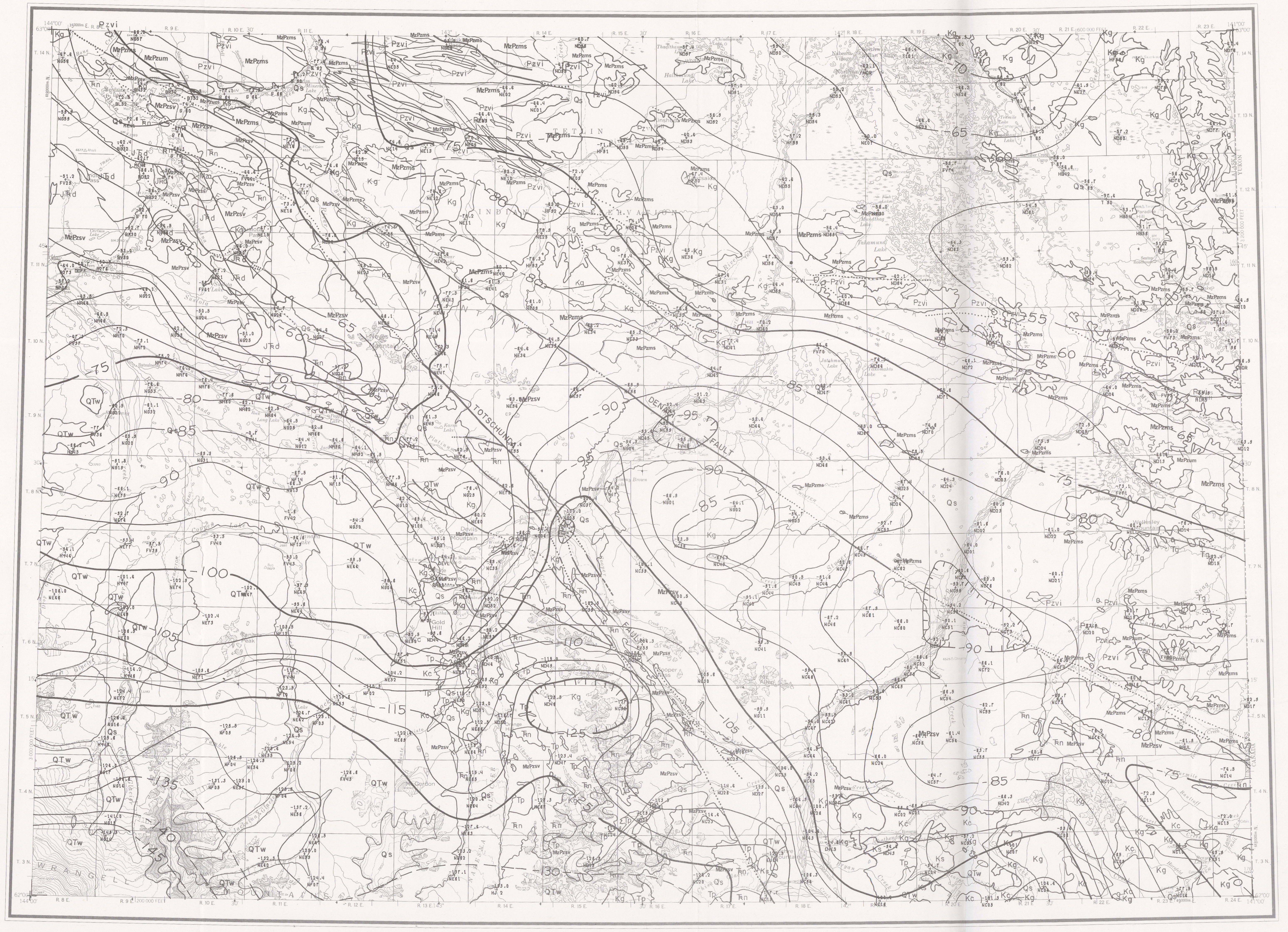
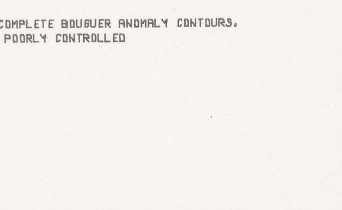
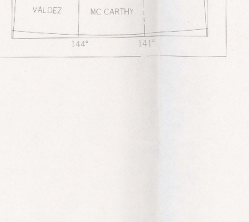


BASE BY U. S. GEOLOGICAL SURVEY, 1965





GRAVITY SURVEYS 1958 TO 1974

GRAVITY INVESTIGATIONS PARTIALLY SUPPORTED BY ALASKA DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

PLOT DATA: 2/20/75

DATA REDUCED WITH THE 1967 INTERNATIONAL ELLIPSOID AND A DENSITY OF 2.67 GRAMS PER CUBIC CENTIMETER

GRAVITY DATUM FROM: BARNES, D.F., U.S. GEOLOGICAL SURVEY FROM OPEN FILE REPORTS, 1968 + 1972

GRAVITY MAP OF THE NABESNA QUADRANGLE, ALASKA

BY

DAVID F. BARNES AND ROBERT L. MORIN

1975

EXPLANATION FOR GENERALIZED GEOLOGIC MAP

[Geology generalized from Richter (1975)]

CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS

Qs } QUATERNARY

SEDIMENTARY AND VOLCANIC ROCKS

QTw } QUATERNARY AND TERTIARY

Ks } Upper(?) Cretaceous
Kc } Lower Cretaceous
} CRETACEOUS

Ꞩn } Upper and(or) Middle Triassic } TRIASSIC

MzPzsv } MESOZOIC AND PALEOZOIC

INTRUSIVE, METAMORPHIC, AND ULTRAMAFIC ROCKS

Tp, Tg } TERTIARY

Kg } CRETACEOUS

JꞨd } JURASSIC AND TRIASSIC

Mza } MESOZOIC

MzPzms, MzPzum } MESOZOIC AND PALEOZOIC

Pzvi } PALEOZOIC

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qs	UNCONSOLIDATED SEDIMENTARY DEPOSITS (Quaternary)

SEDIMENTARY AND VOLCANIC ROCKS

QTw	WRANGELL LAVA (Quaternary and Tertiary)
Ks	CONTINENTAL SEDIMENTARY ROCKS (Upper? Cretaceous)
Kc	CHISANA FORMATION (Lower Cretaceous) Marine and subaerial volcanic rocks
Ꞩn	NIKOLAI GREENSTONE (Upper and(or) Middle Triassic)
MzPzsv	UNDIVIDED SEDIMENTARY AND VOLCANIC ROCKS (Mesozoic and Paleozoic)

INTRUSIVE, METAMORPHIC, AND ULTRAMAFIC ROCKS

Tp	PORPHYRY (Tertiary) Porphyritic andesite to rhyodacite
Tg	UNDIVIDED GRANITIC ROCKS (Tertiary) Chiefly quartz monzonite
Kg	UNDIVIDED GRANITIC ROCKS (Cretaceous) Chiefly granodiorite and quartz monzonite
JꞨd	DIORITE COMPLEX (Jurassic and Triassic)
Mza	ANORTHOSITE (Mesozoic)
MzPzms	UNDIVIDED METAMORPHOSED SEDIMENTARY ROCKS (Mesozoic and Paleozoic)
MzPzum	UNDIVIDED ULTRAMAFIC ROCKS (Mesozoic and Paleozoic)
Pzvi	UNDIVIDED METAMORPHOSED MAFIC VOLCANIC AND INTRUSIVE ROCKS (Paleozoic)

Contact. Dotted where concealed

Fault. Dotted where concealed

DISCUSSION

INTERPRETATION OF THE GRAVITY MAP

The gravity map of the Nabesna quadrangle indicates significant variations in the densities and thicknesses of the rock units that underlie the quadrangle. Most of this gravity relief is indirectly related to regional topographic relief or lithologic variations that are revealed in the rock outcrops. However, some significant features of the gravity map are not easily explained by the mapped geology, and several important features on the geologic map seem to have little gravitational expression. These failures in correlation suggest that there may be considerable differences between the deep and shallow structures of the quadrangle. Understanding these differences may eventually alter the present estimates of the quadrangle's mineral potential.

This discussion of the gravity field reviews the obvious correlations between gravity, topography, and geology, and also some of the features that are less easily explained and deserve further investigation.

The predominant feature of the gravity map is a northeast-to-southwest decrease in Bouguer anomaly from -50 mgals in the Tanana Valley to nearly -150 mgals in the vicinity of the higher Wrangell Mountains. Most of this decrease probably represents an increase in the crustal thickness required to support the high Wrangell Mountains. The empirical relations established by Woollard and Strange (1962) suggest that this decrease probably indicates a change in crustal thickness from about 35 km beneath the valley to 45 km beneath the mountains. Some of this gravity decrease might be attributed to the effect of the large thickness of low-density Cenozoic volcanic rocks that form the mountain peaks. However, during the Copper River basin gravity survey (Andreasen and others, 1964), equivalent gravity anomalies were measured on older rocks that crop out in the valleys between the higher Wrangell peaks, so most of the anomaly probably represents crustal thickening. The Wrangell Mountains are the only Alaskan mountain range in which such low anomalies have been measured, although the thicker crust probably extends southeastward beneath the St. Elias Range, where no data are available. The Nabesna quadrangle thus includes an important regional transition in crustal thickness and tectonic environment.

Although the pronounced change in level of the gravity field from northeast to southwest is the most conspicuous feature of the map, the many irregularities and variations in the regional field are geologically significant. The thinnest crust is represented by the -55-mgal contour that approximately coincides with the lower Chisana topographic basin, which was once considered the main part of the upper Tanana River basin (Miller and others, 1958). The lack of any distinct gravity lows within this topographic basin eliminates the possible presence of any significant Cenozoic depressions with thick fill similar to features found downriver at Minto Flats in the Middle Tanana basin (Barnes, 1961). The gravity decreases again in the extreme northeast corner of the map, which suggests that the crust thickens northward beneath the Yukon-Tanana upland in the adjacent Tanacross quadrangle, and where reconnaissance data (Barnes, 1969) indicate anomalies lower than -80 mgal and a crust slightly thicker than 40 km according to the relation proposed by Woollard and Strange (1962).

However, one of the geologic factors that limits the use of gravity data as a direct indicator of crustal thickness is suggested by another conspicuous feature of the Nabesna map. Along the southern side of the Chisana flats, the regional southwest gravity decrease is defined by a single belt of nearly parallel contours (-60 to -80) that strike diagonally (T.8N., R.24E. to T.14N., R.12E) across the map. This belt approximately coincides with a change in metamorphic grade that is shown on the geologic map of the quadrangle (Richter, 1975). The gradient is thus believed to be primarily an indication of the densities of the rocks forming the upper crust rather than a change in crustal thickness, although the two causes may be interrelated. This pronounced linear contour belt parallels but is centered approximately 20 km north of the trace of the Denali fault, which is the most important boundary on the geologic map. Richter and Jones (1973) speculated that the Denali fault originated as a late Paleozoic subduction zone that probably dipped northward. Accordingly, an alternative interpretation of this gravity gradient is that it may reflect an old plate boundary, the gravitational expression of which is north of the fault trace. The lack of an obvious gravitational gradient coincident with the fault might seem surprising, but a similar lack of pronounced gradients has been noted in other parts of Alaska where unpublished detailed gravity profiles have crossed the fault. However, more detailed examination of the gravity map may provide an indication of the fault. Two small enclosed gravity lows occur where the Nabesna and Chisana Rivers cross the fault, and small flexures of the gravity contours indicate other lows where the fault is crossed by Snag, Stuver, and Tetlin Creeks. For most of its length, the Denali fault is marked by a distinct topographic depression, and these gravity lows are interpreted as bedrock depressions underlying the river fans that are now filled by Quaternary sediments.

In contrast to the Denali fault, the Totschunda fault system seems to have some real gravitational expression, although the gradient across the fault varies from north to south, and the linearity of the contours is decreased by the effects of more local geologic features. The -100-mgal contour is almost parallel to the southern end of the fault, and contours of lower gravity that are closer to the fault are subparallel to it. The gravitational data suggest that the fault may be expressed by a 10- to 15-mgal step in the regional southwest negative gradient. A more striking feature of this part of the gravity map is a suggested deep structural displacement that seems to have occurred along the fault. One of the most obvious features of the gravity map is the east-west belt of -100- to -125-mgal contours that extends across the southwest quarter of the map (T6N), west of the fault line. On the east side of the fault, this same east-west trend is developed at the south edge of the map in the -85- to -105-mgal contours. The gravity data thus suggest that a deep structure has been displaced nearly 30 km to the southeast by right-lateral movement along the fault. Richter and Matson (1971) found evidence for only about 10 km of Holocene movement, but other geophysical and geological evidence suggests older movements as large as 20 to 25 km (Griscom, 1975), and the gravity data suggest the largest movement of all. The cause of the east-west gradient is not fully known, but the width of the contour belt suggests that it is a deep feature; this in part involves a change in crustal thickness. The volcano, Mt. Sanford, probably occurs along the westward extension of the gradient into the Gulkana quadrangle, so the volcanic activity might suggest a deep fracture. No similar feature was observed in the Copper River survey (Andreasen and others, 1964) west of the Wrangells, so the feature is probably associated with the northern limit of the mountains, although it may be older than the mountains. North of the east end of this east-west feature (T.6N., R.16E.), the gravity gradient associated with the Totschunda fault decreases and then reverses in direction so that higher gravity anomalies recur on the south side of the fault, but a few contours are nearly parallel to the fault. The close parallelism between the gravity contours and the Totschunda fault tends to obscure some of the small-scale gravity features that may be associated with the fault. However, there is another small closed gravity low where the Nabesna River crosses the fault (T.8N., R.15E.) and this is presumed to indicate another sediment-filled depression similar to those observed along the Denali fault.

The reversed gravity gradient at the northwest end of the Totschunda fault forms the flank of an arcuate gravity high that extends southeast from the northwest corner of the map (T.12N., R.8E.) and then south to the Nabesna River (T.7N., R.13E.), where it almost seems to be truncated by the east-west gradient mentioned above. This gravity high is a major feature of the south flank of the central Alaska Range because data that were accumulated during the Copper River and Nabesna gravity surveys (Barnes, unpub. data) show that it extends westward for more than the full width of the adjacent Gulkana quadrangle. It resembles gravity highs observed on the flanks of many other Alaskan mountain ranges (Barnes, 1970). The rocks that crop out along the arcuate high are largely older sedimentary and volcanic rocks with scattered outcrops of the Triassic and Jurassic diorite complex, but the scattered outcrops of the even older Nikolai Greenstone and associated gabbroic rocks along the northern edge of the gravity high are believed to be the real cause of the anomaly. The younger rocks are locally in thrust contact with the Nikolai volcanic rocks, which are believed to be denser and to dip southward with increasing steepness so that their maximum gravitational effect occurs along the gravity high. The local gravity high at the extreme southeast corner of the quadrangle (T.3N., R.24E.) is also associated with outcrops of the Nikolai Greenstone, but the structural relations may be reversed, with the anomaly representing denser rock units that dip northward. Evidence concerning the real cause of this anomaly will probably improve when data become available from adjacent parts of Canada.

Discussion of the smaller features of the gravity map is most easily organized on the basis of the intrusions, and their anomalies are briefly mentioned in a north to south succession using Richter's (1975) geologic nomenclature. The gravity low outlined by the -65- and -70-mgal contours on the map's north edge (T.14N., R.20E.) is clearly associated with the Gardiner Creek pluton. Although this pluton is poorly exposed, both the gravity and aeromagnetic data (Griscom, 1975) suggest that it covers a much broader area at fairly shallow depths. A few kilometres to the southwest of this anomaly, northward bends of the -60- and -65-mgal contours (T.12N., R.17E.) suggest that the Cheslina pluton may cause a poorly defined gravity low. In contrast, gravity data in the belt between the two -75-mgal contours near the northwest end (T.11N., R.13E.) suggest that the Tok-Tetlin pluton is probably a gravity high although the contouring in this part of the map depends largely on how the gravity expression of this pluton is interpreted. Other plutons north of the fault have even less distinct gravitational expression and probably have almost the same densities as the rocks they intrude. None of the gravity measurements were made on the small outcrops of the ultramafic rocks, but the aeromagnetic data (Griscom, 1975) indicate that these features are broader at depth than in outcrop. Two measurements at stations NE16 (T.13N., R.11E.) in the northwest and ND19 (T.6N., R.22E.) in the southeast may be near enough to the ultramafic rocks to indicate that they form weak gravity highs and help to confirm the aeromagnetic interpretation of greater size at depth.

South of the Denali fault the gravity expression of the plutons is more obvious and perhaps more important. A distinct gravity high in the center is marked by the closed -85-mgal contour (T.8N., R.17E) that surrounds the Antler Creek pluton. Similarly, the high (T.4N., R.23E.) at the southeast corner of the quadrangle could be partly caused by the more mafic parts of the Klein Creek pluton, although another explanation of this anomaly has already been discussed. Also, a southwestward flexure of the -95-mgal contour encloses the Chisana pluton (T.4N., R.19E.) and suggests that these rocks cause a third gravity high. Density data for rocks from the Nabesna quadrangle are not yet available, and the fact that these plutons appear as gravity highs could result either from their lithologies or from the fact they they intrude lower density flysch. However, the gravity data also suggest that other plutons of the same age are associated with gravity lows. The northward flexure of the -90- to -100-mgal contours near the southeast corner of the map suggest that the southwest part of the Klein Creek pluton is a gravity low (T.3N., R.21E). Similarly, the most obvious local gravity low (T.5N., R.15E.) on the map is the -125-mgal closed contour that surrounds the major part of the Nabesna pluton. The rocks that surround this pluton are generally older than those that surround the plutons causing gravity highs, but the pluton itself is less mafic, so there are two possible explanations for the contrast in gravity expression of the different plutons. More detailed gravity surveys and a good set of density measurements would provide useful information about the form of these plutons, which seem to be associated with porphyry copper mineralization (Richter and others, 1975). The flexures of the -130-mgal contour (T.5N., R.10E.) at the southwest corner of the map suggest that local gravity anomalies could be caused by rocks now buried by the Cenozoic Wrangell Lava. There is no evidence that these anomalies are caused by local eruptive centers, and therefore the anomalies may logically be interpreted as buried plutons. Perhaps future and more refined geophysical exploration and drilling will reveal other plutons and associated mineral deposits that are covered by the volcanic rocks and thus shielded from conventional prospecting techniques.

GRAVITY DATA COLLECTION AND COMPILATION

Record of field measurements

The map summarizes nearly 600 gravity measurements that have been made in the Nabesna quadrangle during a period of more than 20 years. A few initial measurements were made by the University of Wisconsin in the early 1960's (Thiel and others, 1958), but none of these early measurements are incorporated in the present map, which uses later measurements at nearly identical locations. The initial U.S. Geological Survey gravity measurements in the Nabesna quadrangle were made in 1958 by Barnes as part of the Copper River basin gravity survey (Andreasen and others, 1964). The following summer, the road traverses from that survey were extended across the Alaska Range and along the road to the Nabesna mine. In 1962, additional measurements were made along the Alaskan Highway and by float plane landings on lakes selected to provide reconnaissance coverage suitable for a state gravity map (Barnes, 1965 and 1969) that was nearly completed with an additional helicopter traverse in the summer of 1963. No further surveys were made until the summer of 1974 when two weeks of helicopter support were provided for a gravity survey as part of the Alaskan Mineral Resource Assessment Program. The resulting survey is still reconnaissance in nature but reveals significant variations of the gravity field and suggests a few areas where more detailed surveys might be rewarding for future prospecting.

World-Wide gravimeter No. 11 was used for all the gravimeter measurements that preceded the 1962 traverse along the Alaskan Highway. LaCoste and Romberg geodetic meter G-17 was used for that traverse, for the base station network, and for practically all the later measurements made in the Nabesna quadrangle. Elevations on the Glenn and Alaskan highways were obtained in part from the first order level lines of the Coast and Geodetic Survey and in part from surveys made during the highway construction and surfacing. Single-base altimetry was used for most of the remaining elevation control.

Data Reduction

The map shows the variation of the Bouguer anomaly, which is actually the arithmetic difference between a field measurement of gravitational attraction and a theoretical attraction calculated by standardized formulae that predict the theoretical variations of gravity with latitude and elevation (Heiskanen and Vening Meinesz, 1958). However, the present map incorporates some new formulae that were recently recommended by the International Union of Geodesy and Geophysics and that should be briefly mentioned as this may be one of the first United States gravity maps to incorporate these changes. The first change involves gravity datum and scale, which for previous Alaskan gravity surveys had been based on a base station network established by Barnes (1968 and 1972) and tied through a world-wide network (Woollard and Rose, 1963) to an absolute gravity datum at Potsdam, Germany. In 1971, the International Association of Geodesy, which had established the Potsdam datum in 1909, recommended that future gravity measurements be based on a new datum and scale, defined by a world-wide program of pendulum measurements, freefall acceleration measurements, and gravimeter ties (Morelli and others, 1974). This new International Gravity Standardization Net (I.G.S.N. 71) changed the Potsdam datum by 14 mgals and the U.S. Geological Survey's Alaskan gravity base station network by 14.46 mgals in the vicinity of Nabesna. A second change was recommended by the International Association of Geodesy somewhat earlier and is being incorporated into the reduction of U.S. Geological Survey Alaskan gravity data at the same time as the new gravity datum. This change involves the use of a new formula for calculating the theoretical variation of gravity with latitude and is known as the 1967 International Reference Ellipsoid (International Association of Geodesy, 1971). It involves both a decrease in the flattening ratio of the ellipsoid and a change in the equatorial radius. Within Alaska, the combined changes of datum and reference ellipsoid reduce the calculated anomalies by 6 to 9 mgals depending on latitude. Thus, the anomalies shown on this Nabesna map are 8.0 mgal lower than anomalies for similar observed gravities, latitudes, and elevations that might appear on earlier U.S. Geological Survey gravity maps of nearby areas, such as those published for the adjacent Copper River Survey (Andreasen and others, 1963). However, this Nabesna map will conform with the forthcoming State of Alaska gravity map and the present gravity map of Canada (Earth Physics Branch, 1974).

The remaining procedures used in the data reduction followed the standard procedures explained in various published texts, and the specific practices used for Alaskan gravity and altimeter measurements that have been briefly described by Barnes (1972). A standard density of 2.67 g per cm^3 was used in making the Bouguer elevation correction, and second-order terms were applied in the freeair elevation corrections. Terrain corrections were calculated by hand template through Hayford zone F (radius 2.29 km) and extended to 25 km or approximately Hayford zone L (Swick, 1942) or Hammer zone M (Hammer, 1939) by a digital computer program (Plouff, 1966) using previously determined mean elevations for each 1 x 2-minute compartment in the Nabesna 1:63,360 map series and adjacent quadrangles. Elevations obtained from spot elevations and contour interpolation were used for the terrain corrections, but many altimeter elevations were used for the infinite-slab part of the Bouguer correction. The latter procedure was chosen because the altimeter elevations produced anomalies that in many parts of the quadrangle seemed more consistent locally than those obtained from the topographic mapping. A general criterion for the accuracy of topographic map elevations is that 90 percent of the elevations are correct within half a contour interval, which is generally within 100 feet in the Nabesna quadrangle. If the altimetry elevations represent a small improvement in elevation accuracy, 90 percent of the gravity anomalies should have a precision of 2.5 to 3 mgal, or approximately half the gravity contour interval.

Datum Recovery

More detailed surveys within the Nabesna quadrangle could be placed on the same gravity datum by occupation of any Geological Survey gravity base, but the observed gravities listed in the earlier report on this network (Barnes, 1968) should now be corrected to the IGSN 71 datum. Because this map precedes the publication of a corrected base-station network, the descriptions and observed gravities of five principal base stations are listed below:

1) Station BP30 at Slana on the southeast corner of the old road junction of the Glenn Highway and the Nabesna Road on USC&GS bench mark P30; the observed gravity is 981,936.51 mgal.

2) Station DEVL on the Nabesna Road at the southwest corner of Devil's Mountain Lodge on the ground beneath a USGS gravity marker; the observed gravity is 981,837.93 mgal.

3) Station CHIM near the south end of Chisana airstip at the southwest corner of the Wrangell-R ranch cookhouse on the ground below a USGS gravity marker; the observed gravity is 981,780.18 mgals.

4) Station /NOR at Northway airport beacon on top of USC&GS triangulation station "Northway"; the observed gravity is 981,976.60 mgal.

5) Station CBDM on the Alaska Highway at the Canadian border on the ground beneath the bronze friendship plaque; the observed gravity is 981,947.73 mgal.

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