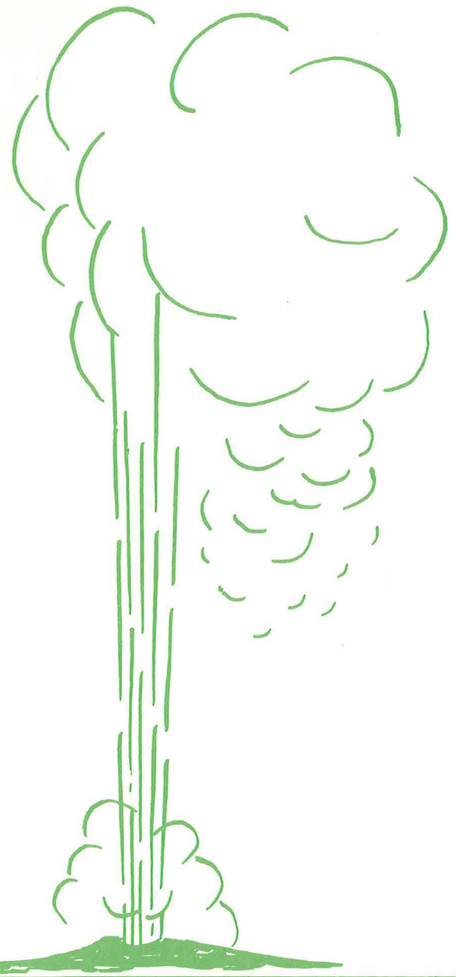

DOE/ET/28416-2

PRELIMINARY TARGETING OF GEOTHERMAL RESOURCES IN DELAWARE

Progress Report for July 15, 1979—May 30, 1980

By
Kenneth D. Woodruff

August 1980

Work Performed Under Contract No. AS02-78ET28416

State of Delaware
University of Delaware
Newark, Delaware

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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Energy under Contract ET-78-S-02-4715

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ILLUSTRATIONS

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GEOPHYSICAL LOGGING

As in the past, the Delaware Department of Natural Resources and Environmental Control endeavored to keep DGS informed of any new deep wells scheduled within the State. None were drilled that were deep enough to provide temperature gradients useful for geothermal exploration. Some modifications to correct a leakage problem were made to the design of the temperature probe built during the previous contract period. No requests were received by DGS for geophysical logging in support of geothermal exploration activities.

drilling of this well should help determine if such a zone indeed exists, and should better define its position. Some work has also been done by DGS on the nature of the apparently thickening sedimentary section in this same area. Smith (unpublished) indicates that Jurassic age rocks may be traced into the mouth of Delaware Bay on DGS seismic line DGS-3 where the top of the Jurassic occurs at about 1,200 to 1,250 meters (3,600 feet). At the mouth of Delaware Bay basement appears to be at a depth of about 2.5 kilometers (see Figure 6) but the exact age or nature of the basement is unknown. Target areas for higher than normal temperatures could therefore include not only a possible hinge zone near the coast but also other grabben-like features occurring inland possibly associated with Mesozoic age faulting.

ADMINISTRATIVE ACTIVITIES AND CONSULTATION

During this contract period a geothermal bill was introduced into the State Legislature. The bill defined the resource and outlined broad policy for future development. The DGS provided technical input on request of the bill's sponsors and pointed out areas where more information will be needed to make management decisions. The bill eventually passed both houses of the State Legislature.

Also during this contract period DOE issued a call for proposals (DE-RP07-801D 12132). Initially, several private consulting firms expressed an interest in the project and requested geologic information from DGS. Data contained in the previous progress report to DOE proved to be of considerable interest to a number of companies. A proposal was subsequently submitted to DOE by the Delaware Energy Office with EBASCO Services Inc. designated by the Energy Office as Project Director. DGS maintained liaison with both the State Energy Office and EBASCO throughout the initial negotiations and contract preparation. Geologic information was provided by DGS to the State Energy Office and EBASCO for inclusion in the contract proposal to DOE.

trend, just east of the Sussex-Currioman Bay trend also discussed by Hansen (1978). The basement rocks at Crisfield have been tentatively identified as metavolcanics (Costain and others, 1979) and would probably be much older than Mesozoic in age.

Other Geothermal Possibilities

The work undertaken for DOE by Costain and others (1978) is based largely on exploration for buried granitic rocks as major heat sources. Granitic intrusives within more basic rocks would normally be reflected as gravity and magnetic lows at the land surface. Subsequent reports to DOE by Costain and his co-workers indicate that this approach has apparently been valid in much of the coastal plain and appears to yield the most consistent results. At the time of drilling the five 1,000 foot DOE test holes in Delaware geophysical data on the type and depth of basement rocks were extremely scanty. Temperature gradients in four of the five Delaware holes were higher than normal and, with the exception of the Dover hole, the two highest gradients were recorded in the area of gravity and magnetic anomalies centered around Bridgeville (DOE holes 34C and 54). As mentioned above, it is possible that the anomalies near Bridgeville could also be indicative of faulting within the basement rocks. It may be possible that a highly faulted basement could locally produce greater than normal temperature gradients due to naturally circulating ground waters along fracture planes. Near the coast,other geophysical data indicates that the pre-Jurassic basement deepens steeply just offshore from southern Delaware. Klitgord and Behrendt (1978) and Grow and others (1978) show "acoustic" basement (crystalline?) at a depth of about 5 kilometers (16,000 feet) at the western end of USGS seismic line 10, about eight miles east of Ocean City, Maryland. However, onshore control in Maryland at a point approximately 20 miles west of line 10 indicates crystalline basement at a depth of only 2 kilometers (6,500 feet). Basement apparently steepens abruptly by means of a "hinge zone" just offshore from the southern Delaware coastline. The exact position of such a zone is uncertain at the moment. However, the State of Delaware has recently submitted a proposal to DOE for a deep geothermal production well at Lewes. Data from the

PRELIMINARY TARGETING OF GEOTHERMAL RESOURCES IN DELAWARE

ABSTRACT

Work completed under a ten and a half month extension of DOE Contract DE-AC02-78ET28416 included additional gravity mapping in southern Delaware, development of a computer program for contouring gravity data, and some preliminary quantitative interpretations of gravity and magnetic data in southern Delaware. No significant changes were made in the original Bouguer gravity map produced during the original contract period as a result of this later mapping.

The SYMAP and SCONTOUR computing programs, developed by Harvard Graphics and adapted in this study for the B7700, were used to generate computer drawn Bouguer gravity maps for the study area. Maximum depths calculated for the top of a gravity anomaly in the Bridgeville area ranged from about 2.3 to 2.7 kilometers (7,500 to 8,000 feet). Depth to magnetic basement in the same general area was calculated to be between about 1.5 and 2.9 kilometers (4,920 and 6,200 feet). Both gravity and magnetic data agree with trends noted on regional maps and suggest that in selected cases fracture zones beneath the coastal plain might be a possible target for future geothermal exploration.

INTRODUCTION

Background

Work described in this report was done under the extension of DOE Contract DE-AC02-78ET28416 which originally covered the period July 15, 1978 to July 14, 1979. The work completed in the initial contract was described in a report to DOE - Preliminary Targeting of Geothermal Resources in Delaware, Progress Report, July 15, 1978 - July 14, 1979, (K. D. Woodruff, 1979). Tasks completed included administrative assistance to DOE and its contractors during the siting and drilling of geothermal gradient wells in Delaware, temperature logging of the DOE test wells

INTERPRETATION OF GEOPHYSICAL DATA

Gravity Measurements

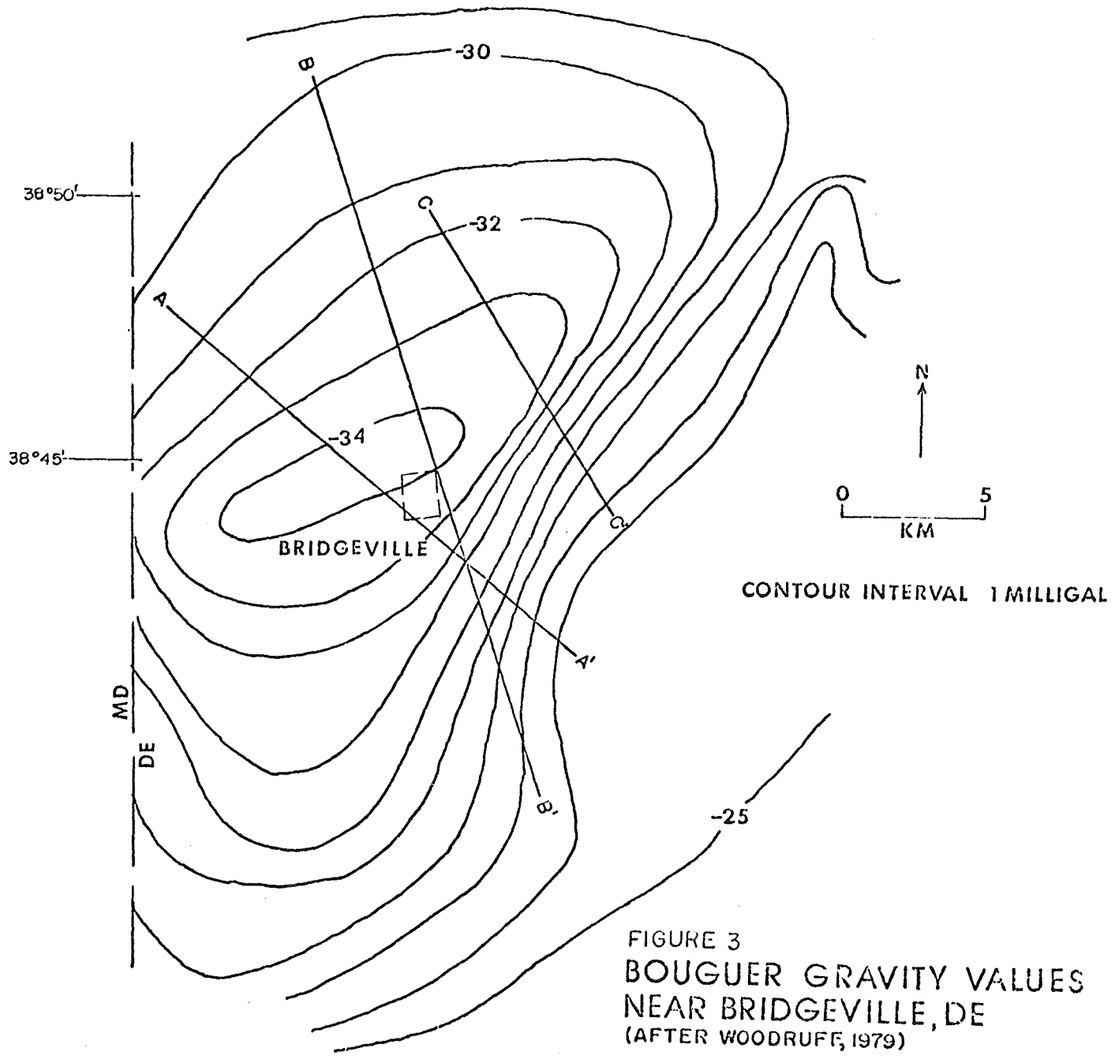
The previous progress report (July 15, 1978-July 14, 1979) pointed out the existence of two major gravity anomalies in southern Delaware, one near Bridgeville and one near Bethany Beach. In this extension period attention was given to the gravity low centered in the Bridgeville area, particularly with regard to determining depths to the gravity contrast. Figure 3, redrawn and smoothed from the original Bouguer gravity map (Woodruff, 1979), indicates the Bouguer values in the Bridgeville area. The maximum anomaly or deviation from the regional Bouguer gravity values is about 9 milligals. Gravity profiles were made across the anomaly (see Figure 4) and the methods described by Skeels (1963) were used to calculate maximum depths to the top of the anomaly. Depths found for profiles A-A', B-B', were about 2.7 kilometers (about 8,800 feet). The maximum depth calculated from gravity profile C-C' was about 2.3 kilometers (about 7,500 feet). The density contrast used in the calculations was 0.2 gr/cc. These solutions do not uniquely define the structure and should be considered as approximations only. The closely spaced contours on the southeast side of the anomaly indicate abrupt lateral density changes such as might be produced by a faulted vertical slab. However, an irregularly shaped intrusive body might also give rise to the pattern observed. If the pattern is due to a faulted slab further calculations indicate that a vertical fault with a distance of about 2.3 kilometers to the center of the throw could produce the pattern noted. These depths are not unreasonable in terms of what is known about basement depths and the tectonic history of the area.

The second anomaly, a broad gravity high centered in the Bethany Beach area, is not as initially attractive as a gravity low in terms of its geothermal significance. Gravity highs in the coastal plain usually indicate the presence of basic rocks which normally do not have significant concentrations of radioactive minerals that could act as heat sources. Therefore, no calculations were made to determine the depth to the gravity anomaly near Bethany Beach. However, a later section of this report discusses possible implications of the high in relation to the regional geologic history and possible alternative geothermal sources.

Aeromagnetic Data

During this contract period the U. S. Geological Survey published Open-File Report 79-1683, Aeromagnetic Map of Parts of Delaware and New Jersey. This work was originally suggested by the DGS in its initial proposal to DOE as a necessary part of DOE's geothermal evaluation of eastern coastal areas. The map proved to be valuable in confirming the features identified from the gravity map and in providing constraints on the depth calculations made from the gravity data.

The published aeromagnetic map is at a scale of 1:250,000. For this study, parts of the map were enlarged to the scale of the gravity map (approximately 1:127,000 or 1 inch = 0.5 miles) so that the two maps could be directly compared and cross-sections constructed. Figure 5 shows the enlarged magnetic map of the Bridgeville area and the locations of the three magnetic profiles from which depth calculations were made. The low of 54,320 gammas is flanked by relative magnetic highs to the north and south. The magnetic low corresponds closely to the center of the gravity low defined by the -34 milligal contour but does not in itself define an anomaly. The anomalous values are the highs to either side. The northeast-southwest magnetic trend is also reinforced by the gravity data. Two of the magnetic profiles, B-B' and C-C', correspond in part to the position of gravity profiles B-B' and C-C'. Methods developed by Peters (1949) and Vacquier and others (1951) were used to compute depths to the magnetic basement. Calculations based on magnetic profiles D-D' and C-C' (see Figure 6) gave average depths to basement of 1.5 and 1.6 kilometers respectively (about 4,920 and 5,250 feet). Line B-B' gave a depth of about 3.5 kilometers (about 11,500 feet). The agreement with depths calculated from the gravity measurements varies considerably depending upon the exact position of the profile on the respective anomaly. The magnetic profiles were not always symmetrical and it was difficult to select proper inflection points. Depths to pre-Jurassic basement compiled by Benson (Figure 7) indicates a basement depth of about 1.7 kilometers (5,580 feet) in the Bridgeville area. Thus, the calculated depths to magnetic basement agree fairly closely (except for line B-B') with the depths to the probable base of unconsolidated coastal plain sediments as determined from other sources.



CONTOUR INTERVAL 1 MILLIGAL

FIGURE 3
BOUGUER GRAVITY VALUES
NEAR BRIDGEVILLE, DE
(AFTER WOODRUFF, 1979)

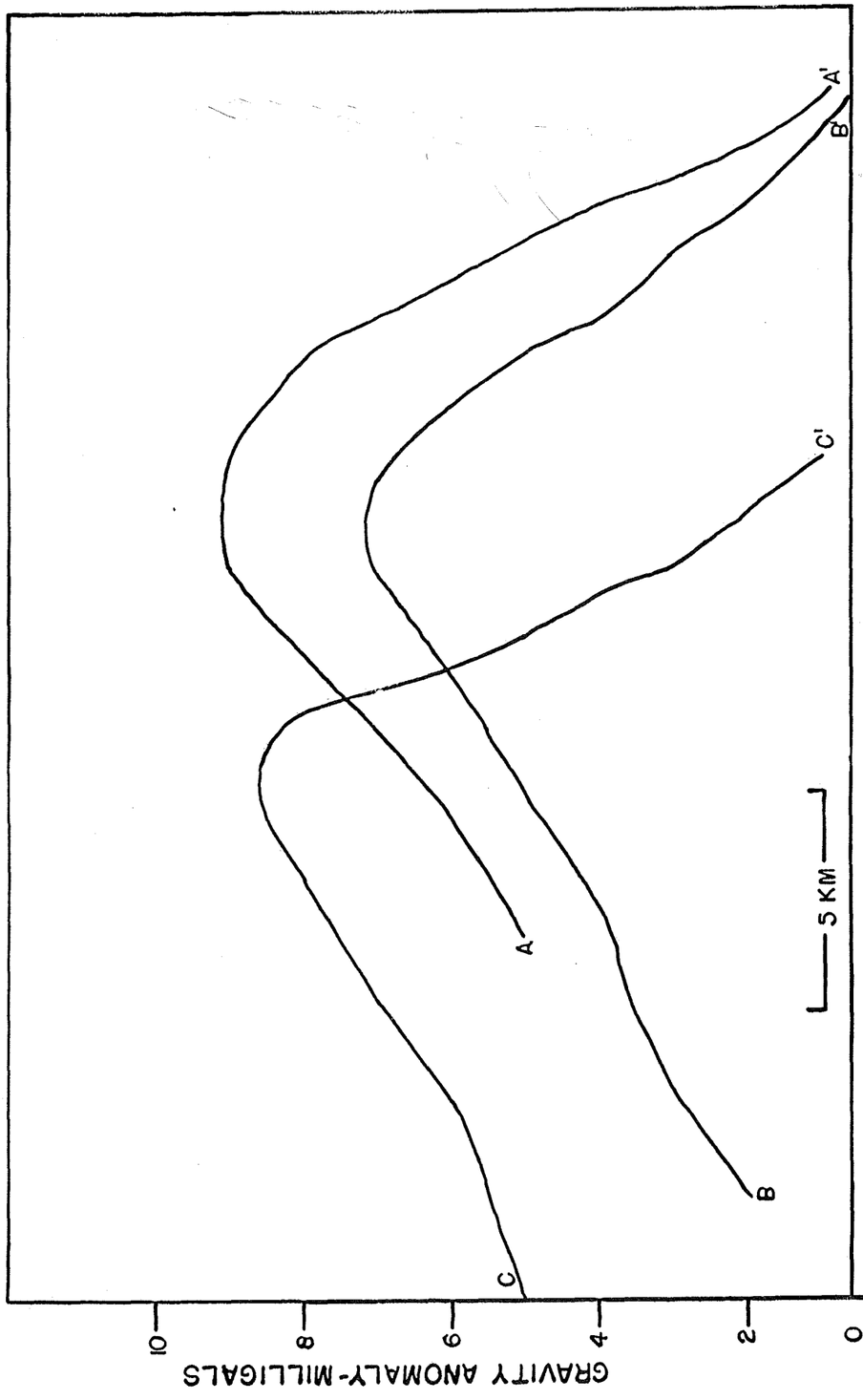


FIGURE 4. GRAVITY PROFILES FOR THE BRIDGEVILLE AREA

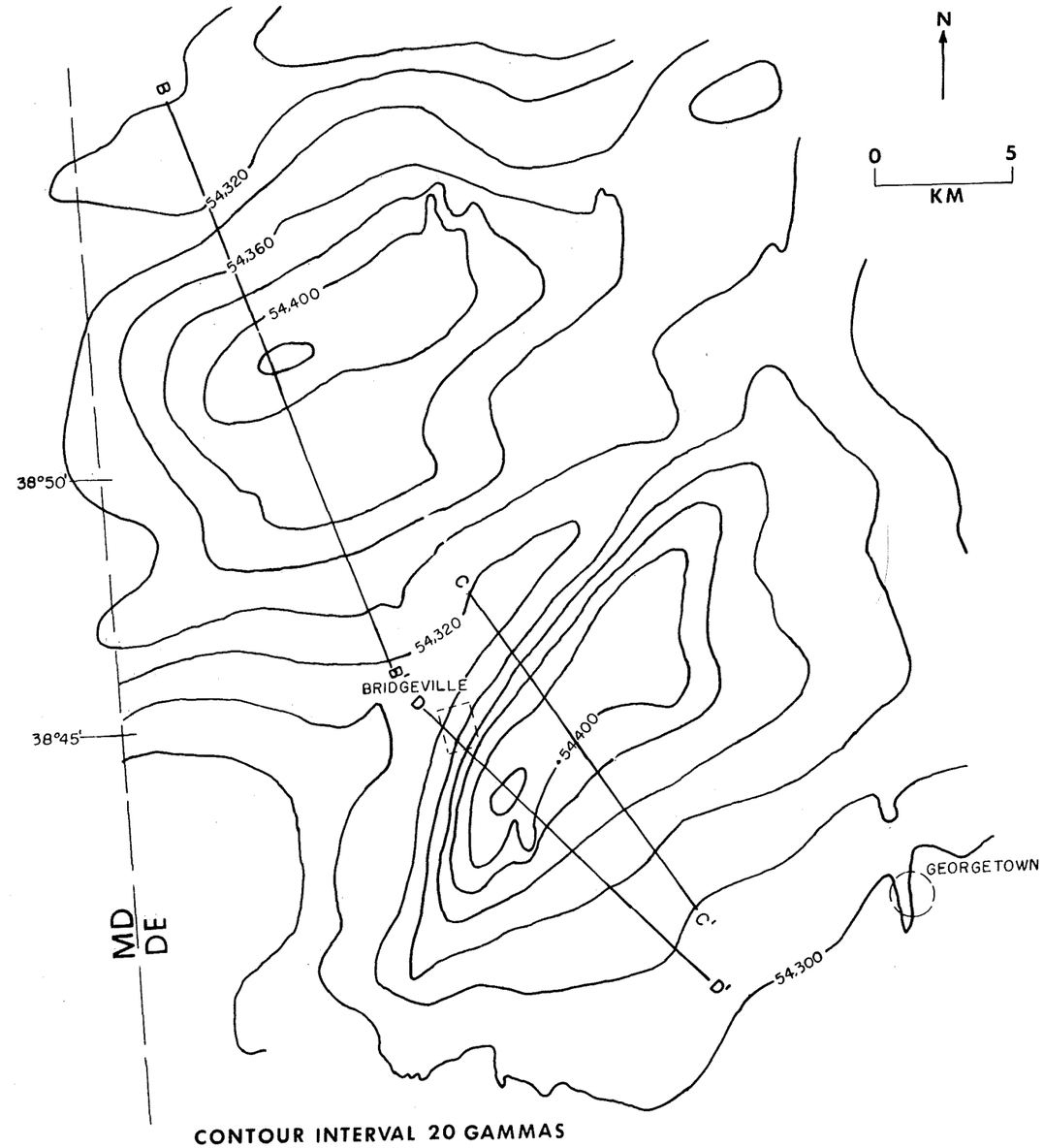


FIGURE 5. MAGNETIC ANOMALY NEAR BRIDGEVILLE, DE. (AFTER USGS, 1979)