CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

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RECONNAISSANCE OF GEOTHERMAL RESOURCES NEAR U.S. NAVAL FACILITIES IN SAN DIEGO, SAN DIEGO COUNTY, CALIFORNIA

1984

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RECONNAISSANCE OF GEOTHERMAL RESOURCES NEAR U.S. NAVAL FACILITIES IN THE SAN DIEGO AREA, CALIFORNIA

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EXECUTIVE SUMMARY

The purpose of this project was to determine and evaluate possible geothermal resources for potential development at U.S. naval reservations in the greater San Diego, California area. The work was done through the auspices of a cooperative agreement between the U.S. Department of Energy, San Francisco Operations Office and the U.S. Department of Navy, China Lake Naval Weapons Center for joint research on geothermal energy at U.S. military installations.

Although southwestern San Diego County (especially the coastal plain) appears to have a slightly higher than normal regional thermal gradient, there is little evidence to support the existence of a major low-temperature geothermal resource potential under or near any of 14 naval facilities located in the San Diego area with the possible exception of the Imperial Beach Naval Air Station. In that particular area ground water temperatures and modest thermal gradients suggest that development wells may have to be drilled to a greater depth than is economically feasible under current technology to find adequate or useful temperatures. Some specific findings follow:

- Temperature versus depth data from four wells located in the coastal plains of the southwestern part of San Diego County were used to calculate a regional thermal gradient of 1.56°F/100 feet for the study area shown on Plate 1. This gradient is only slightly higher than the often quoted "normal" of 1°F/100 feet.

- Often, in previous literature, water wells thought to have elevated discharge temperatures were presented as evidence of a possible geothermal resource in the San Diego area. These wells seemed to be in greater density, in the south bay area near the Imperial Beach Naval Air Station. Little or no other direct evidence suggests the existence of local thermal anomalies in the study area.

- A thorough records search has located 25 wells throughout the San Diego study area with recorded water temperatures of 78°F or greater (Plate 1). Some wells, often listed in the past as being "thermal wells", were found to have typographically, erroneously high temperatures listed in the files. These wells have been removed from the list of warm water wells (Table 2).

- Most of the water well discharge temperatures listed in Table 2 are only modestly high, being in the high 70 to low 80 degrees Fahrenheit range. Some of these temperatures may be the result of the slightly high regional gradient and/or, alternatively, the result of sampling from pressure tanks at well heads on warm, sunny, summer days, when the sun's heat can contribute to the elevated temperature of the water.

- A bounded area shown on Plate 1 encloses most of the wells with the higher recorded temperatures listed in Table 2. This south bay area is the most likely zone having the potential for a viable geothermal resource near a U.S. Navy facility in San Diego. The bounded area includes the eastern half of the Imperial Beach Naval Air Station.

- This zone having the most likely potential for a geothermal resource lies just south of an historic cluster of earthquakes centered in the San Diego Bay and is enclosed within a negative gravity anomaly also roughly encircling San Diego Bay.

- Geothermometric data indicate reservoir temperatures of over 212°F (100°C) in the southern part of this bounded area as well as in the San Dieguito River Valley in the far northwest part of the study area (Plate 1). However, ground water aquifers in both of these areas are known to be heavily intruded with sea water. This contamination invalidates the geothermometric calculations and hence the existence of localized thermal regimes in these areas as predicted using the geothermometry data.

- A conservative average of thermal gradients from selected wells in this bounded area is approximately 1.9°-2.0°F/100 feet. Although this is a modest gradient, it is larger than the regional gradient. Extrapolation of the gradient provides predictions of 150°F temperatures at approximately 4,000 feet depth and 212°F temperatures at 7,300 feet depth. Basement rocks in this area are thought to lie at 4,500-5,000 foot depth.

- Water production in the bounded area is generally good with wells pumping over 300 gal/min common and some (including the warm water well at location No. 316 on Plate 1) producing over 1,000 gal/min. Total dissolved solids (TDS) measurement is generally high due to intruding sea water.

- If the Department of Navy elects to further pursue the potential for geothermal resources underlying naval facilities in the San Diego area, the best area for detailed exploration appears to be the outlined area on Plate 1 that encompasses the eastern part of the Imperial Beach Naval Air Station.

ABSTRACT

A reconnaissance study has found little evidence of potential geothermal resources useful at naval facilities in the greater San Diego metropolitan area. However, there is a zone of modest elevated water well temperatures and slightly elevated thermal gradients that may include the eastern portion of the Imperial Beach Naval Air Station south of San Diego Bay. An increase of 0.3° - 0.4°F/100 feet over the regional thermal gradient of 1.56°F/100 feet was conservatively calculated for this zone. The thermal gradient can be used to predict 150°F temperatures at a depth of approximately 4,000 feet. This zone of greatest potential for a viable geothermal resource lies within a negative gravity anomaly thought to be caused by a tensionally developed graben, approximately centered over the San Diego Bay. Water well production in this zone is good to high, with 300 gal/min. often quoted as common for wells in this area. The concentration of total dissolved solids (TDS) in the deeper wells in this zone is relatively high due to intrusion of sea water. Productive geothermal wells may have to be drilled to depths economically infeasible for development of the resource in the area of discussion.

INTRODUCTION

The Division of Mines and Geology (DMG) has conducted a reconnaissance study in the San Diego, California area to determine if there are geothermal resources of potential use to U.S. naval installations there. The Department of the Navy determined that the geothermal characteristics of their military bases should be studied as part of its program to reduce dependence on petroleum through alternate energy use. The U.S. Department of the Navy and the U.S. Department of Energy (DOE) agreed to the investigation under a cooperative agreement between the Naval Weapons Center, China Lake, California and the DOE's San Francisco Operations Office for joint geothermal research and development at military installations. The DOE provided the funds for the project under Contract Number DE-AC03-83SF11720.

The study area comprises approximately 500 square miles and includes the Del Mar, Poway, La Jolla, La Mesa, Point Loma, National City, Imperial Beach, and portions of the San Vicente and El Cajon 7 1/2 minute U.S. Geological Survey topographic quadrangles. By inspection of the topographic maps and maps supplied by the U.S. Navy, fourteen U.S. Navy facilities have been identified within this area. The most northern military reservation is Miramar Naval Air Station while the most southern is Imperial Beach Naval Air Station (Plate 1).

The climate of the San Diego area is generally mild with average temperatures in the mid-to-high 60 degrees Fahrenheit range. Precipitation, as rainfall in the winter months, averages 10 to 13 inches per year (California Department of Water Resources, 1967).

One of the major emphases of this report was to analyze for geothermal potential all existing well data in the study area, and in particular, data for those wells on U.S. Navy installations. Unfortunately, personnel at the Navy Public Works Center at the San Diego Naval Station knew of only one shallow water well located on any of the military reservations south of the Miramar Naval Air Station. That one well was used for irrigation at the U.S. Naval Recreation Facilities golf course and is too shallow to be useful to the project. Public works personnel at the Miramar Naval Air Station knew that there had been five or six wells on that large reservation at one time, but all but two had been buried, destroyed, or lost. These two wells, labeled G and H (176) on Plate 1, are located in San Clemente Canyon near the City of San Diego refuse site. The wells were investigated by DMG staff on January 19, 1984.

Due to the great paucity of well data on the local naval facilities, it became evident that little direct data for the unknown thermal regimes underlying the military reservations could be obtained. Therefore, data from wells outside the boundaries of the military facilities were gathered to try to observe patterns or anomalies that might be extended beneath the reservations. To this end the mineral analyses data in ground water microfiche files of the California Department of Water Resources (CDWR) were searched for water well discharge temperatures and specific mineral constituents applicable to geothermometry calculations. A total of 368 water wells located in the study area were found to have sufficient data to be useful to the study. These wells are located and labeled numerically on Plate 1 and listed in Appendix A.

The water well locations in the CDWR files are listed by the State Well Numbering System. This system has two basic parts: its township and range and its section location. For example, well location No. 235 on Plate 1 is given as 17S/2W, 04B01. The well is located in Township 17 South, Range 2 West, and Section 4. Each section is subdivided into 16 quarter-quarter sections of 40 acres each; each 40-acre tract is identified by a letter. Letters A-R are used, with letters I and O omitted to avoid confusion with similar appearing numbers. This particular well is in tract "B". Figure 1 shows the lettering system. The final part of the well number is the sequential number of the well within that particular tract. The water wells shown on Plate 1 have generally been plotted to the center of each appropriate 40-acre tract.

In early days of settlement in California, certain areas were set aside as Land Grant Ranchos -- a large proportion of the San Diego area was included in these land grant areas. These areas were not surveyed into township and range subdivisions. Therefore, the extrapolation of surveyed township, range, and section lines introduces some unknown degree of error in the precise location of these water wells.

Additionally, files and reports from the California Department of Conservation, Division of Oil and Gas were searched for data from exploratory petroleum wells that had been drilled in the San Diego area. A total of 31 "wildcat" wells were located in the study area. They are listed in Table 1 and plotted with a letter designation on Plate 1. Most of these wells were drilled in the early part of the century and now no longer can be found. The

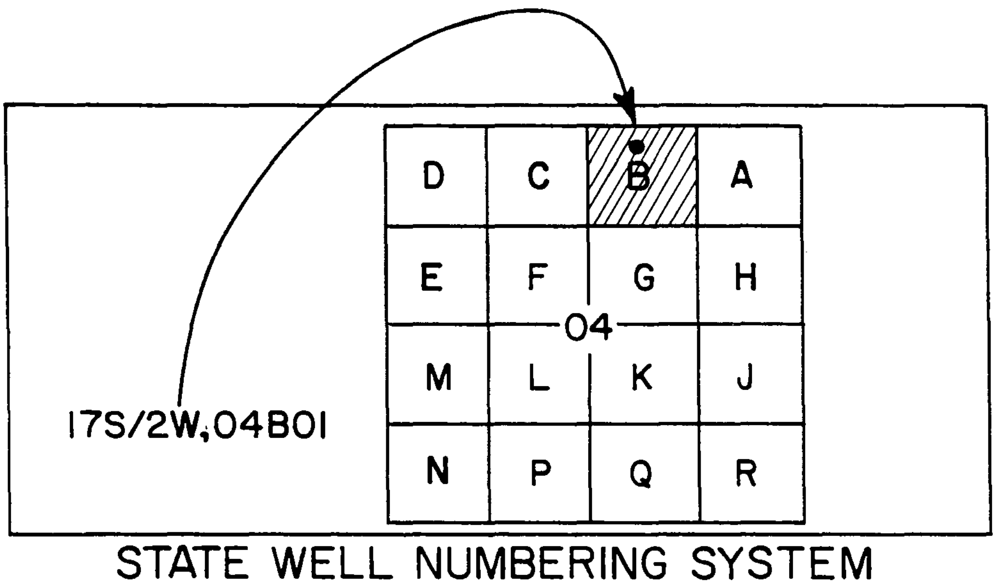
D
C
B
A
E
F
G
H
04
M
L
K
J
17S/2W,04B01
N
P
Q
R
STATE WELL NUMBERING SYSTEM

FIGURE 1.

TABLE 1. Exploratory petroleum and geothermal wells that have been drilled in the San Diego Area. Source of data is California Division of Oil and Gas, 1982.

MAP NO.#	LOCATION	OPERATOR	WELL NAME/NO.	SURFACE ELEV. (FEET)	YEAR DRILLED	TOTAL DEPTH (FEET)	STRATIGRAPHIC INFORMATION - AGE OF ROCKS AT BOTTOM HOLE EXCEPT AS NOTED IN FEET.
A	14S/3W-17	The MacGregor Corp.	"Butler" 1A	389	1929	2032	Eocene
B	14S/3W-18	The MacGregor Corp.	"Butler" 1	289	1926	1460	Basement (basalt) 1084-1460.
C	15S/3W-5	San Diego Sorrento Oil Co.	1	31	1911	1230	Eocene
D	15S/3W-7	Mills Oil Co.	1	300	1927	2775	Eocene
E	15S/3W-14	Homer C. Mills, Inc.	"Mills" 1	450	1932	425	Pliocene
F	15S/3W-20	Tecalote Dome Oil Co.	1	375	1920	2680	Eocene
G	15S/3W-23	Linda Vista Oil Co.	1	284	1920	1509	Eocene
H(176)	15S/3W-23	San Diego Dome Drilling Fund	1	300	1936	1147	Basement (metamorphics)
I	15S/3W-29	D.A. Hargrave	"Edmonde" 1	250	1933	3636	Cretaceous
J	15S/3W-32	La Jolla Petroleum Co.	"La Jolla" 1	330	1944	3750	Pliocene 1010, Eocene 2310, Conglomerate 2503, Cretaceous 3220, Basement (schist) 3720.
K	15S/3W-32	Tull and Waterbury	"Capitol" 1	422	1939	6130	Cretaceous 4410, Basement (schist) 5960.
L	16S/3W-8	Community Oil Well	4	100	1920	2112	Eocene
M	16S/3W-9	Community Oil Well	5	313	1920	1276	Eocene
N	16S/3W-13	J.A. Smith & F.R. Williams	"Balboa" 1	45	1911	5625	Cretaceous
O	16S/3W-20	Borderland Exploration Co., Inc.	2	29	1931	2610	Eocene
P	16S/3W-24	Mission Valley Oil Ent.	1	50	1921	5501	Cretaceous
Q	16S/3W-27	Associated Oil Syn.	1	355	1922	795	Pliocene
R	16S/3W-29	Mission Bay Oil Co.	1	6	1923	450	Pliocene
S	16S/3W-30	Borderland Exploration Co., Inc.	1	40	1930	5101	Cretaceous
T	17S/2W-11	L. Overbaugh & Rufus Choate	1	350	1924	1240	Pliocene
U	17S/2W-23	W.P. Manson	1	290	1922	2310	Eocene
V	18S/1W-6	Todd & Clark	1	320	1924	1000	Pliocene
*1 W	18S/2W-9F	Rohr, Industries	---	---	1981	1160	Pliocene (?)
X	18S/1W-30	Otay Oil Co.	1	385	1910	3500	Cretaceous
Y	18S/1W-31	La Tango Oil Co.	1	400	1911	3005	Cretaceous
Z	18S/2W-21	Palm City Oil Co.	1	50	1938	2150	Pliocene
AA	18S/2W-21	Robert Egger	"Robert Egger" 1	14	1962	5503	Weathered granite 4950, Basement (granite).
BB	18S/2W-22	National City Oil Co.	1	50	1924	2625	Pliocene
CC	18S/2W-31	South Bay Oil & Gas Co.	"James N. Crofton" 1	10	1931	1165	Pliocene
DD	18S/2W-32	San Diego Gas & Petroleum Corp.	1	17	1934	6334	Late Pliocene 300, Eocene 2900, Cretaceous 3900, Basement (volcanics) 5529.
EE	19S/2W-4	Community Oil Well	2	20	1919	119	Late Pliocene
FF	19S/2W-9	Community Oil Well	"Scott" 1	325	pre-1916	1863	Cretaceous

FOOTNOTES:

*1 Information on the Rohr Industries geothermal exploration well is from Miller and others, 1981. This is the only exploratory geothermal well in this list.

records on these wells are not very complete. Often their location as shown on Plate 1 could not be plotted more accurately than to the center of a section. As a result some locations may be only approximate.

Finally, published literature was reviewed for data from any other wells that might provide information on the possible presence of geothermal resources. Two important sources were Wiegand, 1982 and the report on the Rohr Industries geothermal exploration well by Miller and others, 1981.

In addition to the results and analyses of the well review, the report contains discussions on geology, geophysics, and hydrology; an appendix of geothermometric calculated reservoir temperatures for 368 water wells in the study area; and a bibliography of geoscientific reports relating to the San Diego study area.

PREVIOUS LITERATURE

Historic literature apparently does not list any known thermal springs in any area now occupied by a U.S. naval reservation in the San Diego area. In fact, it appears there were none in the entire study area shown on Plate 1. Some more recent literature, however, does mention the existence of some "warm" water wells in the area.

The CDWR, 1967 and 1983, lists many water wells with surface discharge temperatures in the high 60°-70°F range in the San Diego study area. Also are listed perhaps a dozen or more water wells that at one time or another had temperatures recorded in the 80°-100°F range. These wells with supposedly elevated temperatures appeared to be generally located in the South Bay area of San Diego. Wiegand, 1970, suggested that the existence of these wells supports the possible extension of the Rose Canyon fault through the South Bay area. Martin and others, 1980, and Higgins, 1980, list some of these wells as possible evidence of a geothermal resource in this area applicable for direct heat uses. Wiegand, 1982, presented an overview of potential geothermal resources in the study area with concentration again in the South San Diego Bay Region.

Other geothermal related literature includes Herbert, 1977, who, using well water chemistry data from the CDWR files, employed geothermetric algorithms to predict possible geothermal reservoir temperature in the southwest corner of the study area. Rohr Industries (Miller and others, 1981), located approximately two miles south of the San Diego Naval Station, drilled a 1,160-foot deep (cased to 1,143 feet) temperature gradient well to evaluate the potential of geothermal resources underlying their property.

The most recent discussion of geothermal resources associated with the South Bay area is found in a proposed Negative Declaration for an Environmental Impact Report (City of San Diego, 1984) for a geothermal-aquaculture demonstration project. The proposed plan is to divert warm water (96°F) from an existing 1,410-foot deep irrigation well into holding ponds for raising fish. The well is location No. 316 on Plate 1 and Table 2.

A REGIONAL THERMAL GRADIENT

Areas with anomalously higher thermal gradients than the regional gradient are sites of potential geothermal development. Therefore, it is practical to try to establish a regional thermal gradient for the San Diego study. A gradient of 1°F/100 feet is often quoted as the normal world-wide gradient for non-thermal areas.

Unfortunately, there is very little data on which to base a regional temperature gradient. Of the 31 exploratory oil and gas wells drilled in the study area, the records list bottom hole temperatures for only two. Those are 164°F at 6,084 feet at location No. K and 140°F at 5,502 feet at location No. AA on Plate 1. Subtracting a somewhat arbitrarily chosen ambient temperature of 68°F from the bottom hole temperature and then dividing by the total well depth yields an overall well gradient of 1.6°F/100 feet and 1.3°F/100 feet respectively.

Direct measurement of the thermal gradient was made at location No. W and at location No. H (176) on Plate 1. During an attempt to perform downhole temperature measurements at location No. G it was found that the well was dry. (The temperature of the mud at 104 feet was 68.3°F). Location No. W is the Rohr Industries geothermal exploration well. Figure 2 shows a gradient of 1.54°F/100 feet in the bottom portion of the well. The well at location No. H (176) is on the Miramar Naval Air Station. Figure 3 shows a temperature gradient of 1.79°F/100 feet.

Since these are the only directly measured downhole temperatures known and their locations are somewhat dispersed (although only in the coastal plain

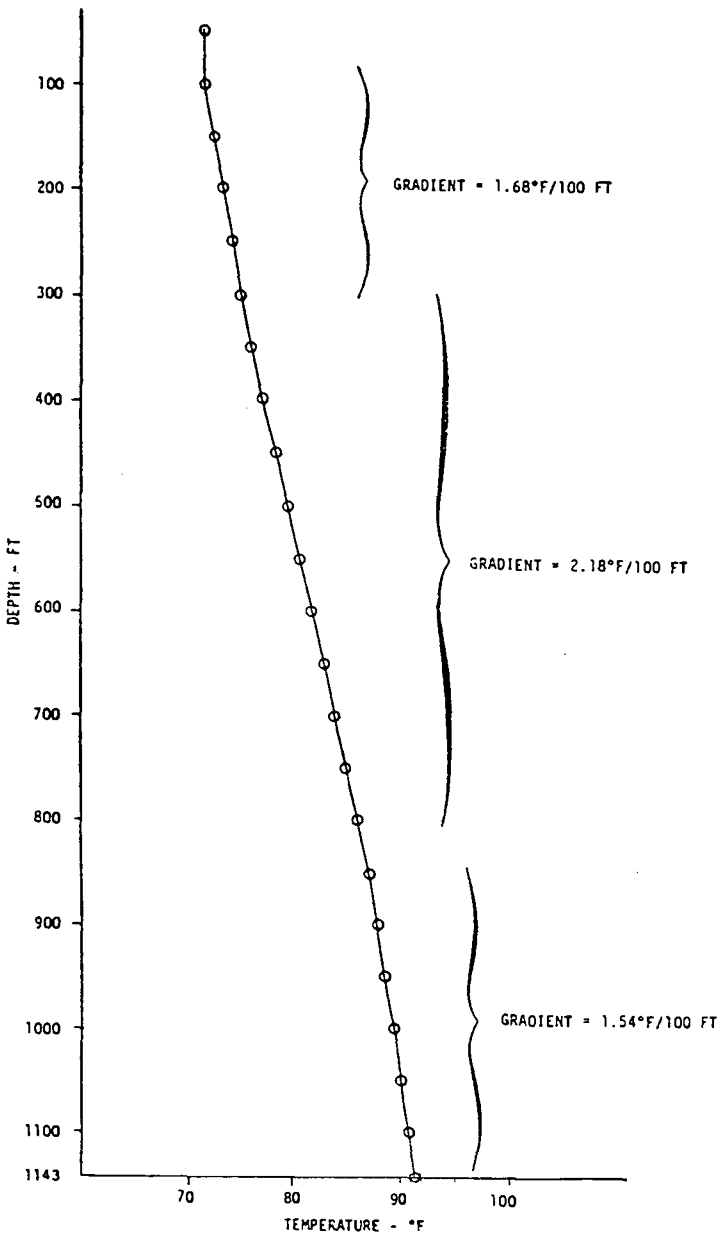

FIGURE 2. Temperature profile of the Rohr Industries geothermal exploration well (Plate 1, Location No. #W). Profile from Miller, 1981.

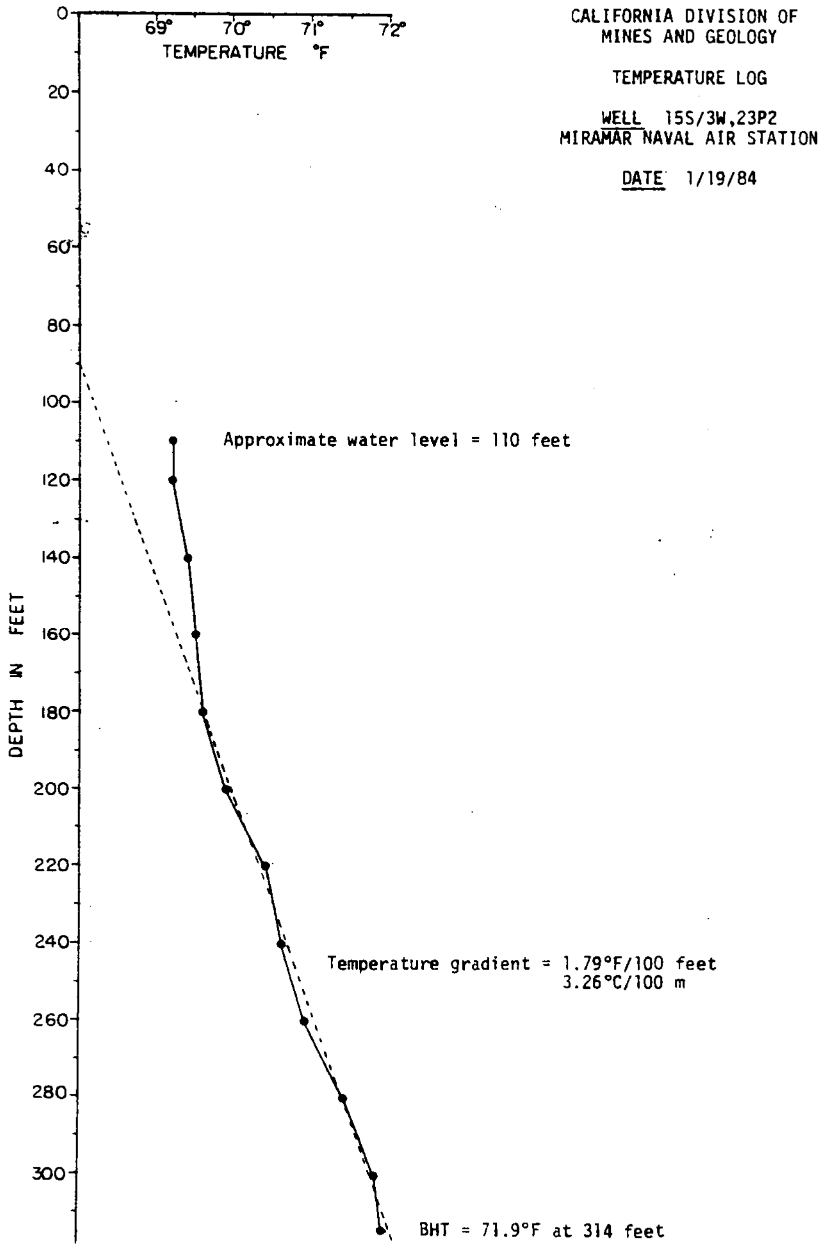

FIGURE 3. Temperature profile of well 15S/3W,23P2 on the Miramar Naval Air Station (Plate 1, Location No. #H [176]).

area) and the four values compare favorably, then the average of the above four gradients could be assumed to approximate the regional thermal gradient. The average is 1.56°F/100 feet. It seems that the regional thermal gradient of the San Diego study area is slightly higher than the "normal" gradient of 1°F/100 feet. Using a gradient of 1.56°F/100 feet a prediction can be made of 150°F temperatures at 5,300 feet depth and 212°F temperatures at approximately 9,000 feet.

DIRECT INDICATIONS OF A GEOTHERMAL RESOURCE

There are no known thermal springs, geysers, or fumaroles suggestive of volcanic activity in the study area of Plate 1. In fact, except for intercalated layers of altered volcanic ash (benotonite) in the Miocene Otay Formation, there are no known Cenozoic volcanic rocks in the area (Martin and others, 1980). The postulated existence of a low-temperature geothermal resource in the San Diego area is entirely predicated upon elevated water temperatures from water wells. These "warmer" water wells were thought to exist primarily in the South Bay San Diego area near Imperial Beach Naval Air Station and in the extreme southeast portion of Plate 1 in the Otay Mesa area (primarily outside the mapped area).

In most studies CDMG uses 68°F as the minimum threshold temperature above which waters are considered to be "geothermal". However, in searching the hundreds of records of water quality data for the San Diego area, it was found that the majority of the recorded temperatures were in the high 60°F to mid 70°F range. These slightly higher than normal well water temperatures are thought to be the result of measuring samples from sun-heated pressure tanks at well heads in summer months and the apparent slightly higher regional thermal gradient or a combination of both. In an attempt to find anomalously higher temperature zones from the regional background a minimum threshold temperature of 78°F was chosen for the purposes of this report. All wells with a recorded temperature of 78°F or greater (whether downhole or surface measurements) are shown as solid symbols on Plate 1. They are also cataloged in Table 2. There are 25 such well locations.

TABLE 2. List of wells in the San Diego Area with recorded temperatures of 78°F or greater and wells with measured temperature gradients.

WELLS IN THE SAN DIEGO AREA WITH RECORDED TEMPERATURES OF 78°F OR GREATER

MAP NO. #	REFERENCE	LOCATION	DATE	TEMPERATURE(°F)	DEPTH(FT.)	GRADIENT(°F/100 FT.)	REMARKS
FOOTNOTE 5							
173	1	15S/2W,19D01	03/28/63	78°	---	---	FOOTNOTE 1.
110	1	15S/1W,14Q01	09/17/58	87°	---	---	FOOTNOTE 1.
137	1	15S/1W,27G01	07/27/54	82°	---	---	FOOTNOTE 1.
138	1	15S/1W,27G05	09/17/58	84°	---	---	FOOTNOTE 1.
186	1	16S/3W,16Q01	10/19/55	78°	---	---	FOOTNOTE 1. This may be the same well as No. #187.
187	1	16S/3W,16R01	10/19/55	78°	---	---	FOOTNOTE 1. This may be the same well as No. #186.
202	1	16S/2W,16C01	07/27/54	80°	---	---	FOOTNOTE 1.
203	1	16S/2W,16D03	06/01/60	78°	---	---	FOOTNOTE 1.
209	1	16S/2W,18L01	06/02/65	82°	---	---	FOOTNOTE 1.
224	1	16S/3W,22P01	05/31/60	79°	---	---	FOOTNOTE 1.
235	1	17S/2W,04B01	07/22/54	78°	---	---	FOOTNOTE 1.
239	1	17S/2W,15J01	07/21/54	79°	---	---	FOOTNOTE 1.
284	1,4	18S/2W,24M01	07/26/56	83°	290	5.2	FOOTNOTES 1,2.
292	1	18S/2W,27G01	09/03/59	78°	---	---	FOOTNOTE 1.
298	1,4	18S/2W,28P01	08/11/53	97°	1790	1.6	FOOTNOTES 1,2. This may be the same well as No. #w2 listed below.
316	1,4	18S/2W,33L10	05/13/70	96°	1410	1.9	FOOTNOTE 2.
341	1	19S/2W,01ND6	11/19/62	78°	---	---	FOOTNOTE 1.
366	1,4	18S/1W,31H01	05/05/58	91°	1150	2.0	FOOTNOTES 1,2.
K	2	15S/3W,32	06/16/42	164°	6084	1.6	FOOTNOTE 3.
W	3	18S/2W,09F	01/81	91.5°	1143	1.54	FOOTNOTE 3. Rohr Industries Geothermal Exploration well.
AA	2	18S/2W,21	11/03/62	140°	5502	1.3	FOOTNOTE 3.
DD	2	18S/2W,32	04/18/35	"Hot Water"	6344	---	
w1	4	300 ft. W of I-5 on Palm Ave.	---	80°	200	6.0	FOOTNOTE 4.
w2	4	SW cor. Grove & 19th St.	---	110°	1750	2.4	FOOTNOTE 4. This well may be the same as No. #298 listed above.
w3	4	NW cor. National & Palm Ave.	---	80°	400	3.0	FOOTNOTE 4.

NONTHERMAL WELLS WITH MEASURED TEMPERATURE GRADIENTS

MAP NO. #	REFERENCE	LOCATION	DATE	TEMPERATURE(°F)	DEPTH(FT.)	GRADIENT(°F/100 FT.)	REMARKS
G	---	15S/3W,23P1	01/19/84	68.3°	104	Dry Well	Temperature shown was measured in the mud at the bottom of the dry well.
H	---	15S/3W,23P2	01/19/84	71.9°	314	1.79	FOOTNOTE 3.

FOOTNOTES:

1. The temperature shown in the table is the only temperature measurement recorded for this well in the California Department of Water Resources Files.
2. The depth shown is from Wiegand, 1982 (Reference No. 4 below).
3. The temperature shown is the bottom-hole temperature obtained from a well log.
4. All data about this well from Wiegand, 1982 (Reference No. 4 below).
5. Map numbers shown on Plate 1. Numbered locations from Reference 1 (see below), lettered locations are petroleum wells from Reference 2, and locations with combined letter and number are locally known water wells from Reference 4.

REFERENCE:

1. California Department of Water Resources, 1983, Mineral analyses of ground water: Microfiche files.
2. California Division of Oil and Gas, 1983, Exploratory wells drilled outside of gas and oil fields in California: Microfilm files.
3. Miller, R.R., Wiegand, J.W., and Larson, T.C., 1981, Geothermal resource assessment and policy development for Rohr Industries: California Energy Commission, Final Report, 63 p.
4. Wiegand, J.W., 1982, Geothermal energy in San Diego, An Overview: Geo-Heat Center Quarterly Bulletin, v. 6, no. 4, p. 26-29.

In some previous literature, certain water wells have been listed as having anomalously high temperatures that, during CDMG's record search, were discovered to be apparent typographic errors in the files. An example is well No. 349 located southeast of the Imperial Beach Naval Air Station (Plate 1). The records show that the well had a temperature recorded at five different times from 1959 to 1967.

Date	Temperature
08/12/59	66°F
04/25/61	67°F
10/24/61	68°F
04/18/62	70°F
04/04/67	94°F

Another example is well No. 254 in the Otay valley (Plate 1).

Date	Temperature
07/13/54	74°F
07/26/56	97°F
07/22/58	76°F
06/06/59	71°F
12/06/60	71°F
07/09/63	74°F

The temperatures circled above were the ones sometimes quoted in previous literature. All such wells with higher temperatures apparently due to typographic error have been removed from the list of warm water wells in Table 2.

The majority of the warm water wells in Table 2 have only one listing of a water temperature measurement in the files (marked as Footnote 1). It is difficult to verify these temperatures since most of these wells are buried, built over, destroyed, plugged, or otherwise unavailable. Most well discharge temperatures are modest, being in the high 70°F to low 80°F range.

As shown on Plate 1, the bounded area in the South Bay area has the greatest density of known warm water wells and contains the wells with the higher recorded temperatures. The bounded area includes the Rohr Industries geothermal exploration well (No. W), two petroleum exploration wells known to have had warm water (Nos. AA and DD), and several water wells with elevated temperatures. The most well documented water well is well No. 316 which is 1410 feet deep. Records show the following surface discharge temperatures for this well over some years:

Date	Temperature
04/16/63	96°F
10/08/63	70°F (probable typographic error)
11/01/63	94°F
03/04/64	96°F
10/15/66	94°F
01/14/65	93°F
08/01/65	84°F
04/04/67	92°F
05/13/69	99°F
05/13/70	96°F

A recent proposal (City of San Diego, 1984) would utilize the thermal water from this well for a fish farming facility.

The enclosed area may represent the best zone for potential low-temperature geothermal development in the study area and certainly represents the best area in which to conduct any future detailed geothermal investigations. The bounded area includes the western end of the Imperial Beach Naval Air Station. There is little or no direct temperature data to indicate a potential favorable geothermal resource near any of the other naval facilities shown on Plate 1.

When downhole temperature data were not available, some overall well thermal gradients were calculated by subtracting 68°F (ambient) from the surface discharge temperature and then dividing that value by the depth of the well. The assumption required to do this is that the discharge temperature is the bottom-of-the-hole temperature. These are the gradients listed in Table 2 without a Footnote 3. Wells Nos. 298, 316, and w 2 may be representative of this technique. Their gradients are 1.6, 1.9, and 2.4 °F/100 feet respectively. The average is 1.97°F/100 feet. This is only slightly higher than the regional gradient of 1.56°F/100 feet calculated in an earlier section of this report from direct downhole temperature data. A gradient of 1.97°F/100 feet can be used to predict 150°F temperatures at approximately 4,000 feet depth and 212°F temperatures at 7,300 feet depth. There are three calculated gradients on Table 2 vastly higher than this average. These values should probably be discounted since their surface discharge temperatures are very modest (80°-81°F) and may be due to measurements made on very warm, sunny days.

Of particular concern should be the temperature profile from the Rohr Industries geothermal exploration well (Figure 2). This well is within the "most favorable area" and is designated location No. W. Figure 2 shows the temperature gradient is decreasing with depth in this well. This is not usually a favorable indicator of an economically feasible low-temperature geothermal resource.

GEOTHERMOMETRY

Herbert (1977) used the Na-K-Ca geothermometer to determine possible temperatures at depth in the Tia Juana and Otay hydrologic units in the southern part of the study area south of San Diego Bay. This report expands that approach to include the area of Plate 1.

Appropriate mineral concentration data for the 368 water wells from California Department of Water Resources files was entered into the "FORTRAN Program to Compute Chemical Geothermometers for Geothermal Fluids" (Rapport, 1982) that is available in the CDMG computer program library. The resulting geothermal reservoir temperatures predicted by use of each geothermometer are listed in Appendix A. The well locations are posted on Plate 1. Because of the consistency of values and the more conservative temperatures, the Na-K-Ca (β = 4/3) geothermometer values were chosen to be contoured on Plate 1. The contour interval is 50°C (90°F).

Generally, throughout the map there are only sporadic zones with predicted reservoir temperatures over 100°C (212°F)and these are usually based on a single well location (Plate 1). However, there are two major localized zones with predicted temperatures over 100°C (212°F) and sometimes over 150°C

(302°F). One is in the northwest corner of the map centered in the San Dieguito River Valley. There are no recorded well water discharge temperatures of 78°F or greater in this area. The second zone is just southeast of Imperial Beach Naval Air Station in an area with known warm water wells that has been discussed in the previous section of this report. Unfortunately, the ground water aquifers in both of these zones are heavily intruded with sea water as discussed in the Hydrology section of this report. Therefore, it is assumed that the anomalously high predicted reservoir temperatures in these two areas are in error due to the sea water contamination of the samples collected from the water wells. A more detailed explanation of the drawbacks of applying geothermometric techniques to well water data from the San Diego area can be found in Herbert, 1977. Suffice to say that the geothermometric predicted reservoir contours shown on Plate 1 should be viewed with great skepticism.

GEOLOGY

The geologic map of Plate 1 has been compiled and generalized from Kennedy (1975); Kennedy and Peterson (1975); Kennedy and Tan (1977); Kennedy, Clark, Greene, and Legg (1980); Kennedy, Greene, Clark, and Bailey (1980); and Kennedy and Welday (1980). The following description is primarily from these sources.

The area lies wholly within the Peninsular Ranges Geomorphic Province which is characterized by a Mesozoic basement of metamorphosed marine sedimentary and volcanic rocks intruded by the Southern California Batholith (which now dominates the terrain of the central and eastern parts of the province) over which are draped clastic sedimentary rocks of marine and nonmarine origin of Cretaceous to Holocene age primarily confined to the coastal area of the province. The map area of Plate 1 encompasses a segment of the narrow coastal plain as well as a portion of the hilly and mountainous terrain to the east. Physiographically, the area can be defined as a relatively unfolded sedimentary series forming marin wave-cut terraces and gently westward sloping mesas that have been incised by southwesterly draining streams forming valleys and canyons. The area is bounded on the east by uplands of erosion resistant basement rocks.

Stratigraphically the oldest rocks cropping out in the area of Plate 1 are Jurassic metamorphosed volcanic and sedimentary rocks of the Santiago Peak Volcanics (Jsp). The volcanic rocks range from basalt to rhyolite but are predominantly dacite and andesite. Often there are intercalated strata of sedimentary marine origin. The Santiago Peak Volcanics are hard and extremely erosion and weather resistant. This formation was intruded during the Cretaceous period by granitic rocks associated with formation of the Southern California Batholith (Kg). These plutonic rocks are primarily quartz diorite and gabbro. Throughout most of the area, the granitic rocks are deeply weathered. The other major Mesozoic rocks cropping out in the area belong to the Point Loma and Cabrillo Formation of the Rosario Group (Kp). These Upper Cretaceous sandstone, clay shale, and cobble conglomerate rocks of marine and nonmarine origin are exposed on Point Loma and around La Jolla north of Mission Bay. Near La Jolla, these rocks are associated with the Rose Canyon Fault zone.

Tertiary sedimentary deposits (Ts) consisting of the Eocene La Jolla and Poway Groups, the Miocene-Pliocene(?) Otay Formation, and the Pliocene San Diego Formation overlie the basement complex. Uplift, erosion, and redeposition during the Tertiary Period (as well as the Quaternary) produced a wide variety of sedimentary rocks ranging from moderately deep-water, fine-grained siltstones, to sandy beach and lagoonal facies, and coarse-grained continental sandstones and conglomerates. These deposits are nearly flat-lying and are generally exposed where the dendritic drainage pattern is incised through the overlying Quaternary sediments (Plate 1). The earlier Tertiary sediments were laid down continuously in an embayment caused by regional tectonic down-warping. Subsidence of the basin and repeated changes in sediment flux resulted in onshore-offshore depositional lapping.

Quarternary sedimentary deposits (Qal) overlying the Tertiary strata include the Pleistocene Lindavista and Bay Point Formations as well as some stream-terrace deposits and Holocene alluvium, beach deposits and artifically compacted fill. The Lindavista Formation consist of near-shore marine and nonmarine sediments that form the major wave-cut terrace deposits in the study area. The Bay Point Formation is a sandstone of marine and nonmarine origin that is well exposed along the present-day coast line.

The Rose Canyon and La Nacion fault zones traverse the map area of Plate 1 on a north-northwest trend. The area encompassing most of the warm water wells south of San Diego Bay lies between these two fault zones (Plate 1), but perhaps is most commonly associated with the Rose Canyon fault zone (Wiegand, 1970). These two fault zones offset Quaternary deposits and are part of a regional northwest-striking right-lateral system that includes the major active Mission Creek, San Andreas, San Jacinto, and Elsinore fault zones to the east and the Coronado Bank, San Diego Trough, and San Clemente fault zones on the west.

The Rose Canyon fault zone is a complex series of discontinuous, but interrelated faults closely associated with small local folds. In the south bay area the sub-parallel, en echelon fault fabric forms the western side of a Quaternary, tensionally developed graben centered near San Diego Bay indicated by a negative gravity anomaly (Figure 5). The slightly elevated water well temperatures found near the Imperial Beach Naval Air Station may be the result of deep circulation and heating of water which then rises rapidly along segments of the Rose Canyon fault zone.

HYDROLOGY

The San Diego study area encompasses parts of seven separate hydrological units as described by the California Department of Water Resources (1967). These are, from north to south, the San Dieguito, Penasquitos, San Diego, Coronado, Sweetwater, Otay, and Tia Juana hydrologic units. They all have a variety of physiographic and hydrologic features, but in general ground water throughout the area is primarily found in reservoirs consisting of alluvium and Pleistocene sediments in the coastal plain sections. The recharge is generally from precipitation and seaward migration of runoff from highlands areas in the eastern portion of the study area. However, an historic decline in annual precipitation and over development of ground water has resulted in a reversal of the seaward hydraulic gradient allowing sea-water intrusion and migration of connate waters into several coastal areas, thus rendering the water quality in these areas inferior. The two most notable examples in the study area are the San Dieguito River Valley (San Dieguito hydrologic unit) in the northwest segment of the map on Plate 1 and the Tijuana River drainage (Tia Juana hydrologic unit) south of San Diego Bay. In the Tia Juana hydrologic unit total dissolved solids (TDS) in well water ranges from 750 to over 5,000 ppm with the higher values predominating. Water levels in wells have declined throughout much of the area with as much as 30 to 70 feet drop between 1945 and 1967 due to the decreased precipitation and over useage.

Ground water is no longer a major source for the water supply in the San Diego area due to the decrease of availability and impaired water quality. Most water is now supplied to the area via aqueduct systems and some surface reservoirs. Apparently none of the naval facilities shown on Plate 1 ever relied on ground water resources for a water supply. Most have no record of ever having a water well drilled on the facility. The exceptions are the U.S. Naval Recreation Facilities golf course where a shallow well is used to irrigate the links and the Miramar Naval Air Station where records show five or six wells had been drilled, but none are currently used and most are lost, buried, or destroyed.

SEISMICITY/GEOPHYSICS

Compared to other southern California areas the San Diego region has an historic relatively quiescent seismicity. Shown on Figure 4 is a dense

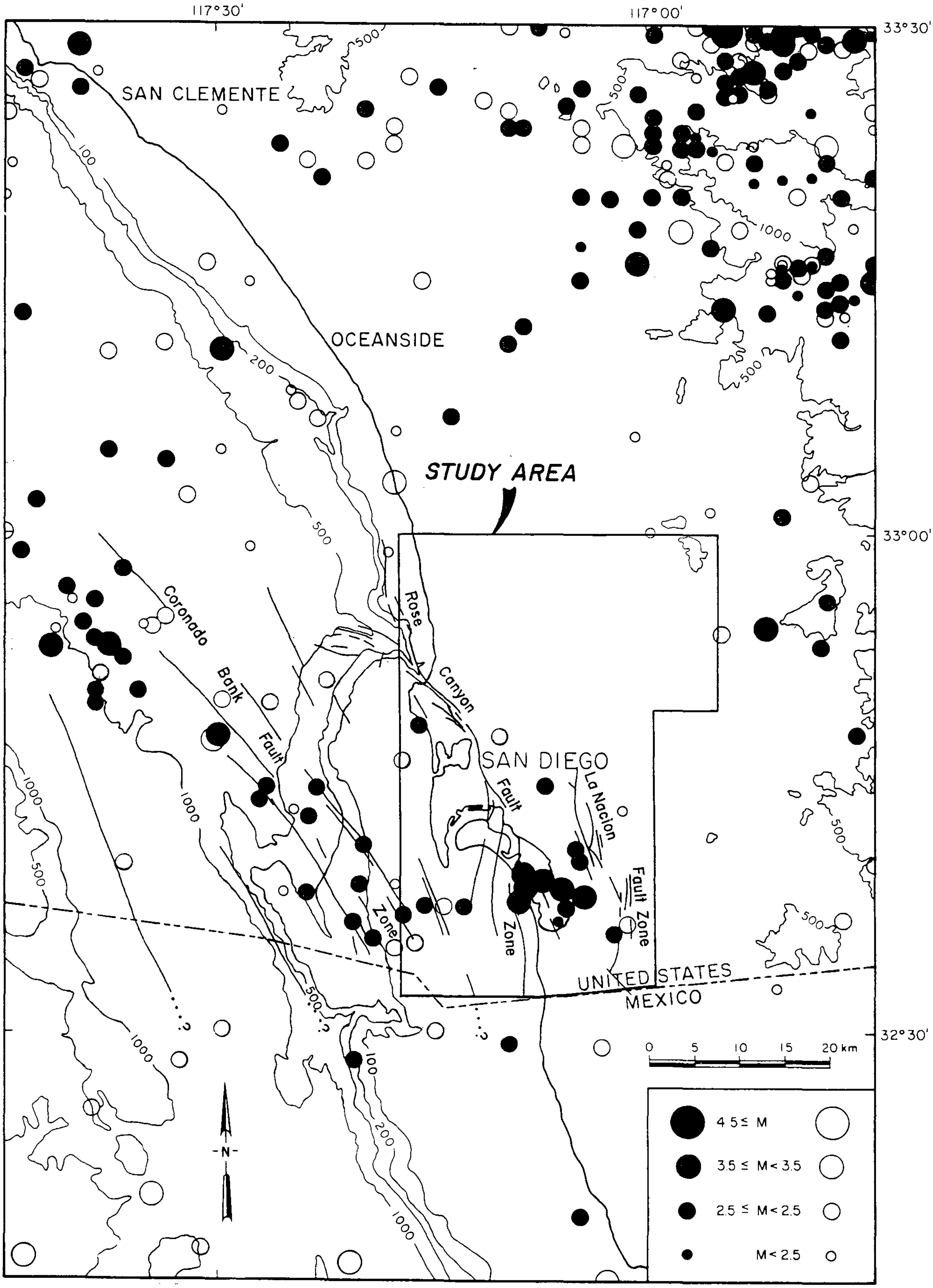

FIGURE 4. Epicenters in the San Diego region from 1932 to 1976. Solid symbol indicates location accuracy of 5km or less. From Kennedy and others, 1980.

grouping of seismic events in the northeast corner of the map. Kennedy and others (1980) attribute these events to activity on the Elsinore fault zone (not shown). A second regional pattern of earthquakes is a northwest linear trend along the Coronado Bank fault zone west of the study area. The remainder of the region has been relatively seismically quiet, except that within the study area there is a cluster of epicentral locations around the south-central portion of San Diego Bay apparently associated with possible extensions of the Rose Canyon fault zone. There also may be a minor north-northwest trend of some epicenters associated with the La Nacion fault zone (Figure 4).

The bounded area shown on Plate 1 thought to represent the best zone for potential low-temperature geothermal development in the San Diego study area lies just south of the assemblage of earthquakes in and around San Diego Bay. The significance (if any) of this relationship is not well understood. One could speculate that the earthquake causal north-northwest trending fault fabric underlying the southern San Diego Bay (Plate 1) continues south-southeastward beneath or within the Quaternary deposits of the Tia Juana hydrologic unit. Kennedy and others (1975) and Wiegand (1970) make just such a speculation. Geophysical surveys discussed in each of those reports have delineated some probable fault related anomalies here, but apparently have not as yet qualified the extent of faulting thought to exist.

The cluster of earthquakes around San Diego Bay is located within a large closed negative gravity anomaly roughly centered in the bay area (Figure 5). The structural basin indicated by the gravity anomaly may represent a tensionally developed graben bounded on the west by the major segments of the Rose

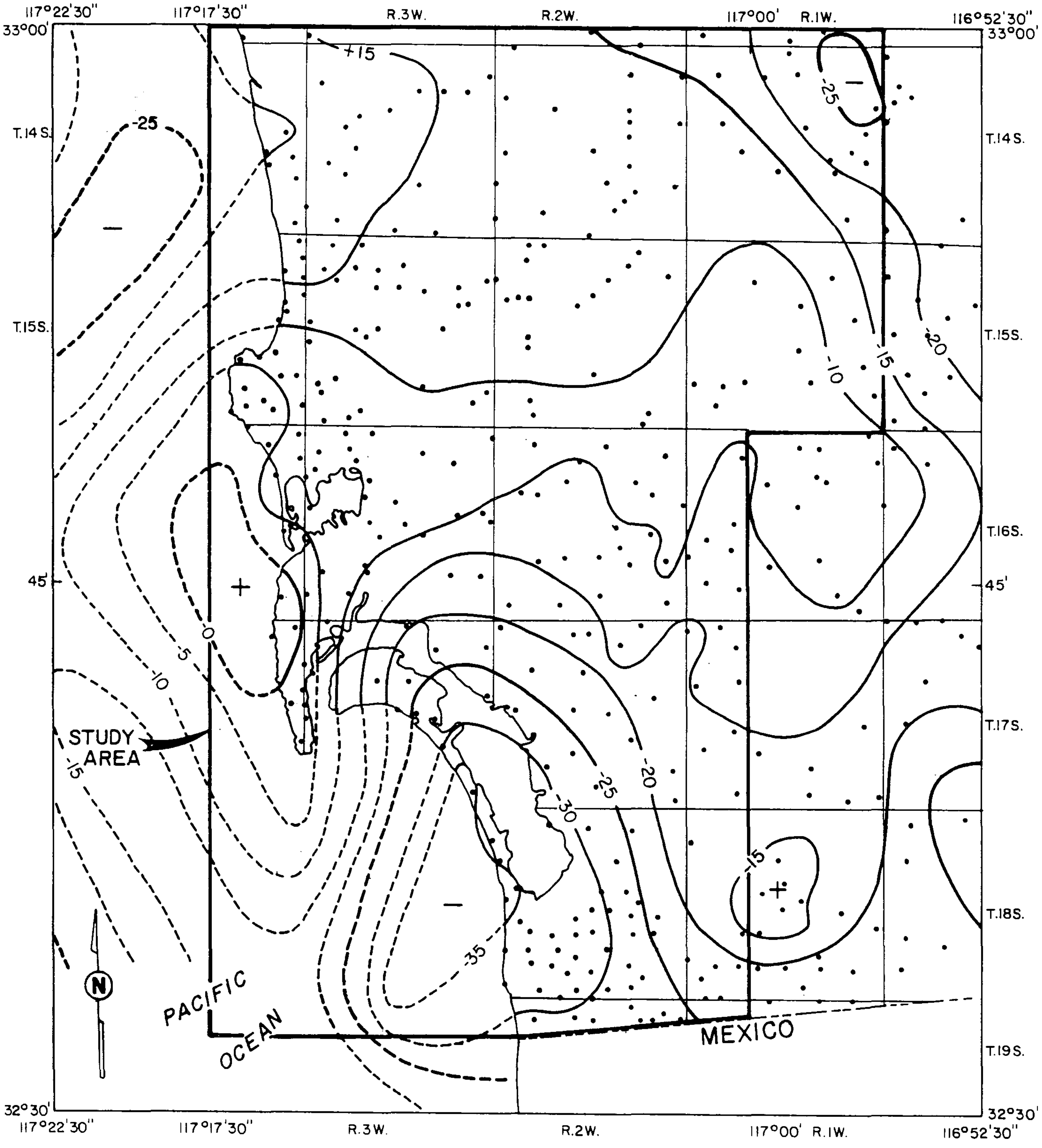

FIGURE 5. Bouguer gravity map of the San Diego region. From Biehler, 1979.

Gravity station

Lines of equal Bouguer anomaly in milligals, dashed in areas of poor control. + indicates gravity high. – indicates gravity low. Reduction density : 2.67 g/cm³

Scale
5 0 5 10 Miles
5 0 5 10 15 Kilometers

Canyon fault zone. Along the bottom of the basin is a series of down-faulted blocks in an area of tension at the junction between two right-stepping strands of the multi-part complex Rose Canyon fault zone (Kennedy and others, 1975 and Kennedy and others, 1980).

As noted by Wiegand (1970), the area of slightly warm water wells shown on Plate 1 is in the south-southeastern "nose" of the gravity low. It is generally thought the warm water area is somehow associated with faulting and hence associated with the graben that was fault produced.

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APPENDIX A

GEOTHERMOMETRY TEMPERATURE VALUES (°C) FOR SELECTED WATER WELLS IN THE SAN DIEGO AREA, CALIFORNIA

MAP NUMBER	LOCATION	SILICA					Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
		CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS			
1	13S/3W,32J1	---	---	---	---	---	133°	133°	59°
2	13S/3W,32J2	---	---	---	---	---	103°	118°	65°
3	13S/3W,32R1	---	---	---	---	---	111°	124°	71°
4	13S/3W,33L3	---	---	---	---	---	140°	142°	73°
5	13S/3W,33L6	---	---	---	---	---	114°	122°	58°
6	13S/3W,33M1	---	---	---	---	---	341°	289°	198°
7	13S/3W,33M2	---	---	---	---	---	105°	115°	52°
8	13S/3W,33Q1	---	---	---	---	---	122°	142°	107°
9	13S/3W,33Q3	---	---	---	---	---	114°	144°	129°
10	13S/3W,34K1	45°	53°	13°	-3°	-61°	40°	72°	47°
11	14S/3W,2Q1	67°	72°	35°	18°	-43°	92°	103°	40°
12	14S/3W,2Q2	70°	75°	39°	21°	-40°	9°	40°	10°
13	14S/3W,3D1	---	---	---	---	---	50°	77°	41°
14	14S/3W,4N1	---	---	---	---	---	57°	77°	27°
15	14S/3W,4P1	---	---	---	---	---	34°	58°	13°
16	14S/3W,5F1	---	---	---	---	---	160°	170°	123°
17	14S/3W,5K2	---	---	---	---	---	125°	142°	100°
18	14S/3W,5N1	---	---	---	---	---	136°	156°	122°
19	14S/3W,6P1	---	---	---	---	---	85°	131°	158°
20	14S/3W,6P2	---	---	---	---	---	78°	106°	78°
21	14S/3W,7C1	74°	78°	42°	24°	-38°	67°	105°	99°
22	14S/3W,7C2	---	---	---	---	---	89°	126°	125°
23	14S/3W,7C3	---	---	---	---	---	99°	137°	141°
24	14S/3W,7C4	---	---	---	---	---	79°	121°	131°
25	14S/3W,7C6	---	---	---	---	---	108°	151°	172°
26	14S/3W,7E1	---	---	---	---	---	47°	88°	88°
27	14S/3W,7E2	---	---	---	---	---	84°	117°	101°
28	14S/3W,7K1	72°	77°	40°	23°	-39°	86°	101°	45°
29	14S/3W,7L1	---	---	---	---	---	83°	100°	47°
30	14S/3W,7L4	---	---	---	---	---	95°	104°	39°
31	14S/3W,7L5	---	---	---	---	---	97°	106°	40°
32	14S/3W,7M1	55°	62°	23°	7°	-53°	36°	72°	57°
33	14S/3W,7M3	---	---	---	---	---	151°	161°	111°
34	14S/3W,7P1	---	---	---	---	---	118°	131°	78°
35	14S/3W,7P4	---	---	---	---	---	95°	105°	40°
36	14S/3W,7P6	---	---	---	---	---	142°	146°	80°
37	14S/3W,8M1	75°	79°	44°	25°	-36°	88°	96°	28°
38	14S/3W,8M2	---	---	---	---	---	67°	84°	29°
39	14S/3W,10B1	39°	47°	7°	-9°	-65°	58°	85°	49°
40	14S/3W,17C2	51°	57°	18°	2°	-56°	58°	87°	54°
41	14S/3W,1K1	---	---	---	---	---	90°	111°	69°
42	14S/3W,1P1	77°	81°	45°	27°	-35°	81°	109°	79°
43	14S/4W,1P2	---	---	---	---	---	76°	104°	76°
44	14S/4W,1Q1	---	---	---	---	---	91°	134°	151°
45	14S/4W,1R1	---	---	---	---	---	79°	108°	81°
46	14S/4W,1R2	---	---	---	---	---	93°	122°	99°

MAP NUMBER	LOCATION	SILICA					Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
		CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS			
47	14S/4W,1R3	---	---	---	---	---	133°	190°	284°
48	14S/4W,1R4	---	---	---	---	---	77°	112°	100°
49	14S/4W,11J2	---	---	---	---	---	66°	103°	95°
50	14S/4W,12B1	65°	71°	33°	16°	-45°	95°	137°	152°
51	14S/4W,12H1	---	---	---	---	---	90°	142°	192°
52	14S/4W,12L1	-5°	6°	-38°	-50°	-100°	118°	147°	131°
53	14S/3W,12H1	---	---	---	---	---	83°	138°	198°
54	14S/3W,16Q1	5°	15°	-28°	-41°	-92°	86°	101°	47°
55	14S/3W,17E1	36°	44°	3°	-12°	-68°	82°	107°	71°
56	14S/3W,17L2	85°	88°	54°	35°	-29°	90°	101°	38°
57	14S/3W,18F1	77°	81°	45°	27°	-35°	92°	100°	33°
58	14S/3W,18F2	81°	84°	49°	31°	-32°	98°	108°	46°
59	14S/3W,18K1	63°	69°	31°	14°	-46°	88°	101°	41°
60	14S/3W,18L1	63°	69°	31°	14°	-46°	90°	102°	42°
61	14S/3W,18L3	70°	75°	39°	21°	-40°	83°	98°	44°
62	14S/3W,18L4	60°	65°	27°	11°	-49°	90°	102°	42°
63	14S/3W,18L5	60°	65°	27°	11°	-49°	88°	101°	42°
64	14S/3W,18L6	-5°	6°	-38°	-50°	-100°	118°	123°	54°
65	14S/3W,18M1	79°	83°	48°	30°	-33°	115°	126°	69°
66	14S/3W,18N1	86°	89°	55°	36°	-28°	110°	125°	74°
67	14S/3W,19H1	85°	88°	54°	35°	-29°	81°	96°	39°
68	14S/3W,19N1	69°	74°	37°	19°	-42°	93°	117°	81°
69	14S/3W,19N3	83°	87°	52°	33°	-30°	73°	90°	36°
70	14S/3W,19P1	77°	81°	45°	27°	-35°	73°	88°	30°
71	14S/3W,19P2	67°	72°	35°	18°	-43°	60°	77°	21°
72	14S/3W,19Q1	---	---	---	---	---	97°	106°	42°
73	14S/3W,10F1	67°	72°	35°	18°	-43°	38°	59°	11°
74	14S/3W,20L2	---	---	---	---	---	67°	84°	27°
75	14S/3W,21D1	78°	82°	47°	28°	-34°	76°	86°	21°
76	14S/3W,23E1	62°	67°	29°	12°	-48°	57°	85°	52°
77	14S/3W,22F1	60°	65°	27°	11°	-49°	62°	88°	53°
78	14S/3W,24J1	---	---	---	---	---	50°	76°	38°
79	14S/3W,29G1	67°	72°	35°	18°	-43°	73°	89°	34°
80	14S/3W,29H1	72°	77°	40°	23°	-39°	65°	83°	30°
81	14S/3W,30F1	107°	107°	78°	57°	-9°	66°	88°	45°
82	14S/3W,30G1	98°	99°	68°	48°	-17°	101°	110°	46°
83	14S/3W,32R1	70°	75°	39°	21°	-40°	59°	81°	36°
84	14S/3W,25A1	85°	88°	54°	35°	-29°	111°	113°	39°
85	14S/4W,25A2	53°	60°	21°	4°	-55°	101°	111°	49°
86	14S/4W,25A3	69°	74°	37°	19°	-42°	87°	102°	47°
87	15S/3W,1Q1	79°	83°	48°	30°	-33°	83°	89°	18°
88	15S/3W,1R1	87°	90°	56°	37°	-26°	125°	124°	47°
89	15S/3W,3N1	62°	67°	29°	12°	-48°	150°	140°	52°
90	15S/3W,3N2	36°	44°	3°	-12°	-68°	119°	121°	49°
91	15S/3W,6H1	62°	67°	29°	12°	-48°	128°	144°	99°
92	14S/1W,6C2	101°	102°	71°	50°	-15°	115°	120°	50°
93	14S/1W,6P1	72°	77°	40°	23°	-39°	94°	108°	50°
94	14S/1W,18K1	102°	103°	72°	51°	-14°	64°	85°	36°

MAP NUMBER	LOCATION	S I L I C A CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS	Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
95	14S/1W,18K2	---	---	---	---	---	10°	42°	16°
96	14S/1W,21H1	111°	110°	81°	60°	-7°	41°	62°	12°
97	14S/1W,36R1	---	---	---	---	---	88°	101°	42°
98	15S/1W,1A1	117°	115°	88°	66°	-1°	151°	158°	101°
99	15S/1W,1J2	62°	67°	29°	12°	-48°	92°	102°	39°
100	15S/1W,1J3	---	---	---	---	---	89°	99°	34°
101	15S/1W,1R1	95°	97°	64°	45°	-20°	104°	111°	43°
102	15S/1W,1R2	79°	83°	48°	30°	-33°	55°	73°	20°
103	15S/1W,11G1	98°	99°	68°	48°	-17°	120°	122°	50°
104	15S/1W,13E1	103°	103°	73°	52°	-13°	120°	123°	51°
105	15S/1W,13J1	---	---	---	---	---	116°	115°	36°
106	15S/1W,13J2	---	---	---	---	---	104°	110°	40°
107	15S/1W,13J3	---	---	---	---	---	99°	108°	43°
108	15S/1W,13N3	75°	79°	44°	25°	-36°	68°	84°	27°
109	15S/1W,13Q1	92°	94°	61°	42°	-23°	111°	111°	35°
110	15S/1W,14Q1	79°	83°	48°	30°	-33°	52°	73°	26°
111	15S/1W,15G1	---	---	---	---	---	79°	93°	34°
112	15S/1W,17B1	75°	79°	44°	25°	-36°	86°	98°	35°
113	15S/1W,22D1	51°	57°	18°	2°	-56°	34°	67°	43°
114	15S/1W,22G1	87°	90°	56°	37°	-26°	72°	89°	34°
115	15S/1W,22G2	---	---	---	---	---	75°	90°	33°
116	15S/1W,22P1	95°	97°	64°	45°	-20°	94°	105°	43°
117	15S/1W,22Q1	92°	94°	61°	42°	-23°	114°	113°	35°
118	15S/1W,22Q2	78°	82°	47°	28°	-34°	100°	105°	34°
119	15S/1W,22Q3	---	---	---	---	---	284°	225°	101°
120	15S/1W,23H4	65°	71°	33°	16°	-45°	142°	128°	33°
121	15S/1W,23H5	79°	83°	48°	30°	-33°	136°	124°	33°
122	15S/1W,23N1	---	---	---	---	---	139°	139°	65°
123	15S/1W,23P1	---	---	---	---	---	123°	125°	51°
124	15S/1W,24B4	---	---	---	---	---	84°	99°	43°
125	15S/1W,24C4	---	---	---	---	---	71°	88°	35°
126	15S/1W,24C5	82°	85°	51°	32°	-31°	110°	114°	42°
127	15S/1W,24C6	---	---	---	---	---	92°	99°	29°
128	15S/1W,24C7	---	---	---	---	---	98°	106°	39°
129	15S/1W,24C9	---	---	---	---	---	90°	100°	36°
130	15S/1W,24D5	78°	82°	47°	28°	-34°	95°	104°	40°
131	15S/1W,24D9	---	---	---	---	---	113°	115°	41°
132	15S/1W,24J1	75°	79°	44°	25°	-36°	97°	104°	36°
133	15S/1W,25F1	107°	107°	78°	57°	-9°	52°	72°	20°
134	15S/1W,25J1	93°	95°	62°	43°	-22°	190°	171°	80°
135	15S/1W,27A05	---	---	---	---	---	90°	101°	39°
136	15S/1W,27B02	---	---	---	---	---	99°	108°	42°
137	15S/1W,27G01	102°	103°	72°	51°	-14°	54°	78°	36°
138	15S/1W,27G05	39°	47°	7°	-9°	-65°	160°	142°	45°
139	15S/1W,27G06	42°	50°	10°	-6°	-63°	153°	141°	52°
140	15S/1W,27G07	114°	113°	85°	63°	-4°	89°	100°	36°
141	15S/1W,27H01	---	---	---	---	---	121°	123°	50°
142	15S/1W,28G01	103°	103°	73°	52°	-13°	70°	89°	40°

MAP NUMBER	LOCATION	SILICA CONDUCTIVE	SILICA ADIABATIC	SILICA CHALCEDONY	SILICA CRISTOBALITE	SILICA AMORPHOUS	Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
143	15S/1W,28K02	92°	94°	61°	42°	-23°	75°	92°	38°
144	15S/1W,29H01	---	---	---	---	---	114°	130°	82°
145	15S/1W,29M01	79°	83°	48°	30°	-33°	86°	97°	33°
146	15S/1W,29Q01	67°	72°	35°	18°	-43°	271°	202°	65°
147	15S/1W,30K01	---	---	---	---	---	135°	135°	61°
148	15S/1W,30K02	---	---	---	---	---	97°	107°	44°
149	15S/1W,30K03	78°	82°	47°	28°	-34°	108°	113°	42°
150	15S/1W,30M01	30°	39°	-3°	-17°	-73°	118°	120°	47°
151	15S/1W,27N01	89°	92°	59°	39°	-25°	85°	95°	30°
152	15S/1W,28Q01	87°	90°	56°	37°	-26°	52°	75°	33°
153	15S/1W,28Q02	78°	82°	47°	28°	-34°	14°	42°	4°
154	15S/1W,28Q03	---	---	---	---	---	54°	78°	37°
155	15S/1W,28Q04	---	---	---	---	---	59°	80°	32°
156	15S/1W,28R01	79°	83°	48°	30°	-33°	67°	86°	36°
157	15S/1W,28R02	92°	94°	61°	42°	-23°	84°	101°	48°
158	15S/1W,33A01	100°	101°	70°	50°	-16°	27°	56°	20°
159	15S/1W,33B01	83°	87°	52°	33°	-30°	6°	36°	5°
160	15S/1W,33C01	92°	94°	61°	42°	-23°	113°	117°	45°
161	15S/1W,34D02	91°	93°	60°	40°	-24°	80°	95°	36°
162	15S/1W,34M01	88°	91°	57°	38°	-26°	32°	59°	23°
163	15S/1W,34M02	83°	87°	52°	33°	-30°	87°	102°	45°
164	15S/1W,34Q01	114°	113°	85°	63°	-4°	44°	67°	22°
165	15S/1W,34R01	113°	112°	84°	62°	-4°	60°	78°	25°
166	15S/1W,34R03	---	---	---	---	---	72°	89°	34°
167	15S/2W,01R02	---	---	---	---	---	98°	121°	84°
168	15S/2W,12K01	89°	92°	59°	39°	-25°	20°	51°	20°
169	15S/2W,13L01	99°	100°	69°	49°	-16°	24°	50°	9°
170	15S/2W,15R01	86°	89°	55°	36°	-28°	60°	84°	43°
171	15S/2W,02K01	78°	82°	47°	28°	-34°	56°	80°	39°
172	15S/2W,05L01	74°	78°	42°	24°	-38°	54°	82°	47°
173	15S/2W,19D01	69°	74°	37°	19°	-42°	44°	75°	46°
174	15S/3W,01M01	72°	77°	40°	23°	39°	95°	105°	41°
175	15S/3W,09K01	67°	72°	35°	18°	-43°	127°	121°	36°
176	15S/3W,23P02	79°	83°	48°	30°	-33°	91°	107°	54°
177	15S/3W,24N01	92°	94°	61°	42°	23°	156°	152°	77°
178	15S/3W,26C01	79°	83°	48°	30°	-33°	73°	95°	51°
179	15S/3W,26Q01	63°	69°	31°	14°	-46°	106°	124°	79°
180	15S/3W,30E01	57°	64°	25°	9°	-51°	38°	62°	18°
181	15S/3W,36D01	63°	69°	31°	14°	-46°	126°	138°	84°
182	16S/3W,05E01	53°	60°	21°	4°	-55°	85°	109°	71°
183	16S/3W,05E03	65°	71°	33°	16°	-45°	58°	84°	47°
184	15S/3W,35G01	60°	65°	27°	11°	-49°	122°	136°	86°
185	15S/3W,35G03	62°	67°	29°	12°	-48°	118°	132°	80°
186	16S/3W,16Q01	65°	71°	33°	16°	-45°	105°	126°	88°
187	16S/3W,16R01	65°	71°	33°	16°	-45°	105°	126°	88°
188	15S/2W,30K01	82°	85°	51°	32°	-31°	25°	70°	77°
189	15S/2W,35R01	120°	118°	92°	70°	2°	31°	55°	11°
190	15S/3W,36L01	60°	65°	27°	11°	-49°	113°	128°	78°

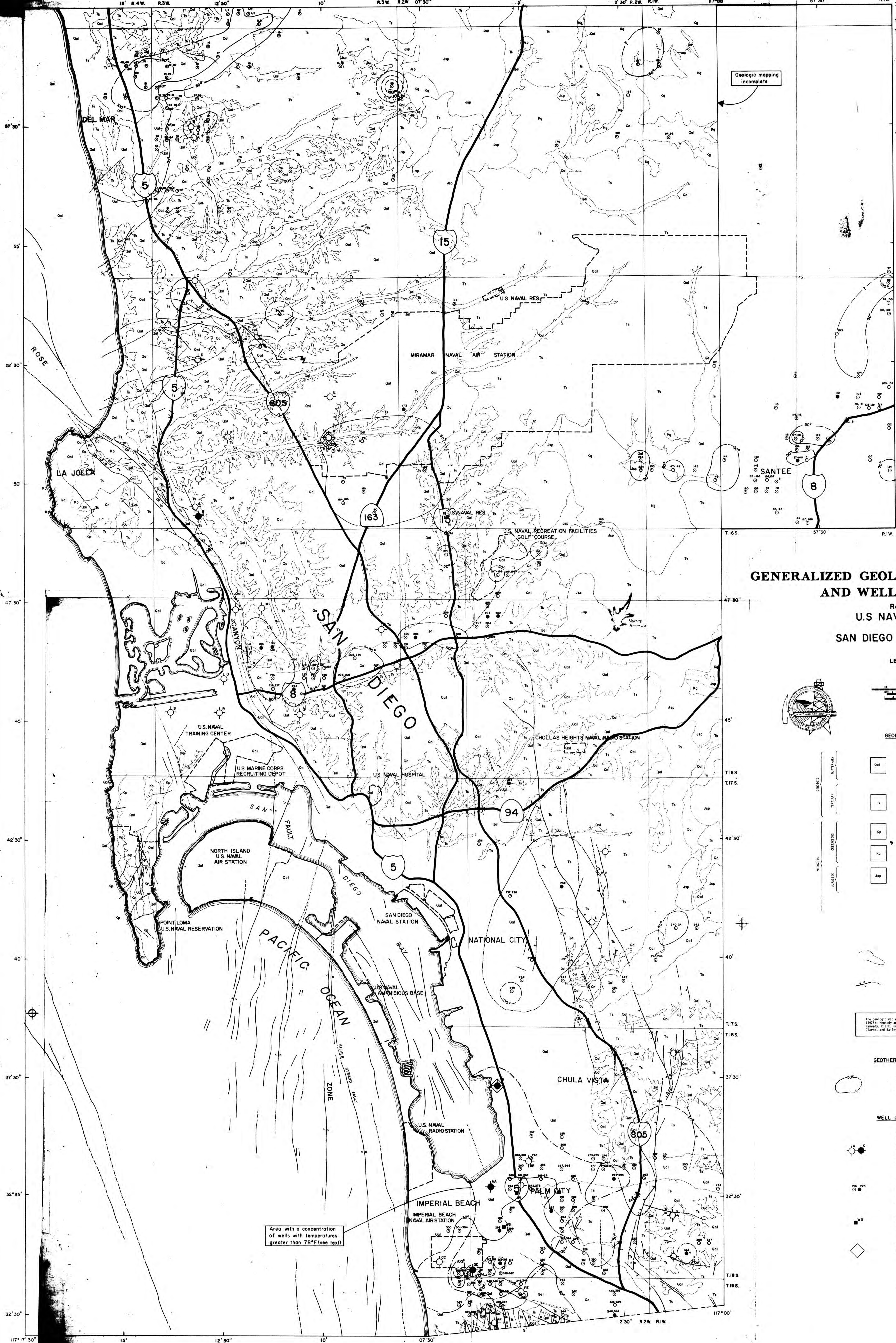
MAP NUMBER	LOCATION	SILICA					Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
		CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS			
191	16S/2W,03L01	62°	67°	29°	12°	-48°	103°	121°	73°
192	16S/2W,03P01	89°	92°	59°	39°	-25°	36°	61°	21°
193	16S/2W,05D01	86°	89°	55°	36°	-28°	72°	83°	18°
194	16S/2W,05M01	36°	44°	3°	-12°	-68°	114°	129°	78°
195	16S/2W,09B01	---	---	---	---	---	45°	70°	28°
196	16S/2W,09B02	---	---	---	---	---	74°	93°	43°
197	16S/2W,09C04	60°	65°	27°	11°	-49°	81°	98°	44°
198	16S/2W,0950C	69°	74°	37°	19°	-42°	88°	103°	49°
199	16S/2W,09C09	---	---	---	---	---	86°	107°	65°
200	16S/2W,09L01	87°	90°	56°	37°	-26°	15°	42°	3°
201	16S/2W,09N01	39°	47°	7°	-9°	-65°	124°	122°	44°
202	16S/2W,16C01	92°	94°	61°	42°	-23°	78°	92°	32°
203	16S/2W,16D03	65°	71°	33°	16°	-45°	59°	77°	23°
204	16S/2W,16E05	86°	89°	55°	36°	-28°	89°	98°	31°
205	16S/2W,16M02	24°	33°	-9°	-23°	-78°	125°	124°	46°
206	16S/2W,17D01	---	---	---	---	---	59°	84°	43°
207	16S/2W,17H01	---	---	---	---	---	49°	71°	24°
208	16S/2W,17L01	62°	67°	29°	12°	-48°	75°	100°	61°
209	16S/2W,18L01	---	---	---	---	---	69°	98°	67°
210	16S/2W,18M01	63°	69°	31°	14°	-46°	73°	98°	61°
211	16S/2W,18N01	102°	103°	72°	51°	-14°	70°	93°	52°
212	16S/2W,18Q03	---	---	---	---	---	80°	97°	45°
213	16S/3W,13Q01	---	---	---	---	---	60°	83°	38°
214	16S/3W,13R01	72°	77°	40°	23°	-39°	78°	93°	35°
215	16S/3W,21J01	---	---	---	---	---	99°	120°	81°
216	16S/3W,21R01	79°	83°	48°	30°	-33°	128°	129°	55°
217	16S/3W,21R04	62°	67°	29°	12°	-48°	93°	115°	76°
218	16S/3W,22G01	63°	69°	31°	14°	-46°	42°	71°	38°
219	16S/3W,22H03	39°	47°	7°	-9°	-65°	71°	113°	120°
220	16S/3W,22H04	72°	77°	40°	23°	-39°	67°	90°	49°
221	16S/3W,22H05	---	---	---	---	---	80°	104°	66°
222	16S/3W,22J01	79°	83°	48°	30°	-33°	88°	106°	56°
223	16S/3W,22K02	---	---	---	---	---	73°	94°	48°
224	16S/3W,22P01	48°	55°	15°	0°	-59°	119°	119°	43°
225	16S/3W,23A01	77°	81°	45°	27°	-35°	19°	49°	17°
226	16S/3W,23A02	18°	28°	-15°	-28°	-82°	119°	125°	58°
227	16S/3W,23E05	79°	83°	48°	30°	-33°	90°	100°	36°
228	16S/3W,23K01	69°	74°	37°	19°	-42°	97°	120°	83°
229	16S/3W,23K02	67°	72°	35°	18°	-43°	39°	67°	32°
230	16S/3W,23M01	72°	77°	40°	23°	-39°	67°	89°	45°
231	16S/3W,23N01	74°	78°	42°	24°	-38°	73°	92°	43°
232	16S/3W,24F01	39°	47°	7°	-9°	-65°	90°	107°	56°
233	15S/2W,25H01	---	---	---	---	---	83°	103°	57°
234	15S/2W,25J01	77°	81°	45°	27°	-35°	114°	123°	60°
235	17S/2W,04B01	92°	94°	61°	42°	-23°	117°	117°	41°
236	17S/2W,08J01	62°	67°	29°	12°	-48°	117°	116°	38°
237	17S/2W,06Q01	---	---	---	---	---	80°	99°	51°
238	17S/2W,16Q02	---	---	---	---	---	87°	104°	52°

MAP NUMBER	LOCATION	SILICA CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS	Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
239	17S/2W,15J01	72°	77°	40°	23°	-39°	81°	104°	62°
240	17S/1W,19K01	70°	75°	39°	21°	-40°	114°	128°	75°
241	17S/1W,19K02	79°	83°	48°	30°	-33°	54°	78°	35°
242	17S/1W,20M01	87°	90°	56°	37°	-26°	41°	70°	38°
243	17S/1W,30E01	---	---	---	---	---	67°	87°	38°
244	17S/1W,30E02	70°	75°	39°	21°	-40°	62°	83°	36°
245	17S/2W,25P04	55°	62°	23°	7°	-53°	65°	86°	39°
246	17S/2W,27E01	32°	41°	-1°	-15°	-71°	126°	131°	64°
247	17S/2W,27R01	---	---	---	---	---	122°	123°	49°
248	17S/2W,28R01	74°	78°	42°	24°	-38°	71°	99°	71°
249	17S/2W,33B01	---	---	---	---	---	106°	131°	101°
250	17S/2W,36D01	---	---	---	---	---	36°	64°	27°
251	18S/1W,19C01	---	---	---	---	---	52°	87°	70°
252	18S/1W,19D01	69°	74°	37°	19°	-42°	65°	96°	71°
253	18S/1W,19H01	---	---	---	---	---	54°	86°	64°
254	18S/1W,20Q01	55°	62°	23°	7°	-53°	65°	92°	58°
255	18S/2W,15J02	---	---	---	---	---	66°	88°	42°
256	18S/2W,15M01	70°	75°	39°	21°	-40°	85°	96°	33°
257	18S/2W,15R01	---	---	---	---	---	109°	115°	48°
258	18S/2W,21A01	---	---	---	---	---	89°	102°	43°
259	18S/2W,21A02	74°	78°	42°	24°	-38°	75°	94°	43°
260	18S/2W,21H01	---	---	---	---	---	85°	100°	45°
261	18S/2W,21J01	---	---	---	---	---	72°	94°	49°
262	18S/2W,21J02	---	---	---	---	---	80°	97°	45°
263	18S/2W,21K01	---	---	---	---	---	54°	74°	25°
264	18S/2W,Q01	---	---	---	---	---	17°	46°	11°
265	18S/2W,22D01	60°	65°	27°	11°	-49°	102°	109°	42°
266	18S/2W,22F02	22°	77°	40°	23°	-39°	32°	59°	21°
267	18S/2W,22H01	---	---	---	---	---	50°	73°	27°
268	18S/2W,22H02	39°	47°	7°	-9°	-65°	123°	121°	41°
269	18S/2W,22L01	74°	78°	42°	24°	-38°	116°	119°	46°
270	18S/2W,22L02	---	---	---	---	---	110°	119°	56°
271	18S/2W,22L03	72°	77°	40°	23°	-39°	53°	75°	29°
272	18S/2W,22N01	72°	77°	40°	23°	-39°	82°	93°	29°
273	18S/2W,22N03	---	---	---	---	---	198°	179°	88°
274	18S/2W,23A11	---	---	---	---	---	73°	88°	31°
275	18S/2W,23B01	67°	72°	35°	18°	-43°	60°	79°	29°
276	18S/2W,23B02	88°	91°	57°	38°	-26°	63°	81°	29°
277	18S/2W,23G01	77°	81°	45°	27°	-35°	70°	86°	29°
278	18S/2W,23H02	77°	81°	45°	27°	-35°	100°	113°	55°
279	18S/2W,23H03	---	---	---	---	---	80°	97°	45°
280	18S/2W,23M01	81°	84°	49°	31°	-32°	96°	104°	37°
281	18S/2W,24F01	81°	84°	49°	31°	-32°	65°	87°	42°
282	18S/2W,24G01	79°	83°	48°	30°	-33°	65°	83°	29°
283	18S/2W,24J01	82°	85°	51°	32°	-31°	70°	87°	34°
284	18S/2W,24M01	70°	75°	39°	21°	-40°	99°	111°	50°
285	18S/2W,24M02	57°	64°	25°	9°	-51°	57°	77°	27°
286	18S/2W,24M03	77°	81°	45°	27°	-35°	63°	85°	40°

MAP NUMBER	LOCATION	S I L I C A CONDUCTIVE	ADIABATIC	CHALCEDONY	CRISTOBALITE	AMORPHOUS	Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
287	18S/2W,26B01	65°	71°	33°	16°	-45°	84°	111°	80°
288	18S/2W,26D01	---	---	---	---	---	52°	76°	34°
289	18S/2W,26E01	72°	77°	40°	23°	-39°	36°	59°	14°
290	18S/2W,26H01	---	---	---	---	---	59°	86°	51°
291	18S/2W,27A02	77°	81°	45°	27°	-35°	65°	83°	32°
292	18S/2W,27G01	82°	85°	51°	32°	-31°	78°	94°	38°
293	18S/2W,27H01	81°	84°	49°	31°	-32°	63°	82°	32°
294	18S/2W,27J01	77°	81°	45°	27°	-35°	46°	72°	33°
295	18S/2W,28G01	70°	75°	39°	21°	-40°	98°	116°	69°
296	18S/2W,28L01	---	---	---	---	---	56°	84°	52°
297	18S/2W,27R01	65°	71°	33°	16°	-45°	47°	72°	31°
298	18S/2W,P01	---	---	---	---	---	---	---	---
299	18S/2W,28Q01	---	---	---	---	---	74°	105°	81°
300	18S/2W,29N01	79°	83°	48°	30°	-33°	35°	68°	43°
301	18S/2W,29P01	78°	82°	47°	28°	-34°	36°	69°	43°
302	18S/2W,29P02	---	---	---	---	---	43°	75°	50°
303	18S/2W,29P04	82°	85°	51°	32°	-31°	43°	74°	46°
304	18S/2W,29P05	74°	78°	42°	24°	-38°	61°	91°	64°
305	18S/2W,32H01	75°	79°	44°	25°	-36°	44°	81°	67°
306	18S/2W,32P01	77°	81°	45°	27°	-35°	84°	118°	108°
307	18S/2W,32P02	63°	69°	31°	14°	-46°	76°	103°	72°
308	18S/2W,32P04	70°	75°	39°	21°	-40°	74°	139°	163°
309	18S/2W,32Q01	---	---	---	---	---	50°	78°	44°
310	18S/2W,32Q03	---	---	---	---	---	63°	86°	43°
311	18S/2W,32R01	---	---	---	---	---	59°	81°	35°
312	18S/2W,33K04	---	---	---	---	---	73°	101°	71°
313	18S/2W,33L01	---	---	---	---	---	116°	144°	124°
314	18S/2W,33L05	---	---	---	---	---	73°	103°	76°
315	18S/2W,33L09	---	---	---	---	---	86°	111°	76°
316	18S/2W,33L10	---	---	---	---	---	111°	136°	106°
317	18S/2W,33M02	69°	74°	37°	19°	-42°	63°	87°	47°
318	18S/2W,33M04	69°	74°	37°	19°	-42°	52°	78°	40°
319	18S/2W,33N02	45°	53°	13°	-3°	-61°	47°	73°	35°
320	18S/2W,33P01	---	---	---	---	---	68°	72°	52°
321	18S/2W,33P05	55°	62°	23°	7°	-53°	22°	51°	17°
322	18S/2W,33P07	65°	71°	33°	16°	-45°	68°	92°	52°
323	18S/2W,34A01	74°	78°	42°	24°	-38°	181°	186°	134°
324	18S/2W,34A02	67°	72°	35°	18°	-43°	46°	72°	33°
325	18S/2W,34F01	---	---	---	---	---	52°	84°	61°
326	18S/2W,34L02	---	---	---	---	---	52°	83°	55°
327	18S/2W,34F01	---	---	---	---	---	64°	86°	42°
328	18S/2W,35D01	---	---	---	---	---	28°	60°	32°
329	18S/2W,35F01	51°	57°	18°	2°	-56°	67°	94°	61°
330	18S/2W,35K01	65°	71°	33°	16°	-45°	44°	71°	32°
331	18S/2W,35L01	---	---	---	---	---	59°	87°	54°
332	18S/2W,35R02	67°	72°	35°	18°	-43°	68°	96°	67°
333	18S/2W,36B01	70°	75°	39°	21°	-40°	57°	88°	61°
334	18S/2W,01E04	65°	71°	33°	16°	-45°	65°	89°	4°

MAP NUMBER	LOCATION	SILICA CONDUCTIVE	SILICA ADIABATIC	SILICA CHALCEDONY	SILICA CRISTOBALITE	SILICA AMORPHOUS	Na-K	Na-K-Ca (1/3)	Na-K-Ca (4/3)
335	18S/2W,01E08	67°	72°	35°	18°	-43°	62°	91°	59°
336	19S/2W,01M09	62°	67°	29°	12°	-48°	78°	98°	52°
337	19S/2W,01M11	65°	71°	33°	16°	-45°	77°	97°	50°
338	19S/2W,01M13	---	---	---	---	---	78°	99°	53°
339	19S/2W,01M14	62°	67°	29°	12°	-48°	112°	125°	70°
340	19S/2W,01N04	---	---	---	---	---	116°	133°	88°
341	19S/2W,01N06	114°	113°	86°	64°	-3°	119°	134°	85°
342	19S/2W,02E01	67°	72°	35°	18°	-43°	82°	103°	57°
343	19S/2W,03A01	67°	72°	35°	18°	-43°	87°	106°	58°
344	19S/2W,03R03	91°	93°	60°	40°	-24°	84°	100°	46°
345	19S/2W,04A05	62°	67°	29°	12°	-48°	57°	80°	37°
346	19S/2W,04A10	---	---	---	---	---	74°	95°	51°
347	19S/2W,04C02	---	---	---	---	---	103°	132°	111°
348	19S/2W,04D01	---	---	---	---	---	60°	87°	51°
349	19S/2W,04D04	70°	75°	39°	21°	-40°	24°	53°	18°
350	19S/2W,04F03	79°	83°	48°	30°	-33°	106°	118°	60°
351	19S/2W,04F04	---	---	---	---	---	54°	85°	58°
352	19S/2W,04H07	---	---	---	---	---	116°	138°	102°
353	19S/2W,04L01	62°	67°	29°	12°	-48°	49°	74°	33°
354	19S/2W,04L04	---	---	---	---	---	69°	93°	53°
355	19S/2W,05A03	---	---	---	---	---	107°	134°	111°
356	19S/2W,05B06	---	---	---	---	---	82°	112°	87°
357	19S/2W,05C06	67°	72°	35°	18°	-43°	52°	97°	111°
358	19S/2W,05G01	---	---	---	---	---	14°	51°	34°
359	19S/2W,05G05	---	---	---	---	---	40°	72°	46°
360	19S/2W,05G18	55°	62°	23°	7°	-53°	40°	74°	53°
361	19S/2W,05H01	---	---	---	---	---	23°	59°	41°
362	19S/2W,05K01	---	---	---	---	---	45°	68°	24°
363	19S/2W,05L02	65°	71°	33°	16°	-45°	66°	98°	78°
364	19S/2W,05Q02	---	---	---	---	---	52°	81°	49°
365	19S/2W,05Q03	---	---	---	---	---	49°	77°	44°
366	18S/1W,31H01	60°	65°	27°	11°	-49°	113°	140°	118°
367	18S/1W,32C01	---	---	---	---	---	66°	98°	76°
368	18S/1W,32D01	---	---	---	---	---	62°	94°	73°

DMG OFR 84-33 RECONNAISSANCE OF GEOTHERMAL RESOURCES NEAR U.S. NAVAL FACILITIES IN SAN DIEGO, SAN DIEGO COUNTY, CALIFORNIA



GEOLOGIC MAP REFERENCES

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GENERALIZED GEOLOGIC, GEOTHERMOMETRIC, AND WELL LOCATION MAP

Relative to the

U.S NAVAL FACILITIES in the SAN DIEGO AREA, CALIFORNIA

by
LESLIE G. YOUNGS

1984

SCALE 1:48,000

GEOLOGIC EXPLANATION

CENOZOIC	QUATERNARY	Qal	Quaternary sedimentary deposits - includes the Pleistocene Lindavista Formation of nearshore marine and nonmarine sediments forming the major wave-cut terrace deposits; the Bay Point Formation consisting of marine and nonmarine sandstone exposed along the coastline areas; early stream-terrace deposits, and Holocene alluvium, beach deposits, and artificial fill.
CENOZOIC	TERTIARY	Ts	Tertiary sedimentary deposits - includes the Eocene La Jolla and Poway Groups, the Miocene-Pliocene (?) Otay Formation, and the Pliocene San Diego Formation. The sequence is composed of continuously deposited, marine and nonmarine, flat lying, and often intertongued sedimentary rocks ranging in wide variety from moderately deep-water, fine-grained siltstones, to sandy beach and lagoonal facies, and coarse-grained continental sandstones and conglomerates.
MESOZOIC	CRETACEOUS	Kp	Upper Cretaceous sandstones, clay shales, and cobble conglomerates of marine and nonmarine origin of the Point Loma and Cabrillo Formations of the Rosario Group.
MESOZOIC	CRETACEOUS	Kg	Primarily quartz diorite and gabbro plutonic rocks of the Southern California Batholith.
MESOZOIC	JURASSIC	Jsp	Metamorphosed volcanic and sedimentary rocks of the Santiago Peak Volcanics.

SYMBOLS

Geologic contact - dashed where approximately located; dotted where concealed.

Fault, showing dip - dashed where approximately located; dotted where concealed; U, upthrown side; D, downthrown side.

The geologic map was compiled and generalized from Kennedy (1975); Kennedy and Peterson (1975); Kennedy and Tan (1977); Kennedy, Clark, Greene, and Legg (1980); Kennedy, Greene, Clarke, and Bailey (1980); and Kennedy and Welday (1980).

GEOTHERMOMETRIC EXPLANATION

Contour of the Na-K-Ca ($\beta = {}^4/_3$) geothermometer estimated reservoir temperature values from Appendix A of the text. Dashed or queried where location inferred or approximated. Temperature values are in °C. The contour interval is 50°C. See text for limitations of data.

WELL LOCATION EXPLANATION

Approximate location of an oil, gas, or geothermal exploration well. Solid symbol indicates that a temperature of 78°F (25.6°C) or greater has been recorded downhole in the well. (The exception is the well labeled DD. There are no recorded temperatures for this well in the files, but a letter dated 1935 mentions "hot water" flowing from the well). These wells are listed in Table 1 of the text and the warm water wells are also listed in Table 2. Data are from California Division of Oil and Gas (1983 and 1982) and Miller and others (1981).

Approximate location of a water well with sufficient geochemical analysis to be used in geothermometric calculations. The data are listed in numerical well number order in Appendix A of the text. Solid symbol indicates that a temperature of 78°F (25.6°C) or greater has been recorded in the discharge from the well. These data are listed in numerical well order on Table 2 of the text. Data are from California Department of Water Resources (1983 and 1967).

Approximate location of a water well with a temperature equal to or greater than 80°F (26.7°C). These wells are listed in numerical order on Table 2 of the text. These location data are from Wiegand (1982).

Approximate location of a well that has had a downhole temperature probe survey. These wells are indicated in Table 2 of the text and the profiles are shown in Figures 2 and 3.

Note: At a few well locations combination symbols are used. An example is Well H (also labeled No. 176) in T15S/R3W, section 23 on Miramar Naval Air Station. This well was originally drilled for petroleum exploration in 1936 and was later used as a water well. The California Department of Water Resources subsequently obtained geochemical data from the well and in January 1984 the California Division of Mines and Geology performed a downhole temperature probe survey in this well; hence the combination symbol.