A Gravity Study of the Northern Part of the Arctic National Wildlife Range, Alaska

By B. A. KOSOSKI, H. N. REISER, C. D. CAVIT, *and* R. L. DETTERMAN

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By B. A. Kososki, H. N. Reiser, C. D. Cavit, and R. L. Detterman

ABSTRACT

Interpretation of all publicly available onshore gravity data provides a basis for outlining regional elements of the basement and overlying structure in the northern part of the Arctic National Wildlife Range. Major post-Carboniferous sedimentary basins whose centers lie offshore on the Beaufort Shelf extend onshore in the northern part of the study area. There is strong evidence that dense basement rocks beneath these onshore extensions rise to relatively shallow depths along the northeast Alaskan coast. Geologic studies and interpretation of the gravity data indicate that the gross structural and stratigraphic framework of this area is similar to that of the Prudhoe Bay region to the west.

A high potential for petroleum accumulation in the Wildlife Range is indicated by the surface presence of oil seeps, oil sands, and outcrops of reservoir and source rocks along the southern margins of the onshore basinal areas. Present data suggest that the greatest potential for onshore accumulations of hydrocarbons lies in the area south and east of Barter Island and that possibilities exist there for commercially substantial reserves. The potential of this area cannot be fully assessed, however, until the subsurface extent of several major unconformities is known. Unfortunately, gravity data alone are of little use in such determinations.

South of the mountain front, large granitic intrusions are marked by a sharply defined gravity minimum. The subsurface distribution of these bodies could probably be mapped by detailed gravity surveys. Detailed aeromagnetic surveys should serve equally well for such a purpose.

INTRODUCTION

U.S. Geological Survey field parties operating from the Barter Island Air Force Station in northeastern Alaska during the summers of 1975 and 1976 completed a reconnaissance gravity survey of the northern part of the Arctic National Wildlife Range. The area encompassed by the survey is bounded on the east by the Canadian border, on the west by the Cannng River (the western boundary of the Wildlife Range), on the north by the Beaufort Sea, and on the south by the crest of the Brooks Range. Most of the gravity stations are located in the Arctic Coastal Plain and northern Arctic Foothills. Gravity control was also established south of the mountain front along major river drainages.

This report presents the results of the reconnaissance gravity program and discusses their implications for interpretations of the bedrock geology and petroleum potential of this part of the wildlife range. The interpretations should prove useful as guides to partially hidden subsurface structural features and also in locating areas generally favorable for the application of more exact exploration techniques. The report is actually one part of a regional geologic study of the Arctic National Wildlife Range conducted by the U.S. Geological Survey at the request of the U.S. Fish and Wildlife Service.

PREVIOUS WORK

The first published gravity measurements in this area were made in the 1950's by geophysicists from the University of Wisconsin (Thiel and others, 1958). These stations were later augmented with measurements made by U.S. Geological Survey field parties operating from Lake Peters, Barter Island, Umiat, Barrow and Arctic Village. The combined results of these early gravity surveys were briefly discussed by Barnes (1970). The results of the 1975 and earlier surveys were first released as a series of four open-file maps (Barnes and others, 1976). The two western maps in this series included some stations with 5-mgal (milligal) errors. These stations have been corrected in this publication. The gravity map of Alaska (Barnes, 1976) also incorporates the 1975 data together with some of the earlier results. This map shows how the gravity field in the northern part of the wildlife range is related to that of nearby areas.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following U.S. Geological Survey personnel: I. L. Tailleur and C. F. Mayfield for their contribution to the 1975 field program, D. M. Giovannetti for his help during the 1976 field program, and D. F. Barnes for his invaluable assistance in carrying out both the field operations and the reduction of the gravity data. The project was also greatly aided by the support facilities at Barter Island provided by the U.S. Air Force.

DATA ACQUISITION AND COMPILATION

Instrumentation.—The 1975 and 1976 field parties operating in the wildlife range used LaCoste and Romberg[1] geodetic meters. Earlier gravity observations were made with World-Wide and Worden gravimeters (Barnes, 1965). Meter calibration was checked on the U.S. Geological Survey's calibration range near Menlo Park, Calif.,

[1]Use of trade names is for descriptive purposes only and does not constitute endorsement of these products by the U.S. Geological Survey.

and on a 194-mgal calibration loop near Anchorage, Alaska, and (or) on a 143-mgal calibration loop established on Murphy dome near Fairbanks, Alaska.

Elevation control.—Wherever possible, bench mark and sea-level elevations (from standard topographic sheets) were used for gravity station elevation control, but such control is extremely scarce in the Arctic National Wildlife Range. Therefore most of the station elevations were determined by altimetry. Although this method is less accurate than trigonometric surveying, several hundred comparisons between elevations determined by altimetry and by vertical angle triangulation or photogrammetric estimation indicate that 90 percent of the altimetry elevations are within 50 feet of the surveyed elevation if the observations are within 100 miles of an altimeter base station (Barnes, 1965). Since most of the gravity stations in the wildlife range are in river basins, it was possible to cross-check the altimetry elevations by plotting river gradients. The results obtained substantiate a maximum error in station elevation of less than 50 feet, corresponding to a maximum error of less that 3 mgal in the Bouguer gravity values (using a Bouguer density of 2.67 g/cm^3).

Position control.—Although several gravity stations were located at U.S. Coast and Geodetic Survey benchmarks, most were located by reference to topographic features and drainage intersections depicted on Geological Survey topographic maps (scale 1:63,360). Ninety-five percent of the station sites are believed accurate to within about 0.1 minute of latitude or longitude.

Gravimeter drift control.—Prior to reduction of the gravity data, a correction was applied for instrument drift—the variation in observed gravity values that would be noted if the instrument were read repeatedly at one site. Instrument drift was determined by looping back to base stations established at Barter Island and Lake Peters. The average time interval between base station ties was approximately 3½ hours. Maximum recorded instrument drift was 0.18 mgal.

Data reduction.—A gravity anomaly value is the difference between an observed value of gravity on an absolute basis and the theoretical gravity value at that latitude, longitude, and elevation. To obtain the Bouguer gravity anomalies shown on the map, an additional correction (the Bouguer correction) was applied to partially compensate for the gravimetric effects of the material between the station and sea level datum. So that the results reported here would conform with the gravity map of the State of Alaska (Barnes, 1976) and the gravity map of Canada (Canada Earth Physics Branch, 1974), the 1967 international reference ellipsoid formula (International Association of Geodesy, 1971) was used to calculate the theoretical variations of gravity with latitude.

Actual reduction of the gravity data followed the standard methods described in numerous publications. The second-order term ($-0.0007 \cos 2\phi$, where ϕ is the geocentric latitude) was used in calculating the free-air correction. A standard density of 2.67 g/cm^3 was used to calculate Bouguer anomalies. Terrain corrections were not applied to the data.

Prior to 1975, Alaskan gravity base stations were tied through the North American gravity control network (Behrendt and Woollard, 1961) and the worldwide gravity control network (Woollard and Rose, 1963) to the absolute gravity value of the World Base Station in Potsdam, Germany. Beginning with publication of the gravity map of the Nabesna quadrangle, Alaska (Barnes and Morin, 1975), however, the U.S. Geological Survey has used the International Gravity Standardization Net as the reference datum for calculating theoretical gravity values of Alaskan base stations. Adoption of the International Gravity Standardization Net shifted the World Base Station absolute gravity value by 0.014 gals (Barnes and Morin, 1975). Similar changes were observed in the gravity values of stations in the Alaskan gravity base station network to which the data used in this publication are tied.

The specific procedures used in the acquisition and compilation of Alaskan gravity and altimetry data are given by Barnes (1972).

Residual gravity separation.—Since the geologic bodies of interest in both mineral and petroleum exploration produce gravity anomalies that are relatively small in magnitude and extent, various filtering techniques have been developed and used to enhance the smaller gravity anomalies at the expense of the broad, longer wavelength anomalies of continental or regional extent. The method of data enhancement used in this reconnaissance gravity study involves graphically separating the Bouguer gravity field into first-order regional and second-order residual components. A first-order approximation to the regional gravity gradient was used because the strong north-trending regional gradient evident in the data most likely results primarily from a gradual increase in crustal thickness from the Alaskan coast to the crest of the Brooks Range. To determine and remove the regional gravity component, 11 north-trending gravity profiles were plotted from plate 1 between the Canadian border and the Canning River at intervals of 30 minutes of longitude. First-order regression lines were then fitted to each profile by the method of least squares (see fig. 1). The slopes of these lines were assumed to represent the regional gravity gradient. As noted on figure 1, it was necessary to adjust the slope of the regression lines, and hence the regional gravity gradient, on the two of the profiles west of long 145° W. to produce a tractable gravity field. In this area a thick, relatively

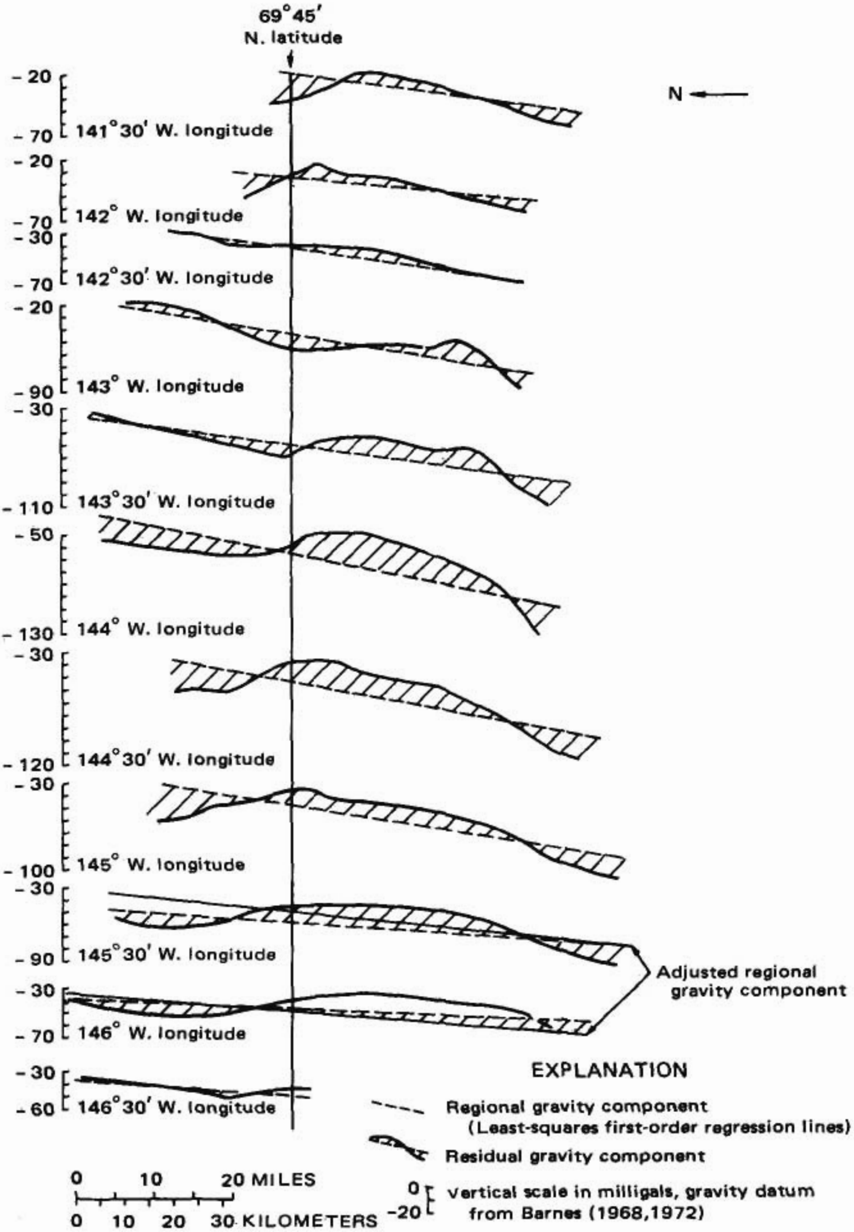

FIGURE 1.—Residual and regional components of the Bouguer gravity field, northern part of the Arctic National Wildlife Range, Alaska.

low-density Tertiary section in the north and three small mountain ranges in the south (Sadlerochit Mountains, Shublik Mountains, and

Third Range) complicate the regional gravity field. To the extent that this preliminary adjustment is nonobjective, however, the resulting interpretations in this area may be distorted or in error.

Along each north-trending profile the calculated regional gravity component was graphically subtracted from the Bouguer gravity field. The results were then recontoured to produce the residual gravity map shown in plate 2. Several of the more conspicuous and important gravity anomalies are labeled and discussed in the text.

GENERAL GEOLOGY AND SUBSURFACE STRUCTURE

The geologic history of the northern part of the Arctic National Wildlife Range appears to be similar to that of the Prudhoe Bay area to the west. Both areas may be considered to be part of the same geologic province. This geologic continuity is demonstrated in the correlation of Prudhoe well logs with bedrock exposures in northeastern Alaska. An apparent deep sedimentary basin north of the mountain front in northeastern Alaska can be compared to the Colville geosyncline south of Prudhoe Bay. The gravity data, furthermore, suggest a general uplifting of basement rock along the northeastern Alaskan coastline analogous to the structurally uplifted basement along the Barrow arch in the Prudhoe Bay area.

Known basement in the Prudhoe Bay area consists of weakly metamorphosed rocks of early Paleozoic age. In northeastern Alaska, the basement is composed of similar weakly metamorphosed rocks of early Paleozoic age, in addition to probable Precambrian age rocks. Basement lithology consists predominantly of fine-grained clastic metasedimentary rocks. In the older (Precambrian) basement, however, carbonate and metavolcanic sequences also occur. Unmetamorphosed rocks of middle and late Paleozoic to Cenozoic age overlie the basement with sharp angular unconformity. Surface measurements indicate that the maximum total thickness of the sedimentary sequence may be as much as 7,000 m. These strata presumably thin to the northeast as they lap onto the shallower coastal basement high suggested by the gravity data.

In addition to this thinning, any one of several known regional unconformities may have radically affected the subsurface stratigraphic column. The significance of these unconformities is well demonstrated in outcrops south and east of the basin and in both outcrops and wells farther to the west. In all such localities a pervasive unconformity has been mapped at the base of the Upper Cretaceous rocks. An important regional unconformity is also recognized at the base of the Lower Cretaceous strata. This unconformity is demonstrated most notably in the West Staines State No. 1 well located in T. 9 N., R. 23 E. (pl. 1), where Lower Cretaceous rocks rest directly on basement. Southeast of the basin Triassic rocks rest directly on basement (about 40 km east of the Canadian border). An unconformity is also evident at the base of the Permian section in outcrops south of the basin.

DENSITY MEASUREMENTS OF OUTCROP SAMPLES

To aid in the interpretation of the reconnaissance gravity data from the northern part of the wildlife range, the densities of rock samples from most of the major rock units exposed in northeastern Alaska were measured and average densities calculated for the various rock formations. These samples were obtained by geologists with the U.S. Geological Survey during field investigations conducted over the past 9 years. The formations that were sampled dip beneath the surficial deposits of the coastal plain and are most likely present in the subsurface north of the exposed outcrops. These rocks thus contribute substantially to the observed gravity field in that area. Table 1 shows the results of 167 density measurements made on outcrop samples from the wildlife range. A summary of the density information is given in table 2. As indicated in this table, the density contrasts are largest within the basement rocks and between the Tertiary, Upper Cretaceous, and older sedimentary rock units. Density sample locations are shown on plate 3, a generalized geologic map of the study area.

INTERPRETATION OF THE GRAVITY MAP

DEEP CRUSTAL STRUCTURE

The general relation between regional Bouguer gravity anomalies, surface elevation, and crustal thickness is well established (Andreev, 1958; Demenitskaya, 1959; Woollard, 1959, 1962). Simply stated, Bouguer gravity anomalies over large regions are inversely related to both crustal thickness and regional elevations. In the northern part of the wildlife range this relation is exemplified by a regional longitudinal profile drawn along long 143°30′ W. (fig. 2). As noted on this profile, from the Beaufort Sea coast inland toward the Brooks Range to the south, Bouguer gravity anomaly values gradually decrease as the surface elevation increases. Although this regional decrease in gravity is a source of confusion in the interpretation of local anomalies, it can be related to changes in both surface elevation and crustal thickness and provides valuable information concerning deep crustal structure. From the estimated regional gravity gradient (see section entitled "Residual Gravity Separation") and the equation h=Bouguer anomaly/$2\pi\gamma\Delta\rho$, where h=increase in crustal thickness, γ the gravitional constant, and $\Delta\rho$ the crust-mantle density contrast (assumed to be 0.45 g/cm^3), the slope of the crust-mantle interface can be estimated. A slope of 0.03 km/km was obtained for this interface

TABLE 1.—*Sample densities*, in g/cm³

Map unit	Map No.	Field collection No.	Description	Latitude, longitude, township, and range	Density
Post-Carboniferous samples					
Sagavanirktok Formation	1	69 ADt 148	Sandy siltstone	69°55.6'; 144°35.0'; T. 7 N.; R. 30 E.	2.01
	2	71 ADt 356	Calcareous silty sandstone	70°0.5'; 143°1.9'; T. 8 N.; R. 36 E.	1.94
Colville Group: Prince Creek Formation; Schrader Bluff Formation	3	70 ADt 255	Silty shale	69°51.8'; 145°16.6'; T. 6 N.; R. 27 E.	2.66
	4	70 ADt 258	Silty sandstone	69°45.0'; 145°20.4'; T. 5 N.; R. 27 E.	2.27
	5	70 ADt 264	Calcareous sandstone	69°42.5'; 146°13.8'; T. 4 N.; R. 24 E.	2.57
Seabee Formation	6	69 ADt 52	Tuff	69°33.6'; 145°28.2'; T. 2 N.; R. 27 E.	2.58
	7	70 ADt 240 U6	Calcareous silty shale	69°33.7'; 145°49.7'; T. 2 N.; R. 26 E.	2.18
	8	71 ADt 355	Limy sandstone	69°53.4'; 143°7.2'; T. 6 N.; R. 36 E.	2.61
	9	71 ADt 358	do	69°57.2'; 142°56.2'; T. 7 N.; R. 37 E.	2.56
Bathtub Graywacke	10	70 ADt 210 U1	Graywacke	69°6.7'; 142°41.3'; T. 4 S.; R. 39 E.	2.65
	11	70 ADt 210 U4	Pebble conglomerate	69°6.7'; 142°41.1'; T. 4 S.; R. 39 E.	2.61
	12	71 ADt 309 A	Graywacke	69°6.0'; 142°17.9'; T. 4 S.; R. 41 E.	2.60
	13	71 ADt 309 C	do	69°6.0'; 142°17.9'; T. 4 S.; R. 41 E.	2.62
	14	71 ADt 337	Micaceous sandstone	69°32.7'; 143°58.2'; T. 2 N.; R. 33 E.	2.58
	15	71 ADt 338	do	69°32.0'; 144°9.0'; T. 2 N.; R. 32 E.	2.68
Kongakut Formation: Siltstone member	16	70 ADt 210 U11	Siltstone	69°6.7'; 142°41.1'; T. 4 S.; R. 39 E.	2.64
	17	71 ADt 309 E	Sandy siltstone	69°6.0'; 142°17.9'; T. 4 S.; R. 41 E.	2.71
Pebble shale member	18	70 ADt 209	Siltstone	69°7.3'; 142°35.6'; T. 4 S.; R. 39 E.	2.71
	19	71 ADt 288 U5	Pebbly siltstone	69°36.2'; 146°7.6'; T. 3 N.; R. 24 E.	2.68
	20	71 ADt 314	Pebbly manganiferous siltstone	69°6.4'; 142°16.6'; T. 4 S.; R. 41 E.	2.67

	21	71 ADt 316	Siltstone	69°5.7'; 142°12.6'; T. 4 S.; R. 41 E.	3.12
	22	71 ADt 331	Manganiferous siltstone	69°28.2'; 143°54.7'; T. 1 N.; R. 33 E.	2.79
Kemik sandstone member	23	69 ADt 29	Sandstone	69°35.1'; 145°40.5'; T. 3 N.; R. 26 E.	2.49
	24	69 ADt 31	do.	69°33.8'; 145°27.0'; T. 2 N.; R. 27 E.	2.73
	25	70 ADt 215 U1	do.	69°33.4'; 145°19.4'; T. 2 N.; R. 28 E.	2.61
	26	70 ADt 234	do.	69°30.9'; 146°22.0'; T. 2 N.; R. 23 E.	2.58
	27	70 ADt 240 U3	Conglomeratic sandstone	69°33.7'; 145°49.7'; T. 2 N.; R. 26 E.	2.52
	28	70 ADt 279	Sandstone	69°23.8'; 146°24.7'; T. 1 N.; R. 23 E.	2.53
Clay shale member	29	70 ADt 213	Siltstone	69°7.7'; 142°36.3'; T. 4 S.; R. 39 E.	2.88
Kingak Shale	30	69 ADt 40A	do.	69°33.5'; 145°19.9'; T. 2 N.; R. 28 E.	2.55
	31	70 ADt 215 U4	do.	69°33.4'; 145°19.4'; T. 2 N.; R. 28 E.	2.53
	32	70 ADt 215 U5	do.	69°33.4'; 145°19.4'; T. 2 N.; R. 28 E.	2.57
	33	71 ADt 302-0-555	Silty shale	69°19.8'; 145°22.7'; T. 1 S.; R. 28 E.	2.63
Karen Creek Sandstone	34	70 ADt 260 +15'	Quartzitic sandstone	69°22.2'; 144°48.7'; T. 1 S.; R. 30 E.	2.63
	35	70 ADt 260 +39'	do.	69°22.2'; 144°48.7'; T. 1 S.; R. 30 E.	2.55
	36	70 ADt 260 +67'	do.	69°22.2'; 144°48.7'; T. 1 S.; R. 30 E.	2.57
	37	70 ADt 262 +6'	do.	69°19.6'; 145°24.1'; T. 1 S.; R. 28 E.	2.63
	38	70 ADt 262 +23'	do.	69°19.6'; 145°24.1'; T. 1 S.; R. 28 E.	2.64
	39	70 ADt 262 +70'	do.	69°19.6'; 145°24.1'; T. 1 S.; R. 28 E.	2.64
	40	71 ADt 283 U9	do.	69°29.8'; 143°8.6'; T. 2 N.; R. 37 E.	2.59
Shublik Formation	41	69 ADt 38	Phosphatic limestone	69°34.6'; 145°25.8'; T. 3 N.; R. 27 E.	2.55
	42	69 ADt 105 U2	Calcareous siltstone	69°32.3'; 145°11.6'; T. 2 N.; R. 28 E.	2.56
	43	69 ADt 105 U5	Limestone	69°32.3'; 145°11.6'; T. 2 N.; R. 28 E.	2.66
	44	69 ADt 136	Phosphatic limestone	69°24.5'; 145°18.3'; T. 1 N.; R. 28 E.	2.69
	45	70 ADt 228 U4	Limestone	69°6.3'; 146°53.2'; T. 4 S.; R. 22 E.	2.61
	46	70 ADt 228 U7	Phosphatic limestone	69°6.3'; 146°53.2'; T. 4 S.; R. 22 E.	2.44
	47	71 ADt 283 U8	do.	69°29.8'; 143°8.6'; T. 2 N.; R. 37 E.	2.65

TABLE 1.—*Sample densities*, in g/cm³—Continued

Map unit	Map No.	Field collection No.	Description	Latitude, longitude, township, and range	Density
Post-Carboniferous samples—Continued					
Sadlerochit Group:					
Ivishak Formation:					
Fire Creek Siltstone Member	48	69 ADt 104 U6	Sandstone	69°32.2'; 145°11.8'; T. 2 N.; R. 28 E.	2.69
	49	69 ADt 134 U13	Siltstone	69°24.9'; 145°18.8'; T. 1 N.; R. 28 E.	2.68
	50	70 ADt 201 U6	Micaceous siltstone	69°19.6'; 146°33.7'; T. 1 S.; R. 23 E.	2.58
	51	70 ADt 224 U2	Siltstone	69°1.2'; 146°54.2'; T. 5 S.; R. 22 E.	2.62
	52	71 ADt 283 U6	do	69°29.8'; 143°8.6'; T. 2 N.; R. 37 E.	2.62
Ledge Sandstone Member	53	69 ADt 36 G1	Sandstone	69°35.3'; 145°24.0'; T. 3 N.; R. 27 E.	2.61
	54	69 ADt 142 U10	Quartzitic sandstone	69°41.2'; 140°50.3'; T. 4 N.; R. 30 E.	2.44
	55	71 ADt 283 U5	Sandstone	69°29.8'; 143°8.8'; T. 2 N.; R. 37 E.	2.59
	56	71 ADt 326 U8	Quartzitic sandstone	69°25.4'; 141°1.4'; T. 1 N.; R. 45 E.	2.63
	57	71 ADt 327 U7	Conglomeratic sandstone	69°35.0'; 142°29.5'; T. 3 N.; R. 39 E.	2.43
Kavik Member	58	69 ADt 65 U4	Siltstone	69°27.2'; 145°18.2'; T. 1 N.; R. 28 E.	2.66
	59	69 ADt 134 U9	do	69°24.9'; 145°18.8'; T. 1 N.; R. 28 E.	2.67
	60	70 ADt 193 U5	do	69°17.1'; 146°21.6'; T. 2 S.; R. 24 E.	2.59
	61	71 ADt 290 U6	Quartzitic siltstone	69°32.2'; 143°9.2'; T. 1 S.; R. 37 E.	2.57
	62	71 ADt 296 U4	Siltstone	69°27.2'; 143°28.9'; T. 1 N.; R. 35 E.	2.62
Echooka Formation:					
Ikiakpaurak Member	63	69 ADt 159 U3	Silty quartzitic sandstone	69°35.9'; 145°51.8'; T. 3 N.; R. 25 E.	2.57
	64	70 ADt 189 U2	Quartzitic sandstone	69°27.9'; 145°53.1'; T. 1 N.; R. 25 E.	2.68
	65	70 ADt 224 U11	Quartzitic siltstone	69°1.4'; 146°55.6'; T. 5 S.; R. 22 E.	2.69
	66	70 ADt 270 U4	Silty quartzitic sandstone	69°26.4'; 144°37.0'; T. 1 N.; R. 31 E.	2.65
	67	71 ADt 283 U1	Quartzitic siltstone	69°29.8'; 143°8.6'; T. 2 N.; R. 37 E.	2.67

	68	71 ADt 328 U2	Quartzite	69°25.4'; 141°1.4'; T. 1 N.; R. 45 E.	2.70
Joe Creek Member		71 ADt 318 E	Chert and quartzite	Location off map	2.59
		71 ADt 318 G	Limestone	Location off map	2.58
		71 ADt 348 U1	Crinoidal limestone	Location off map	2.62
Carboniferous and pre-Carboniferous samples					
Lisburne Group, undivided	69	68 ARr 32.3	Biogenetic limestone	69°39.2'; 144°37.1'; T. 4 N.; R. 31 E.	2.58
	70	68 ARr 36b	do	69°31.3'; 145°48.8'; T. 2 N.; R. 26 E.	2.64
	71	69 ARr 184	Coarse-grained limestone	69°36.3'; 146°2.0'; T. 3 N.; R. 25 E.	2.66
	72	70 ARr 245	Limestone	69°4.6'; 146°0.0'; T. 4 S.; R. 25 E.	2.67
	73	70 ARr 276a	do	69°16.4'; 146°6.1'; T. 2 S.; R. 25 E.	2.61
	74	73 ARr 819	Biogenetic limestone	69°21.5'; 142°17.5'; T. 1 S.; R. 41 E.	2.66
Endicott Group	75	68 ARr 43	Quartzite	68°15.7'; 144°28.1'; T. 2 S.; R. 32 E.	2.62
	76	69 ARr 32a	Silty sandstone	69°30.8'; 146°5.1'; T. 2 N.; R. 25 E.	2.62
	77	69 ARr 32b	Shaly quartzite	69°30.8'; 146°5.1'; T. 2 N.; R. 25 E.	2.60
	78	69 ARr 123	Quartzite conglomerate	69°12.4'; 144°42.2'; T. 3 S.; R. 31 E.	2.64
	79	69 ARr 126	Quartzite	69°23.2'; 145°31.8'; T. 1 S.; R. 27 E.	2.67
	80	69 ARr 185	Quartzite conglomerate	69°37.8'; 146°0.8'; T. 3 N.; R. 25 E.	2.60
	81	70 ARr 243	Shaly limestone	69°0.8'; 146°0.5'; T. 5 S.; R. 25 E.	2.66
	82	70 ARr 243a	Quartzite conglomerate	69°0.8'; 146°8.5'; T. 5 S.; R. 25 E.	2.61
	83	70 ARr 275	do	69°11.8'; 146°4.7'; T. 3 S.; R. 25 E.	2.57
	84	70 ARr 360	Silicified siltstone	69°14.8'; 146°52.5'; T. 2 S.; R. 22 E.	2.58
Nanook Limestone	85	68 ARr 4	Limestone	69°31.5'; 145°39.3'; T. 2 N.; R. 26 E.	2.68
	86	68 ARr 4a	do	69°31.5'; 145°39.3'; T. 2 N.; R. 26 E.	2.67
	87	68 ARr 4b	do	69°31.5'; 145°39.3'; T. 2 N.; R. 26 E.	2.68
	88	68 ARr 4c	do	69°31.5'; 145°39.3'; T. 2 N.; R. 26 E.	2.71
Katakturuk Dolomite	89	69 ARr 22	Dolomite	69°33.1'; 146°8.3'; T. 2 N.; R. 24 E.	2.77

TABLE 1.—*Sample densities*, in g/cm³—Continued

Map unit	Map No.	Field collection No.	Description	Latitude, longitude, township, and range	Density
Carboniferous and pre-Carboniferous samples—Continued					
Katakturuk Dolomite—Continued.	90	69 ARr 24	do	69°33.0'; 145°53.0'; T. 2 N.; R. 25 E.	2.71
	91	69 ARr 26	do	69°33.4'; 145°56.1'; T. 2 N.; R. 25 E.	2.81
	92	69 ARr 60	do	69°32.5'; 145°34.1'; T. 2 N.; R. 27 E.	2.58
	93	70 ARr 381	do	69°36.8'; 145°39.0'; T. 3 N.; R. 26 E.	2.78
Granitic rocks	94	69 ARr 131	Granodiorite (?)	69°8.9'; 143°42.9'; T. 3 S.; R. 35 E.	2.70
	95	69 ARr 159	Granodiorite	69°17.4'; 144°0.8'; T. 2 S.; R. 34 E.	2.63
	96	69 ARr 161	do	69°12.9'; 144°0.1'; T. 3 S.; R. 34 E.	2.63
	97	69 ARr 168	Granodiorite (?)	69°17.6'; 143°58.3'; T. 2 S.; R. 34 E.	2.61
Neruokpuk Formation: Chert and phyllite unit	98	70 ARr 286	Chert	69°0.5'; 145°33.9'; T. 5 S.; R. 28 E.	2.67
	99	70 ARr 288	Phyllitic siltstone	69°3.9'; 145°24.5'; T. 4 S.; R. 28 E.	2.86
	100	70 ARr 306	Gray to black chert breccia	69°4.8'; 143°5.0'; T. 4 S.; R. 37 E.	2.62
	101	71 ARr 657	Chert	69°0.7'; 143°47.6'; T. 5 S.; R. 35 E.	2.73
	102	71 ARr 643	Gray banded chert	69°3.8'; 143°6.2'; T. 4 S.; R. 37 E.	2.58
	103	71 ARr 652	White vitreous chert	69°1.7'; 143°17.3'; T. 5 S.; R. 37 E.	2.65
Calcareous siltstone and sandstone member and black phyllite and sandstone member.	104	69 ARr 12b	Ferruginous calcareous sandstone	69°19.6'; 144°59.2'; T. 1 S.; R. 30 E.	2.71
	105	69 ARr 12c	Ferruginous calcareous phyllitic siltstone.	69°19.6'; 144°59.2'; T. 1 S.; R. 30 E.	2.72
	106	70 ARr 277	Calcareous siltstone	69°13.7'; 146°0.8'; T. 2 S.; R. 25 E.	2.80
	107	70 ARr 288a	do	69°3.5'; 145°24.5'; T. 4 S.; R. 28 E.	2.67
	108	71 ARr 511	Dark-gray phyllitic siltstone	69°14.5'; 141°44.9'; T. 2 S.; R. 43 E.	2.74
	109	71 ARr 512	Calcareous micaceous fine-grained sandstone.	69°13.2'; 141°46.9'; T. 2 S.; R. 43 E.	2.58
	110	71 ARr 584a	Calcareous micaceous sandstone	69°12.3'; 141°39.6'; T. 3 S.; R. 43 E.	2.66

	111	71 ARr 589	Phyllitic siltstone	69°6.3'; 141°1.0'; T. 4 S.; R. 46 E.	2.66
	112	71 ARr 721	Ferruginous sandstone	69°15.7'; 142°8.0'; T. 2 S.; R. 41 E.	2.71
Limestone member, argillite, and limestone member, phyllite and argillite unit, and phyllite and quartzite unit.	113	70 ARr 233	Sandy limestone	69°29.8'; 141°11.0'; T. 2 N.; R. 46 E.	2.55
	114	70 ARr 233y	do	69°29.8'; 141°11.0'; T. 2 N.; R. 45 E.	2.64
	115	70 ARr 466	Silicified brecciated mudstone	69°32.7'; 141°41.8'; T. 2 N.; R. 42 E.	2.69
	116	71 ARr 494y	Phyllite	69°22.7'; 141°38.6'; T. 1 S.; R. 43 E.	2.69
	117	71 ARr 494z	Quartzite	69°22.7'; 141°38.6'; T. 1 S.; R. 43 E.	2.68
	118	71 ARr 670	Micaceous siltstone	69°24.4'; 141°9.4'; T. 1 N.; R. 46 E.	2.71
	119	73 ARr 806	Marlstone	69°27.2'; 142°52.6'; T. 1 N.; R. 38 E.	2.70
	120	73 ARr 813	Calcareous sandstone	69°28.0'; 142°54.2'; T. 1 N.; R. 38 E.	2.69
	121	73 ARr 813b	Black recrystallized limestone	69°28.0'; 142°54.2'; T. 1 N.; R. 38 E	2.64
	122	73 ARr 835	Silicified phyllite	69°32.4'; 142°24.6'; T. 2 N.; R. 40 E.	2.62
	123	73 ARr 836b	Silicified mudstone	69°31.5'; 142°21.2'; T. 2 N.; R. 40 E.	2.66
Quartzite and semischist member	124	69 ARr 8r	Schistose quartzite	69°16.3'; 145°0.6'; T. 2 S.; R. 29 E.	2.69
	125	69 ARr 128	Sheared quartzite	69°8.7'; 145°8.8'; T. 3 S.; R. 29 E.	2.66
	126	69 ARr 148	Phyllitic siltstone	69°16.6'; 144°37.7'; T. 2 S.; R. 31 E.	2.59
	127	69 ARr 202	Schistose quartzite	69°16.7'; 145°23.6'; T. 2 S.; R. 28 E.	2.69
	128	70 ARr 290	do	69°4.1'; 145°8.1'; T. 4 S.; R. 29 E.	2.65
	129	70 ARr 315c	do	69°12.0'; 142°43.7'; T. 3 S.; R. 39 E.	2.66
	130	70 ARr 315d	Quartzite schist	69°12.0'; 142°43.7'; T. 3 S.; R. 39 E.	2.66
	131	70 ARr 315g	Chloritic quartzite	69°12.0'; 142°43.7'; T. 3 S.; R. 39 E.	2.69
	132	70 ARr 316a	Schistose siltstone	69°14.0'; 142°47.5'; T. 2 S.; R. 39 E.	2.69
	133	70 ARr 316b	Schistose wacke	69°14.0'; 142°47.5'; T. 2 S.; R. 39 E.	2.62
Volcanic and volcaniclastic rocks. As mapped includes carbonate, argillaceous, and cherty rocks.	134	68 ARr 28	Diabase	69°38.7'; 144°37.6'; T. 3 N.; R. 31 E.	2.98
	135	69 ARr 43	Volcanic (mafic) rocks	69°31.8'; 145°31.6'; T. 2 N.; R. 27 E.	2.80
	136	69 ARr 74	Metavolcaniclastic (mafic) rocks	69°26.2'; 144°23.9'; T. 1 N.; R. 31 E.	2.90

TABLE 1.—*Sample densities*, in g/cm³—Continued

Map unit	Map No.	Field collection No.	Description	Latitude, longitude, township, and range	Density
Carboniferous and pre-Carboniferous samples—Continued					
Volcanic and volcaniclastic rocks—Continued.	137	69 ARr 76	Metaflow (mafic)	69°27.3'; 144°23.6'; T. 1 N.; R. 31 E.	2.95
	138	69 ARr 78	do	69°27.4'; 144°19.7'; T. 1 N.; R. 32 E.	2.71
	139	69 ARr 113	Metaigneous (mafic) rocks	69°5.7'; 144°31.4'; T. 4 S.; R. 31 E.	3.13
	140	69 ARr 197a	Metabasalt	69°38.1'; 145°2.9'; T. 3 N.; R. 29 E.	3.20
	141	70 ARr 292	Volcanic (mafic) rocks	69°2.7'; 145°48.7'; T. 4 S.; R. 26 E.	2.72
	142	70 ARr 294c	Basalt	69°1.5'; 145°48.7'; T. 5 S.; R. 26 E.	2.93
	143	70 ARr 298	Volcaniclastic rocks	69°0.7'; 146°3.2'; T. 5 S.; R. 25 E.	2.79
	144	70 ARr 329	Basalt	69°20.8'; 142°34.9'; T. 1 S.; R. 39 E.	2.80
	145	70 ARr 329	do	69°19.6'; 142°27.5'; T. 1 S.; R. 40 E.	2.80
	146	70 ARr 331	Porphyritic basalt	69°19.3'; 142°27.1'; T. 1 S.; R. 40 E.	2.90
	147	70 ARr 331	Agglomerate	69°19.7'; 142°25.9'; T. 1 S.; R. 40 E.	2.69
	148	70 ARr 352	Basalt	69°32.1'; 146°3.3'; T. 2 N.; R. 25 E.	2.91
	149	70 ARr 353b	Agglomerate	69°32.1'; 146°3.6'; T. 2 N.; R. 25 E.	2.79
	150	70 ARr 446	Chloritized tuff	69°2.1'; 144°45.3'; T. 5 S.; R. 31 E.	2.65
	151	70 ARr 448	Chloritized flow	69°1.9'; 144°51.4'; T. 5 S.; R. 31 E.	2.87
	152	70 ARr 462a	Metavolcaniclastic rocks	69°35.0'; 141°51.6'; T. 3 N.; R. 42 E.	2.74
	153	71 ARr 592a	Metabasalt	69°16.1'; 141°38.5'; T. 2 S.; R. 43 E.	2.80
	154	71 ARr 592b	Vesicular metaflow	69°16.1'; 141°38.5'; T. 2 S.; R. 43 E.	2.66
	155	71 ARr 617 a2	Metavolcaniclastic (mafic) rocks	69°27.7'; 141°24.3'; T. 1 N.; R. 44 E.	2.83
	156	71 ARr 617a3	do	69°27.7'; 141°24.3'; T. 1 N.; R. 44 E.	2.73
	157	71 ARr 617b	Metadiabase	69°27.7'; 141°24.3'; T. 1 N.; R. 44 E.	2.77

158	71 ARr 617b2	Metavolcaniclastic (mafic) rocks	69°27.7'; 141°24.3'; T. 1 N.; R. 44 E.	2.91
159	71 ARr 620	Metavolcaniclastic rocks	69°27.0'; 141°16.8'; T. 1 N.; R. 44 E.	2.68
160	71 ARr 620	Sandstone	69°27.0'; 141°16.8'; T. 1 N.; R. 44 E.	2.60
161	71 ARr 623	Diabase	69°27.4'; 141°12.9'; T. 1 N.; R. 44 E.	2.76
162	71 ARr 648	Vesicular basalt flow	69°7.0'; 143°11.0'; T. 4 S.; R. 37 E.	2.66
163	71 ARr 654	Basalt flow	69°6.2'; 143°28.8'; T. 4 S.; R. 36 E.	2.73
164	72 ABe 205b	Basaltic tuff	69°28.6'; 142°27.9'; T. 1 N.; R. 39 E.	2.75
165	73 ARr 825	Metavolcaniclastic rocks	69°34.2'; 141°51.4'; T. 3 N.; R. 42 E.	2.82
166	73 ARr 836a	Metabasalt dike	69°31.5'; 142°21.2'; T. 2 N.; R. 40 E.	2.89
167	73 ARr 838	Metavolcanic flow	69°32.4'; 142°11.2'; T. 2 N.; R. 40 E.	2.77

TABLE 2.—*Summary of density measurements, in* g/cm³

Rock type	Number of samples	Density range	Average density
Post-Carboniferous samples			
Sagavanirktok Formation	2	1.94–2.01	1.98
Colville Group	10	2.18–2.66	2.49
Bathtub Graywacke and Kongakut Formation, undivided	20	2.49–3.12	2.67
Kingak Shale	4	2.53–2.63	2.57
Karen Creek Sandstone, Shublik Formation, and Sadlerochit Group, undivided	38	2.44–2.70	2.61
Carboniferous and pre-Carboniferous samples			
Lisburne Group, undivided	6	2.58–2.67	2.64
Endicott Group	10	2.57–2.67	2.62
Nanook Limestone	4	2.67–2.71	2.69
Katakturuk Dolomite	5	2.58–2.81	2.73
Granitic rocks	4	2.61–2.70	2.64
Neruokpuk Formation:			
Chert and phyllite unit	6	2.58–2.86	2.69
Calcareous siltstone and sandstone member and black phyllite and sandstone member	9	2.58–2.80	2.69
Limestone member, argillite, and limestone member, phyllite and argillite unit, and phyllite and quartzite unit	11	2.55–2.71	2.66
Quartzite and semischist member and ferruginous sandstone member	10	2.59–2.69	2.66
Volcanic and volcaniclastic rocks (as mapped includes carbonate, argillaceous, and cherty rocks)	34	2.60–3.20	2.81

along long 144°30′ W. (fig. 2). This result suggests an increase in crustal thickness of approximately 2.7 km between Barter Island on the Alaskan coast and the crest of the Brooks Range to the south.

STATE OF ISOSTATIC BALANCE

In areas of smooth topography, such as the Arctic Coastal Plain, free-air gravity anomalies provide a direct measure of the degree of isostatic compensation. An average free-air anomaly of zero generally indicates that the topographic relief of an area is compensated. In the Arctic National Wildlife Range the average free-air anomaly on the coastal plain is −24 mgals. Although this free-air anomaly might be related to a lack of isostatic compensation at great depth, it more likely results from the presence of a thick, relatively low density sedimentary section at shallow depths beneath the tundra surface. Assuming a density contrast of 0.20 g/cm³ between the sedimentary rocks and basement and no other density complications, the calculated free-air anomaly could be generated by a sedimentary section averaging 2,865 m in thickness.

Where the topography is not smooth, such as in the southern part of the mapped area, free-air anomalies are closely correlated with short-wavelength changes in elevation. The compensating masses at depth, however, generally balance the longer wavelength components of the topographic field; thus in these areas correlations between

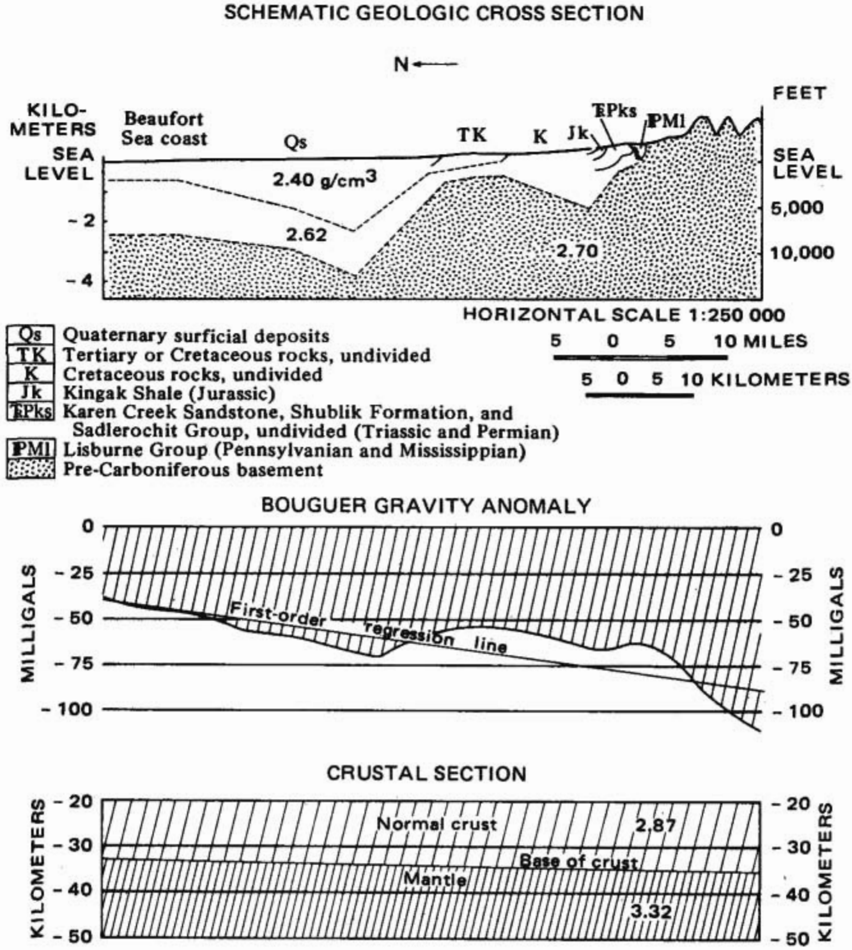

FIGURE 2.—Relation of Bouguer gravity anomalies to geology, topography, and crustal structure; section taken along long 143°30′ W.

long-wavelength free-air anomalies and regional elevation are also intimately related to the concept of isostasy. On the basis of present data, the average free-air anomaly south of the mountain front is +7 mgals. Although this average free-air anomaly suggests that the mountains in this area are compensated and in near isostatic equilibrium, it must be recognized that the present distribution of gravity stations does not represent a normal sampling, since the vast majority of the stations are located in river valleys. Free-air anomaly values measured on the mountain tops would be much higher.

If one considers the gravity measurements in the Sadlerochit Mountains separately, the resulting average free-air anomaly in these mountains is +26 mgal. Additional gravity stations located on the mountain tops would make this value somewhat higher. The free-air anomaly observed in these mountains may result from the lack of a compensating increase in crustal thickness beneath these mountains. The relatively short width of the Sadlerochit Mountains (less than 20 km) is consistent with this interpretation.

SHALLOW GEOLOGIC STRUCTURE

Gravity anomaly A–1.—Anomaly A–1 on the residual gravity map (pl. 2) is a broad negative anomaly centered over a large outcropping granitic intrusion composed primarily of quartz monzonite. Density measurements of outcrop samples of this intrusion indicate an average density of 2.64 g/cm^3 compared to an average density of 2.68 g/cm^3 for the surrounding rocks. Although this represents a relatively small density contrast, in conjunction with the large size and discordant shape of the intrusive mass this density difference probably contributes substantially to the magnitude of anomaly A–1. Because the gravity data have not been corrected for terrain effects, part of this anomaly may also be attributed to the rugged topography of the area. If terrain effects and any remaining isostatic contributions to residual anomaly A–1 were eliminated, both the wavelength and magnitude of this anomaly might be reduced considerably. The granitic intrusions may then be characterized by much smaller negative gravity anomalies. Aeromagnetic or detailed gravity surveys in this area could prove valuable in tracing the subsurface distribution of these intrusive bodies.

Gravity anomaly A–2.—The east-trending positive gravity anomaly belt designated A–2 on plate 2 can be attributed to a southward shallowing of basement rocks of pre-Carboniferous age. The reason for the relatively large amplitude of this anomaly near the center of the map area is unknown. A reconnaissance aeromagnetic survey of northeastern Alaska (Brosgé and others, 1970) and exposures of pre-Mesozoic volcanic and volcaniclastic rocks south and west of this anomaly (T. 1 N., R. 32, 33 E.; T. 3 N., R 31, 32 E.) suggest that these dense basement rocks may also be present in the subsurface. The density of volcanic and volcaniclastic rocks exposed in this part of the wildlife range averages 2.81 g/cm^3; thus any substantial subsurface distribution of these rocks could account for the relatively large positive residual gravity anomaly in this area.

Gravity anomaly A–3.—Anomaly A–3 is a large negative residual gravity anomaly centered near the shore in Camden Bay. Geologic evidence indicates that this gravity anomaly results primarily from a deep sedimentary basin composed mostly of thick, low-density Cretaceous and Tertiary rocks. Two-dimensional Talwani modeling

(Talwani and others, 1959) of the gravity data based on the measured thickness of exposed Tertiary and older sedimentary rocks to the south, along with density measurements from outcrop samples of these rocks, indicates that the sedimentary section producing residual anomaly A–3 is more than 5,500 m thick near its offshore center in Camden Bay. The gravity data suggest that major onshore projections of this deep sedimentary basin occur south, southwest, and southeast of Camden Bay. The synclinal axes of the southwest and southeast projections are shown in plate 2. Model studies of the gravity data indicate that at least 3,800 m of sedimentary section is still present along the southeast synclinal axis at long 143°30′ W. (fig. 2). The residual gravity data (pl. 2) also suggest that the sedimentary section along this synclinal axis continues to thin to a minimum thickness in the vicinity of T. 6 N., R. 38 E. The section then apparently begins to thicken eastward toward the offshore center of gravity anomaly A–5.

Along the southwestern synclinal axis, a somewhat questionable regional gravity component (see section entitled "Residual Gravity Separation") makes any interpretation of the gravity data both difficult and questionable. Well control to the west, however, provides some information on the depth to basement in this area. In the West Staines State No. 1 well located in T. 9 N., R. 23 E., Lower Cretaceous rocks rest directly on basement at a depth of 3,999 m. The available gravity data suggest that a thicker sedimentary section is present south of this well along the southwest-trending synclinal axis shown on plate 2.

South of Camden Bay, along the flank of gravity anomaly A–3, is the exposed northeast-trending Marsh Creek anticline. The slight expression of this conspicuous fold in the map of Bouguer gravity anomalies (pl. 1) and in the residual anomaly map (pl. 2) suggests that the Marsh Creek anticline does not involve any strongly contrasting density units at depth. Consideration of the regional structural style also suggests that deeper stratigraphic rock units may not be involved in this anticline (C. G. Mull, oral commun., Aug. 1976). The gravity data presently available certainly indicate that basement is not involved in this structure. Although the Marsh Creek anticline could extend northeast into the Beaufort Sea (Grantz and others, 1975), the gravity data also suggest that it is a much more localized structure.

Gravity anomaly A–4.—Anomaly A–4 is a strongly developed, broad positive element located southeast of Barter Island. Although the lack of additional subsurface control does not rule out the possibility that this anomaly results from density variations within the basement, the authors prefer to interprete anomaly A–4 as the expression of a structurally uplifted basement platform onto which the superjacent sedimentary rocks thin. A qualitative interpretation of the gravity data suggests that this basement high trends north-northwest, approximately parallel to the northeast Alaskan coast. Near the Barter Island area the interpreted high apparently projects offshore onto the Beaufort Shelf.

If the above interpretation is valid, several similarities appear to exist between the subsurface geology south and east of Barter Island and the geology of the Prudhoe Bay oil field to the west. The reservoir and source rocks in the subsurface at Prudhoe Bay field are exposed along the northern flank of the Brooks Range in the Arctic National Wildlife Range. These same rocks, if not truncated beneath buried unconformities, could be present in the subsurface south and east of Barter Island.

Known oil seeps and outcropping oil sands suggest a high potential for petroleum accumulation in this area. Oil seeps occur on Manning Point in T. 9 N., R. 34 E., and on Angun Point in T. 7 N., R. 39 E. Oil-saturated sands are exposed within the Cretaceous outcrop in T. 7 N., R. 35 E. (pl. 1). Unless critical parts of the stratigraphic section are not preserved, the potential for hydrocarbon accumulation south and east of Barter Island could be excellent. A small exposure of Jurassic rocks in T. 6 N., R. 36 E. (pl. 1) indicates that at least some of the older sedimentary rocks are present. Unfortunately, with gravity data alone, it cannot be determined whether important reservoir and source rocks have been truncated in the subsurface.

In conjunction with that part of gravity anomaly A–2 west of Demarcation Bay, anomaly A–4 suggests a general thinning of the sedimentary section approximately parallel to the Alaskan coast between Barter Island and the Canadian border. An onshore extension of a sedimentary basin, in the vicinity of gravity anomaly A–5, from the east and offshore may be superimposed on this region of shallower basement, effectively dividing positive element A–4 from the eastern-most part of positive element A–2.

Gravity anomaly A–5.—Anomaly A–5 is attributed to the onshore westerly projection of a sedimentary basin centered somewhere on the Beaufort Shelf. Since most of this anomaly occurs offshore and is not controlled by the data in this report, it is not discussed further.

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