QUARTERLY REPORT

October 17, 1979 through January 4, 1980

Contract Number DE-A507-76ID12029

Agreement Number DE-FC07-79ID12033

GEOTHERMAL STUDIES IN MONTANA WITH A SUMMARY REPORT ON GEOPHYSICAL INVESTIGATIONS AT WARM SPRINGS STATE HOSPITAL

John Sonderegger
Charles Wideman
Joseph Donovan
James Halvorson
Sandra Kovacich
James Schofield
Glenn Wyatt

January 5, 1980

MBMG Open-File Report 37

STATE WIDE PROGRAM

Data points and a stable-base overlay depicting areas of geothermal potential have been sent to Dave Clark. The point specific data were sent both in paper copy and on magnetic tape. A meeting with NOAA personnel is expected late in January, possibly in conjunction with the DGE meeting for the western state-coupled teams later this month. A scale of 1:1,000,000 was finally chosen by Dave and myself (JS) for this initial map in order to keep printing costs reasonable.

Information exchange and cooperation has continued concerning the Poplar Dome study on the Fort Peck Reservation. A final version of P.R.C. Toups' preliminary report, which includes resource assessment, is due in about two weeks.

The annotated bibliography of geothermal research in Montana is now ready to go to the editor. The manuscript compiling isotopic age dates for Montana was considered to be too large and to contain too few unpublished dates to be printed in Isochron/West. Consequently, the Montana Bureau of Mines and Geology will publish these data as soon as the pre-Cambrian dates have been added to the manuscript. A July 1, 1980 publication date is projected.

Considerable time and effort were spent trying to arrange an expanded research program involving DOE, the State of Montana (through the Department of Natural Resources and Conservation), and Montana Tech. At present the level of state support is unclear, but will not be less than 20,000 dollars. The college can provide the deficiency in matching funds, but at a real cost to the project in the drilling area as previously unlisted costs (equipment rental, etc.) will have to be shown to provide the total state-match percentage as proposed. Dr. Wideman is now on an 18-month sabbatical from the College and is functioning as the Bureau's Geophysics Division Chief.

AREAL STUDIES

Reduction and interpretation of geophysical data collected to date have been supervised by Dr. Wideman. A summary paper on the study at the Warm Springs State Hospital site has been submitted to Northwest Geology by Halvorson and Wideman; a copy of the manuscript submitted is included as Appendix A. At present, interpretation of data from Ennis is nearly complete. A technical paper for each of these areas plus West Yellowstone, Radersburg, and Camas will be combined as a Bureau publication; the projected publication date is February 1981. The geophysical work done by James Schofield in the Centennial Valley area is nearly complete and will be included in the report on that area.

Hydrologic studies have continued in the Radersburg and Camas study areas. A preliminary evaluation of the Camas area study is expected by the end of January. The Radersburg work is progressing on schedule and a copy of an abstract submitted to GSA based upon this work is included as Appendix B. Post-irrigation well recovery data in the Radersburg basin strongly suggest upward leakage from a lower aquifer unit, presumably the Madison Limestone.

NOTE ADDED AT PHOTOCOPY STAGE: The abstract failed to arrive in the mail, so it will be included in next month's report.

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APPENDIX A

GEOPHYSICAL STUDY

AT

WARM SPRINGS STATE HOSPITAL

A GEOPHYSICAL INVESTIGATION OF THE WARM SPRINGS MONTANA AREA

by

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and

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Submitted to Northwest Geology

December, 1979

A GEOPHYSICAL INVESTIGATION

OF THE WARM SPRINGS MONTANA AREA

The Deer Lodge Valley in southwestern Montana is the site of several moderate temperature thermal springs. Of these occurrences, the geothermal system on the grounds of the Warm Springs State Hospital shows considerable potential for the development of the energy source.

During the summer and fall of 1978 a geophysical survey was conducted in the vicinity of the State Hospital to gather information about the geothermal system. Possible targets for the survey included both basement and near-surface geologic features.

It is possible that the placement of the spring is the result of a structural feature in the rock underlying the valley fill. It was hoped that gravity data would reflect the presence of such a feature.

The arrival of water at the surface is accompanied by a deposition of material from solution. This suggests that deposition may also occur in the valley fill along the path of the ascending water. The increased density that would be expected with this deposition became one possible target of a detailed gravity survey in the vicinity of the spring.

It was also expected that the resistivity of the area would be affected by the geothermal water and thus allow mapping of its near-surface lateral extent.

LOCATION

Warm Springs is located in the southern part of the Deer Lodge Valley, west of the Clark Fork River. The Anaconda and Flint Creek mountain ranges create the western boundary of the valley and the

Boulder batholith and the Lowland Creek Volcanics form more gentle topography to the east. The Warm Springs State Hospital is approximately 25 miles from Butte by Interstate Highway 90.

PREVIOUS WORK

The geology and ground water resources of the Deer Lodge Valley are discussed in U.S. Geological Survey Water Supply Paper 1862. Included in the paper is a residual gravity map of the Deer Lodge Valley. Water data from the Warm Springs system and other southwestern Montana thermal springs is given in the U.S. Geological Survey Open File Report 78-438. Montana Bureau of Mines and Geology Special Publication 22 is a geological map of a portion of the Flint Creek Range west of the study area. U.S. Geological Survey Geophysical Publication 538 is an aeromagnetic map that includes the Deer Lodge Valley.

GEOLOGY

The Anaconda and Flint Creek Ranges are composed of Precambrian through Cretaceous sediments and metasediments with numerous igneous intrusives. Three periods of glaciation have occurred in the Flint Creek Range and deposited moraine and outwash material in the Deer Lodge Valley (Mutch, 1960).

Cretaceous quartz monzonite of the Boulder batholith and the Eocene tuffs and lava flows of the Lowland Creek volcanics outcrop a short distance east of the study area.

Valley formation probably began in the early Tertiary, before the Eocene deposition of the Lowland Creek volcanics (Konizeski, 1968). Fault scarps along the western side of the valley indicate relatively recent movement however no surface evidence for faulting along the eastern valley margin is apparent (Schofield, 1979). Valley fill consists of consolidated and unconsolidated Tertiary sediments and Quaternary alluvium (Konizeski, 1968).

SURVEY METHODS

Figure 1 is a map of the Warm Springs area showing the location of the gravity stations. Station spacing generally did not exceed three-hundred feet. Station elevations were taken from a level net and recorded to the nearest one-hundredth of a foot. Free air, latitude and Bouguer corrections were made upon the data but no terrain corrections were performed.

Resistivity data were gathered with an Eltran array of fifty meter "a" spacing. The survey was designed for profiling the area. Detailed surveys were performed in selected areas using and expanding Wenner array for which the "a" spacings varied from one meter to one hundred meters.

RESULTS

Figure 2(a), (b) and (c) are cross sections constructed utilizing a two-dimensional modeling program (Fleming, 1977). Figures 2(a) and (b) represent an east-west section passing through the spring, beginning approximately 22,000 feet west of the spring and ending approximately 11,000 feet to the east. The location of section 2(c) is shown on figure 1. In all profiles the crosses represent gravity data and the solid lines are the computer-calculated anomalies resulting from the assumed subsurface configuration.

Data for profiles 2(a) and (b) was taken from the U.S. Geological Survey Water Supply Paper 1862. In figure 2(a) a density of 2.2 g/cm^3 was chosen for the valley fill and 2.67 g/cm^3 for the basement material.

These values are in agreement with Burfiend (1967). A density log from a well drilled on the hospital grounds in November of 1979 shows that the average density of the valley fill may be only 2.0 g/cm^3. Figure 2(b) is a profile modeled to this density contrast. Figures 2(a) and (b), although generally similar in cross sectional shape, clearly show the variation of valley fill depth estimates resulting from the two density contrasts.

The small changes of slope that occur along the gravity profile near the east side of the valley are interpreted to be indicative of changes in the basement configuration. It is possible that these changes could be interpreted as expressions of normal faulting along the eastern edge of the valley.

Data for cross section 2(c) was taken from the residual gravity map shown in figure 3. The profile indicates a highly variable near-surface density distribution with the present-day springs occurring at a boundary between a gravity high and a gravity low.

Other notable features of the residual gravity map are the closed low near the upper-right corner of the map and the high southeast of the spring. The magnitude and area of the closed low probably indicate a small, near surface mass, the center of which may be 100 meters below the surface as calculated by the half-width method (Telford, et.al., 1976).

Applying the half-width method to the gravity high southeast of the spring it can be found that the center of mass may lie 195 meters below the surface. A possible interpretation of the high is that it is the expression of the deposition of materials in the near-surface gravels.

The following calculation is based upon the assumption that valley fill with a density in the range of 2.0 to 2.2 g/cm^3 may undergo a density increase of 0.3 to 0.4 g/cm^3 as the porosity decreases from 20 percent to 5 percent. Applying the increase of 0.4 g/cm^3 to a spherical mass of 150 meter radius and center of mass 195 meters below the surface the added attraction becomes:

$$g = \frac{4/3 \pi R^3 d}{z^2} \times G$$

where d = the density
$4/3 R^3$ = the volume
z = depth to center of mass
G = gravitational constant $6.67 \times 10^{-8} \frac{\text{dynes-cm}^2}{g^2}$

$$g = 4/3 \pi \frac{(150m \times 100cm/m)^3 \times 0.4g/cm^3}{(195m \times 100cm/m)^2} \times G$$

g = 0.000992 gals or 0.992 milligals.

This value is in close agreement with the observed variations of gravity but would vary slightly with different densities or porosities.

Figure 4 is a contour map of the resistivity data taken in the vicinity of the spring. The contours show that the lowest resistivities surround the spring. The northeast trend of the contoured low might be attributed to the natural flow of the water as it reaches the surface. An alternate interpretation is that the northeast trend of the low indicates the position of the water entering the area. However, a free-flowing, warm water spring was encountered while excavation was being done for a basement approximately 800 feet east of the present spring and the occurrence of warm basements in houses southeast of the spring (Painter, 1978) indicates that the warm waters are present southeast of the spring. A distortion in the 10 ohm-meter contour also occurs southeast of the spring in the vicinity of the anomalous gravity high.

DISCUSSION OF RESULTS

Valley cross sections based upon an evaluation of gravity values for the Deer Lodge Valley show that the location of the warm spring seems to be associated with a change of basement configuration that could be interpreted as faulting along the east side of the valley.

The residual gravity map of the area adjacent to the spring shows a gravity low northeast of the spring and a slight gravity high to the east and southeast of the spring. No present explanation exists for the gravity low other than it is the expression of a near-surface body of low density material. The high, however, may be the expression of a slight density increase resulting from the deposition of materials from migrating geothermal waters as they cool near the surface. Such deposition may block the migrating water and control its dispersion through the gravels. Based upon this hypothesis, the gravity high may indicate that the waters reach the near surface somewhere to the southeast of the present springs.

The resistivity map of the area indicates that a near surface low resistivity zone surrounds the present day spring. The zone broadens to the north and northeast and extends into the region of the previously mentioned gravity low. The resistivity data may be representative of a system in which geothermal water reaches the near-surface and spreads laterally, the northeast elongation being due to the natural hydrologic gradient. Houses with warm basements and the discovery of a small spring indicate that the water may first reach the near-surface southeast of the present spring. A distortion in the 10 ohm-meter contour occurs in the vicinity of the anomalous gravity high.

ACKNOWLEDGEMENTS

Support for this work was provided by a grant from the Montana Department of Natural Resources and Conservation, contract no. RAE-515-WDMN-781. The author wishes to thank Dr. John Sonderegger, Dr. Hugh Dresser and J. D. Schofield for their valuable input.

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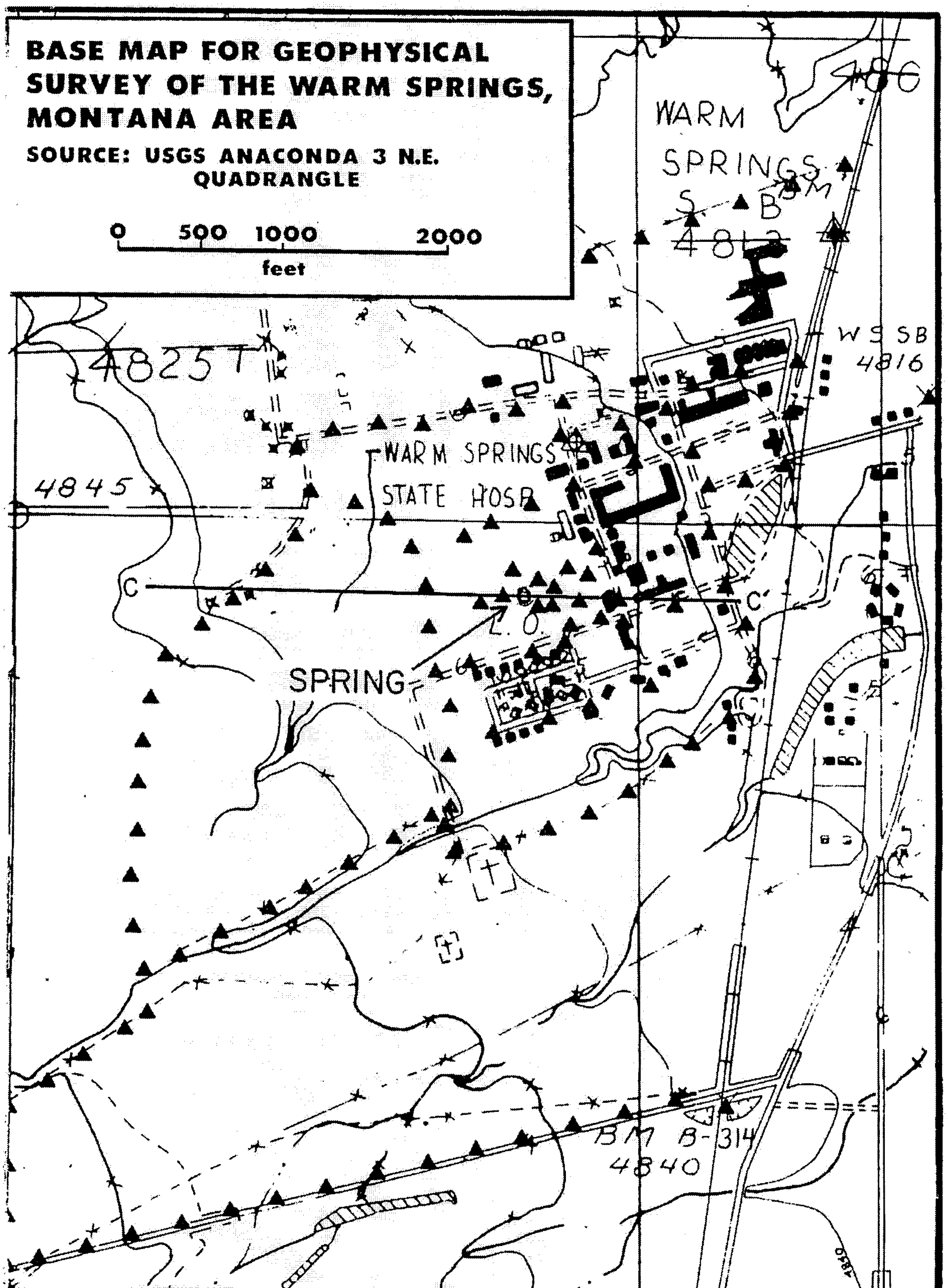

Figure 1. Map of the Warm Springs area showing gravity station locations and the location of cross section 2(c).

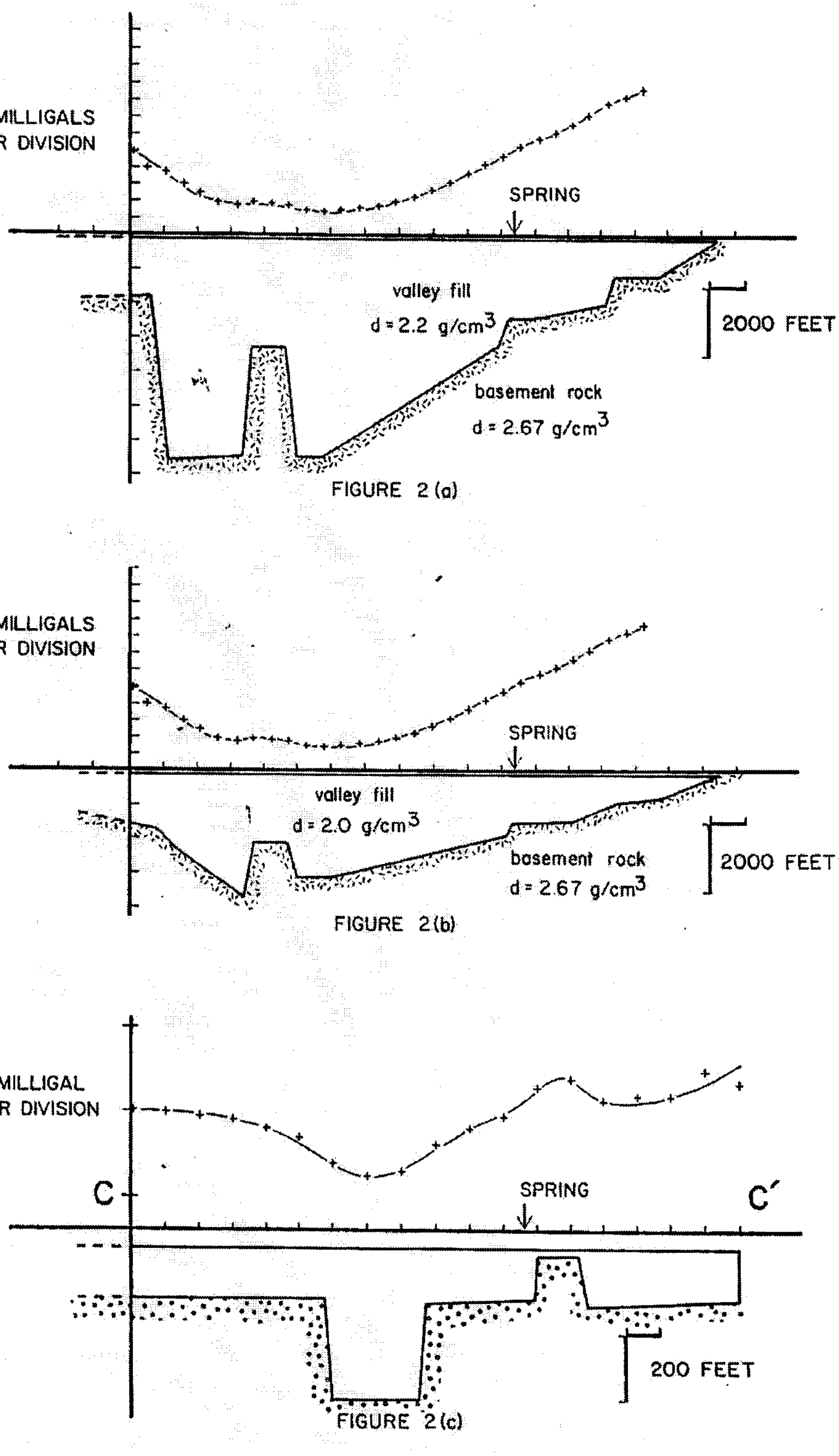

Figure 2. Figures 2(a) and (b) represent an east-west section across the Deer Lodge Valley showing two possible interpretations of the basement configuration resulting from two different valley-fill densities. Figure 2(c) shows the near-surface density distribution within the valley fill. Crosses indicate gravity data and the lines show the computer-calculated anomalies resulting from the assumed subsurface configuration.

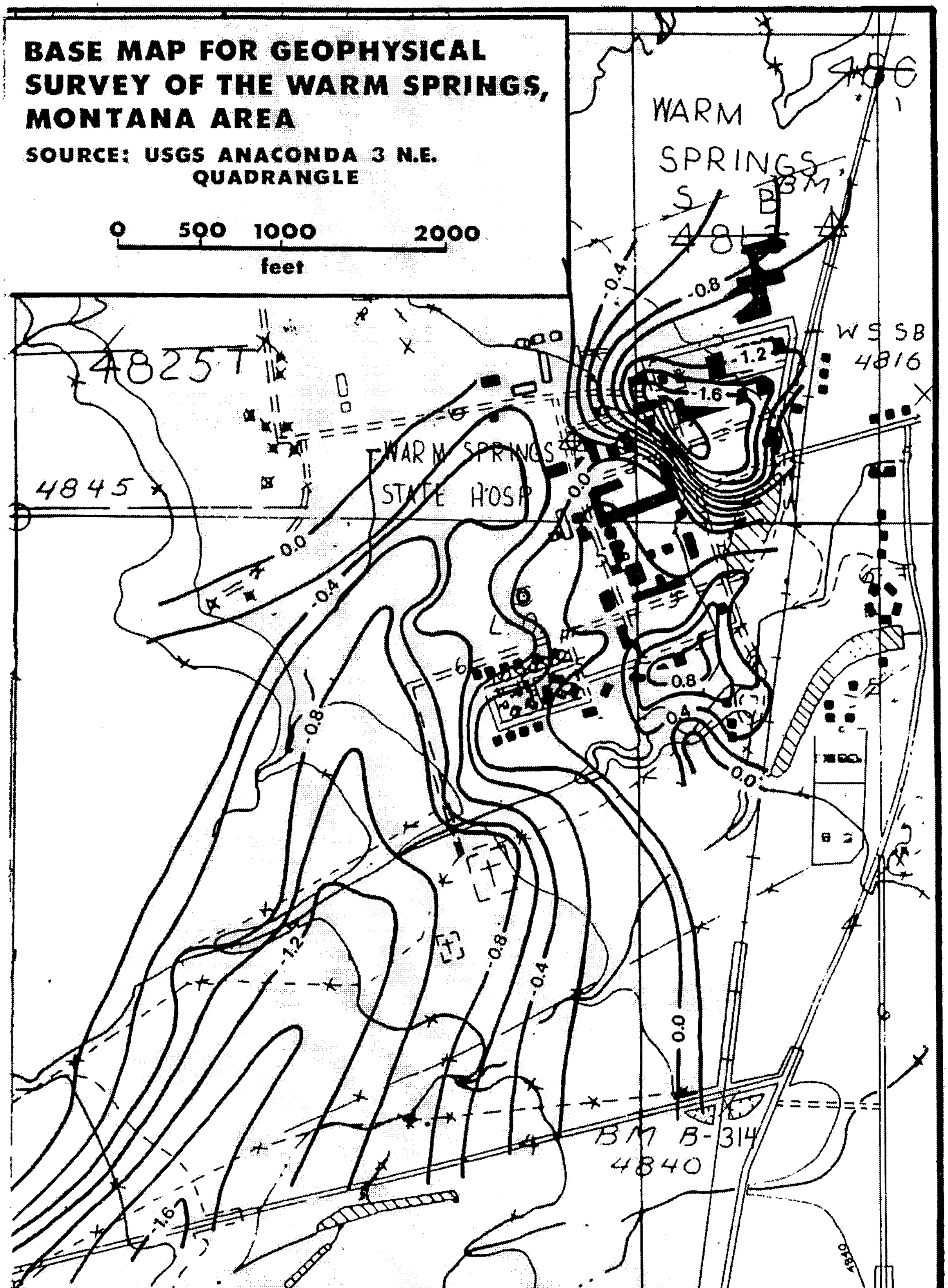

Figure 3. Residual gravity map of the Warm Springs area. 0.2 milligal contour interval.

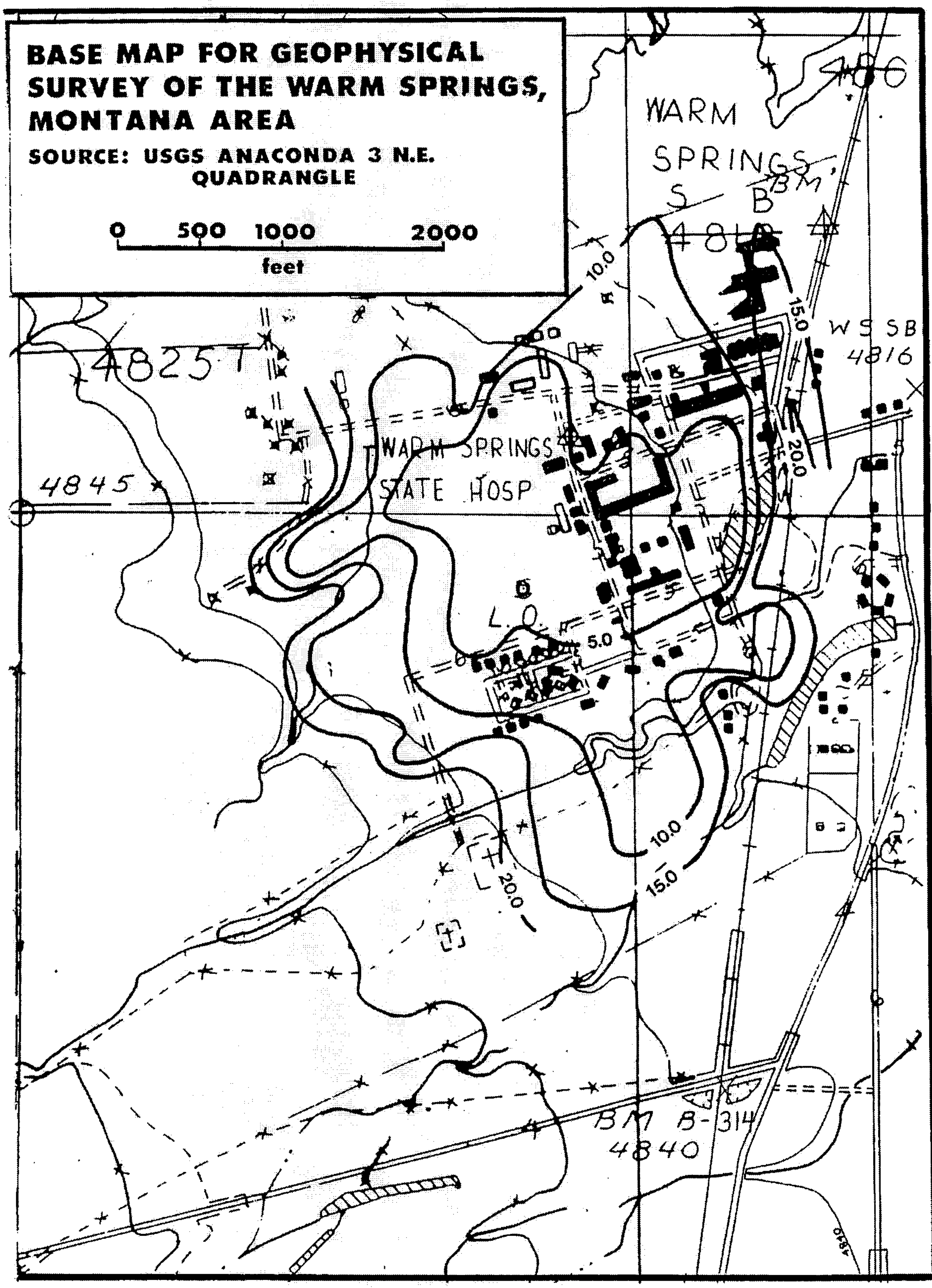

Figure 4. Resistivity contour map of the Warm Springs area based upon 50 meter Eltran dipole profiles. 5 ohm-meter contour interval.