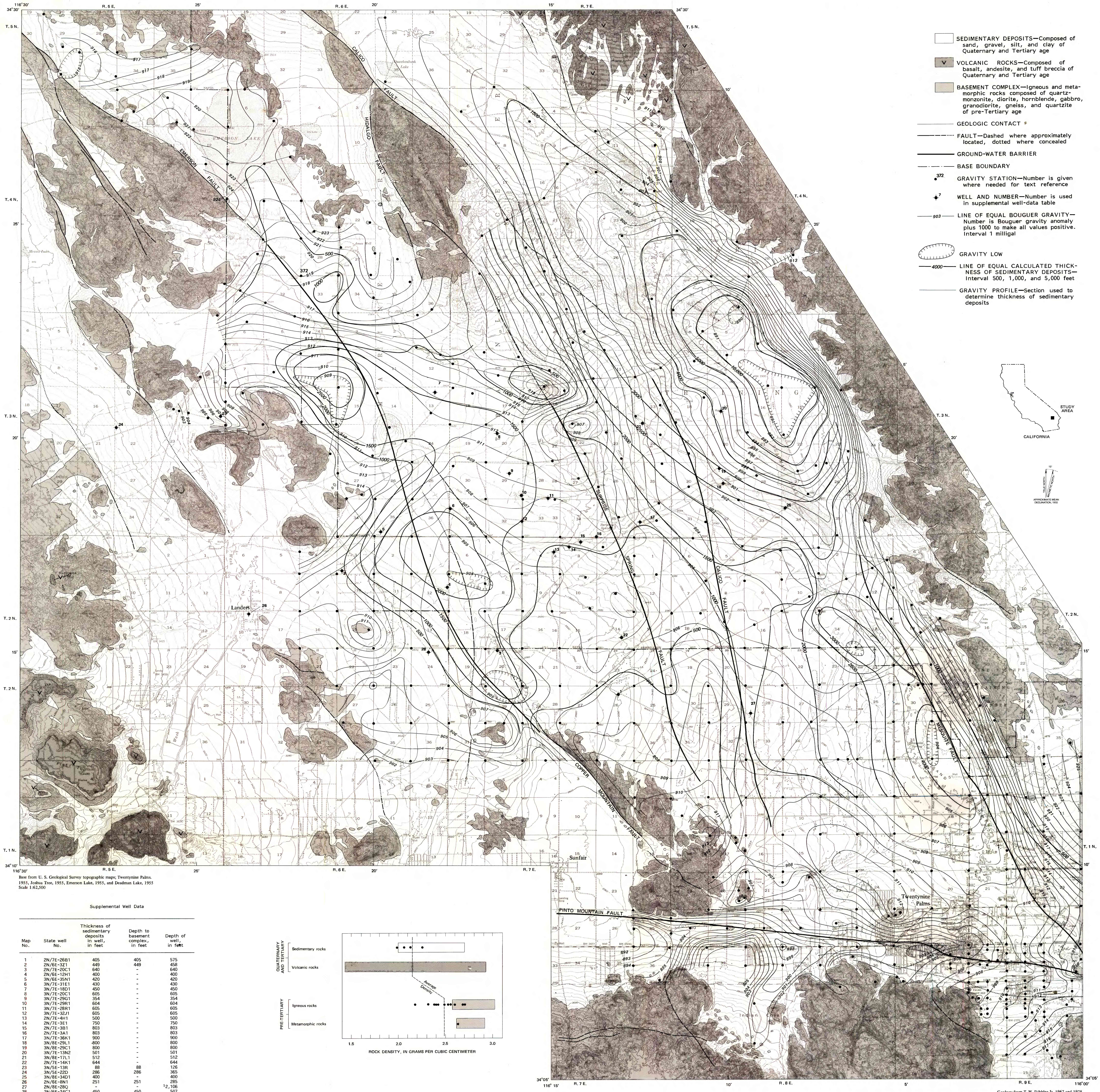
Prepared in cooperation with the
U. S. MARINE CORPS, DEPARTMENT OF THE NAVY

WATER–RESOURCES INVESTIGATIONS
REPORT 84-4005



Base from U. S. Geological Survey topographic maps; Twentynine Palms. 1955, Joshua Tree, 1955, Emerson Lake, 1955, and Deadman Lake, 1955
Scale 1:62,500

Geology from T. W. Dibblee Jr., 1967 and 1968. Gravity measurement by John R. Pendleton, Linda R. Woolfenden, J. P. Akers, and W. R. Moyle Jr., 1981-82 and Biehler and others (1984).

SCALE 1:62,500

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

SEDIMENTARY DEPOSITS—Composed of sand, gravel, silt, and clay of Quaternary and Tertiary age

VOLCANIC ROCKS—Composed of basalt, andesite, and tuff breccia of Quaternary and Tertiary age

BASEMENT COMPLEX—Igneous and metamorphic rocks composed of quartz-monzonite, diorite, hornblende, gabbro, granodiorite, gneiss, and quartzite of pre-Tertiary age

GEOLOGIC CONTACT

FAULT—Dashed where approximately located, dotted where concealed

GROUND-WATER BARRIER

BASE BOUNDARY

GRAVITY STATION—Number is given where needed for text reference

WELL AND NUMBER—Number is used in supplemental well-data table

LINE OF EQUAL BOUGUER GRAVITY—Number is Bouguer gravity anomaly plus 1000 to make all values positive. Interval 1 milligal

GRAVITY LOW

LINE OF EQUAL CALCULATED THICKNESS OF SEDIMENTARY DEPOSITS—Interval 500, 1,000, and 5,000 feet

GRAVITY PROFILE—Section used to determine thickness of sedimentary deposits

Supplemental Well Data

Map No.	State well No.	Thickness of sedimentary deposits in well, in feet	Depth to basement complex, in feet	Depth of well, in feet
1	2N/7E-26B1	405	405	575
2	2N/6E-3Z1	449	449	458
3	2N/7E-20C1	640	-	640
4	2N/6E-12H1	400	-	400
5	3N/6E-35N1	420	-	420
6	3N/7E-31E1	430	-	430
7	3N/7E-18D1	450	-	450
8	3N/7E-20C1	605	-	605
9	3N/7E-29G1	354	-	354
10	3N/7E-29R1	604	-	604
11	3N/7E-28R1	605	-	605
12	3N/7E-32J1	605	-	605
13	2N/7E-4H1	500	-	500
14	2N/7E-3E1	750	-	750
15	2N/7E-3B1	803	-	803
16	2N/7E-3A1	803	-	803
17	3N/7E-36K1	900	-	900
18	3N/8E-29L1	800	-	800
19	3N/8E-29C1	800	-	800
20	3N/7E-13N2	501	-	501
21	3N/8E-17L1	512	-	512
22	2N/7E-14K1	644	-	644
23	3N/5E-13R	88	88	126
24	3N/5E-22D	286	286	365
25	3N/8E-34D1	400	-	400
26	2N/6E-8N1	251	251	285
27	2N/8E-28Q	-	-	[1]2,106
28	2N/6E-24C1	450	450	507

[1]Struck "granite wash" near bottom of hole, may be decomposed granite.

INTRODUCTION

Location and General Features

A gravity study has been made of the Twentynine Palms area covering about 375 mi² (square miles) of the Twentynine Palms Marine Corps Base and vicinity, Calif. The main facility of the Twentynine Palms Marine Corps Base, an area of about 1,000 mi², is about 130 mi east of Los Angeles and 5 mi north of Twentynine Palms. Towns in or adjacent to the study area are Twentynine Palms, Sunfair, Joshua Tree (off map), and Landers. The study area covers about 210 mi² in the southwest corner of the Marine Corps Base, and about 165 mi² outside the base. The area adjacent to the base is rural to undeveloped. The base is completely undeveloped except for the main facility and a water-well field at Surprise Spring, and is used principally for military exercises and training.

The study area is a large sedimentary filled valley surrounded by numerous hills and mountains of igneous and metamorphic rocks (Precambrian? and Mesozoic age), and is crossed by several large and many small faults. The geology of the area has been mapped by Dibblee (1967a, b, c, and 1968) and is shown in simplified form on the gravity map. Four of the large faults on the base (Emerson-Copper Mountain, Hidalgo-Surprise Spring, Calico, and Mesquite) act as ground-water barriers. Water-level measurements (Bader and Moyle, 1960) from wells on each side of these faults show the barrier effect. Schaefer (1978) reported a 300-ft offset in the water table at Surprise Spring along the Surprise Spring fault. Water is at land surface west of the fault, and 300 ft below land surface east of the fault. Several of these ground-water barriers have been used as boundaries for ground-water basins by various investigators such as Schaefer (1978).

Purpose and Scope of Work

The entire Marine Corps Base water supply is dependent on ground water. Water levels in wells near Surprise Spring have declined a maximum of 100 ft between 1950 and 1982. Because of the water-level declines and possible expansion of base facilities, the U.S. Marine Corps, Department of the Navy asked the Geological Survey to make a multiphase study of the feasibility for basin recharge with imported water. The purpose of the gravity survey, the first phase of the multiphased study, is to determine the thickness of the sedimentary deposits that contain the bulk of the water within the study area.

A map showing lines of equal sedimentary thickness was constructed from 495 gravity measurements obtained in the study area. This work included detailed measurements along profiles across areas where suspected ground-water recharge enters the study area from adjacent areas. It also included a profile across the ground-water outflow section from the study area. In all, 13 profiles were made to construct the thickness map, and all these profiles have been modeled using two-dimensional computer programs developed by Talwani (1968).

Previous Work and Acknowledgments

Previous studies by the Geological Survey (1973 and 1982) include Mendenhall (1909), Waring (1915), Thompson (1921 and 1929), Worts (1953), Dutcher (1960), Dyer (1960a, b), Riley and Bader (1961), Weir (1962), Weir and Dyer (1961), Johnston (1963), Bader (1963), Giessner (1965), Giessner and Robson (1966), Moyle (1961 and 1974a, b), and Lewis (1972). Reports by Federal agencies other than the Geological Survey include the U.S. Bureau of Reclamation (1967 and 1972). Publications by State agencies include Bader and Moyle (1960), California Division of Oil and Gas (1964), and Chapman (1966). Private consultant reports include Wagner (1951), and Neptune and Gregory (1951). These reports contain geological and hydrological data such as water-level measurements in wells, pumping tests on wells, annual pumpage by well, hydrographs, chemical analyses of water, drillers' logs of wells (Bader and Moyle, 1960), geologic mapping (Dibblee, 1967a, b, c, and 1968), estimated annual recharge (Lewis, 1972), and other types of information. Each of these reports contributes to the overall understanding of the geologic and hydrologic framework of the basins or aids in the reduction of the gravity data. Reports used to reduce the gravity data include Hayford and Bowie (1912), Mabey (1960), Zbur (1963), Woollard and Rose (1963), Plouff (1966), Talwani (1968), Robbins and others (1973), Rotstein and others (1976), Jachens and Roberts (1981), and Biehler and others (1984).

The author acknowledges the work done by the many investigators listed in the references. Their reports have aided materially to this study. In addition, the author would like to acknowledge base personnel (both military and civilian) that assisted in this study. A special thanks goes to Ralph Brown, Natural Resources Manager at the Twentynine Palms Marine Corps Base, for his help in coordinating access to the ranges on the base.

GRAVITY SURVEY

Gravity surveys measure differences in the attraction of gravity at the Earth's surface caused by differences in density of the material beneath the surface. The differences may be used to indicate geologic structure and general shape of the basement complex beneath the sedimentary deposits. Because of some density variations between rock types, the complete Bouguer gravity anomaly map should not be interpreted as indicating depth to basement complex directly. In general, a gravity low corresponds to a thick sedimentary section and a gravity high corresponds to a thin sedimentary section.

Field Work

Throughout the study area during 1981-82, gravity measurements were made about 1 mi apart; however, some measurements along profiles are closer to give greater detail, and some are farther apart where access into the area is difficult. All measurements were made with Worden[1] gravity meters (No. 782 and No. 1083) having meter constants of 0.45779 and 0.20398 mgal (milligals) per scale division, respectively. A few measurements on the northern edge of the study area, made by Biehler and others (1984), were used for this report.

All gravity measurements made for this study were tied to a local base station[2] at the northeast corner of Valle Vista Road and Utah Trail, which is 1 mi east and 4 mi north of the center of Twentynine Palms near the main entrance to the Marine Corps Base. This local base station was established relative to the California Base Station Network by tying to the California Base Station Network at Amboy, Calif. (Chapman, 1966, Station 292), and is thus on the Woollard and Rose (1963) gravity datum. The error of closure between the Amboy station and the local base station at Twentynine Palms was 0.1 scale division or 0.02 mgal.

[1]The use of the brand name is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

[2]Base station is located at a bench mark about 25 ft northeast of the intersection of Valley Vista and Utah Trail in T.2 N., R.9 E., sec. 3, San Bernardino base line and meridian.

Reduction of Data

Data were corrected manually for meter drift and terrain effects to 2.29 km (kilometers) using tables developed by Hayford and Bowie (1912). The data were then entered into a computer and corrected for latitude, altitude (combined free air and Bouguer effects), Earth curvature, and terrain effects from 2.29 to 90 km. A density of 2.67 g/cm³ (grams per cubic centimeter) was used for the Bouguer reduction. Terrain corrections for all regions from 2.29 km to 90 km from each station were made using Plouff's (1966) computer program and previously digitized topography from Robbins and others (1973). The resulting computer readout lists the complete Bouguer gravity anomaly for each station which was then used to construct the contours.

To eliminate negative values, 1,000 mgal were added to each Bouguer anomaly value. Thus, for example, the true Bouguer anomaly corresponding to the 910 contour shown on the map is -90 mgal.

Bouguer Gravity Anomaly Map

The Bouguer gravity anomaly map was contoured from the plotted data points. The gravity values (Bouguer anomaly +1000) range from a high of 925 mgal in the mountains at the northwest corner of the study area to a low of 890 mgal in the northeast part of the study area.

Included on the gravity anomaly map are the geologic contacts between the basement complex and sedimentary deposits and the locations of faults (after Dibblee, 1967a, b, c, and 1968), and a diagram showing rock densities. The bars on the diagram show the upper and lower limits of rock densities measured by Mabey (1960) in his gravity survey of the western Mojave Desert. The circles show the measured densities of rocks from the study area. Data from 17 rock samples indicate that the basement complex in the Twentynine Palms area has an average density of 2.49 g/cm³. The sedimentary deposits have an average density of 2.15 g/cm³, and a density contrast of 0.34 g/cm³. Based on these limited number of samples, the computed depth to basement complex using 0.34 g/cm³ agrees favorably with depth to basement complex shown on well logs between 400 and 2,100 ft deep.

Interpretation of Gravity Data

To interpret the data, the regional gradient must be removed from the Bouguer gravity map. A computer program written by Jachens and Roberts (1981) was run on the U.S. Geological Survey computer in Menlo Park, Calif., to remove the regional gradient due to isostatic compensation of topography. This program did not remove the gravity variations caused by density variations within the basement complex rocks. Jachens (U.S. Geological Survey, oral commun., 1982) suggested that the regional gradient variations from this source be removed as a single correction over each short profile between basement complex outcrops.

The regional gradient along each profile was removed before two-dimensional modeling was done. Thirteen gravity profiles were modeled between basement complex outcrops in the study area. Each profile was made assuming a density contrast of 0.34 g/cm³. After modeling was completed, the calculated depth to basement complex was compared with the depths determined from logs of wells located in the same area.

Although many wells have been drilled in the study area, only three wells reach basement complex near where profiles were made. Well 2N/7E-26B1 (map No. 1) has a computed depth of 400 ft and a well log depth of 405 ft. Well 2N/6E-3Z1 (map No. 2) has a computed depth of less than 500 ft and a well log depth of 449 ft. One oil test hole, 2N/8E-28Q (map No. 27), was drilled to a depth of 2,106 ft. Data in the California Division of Oil and Gas Report (1964, p. 55) show this well encountered "granite wash" at the bottom of the hole. This may indicate decomposed granite in the lower part of the well. From this description the exact depth to basement complex could not be determined; however, the gravity data indicate the depth to basement complex is between 1,500 and 2,000 ft. All other computed depths are deeper than the total depth of the wells in the same areas. Thus, there is some rough confirmation of depths to basement complex computed from gravity data from a few shallow wells, but there is no check on computed depths greater than 2,000 ft.

The supplemental well data show the thickness of material penetrated at each well. After profiling was completed, lines of equal thickness of sedimentary deposits were added to the Bouguer gravity map by contouring the calculated depths along the profiles.

Error Analysis

Zbur (1963) shows that sedimentary deposits in desert basins become more dense with depth, and the density contrast between basement complex rocks and sedimentary deposits generally range between 0.5 and 0.3 g/cm³. Rotstein and others (1976) state that in general, "A density contrast of 0.5 g/cm³ might better fit basins less than 1 km deep. A density contrast of 0.4 g/cm³ will best fit basins between 1 and 2 km deep, and a density contrast of 0.3 g/cm³ best represents deeper basins." For this study, 0.34 g/cm³ was used for all profiles, producing very good results in areas where depth to basement complex (based on well logs) is 0.6 km (2,100 ft) or less.

To compute possible errors introduced because of incorrect average bulk density contrast values, densities of 0.3 and 0.4 g/cm³ were used on the profile that crosses the valley at the north end of Deadman Lake at the largest gravity anomaly in the study area. Using these values, the model shows that if 0.3 g/cm³ is used, the maximum thickness of sedimentary fill would be about 15,500 ft, and if 0.4 g/cm³ is used, the minimum thickness of sedimentary fill would be about 8,300 ft. Using 0.34 g/cm³, the thickness of sedimentary deposits is about 10,500 ft. Since the results using 0.34 g/cm³ in areas where depth to basement complex is 0.6 km (2,000 ft) deep or less correlate so well with well log depths, it would seem reasonable that the deep part of the basin has a density contrast of 0.34 g/cm³ or less. This indicates the sedimentary deposits in the basin are at least 10,500 ft thick.

Some two-layer profiles were also modeled along this same profile in an error-analysis procedure. These profiles could not be used because of the lack of well log data to verify the assumptions used in construction of the profiles; however, they did not drastically differ from the single layer model.

CHEMICAL ANALYSES OF WATER

The gravity data show that areas of good and poor quality water are separated by a buried bedrock ridge southeast of Emerson Lake and northeast of the Emerson fault. Gravity station 387 shows this ridge to be about 250 ft below land surface.

Chemical analysis of water from three wells near Ames Lake in T.4 N., R.6 E., sec. 27, show large differences in amounts of various constituents dissolved in the water (Riley and Bader, 1961, p. 72). This is probably due to well depth, which ranges from 63 to 182 ft. The dissolved solids in these three wells range from 523 to 2,230 mg/L (milligrams per liter) and fluoride ranges from 1.9 to 100 mg/L. Water from these wells do not meet the recommended criteria for drinking water. Other wells near Ames Lake and Emerson Lake also contain poor quality water. Between Ames Lake and Surprise Spring the data show that all wells contain water of good quality, ranging in dissolved solids from about 100 to 200 mg/L.

SUMMARY AND CONCLUSIONS

The sedimentary deposits that overlie the basement complex in the study area range in thickness from less than 1 ft at the edge of the valley at the basement complex outcrop, to a calculated depth of 10,500 ft near the center of the gravity low in the northeast part of the study area. This estimated depth may be as much as 25 percent greater in areas where the depth to basement complex is greater than 2,000 ft if the density contrast is less than the 0.34 g/cm³ used in the model.

The map shows four areas of thick alluvial deposits beneath the Marine Corps Base. The area west of the Mesquite fault near the Marine Corps Training Center headquarters in T.2 N., R.9 E., has a maximum calculated thickness of sedimentary deposits of 4,700 ft. In the southwestern corner of the base, the maximum calculated thickness of sedimentary deposits is about 2,300 ft. In the area near the western edge of the base southeast of Emerson Lake, two thick sedimentary sections exist on each side of the Emerson fault. The section on the northeast side of the Emerson fault near Ames Lake is about 1,000 ft thick, and on the southwest side is about 2,700 ft thick.

Some faults act as barriers to ground-water movement in sedimentary deposits (Bader, 1963). The surface expression of these faults has been mapped by Dibblee (1967a, b, c, and 1968). The barrier effect of these faults at the water table may be shown at a different location than the surface expression if the dip of the fault is not vertical. Where known, faults and ground-water barriers are both shown on this map.

The map also shows areas where the basement complex has an altitude about the same as that of the water table in the sedimentary deposits. These areas have poor potential for developing production wells for water supply.

The most important use of this map will be in later phases of the overall study, when the map will be used to determine the amount of ground water in storage in the individual basins.

SELECTED REFERENCES

Bader, J. S., 1963, Effect of faulting in alluvium on the occurrence, movement, and quality of ground water in the Twentynine Palms area, California (abstract): Geological Society of America Special Paper 73, p. 22, (San Bernardino County).
Bader, J.S., and Moyle, W.R., Jr., 1960, Data on water wells and springs in the Yucca Valley-Twentynine Palms area, San Bernardino and Riverside Counties, California: California Department of Water Resources Bulletin 91-2, 163 p.
Biehler, Shawn, Tang, R. W., Ponce, D. A., and Oliver, H. W., 1984, Bouguer gravity map of California, San Bernardino sheet: California Division of Mines and Geology, scale 1:250,000.
California Division of Oil and Gas, 1964, Exploratory wells drilled outside of oil and gas fields in California: San Francisco, Calif., 320 p.
Chapman, R. H., 1966, Gravity base station network: California Division of Mines and Geology, Special Report 90, 49 p.
Dibblee, T. W., 1967a, Geologic map of the Deadman Lake quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-488, scale 1:62,500.
------1967b, Geologic map of the Emerson Lake quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-490, scale 1:62,500.
------1967c, Geologic map of the Joshua Tree quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-516, scale 1:62,500.
------1968, Geologic map of the Twentynine Palms quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-561, scale 1:62,500.
Dutcher, L. C., 1960, Ground-water conditions during 1959 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 26 p.
Dyer, H. B., 1960a, Ground-water conditions during 1960 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 32 p.
------1960b, High water levels beneath the Twentynine Palms Marine Corps Wherry Housing: U.S. Geological Survey Letter Report, July 18, 1960, 5 p.
Giessner, F. W., 1965, Ground-water conditions during 1964 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 30 p.
Giessner, F. W., and Robson, S. G., 1966, Ground-water conditions during 1965 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 27 p.
Hayford, J. F., and Bowie, William, 1912, Geodesy--the effect of topography and isostatic compensation upon the intensity of gravity: U.S. Coast and Geodetic Survey Special Publication 10, 132 p.
Jachens, R. C., and Roberts, C. W., 1981, Documentation of a Fortran program, "Isocomp," for computing isostatic residual gravity: U.S. Geological Survey Open-File Report 81-574, 26 p.
Johnston, P. M., 1963, Ground-water conditions during 1963 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 37 p.
Lewis, R. E., 1972, Ground-water resources of the Yucca Valley-Joshua Tree area, San Bernardino County, California: U.S. Geological Survey Open-File Report, 51 p.
Mabey, D. R., 1960, Gravity survey of the western Mojave Desert, California: U.S. Geological Survey Professional Paper 316-D, p. 51-73.
Mendenhall, W. C., 1909, Some desert watering places in southeastern California and southwestern Nevada: U.S. Geological Survey Water-Supply Paper 224, 98 p.
Moyle, W. R., Jr., 1961, Data on water wells in the Dale Valley area, San Bernardino and Riverside Counties, California: California Department of Water Resources Bulletin 91-5, 55 p.
------1974a, Temperature and chemical data for selected thermal wells and springs in southeastern California: U.S. Geological Survey Water-Resources Investigations 33-73, 12 p.
------1974b, Geohydrologic map of southern California: U.S. Geological Survey Water-Resources Investigations 48-73, 1 map sheet.
Neptune and Gregory, Architects and Engineers, 1951, Hydrological report on the ground-water resources of the area northwest of Twentynine Palms for the Marine Corps Training Center, prepared by W. O. Wagner, Consulting Hydraulic Engineer, 32 p.
Plouff, Donald, 1966, Digital terrain corrections based on geographic coordinates [abstract and preprint]: Geophysics, v. 31, p. 1208.
Riley, F. S., and Bader, J. S., 1961, Data on water wells on Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 72 p.
Robbins, S. L., Oliver, H. W., and Plouff, Donald, 1973, Magnetic tape containing average elevations of topography in California and adjacent regions for areas of 1 x 1 minute and 3 x 3 minutes in size: U.S. Geological Survey Report, 31 p. text, magnetic tape; available as NTIS-PB-19794 from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va.
Rotstein, Yair, Combs, Jim, and Biehler, Shawn, 1976, Gravity investigation in the southeastern Mojave Desert, California: Geological Society of America Bulletin, vol. 87, document No. 60704, p. 981-993.
Schaefer, D. H., 1978, Ground-water resources of the Marine Corps Base, Twentynine Palms, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations 77-37, 29 p.
Talwani, Manik, 1968, Talwani two-dimensional gravity program, program number W9206: U.S. Geological Survey, Computer Center Division, Computer Center Documentation.
Thompson, D. G., 1921, Routes to desert watering places in the Mojave Desert region, California: U.S. Geological Survey Water-Supply Paper 490B, 269 p.
------1929, The Mojave Desert region, California: U.S. Geological Survey Water-Supply Paper 578, 759 p.
U.S. Bureau of Reclamation, 1967, Interim report, Inland Basins Projects, Morongo-Yucca upper Coachella Valley, California: Boulder, Colo., 92 p. and addendum.
------1972, Inland Basins Projects: Boulder, Colo., VII-53 to 62.
U.S. Geological Survey, 1973, Water-resources data collected on the Marine Corps Base area, Twentynine Palms, California, July 1970 through June 1973: 9 p.
------1982, Water resources data for California, water year 1981--vol. 1; Colorado River basin, southern Great Basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River: U.S. Geological Survey Water-Data Report CA-81-1, 417 p.
Wagner, W. O., 1951, Investigation of water resources for Marine Corps Artillery Training Camp, Twentynine Palms area, California: consulting report, 22 p.
Waring, G. A., 1915, Springs of California: U.S. Geological Survey Water-Supply Paper 338, 410 p.
Weir, J.E., Jr., 1962, Ground-water conditions during 1962 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 42 p.
Weir, J. E., Jr., and Dyer, H. B., 1961, Ground-water conditions during 1961 at the Marine Corps Base, Twentynine Palms, California: U.S. Geological Survey Open-File Report, 50 p.
Woollard, G.P., and Rose, J.C., 1963, International gravity measurements: Madison, Wis., University of Wisconsin, Geophysics and Polar Research Center, 518 p.
Worts, G. F., Jr., 1953, Twentynine Palms investigation: U.S. Geological Survey statement of preliminary findings, 6 p.
Zbur, R. T., 1963, A geophysical investigation of Indian Wells Valley, California: U.S. Naval Ordnance Test Station, Technical Paper 2795, China Lake, Calif., 98 p.

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BOUGUER GRAVITY ANOMALY MAP OF THE TWENTYNINE PALMS MARINE CORPS BASE AND VICINITY, CALIFORNIA
SHOWING THICKNESS OF SEDIMENTARY DEPOSITS, DEEP WELLS, AND GEOLOGY

By
W. R. MOYLE, JR.
1984