Key in envelope

REGIONAL GRAVITY SURVEY OF THE MOAB-NEEDLES AREA, GRAND, SAN JUAN, EMERY, GARFIELD AND WAYNE COUNTIES, UTAH

by

H. R. Joesting, J. E. Case, and Donald Plouff

Contents

Regional gravity survey of the Moab-Needles area, Grand, San Juan, Emery, Garfield and Wayne Counties, Utah

By H. R. Joesting, J. E. Case, and Donald Plouff

Introduction

This discussion is to accompany the gravity map of the Moab-Needles area. A more complete analysis of regional geophysical surveys in the area is being compiled.

The gravity survey on which the accompanying map was based was made with a Worden gravity meter, with a constant of about 0.5 milligal per scale division. Base station gravity values were established by a three-step looping method (Nettleton, 1940). These were tied through a network of base stations to the U. S. Coast and Geodetic Survey pendulum station "Egnar", near Egnar, Colorado. Horizontal control was provided by U. S. Geological Survey multiplex topographic maps, scale 1:24,000. Single-base altimetry was used to establish elevations at most of the stations. Triangulation stations, bench marks, and photogrammetric elevations were also used where possible. Elevations for a number of stations in Upheaval Dome and Upheaval Canyon were established by transit-stadia traverses.

Bouguer anomalies were computed with an elevation factor of 0.062 milligal per foot, corresponding to a density of 2.5 g per cm^3. The international gravity formula of 1930 was used in reducing the anomalies to sea level. Three hundred milligals was added to the anomaly at each station, so that all values are positive.

Terrain corrections through Hammer's J-ring (Hammer, 1939) were made for most of the stations. Corrections through the N-ring were necessary in the southern part of the area, near the Abajo Mountains. Terrain corrections were as large as 8 milligals in the Upheaval Dome area, and as large as 11 milligals in Cataract Canyon, below the junction of the Colorado and Green Rivers.

Elevations of stations determined by altimetry are generally less than 20 feet in error, equivalent to 1.2 milligals. They may be as large as 30 feet in Upheaval Dome and in parts of a traverse east of the Colorado River, equal to nearly 2 milligals. Inaccuracies in elevations determined by altimeter are therefore the principal sources of error in the reduced values of gravity, as errors in observed gravity and in latitude corrections are generally less than 0.1 milligal each, and errors in terrain corrections are generally less than 0.5 milligal.

Information on the geology of the Moab-Needles area is available in publications of Baker (1933, 1946), Dane (1935), and McKnight (1940). Subsurface stratigraphy of parts of the Colorado Plateau, including the Moab-Needles area has been described by Wengerd and Strickland (1954). Cooper (1955), Lockman-Balk (1956), Herman and Sharps (1956), Herman and Barkell (1957), Baars (1958), Neff and Brown (1958), and Wengerd (1958). Subsurface information is also available from well logs in oil scouts' reports. Photogeologic maps of the area by Bates (1955), Bergquist (1955), Detterman (1955), Hackman (1955), Hemphill (1955), Hosley (1953), Platt (1954, 1955 a, b), Sable (1955) and Tolbert (1956) have been published.

The authors are indebted to J. H. Stewart, P. L. Williams, D. G. Wyant,

and E. M. Shoemaker, all of the Geological Survey, and to Glen Ruby, Consulting Geologist, for additional information on stratigraphy and structure. A brief report on geophysical investigations at Upheaval Dome was prepared by Joesting and Plouff (1958).

The following geologic summary was prepared on the assumption of prior knowledge by the reader of the Moab-Needles area.

The Moab-Needles area is in the Paradox Basin of Pennsylvanian age, which is characterized by thick deposits of evaporites that locally form the cores of salt anticlines. The sedimentary rocks at the surface dip gently northward from the Monument upwarp south of the area toward the Uinta Basin to the north. The area straddles a deep-seated zone within the Paradox Basin that separates the basin into a deeper northern portion and a shallower southern portion, as discussed later.

The principal structures are the Salt Valley, Moab, and Cane Creek salt anticlines in the northern part of the area. Smaller structures found in the central and southern parts include Upheaval, Shafer, and Gibson domes; Lockhart and Meander anticline; and the Needles fault zone adjoining Meander anticline. These structures, which are related mainly to plastic flow of evaporites, are superimposed on the northerly regional dip, which totals about 5,000 feet in the area of the gravity map, measured on Cretaceous horizons.

Sedimentary rocks exposed in the area range in age from Pennsylvanian to Upper Cretaceous. In addition, there are minor deposits of Quaternary alluvium, talus, and wind-blown material (McKnight, 1940). Cretaceous rocks are confined to the northern part of the area. Rocks of Jurassic, Triassic, and Permian age are exposed in the uplands, mesas, and canyon walls, and rocks of Pennsylvanian age are found in the deeper canyons and in some of the breached salt anticlines. Sedimentary rocks of Mississippian, Devonian, and Cambrian age have been penetrated by drills, but Precambrian basement rocks have not been reached in the Moab-Needles area. There are no known occurrences of igneous rocks.

Rocks younger than Pennsylvanian consist mainly of shale, siltstone, and sandstone, and have an average density of about 2.4 to 2.5 g per cm^3. The Hermosa Formation of Pennsylvanian age contains an upper limestone, shale, and sandstone member of density about 2.6 g per cm^3; a thick middle evaporite member--the Paradox Member--of density about 2.2 to 2.3 g per cm^3; and a lower limestone and shale member of density about 2.65 g per cm^3. The pre-Pennsylvanian sedimentary rocks are made up of limestone, shale, dolomite and sandstone. Their density is estimated to be about 2.65 g per cm^3.

The thickness of the sedimentary section is estimated to be about 6,000 feet in the southern part of the area and at least 15,000 feet in the northern part. The evaporites in the Moab salt anticline are more than 10,000 feet thick, but the original undisturbed thickness was probably no greater than 4,000 feet, and diminished toward the south and west.

Although Precambrian basement rocks have not been reached by drilling in the Moab-Needles area, biotite granite has been found in deep wells to the east and west, and a wide variety of Precambrian crystalline rocks has been found in the Uncompahgre Plateau to the east. These range in density from about 2.65 to 3.0 g per cm^3, and the Precambrian rocks of the Moab-Needles area probably have a comparably wide range in density.

6 page 8 is next

Discussion of the gravity map

The largest gravity effects are associated with contrasts in densities of large lithologic units in the Precambrian basement, and with thickened masses of low-density evaporites in the Salt Valley and Moab anticlines.

The gravity map is dominated by a 40-milligal regional northward decrease from the highs in the Holeman Springs Basin-Lockhart Basin-Harts Draw areas to a broad low near Bartlett Flat and Arts Pasture. This large regional gradient reflects 1)northerly and northeasterly deepening of the Precambrian basement, 2) lower-density basement rocks to the north than to the south, and 3) depositional thickening of low-density evaporites; the change is along the zone of steepest gravity gradient.

Analysis of aeromagnetic anomalies indicates that the basement lies at about sea level at Upheaval Dome, and about 1,000 feet below sea level at Grays Pasture (Joesting and Plouff, 1958). These anomalously shallow indications are in agreement with indications of the gravity data.

The zone of steepest gradient between Taylor Canyon on the west and Cane Springs Canyon on the east probably marks a deep-seated structure that divides the Paradox Basin into a southern shallow part and a northern deeper part. The Paradox evaporites thicken to the northeast across this zone. The contact between higher- and lower-density basement rocks already mentioned evidently coincides with the deep-seated structure.

The observed gravity anomaly, including the steep gradient, can be reproduced by a 2-dimensional model with the following characteristics: the evaporites (density 2.2 g per cm^3) thicken from about 1,300 feet in the Holeman Spring Basin area to about 3,500 feet at Big Flat, the pre-evaporite sedimentary rocks and the basement are down-dropped about 1,000 feet to the north along the steepest part of the gravity gradient, and about 500 feet near Upheaval Dome. The density of the basement was assumed to be 2.7 g per cm^3 north of the main displacement and 3.0 g per cm^3 to the south. The density of the pre-evaporite sediments was assumed to be 2.65 g per cm^3 and the thickness about 1,500 feet throughout. The observed anomaly can, of course, be reproduced by other models, but the one described here is geologically reasonable and in agreement with available subsurface and aeromagnetic data.

Contours defining the strong regional gradient at Taylor Canyon and Grays Pasture split near Hatch Point. The main gradient continues easterly to the La Sal Mountains region. The southern part trends southeast and presumably also represents a zone of density contrasts within the Precambrian basement, as well as thickening evaporites and increasing depth of the basement toward Lisbon Valley.

The broad, circular low at the Needles, in the southern part of the area, may be related both to salt thickening and intrabasement density contrasts.

The high near Beef Basin in the extreme southern part of the area is at the northern end of the Monument Upwarp. It is related mainly to structural uplift, and partly to thinning of salt. The adjoining high west of the Colorado River may be related to a deep-seated northwestward continuation of the Monument Upwarp that is not reflected in surficial structure.

The 26-milligal gravity low associated with the Salt Valley salt anticline in the northeastern part of the area has a computed amplitude of 8,000 feet above the top of the evaporites on either side of the anticline (Joesting and Case, in press), assuming a density contrast of 0.35 g per cm^3 between the salt and the adjacent sedimentary rocks. The computed vertical extent of the anticline would, of course, be larger if a smaller density contrast were used.

A residual low of 20-22 milligals is found over the Moab Valley salt anticline. The regional gradient across Moab Valley indicates that the pre-salt basement is deeper beneath and northeast of the valley than to the southwest. Drill data bear out this interpretation. The computed amplitude of the evaporite core of the anticline is about 8,000 feet.

A slight flattening of the strong regional gravity gradient at Cane Creek anticline is perhaps related to salt thickening, but the comparatively low precision of the gravity survey and wide spacing of stations may have combined to obscure its small effect.

At Upheaval Dome there is a 2-3 milligal residual high on which is superimposed a one-milligal low. Upheaval Dome is probably a salt structure, but its estimated associated anomaly of 1.5 to 2 milligals is obscured by regional gravity effects and by local terrain effects. Terrain corrections in the area were as large as 8 milligals.

References

Published reports

Baars, D. L., 1958, Cambrian stratigraphy of the Paradox basin region, in Intermountain Assoc. Petroleum Geologists Guidebook 9th Ann. Field Conf., 1958, p. 93-101.

Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 841 95 p., 11 pls.

Baker, A. A., 1946, Geology of the Green River Desert-Cataract Canyon region, Emery, Wayne, and Garfield Counties, Utah: U. S. Geol. Survey Bull. 951, 122 p., 20 pls.

Cooper, J. C., 1955, Cambrian, Devonian, and Mississippian rocks of the Four Corners area: Four Corners Geol. Soc. Field Conf. Guidebook, p. 59-65.

Dane, C. H. 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, 184 p., 21 pls.

Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, v. 4, p. 184-194.

Herman, George, and Barkell, C. A., 1957, Pennsylvanian stratigraphy and productive zones, Paradox salt basin: Am. Assoc. Petroleum Geologists Bull., v. 21, no. 5, p. 861-881

Herman, George, and Sharps, S. L., 1956, Pennsylvanian and Permian stratigraphy of the Paradox salt embayment, in Intermountain Assoc. Petroleum Geologists Guidebook 7th Ann. Field Conf. Guidebook, p. 77-84.

References

Published reports

Joesting, H. R., and Plouff, Donald, 1958, Geophysical studies of the Upheaval Dome area, San Juan County, Utah, in Intermountain Assoc. Petroleum Geologists Guidebook 9th Ann. Field Conf., p. 86-92.

Joesting, H. R., and Case, J. E., in press, Regional geophysical studies in the Salt Valley-Cisco area, Utah and Colorado: Am. Assoc. Petroleum Geologists Bull.

Lochman-Balk, Christina, 1956, Cambrian stratigraphy of eastern Utah: in Intermountain Assoc. Petroleum Geologists Guidebook 7th Ann. Field Conf. Guidebook, p. 58-64.

McKnight, E. T., 1940, Geology of area between Green and Colorado Rivers, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 908, 147 p., 13 pls.

Neff, A. W. and Brown, S. C., 1958, Ordovician-Mississippian rocks of the Paradox basin, in Intermountain Assoc. Petroleum Geologists Guidebook 9th Ann. Field Conf., p. 78-85.

Nettleton, L. L., 1940, Geophysical prospecting for oil: New York, McGraw Hill Book Co., p. 38-39.

Wengerd, S. A., 1958, Pennsylvanian stratigraphy, southwest shelf, Paradox basin, in Intermountain Assoc. Petroleum Geologists Guidebook, 9th Ann. Field Conf., 1958, p. 109-134.

Wengerd, S. A., and Strickland, J. W., 1954, Pennsylvanian stratigraphy of Paradox salt basin, Four Corners region, Colorado and Utah: Am. Assoc. Petroleum Geologists Bull., v. 38, no. 10, p.2157-2199.

Published photogeologic maps

Bates, C. E., 1955, Photogeologic map of the Moab 10 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-116.

_____1955, Photogeologic map of the Moab 11 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-107.

_____1955, Photogeologic map of the Carlisle 3 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-68.

_____1955, Photogeologic map of the Carlisle 6 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-71.

Bergquist, W. E., 1955, Photogeologic map of the Moab 13 Quadrangle, Utah, U. S. Geol. Survey Misc. Geol. Inv. Map I-118.

Detterman, J. S., 1955, Photogeologic map of the Carlisle 2 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-67.

Hackman, R. J., 1955, Photogeologic map of the Carlisle 14 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-6.

_____1955, Photogeologic map of the Carlisle 15 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-76.

Hemphill, W. R., 1955, Photogeologic map of the Moab 16 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-83.

Hosley, V. M., 1953, Photogeologic map of the Moab 15 Quadrangle, Utah: U. S. Geol. Survey TEMR 598.

Platt, J. N., 1954, Photogeologic map of the Carlisle 13 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-2.

_____1955 a, Photogeologic map of the Carlisle 11 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-74.

_____1955b, Photogeologic map of the Carlisle 12 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-75.

Sable, V. H., 1955, Photogeologic map of the Carlisle 4 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-69.

Sable, V. H., 1955, Photogeologic map of the Carlisle 5 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-70.

_____1955, Photogeologic map of the Carlisle 7 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-72.

_____1955, Photogeologic map of the Moab 12 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-117

_____1955, Photogeologic map of the Moab 14 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-119.

Tolbert, G. H., 1956, Photogeologic map of the Carlisle 1 Quadrangle, Utah: U. S. Geol. Survey Misc. Geol. Inv. Map I-180.