THE ALASKA EARTHQUAKE, MARCH 27, 1964:

REGIONAL EFFECTS

Gravity Survey and Regional Geology of the Prince William Sound Epicentral Region, Alaska

By J. E. CASE, D. F. BARNES, GEORGE PLAFKER, and S. L. ROBBINS

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THE
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SERIES

The U.S. Geological Survey is publishing the results of investigations of the earthquake in a series of six Professional Papers. Professional Paper 543 describes the regional effects of the earthquake. Other Professional Papers describe the effects of the earthquake on communities; the effects on hydrology; the effects on transportation, communications, and utilities; and the history of the field investigations and reconstruction effort.

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GRAVITY SURVEY AND REGIONAL GEOLOGY OF THE PRINCE WILLIAM SOUND EPICENTRAL REGION, ALASKA

By J. E. Case, D. F. Barnes, George Plafker, and S. L. Robbins

ABSTRACT

Sedimentary and volcanic rocks of Mesozoic and early Tertiary age form a roughly arcuate pattern in and around Prince William Sound, the epicentral region of the Alaska earthquake of 1964. These rocks include the Valdez Group, a predominantly slate and graywacke sequence of Jurassic and Cretaceous age, and the Orca Group, a younger sequence of early Tertiary age. The Orca consists of a lower unit of dense—average 2.87 g per cm³ (grams per cubic centimeter)—pillow basalt and greenstone intercalated with sedimentary rocks and an upper unit of lithologically variable sandstone interbedded with siltstone or argillite. Densities of the clastic rocks in both the Valdez and Orca Groups average about 2.69 g per cm³. Granitic rocks of relatively low density (2.62 g per cm³) cut the Valdez and Orca Groups at several localities.

Both the Valdez and the Orca Groups were complexly folded and extensively faulted during at least three major episodes of deformation: an early period of Cretaceous or early Tertiary orogeny, a second orogeny that probably culminated in late Eocene or early Oligocene time and was accompanied or closely followed by emplacement of granitic batholiths, and a third episode of deformation that began in late Cenozoic time and continued intermittently to the present.

About 500 gravity stations were established in the Prince William Sound region in conjunction with postearthquake geologic investigations. Simple Bouguer anomaly contours trend approximately parallel to the arcuate geologic structure around the sound. Bouguer anomalies decrease northward from +40 mgal (milligals) at the southwestern end of Montague Island to −70 mgal at College and Harriman Fiords. Most of this change may be interpreted as a regional gradient caused by thickening of the continental crust. Superimposed on the gradient is a prominent gravity high of as much as 65 mgal that extends from Elrington Island on the southwest, across Knight and Glacier Islands to the Ellamar Peninsula and Valdez on the northeast. This high coincides with the wide belt of greenstone and pillow basalt of the Orca Group and largely reflects the high density of these volcanic rocks. A large low in the east-central part of the sound is inferred to have a composite origin, and results from the combined effects of low-density sedimentary and granitic rocks.

The Prince William Sound gravity high extends southwest-northeast without major horizontal offset for more than 100 miles. Thus the belt of volcanic rocks causing the high constitutes a major virtually continuous, geologic element o south-central Alaska.

INTRODUCTION

Following the Alaska earthquake of March 27, 1964, the U.S. Geological Survey made an intensive investigation of the effects of the earthquake in the Prince William Sound region where the epicenter was located. Concurrent investigations included studies of the regional geology, changes of land level, faulting, and effects of waves on shorelines which were summarized by Plafker and Mayo (1965). At the same time, this gravity survey, mentioned briefly by Barnes and Allen (1965), was conducted in order to establish the regional geologic and tectonic setting of the earthquake. Geologic sections of this report were prepared by Plafker and Case, the gravity sections by Case, Barnes, and Robbins.

STRATIGRAPHY

The geologic map of Prince William Sound (fig. 1) has been generalized and modified from published small-scale geologic maps compiled by Grant and Higgins (1910) and Moffit (1954). Structural data were gained from reconnaissance studies by George Plafker, L. R. Mayo, and J. E. Case in 1964. Some geologic details on Knight Island are based on recent mapping by Richter (1965). The ages of the

Geology compiled from Moffit (1954) and Grant and Higgins (1910) supplemented with reconnaissance mapping by George Plafker, L. R. Mayo, and J. E. Case during 1964

1.—Generalized geologic map of the

EXPLANATION

QUATERNARY — Recent

Qu
Unconsolidated deposits

UNCONFORMITY

TERTIARY — Eocene

Tos
Sedimentary rocks of Orca Group
Slightly metamorphosed and complexly folded marine sandstone and dark-gray to black or reddish-brown hard siltstone and argillite. Includes minor amounts of conglomerate, limestone, and basaltic lava flows. Contains plant material of Tertiary age and nondiagnostic marine megafossils

Tov
Volcanic rocks of Orca Group
Gently to moderately folded, greenish-black slightly altered basaltic flows (greenstone) that commonly exhibit pillow structures. Intertongues with massive conglomerate and breccia and thin-bedded argillite and sandstone. Contains marine megafossils of probable middle to late Eocene age

gr
Granitic rocks
Granite and quartz diorite in stocks, dikes, and sills that intrude Valdez and Orca Groups

UNCONFORMITY

JURASSIC (?) AND CRETACEOUS

KJv
Valdez Group
Tightly folded and metamorphosed marine graywacke and dark-gray to black slate containing minor amounts of argillite and conglomerate

Glacier

Contact
Dashed where approximately located; dotted where inferred

U
Fault
Dashed where approximately located; dotted where inferred. U, upthrown side

90 10 50
Anticline **Overturned anticline**
Minor folds
Showing trace of axial plane, plunge of axis, and dip of limbs

60 75 90
Upright **Overturned** **Vertical**
90 on up side
Generalized strike and dip of beds

45
Strike and dip of foliation

Prince William Sound region, Alaska.

Valdez and Orca Groups have been revised by reinterpretation of the collections from the Valdez Group and by studies of a new fossil collection from the Orca Group (Plafker and MacNeil, 1966).

The geologic units in Prince William Sound shown on figure 1 include: (1) the Valdez Group, a sequence of eugeosynclinal clastic rocks of Jurassic(?) and Cretaceous age; (2) the Orca Group, a sequence of early Tertiary age which can be subdivided, in a general way, into a lower predominantly volcanic unit and an upper predominantly sedimentary unit; (3) bodies of granitic rocks which intrude both the Valdez and Orca Groups; and (4) unconsolidated continental and marine deposits of Quaternary age.

VALDEZ GROUP

The Valdez Group includes the oldest bedded rocks exposed in the Prince William Sound region. As defined by Schrader (1900, p. 408), the Valdez is a lithologically monotonous sequence of slate, argillite, and metamorphosed graywacke that is exposed along the northern and western shores of the sound and also underlies much of the adjacent Chugach and Kenai Mountains. The sequence is characterized by thin to thick beds of light-gray or tan-weathering poorly sorted sandstone of graywacke type which is rhythmically interbedded with thin-bedded, finely laminated dark-gray to black argillite and slate. In the vicinity of granitic intrusive rocks, the slate and argillite are locally altered to phyllite and the graywacke to semischist. Thin units of stretched pebble or cobble conglomerate and lenses of altered basaltic flows or intrusives occur locally within the sequence.

The sedimentary sequence assigned to the Valdez Group is probably tens of thousands of feet thick. The thickness cannot be accurately measured because the sequence lacks key beds and the units are duplicated and interrupted by complex folding and faulting.

Determinative fossils from the Valdez Group, and probably equivalent sequences elsewhere along the margin of the Gulf of Alaska, include *Inoceramus* and *Aucella* that indicate a Jurassic(?) and Cretaceous age for the Valdez (D. L. Jones, oral commun., Nov. 24, 1965).

ORCA GROUP

The predominantly volcanic unit that forms the lower part of the Orca Group crops out in a discontinuous belt 52 miles long and up to 12 miles wide that trends from the mainland east of Valdez Arm southwestward through Glacier, Lone, Knight, Bainbridge, Evans, and Elrington Islands (fig. 1). The unit consists principally of slightly altered greenish-black dense basaltic lava flows, pillow lavas, flow breccias, and coarser textured diabase intrusives which have collectively been termed "greenstone." Most of the flows are characterized by strikingly well formed pillow structures. The volcanic rocks intertongue with thick beds of conglomeratic argillite, conglomerate, dark-gray siltstone or argillite, and graywacke sandstone. The thickness of the unit differs markedly along the length of the outcrop belt. Along the southeast shore of Valdez Arm it is several thousand feet thick (Capps and Johnson, 1915, p. 45). The greatest thickness of the unit probably occurs on and near Knight Island. The volcanic rocks dip 40°–80° W. across most of an outcrop belt as much as 11 miles wide. The breadth and dips indicate an apparent thickness of about 40,000 feet, but it is entirely possible that there has been significant repetition by folding and faulting. Marine megafossils collected during the 1964 reconnaissance survey indicate that the volcanic unit is of early Tertiary (probably middle to late Eocene) age (Plafker and MacNeil, 1966).

The predominantly sedimentary unit that comprises the upper part of the Orca Group includes the bedded rocks that occur especially on the eastern and southern shores of the sound and on the islands of the central part of the sound (fig. 1). In its gross aspects the unit is distinguished from the Valdez Group by a somewhat more variable lithology and a generally lower degree of metamorphism. The sequence consists mainly of thin to thick beds of graywacke sandstone, but also includes light-colored arkosic, carbonaceous, tuffaceous, calcareous and conglomeratic sandstones. The sandstone commonly is interbedded with dark-gray to black or reddish-brown dense hard siltstone or argillite which locally contains abundant carbonized plant remains. Minor amounts of light-gray-weathering limestone occur as thin beds and concretions within the siltstone or argillite. Tabular and lenticular masses of basaltic lavas are locally interbedded with the clastic rocks, most notably on Hinchinbrook Island and the adjacent mainland to the east. The unit is at least several thousand feet thick, but complex folding and faulting preclude a reliable measurement.

The only fossils diagnostic of age that have been obtained from the sedimentary unit are *Alnus* pollen that indicates a post-Mesozoic age (W. R. Evitt, written commun., Nov. 10, 1964). The unit overlies, and probably is in part interbedded with, the volcanic sequence of the Orca Group from which lower Tertiary fossils have been collected.

GRANITIC ROCKS

Granitic rocks intrude the Valdez Group at numerous localities in the northwestern part of Prince William Sound, and a single large intrusive mass cuts the Orca Group on the mainland in the eastern part of the sound. The intrusive rocks consist mainly of pale-pink to pinkish-gray porphyritic biotite granite and light-gray hornblende-biotite quartz diorite. The granite body that cuts the Orca Group on the mainland in the eastern part of the sound can be no older than the rocks it intrudes (early Tertiary) and may be slightly younger. The remaining granitic bodies that intrude the Valdez Group are lithologically similar and probably belong to the same epoch of intrusion, although the available data do not preclude a pre-Orca age.

UNCONSOLIDATED DEPOSITS

The Mesozoic and Tertiary rocks of the Prince William Sound region are overlain with marked angular unconformity by nearly flat-lying fluvial, glacial, and marine deposits of gravel, sand, mud, and till. The various types of these unconsolidated deposits are not differentiated on figure 1.

ROCK DENSITIES

The densities of approximately 50 hand specimens representing the major lithologic units (except the unconsolidated sediments) were measured by comparing their weight in air and water (table 1). No effort was made to determine the effect of porosity on the measured densities, but tests of the influence of porosity on densities of similar rocks from other parts of Alaska have shown that the effect is negligible.

TABLE 1.—*Densities of Prince William Sound rock units*

Rock unit	Specimens	Densities (g per cm³)		
		Minimum	Maximum	Average
Granite	8	2.58	2.69	2.62
Sedimentary rocks of Orca Group	16	2.63	2.75	2.69
Volcanic rocks of Orca Group	8	2.78	2.96	2.87
Sedimentary rocks of Valdez Group	10	2.64	2.74	2.69

The heaviest rocks in the assemblage are volcanic rocks of the Orca Group and the lightest are the granitic intrusive rocks. The sampling is not sufficiently representative to establish definitely the lack of density contrast between the Orca sedimentary rocks and the older, more metamorphosed Valdez sedimentary rocks. However, seven slate samples from the combined groups had an average density of 2.74 g per cm^3 (grams per cubic centimeter), whereas 17 argillite and graywacke samples averaged 2.67 g per cm^3. Furthermore, four metagraywacke samples from the Valdez Group averaged 2.69 against 2.66 for the four less-metamorphosed graywacke samples from the Orca Group. Thus, overall densities of the two formations would depend on the relative abundance of these rock types. No samples were obtained from the Quaternary deposits which probably have an average density of about 2 g per cm^3.

STRUCTURE

The Valdez Group was intensely folded and faulted during a major period of orogeny which is tentatively placed in the time interval from Early Cretaceous to early Tertiary. The strike of bedding planes and the trend of fold axes are almost east-west in the region east of Valdez Arm, and the trend swings abruptly southwestward in the region west of the arm. Folds are characteristically tightly appressed and overturned toward the south; drag folds and minor thrust faults are common.

A second major period of orogeny that probably culminated in late Eocene or early Oligocene time (Plafker and MacNeil, 1966) complexly folded and faulted the Orca Group and intensified the deformation of older rocks. It was accompanied by, or closely followed by, emplacement of granitic batholiths. The strike of bedding planes and fold axes approximately parallels the structural trends of the older rocks, but they are notably divergent at many localities. The folds range from open to tightly appressed and locally are overturned both towards the north and south. They are of small amplitude and lateral extent and are complicated by intricate drag folding and minor thrust faults.

The most recent period of deformation, which has continued intermittently since late Cenozoic time, is attested by the uplift of the adjacent Chugach and Kenai Mountains, by the frequent earthquakes in the region, and by recent surface faulting.

All the rocks of the Prince William Sound region are intensely fractured and complexly faulted. The major lineaments show up on aerial photographs as conspicuous linear depressions and have been delineated in photogeological studies by Condon and Cass (1958) and Condon (1965). Two preexisting faults that displace sedimentary rocks of the Orca Group on Montague Island (fig. 1) were reactivated during the March 27 earthquake (Plafker, 1965). The only faults thus far recognized in the region that juxtapose lithologically distinctive sequences are in the Valdez Arm area (fig. 1) where rocks of the Valdez Group have been thrust from the northeast over the younger rocks of the Orca Group (Capps and Johnson, 1915, p. 62–63). Topographic and geologic evidence suggests the presence of major faults at other places where contact relationships are obscured by the lack of key beds, the presence of brecciation and shearing associated with minor folding and faulting, and the extensive areas covered by water, unconsolidated deposits, or vegetation. According to Moffit (1954, p. 275), there are no known depositional contacts between the Valdez and Orca Groups anywhere in Prince William Sound.

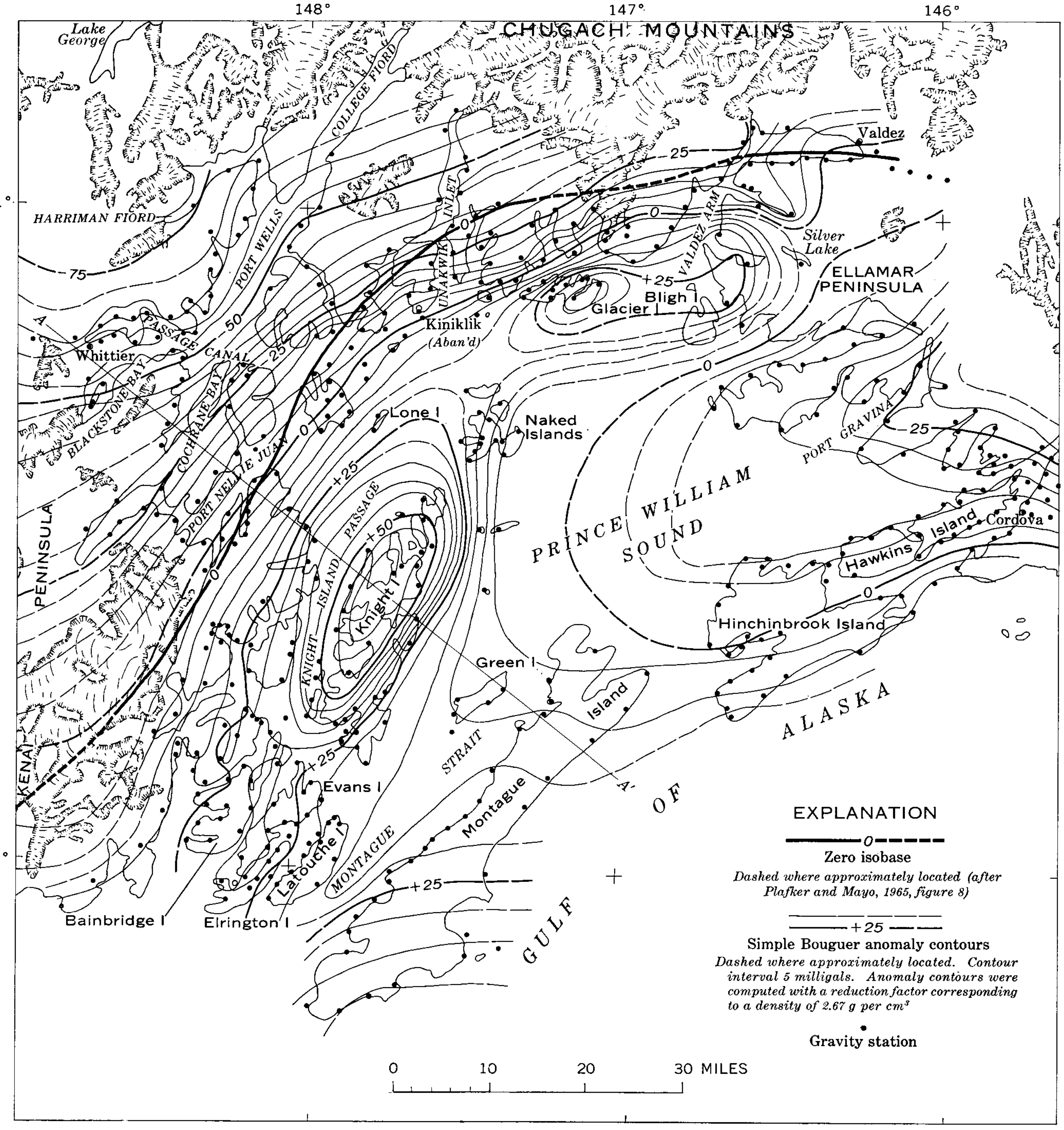
At least seven major shear zones as much as 1,000 feet wide transect the area mapped by Richter (1965, p. 14) on Knight Island. Richter reports that there is no good evidence to indicate the sense or motion along the shear zones, but left-lateral strike-slip movement of as much as half a mile is weakly suggested by the supposed dislocation of a coarse-grained gabbro body along one of the zones.

On Knight Island the thick sequence of volcanic rocks dips westward beneath probably older rocks of the Valdez Group which crop out west of Knight Island Passage. Here, the structural relationships suggest the possibility that the two units may be separated by a westward-dipping overthrust concealed beneath Knight Island Passage.

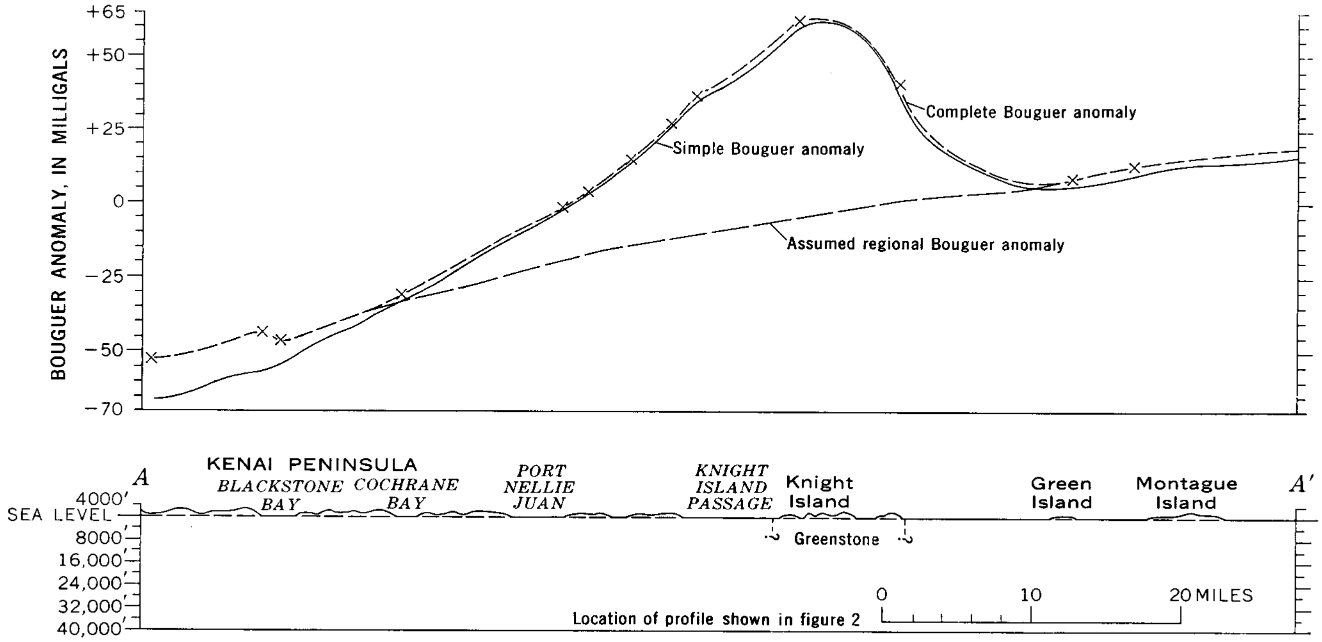
GRAVITY

Gravity was measured at approximately 500 stations within the sound (fig. 2). Most of the measurements were made with LaCoste and Romberg portable geodetic meter G–17, but approximately 75 measurements were made with a World-Wide meter. The measurements are based on absolute gravity values of 981,954.90 mgal beneath bench mark "A71" at Cordova Post Office, 982,008.00 mgal at bench mark "H11" in Valdez, and 981,921.30 mgal at bench mark "L31" in Anchorage that were established by at least three postquake ties to the North American Standardization Pendulum station (Woollard and Rose, 1963) at Fairbanks. These values differ by as much as 0.5 mgal from previous values measured near the stations established by Thiel and others (1958) prior to the earthquake. These deviations reflect small differences in location, adjustments in the North American gravity network, and changes caused by the Alaska earthquake (Barnes, 1966). During the survey, float-plane flights were used to establish 10 subsidiary base stations within the sound. Most of the remaining measurements were made at shoreline points reached by small-boat traverses. Base stations were occupied at intervals of 1–4 days. A few inland stations were reached by automobile or aircraft trips. The drift and calibration characteristics of meter G–17 are such that the accuracy of 95 percent of observed gravity values should be better than 0.2 mgal. Contouring in the water-covered parts of Prince William Sound was helped by surface-ship gravity measurements made by the U.S. Coast and Geodetic Survey ship *Surveyor*. W. H. Bastian and L. R. Mayo assisted in the collection of the gravity data, and L. J. LaPointe made some of the computations.

Most of the gravity stations were located on beaches or rocks along the shoreline. Elevation control was obtained by measuring the height of the station above water level and making a tide correction to obtain an elevation relative to mean sea level. A few stations were occupied at tidal bench marks and a few at geodetic bench marks established prior to the earthquake. Elevations at bench marks with respect to mean sea level had changed, owing to the tectonic deformation that accompanied the earthquake, so corrections to post-earthquake mean sea level were required for these stations. Elevations of all shoreline stations are probably correct to within 3 feet, and the elevations of the few stations not on the seacoast should be correct to within 20 feet. Location control was provided by topographic maps of the Geological Survey, scale 1:63,360. Simple Bouguer anomalies were computed with a reduction factor corresponding to a density of 2.67 g per cm^3. Simple Bouguer anomaly values are probably accurate to within about 1 mgal. Terrain corrections were made for a few stations close to the line A–A' (fig. 3) and ranged from 0.2 to 13.5 mgal for terrain through zone O of Hayford-Bowie (Swick, 1942).



2.—Simple Bouguer anomaly map, Prince William Sound region, Alaska.



3.—Gravity anomalies and profile across Prince William Sound.

GENERAL FEATURES OF THE GRAVITY MAP

The simple Bouguer anomaly contours indicate a general trend from positive values over the Alaskan Continental Shelf to negative values on the mainland. Values are as high as +40 mgal at the southwestern part of Montague Island and decrease to −70 mgal at College and Harriman Fiords (fig. 2). Contours are crudely arcuate around Prince Willian Sound, roughly paralleling the dominant trend of the geologic structure. Superimposed on this regional pattern are the arcuate Prince William Sound gravity high, which is largest over Knight Island, and the broad gravity low covering Port Gravina and the southeastern part of the sound. The high coincides with a belt of greenstone and pillow basalt and is inferred to be caused by these rocks. The low is probably caused by a thick accumulation of recent sedimentary deposits, a granitic intrusive rock, and, in some areas, terrain effects. In part the low is an "apparent" low due to the combined effect of the high to the northwest and the regional gradient. No other major correlations between the pattern of gravity anomalies and the mapped geologic features are apparent at this stage of interpretation.

The new data provide a more complete gravity map of the Prince William Sound area than was available from the limited number of measurements made by Thiel and others (1959) which served as the basis for earlier Alaskan gravity maps (Woollard and others, 1960, fig. 2; Ivanhoe, 1961). These maps showed the high gravity values in the southern part of the sound and the low values in the Chugach Mountains. However, neither the magnitude nor the estent of the Prince William Sound high to the north and northeast was recognized, although Woollard and others correctly interpreted the anomaly as being caused by mafic rock (1960, p. 1029). Furthermore, we have measured lower gravity values in the Chugach Mountains than did Thiel's group, so the gradient on the northwest side of Prince William Sound high is steeper, and causes a much larger gravity difference than had been previously indicated by Woollard and others (1960). Between Knight Island and Harriman Fiord there is a total change of 135 mgal in 40 miles, in contrast to the change of about 60 mgal shown by Woollard and others. Between College Fiord and Kiniklik (near a low part of the Prince William Sound positive anomaly) there is a change of 70 mgal in 20 miles, in contrast to the change of about 50 mgal shown by Woollard and others.

The zero isobase separating the areas of subsidence and uplift during the Alaska earthquake of March 27, 1964 (Plafker, 1965, fig. 2; Plafker and Mayo, 1965, fig. 8) approximately coincides with the steepest part of the gradient along the northwest side of the sound and locally parallels the gravity contours. This relationship could be purely coincidental, or it could be that the gradient represents, at least in part, a fault or hinge line at depth along which movement occurred during the earthquake. Press and Jackson (1965, p. 867) have postulated a near-vertical fault which lies within 15 kilometers of the surface beneath the zero isobase and extends to a depth of 100–200 km. However, such a fault could explain only a part of the gradient on the north side of Knight Island, and its postulated configuration appears to be contrary to most of the available geologic and seismologic data (Plafker, 1965, p. 1686).

The large steep gradient on the south side of the island suggests that the relatively dense greenstones are the real cause of the Knight Island anomaly. Such interpretation, based on observed geology and measured density variations, seems preferable in view of the data presently available, and it forms the basis of the remaining discussion. However, future data may show that some of the Prince William Sound anomalies are caused by tectonic features that have not yet been recognized.

REGIONAL GRAVITY GRADIENT

In order to delineate the regional gravity field, which is presumed to reflect variations in crustal thickness and density, the local anomalies due to the greenstone belt must be removed by analytical or graphical methods. Conversely, in order to isolate the anomaly caused by the greenstone belt, a regional gravity gradient must be removed. Obviously, a unique solution in removal of either the local anomaly or the regional is impossible, but reasonable approximations can be made for both the regional and local anomalies.

Relationships between local geology, simple Bouguer anomaly, and complete Bouguer anomaly along a profile extending from southeast of Montague Island to the head of Passage Canal are shown in figure 3. The complete Bouguer anomaly profile is approximate: values at stations near the line of profile for which terrain corrections were made were projected to the line of profile. The complete Bouguer anomaly profile shows a regional gravity gradient that is nearly linear or slightly convex upward. For the following analysis, it is assumed that the regional gravity gradient is determined by the complete Bouguer gravity values at Montague Island and at the Kenai Peninsula. The assumed regional gradient between these points is shown by the long-dashed line (fig. 3). Data obtained from the U.S. Coast and Geodetic Survey ship *Surveyor* on the Continental Shelf and by Thiel and others (1959) at Middleton Island, about 50 miles southeast of Montague Island, suggest that approximately the same regional gradient extends to the continental slope. The gradient may be assumed to represent a gradual increase in crustal thickness from the continental margin to the northeast side of the sound.

Woollard and others (1960) showed a similar gravity gradient and inferred increase in crustal thickness from about 24 km at Middleton Island to 33 km at Cordova and 37 km under the Chugach Mountains on their north-south profile through Middleton Island, Cordova, and Valdez. However, from reinterpretation of seismic data obtained by Tatel and Tuve (1956) from shots fired in College Fiord, Woollard and others believe that the crust is thicker beneath Prince William Sound than the gravity data suggested. They derived a crustal thickness in Prince William Sound of about 50 km. The traveltime curves show high velocities east of Valdez, suggestive of mafic rocks where our new data show a possible extension of the Prince William Sound gravity high.

Analysis of the new gravity data indicates that the regional gravity gradient is reasonably consistent with a change in crustal thickness from about 50 km near College Fiord (Woollard and others, 1960) to about 20 km near the continental margin, as measured by Shor (1962) southeast of Kodiak.

PORT GRAVINA GRAVITY LOW

The broad gravity low in the southeastern part of the Prince William Sound is best developed at the eastern end of Port Gravina. There it is in part related to the granitic pluton that extends from Port Gravina eastward into the Chugach Mountains (fig. 1), although the outcrop area is small in comparison to the area of the gravity anomaly. However, the anomaly probably also reflects a thick accumulation of poorly consolidated sediments in the central and eastern parts of the sound. Its apparent extension into Montague Strait is influenced by terrain effects. Sample terrain corrections for two stations along the steep shoreline of the strait showed that the complete Bouguer anomalies at these stations are as much as 10 mgal higher than the simple Bouguer values contoured on the map. Corrections of this magnitude would tend to straighten the +15 and +20-mgal contours in Montague Strait and to eliminate much but not all of the tonguelike low shown by the contours on figure 2. The gravity low is also an apparent low imposed by the Prince William Sound high on the regional gravity gradient.

The low which would remain in Montague Strait after terrain corrections and much of the low which occupies the central and southeastern part of the sound in part represent thick, poorly consolidated glacial and marine sedimentary deposits. The average water depths in the central and eastern parts of the sound are shallow, about 300–800 feet, whereas water depths of 1,000–2,000 feet are common in the northwestern part of the sound and in some of the narrower passages and fiords. If the sound were once glaciated to a depth equivalent to the present water depths in the fiords, poorly consolidated material as much as 1,000–1,500 feet thick may be present at the site of the gravity low. However, sparker data obtained from the U.S. Coast and Geodetic Survey ship *Surveyor* (R. C. Malloy, oral commun., 1964, 1965) suggest that 500 feet of sediment may be the maximum accumulation in most of the southeastern part of the sound. This thickness would account for not more than 10 mgal of the gravity low.

The main cause of the gravity low in the southeastern part of the sound is thus presumed to be the granitic rocks which crop out near Port Gravina and which probably extend westward beneath the cover of sedimentary rocks. Although the one sample obtained from the Port Gravina pluton had a density as high as the average of the Valdez and Orca sedimentary rocks, samples from plutons on the opposite side of the sound indicate that the average density of the Prince William Sound granite is about 0.07 g per cm^3 less than the densities of the Valdez and Orca sedimentary rocks. The absence of gravity lows over the intrusive bodies on the northwestern side of the sound suggests that they are smaller and that the Port Gravina intrusive is larger and possibly less dense. However, terrain corrections and precise contouring might also show small negative anomalies associated with the intrusive rocks on the northwest.

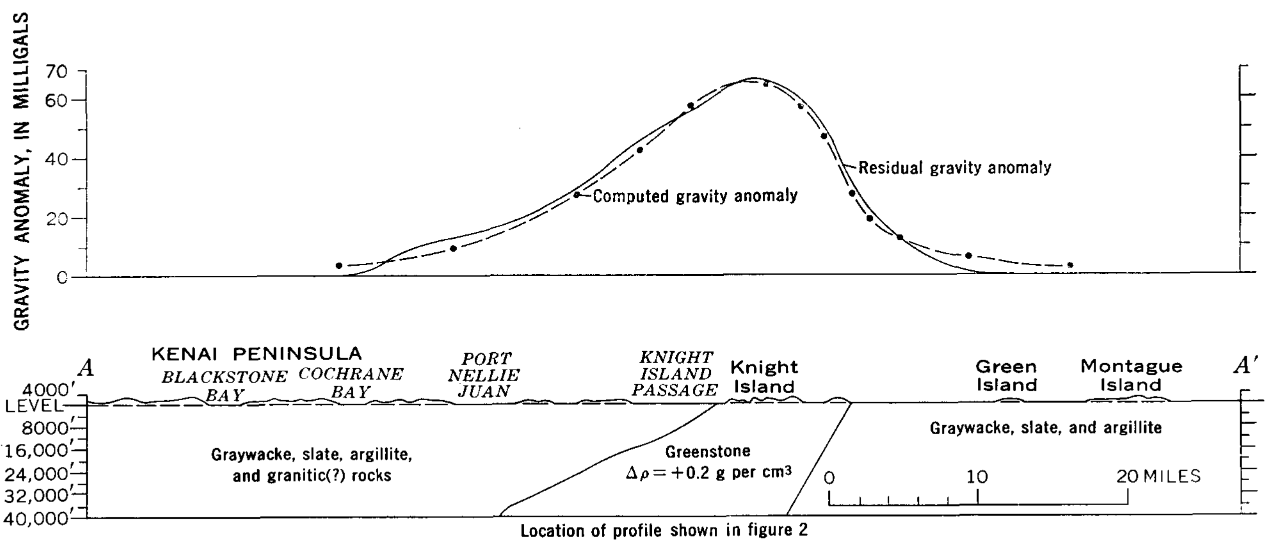
PRINCE WILLIAM SOUND GRAVITY HIGH

When the assumed regional Bouguer anomaly values are subtracted from the observed Bouguer anomaly profile, a residual positive anomaly of as much as 67 mgal can be isolated over the Knight Island greenstone (fig. 4). The residual anomaly is asymmetrical: the gradient on the southeast flank is much steeper than on the northwest flank of the anomaly. The steepness of the gradient on the southeast flank indicates that most of the relatively dense rock mass causing the anomaly probably lies at shallow depth—within the upper 10 km of the crust.

The greenstones and pillow basalts in general dip steeply. Richter (1965) has postulated that the belt of greenstone cut by shear zones may represent a complex anticlinal structure whose axis follows the approximate centerline of Knight Island. The breadth of exposures on Knight Island is about 8 miles, or 42,000 feet, and the sequence probably extends downward at least an equivalent amount if the steep dips are maintained at depth.

Available density measurements for rocks in Prince William Sound indicate that the average density of the greenstones is greater than that of the graywacke, slate, and granite with which the greenstones are in contact (table 1). The average density of the greenstone is 2.87 g per cm^3, the slate and graywacke is 2.69 g per cm^3, and the granitic rock is 2.60 g per cm^3. Thus the density contrast between greenstone and the adjacent rocks is about 0.1–0.2 g per cm^3.

A simplified model of the greenstone mass on Knight Island has a computed gravitational effect which approximates the residual anomaly (fig. 4). In construction of the model and computation of its gravitational effects, the following



4.—Interpretation of the gravity anomaly over Knight Island. $\Delta\rho$ is the density contrast.

assumptions were made: (1) the source of the anomaly is two-dimensional, that is, its length is great with respect to its breadth; (2) the average density contrast of the greenstone mass is about +0.2 g per cm^3; (3) the width of the anomalous mass at the surface is about 40,000 feet; (4) it extends downward to a depth of about 40,000 feet below sea level, and (5) the contacts of the anomalous mass dip northwest, and the northwestern contact dips more gently than the southeastern. Thus the model represents a mass whose breadth increases with depth. This configuration is consistent with Richter's hypothesis that the volcanic rocks form a major anticline.

Gravitational effects of the simplified model were computed by the method described by Hubbert (1948). The computed effects approximately coincide with the residual anomaly, both in total amplitude and in gradient. Slight changes in density contrast or in dimensions of the mass would produce an exact match, but these changes are not warranted because the dimensional assumptions and the regional gradient are more uncertain. The significant facts are: (1) a large greenstone mass is the most probable cause of the Knight Island anomaly; (2) its density is slightly greater than that of the adjacent rocks; (3) the mass probably extends to great depth, 40,000 feet or more below sea level; and (4) the gravity data indicate that faults may border both flanks of the Knight Island greenstone.

The gravity highs form a continuous belt from the greenstone outcrops on Elrington and Latouche Islands, through the area of maximum width of outcrop on Knight Island, to another high over the greenstone outcrops on Glacier Island, and then across Valdez Arm to the outcrops on Ellamar Peninsula. No large greenstone outcrops have been mapped northeast of the Ellamar outcrops, and a Bouguer gravity measurement of −1.3 mgal at the southeast end of Silver Lake suggests that the greenstones there are deeper and smaller. However, uncompleted surveys show positive gravity values 10 miles east of Valdez on the Richardson Highway, and 40–50 miles east of Valdez along the Tasnuna River up to its junction with the Copper River which could be continuous with the Prince William Sound high. If so, the incomplete data thus suggest that the belt of gravity highs may extend for 150 miles from Elrington Island at the coast to a point on the Copper River, where it is more than halfway across the Chugach Mountains. The computed profile (fig. 4) crosses the greenstone belt where the gravity anomaly associated with it is largest. Although the magnitude of the high varies along the belt, the fact that there are no major horizontal offsets of the anomaly northeast of Elrington Island suggests that no major post-Eocene faults having strike-slip displacement measureable in tens of miles obliquely cut the belt of gravity highs. The gravity survey has thus shown that the greenstone belt, which may be part of an ancient volcanic arc, constitutes one of the more continuous and significant geologic units along the Gulf of Alaska coastline.

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