GEOLOGIC INTERPRETATION OF MAGNETIC DATA IN THE COPPER RIVER BASIN, ALASKA

By

Gordon E. Andreasen, Arthur Grantz, and Isidore Zietz

This report and accompanying illustrations have not been edited or reviewed for conformity to Geological Survey standards or nomenclature.

U. S. GEOLOGICAL SURVEY

Released to open files

CONTENTS

CONTENTS (continued)

ILLUSTRATIONS

GEOLOGIC INTERPRETATION OF MAGNETIC DATA

IN THE COPPER RIVER BASIN, ALASKA

By

Gordon E. Andreasen, Arthur Grantz, and Isidore Zietz

Abstract

An aeromagnetic survey was made of approximately 6,500 square miles of the Copper River Basin, Alaska, in 1954 and 1955. The survey area is bounded approximately by the Alaska Range on the north, the Wrangell Mountains on the east, the northern Chugach Mountains on the south, and the Talkeetna Mountains on the west. Continuous total intensity magnetic data were recorded along north-south flight lines spaced one mile apart.

The magnetic data, compiled as a total intensity contour map, show patterns that closely parallel the generally arcuate geologic "grain" and seem to correlate with lithology and with geologic structure. Areas where volcanic rocks crop out are indicated by characteristic configuration of magnetic contours. The magnetic data suggest that Lower Jurassic volcanic rocks exposed in the Talkeetna and northern Chugach Mountains underlie sedimentary rocks in the southwest quadrant of the survey area. The data also indicate that Tertiary and Quaternary lavas of the Wrangell Mountains occur at shallow depths in the eastern part of the Copper River Basin in the vicinity of Mt. Drum. Alternating bands of high and low magnetic values that characterize much of the northern third of the survey area are interpreted to be products of the plutonic rocks and metamorphosed volcanic and

sedimentary rocks that crop out at many places in this area.

Two major areas of low magnetic gradient outline areas where sedimentary rocks may be thick. One area is located in the southwest part of the survey area; another larger area occupies most of the southeast quadrant of the Copper River Basin. Negative gravity anomalies, also indicating areas where sedimentary rocks may be thick, correlate well with the areas of low magnetic gradient.

Introduction

An aeromagnetic survey of the Copper River Basin was made by the U. S. Geological Survey in 1954 and 1955. John R. Henderson was in charge of the 1954 flying and Andreasen completed the survey in 1955. The survey area, approximately 6,500 square miles, is bounded by the Alaska Range on the north, the Wrangell Mountains on the east, the northern Chugach Mountains on the south, and the Talkeetna Mountains on the west (fig. 1). About 75 north-

Figure 1. Index map showing location of the Copper River Basin survey area.

south traverses, approximately 80 miles long and spaced one mile apart, were flown at a flight elevation of 4,000 feet above mean sea level, except locally where topography required higher flight elevations. The flight lines extend north from the northern Chugach Mountains to latitude 63°00'. The easternmost line is at longitude 145°00' and the westernmost line is approximately at longitude 147°30'.

Continuous total intensity magnetic data along flight traverses were obtained from a modified AN/ASQ-3A airborne magnetometer with a fluxgate-

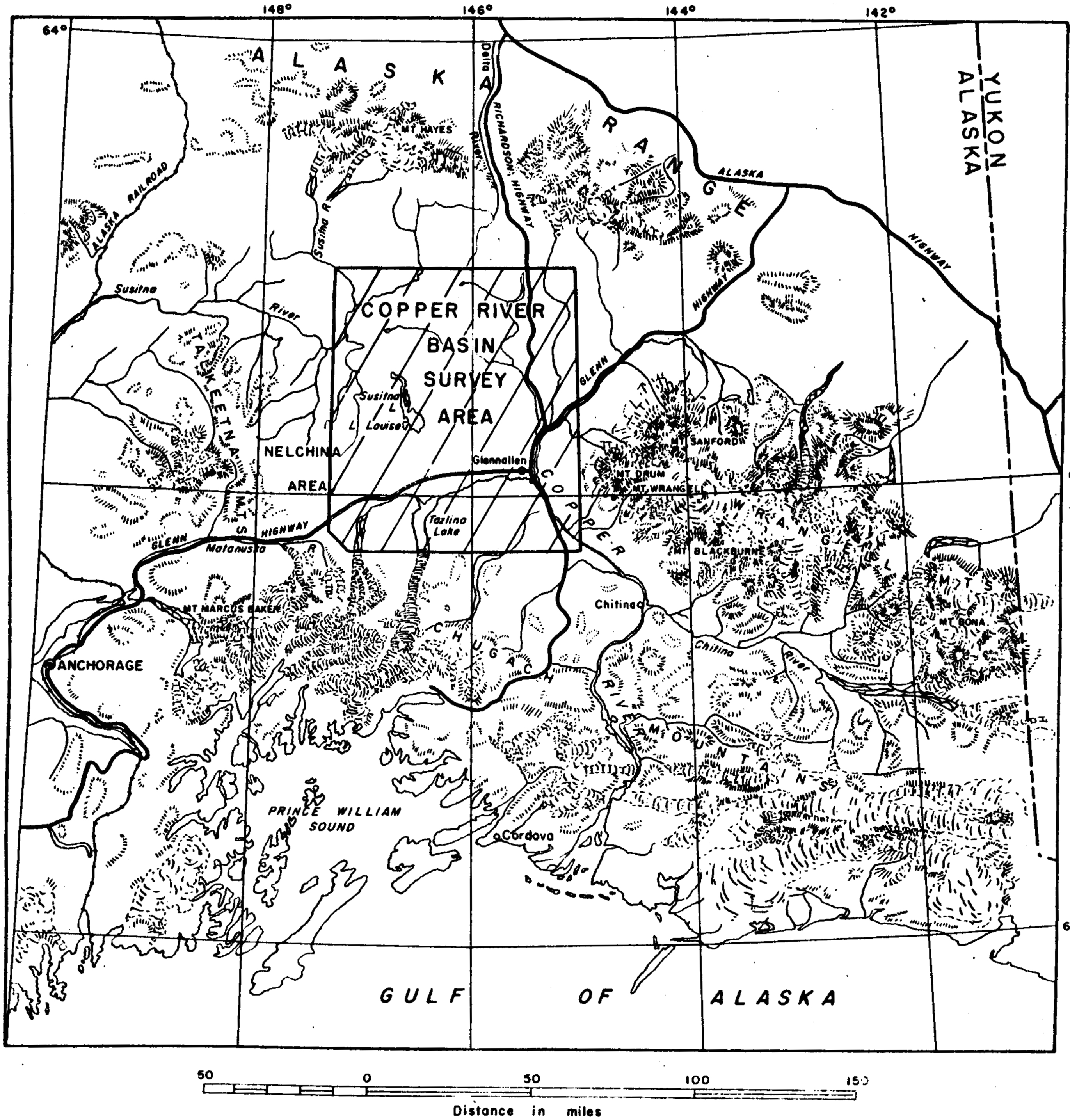

Figure 1 – Index map showing location of the Copper River Basin survey area

type detecting element towed about 75 feet below a DC-3 aircraft. Flight lines plotted on topographic maps were used for flight guidance. The actual flight paths were recorded by a gyro-stabilized continuous strip-film camera. These data have been compiled as a total intensity magnetic contour map (Andreasen and others, 1958).

The airborne magnetometer survey was flown in support of geologic field mapping projects in and adjacent to the survey area with the expectation that the magnetic patterns would provide information useful in the geologic mapping and the interpretation of the subsurface geology.

The geologic description of the Copper River Basin area and the accompanying geologic map were prepared primarily from the references listed at the end of this report. However, some changes in interpretation of the material in these reports have been made to resolve conflicts in the published data and to incorporate the results from recent field work. A few field observations by John R. Williams, Donald R. Nichols, and Darwin L. Rossman, U. S. Geological Survey, in the southeastern part of the area, Florence R. Collins, and Florence R. Weber, also of the Survey, along the Richardson Highway, and regional mapping by Grantz, in the Nelchina area and southern Copper River Basin have been included. The Nelchina area occupies the southeast foothills of the Talkeetna Mountains and lies west of the southern Copper River Basin.

The preliminary Bouguer gravity anomaly map was prepared by David F. Barnes of the U. S. Geological Survey from data collected in 1958 and 1959.

Geology of the area

The Copper River Basin is a structural and topographic basin drained chiefly by the Copper River and, secondarily, by the Susitna, Matanuska, and Delta Rivers. In part the basin marks a lower position of the underlying low-relief Eocene surface than in the surrounding mountains.

Quaternary glacial and alluvial deposits, and in places continental deposits of Eocene age are present over most of the basin and conceal the older rocks (fig. 2). The pre-Eocene rocks in general form eastward-

---

Figure 2. Generalized geologic map of the Copper River Basin area, Alaska.

---

trending arcs that are concave south (see Payne, 1955). These arcs existed in Mesozoic and earliest Tertiary time and are delineated by the strike of geologic contacts, faults, and topographic features. Among the arcuate features are two belts of Early Jurassic and older rocks, containing numerous bodies of plutonic intrusive rocks called the Seldovia and Talkeetna geanticlines. These geanticlines trend eastward through the northern part of the Chugach Mountains and the northern half of the Copper River Basin respectively. Between them lies a belt of marine sedimentary rocks of Middle Jurassic through Late Cretaceous age, which were deposited in the Matanuska geosyncline. These rocks trend into the basin from the Matanuska Valley on the west and the Chitina Valley on the southeast, but are exposed at only a few places within the basin.

Rock units

A variety of metamorphosed sedimentary and volcanic rocks of Carboniferous and older(?) age crop out in and adjacent to the Copper River Basin. These rocks are of very low to intermediate metamorphic grade. Their lithology, age, and correlation have been determined at only a few places and for the purpose of this report they are grouped into two map units. One unit (Cvs) includes metamorphosed volcanic and sedimentary rocks which occur in the Talkeetna geanticline and crop out in a low range of eastward-trending hills in the northern part of the basin; the Tetelna volcanics, which crop out east of the Chistochina River; and the Dadina schist and Strelna formation, which crop out between Mt. Drum and the lower Chitina River. Andesitic and basaltic lavas and tuffs which in most places have been altered to greenstone and greenschist predominate, but the unit contains slate, quartzite and quartzose schist, phyllite, biotite schist, limestone, schistose amphibolite, shale, and chert. Chlorite and magnetite are abundant in the meta-volcanic rocks. Diorite, quartz-diorite, and mafic intrusives, in many places altered, have been recognized in this unit but most have not been mapped. The Strelna formation of the Chitina Valley is more than 6,500 feet thick.

The second map unit of Carboniferous and older(?) rocks (Cs), consisting mostly of metamorphosed sedimentary rocks, occurs in the southeastern and northeastern part of the Copper River Basin. It contains argillite, quartzite, conglomerate, siliceous sediments, limestone, quartz, mica schist, and some tuff and lava flows, and it includes the Klutina group and the Chisna formation. Plutons of diverse lithologies have intruded these rocks and undoubtedly many more occur than have been mapped.

Altered basalt and andesite flows with intercalated tuffaceous and shaly beds of Permian and Triassic(?) age (TrPv) crop out in the Chitina Valley, where they are known as the Nikolai greenstone, and in a broad band across the northern part of the Copper River Basin. They are over 5,000 feet thick in the northern part of the survey area. About 5,000 feet of Late Triassic sedimentary rocks (Trs) (the Chitistone and Nizina limestones and McCarthy shale) overlie the Nikolai greenstone in the Chitina Valley.

Altered andesitic (rhyolite to basalt) marine pyroclastic rocks, lava flows, and tuffaceous sedimentary rocks (Jv) occur in the Talkeetna Mountains and the northern Chugach Mountains west of Tazlina Lake. The upper beds of the sequence are predominantly sedimentary. These rocks are part of the Talkeetna formation of Early Jurassic age and are at least several thousand feet thick. The formation is not present in the Chitina Valley and has not been reported from the eastern and northern parts of the Copper River Basin. Volcanic rocks in the northern Chugach Mountains between Tazlina Lake and Stuck Mountain have been referred to the Lower Jurassic (Talkeetna formation) by Chapin (1918, pl. 2) and to the Carboniferous by Moffit (1938, pl. 2). These are mapped as JCv on figure 2, for rocks of both systems may be included in this map unit.

A unit of marine sedimentary rocks (KJs) deposited in the Matanuska geosyncline rests unconformably upon the Talkeetna formation in the southwestern part of the Copper River Basin and on Late Triassic and older rocks in the Chitina Valley. They crop out nowhere else in the Copper River Basin and were probably never deposited in its northern part. In the southwest Copper River Basin they consist of siltstone, shale, sandstone, conglomerate, and limestone of the Tuxedni, Chinitna, and Naknek formations of Jurassic age, the Nelchina limestone and associated beds of Early Cretaceous age, and the Matanuska formation of Late Cretaceous age. The Jurassic and Lower Cretaceous beds total about 7,500 feet in thickness and chiefly occur north of the Matanuska formation, which may total 10,000 feet in thickness. The Kennicott formation, Kotsina conglomerate, and several unnamed units in the Chitina Valley are included in the KJs and in places are thousands of feet thick.

Igneous masses ranging in size from dikes to batholiths occur mainly in the rocks of the Seldovia and Talkeetna geanticlines. Except for those associated with the Wrangell lavas, they range in age from late Paleozoic to later Cretaceous, or possibly Paleocene. Quartz-diorite is most common but granodiorite, granite, gabbro, and ultramafic rocks occur. Some of the intrusive rocks have been metamorphosed. Only the largest have been mapped, and even these only in places. The intrusives shown on figure 2 as Ui are but a small portion of those that occur in the area.

Continental sediments of Eocene age (Tc) were deposited on an extensive surface of low relief which was formed in Eocene time. These sediments consist of sandstone, conglomerate, siltstone, and claystone, and locally include beds of coal. Eocene plants have been collected from them at a few places. Several hundred feet of these rocks are present in the southwestern part of the basin, but complete sections have not been found and they may be much thicker where buried by Quaternary deposits. The Eocene sedimentary rocks are more than 2,000 feet thick in the northern part of the basin, where they have been named the Gakona formation.

The Wrangell lavas (QTv) comprise the bulk of the Wrangell Mountains. They include lavas of Eocene and Quaternary age and in places are interbedded with Pleistocene glacial deposits. They consist chiefly of andesite lava flows with associated pyroclastic rocks, but contain some basalt and dacite. Basalt flows and minor amounts of more felsic rocks and pyroclastic rocks crop out extensively in the southeast Talkeetna Mountains. Eocene plants have been collected from the pyroclastic rocks.

Glacial and alluvial deposits of Quaternary age mask older rocks in most of the Copper River Basin. These deposits are more than 600 feet thick in places, and may exceed 1,000 feet.

Structure

The arcuate, eastward trend of most geologic features across south-central Alaska is well developed in the Copper River Basin. The north face of the Chugach Mountains marks a structural front which follows this trend. The strike of the Mesozoic marine rocks and their basal contacts in the Nelchina area and Chitina Valley, the aligned bedrock hills in the northern Copper River Basin, the trends of the Carboniferous and older(?) volcanic and sedimentary rocks and the belt of Permian and Triassic volcanic rocks in the northern part of the basin, also reflect the regional trend.

East- and northeast-striking faults, fault blocks, and folds, dominate the structure of the Nelchina area. The probable extension of the Castle

Mountain reverse fault which lies on the north side of the Matanuska Valley trends eastward across the Nelchina area to the Copper River Basin, but much of its displacement is dissipated in northeast-striking branch faults in the Nelchina area. The Eocene sedimentary rocks and the Cenozoic lavas in most places dip gently but locally dip steeply and are faulted.

Unconformities within the Jurassic, Cretaceous, and Tertiary rocks, and the erosion they represent, have had an important influence on the distribution of the Jurassic and younger sedimentary formations. The marine sedimentary rocks of Mesozoic age have been deposited as a series of overlapping prisms, and all do not occur in any one vertical section. The Eocene sedimentary rocks have been deposited in basins and on pediments whose distribution is unrelated to the patterns of Mesozoic deposition.

Magnetic interpretation

The aeromagnetic data for the Copper River Basin have been compiled as a total intensity contour map (fig. 3). The data were obtained as

---

Figure 3. Aeromagnetic map of the Copper River Basin survey area, Alaska.

---

continuous profiles along each flight line.

Methods

The methods of magnetic interpretation used in this report are essentially the same as those described by Vacquier, and others (1951). Briefly, the assumptions upon which the magnetic interpretation is based are: (1) anomalies of large amplitude and areal extend are produced by contrasts in magnetic susceptibility (abrupt changes in topography of a magnetic rock unit produce only relatively small-amplitude anomalies); (2) the anomaly-producing rocks are magnetically homogeneous and are magnetized by induction in the earth's field; (3) remanent magnetization is in the direction of the earth's field, or is negligible; (4) the rock masses producing anomalies possess plane surface, vertical sides, and are of infinite depth extent. A magnetic rock mass with a thickness equal to or greater than the height of the magnetometer above its upper surface appears, magnetically, to be of infinite depth extent. If remanent magnetization is large and of random orientation, or if the magnetic mass is too thin to meet the "infinite depth extent" requirement, the method is not applicable. Depth estimates based on the magnetic field produced by a thin sheet of magnetic mass are invariably too shallow. In this report, depth estimates are based on the assumption of infinite depth extent.

For the few anomalies suitable to quantitative analysis by this method, the estimation of depths to the upper surface of the magnetic rock units involves the comparison of observed profiles with suitable computed profiles for rectangular prismatic models. An approximation of depths of burial may be obtained by measuring the horizontal extent of the steepest gradient of the anomaly, taken at right angles to the contours.

However, for the most part the interpretation of the Copper River aeromagnetic data involves the comparison of magnetic patterns over anomaly-producing rocks of known lithology to the patterns observed in areas where similar anomaly-producing rocks are masked by a cover of essentially non-magnetic sedimentary rocks.

The earth's normal magnetic gradient has not been removed from the aeromagnetic contour map. According to Vestine (Vestine and others, 1947) the earth's normal total magnetic intensity in the Copper River region increases approximately 5 gammas per mile in a northeasterly direction.

Regional magnetic patterns

The principal magnetic patterns of the Copper River Basin are shown on a simplified aeromagnetic map (fig. 4). This map is contoured at intervals

Figure 4. Simplified aeromagnetic map of the Copper River Basin survey area, Alaska, showing principal magnetic features.

of 200 and 600 gammas so that only the gross magnetic features are shown. The areas with magnetic intensity of less than 4,500 gammas (arbitrarily chosen) are shaded so that the several distinct magnetic patterns are more clearly apparent. Figure 4 shows that the general trends of the total magnetic intensity parallel the arcuate geologic grain of the area. Examples are: the east-trending magnetic highs over the northern Chugach Mountains, and the east-trending belts of magnetic highs and lows, called the MacLaren-Gulkana anomalies, across most of the northern third of the Copper River Basin. Perhaps the most prominent magnetic anomaly, called the West Fork feature, traverses the area at approximately 62°35' latitude. This anomaly is bounded on the north by a steep magnetic gradient that is continuous for at least 75 miles and is several hundred gammas in amplitude. The Tyone Creek anomalies, in the west-central part of the Copper River Basin, comprise another distinct

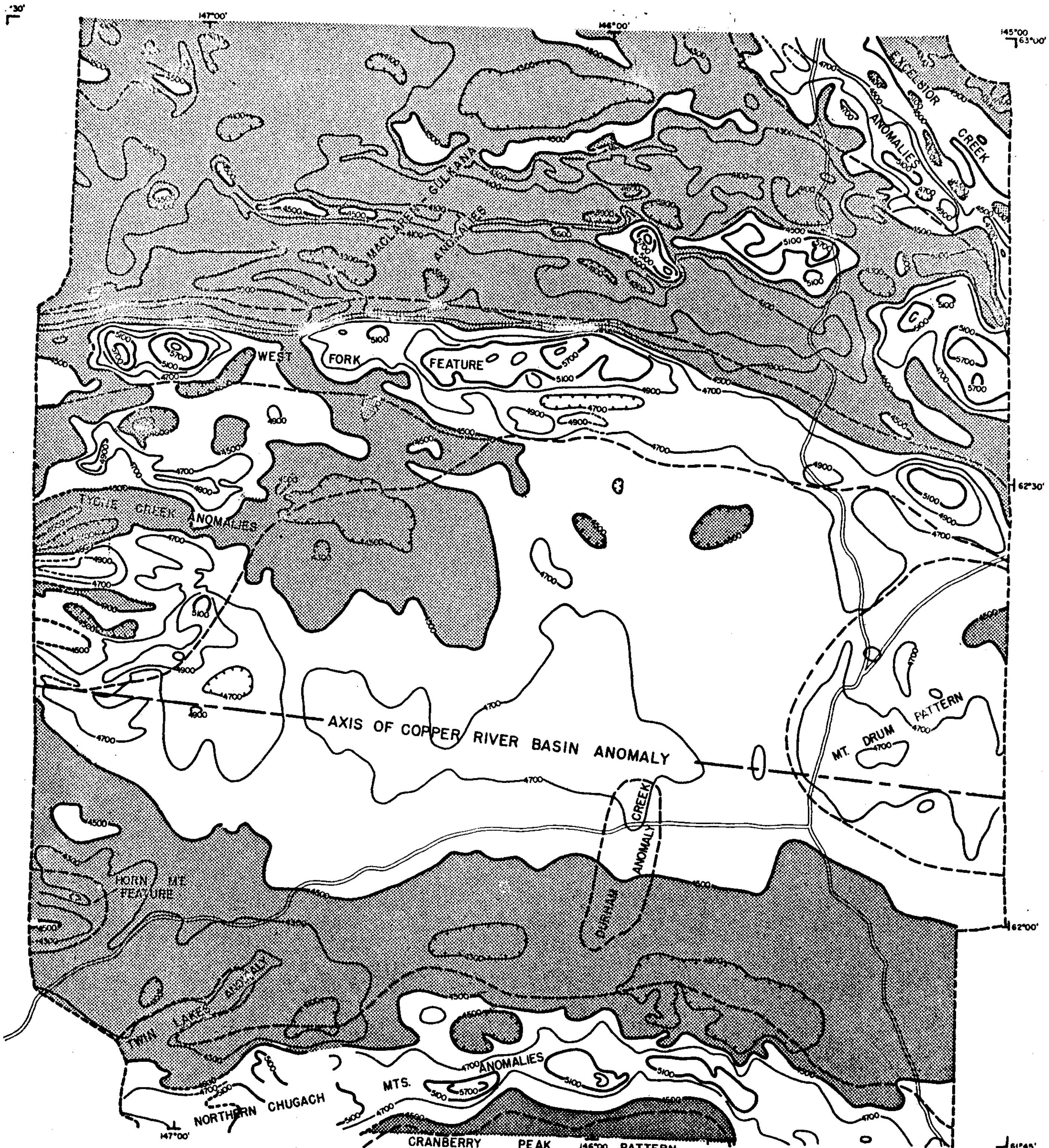

FIG. 4–SIMPLIFIED AEROMAGNETIC MAP OF THE COPPER RIVER BASIN SURVEY AREA, ALASKA
SHOWING PRINCIPAL MAGNETIC FEATURES
(Areas of less than 4500 gammas are shaded)

Contour intervals 200 and 600 gammas
Flight elevation 4000 feet above mean sea level

magnetic feature. Here numerous steep-gradient anomalies have amplitudes ranging from about 200 to 700 gammas. Another distinct group of magnetic anomalies, called the Mt. Drum pattern, occurs at the east edge of the area from about latitude 62°00' to 62°25'. These and several other magnetic features (named on figure 4) are discussed below.

Anomalies attributed to Triassic and Paleozoic rocks - northern one-third of the survey area

Excelsior Creek anomalies.-- The Excelsior Creek anomalies, located in the extreme northeast corner of the survey area (figs. 3 and 4), form belts of essentially linear magnetic highs and lows trending southeast. The individual anomalies range in amplitude from a few hundred gammas to about 1,200 gammas. The steep gradients characteristic of these anomalies indicate that the disturbing rock masses are at or very near to the ground surface. In figure 4 it is seen that these anomalies from a simple pattern of parallel regional anomalies if grouped with respect to the 4,500 gamma contour.

The Excelsior Creek anomalies are interpreted to be produced by southeast-trending belts of rocks which include the Permian and Triassic(?) basalt and andesite (TrPv on fig. 2). The volcanic rocks have been mapped over part of the southwesternmost of the two regional magnetic highs. The Excelsior Creek anomalies cross-cut the magnetic and geologic trend that is dominant to the west; hence the southwest margin of the anomalies is interpreted to mark a structural discontinuity.

Maclaren-Gulkana anomalies.-- Metamorphosed volcanic and sedimentary rocks of Carboniferous and older(?) age (Cvs) have been mapped in the aligned, isolated hills that trend eastward across the northern third of the survey area in the region of the Maclaren and Gulkana Rivers. Magnetically this area is characterized by east-trending belts of steep-gradient magnetic highs and lows ranging in amplitude from a few hundred gammas to over 2,000 gammas. The east-west magnetic lineations reflect the trends of the rock masses producing the anomalies, as in the case of the Excelsior Creek anomalies. The bands of magnetic highs may be produced by igneous rock and the bands of magnetic lows by weakly magnetic igneous rocks or by sedimentary rocks. Such alternating bands of igneous and sedimentary rocks could provide the appreciable and abrupt change in magnetic susceptibility or magnetite content necessary to produce the observed magnetic patterns. It is unlikely that topographic relief on the upper surface of the magnetic rock mass alone could account for the amplitudes of the observed magnetic anomalies in this area, though it may have increased them somewhat. The steep gradients characteristic of most of the Maclaren-Gulkana anomalies suggest that the magnetic rock masses are at or near the surface.

At present, the lack of detailed geologic information in the Maclaren-Gulkana area precludes any attempt to correlate magnetic patterns with rock types. For example, the magnetic effect of the numerous, but unmapped, igneous intrusive rocks of many types known to crop out in this area is uncertain. However, the three areas of igneous rock (Ui) shown on figure 2 are in the vicinity of magnetic lows.

The magnetic map with its pronounced magnetic trends should aid geologic mapping in this area where bedrock is in most places hidden by surficial deposits.

West Fork feature. -- The magnetic high that traverses the survey area at about latitude 62°35' is essentially one anomaly with several superimposed magnetic highs and lows. The West Fork of the Gulkana River closely follows this trend. This prominent magnetic anomaly, called the West Fork feature, is at least 75 miles long and averages 6 or 7 miles in width. The West Fork feature is essentially two-dimensional and its north slope is characterized by a remarkably linear magnetic gradient. This gradient indicates a significant and abrupt change in lithology, as might be produced by a linear rock mass with high magnetite content in contact along major faults or very steep contacts with rocks of much lower magnetite content. The south slope of the anomaly is obscured by many superimposed steep-gradient, intense magnetic highs and lows presumably produced by near-surface volcanic or intrusive rocks. The south edge is not as well defined as the north edge, and is obscure near the western part of the survey area. If the West Fork feature is extended west it trends into the dioritic rocks of the Talkeetna batholith in the Talkeetna Mountains.

Depth estimates to the upper surface of the disturbing mass may be calculated from the magnetic gradient on the north side of the feature. These depths range from 700 to 1,000 feet below land surface from the western edge of the survey area to the vicinity of Fish Lake, near longitude 146°00'. Just east of 146°00' the depth of the upper surface is about 1,500 feet, and where the Gulkana River crosses the feature, its depth is approximately 1,800 feet.

The top of the mass producing the anomaly continues to deepen to the east, and about two miles east of the Richardson Highway it is about 3,000 feet below ground surface. Estimates of depth to the feature near the eastern margin of the survey area are 4,000 to 5,000 feet. The gradient observed on the north side of the anomaly is steeper than the gradient on the south side, indicating that the disturbing mass dips south.

The West Fork feature changes in character along a northeast-trending magnetic contact near Fish Lake. West of Fish Lake the West Fork feature is characterized by numerous superimposed steep-gradient magnetic highs, while to the east the superimposed magnetic highs are subdued or absent. This change, and the deepening of the anomaly-producing mass east of Fish Lake, suggest that northeast-trending magnetic contact reflects a fault or flexure which places the disturbing rock mass at a greater depth to the east.

The West Fork feature lies between mapped areas of metamorphosed Carboniferous and older(?) volcanic and sedimentary rocks to the north and the partly altered volcanic rocks which crop out north of Tyone Lake and are tentatively correlated with the Lower Jurassic volcanic sequence. Possibly the south edge of the West Fork feature marks a contact or fault which forms the northern boundary of the Lower Jurassic volcanic rocks in the west half of the survey area. The volcanics are inferred (see following paragraph) to be absent or thin in the eastern part of the survey area. East of Fish Lake nonmagnetic rocks overlie the rocks producing the West Fork feature and presumably also overlie laterally adjacent nonmagnetic rocks that occur to the south.

Anomalies attributed to Lower Jurassic volcanic rocks - southwestern part of the survey area

The gnarled, steep-gradient, high amplitude magnetic anomalies observed in the west-central part of the survey area near Tyone Creek, Horn Mountains, and the northern Chugach Mountains, occur over Lower Jurassic volcanic rocks which are at or near the surface. Where the magnetic pattern becomes more open, gradients less steep, and amplitudes of anomalies lower, as between the Tyone Creek, Horn Mountains, and northern Chugach Mountains anomalies, the volcanic rocks are buried by sedimentary rock. The Lower Jurassic volcanic rocks exposed in the Tyone Creek area, the Horn Mountains, and the northern part of the Chugach Mountains, are inferred, on the basis of similar but subdued magnetic patterns, to be present beneath the sediments of the southern Copper River Basin, as far east as the dotted line near 146°15' west longitude. East of this line the magnetic pattern is different; the contours are more widely spaced, and the volcanic rocks may be inferred to be thin, absent, or deeply buried. The most plausible interpretation is the absence or great thinning of the volcanic rocks east of the dotted line because the Lower Jurassic volcanic rocks are reported to be absent from the section in the Chitina Valley (southeastern corner, fig. 2). The Tyone Creek anomalies and the small magnetic highs associated with the West Fork feature are believed to be produced by rocks of different lithology, but the boundary between the two is rather obscure. A dotted line on figure 3 approximately separates the two magnetic features.

Tyone Creek anomalies. -- The upper surface of the anomaly-producing rocks in the Tyone Creek area is calculated to be at or very near ground surface over most of the area west and north of the dashed line on figure 3. The rocks interpreted to produce most if not all of the Tyone Creek anomalies are the Lower Jurassic volcanic rocks (Talkeetna formation) which crop out over much of this area. The magnetic map shows that these volcanic rocks extend at shallow depth under the adjacent area to the north that is masked by alluvial or glacial deposits.

Areas where Lower Jurassic volcanic rocks are buried by nonmagnetic rocks. -- The dashed lines shown on the aeromagnetic map (fig. 3) approximately separate areas where magnetic rocks are at or near the surface from areas where magnetic rocks occur at greater depths. These lines, therefore, represent "lines of zero depth."

The magnetic pattern between the dashed "line of zero depth" bordering the northern Chugach Mountains anomalies, and the dotted line at about longitude 146°15' is also interpreted to have been produced by the Lower Jurassic volcanic rocks. However, the disturbing rocks in this area are further away from the plane of magnetic observation than in the Tyone Creek area, the Horn Mountains, or the northern Chugach Mountains, as evidenced by the less steep gradients and smaller amplitudes of the anomalies. The "line of zero depth" southeast of the Tyone Creek anomalies possibly represents a fault or homocline that may have placed the volcanic rocks at greater depths to the east and southeast.

It may be noted from an inspection of figure 3 that the magnetic pattern between the "lines of zero depth" shows a northeastern lineation approximately parallel to the trend of faults and fault blocks in the Nelchina area which lies immediately west of the southwestern Copper River Basin (fig. 2). This suggests that the structure of the southwestern Copper River Basin is similar to that of the Nelchina area. The anomalies in the southwestern Copper River Basin may be produced by magnetic rock masses at shallow or intermediate depths and might delineate steep-sided fault blocks or faulted anticlines such as occur at Sheep Mountain or the Horn Mountains in the Nelchina area. The magnetic field observed over the east end of the Horn Mountains fault block, for example, differs from the magnetic field to the north and to the south, where magnetic rocks are more deeply buried. The areas of lowest magnetic gradient and amplitude in the southwestern Copper River Basin might indicate interblock areas of thicker sediments.

The Lower Jurassic volcanic rocks producing the Tyone Creek and Horn Mountains anomalies are also present in the intervening area under a cover of Jurassic and Cretaceous marine sedimentary rocks. The marine rocks rest unconformably on the Lower Jurassic volcanic rocks and dip to the south and southeast from the area of the Tyone Creek anomalies to a structural low near the Little Nelchina River. Here the volcanic rocks are overlain by about 4,500 to 6,000 feet of sedimentary rocks. The increase in thickness of the marine sedimentary rocks from the Tyone Creek anomaly area to the vicinity of the Little Nelchina River is reflected by a similar increase in depths calculated from anomalies produced by the underlying volcanic rocks. The sedimentary rocks are about 4,000 to 5,000 feet thick at the fault bounding the Horn Mountains block on the north. South of this fault the Lower Jurassic volcanic rocks are at or near the surface.

If the magnetic character of the Lower Jurassic volcanic rocks in the southwestern Copper River Basin is essentially the same as in the areas of outcrop, and if they are at least a few thousand feet thick, it is possible to determine the approximate depth of the top of the magnetic blocks through application of the method of upward continuation developed by Henderson and Zietz (1949). A magnetic profile along a flight line over exposed Lower Jurassic volcanic rocks may be projected upward until it resembles an observed north-south profile over the area interpreted to be underlain by the same rocks at depth. As the magnetic profile is continued upwards, the gradients and amplitudes decrease. Profile A-A' (figs. 3 and 5) was continued upward to several levels of observation.

Figure 5. Upward continuation of the magnetic field observed over outcrops of Lower Jurassic volcanic rocks (A-A') compared to an observed magnetic profile (B-B') where these rocks are at depth.

The projected profiles were then compared to profile B-B' (figs. 3 and 5). Profiles A-A' and B-B' were observed at a flight elevation of 4,000 feet above mean sea level. When A-A' was continued upward to 9,000 and 10,000 feet above sea level, it compared favorably with profile B-B'. Magnetic

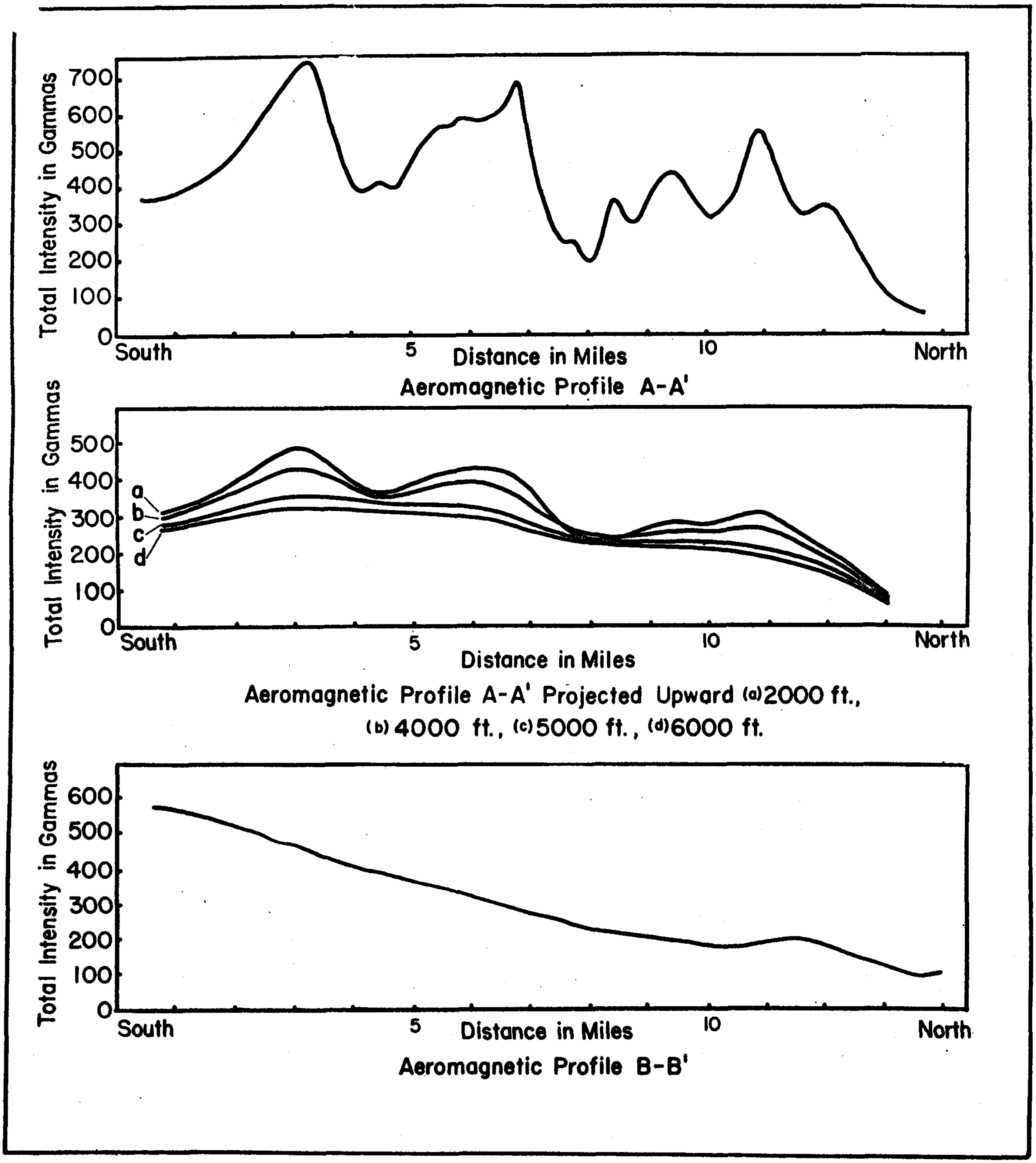

Figure 5 -- Upward continuation of the magnetic field observed over outcrops of Lower Jurassic volcanic rocks (AA') compared to an observed magnetic profile (BB') where these rocks are at depth.

profile A-A', its upward continuations, and B-B' are shown in figure 5. It is seen that profile A-A' would closely resemble B-B' if A-A' had been flown at 9,000 or 10,000 feet above mean sea level. Since the Lower Jurassic rocks are at or near the surface in the vicinity of A-A', they could very likely be present in the vicinity of B-B' at a depth equivalent to the distance of upward continuation, namely, 5,000 to 6,000 feet.

The depth estimate determined by the use of the upward continuation method is consistent with the depth estimates obtained by the Vacquier method (Vacquier and others, 1951) but is considered maximal because of the assumptions inherent in the method of upper continuation. Though most of the magnetic anomalies in the area where volcanic rocks are thought to occur at depth are not entirely satisfactory for depth analysis, their slopes indicate that where they are closest to the surface the disturbing rock masses are buried from 2,000 to 5,000 feet below land surface. However, if the inferred volcanic rocks thin significantly to the east, depth estimates based on the anomalies may be too shallow; hence the anomaly-producing rocks may be more deeply buried.

Horn Mountains feature. -- The Horn Mountains can be idealized as a fault block of Lower Jurassic volcanic rocks in contact with sedimentary rocks to the north and to the south. The volcanic rocks produce two steep-gradient magnetic anomalies, called the Horn Mountains feature, which extend east into the Copper River Basin approximately five miles beyond the last outcrops of volcanic rocks. They are here terminated by a northeast-trending magnetic gradient (fig. 3) that could possibly have been produced by the fault bounding the Horn Mountains fault block on the east. Another magnetic gradient coincides with and is interpreted to represent the north-bounding fault of the Horn Mountains fault block. This gradient continues east-southeastward from the last exposure of the fault and terminates at the northeast-trending gradient. The faults bounding the Horn Mountains on the north and south sides and their extensions determined from the magnetic data conform to the patterns of faulting observed in the Nelchina area.

Northern Chugach Mountains anomalies. -- The steep-gradient, east-trending intense magnetic anomalies observed over the northern Chugach Mountains are essentially uniform in character across the survey area and are produced by magnetic rocks at or near the surface. These anomalies are attributed to Lower Jurassic lavas and tuffs, known to crop out in the northern Chugach Mountains as far east as Tazlina Lake. Similar rocks, whose age has not been determined, continue in the foothills to St. Anne Lake and possibly to the southeastern corner of the survey area. The rocks east of St. Anne Lake were considered by Chapin (1918) to be of Early Jurassic age and by Moffitt (1938) to be of Carboniferous age. The numerous plutons known to be present in the northern Chugach Mountains are not sufficiently well mapped to permit correlation with the observed magnetic anomalies. However, some of these are associated with magnetic highs.

The low-gradient, east-trending magnetic contours observed in the southeastern Copper River Basin just north of the Chugach Mountains anomalies indicate that if the magnetic rocks producing the northern Chugach Mountains anomalies continue northward under the sediments of the south-eastern

Copper River Basin, they are deeply buried.

Twin Lakes anomaly. -- An irregular faulted anticline, in places exposing Lower Jurassic volcanic rocks along its axis, is located about one mile south of Twin Lakes, in the southwestern corner of the survey area (figs. 2 and 3). The flanks of the structure consist of Cretaceous marine sedimentary rocks. The contrast between the magnetic susceptibility of the volcanic rocks and the essentially nonmagnetic sedimentary rocks produces the sharp Twin Lakes magnetic anomaly along the crest of the structure. The anomaly and the faulted anticline have a northeastern trend. The anomaly continues into the Copper River Basin, a few miles beyond the last outcrops.

Anomalies in the southeastern part of the survey area

Durham Creek anomaly. -- The magnetic anomaly observed in the central part of the Copper River Basin, several miles north of the Chugach Mountains near Durham Creek, has a maximum amplitude of about 125 gammas at its south end. This high yields a depth estimate of 2,000 feet to 3,000 feet to the upper surface of the disturbing mass. Magnetic rocks causing this high apparently continue northward at an indeterminable depth about five miles north of the Glenn Highway, as evidenced by the flexure in the east-west trending magnetic contours. This area is approximately enclosed by the dotted line (fig. 3).

The Durham Creek anomaly is caused by a magnetic rock mass that is not deeply buried. The magnetic rock is most likely igneous and the low amplitude anomaly could be produced by a local, steep-sided, structural high on a magnetic basement surface, or may indicate an intrusive body. A few other anomalies with north-south trends, but much smaller and with lower amplitudes occur to the east and west at the Durham Creek anomaly.

Cranberry Peak pattern. -- The Cranberry Peak pattern, located between the dotted line and the southern border of the survey area (fig. 3), is characterized by low magnetic gradients. This pattern is interpreted to have been produced by the metamorphosed sedimentary rocks of Carboniferous and older (?) age which are reported just north of Klutina Lake in the vicinity of Cranberry Peak. Most of the area that is mapped as metasedimentary rock is characterized by low magnetic gradients except in the extreme northeast part. The approximately 2,000 gamma anomaly northeast of Mt. Carter cannot be attributed to the metasedimentary rocks mapped there and suggests that this area is underlain at shallow depths, or at the surface, by the rocks that produce the northern Chugach Mountains magnetic anomalies.

Mt. Drum pattern. -- The Mt. Drum anomalies comprise a magnetic pattern that projects fanlike from the eastern edge of the survey area (fig. 3). The magnetic pattern is interpreted to have been produced by andesitic lavas from the now extinct and dissected Mt. Drum volcanic cone, the most westerly of the group of volcanoes which form the Wrangell Mountains. This interpretation is based on the proximity of the magnetic pattern to Mt. Drum, its coincidence with the topographic apron of Mt. Drum, and its semicircular outline concentric to the mountain.

The anomalies within the Mt. Drum pattern are considered unsuitable for quantitative depth analysis. However, the steep magnetic gradients seen in the center of the pattern near the edge of the survey area suggest that the lavas there are at or near ground surface. The magnetic gradients diminish toward the semicircular rim of the pattern indicating that the lavas become thinner and more deeply-buried, perhaps more than 500 feet near the rim.

Copper River Basin anomaly. -- Immediately north of the Glenn Highway is a very broad east-trending magnetic anomaly with an amplitude of approximately 300-400 gammas (fig. 4). Its character may be seen in figure 6

Figure 6. Three north-south aeromagnetic profiles across the Copper River Basin survey area, Alaska.

---

which shows three observed north-south magnetic profiles across the survey area along traverses a-a', b-b', and c-c' (fig. 2). The axis of the anomaly, approximately located along latitude 62°15', follows the projected trend of the Matanuska geosyncline, but lies north of its deepest part on what may be tectonically the more stable side of the geosyncline. The large amplitude and low gradient of the Copper River Basin anomaly indicate that it is produced by a magnetic block (possibly a plutonic rock mass) whose upper surface may be buried as much as 10 miles. Similar magnetic anomalies over geosynclinal belts have been observed over the Cook Inlet (Grantz, Zietz, and Andreasen, 1960) and the Great Valley of California (Grantz and Zietz, 1960).

Areas where sedimentary rocks may be thick

Low gradient, or "flat," magnetic patterns often indicate great thicknesses of sedimentary rocks. However, the same pattern could be produced by near-surface nonmagnetic crystalline rocks. Additional information, geologic or geophysical, is often necessary to help resolve this inherent ambiguity. Furthermore, igneous rocks (some lavas, for example) within a sedimentary section may produce magnetic anomalies of sufficient intensity to effectively mask anomalies produced by any magnetic rocks occurring beneath the entire sedimentary section. In such cases, only the thickness of the sedimentary rocks above the volcanic rocks within the sedimentary section may be estimated.

In the southern half of the Copper River Basin there are significant areas of low magnetic gradient. In the southwest, sedimentary rocks may be locally thick where they overlie volcanic rocks. The magnetic lineations here may reflect structural patterns similar to the Nelchina area and the observed magnetic gradients may be caused by fault blocks or faulted anticlines of Lower Jurassic volcanic rocks, as in that area. The magnetic rocks are estimated to be buried 2,000 to 5,000 feet below land surface. If, however, the magnetic rocks are thin, these depth estimates would be too shallow. Areas of very low magnetic gradient may reflect the interblock areas where sedimentary rocks are thicker. One of these areas southwestward from Old Man Lake (between Lake Louise and Glenn Highway).

An extensive area of very low magnetic gradients, and possibly thick sedimentary rocks, occurs in the southeastern part of the Copper River

Basin of the Mt. Drum pattern. This area is bounded on the north by the West Fork feature and on the south by the northern Chugach Mountains anomalies. Within this general area are three zones of especially low magnetic gradients: (1) the Copper Center vicinity, (2) the area south of Crosswind Lake, and (3) the area between Gulkana and Ewan Lake.

The preliminary map of simple Bouguer gravity anomalies, shown in figure 7, provides some additional geophysical information relevant to

---

Figure 7. Preliminary map of simple Bouguer gravity anomalies in Copper River Basin, Alaska.

---

the southern half of the Copper River Basin. An interpretation of this map, however, is beyond the scope of this report. It has been included only to show the close agreement between areas of gravity minima, which may indicate great thicknesses of sedimentary rock, and areas of low magnetic gradient.

The gravity map shows three distinct minima, or negative anomalies. The largest of these is centered around Old Man Lake and extends over most of the southwestern Copper River Basin. This gravity minimum, called Old Man Lake gravity anomaly, correlates with the generally low magnetic gradients characteristic of this area. A second gravity minimum occurs in the southeastern Copper River Basin in the vicinity of Glennallen. This gravity minimum, called the Glennallen gravity anomaly, correlates with the low magnetic gradients in the Copper Center vicinity. The third gravity minimum, called the Gakona gravity anomaly, occurs north and west of the settlement of Gakona. The magnetic gradients in this area are also low. The absence of closure of the Glennallen and Gakona gravity anomalies, which are open to the east, may be attributed to their nearness to an isostatic low associated with the Wrangell Mountains.

The Glennallen gravity anomaly is along the projection of the belt of Mesozoic and Tertiary sedimentary rocks which occur along the southern side of the Wrangell Mountains and occurs over an area of very low magnetic gradients which trends through Copper Center and Glennallen. Another area of low magnetic gradients and low gravity along this same projection lies south and southeast of Crosswind Lake. If the Mesozoic and Tertiary sedimentary rocks mapped on the south side of the Wrangell Mountains extend northwestward into the Copper River Basin, they may be thickest in the very low magnetic gradient area trending through Copper Center and Glennallen and in the area south and southeast of Crosswind Lake. This area trends just north of the Durham Creek magnetic anomaly.

The area of lowest magnetic gradient between the settlement of Gulkana and Ewan Lake is slightly southwest of the Gakona gravity anomaly area, but the magnetics are also low-gradient over the area of the gravity anomaly except southeast of Gakona where the magnetic patterns reflect the occurrence of the Mt. Drum lavas.

The magnetic and gravity data do not preclude the occurrence of non-magnetic crystalline rocks at shallow depths in the eastern Copper River Basin. Indeed, crystalline rocks (metamorphosed Carboniferous sedimentary rocks) crop out in areas of rather low magnetic gradients and low gravity along the Edgerton Highway. However, lower magnetic gradients and lower gravity are observed immediately to the north of this area in the belt of very low magnetic gradients trending through Copper Center.

In general, the agreement between areas of low magnetic gradients and gravity minima strengthens the possibility that thick sections of sedimentary rocks underlie many parts of the southern Copper River Basin. In the southwestern part of the Copper River Basin the sedimentary section may include an unknown thickness of volcanic rocks.

Conclusions

The aeromagnetic data observed over approximately 6,000 square miles in the Copper River Basin provide considerable information of geologic interest. In general, the magnetic patterns correlate with the regional east-trending geologic grain and topographic features. Areas where volcanic rocks crop out are well defined by the observed magnetic patterns and these rocks are reliably interpreted to be present elsewhere under a cover of younger nonmagnetic rocks.

Approximately the northern one-third of the survey area is characterized by bands of steep-gradient east-trending magnetic highs and lows produced by alternating bands of magnetic and nonmagnetic rocks at or near the land surface. The lack of detailed geologic mapping in this area precludes positive correlation with rock units. The observed magnetic patterns, however, should be of considerable help in future geologic mapping.

The magnetic anomalies observed in the west-central part of the survey area are produced by the Lower Jurassic volcanic rocks of the Talkeetna formation. The magnetic pattern over most of the southwest part of the survey area is interpreted to have been produced by the Lower Jurassic volcanic rocks generally present under the sedimentary rocks at depths ranging from about 2,000 to 5,000 feet, or more if the volcanic rocks are thin.

The steep-gradient, high amplitude magnetic anomalies elongated in an easterly direction over the northern Chugach Mountains, are interpreted to have been produced by volcanic rocks with associated intrusives. The metamorphosed sedimentary rocks of Carboniferous and older(?) age reported in the Cranberry Peak area of the northern Chugach Mountains are characterized by low magnetic sediments.

The lavas of the Wrangell Mountains are well outlined by their magnetic pattern. They deepen and probably thin to the west, and in the vicinity of Glennallen may be covered by 500 feet, or more, of glacial deposits.

Two broad areas with low-gradient magnetic intensity occur in the Copper River Basin. The first area occupies the southwestern part of the survey area. The second area approximately parallels the course of the Copper River. Within the latter area are three zones of very low-gradient magnetic intensity: (1) the Copper Center vicinity, (2) the area immediately south of Crosswind Lake, and (3) the area between Gulkana and Ewan Lake.

Three negative gravity anomalies, which may indicate areas where sedimentary rocks are thick, correlate with areas of low magnetic gradients: a broad easterly-trending gravity low in the southwest Copper River Basin centered approximately at Old Man Lake; a gravity low in the vicinity of Glennallen; and a gravity low north and west of Gulkana.

Literature cited

Andreasen, G. E., Dempsey, W. J., Henderson, J. R., and Gilbert, F. P., 1958, Aeromagnetic map of the Copper River Basin, Alaska: U. S. Geol. Survey Geophys. Inv. Map GP-156.

Chapin, Theodore, 1918, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, 67 p.

Grantz, Arthur, 1953, Geology of the Nelchina area, Alaska: U. S. Geol. Survey open-file report.

Grantz, Arthur, Zietz, Isidore and Andreasen, Gordon, 1960, An aeromagnetic reconnaissance of the Cook Inlet area, Alaska: U. S. Geol. Survey open-file report.

Grantz, Arthur, and Zietz, Isidore, 1960, Possible significance of broad magnetic highs over belts of moderately deformed sedimentary rocks in Alaska and California: U. S. Geol. Survey Prof. Paper 400 B.

Henderson, R. G., and Zietz, Isidore, 1949, The upward continuation of anomalies in total intensity fields: GEOPHYSICS, v. 14, no. 4, p. 517-534.

Mendenhall, W. C., 1905, Geology of the Central Copper River Region, Alaska: U. S. Geol. Survey Prof. Paper 41, 133 p.

Moffit, F. H., 1912, Headwater regions of Gulkana and Susitna Rivers, Alaska: U. S. Geol. Survey Bull. 498, 82 p.

____________, 1938, Geology of the Chitina Valley and adjacent area, Alaska: U. S. Geol. Survey Bull. 894, 137 p.

___________ , 1938, Geology of the Slana-Tok district, Alaska: U. S. Geol. Survey Bull. 904, 54 p.

Moffit, F. H., 1954, Geology of the eastern part of the Alaska Range and adjacent area: U. S. Geol. Survey Bull. 989-D, p. 63-218.

Payne, T. G., 1955, Mesozoic and Cenozoic tectonic elements of Alaska: U. S. Geol. Surv. Misc. Geol. Inv. Map I-84.

Thiel, E., Bonini, W. E., Ostenso, N., and Woollard, G. P., 1958, Gravity measurements in Alaska: Woods Hole Oceanographic Institution, Tech.Reports, Ref. 58-54, 104 p.

Vacquier, V., Steenland, N. C., Henderson, R. G., and Zietz, I., 1951, Interpretation of aeromagnetic maps: Geol. Soc. America, Memoir 47, 151 p.

Vestine, E. H., Laporte, L., Lange, I., Cooper, C., and Hendrix, W. C., 1947, Description of the earth's main magnetic field and its secular change, 1905-1945: Dept. of Terrestrial Magnetism, Carnegie Institute of Washington, Pub. 578, p. 466.