

Co-investigators Swanberg and Morgan (in press) have subjected several hundred thousand groundwaters to detailed geothermal scrutiny including several hundred waters near Albuquerque. However, these studies have utilized only data collected by the federal government. Thus, the first part of the geochemistry study will involve obtaining the chemistry data from state and local files and searching the data for geothermal information. It is anticipated that much of the available chemical data would represent waters collected from near the Rio Grande, with lesser volumes of data to the east and west. Thus, it will be necessary to selectively sample waters in the vicinity of Albuquerque, particularly to the west.

Prior to the drilling of specific heat flow holes, it is proposed to measure temperature gradients in whatever drill holes are available in the Albuquerque area. Our experience has shown that it should be possible to find several hundred abandoned wells which will be suitable for thermal logging. Most will be less than 200 m in depth and most will extend only a few tens of meters or so below the water table. Still it should be possible to use these data to infer a preliminary distribution of subsurface temperatures and thus more accurately select locations for the high cost data acquisition program.

Data Acquisition - High Cost Detailing

The high cost exploration program consists of drilling 5-10, 100-200 m thermal gradient/heat flow holes. Drilling of the holes would be accomplished using the rotary rig operated by Sandia Laboratories. These holes are intended to supplement the data from existing holes in locations judged favorable after the low cost program is completed. Heat flow patterns similar to those illustrated in Figure 7 would be considered indicative of a geothermal source controlled by deep faults.

Coupled with the heat flow measurements, an electrical resistivity program would be initiated at the most encouraging locations. The resistivity studies would proceed hand-in-hand with the thermal logging program and include Schlumberger and/or dipole-dipole sounding.

The University of New Mexico (Jiracek and others, 1976; Smith, 1977) completed a successful resistivity field test in the Albuquerque Basin in 1975 surrounding the Shell Oil Co. Santa Fe Test No. 1 (Figures 2, 3, 4, 5; Table 1). In particular, the Schlumberger sounding shown in Figure 8 resulted in the interpretation of two significant horizons at 380 m and 3,210 m depth. In the first case the depth agrees exactly with the fresh/saline groundwater interface (Hiss and others, 1975) in the drill hole. This important interface of groundwater quality and the agreement of the Precambrian basement depth (3,339 m) with the 3,210 m discontinuity dictate using Schlumberger soundings in our program. An example of the ability of the dipole-dipole method to detect hidden fault zones is illustrated in Figure 9 at Las Alturas Estates near Las Cruces. The contrast on the east side of the figure is interpreted as a buried fault block along which the geothermal fluids encountered at the hot well (Figure 9) may be rising.

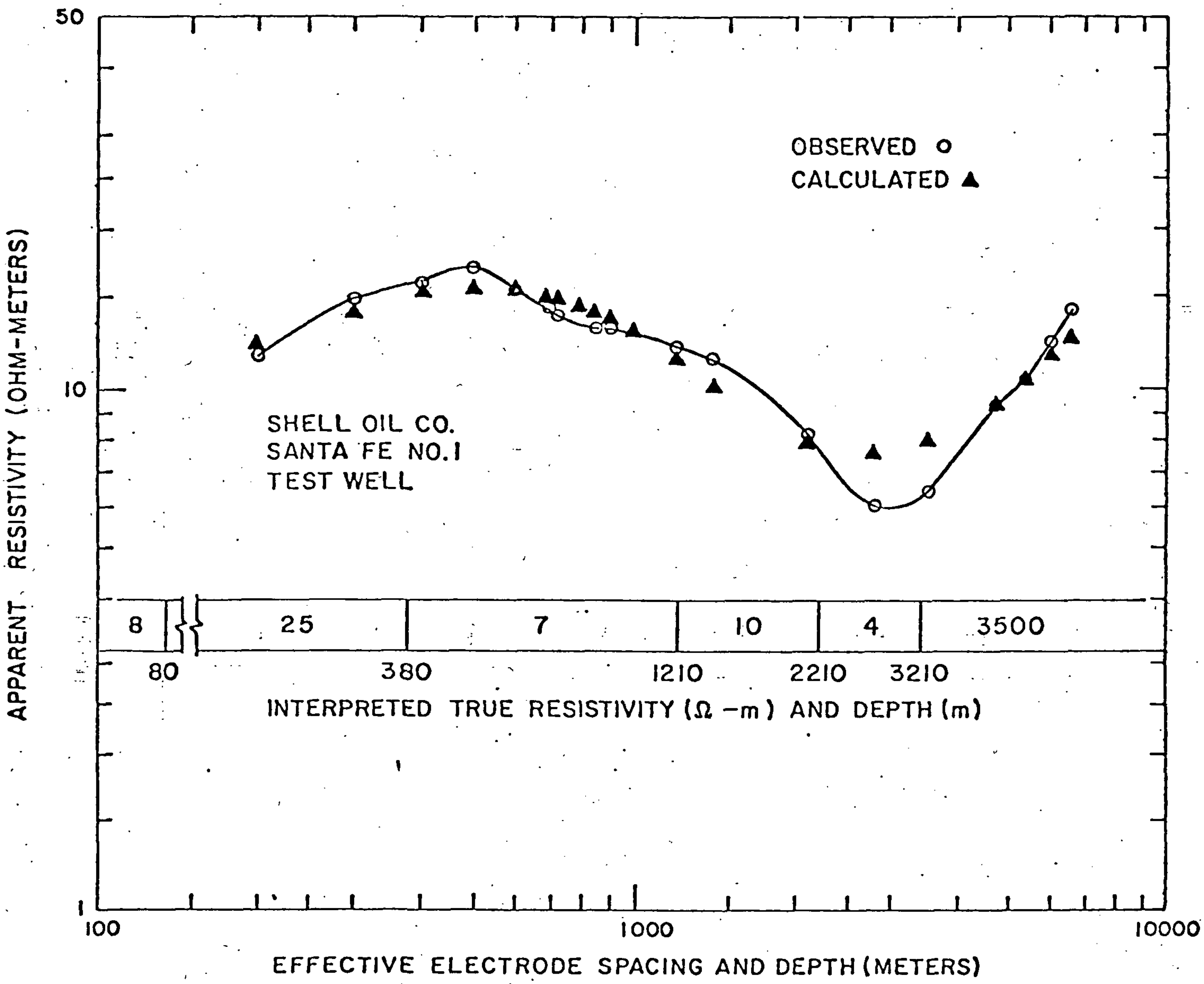


Figure 8. Results of combined asymmetic Schlumberger and equatorial bipole-dipole sounding near Shell Oil Co. Santa Fe No. 1 test well and interpreted six-layer model (from Jiracek and others, 1976).

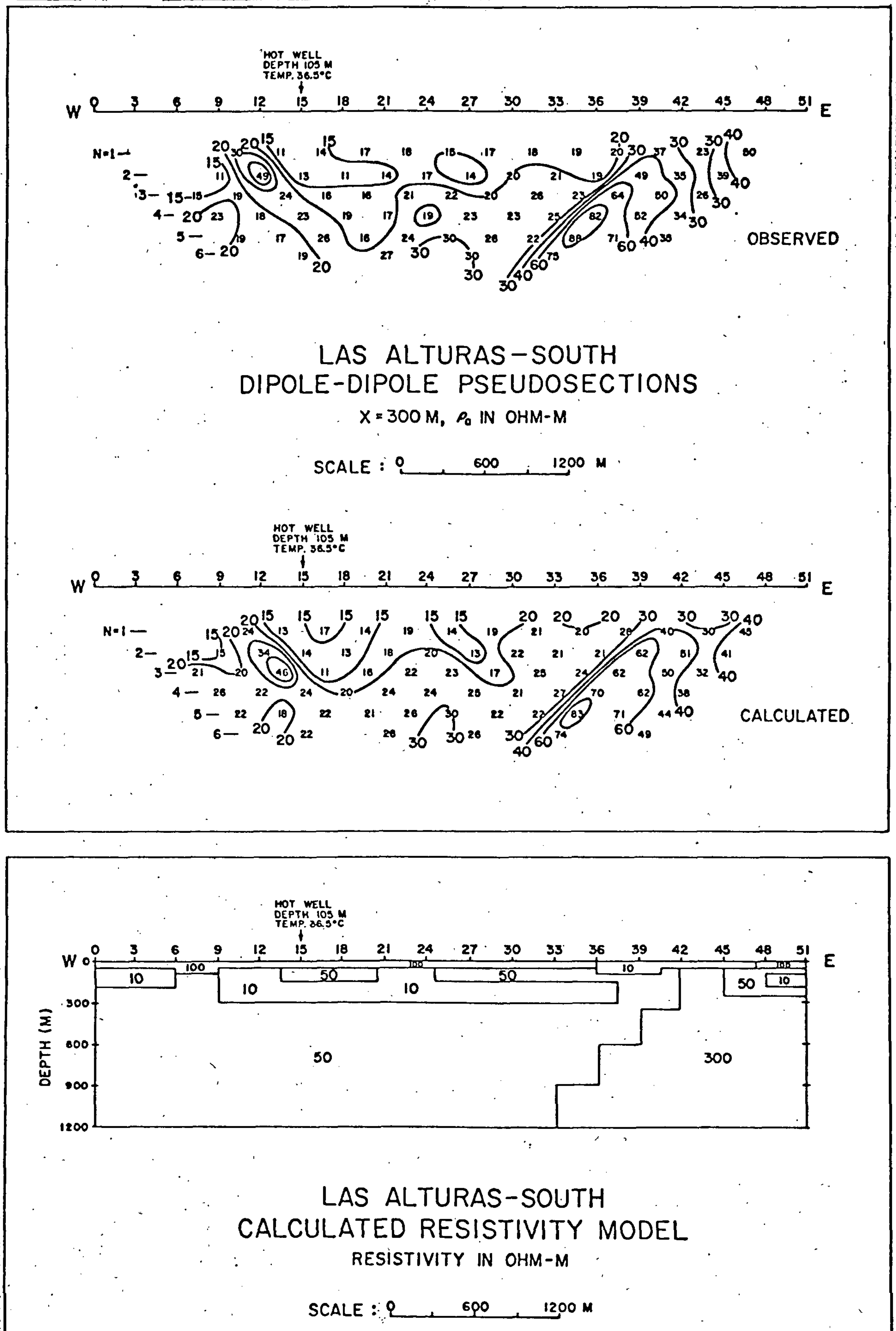


Figure 9. Results of dipole-dipole soundings at Las Alturas Estates and interpreted two-dimensional model calculations (from Jiracek and Gerety, 1978).

Modeling and Evaluation of Exploration Program

The exploration program outlined above would conclude with the combined modeling of all data and a juncture decision (Table 2). If results are discouraging a recommendation to discontinue the program would be made. If the results yield encouraging aspects then a possible follow-up exploration sequence leading to deep reservoir assessment drilling would be recommended. If deep drilling assessment is initiated we envision the program to be managed by personnel from Sandia Laboratories. M. Reiter (personal communication, April 1978) has agreed in principle to thermally measure any deep holes with his extended logging capability. As indicated in Table 2, the proposed exploration phase of the program would reach the juncture decision within one year.

REFERENCES

Bachman, G.O., Marvin R.F., Mehnert, H.H., and Merritt, V., 1975, K-Ar ages of the basalt flows at Los Lunas and Albuquerque, central New Mexico: Isochron/West, no. 13, p. 3-4.

Bjorklund, L.T., and Maxwell, B.W., 1961, Availability of ground water in the Albuquerque area, Bernalillo and Sandoval Counties, New Mexico: New Mexico State Engineer Tech. Rpt. 21, 117 p.

Blackwell, D.D. and Chapman, D.S., 1977, Interpretation of geothermal gradient and heat flow data for Basin and Range geothermal systems: Geothermal Resources Council, Trans., v. 1, p. 19-20.

Cordell, L., Joesting, H.R., and Case, J.E., 1973, Complete Bouguer Anomaly Gravity map of the Albuquerque-Grants area, New Mexico: open file map, U.S. Geol. Survey, Denver, Colorado.

Goldstein, N.E., 1977, Northern Nevada geothermal exploration strategy analysis: Lawrence Berkeley Lab., LBL-7012, 55 p.

Hatton, K., 1977, Report to the legislature regarding senate joint memorial 2: Feasibility of heating and cooling state capitol complex and other state-controlled facilities with geothermal energy: State of New Mexico, Office of State Geologist, 18 p.

Hiss, W.L., Trainer, F.W., Black, B.A., and Posson, D.R., 1975, Chemical quality of groundwater in the northern part of the Albuquerque-Belen Basin, Bernalillo and Sandoval Counties, New Mexico: New Mexico Geol. Soc. Guidebook, 26th field conf., p. 219-235.

Jiracek, G.R., Smith, C. and Dorn, G.A., 1976, Deep geothermal exploration in New Mexico using electrical resistivity: Proc. Second U.N. Symp. Devel. and Use of Geothermal Resour., p. 1095-1102.

Jiracek, G.R. and Gerety, M.T., 1978, Comparison of surface and downhole resistivity mapping of geothermal reservoirs in New Mexico: Geothermal Resources Council, Trans., v. 2 (in press).

Kauffman, D., and Houghton, A.V., 1978, Engineering and economic analysis of hot water geothermal energy for Albuquerque area: New Mexico Energy Research and Development Program Research Grant.

Kelley, V.C., 1977, Geology of Albuquerque Basin, New Mexico: N.M. Bur. of Mines and Miner. Res., Mem. 33, 57 p.

Reistad, G.M., 1976, Potential for nonelectrical applications of geothermal energy and their place in the national economy: Proc. Second U.N. Symp. Devel. and Use of Geothermal Resour., vol. 3, p. 2155-2164.

Reiter, M., Edwards, C.L., Hartman, H., and Weidman, C., 1975, Terrestrial heat flow along the Rio Grande rift, New Mexico and Southern Colorado: Geol. Soc. America Bull., v. 86, p. 811-818.

Sanford, A.R., Budding, A.J., Hoffman, J., Alptekin, O., Rush, C. and Toppozada, T., 1972, Seismicity of the Rio Grande rift zone in New Mexico: New Mex. State Bur. of Mines and Miner. Res., Circ. 120, 19 p.

Smith, C., 1977, On the electrical evaluation of three southern New Mexico geothermal resource areas: unpublished M.S. thesis, University of New Mexico, Albuquerque.

Swanberg, C.A., Morgan, P., Stoyer, C.H., and Witcher, J.C., 1977, An Appraisal study of the geothermal resources of Arizona and adjacent areas of New Mexico and Utah and their value for desalination and other uses: New Mexico Energy Inst., Rpt. 006, 76 p.

Ward, S. H., 1977, Geothermal exploration architecture: Department of Geology and Geophysics, University of Utah, Tech. Rpt. 77-2.

NEW MEXICO STATE UNIVERSITY ®
Physical Science Laboratory
BOX 3-PSL, LAS CRUCES, NEW MEXICO 88003
AREA (505) 522-4400 TWX 910-983-0541

APR 26 1979

24 April 1979

Dr. Phillip M. Wright, Associate Director
University of Utah Research Institute
Earth Science Laboratory
420 Chipeta Way, Suite 120
Salt Lake City, UT 84108

Dear Dr. Wright:

Thank you for your letter of April 4, 1979. We do have the capability of producing maps from our data base. At the present time we are able to generate two types of maps:

a. By using a typewriter computer terminal we can plot a wide variety of points related to data in our files. The results are limited to the precision allowed by a typewriter. These plots are useful for showing the relative positions of hydrothermal sites and cities or for generating bar charts or simple x-y charts. The APL language is used to create such plots, which can be set up and produced in a few hours.

b. A second type of map can be produced on the computer-controlled Versatec Plotter. These maps can have both continuous lines and isolated symbols. The ability to produce name labels is built into the program. The Versatec allows greater precision than the typewriter. This technique is being used to plot county boundaries and geothermal energy economic development regions.

We are enclosing samples of maps produced by the two techniques. If you are interested in specific plots, perhaps we can make them for you.

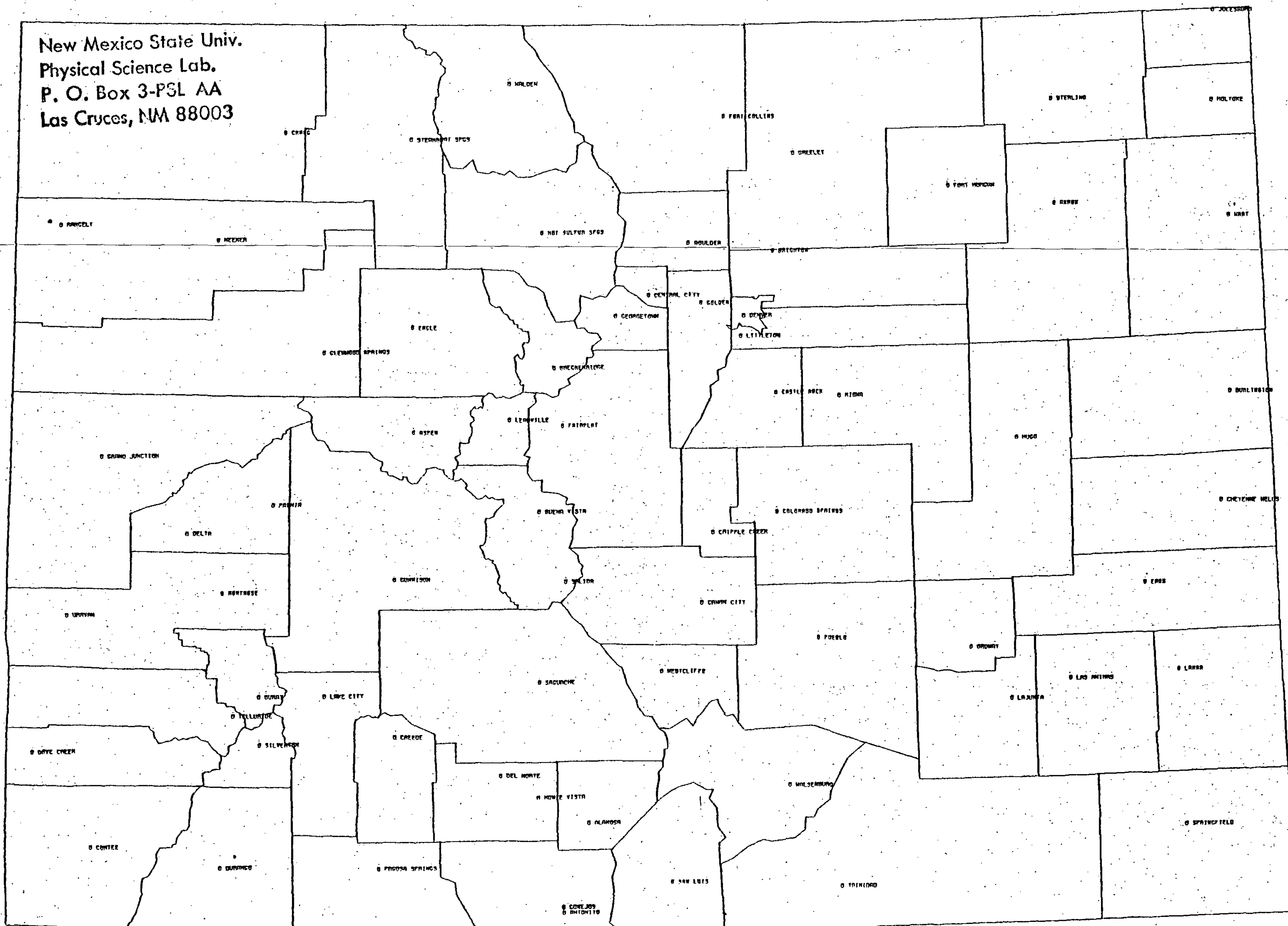
Sincerely,

Patrick L. O'Dea

Patrick L. O'Dea

APR 23 1979

Colorado Counties. (Reduced from Versatec plot.)



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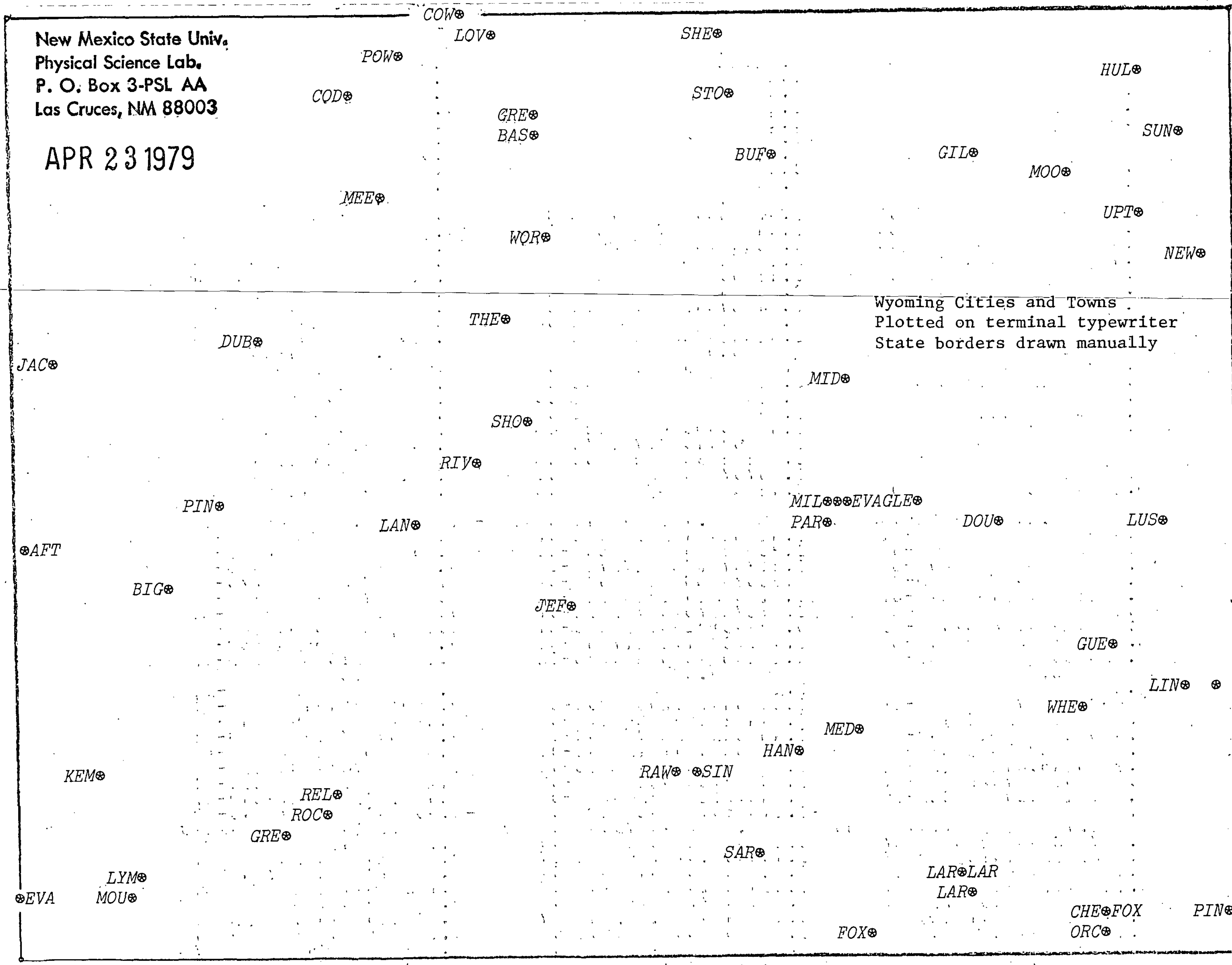
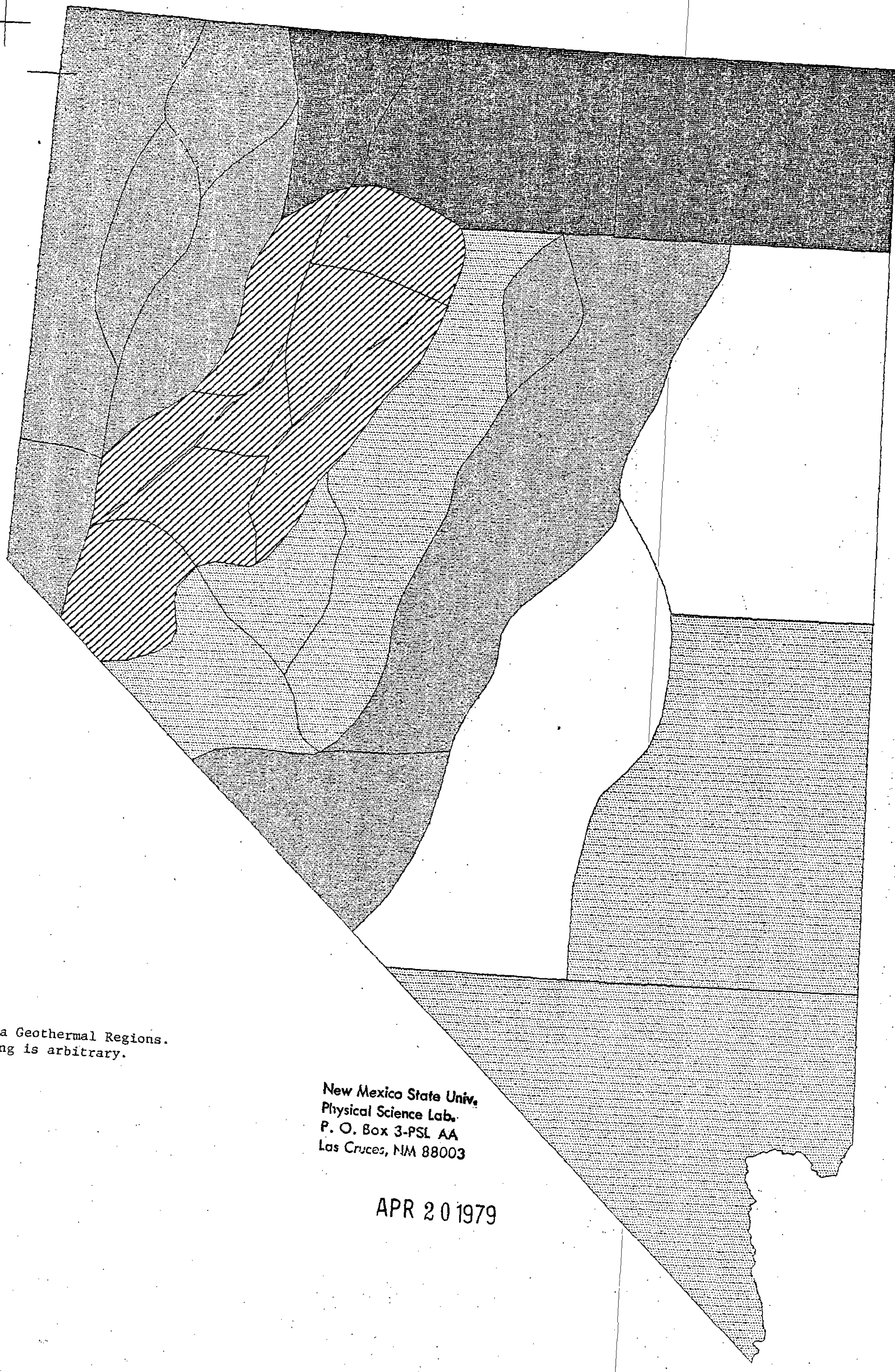
Physical Science Lab.
P. O. Box 3-PSL AA
Las Cruces, NM 88003

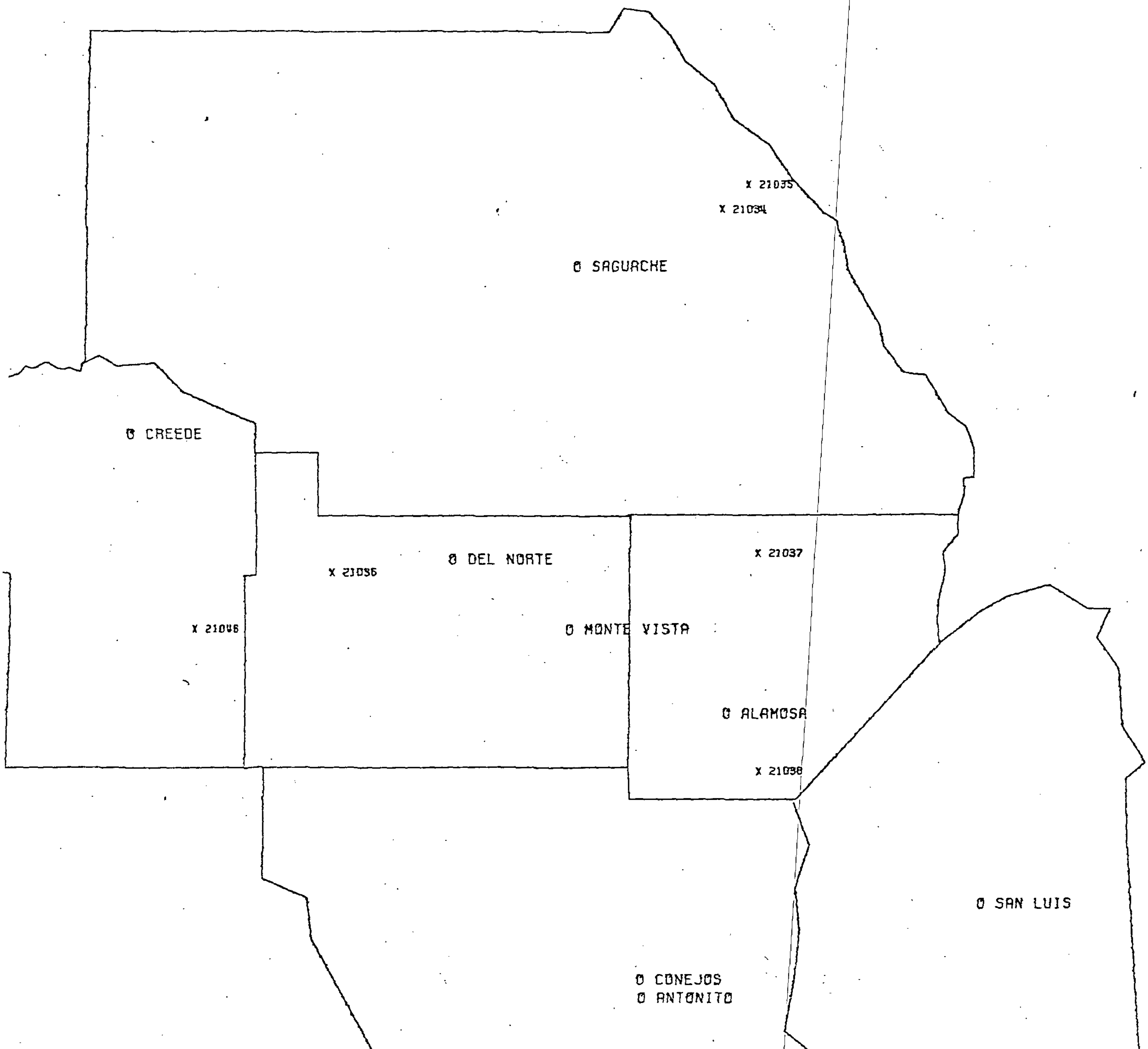


Wyoming Cities and Towns
Plotted on terminal typewriter
State borders drawn manually



Nevada Geothermal Regions.
Shading is arbitrary.

New Mexico State Univ.
Physical Science Lab.
P. O. Box 3-PSL AA
Las Cruces, NM 88003



Sample plot of San Luis Valley, Colorado, showing selected towns and hydrothermal sites. Lines indicate county boundaries.

xerox to
→ Clay Nichols

NEW MEXICO ENERGY INSTITUTE

Box 3EI/Las Cruces, New Mexico 88003
Telephone (505) 646-1745

NEW MEXICO STATE UNIVERSITY ®

November 22, 1977

Mr. Mike Wright
University of Utah Research Institute
Research Park
391 Chipeta Way
Salt Lake City, Utah 84108

Dear Mr. ~~Wright~~: Mike

Attached is a list of the apparent best geothermal sites in New Mexico. Our State program is still collecting geophysical data and may change this list.

I hope to see you again in the near future.

Sincerely,

Robert L. San Martin
Director

/bjm
Attachment
cc: Davy Crockett

SOME OF THE BEST GEOTHERMAL SITES IN NEW MEXICO

Name	Latitude	Longitude	Estimated Sub-Surface Temperature (°C)	
Valles Calderra	35° 43' N	106° 32' W	240°C	
Lighting Dock	23° 08.5' N	108° 50' W	170°C	Sub-Surface
Radium Springs	32° 30' N	106° 59.5' W	160°C	temperature
Lower Frisco	33° 15' N	108° 47' W	150°C	(estimated)
Jemez Hot Springs	35° 47' N	106° 41' W	135°C	
Gila Hot Springs	33° 12' N	108° 12' W	125°C	
Sulphur Springs	32° 54.42' N	106° 36.84' W	69°C (Surface temp.)	
Lyons Hunting Lodge Hot Springs	33° 11.52' N	108° 10.8' W	52°C (Surface temp.)	
Faywood Hot Springs	32° 33.24' N	107° 59.64' W	54°C (Surface temp.)	
Mimbres Hot Springs	32° 45.18' N	107° 5.0'	62°C (Surface temp.)	

→ Xerox to Davey Crockett

NEW MEXICO ENERGY INSTITUTE

Box 3EI/Las Cruces, New Mexico 88003
Telephone (505) 646-1745

NEW MEXICO STATE UNIVERSITY ®

November 21, 1977

Dr. Phillip M. Wright
Senior Geophysicist
University of Utah
Research Institute
391 Chipeta Way
Salt Lake City, UT 84108

Dear Mike:

Thank you very much for the phone call and update that you gave me last week after you had returned from Seattle. I am looking forward to interacting with you as we continue the development of the Low-Temperature Geothermal Program in the state of New Mexico

I would like to reiterate to you what I understood as the sense of the telephone conversation we had. It was my understanding that the Institute's interface in this program is to provide technical assistance as needed by the cooperating organizations. I also recalled your assessment that based on the briefing you received in my office, the interactions you have had with several of our geophysicists and geological engineers, that New Mexico very likely has sufficient expertise to fill this void in the development of this state program. In addition, I recall you stated it is likely your primary interaction would be on Phase I of the development program, and that would principally be to ensure uniformity of type and quality of data for the geothermal maps to be compatible with the information from the other participating states.

I hope we will all be able to understand in the near future what the interactions are to be between the Idaho Operations Office, the University of Utah Research Institute, and the Los Alamos Scientific Laboratory. I believe my state of knowledge in this matter is equal to yours, and I hope we will be able to keep each other informed in this regard.

Again, I look forward to interacting with you in the future.

Sincerely,

R. L. San Martin
Director

go

New Mexico Energy Inst
→ Bob San Martin

3 Nov 77
w/ Chan Swanberg

good correlation between Coskun's HO and Si geoth

4 st dev above mean as sure geoth sample -- & 2 sd as potential

histogram of various geol pars

w/ Bob San Martin - 3 Nov. 77
→ El Paso → SLC -

RSM - in working w/ OR groups, wanted to set out quantity of work set before each quarter →

Re: Project management - would decide what is to be done, then appoint the right guy -

Dr. Dow - vice pres Res NMSU -

ERDA - USGS - USFS - NMEI - STATE OF NEW MEXICO AGREEMENT

New Mexico Low Temperature Geothermal Reservoir Assessment and Confirmation Cooperative Program.

The purpose of this agreement is to establish a reservoir assessment and confirmation program for the State of New Mexico and to develop a basis of understanding between the principal contributors to the project: the Division of Geothermal Energy of the U.S. Energy Research and Development Administration (ERDA-DGE), the Geothermal Research Program of the U.S. Geological Survey (USGS), the New Mexico Energy Institute at New Mexico State University, and the New Mexico Department of Energy and Minerals. In recognition of the economies to be gained and the benefits that accrue as a result of the multidisciplinary integrated technical programs applied to the assessment effort, each principal will contribute funds and manpower to the project as appropriate. It is the intention of the parties involved in this agreement to implement the project through ERDA contracts with the New Mexico Energy Institute at New Mexico State University and letters of agreement among the USGS, ERDA, and the New Mexico Department of Energy and Minerals. Detailed planning will be accomplished by a working group composed of representatives of the four parties to this agreement.

Objectives

The objectives of this program are (1) to extend the inventory of geothermal resources in New Mexico to include the low temperature reservoirs ($35^{\circ}C < T < 90^{\circ}C$) most suitable for direct heat applications, and (2) to stimulate reservoir confirmation studies at sites with an apparent but unquantified potential for direct heat applications development.

Several of the major urban centers of New Mexico, its agricultural areas, and its important mineral producing regions appear to be near low to moderate temperature geothermal reservoirs. Little utilization of this resource has occurred to date. A major factor in this lack of utilization is the lack of knowledge concerning the location, extent, and quality of the reservoirs. The reservoir confirmation studies being initiated are designed to contribute to the stimulation of public interest in the geothermal resource as a viable energy option in the State of New Mexico.

Research Plan

The program will be implemented in two phases; the first dealing with a State-wide survey of available data, and the second concerned with site specific reservoir confirmation studies. Phase one will involve two major activities: the incorporation of low temperature geothermal data into the USGS GEOTHERM data base, and the preparation of a preliminary report which will summarize and synthesize the available low temperature data. The report will emphasize the known geographic distribution and water quality data for the resource which appears suitable for direct heat applications. Phase one studies will also indentify candidate sites for reservoir confirmation activities. Preliminary environmental analyses will also be accomplished in phase one. The important decision point in the project will be late in phase one (winter 77-78) when the results of phase one are evaluated by the project's working group and phase two is planned.

It is the intention of the parties to this agreement to participate in the second, site-specific phase of the program if promising but unquantified low or moderate temperature sites are identified in phase one. Phase two will involved intermediate depth (300-600 meter) confirmation drilling for reservoir evaluation at one or more sites. These sites will be selected to achieve a maximum impact in terms of contributing to public awareness of the potential for development of the low temperature geothermal resources of the State.

The anticipated term of the program is 3 years. Phase one will be completed with the publication by the New Mexico Energy Institute at New Mexico State University of a preliminary report within six months from the initiation of the study. Required reconnaissance studies will be initiated early in phase one. These reconnaissance studies along with already available information will provide the site-selection information for detailed site studies of phase two in 1978. Confirmation drilling activities and reservoir testing will be concluded in late calendar year 1978 or early 1979.

Responsibilities

The New Mexico Energy Institute at New Mexico State University will provide the Project Manager who will serve as the coordinator for the various State agencies participating in the project. It is anticipated that these will include (but not necessarily be limited to) New Mexico Department of Energy and Minerals, New Mexico Oil Conservation Commission, New Mexico Land Office, New Mexico Engineer's Office, Environmental Improvement Agency, Public Service Commission, New Mexico Department of Development, New Mexico Municipal League, New Mexico Bureau of Mines, Los Alamos Scientifc Laboratories, Sandia Laboratories, University of New Mexico, New Mexico State University, and the New Mexico Institute of Mining & Technology.

The New Mexico Energy Institute at New Mexico State University will provide a preliminary report at the end of phase one which summarizes the known distribution and quality of the geothermal reservoirs that appear suitable for direct heat applications. This report will be based on available geological, geochemical, geophysical, hydrological, and environmental data. Date gathered in this effort will be provided to the USGS for incorporation into the GEOTHERM data base. The New Mexico Energy Institute at NMSU will coordinate the site-specific studies of the second phase and will be responsible for subcontracting for surveys and drilling operations.

The USGS Geothermal Research Program which will contribute to the planned program has among its objectives the characterization and national inventory of all types of geothermal resources. These include those moderate and low temperature resources most suitable for direct heat applications. The USGS will designate a coordinator for the New Mexico studies who will provide technical advice to the project manager. The USGS coordinator will also assist in the transfer of data from the project to the GEOTHERM data file, and will coordinate ongoing and planned geoscience studies in the USGS geothermal program with the present project.

ERDA-DGE participation and support for the project will be primarily through its Direct Heat Applications Reservoir Confirmation Program. The ERDA program manager for this program will provide technical management of contracts between the New Mexico Energy Institute at NMSU and DGE, and will maintain liaison with the USGS. He will also coordinate and maintain appropriate interfaces between this program and other DGE programs (i.e. regional planning, exploration technology, direct heat utilization technology, and environmental studies).

The coordination of surface activities, environmental assessment and use regulations on land managed by the USFS will be the responsibility of the USFS. ERDA-DGE will also provide support for environmental studies appropriate for each of the sites selected for phase two studies.

This agreement and the program may be expanded as appropriate to include direct participation by the Bureau of Land Management, the Bureau of Indian Affairs, and Tribal representatives, depending on the status of sites nominated for phase two studies.

James C. Bresee, Director
Division of Geothermal Energy
Energy Research and Development Administration

Robert I. Tilling, Chief
Office of Geochemistry and Geophysics
U.S. Geological Survey

Forest Service
Department of Agriculture

Fred O'Cheskey, Secretary
Department of Energy and Minerals
State of New Mexico

for Board of Regents of New Mexico State University
by Gerald W. Thomas, President
New Mexico State University

Robert L. San Martin, Director
New Mexico Energy Institute at New Mexico State University

EG&G

geoMetrics
395 Java Drive
Sunnyvale, California 94086 U.S.A.
(408) 734-4616
Cable: "GEOMETRICS" Sunnyvale
Telex No: 357-435

Subject: Completion of the 1977 group participation survey in Southwestern New Mexico, 48,500 line miles.

Gentlemen,

GeoMetrics has completed the data collection phase of its 1977 group participation Aeromagnetic and Radiometric Survey in southwestern New Mexico. This detailed survey (0.33 mile spacing, at 0.5 gamma sensitivity) has produced some of the highest quality magnetic and radiometric data available in southwestern New Mexico. Data delivery to purchasers will begin in October and shall continue on an incremental basis to completion at the end of November 1977.

Since this project consisted of both magnetics and radiometrics, several separate options are available to prospective data purchasers. The options are as follows:

A. Purchase of the magnetic data only, as described - $60,300.

B. Purchase of the radiometric data only, as described $25,000.

C. Purchase of both magnetic and radiometric data, as described - $75,000.

D. Corrected radiometric tape, add $4,000 to B or C above.

These data are available in the following formats:

A. Magnetic data - Contour maps at a scale of 1:62,500, and a scale of 1:250,000 for a total of 48,500 line miles. Computer generated analog strip charts at a linear scale of 1:62,500, containing magnetic data, radar altimeter data, and barometric altimeter data. In addition digital tapes containing the magnetic data, radar and barometric altimeter data, diurnal data, and X Y location for each data sample.

B. Radiometric data - The radiometric data are available in digital tape form only for a total of 48,500 line miles. Two options are available - (1) Raw gamma ray spectrometer data consisting of total count, potasium, uranium, and thorium plus cosmic ray data (3 to 6 MeV), radar altimeter data, and X Y locations. (2) The same as one above plus the radiometric data corrected for Compton scatter, altitude, aircraft and cosmic background, and the three ratios (add $4,000 for this option).

geoMetrics

A detailed summary of the survey specifications and instrumentation are enclosed in attachment A. If you have any questions concerning detailed specifications, data quality, etc, please contact the undersigned.

Sincerely,

RA Fowler by J. Marshall Thompson

Robert A. Fowler
Manager, Airborne Geophysics

RAF:kg
Attachments

geoMetrics

SURVEY AREA

The airborne survey covers the southwestern portion of New Mexico as shown on the attached map.

DELIVERABLE ITEMS

The following items shall be delivered for the magnetic data option:

1. Total intensity contour map IGRF removed, machine-drawn at a scale of 1:62,500, and 1:250,000 in UTM projection, contour interval 20 gamma with 10 gamma shading, gradient permitting. One reproducible mylar copy. The final 1:62,500 maps will be prepared as two seperate sheets. Sheet one, total field maps, will be presented with shaded contours. The second sheet, flight path recovery, will be displayed as super-imposed over screened topographical background. The 1:250,000 scale will be composited to provide one single map rather than standard AMS sheets.

2. One (1) set of four-variable digital data profile plots will be presented at a linear scale of 1:62,500. Each profile shall contain residual field after removal of IGRF and diurnal correction at 2 scales (200 and 2000 gammas), barometric and radar altimeter data, and the difference between the radar and barometric altitude.

3. Digital magnetic tapes in an unlabled BCD format (or in a format to be defined) containing the same data as in number 2 above plus fiducial information, diurnal data and latitude and longitude correct to nearest 0.1 second. Optional is the corrected residual field data interpolated at a rectangular grid for subsequent filtering operations. (For both tapes add an additional $500.00).

The following shall be delivered for the radiometric data option:

1. The basic data to be delivered are digital magnetic tapes in an unlabled BCD format containing the raw radiometric data (total count, potassium, uranium, thorium, and total count 3-6 MeV, cosmic data), fiducial information, radar altimeter, latitude and longitude. Optional are the data corrections for altitude and Compton scatter. These corrected data will be presented in tape form combined with the raw data tape at an additiona price of $4,000 per participant (requires a minimum of three purchasers).

SURVEY SPECIFICATIONS

1. Magnetometer sensitivity - 0.5 gammas.

2. Altitude - 500 feet ± 20% within aircraft performance and safety limitations. Where maintenance of altitude within these specifications is impossible due to inability of aircraft to climb or descend rapidly enough, every reasonable attempt will be made to improve the data through reflight. The technique to be utilized will be "downhill" flying on both sides of the peak or ridgeline. Data for contouring will then be "matched" using the terrain clearance crossover points.

3. Traverse line separation - 0.33 miles.
4. Traverse line direction - north/south with tie lines flown east/ west.
5. Tie line separation = 5 miles (15 to 1 ratio), but placed in such a manner to minimize altitude and gradient effects.
6. Objective line spacing tolerance ± 25% but not to exceed ± 40%.
7. Diurnal limitations - 5 gammas in 3 minutes non linear.

SURVEY EQUIPMENT AND PROCEDURES

Equipment

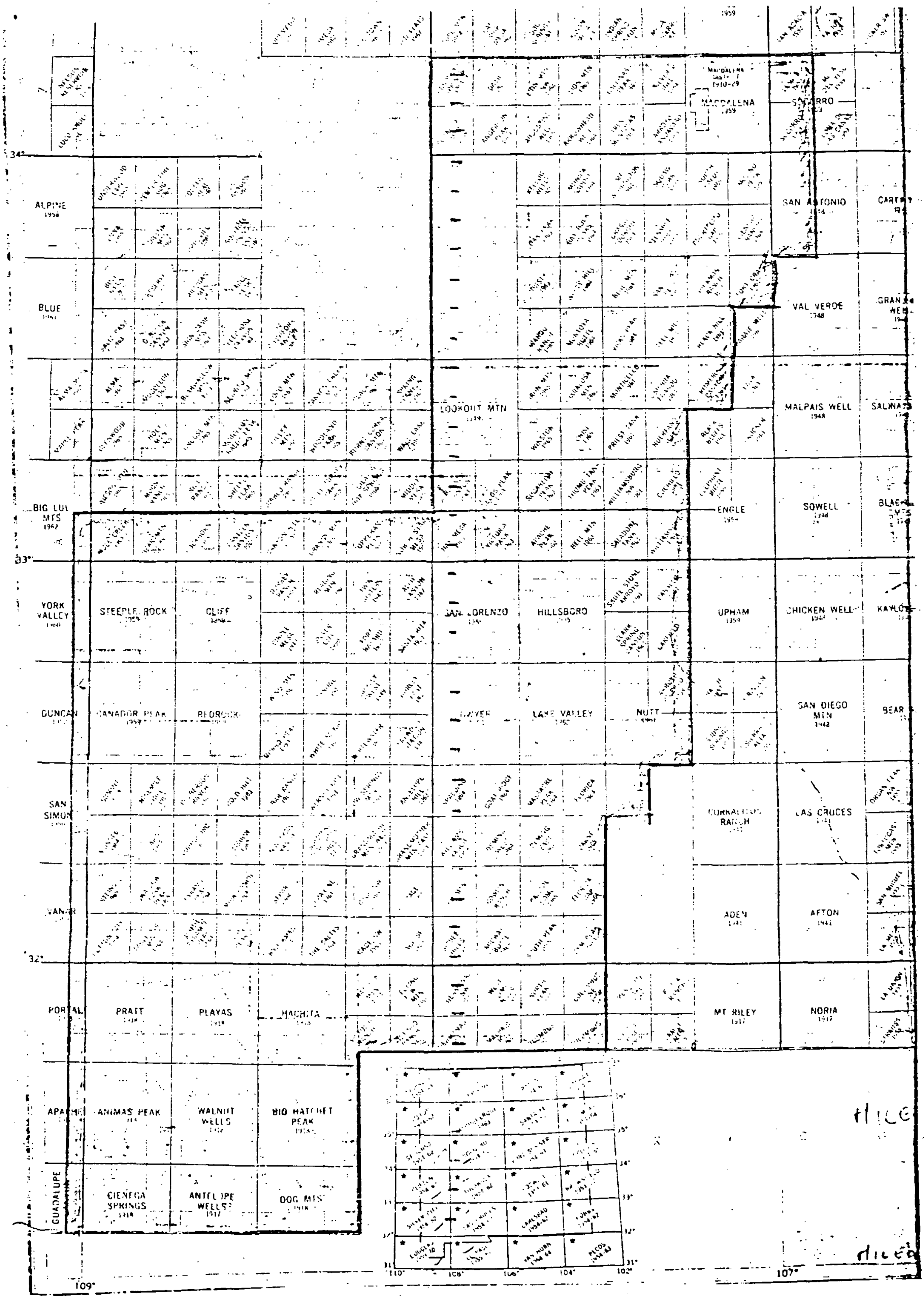
1. A GeoMetrics Airborne High Performance Proton Magnetometer, Model G-803 HP with sensitivity of 0.5 gammas at a doppler controlled sample interval of 50 meters (164 feet).
2. Recording Radar Altimeter - Sperry AA 200 Radar Altimeter.
3. Recording barometric altimeter - use of the aircraft encoding altimeter will be attempted, but if this proves impracticle, a Rosemont barometric altimeter will be used.
4. An integrated navigation system comprised of the following units:
   a) Singer: SKK 1000 Doppler Navigation
   b) Singer: Track Navigation Computer SKQ-601
   c) Sperry: C-12 Gyro Stabilized compass
5. A Hulcher 35 mm Tracking Camera, doppler controlled, continuous strip with wide angle lens.
6. Analog Recorder (HP 7128) doppler controlled recording following data:
   a) Magnetometer
   b) Radar Altimeter
   c) Associated event and time markers
7. GeoMetrics GAX 1000 crystal package containing 1024 cubic inches of NaI crystal, temperature stabilized.
8. A GeoMetrics GR-800 Digital Gamma Ray Spectrometer to record total count, potassium, uranium, thorium and cosmic in both analog and digital form sampled at a spatial interval of 50 meter (164 feet).
9. An Exploranium MARS 6 Analog Recorder to record the gamma ray spectrometer data.
10. A GeoMetrics Digital Data Acquisition System, Model 704 recording the following on magnetic tape:
    a) Magnetometer
    b) Data scan/fiducial number identical to that recorded on camera film
    c) Manually inserted information, i.e., date, survey area, and flight line number.
    d) Radar altimeter (by analog-to-digital conversion)

e) Barometric Altimeter (by analog-to-digital conversion if the encoding altimeter proves infeasible)

f) Digital clock

g) Gamma Ray Spectrometer data - total count, potassium, uranium, thorium, and cosmic.

11. A GeoMetrics Model G-806 High Performance Proton Magnetometer 0.5 gamma sensitivity base station. Data recorded on an analog recorder at a speed of 2 minutes per inch and digitized for presentation.



34°
ALPINE
1958
BLUE
MAGDALENA
1959
SOCORRO
SAN ANTONIO
VAL VERDE
1948
LOOKOUT MTN
MALPAIS WELL
1948
BIG LUE MTS
1962
ENGLE
SOWELL
1948
33°
YORK VALLEY
STEEPLE ROCK
CLIFF
SAN LORENZO
HILLSBORO
UPHAM
1959
CHICKEN WELL
DUNCAN
REDROCK
LAKE VALLEY
NUTT
SAN DIEGO MTN
1948
BEAR
SAN SIMON
LAS CRUCES
ADEN
AFTON
32°
PRATT
PLAYAS
HACHITA
MT RILEY
1917
NORIA
1917
ANIMAS PEAK
WALNUT WELLS
BIG HATCHET PEAK
CIENEGA SPRINGS
1918
DOG MTS
1918
GUADALUPE
109°
107°

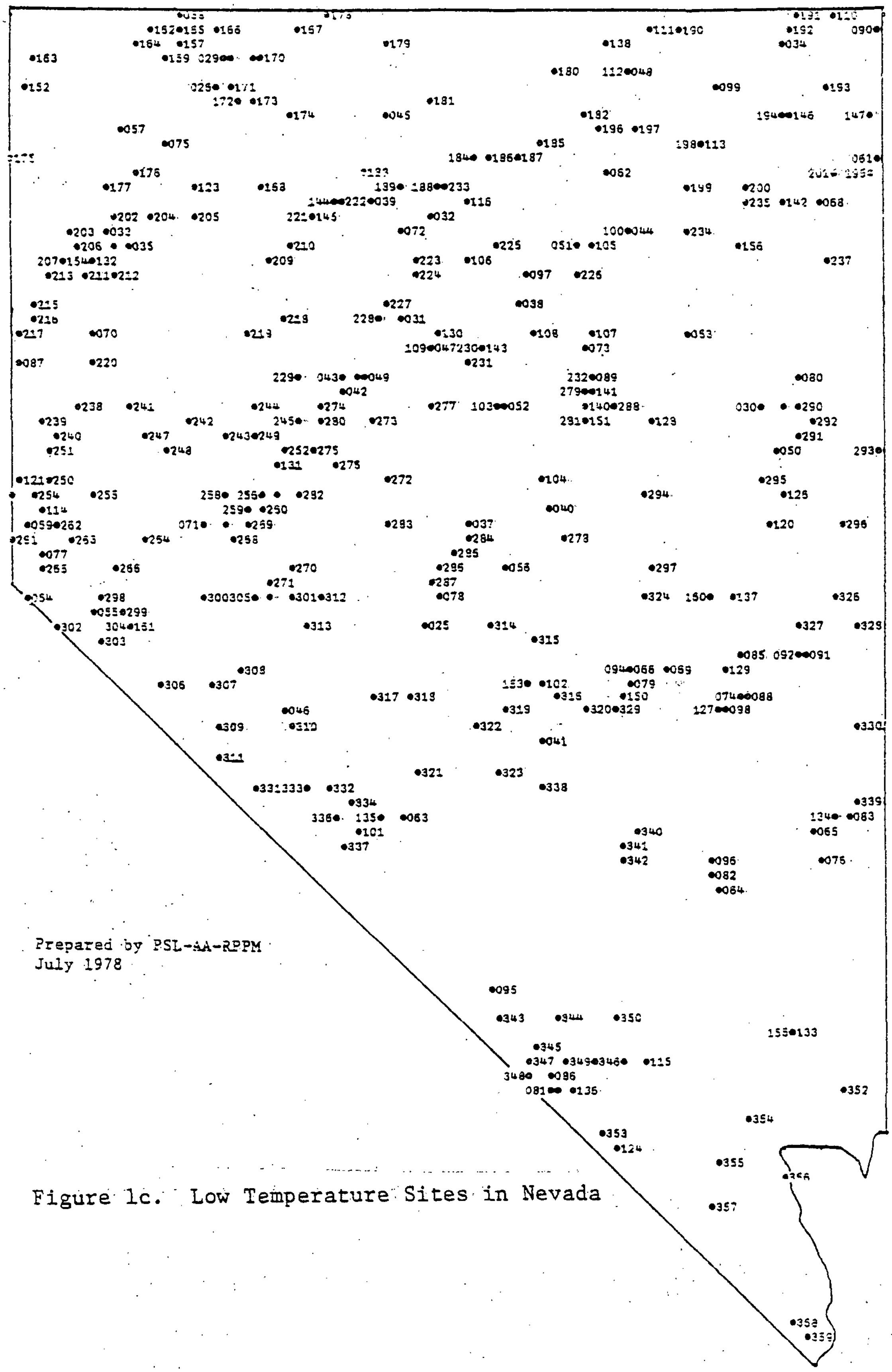
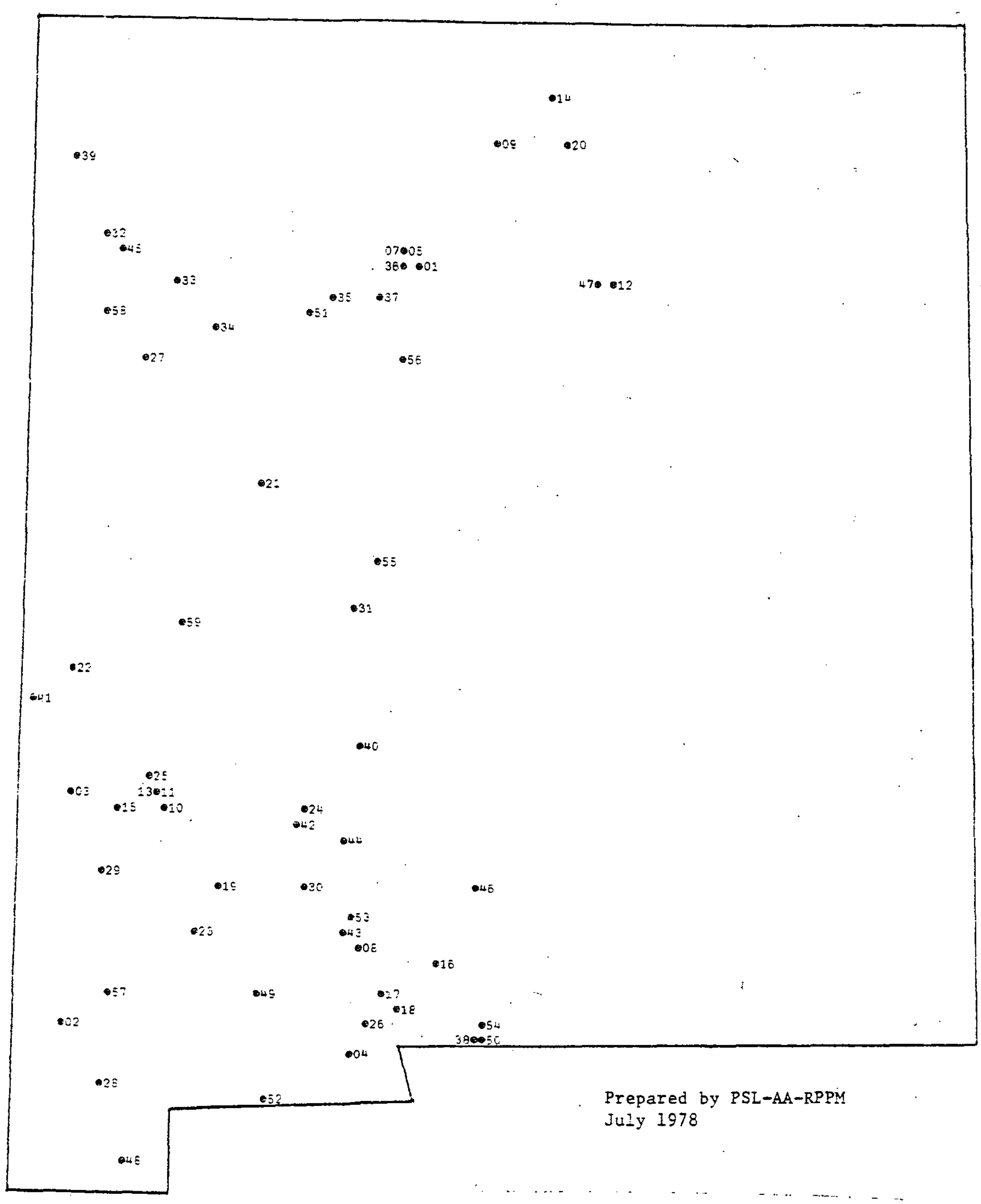
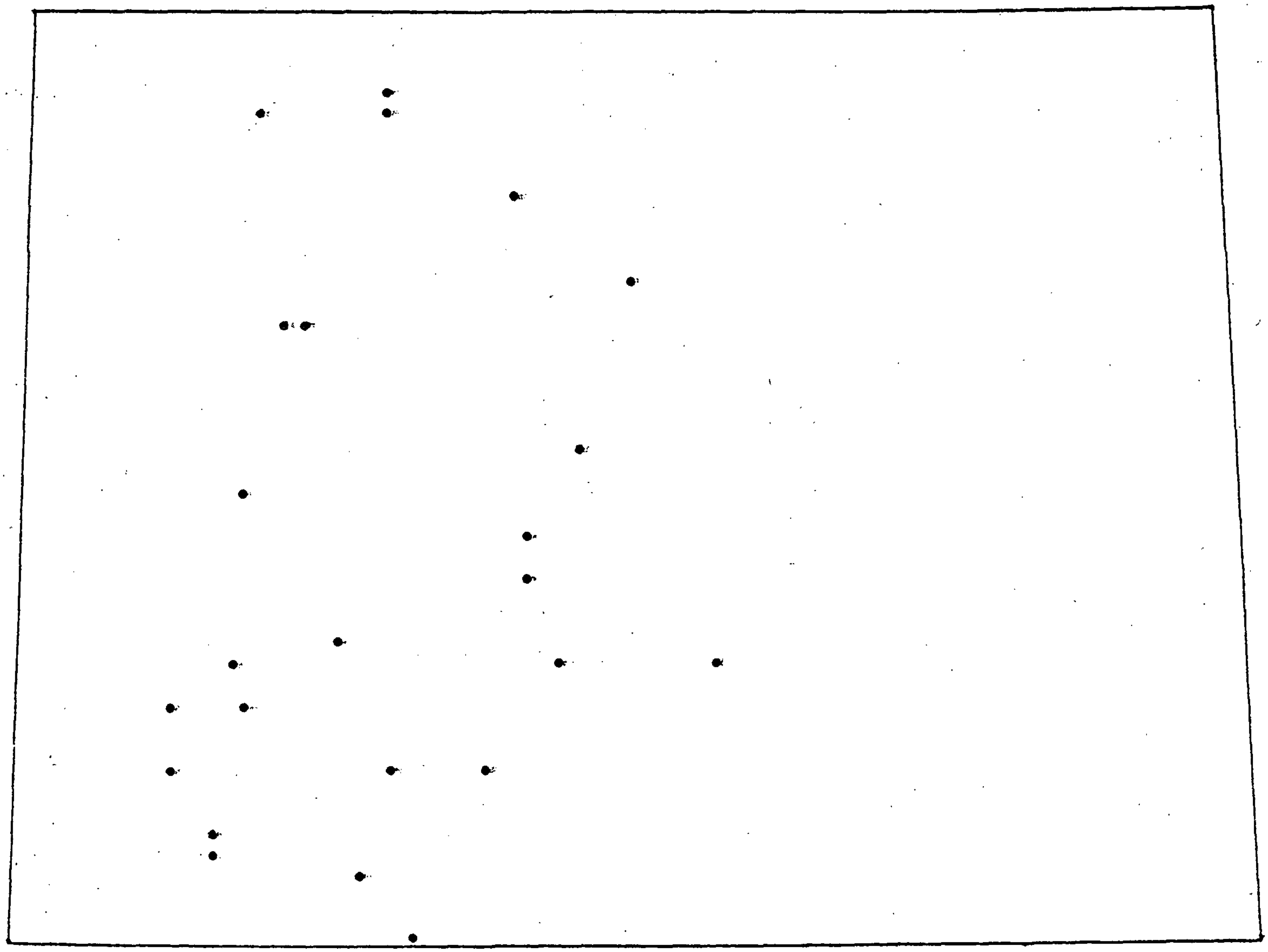


Figure 1c. Low Temperature Sites in Nevada



Prepared by PSL-AA-RPPM
July 1978

Geothermal Sites in New Mexico.



Prepared by PSL-AA-RPPM
July 1973

Figure 2b. Technically Feasible Low Temperature Geothermal Sites in Colorado.

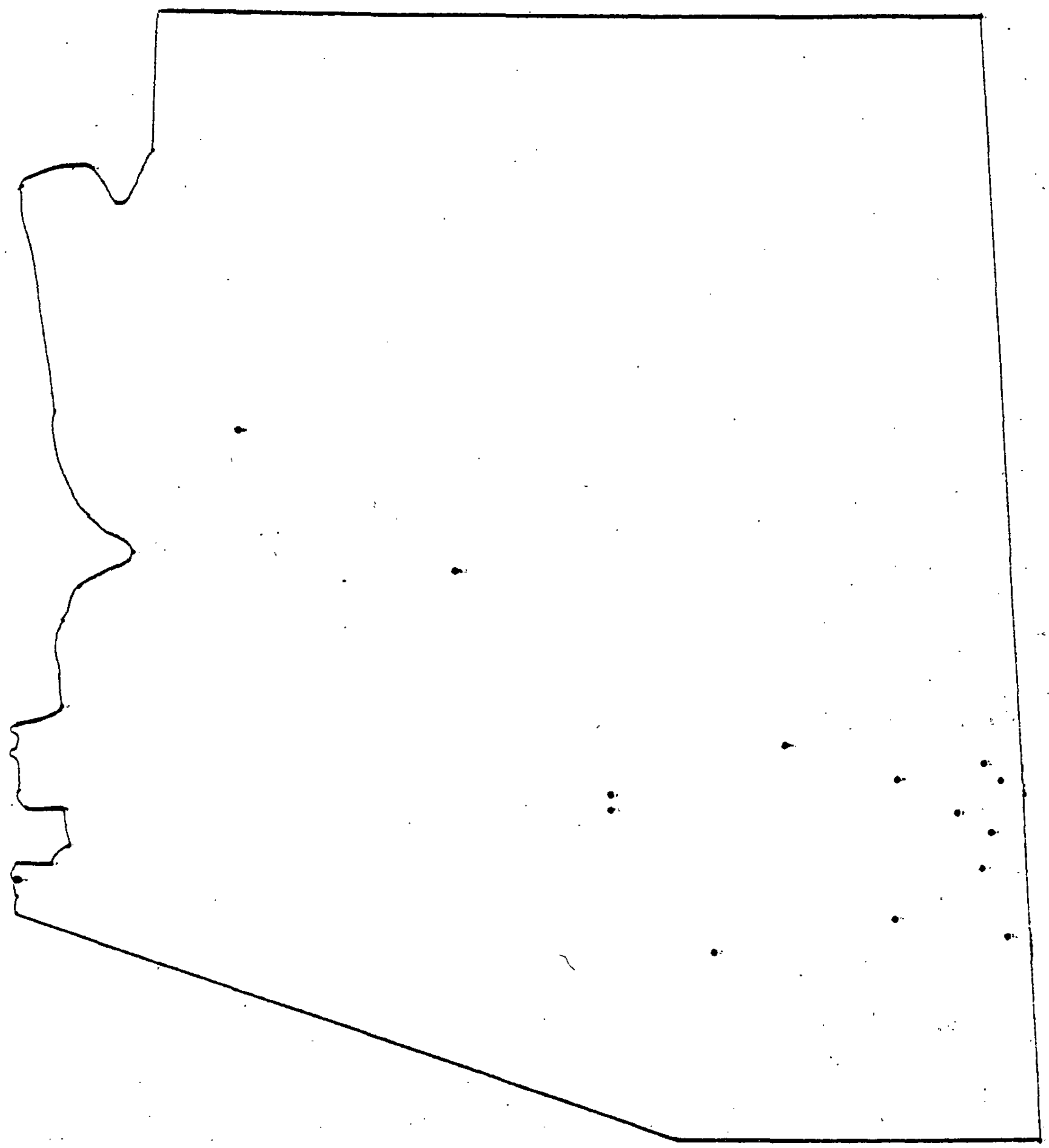


Figure 2a. Technically Feasible Low Temperature Geothermal Sites in Arizona.

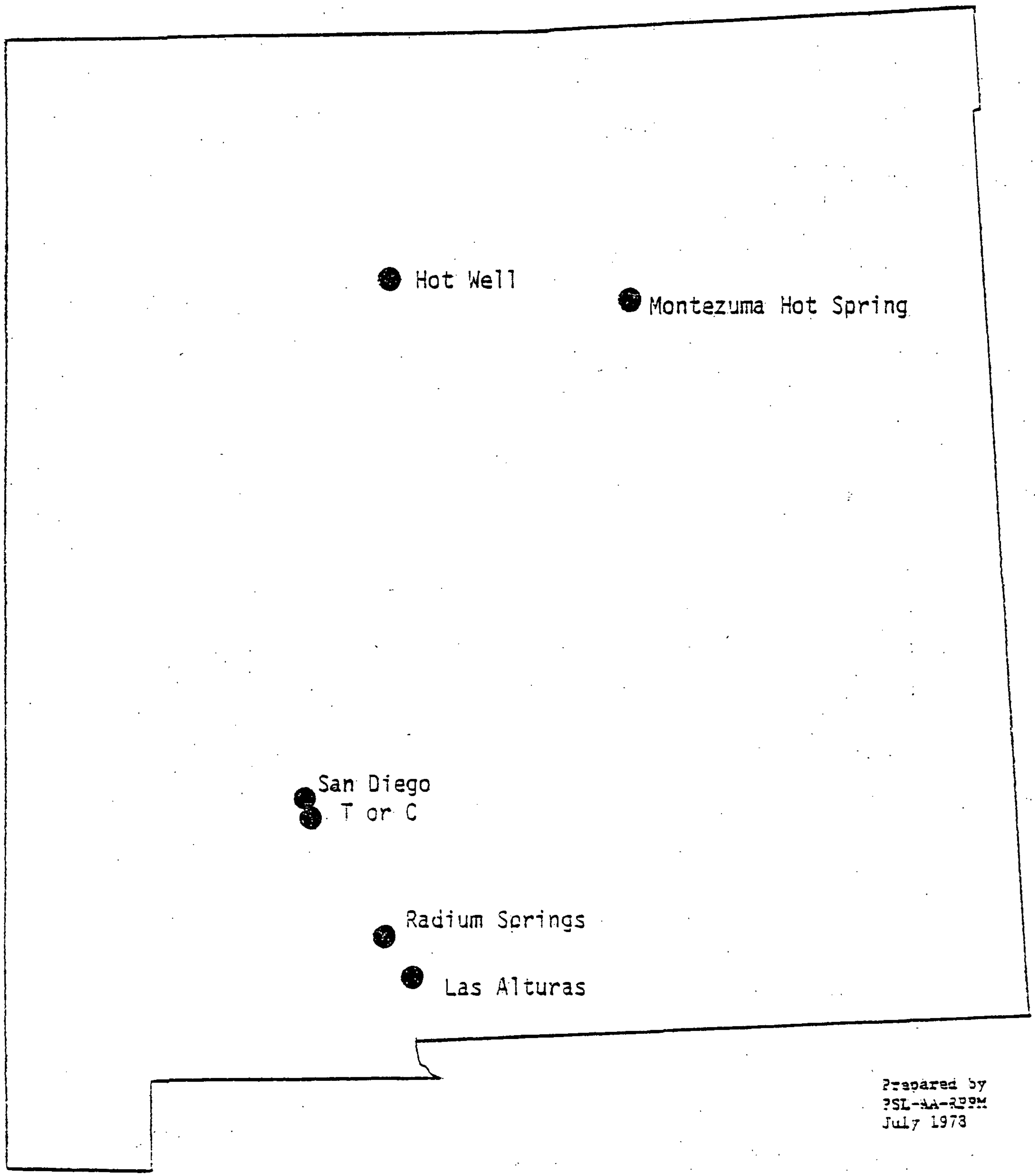


Figure 3d. Economically Feasible Low Temperature Geothermal Sites in New Mexico

CONTENTS

SITE ID	SITE NAME	CNTY CODE	LAT		LONG		TSP	RNG	S	RSVR VOL	SO	TSS	SO	TS	SO	SWE	SWM
4001	POWER RANCH AREAS	407	33	17	111	41				2.50	1	0		0		184	0
4002	CLIFTON HOT SPRINGS	406	33	4	109	18				2.25	1	0		0		160	0
4003	VERDE HOT SPRINGS	413	34	22	111	43				2.25	1	0		0		150	0
4004	GILLARD HS	406	32	58	109	21				2.25	1	0		0		140	0
4005	EAGLE CREEK H S	402	33	3	109	26				2.25	1	0		0		130	0
4006	COOLIDGE H S	404	33	10	110	32				2.25	1	0		0		120	0
4007	COFFERS H S	408	34	42	113	35				2.25	1	0		0		120	0
4008	CAT TANK	405	32	44	109	23				2.25	1	0		0		115	0
4009	JAVELINA PEAK	405	32	31	109	26				2.25	1	0		0		110	0
4010	SAFFORD AREA	405	32	51	109	34				2.25	1	0		0		110	0
4011	INDIAN H S	405	33	0	109	54				2.25	1	0		0		105	0
4012	CASTLE H S	413	33	59	112	22				2.25	1	0		0		105	0
4013	COOLIDGE AREA	411	32	54	111	34				2.25	1	0		0		0	61
4014	RADIUM SPRINGS	414	32	44	114	4				2.25	1	0		0		50	50
4015	HOOKERS H S	402	32	20	110	14				2.25	1	0		0		53	53
4016	BUCKHORN AREA	407	33	25	111	42				2.25	1	0		0		0	49
4017	AGUA CALIENTE	407	33	0	113	18				2.25	1	0		0		0	46
4018	ARTESIAN H W	405	32	43	109	43				2.25	1	0		0		0	44
4019	MT GRAHAM	405	32	52	109	45				2.25	1	0		0		0	44
4020	LUCATS SPA	405	32	45	109	45				2.25	1	0		0		0	42
4021	PALOMAS MTS	414	33	0	113	31				2.25	1	0		0		0	42
4022	BARNGAN MTN	414	33	7	113	25				2.25	1	0		0		0	39
4023	THEBA	407	32	56	112	45				2.25	1	0		0		0	38
4024	BOWIE AREA	402	32	19	109	29				2.25	1	0		0		0	36
4025	MOBIL AREA	407	33	12	112	22				2.25	1	0		0		0	35
4026	ARTESIA AREA	405	32	41	109	42				2.25	1	0		0		0	33
4027	TOM NIECE WARM SPR	405	33	4	109	59				2.25	1	0		0		0	32
4028	PHOENIX TEMPE	407	33	24	112	0	1N	4E		2.25	1	34	4	0		150	0
4029	ELOY	411	32	45	111	35	10S	8E		2.25	1	27	4	0		0	0
4030	FLORENCE	411	33	05	111	18	4S	10E		2.25	1	28	4	0		0	0
4031	COOLIDGE	411	33	02	111	35	5S	8E		2.25	1	42	4	0		0	0

WYOMING

CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG
16001	AFTON	LINCOLN	1290	42 44	110 55
16002	BASIN	BIG HORN	1145	44 24	108 02
16003	BIG PINEY	SUBLETTE	570	42 32	110 06
16004	BUFFALO	JOHNSON	3394	44 21	106 40
16005	CASPER	NATRONA	39361	42 50	106 20
16006	CHEYENNE	LARAMIE	40914	41 08	104 50
16007	CODY	PARK	5161	44 32	109 04
16008	DOUGLAS	CONVERSE	2677	42 48	105 23
16009	DUBOIS	FREMONT	898	43 32	109 36
16010	EVANSTON	UINTA	4462	41 16	110 58
16011	EVANSVILLE	NATRONA	832	42 51	106 16
16012	FOX FARM	LARAMIE	1329	00 00	000 00
16013	GILETTE	CAMBELL	7194	44 18	105 30
16014	GLENROCK	CONVERSE	1515	42 52	105 52
16015	GREEN RIVER	SWEETWATER	4196	41 33	109 27
16016	GREYBULL	BIG HORN	1953	44 30	108 02
16017	GUERNSEY	PLATTE	793	42 17	104 45
16018	JACKSON	TETON	2101	43 28	110 45
16019	KEMMERER	LINCOLN	2292	41 47	110 33
16020	LANDER	FREMONT	7125	42 49	108 44
16021	LARAMIE	ALBANY	23143	41 20	105 38
16022	LOVELL	BIG HORN	2371	44 50	108 15
16023	LUSK	NIOBRARA	1495	42 47	104 26
16024	LYMAN	UNITA	643	41 20	110 16
16025	MILLS	NATRONA	1724	42 50	106 24
16026	MOORCROFT	CROOK	981	44 15	104 58
16027	MOUNTAIN VIEW	NATRONA	1641	41 16	110 20
16028	NEWCASTLE	WESTON	3432	43 52	104 14
16029	ORCHARD VALLEY	LARAMIE	1015	41 04	104 50
16030	PARADISE VALLEY	NATRONA	1764	42 49	106 24
16031	PINE BLUFFS	LARAMIE	937	41 10	104 06
16032	PINEDALE	SUBLETTE	948	42 51	109 50
16033	POWELL	PARK	4807	44 45	108 46
16034	RAWLINS	CARBON	7855	41 46	107 16
16035	RIVERTON	FREMONT	7995	43 02	108 22
16036	ROCK SPRINGS	SWEETWATER	11657	41 35	109 13
16037	SARATOGA	CARBON	1181	41 28	106 48
16038	SHERIDAN	SHERIDAN	10856	44 48	106 57
16039	SHOSHONI	FREMONT	562	43 15	108 04
16040	SUNDANCE	CROOK	1056	44 23	104 22
16041	THERMOPOLIS	HOT SPRINGS	3063	43 39	108 12
16042	TORRINGTON	GOSHEN	4237	42 05	104 11
16043	UPTON	WESTON	987	44 05	104 36
16044	WARREN	LARAMIE	4527	00 00	000 00
16045	WHEATLAND	PLATTE	2498	42 03	104 57
16046	WORLAND	WASHAKIE	5055	44 01	107 58

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE AND LONGITUDE

B

Prepared by PSL AA RPPM
28 August 1978

NEW SITE ID (10-STATE REGION)

20000: Arizona
21000: Colorado
22000: Idaho
23000: Montana
24000: Nevada
25000: New Mexico
26000: North Dakota
27000: South Dakota
28000: Utah
29000: Wyoming

20001	4001	POWER RANCH AREAS	407	33	17	111	41			2.50	1	0		0	184	0	0		0	0
20002	4002	CLIFTON HOT SPRINGS	406	33	4	109	18			2.25	1	0		0	160	0	0		0	0
20003	4003	VERDE HOT SPRINGS	413	34	22	111	43			2.25	1	0		0	150	0	0		0	0
20004	4004	GILLARD HS	406	32	58	109	21			2.25	1	0		0	140	0	0		0	0
20005	4005	EAGLE CREEK H S	402	33	3	109	26			2.25	1	0		0	130	0	0		0	0
20006	4006	COOLIDGE H S	404	33	10	110	32			2.25	1	0		0	120	0	0		0	0
20007	4007	COFFERS H S	408	34	42	113	35			2.25	1	0		0	120	0	0		0	0
20008	4008	CAT TANK	405	32	44	109	23			2.25	1	0		0	115	0	0		0	0
20009	4009	JAVELINA PEAK	405	32	31	109	26			2.25	1	0		0	110	0	0		0	0
20010	4010	SAFFORD AREA	405	32	51	109	34			2.25	1	0		0	110	0	0		0	0
20011	4011	INDIAN H S	405	33	0	109	54			2.25	1	0		0	105	0	0		0	0
20012	4012	CASTLE H S	413	33	59	112	22			2.25	1	0		0	105	0	0		0	0
20013	4013	COOLIDGE AREA	411	32	54	111	34			2.25	1	0		0	0	61	0		0	0
20014	4014	RADIUM SPRINGS	414	32	44	114	4			2.25	1	0		0	0	50	0		0	0
20015	4015	HOOKERS H S	402	32	20	110	14			2.25	1	0		0	0	53	0		0	0
20016	4016	BUCKHORN AREA	407	33	25	111	42			2.25	1	0		0	0	49	234	4	0	0
20017	4017	AGUA CALIENTE	407	33	0	113	18			2.25	1	0		0	0	46	0		0	0
20018	4018	ARTESIAN H W	405	32	43	109	43			2.25	1	0		0	0	44	0		0	0
20019	4019	MT GRAHAM	405	32	52	109	45			2.25	1	0		0	0	44	0		0	0
20020	4020	LUCATS SPA	405	32	45	109	45			2.25	1	0		0	0	42	0		0	0
20021	4021	PALOMAS MTS	414	33	0	113	31			2.25	1	0		0	0	42	0		0	0
20022	4022	BARNGAN MTN	414	33	7	113	25			2.25	1	0		0	0	39	0		0	0
20023	4023	THERA	407	32	56	112	45			2.25	1	0		0	0	38	0		0	0
20024	4024	BOWIE AREA	402	32	19	109	29			2.25	1	0		0	0	36	0		0	0
20025	4025	MOBIL AREA	407	33	12	112	22			2.25	1	0		0	0	35	0		0	0
20026	4026	ARTESIA AREA	405	32	41	109	42			2.25	1	0		0	0	33	0		0	0
20027	4027	TOM NIECE WARM SPR	405	33	4	109	59			2.25	1	0		0	0	32	0		0	0
20028	4028	PHOENIX TEMPE	407	33	24	112	0	1N	4E	2.25	1	34	4	0	150	0	0		0	0
20029	4029	ELOY	411	32	45	111	35	10S	8E	2.25	1	27	4	0	0	0	108	4	0	0
20030	4030	FLORENCE	411	33	05	111	19	4S	10E	2.25	1	28	4	0	0	0	479	4	0	0
20031	4031	COOLIDGE	411	33	02	111	35	5S	8E	2.25	1	42	4	0	0	0	514	4	0	0
20032	4032	CASA GRANDE	411	32	53	111	45	6S	6E	2.25	1	24	4	0	0	0	260	4	0	0
20033	4033	MAMMOTH	411	32	42	110	35	9S	7E	2.25	1	32	4	0	0	0	536	4	0	0
20034	4034	PAPAGO FARMS	410	31	47	112	19	19S	1E	2.25	1	31	4	0	0	0	208	4	0	0
20035	4035	WIKIEUP	408	34	39	113	39	15N	3W	2.25	1	22	4	0	0	0	0		0	0
20036	4036	SAN BERNADINO BASALT	402	31	24	109	24	23S	29E	2.25	1	0		0	150	0	0		0	0
20037	4037	SPRINGERVILLE	401	34	6	109	18			2.25	1	0		0	150	0	0		0	0
20038	4038	ST JOHNS	401	34	24	109	24			2.25	1	0		0	150	0	0		0	0
20039	4039	JOSEPH CITY	409	34	48	110	24			2.25	1	0		0	150	0	0		0	0

Nevada Geothermal Sites With No Listed Temperature

6164 VIRGIN VALLEY
6166 LITTLE SAGE HEN SPRI
6167 JORDAN MEADOW MTN.
6179 GOOSEY LAKE FLAT
6180 DEEP CRK.-SULPHUR CK
6182 BURNS CREEK
6184 MIDAS
6186 HOT LAKE
6187 WILLOW CRK. RESERVOI
6188 EVANS CREEK
6194 WILKINS
6196 GONCE CREEK
6197 NORTH FORK
6199 WINTER CREEK
6200 CLOVER VALLEY
6202 FLY RANCH, N.E.
6203 SQUAW VALLEY
6204 CHOLONA
6205 SULPHUR
6223 KENT SPRING
6225 SHEEP CREEK RANGE
6226 PINE CREEK
6227 DRY LAKE
6228 NEEDLE PEAK
6229 N.Y. CNYN KAOLIN DEP
6234 COLD CREEK
6235 WINCHETT LAKE
6237 DOLLY VARDEN
6239 DOGSKIN MOUNTAIN
6241 NORTH VALLEY
6242 HUXLEY
6243 CARSON SNK ALK FLT W
6244 LONE ROCK
6245 COMSTOCK MINE, HMBLT
6247 EAGLE SALT WORKS
6248 HOT SPRINGS MTNS
6249 CARSON SNK, AF EAST
6250 SPANISH SPRINGS
6251 LOCKWOOD
6206 SAWMILL
6208 GERLACH, N.E.
6209 SOUTHERN EUGENE MTNS
6210 DUN GLEN CREEK
6211 NORTH FOX RANGE
6212 SELENITE PEAK
6213 BUFFALO CREEK
6215 SMOKE CREEK
6217 SAND PASS
6220 NUGENT SPRINGS
6253 DEEP CANYON
6256 TABLE MOUNTAIN
6257 PIROUETTE MOUNTAIN
6258 RAINBOW MOUNTAIN
6259 SO. STILLWATER RANGE
6260 FAIRVIEW VALLEY
6262 COMSTOCK MINING DIST
6264 CHURCHILL VALLEY
6266 CARSON HILL
6268 FOUR MILE FLAT
6269 NORTH SAND SPS. RANG
6270 BELL FLAT
6271 EAGLEVILLE
6273 WILD HORSE
6274 SENATOR
6275 MT. GRANT
6280 NORTHERN CLAN ALPINE
6282 SOUTH CLAN ALPINE MO
6283 BIRCHIM CREEK
6284 CLIPPER GAP CANYON
6285 KINGSTON
6286 WILDCAT CANYON
6287 MC LEOD'S RANCH SP.
6289 DUCK CREEK
6293 PLEASANT VALLEY
6294 PANCAKE SUMMIT
6296 SNAKE RANGE
6297 BULL CREEK
6299 MOUNT WILSON
6304 WILSON HOT SPRINGS
6308 SODA SPRING VALLEY
6310 RHODES SALT MARSH
6311 HUNTOON VALLEY
6313 KELLY'S WELLS
6317 RAYSON HILLS
6318 WILSON SPRING
6320 LUNAR CRATER
6321 TONOPAH MINING DISTR
6324 DUCKWATER
6325 WILLIAMS HOT SPRINGS
6326 DOYLES WELL
6327 SCHELL CREEK RANGE
6328 GRANITE PEAK
6331 BASALT
6333 GAP SPRING
6334 MT. DIABLO
6336 VALCALDA SPRING
6337 SOUTHERN CLAYTON V.
6342 SAND SP. VALLEY SOUT.

PSL-AA
28 August 1978

D

ARIZONA GEOTHERMAL SITES

Heat Content and Equivalent Electric Potential

Site ID	Res Vol Km^3	Temp °C	Heat Content Q	Elec Pot MW 30
4004	2.25	140	169	45
4005	2.25	130	155	41
4006	2.25	120	142	38
4007	2.25	120	142	38
4008	2.25	115	135	36
4009	2.25	110	128	34
4010	2.25	110	128	34
4011	2.25	105	122	32
4012	2.25	105	122	32
4013	2.25	61	62	16
4014	2.25	50	47	12
4015	2.25	53	51	14
4016	2.25	49	46	12
4017	2.25	46	42	11
4018	2.25	44	39	10
4019	2.25	44	39	10
4020	2.25	42	36	10
4021	2.25	42	36	10
4022	2.25	39	32	8
4023	2.25	38	31	8
4024	2.25	36	28	7
4025	2.25	35	27	7
4026	2.25	33	24	6
4027	2.25	32	23	6
4029	2.25	27	16	4
4030	2.25	28	18	5
4031	2.25	42	36	10
4032	2.25	24	12	3
4033	2.25	32	23	6
4034	2.25	31	22	6
4035	2.25	22	9	2
4045	2.25	134	161	43
4046	2.25	138	166	44
4047	2.25	64	66	18
4048	2.25	147	178	47
4049	2.25	87	97	26
4050	2.25	113	132	35
4051	2.25	110	128	34
4052	2.25	49	46	12
4053	2.25	40	34	9

✓ pJ

40 5

+/J[;5]

781 MW30 for AZ

E

31073340l MKTOUT

```
PROJECT ID NO.        7001
SITE NAME             VALLES CALDERA         NM
LOCATION              35 53 N     106 32 W
TEMPERATURE           240 DEGREES C
AREA POPULATION        60866
```

CITY	STATE	COUNTY	POPULATION	DISTANCE
ESPANOLA	NM	RIO ARRIBA3	4528	27
LOS ALAMOS2	NM	LOS ALAMOS	11310	13
SANTA FE	NM	SANTA FE	41167	36
WHITE ROCK12	NM	LOS ALAMOS	3861	17

Variables:

Radius from Site, Miles

Site Temperature

Population

Program selects all sites above a preset temperature, within a preset radius of population centers, and consisting of a preset number of inhabitants. Sample is for New Mexico, temp higher than 150°C, population greater than 1000, and within 50 miles of site.

Nevada Geothermal Sites Within 5 Miles of Each Other

Site Id	Site Id	Miles
6002	6247	4
6003	6114	2
6013	6132	2
6014	6043	5
6014	6049	5
6014	6125	3
6016	6058	4
6026	6149	1
6026	6171	4
6029	6169	4
6030	6118	0
6033	6208	5
6042	6043	5
6044	6100	1
6046	6310	5
6047	6109	1
6048	6112	0
6049	6125	2
6052	6103	4
6061	6195	5
6066	6094	0
6067	6081	3
6067	6084	3
6067	6117	0
6069	6119	1
6074	6088	1
6081	6084	2
6081	6117	3
6081	6122	4
6081	6139	5
6082	6096	3
6084	6117	3
6084	6122	4
6084	6136	5
6084	6139	4
6085	6129	5
6086	6122	2
6086	6139	2
6089	6232	0
6091	6092	1
6091	6093	2
6092	6093	1
6098	6127	3
6102	6153	4
6113	6198	2
6121	6254	5
6122	6139	1
6131	6252	5
6133	6155	0
6140	6141	2
6140	6279	1
6141	6279	1
6142	6236	0
6143	6230	0
6144	6222	3
6145	6221	1
6146	6194	4
6148	6170	3
6149	6171	4
6150	6329	1
6151	6281	0
6154	6207	0
6157	6159	4
6157	6165	5
6160	6325	0
6161	6304	1
6171	6172	3
6223	6224	5
6227	6228	5
6239	6240	5
6262	6263	4
6285	6286	5
6315	6362	4
6322	6364	5
6341	6342	2
6347	6348	4

Prepared by
NMSU-PSL-RPPM
11 Aug 78

NEW MEXICO: ACREAGE LEASED AND CONTROLLING AGENCY

TOTAL LAND (CURRENT LEASE)

Prepared by PSL AA RPPM
28 August 1978

SITE	NAME	COUNTY	PRIVATE	STATE	INDIAN	FEDERAL	TOTAL
7001	VALLES CALDERA	723	100000		30000	39000	169000
7002	LIGHTNING DOCK	712	15300	37820		46552	99672
7003	LWR SAN FRANCISCO HS	702				5760	5760
7004	KILBOURNE HOLE	707	1257	3153		94512	98922
7005	SAN ANTONIO HS (JEME	723	20000			11860	31860
7006	SPENCE SP (JEMEZ)	723					
7007	MC CAULEY SP (JEMEZ)	723					
7008	RADIUM SPRINGS	707	1681	1681		21221	23583
7009	OJO CALIENTE	721		160			160
7010	GILA HS-BELOW BRIDGE	709				3201	3201
7011	GILA HS-MIDDLE FORK	702					
7012	MONTEZUMA HS	725					
7013	GILA HS-DOC CAMPBELL	702					
7014	MAMBY'S HS	729					
7015	TURKEY CREEK	709					
7016	WHITE SANDS	707					
7017	LAS ALTURAS	707					
7018	BERINO - MESQUITE	707					
7019	MIMBRES HS	709		2500			2500
7020	PONCE DE LEON	729					
7021	E SAN AUGUSTIN PLAIN	728					
7022	UPR SAN FRANCISCO HS	702					
7023	FAYWOOD HS	709		1920			1920
7024	T OR C	727	120				120
7025	GILA HS-UPR MDL FRK	702		640			640
7026	W MESA-BLACK MNTN	707					
7027	CLOSSON	732					
7028	PLAYAS VALLEY	712					
7029	CLIFF AREA	709					
7030	DERRY WARM SPRING	727		960			960
7031	SEDILLO SPRING	728					
7032	TOHATCHI AREA	717					
7033	CROWN POINT	717					
7034	NORTHEAST OF PREWITT	717					
7035	GUADALUPE SP	723					
7036	HOT WELL	723					
7037	SAN YSIDRO	723		1915			1915
7038	HUECO-S TULAROSA BAS	719					
7039	SAN JUAN BASIN	724					
7040	CROCKER	727					
7041	FREIBORN CANYON	702		1920			1920
7042	LAS PALOMAS	707		640		9440	10080
7043	RINCON EAST	707		320			320

NEW MEXICO: ACREAGE LEASED AND CONTROLLING AGENCY
TOTAL LAND(PENDING LEASE)

Prepared by PSL AA RPPM
28 August 1978

SITE	NAME	COUNTY	PRIVATE	STATE	INDIAN	FEDERAL	TOTAL
7001	VALLES CALDERA	723					
7002	LIGHTNING DOCK	712					
7003	LWR SAN FRANCISCO HS	702					
7004	KILBOURNE HOLE	707				12000	12000
7005	SAN ANTONIO HS (JEME	723					
7006	SPENCE SP (JEMEZ)	723					
7007	MC CAULEY SP (JEMEZ)	723					
7008	RADIUM SPRINGS	707				15000	15000
7009	OJO CALIENTE	721				7000	7000
7010	GILA HS-BELOW BRIDGE	709					
7011	GILA HS-MIDDLE FORK	702				1000	1000
7012	MONTEZUMA HS	725	1000				1000
7013	GILA HS-DOC CAMPBELL	702				1000	1000
7014	MAMBY'S HS	729	1000				1000
7015	TURKEY CREEK	709				1000	1000
7016	WHITE SANDS	707				1000	1000
7017	LAS ALTURAS	707	1000	1000			2000
7018	BERINO - MESQUITE	707	1000				1000
7019	MIMBRES HS	709	7500				7500
7020	PONCE DE LEON	729	1000				1000
7021	E SAN AUGUSTIN PLAIN	728	1000	1000		1000	3000
7022	UPR SAN FRANCISCO HS	702				1000	1000
7023	FAYWOOD HS	709					
7024	T OR C	727					
7025	GILA HS-UPR MDL FRK	702				1000	1000
7026	W MESA-BLACK MNTN	707					
7027	CLOSSON	732				1000	1000
7028	PLAYAS VALLEY	712	1000				1000
7029	CLIFF AREA	709	1000				1000
7030	DERRY WARM SPRING	727					
7031	SEDILLO SPRING	728					
7032	TOHATCHI AREA	717			1000		1000
7033	CROWN POINT	717			1000		1000
7034	NORTHEAST OF PREWITT	717	1000				1000
7035	GUADALUPE SP	723	1000				1000
7036	HOT WELL	723				1000	1000
7037	SAN YSIDRO	723				19600	19600
7038	HUECO-S TULAROSA BAS	719			1000		
7039	SAN JUAN BASIN	724					1000
7040	CROCKER	727					
7041	FREIBORN CANYON	702				1000	1000
7042	LAS PALOMAS	707					
7043	RINCON EAST	707				1000	1000

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Prepared by PSL AA RPPM
28 August 1978

NEW MEXICO: ACREAGE LEASED AND CONTROLLING AGENCY

FEDERAL LAND (CURRENT LEASE)

SITE	NAME	COUNTY	PUBLIC (BLM)	NAT'L FOR	MIL	NAT'L PARK	TOTAL
7001	VALLES CALDERA	723		39000			39000
7002	LIGHTNING DOCK	712	46552				46552
7003	LWR SAN FRANCISCO HS	702		5760			5760
7004	KILBOURNE HOLE	707	94512				94512
7005	SAN ANTONIO HS (JEME	723		11860			11860
7006	SPENCE SP (JEMEZ)	723					
7007	MC CAULEY SP (JEMEZ)	723					
7008	RADIUM SPRINGS	707	21221				21221
7009	OJO CALIENTE	721					
7010	GILA HS-BELOW BRIDGE	709		3201			3201
7011	GILA HS-MIDDLE FORK	702					
7012	MONTEZUMA HS	725					
7013	GILA HS-DOC CAMPBELL	702					
7014	MAMBY'S HS	729					
7015	TURKEY CREEK	709					
7016	WHITE SANDS	707					
7017	LAS ALTURAS	707					
7018	BERINO - MESQUITE	707					
7019	MIMBRES HS	709					
7020	PONCE DE LEON	729					
7021	E SAN AUGUSTIN PLAIN	728					
7022	UPR SAN FRANCISCO HS	702					
7023	FAYWOOD HS	709					
7024	T OR C	727					
7025	GILA HS-UPR MDL FRK	702					
7026	W MESA-BLACK MNTN	707					
7027	CLOSSON	732					
7028	PLAYAS VALLEY	712					
7029	CLIFF AREA	709					
7030	DERRY WARM SPRING	727					
7031	SEDILLO SPRING	728					
7032	TOHATCHI AREA	717					
7033	CROWN POINT	717					
7034	NORTHEAST OF PREWITT	717					
7035	GUADALUPE SP	723					
7036	HOT WELL	723					
7037	SAN YSIDRO	723					
7038	HUECO-S TULAROSA BAS	719					
7039	SAN JUAN BASIN	724					
7040	CROCKER	727					
7041	FREIBORN CANYON	702					
7042	LAS PALOMAS	707					
7043	RINCON EAST	707	9440				9440

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NEW MEXICO:ACREAGE LEASED AND CONTROLLING AGENCY

FEDERAL LAND (PENDING LEASE)

Prepared by PSL AA RPPM
28 August 1978

SITE	NAME	COUNTY	PUBLIC	NATL FOR	MIL	NATL PARK	TOTAL
7001	VALLES CALDERA	723					
7002	LIGHTNING DOCK	712					
7003	LWR SAN FRANCISCO HS	702					
7004	KILBOURNE HOLE	707	12000				12000
7005	SAN ANTONIO HS (JEME	723					
7006	SPENCE SP (JEMEZ)	723					
7007	MC CAULEY SP (JEMEZ)	723					
7008	RADIUM SPRINGS	707					
7009	OJO CALIENTE	721	15000				15000
7010	GILA HS-BELOW BRIDGE	709	7000				7000
7011	GILA HS-MIDDLE FORK	702		1000			1000
7012	MONTEZUMA HS	725					
7013	GILA HS-DOC CAMPBELL	702		1000			1000
7014	MAMBY'S HS	729					
7015	TURKEY CREEK	709		1000			1000
7016	WHITE SANDS	707			1000		1000
7017	LAS ALTURAS	707					
7018	BERINO - MESQUITE	707					
7019	MIMBRES HS	709					
7020	PONCE DE LEON	729					
7021	E SAN AUGUSTIN PLAIN	728					
7022	UPR SAN FRANCISCO HS	702					
7023	FAYWOOD HS	709					
7024	T OR C	727					
7025	GILA HS-UPR MDL FRK	702		1000			1000
7026	W MESA-BLACK MNTN	707					
7027	CLOSSON	732		1000			1000
7028	PLAYAS VALLEY	712					
7029	CLIFF AREA	709					
7030	DERRY WARM SPRING	727					
7031	SEDILLO SPRING	728					
7032	TOHATCHI AREA	717					
7033	CROWN POINT	717					
7034	NORTHEAST OF PREWITT	717					
7035	GUADALUPE SP	723					
7036	HOT WELL	723	1000				1000
7037	SAN YSIDRO	723	19600				19600
7038	HUECO-S TULAROSA BAS	719					
7039	SAN JUAN BASIN	724					
7040	CROCKER	727					
7041	FREIBORN CANYON	702		1000			1000
7042	LAS PALOMAS	707					
7043	RINCON EAST	707	1000				1000