An Aeromagnetic Reconnaissance of the Cook Inlet Area Alaska

By ARTHUR GRANTZ, ISIDORE ZIETZ, *and* GORDON E. ANDREASEN

GEOPHYSICAL FIELD INVESTIGATIONS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 316-G

A regional geologic interpretation of the magnetic field over the Cook Inlet area

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

GEOPHYSICAL FIELD INVESTIGATIONS

AN AEROMAGNETIC RECONNAISSANCE OF THE COOK INLET AREA, ALASKA

By Arthur Grantz, Isidore Zietz, and Gordon E. Andreasen

ABSTRACT

Forty-two east-west aeromagnetic lines were flown across the Cook Inlet-Susitna Lowland between Chelatna Lake and Seldovia at a flight altitude of about 2,500 feet. The lines traverse all or part of five Mesozoic tectonic elements that dominate the structure of the Cook Inlet area. Each of these tectonic elements, the Alaska Range geosyncline, the Talkeetna geanticline, the Matanuska geosyncline, the Seldovia geanticline, and the Chugach Mountains geosyncline, has a characteristic magnetic pattern.

The aeromagnetic data, compiled as total-intensity aeromagnetic profiles, show several significant features which are consistent with the structural grain of the area. A two-dimensional anomaly was observed near the east edge of the area on all but the southernmost profiles, where it became obscure. Geologic evidence suggests that this feature, the Knik Arm anomaly, is produced by plutonic rocks that have been intruded along the Seldovia geanticline. Southeast of this anomaly the profiles are almost flat. This flatness indicates that magnetic rocks are deeply buried in this area, which is underlain by slate and graywacke deposited in the Chugach Mountains geosyncline.

Near the west shore of Cook Inlet the character of the magnetic profiles changes abruptly. The line of change, called the Moquawkie magnetic contact, indicates a lithologic change trending northeast. To the northwest there are many large steep-gradient anomalies and to the southeast the anomalies have gentle gradients. In the north this inferred contact is correlated with the Castle Mountain high-angle reverse fault which has been mapped along the north side of the Matanuska Valley. This fault separates the volcanic and plutonic rocks of the Talkeetna geanticline to the northwest from the sedimentary rocks of the Matanuska geosyncline to the southeast. In lower Cook Inlet the Moquawkie magnetic contact joins the Bruin Bay fault. Between these faults the Moquawkie contact marks the position of smaller faults or an unconformity between sedimentary rocks to the southeast that rest on, or are faulted against, volcanic or plutonic rocks to the northwest.

In the northwestern part of the Susitna Lowland the magnetic profiles are almost flat, and are interpreted to occur over slate and graywacke deposited in the Alaska Range geosyncline. The change to this magnetic pattern from the pattern with steep gradients over the Talkeetna geanticline is abrupt. The line of change is called the Peters Creek magnetic contact.

The aeromagnetic profiles are smoothest, and therefore sedimentary rocks of the Matanuska geosyncline and Shelikof trough are inferred to be thickest, in the area between the Moquawkie contact on the northwest and the Knik Arm anomaly and the west front of the Kenai Mountains on the southeast. It is inferred that most of the Susitna and Beluga Lowlands are not underlain by great thicknesses of sedimentary rocks. However, sedimentary rocks may be thick under part of the Beluga Lowland south of Beluga Lake and under part of the central portion of the Susitna Lowland.

INTRODUCTION

The coal-bearing and petroliferous strata of Cook Inlet have been known since the 18th- and 19th-century European explorations in Alaska, and detailed studies of the limited areas in which they crop out are now well advanced. Most of the Cook Inlet-Susitna Lowland is covered by the waters of Cook Inlet and by extensive deposits of glacial and alluvial materials. The coal-bearing rocks, which are of early Tertiary age, can be studied at relatively few places. The strata from which oil and gas seepages are known are of Mesozoic age and crop out in only two areas, both at the margins of the Cook Inlet Lowland. Thus, the data needed to estimate the areal extent, structure, and thickness of these deposits must come from geophysical investigations or exploratory drilling.

In 1954 the Geological Survey undertook a reconnaissance airborne magnetometer survey of the Cook Inlet-Susitna Lowland (figs. 43, 44) as a first step toward a regional understanding of the subsurface geology and the evaluation of the petroleum potential of the covered areas. The presence of linear structural-lithologic elements in the Cook Inlet region, commonly resulting in juxtaposed belts of contrasting magnetic properties, made the method seem particularly applicable.

AEROMAGNETIC DATA

Forty-two east-west aeromagnetic lines were flown across the Cook Inlet-Susitna Lowland during June of 1954 and 1958 at an altitude of about 2,500 feet above sea level except where higher altitudes were required to clear mountainous terrain. The lines, which are plotted on plate 18, are widely spaced and only regional trends were investigated. Between Anchorage and Houston the flight lines are 2 miles apart but elsewhere they may be as much as 16 miles apart. Because of the wide spacing no attempt was made to construct a contoured map.

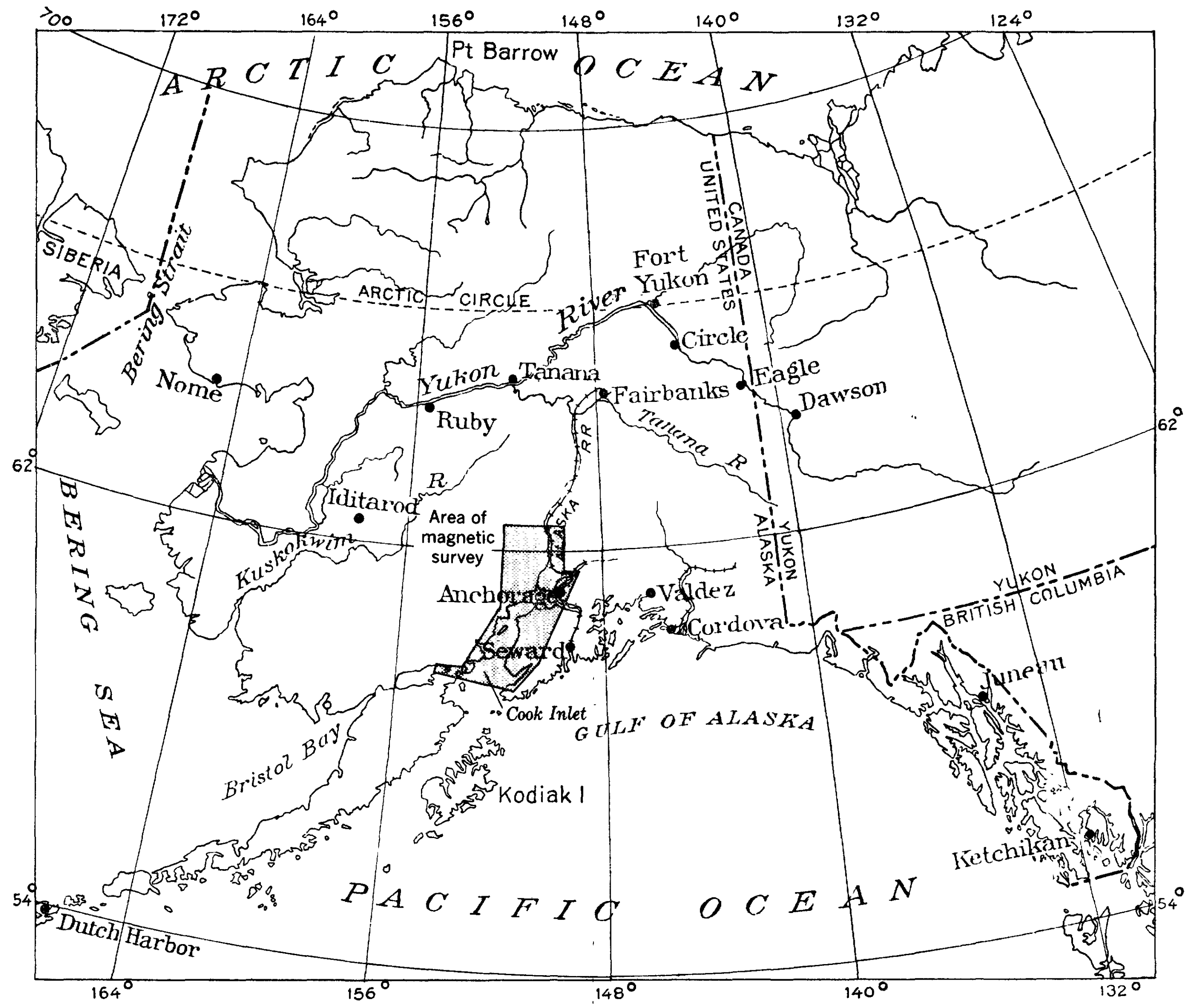

FIGURE 43.—Index map of Alaska showing location of Cook Inlet and the area surveyed with the airborne magnetometer.

All the lines extend eastward from the foothills of the southern Alaska Range. The northern lines terminate in the foothills of the Talkeetna Mountains, the southern lines at the western front of the Chugach-Kenai Mountains. The northernmost line (25) crosses the Susitna Lowland 5 miles north of Talkeetna and the southernmost line (213) crosses lower Cook Inlet from Ursus Cove to Seldovia.

Continuous total-intensity aeromagnetic profiles were made with a modified AN/ASQ-3A airborne magnetometer which has a detecting element towed about 75 feet below the airplane. Flight lines plotted on reconnaissance topographic maps (scale 1:250,000) were used for pilot guidance and the actual flight path was recorded by a gyrostabilized continuous-strip camera. The aeromagnetic data have been compiled as total intensity magnetic profiles and are shown on plates 19, 20, and 21. The profiles are not adjusted to a common datum. Major checkpoints appear on plate 18 and on the corresponding profiles on plates 19, 20, and 21.

METHODS OF INTERPRETATION

The principal method for estimating the depth of magnetic rocks that was used in the present investigation is based upon the work of Vacquier and others (1951). They found that the depth to the top of a magnetic mass represented by a suitable anomaly approximates the horizontal extent of the steepest slope of the anomaly measured normal to the magnetic contours. Depth approximations based upon profiles that are oblique to the magnetic contours are too large and must be adjusted. Some depth estimates based upon the half-widths of small anomalies were also made.

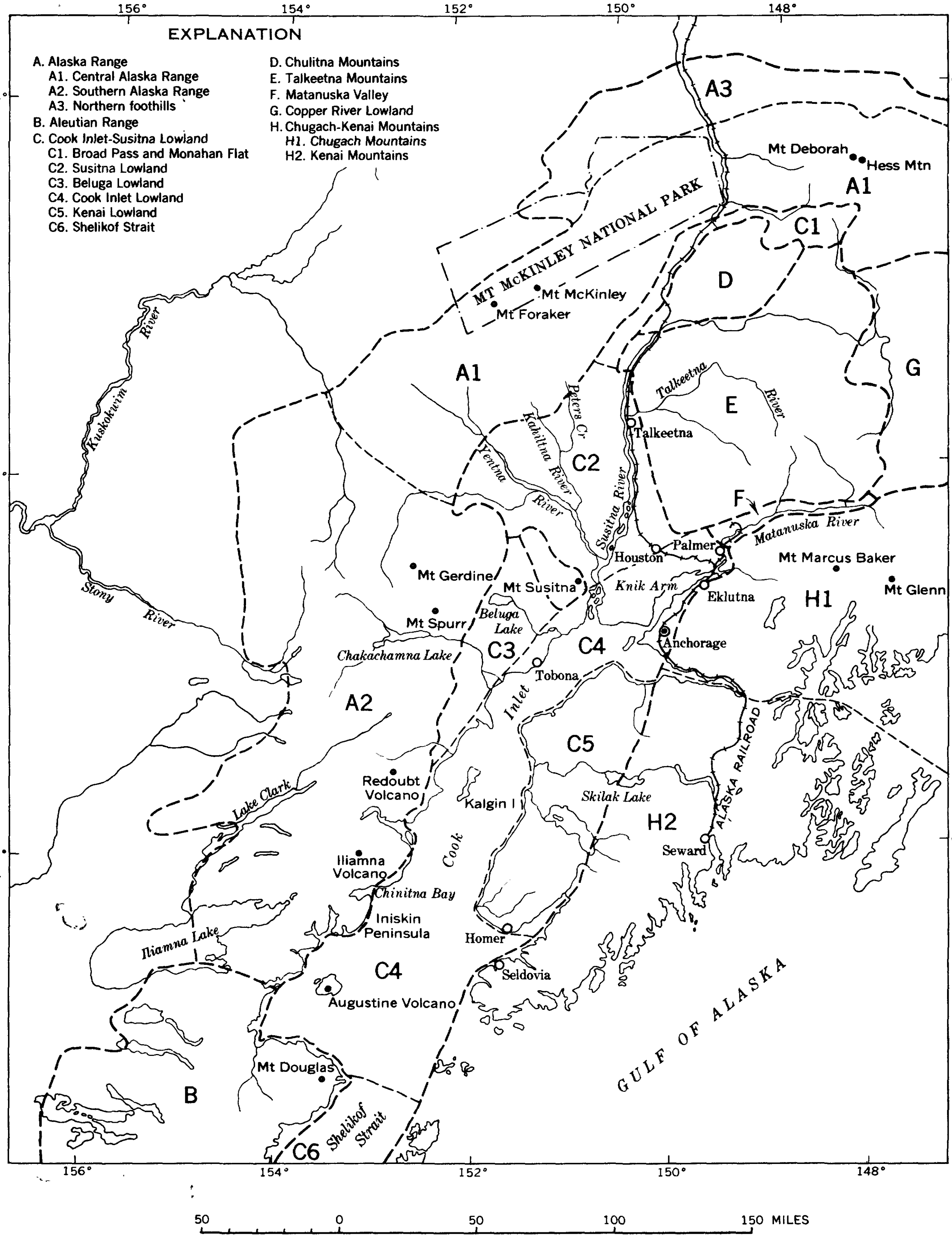

FIGURE 44.—Major physiographic provinces of the Cook Inlet area, Alaska.

The simplifying physical assumptions upon which the principal method of depth estimation depends are summarized by Zietz and Henderson (1955). Although presented in terms of susceptibility contrasts in the crystalline basement, the method can also be applied to areas such as Cook Inlet, where magnetic rocks occur above crystalline basement. Anomalies for which the assumption of infinite depth is not valid will yield depth estimates that are too shallow. Zietz and Henderson (1955, p. 307) state:

It is assumed that anomalies large in areal extent and amplitude are usually due to lithologic contrasts in the basement complex rather than to the relief of the basement surface. This assumption is based on theoretical considerations, since sharp topographic rises in the basement rock will yield anomalies of relatively small amplitude. It is assumed further that the basement rocks are either magnetized by induction in the earth's magnetic field or have a remanent magnetization in the direction of the field and that this magnetization is constant with depth. In addition, the basement is assumed to be broken up into regions having vertical sides, plane horizontal surfaces with rectangular cross sections, infinite depth extent, and internal magnetic homogeneity. These are assumptions of mathematical convenience but they are not entirely without justification.

In general, sedimentary rocks have very low magnetic susceptibilities while those of most igneous rocks are moderate to strong; however, exceptions are not uncommon. At a few places in the Cook Inlet area evidence indicates that these generalizations may need to be modified.

REGIONAL GEOLOGY

MAJOR TECTONIC ELEMENTS

The generalized geology of the Cook Inlet area is shown on plate 18. Geologically this area is dominated by five narrow, parallel, and arcuate tectonic elements developed in Mesozoic time upon which a subparallel trough was superimposed in Eocene time (Payne, 1955). These are outlined in figure 45. The rocks of the Alaska Range geosyncline trend west and southwest from the vicinity of Mount Hayes across the southern two-thirds of the Alaska Range and the northwest Susitna Lowland. The Talkeetna geanticline trends through the southern Talkeetna Mountains and the southern Alaska Range. The rocks of the Matanuska geosyncline underlie the Matanuska Valley and the southeast side of the Alaska Peninsula and are inferred to underlie a large part of the Cook Inlet and Kenai Lowlands. The rocks that were uplifted in the Seldovia geanticline crop out in the northwest foothills of the Chugach-Kenai Mountains near Seldovia and northeast of Skilak Lake and are inferred to underlie the southeast side of the Cook Inlet and Kenai Lowlands. The rocks of the Chugach Mountains geosyncline underlie the central Chugach-Kenai Mountains and border the Kenai Lowland near Tustumena Lake. Nonmarine sedimentary rocks that were deposited in the Shelikof trough in Eocene time underlie the Cook Inlet-Susitna Lowland.

References to sources of the information in this geologic summary would be so numerous as to be cumbersome, and are omitted. The summary is drawn from the geologic reports on Alaska that are listed in "Selected references" and from unpublished work by the Geological Survey. Some reinterpretation of the data in these reports has been incorporated in the following sections.

ROCK UNITS

The oldest rocks known in the area are metamorphic rocks of Precambrian or early Paleozoic age, which crop out near Iliamna Bay and at Willow Creek, in the southwestern Talkeetna Mountains. Slate and chert, probably of late Paleozoic age, also crop out near Iliamna Bay. Basalt and diabase, altered to greenstone and probably of Permian or Triassic age, crop out near Iliamna Bay and also south of Kachemak Bay, where they may be over 3,000 feet thick. Limestone and chert of Late Triassic age also crop out in both areas; near Iliamna Bay these are over 3,000 feet thick and include the Kamishak formation. A belt of crystalline limestone and siliceous schist that strikes a little east of north through the entrance to Seldovia Bay may be Late Triassic limestone and chert that has been metamorphosed in a fault zone. Crystalline limestone, slate, and quartzite, possibly Triassic in age, occur along the margin of the batholith in the western Talkeetna Mountains.

A thick sequence of interbedded lava flows and pyroclastic and marine sedimentary rocks of Early Jurassic age, locally assigned to the Talkeetna formation, is widespread in the Cook Inlet area and probably underlies the Matanuska geosyncline and most of the Cook Inlet Lowland at depth. These rocks are 8,000 or more feet thick west of Cook Inlet, and several thousand feet thick near the upper Matanuska Valley. The volcanic rocks are more or less altered and usually described as greenstones. Andesite predominates but rhyolite, basalt, and dacite are locally abundant.

Over much of the northwest Susitna Lowland and adjacent slopes of the Alaska Range a thick sequence of slate, argillite, and graywacke with some conglomerate and quartzite is exposed. These rocks are folded and faulted, often complexly, and contain large plutons. They have yielded fossils that are of Jurassic or Cretaceous age, and fossils of Early Cretaceous age have been found in similar rocks in the Chulitna drainage (Inlay and Reeside, 1954, p. 235–236). The Tordrillo formation of the Alaska Range and slate, graywacke,

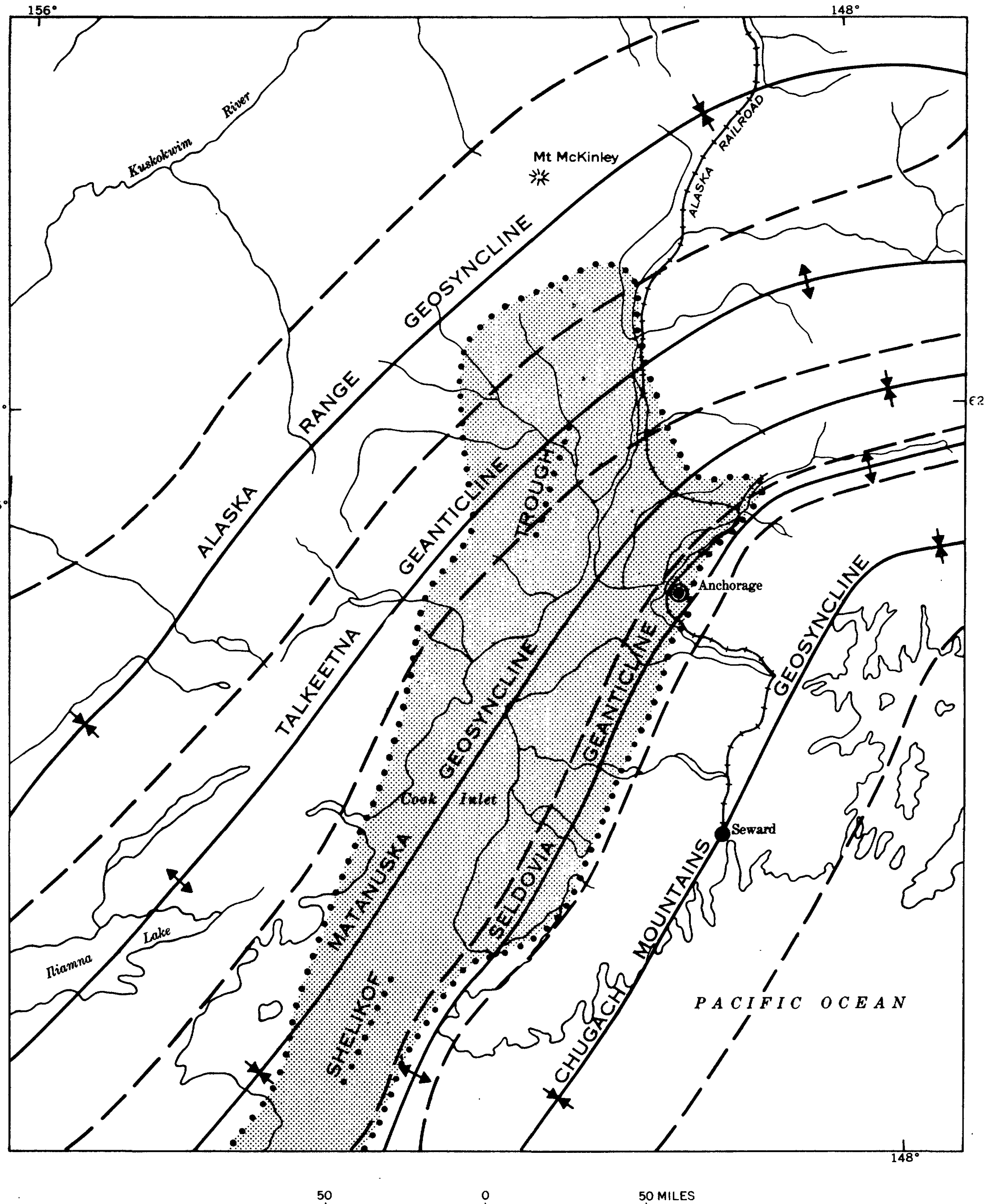

FIGURE 45.—Outline of the Mesozoic and Cenozoic tectonic elements of the Cook Inlet area, Alaska. (After Payne, 1955.)

and microcrystalline schist north of the lower Talkeetna River (Paige and Knopf, 1907, p. 11–12) are mapped with the slate and graywacke of the Susitna Lowland on plate 18.

A great thickness of clastic rocks was deposited in the Chugach Mountains geosyncline in Jurassic and Cretaceous time. These rocks border the Kenai Lowland between Kachemak Bay and Skilak Lake and may underlie it in the adjacent area.

The Matanuska geosyncline received clastic marine sediments during Middle Jurassic through Late Cretaceous time. It probably was not as deep as the adjacent and largely contemporaneous Alaska Range and Chugach Mountains geosynclines. It was more stable while receiving sediments and did not subsequently undergo the intense deformation that characterizes the adjacent geosynclines. The sedimentary rocks of the Matanuska geosyncline are characterized by sandstones that are gradational in lithology between graywacke and arenite, whereas the sedimentary rocks of the Alaska Range and Chugach Mountains geosynclines are characterized by graywacke. At the head of the Matanuska River and elsewhere in southern Alaska, and therefore possibly in the Cook Inlet area, the Middle Jurassic through lower Lower Cretaceous sedimentary rocks are thickest in the north side of the Matanuska geosyncline and the upper Lower and Upper Cretaceous sedimentary rocks are thickest in the south side of the geosyncline. West of Cook Inlet, Middle and Upper Jurassic sedimentary rocks of the Matanuska geosyncline have been divided into the Tuxedni, Chinitna, and Naknek formations and are about 15,000 feet thick. In the Matanuska Valley the Matanuska formation of late Early and Late Cretaceous age was deposited in the geosyncline and is more than 4,000 feet thick. In the headwaters of the Matanuska River the Matanuska formation may be as much as 14,000 feet thick, and the Middle Jurassic through Lower Cretaceous beds of the Tuxedni, Chinitna, and Naknek formations and Nelchina limestone are about 9,000 feet thick.

Beginning in early Middle Jurassic time large batholiths intruded the Lower Jurassic rocks of the southern Alaska Range and Talkeetna Mountains and either initiated or coincided with the formation of the Talkeetna geanticline. Either at this time, or as late as Early Cretaceous, stocks and a small batholith intruded the Lower Jurassic and older rocks in the northwest foothills of the Chugach-Kenai Mountains and may have been associated with the formation of the Seldovia geanticline. The batholiths and stocks in each of these areas are composed chiefly of quartz diorite, but contain very large masses of diorite, granodiorite, and other types of granitic rock.

Large areas in the southern Alaska Range west and north of Beluga Mountain are underlain by plutons of Jurassic(?) and Cretaceous age. Here granites are most abundant but dioritic rocks also occur. These plutons intrude Jurassic or Cretaceous sedimentary rocks and may be younger as a group than the predominantly dioritic intrusive bodies that lie closer to the Matanuska geosyncline.

Nonmarine sedimentary rocks of the Chickaloon formation and the overlying Wishbone formation were deposited in the Matanuska Valley area in Paleocene and Eocene time. These rocks are between 5,000 and 7,000 feet thick and are overlain by 700 feet or more of nonmarine conglomerate—the Tsadaka formation of Eocene or younger age.

The Shelikof trough received nonmarine sediments of the Kenai formation in Eocene or later time. This formation crops out at many places in the Cook Inlet area. Outcrops in the southern Kenai Lowland expose more than 5,000 feet of the formation, but its base is not exposed there. Wells drilled for oil in the west part of the lowland penetrated between 2 and 3 miles of nonmarine Tertiary sedimentary rocks. In the Tustumena Lake area nonmarine Teritiary sediments occur which may be younger than the Kenai formation, and in the Yentna district the formation is in places overlain by later Tertiary conglomerate.

Remnants of once-extensive lavas of probable post-Kenai Eocene age cap the central Talkeetna Mountains. Volcanoes were built in the west part of the Cook Inlet area in late Tertiary and Quaternary time, and thick glacial and alluvial deposits accumulated in the northern Cook Inlet and Susitna Lowland areas in Quaternary time.

STRUCTURE AND UNCONFORMITIES

The predominant strike of geologic contacts and major faults and folds in the Cook Inlet area parallels the trend of the Matanuska geosyncline. The basal contacts of the sedimentary rocks in the Matanuska geosyncline with the older rocks of the adjacent geanticlines are unconformities which dip toward the basin at gentle to moderate angles on the northwest side, and at steep angles on the southeast side of the geosyncline. These basal contacts are offset in places by large northwestward-dipping reverse faults including the Castle Mountain and Bruin Bay faults adjacent to the Talkeetna geanticline, and by smaller faults, many of them oblique, adjacent to the Seldovia geanticline. These faults are parallel or subparallel to the regional structural grain, and at many places now bound the rocks of the geosyncline. At one point the Castle Mountain fault, which forms the north boundary of the rocks of the geosyncline in the Matanuska Valley, is reported to have a vertical displacement of about 4,000 feet (Barnes and Payne, 1956, p. 26) and some evidence indicates that locally the vertical displacement may be about 10,000 feet (Martin and Katz, 1912b, pl. 15). Similar faults west of Cook Inlet have vertical displacements of 4,000 to 6,000 feet. Quaternary deposits have been displaced by a fault marked by west-southwestward striking scarps between Houston and the Susitna River.

Unconformities separate most of the formations that were deposited in the Matanuska geosyncline and the Shelikof trough. These unconformities record periods of erosion which have been important in determining the present distribution and thickness of many of these formations.

MAGNETIC FEATURES AND INTERPRETATION

MAJOR MAGNETIC FEATURES OF THE COOK INLET AREA

The total intensity magnetic field in the Cook Inlet area is characterized by northeastward-trending anomalies and by trend lines that are generally arcuate. The trend of the magnetic features conforms with the strike of the major geologic features of the area.

The magnetic features of the Cook Inlet area are superimposed upon a regional magnetic field which decreases to the southwest at a gradient of about four gammas per mile. The appearance of the anomalies in the Cook Inlet area would be only slightly altered if the regional magnetic gradient were removed from the magnetic profiles. The gradients of the west sides of magnetic highs would be slightly decreased, those of the east sides would be slightly steepened, and some anomalies that appear as benches on the profiles would appear as low-amplitude closed anomalies if the regional gradient were removed.

For convenience, most of the major magnetic features are designated by numbers in the text and on plates 18 to 21. Minor features are designated by the number of the major feature they are associated with, and by a letter. The magnetic features are discussed from northwest to southeast.

The Kahiltna magnetic pattern (1) occurs over the northwest Susitna Lowland. It is characterized by almost flat magnetic profiles and occurs over sedimentary rocks that were deposited in the Alaska Range geosyncline. A contact between the Kahiltna magnetic pattern and an extensive area of large-amplitude magnetic anomalies trends southwest across the Susitna Lowland and approximates the contact between the Alaska Range geosyncline and the Talkeetna geanticline. It is called the Peters Creek magnetic contact (2). The area of large-amplitude anomalies southeast of the Peters Creek contact is called the Mount Susitna anomaly group (3). This group of anomalies occurs over the rocks that are exposed in the Talkeetna geanticline. A southwestward-trending magnetic contact bounds the Mount Susitna anomaly group on the southeast. Called the Moquawkie magnetic contact (4), it reflects the contact between the predominantly magnetic rocks that are exposed in the Talkeetna geanticline and the sedimentary rocks of the Matanuska geosyncline.

The magnetic profiles across Cook Inlet and the adjacent lowlands display low gradients but are broadly arched on many profiles. An exception occurs west of the southern part of Cook Inlet near Iniskin, Chinitna, and Tuxedni Bays. Here narrow steep-gradient anomalies are superimposed on low-gradient magnetic anomalies and form a characteristic group of magnetic features, the Iniskin magnetic pattern (5). This pattern occurs over Jurassic sedimentary rocks deposited in the Matanuska geosyncline. It is separated from the area of low-gradient magnetic anomalies over Cook Inlet by a steep westward-facing magnetic slope, the Chinitna magnetic gradient (6). The low-gradient magnetic profiles over the Cook Inlet-Kenai Lowland are referred to as the Cook Inlet magnetic pattern (7). Magnetic rocks are deep in this area, which is inferred to be underlain by sedimentary rocks that were deposited in the Matanuska geosyncline and the Shelikof trough. The broadly arched character of the profiles across Cook Inlet represents the two-dimensional Cook Inlet magnetic anomaly. This anomaly is interpreted to reflect the presence at great depth of a large elongate mass of magnetic rock trending parallel to the Matanuska geosyncline.

A large positive two-dimensional anomaly with steep gradients trends parallel to the Cook Inlet-Kenai Lowland near its eastern margin. It is called the Knik Arm anomaly (8) and is interpreted to be produced by rocks associated with Seldovia geanticline. A possible extension of this anomaly (9) occurs near Seldovia. A magnetic trend line (10) at the east base of the Knik Arm and Cook Inlet magnetic anomalies marks the west edge of the Skilak magnetic pattern (11). The Skilak pattern occurs mainly over slate and graywacke of the Chugach Mountains geosyncline.

KAHILTNA MAGNETIC PATTERN

The western parts of magnetic profiles 25, 33, and 41 are almost flat and slope gently westward with the regional magnetic gradient. This area of almost flat profiles comprises the Kahiltna magnetic pattern. (See pls. 18, 19(1).) Only a few small anomalies, superimposed on the gently sloping regional magnetic gradient, were recorded in this area. The east boundary of the pattern is marked by a 300- to 800-gamma rise in magnetic intensity; the western boundary was not reached by the flight lines.

The flat parts of the profiles occur over Mesozoic slate and graywacke and locally over Tertiary nonmarine sedimentary rocks. The profiles indicate that the rocks of both formations are nonmagnetic. Thus the magnetic data provide no basis for estimating the thickness of Tertiary sediments in the northwest part of the Susitna Lowland. The magnetic data suggest that the base of the slate and graywacke sequence is very deep or that the sequence rests on a great thickness of nonmagnetic rocks. Because the slate and graywacke sequence is structurally complex and underlies a large area, it may indeed be very thick. It is also free of even moderately magnetic large intrusive bodies where it is crossed by the magnetic profiles. The small superimposed anomalies may be produced by mafic dikes of the type that were reported by Capps (1913, p. 46) to cut the slate and graywacke.

PETERS CREEK MAGNETIC CONTACT

The Peters Creek magnetic contact (2) is located approximately at the boundary between the Alaska Range geosyncline and the Talkeetna geanticline. It is marked by the rise in magnetic intensity at the eastern boundary of the Kahiltna magnetic pattern. Just west of checkpoint 94 on profile 25 and checkpoint 4900 on profile 50 the rise in magnetic intensity is steep, indicating that the contact between nonmagnetic and magnetic rocks is steep and close to the surface. Several miles east of checkpoint 35 on profile 33 and near checkpoint 67 on profile 41 the magnetic gradient is moderate and the upper surface of the magnetic rock mass must either dip westward or be at greater depth.

Two interpretations of this contact that are compatible with the known geology are: (a) It reflects a locally buried fault, or possibly a steeply dipping unconformity, between granitic or volcanic rocks on the east and the slates and graywackes on the west. In places this contact may be buried by Cenozoic deposits. (b) It represents the contact of an intrusive into the slate and graywacke which reaches the surface only in some places; elsewhere it is overlain either by a roof of slate and graywacke, which thins eastward, or by Cenozoic deposits.

The Peters Creek magnetic contact (2) as drawn on plates 18, 19 crosses an outcrop of slate and graywacke in the Yenlo Hills. The magnetic contact is probably irregular and the magnetic profiles, spaced 8 miles apart near the Yenlo Hills, cannot precisely delineate its position. Perhaps the changes in lithology that produce the Peters Creek magnetic contact pass beneath the Yenlo Hills at depth or swing southeast of them.

MOUNT SUSITNA ANOMALY GROUP

MAJOR MAGNETIC FEATURES

A profusion of both high and low magnetic-intensity anomalies characterizes the Mount Susitna anomaly group, which is bounded on the northwest by the Peters Creek magnetic contact (2) and on the southeast by the Moquawkie magnetic contact (4). It includes both the highest and lowest magnetic intensities recorded during the survey, but many of the anomalies are moderate or low in gradient and amplitude. The Mount Susitna anomaly group contrasts sharply with the low-gradient Kahiltna pattern to the northwest and the Cook Inlet pattern (7) to the southeast. Its anomalies are produced by Lower Jurassic and older volcanic and metamorphic rocks and Jurassic and Cretaceous(?) plutons of the Talkeetna geanticline. In places these rocks are covered by Tertiary and Quaternary deposits. Anomalies of the group are labelled 3 and 3A to 3G on plates 18 to 21.

Anomalies of high magnetic intensity were found over Mount Susitna and the adjacent area on the west and north. The most intense anomalies observed in this area reach 1,000 gammas. The magnetometer was close to the ground over the mountain when it recorded the largest anomalies and this contributed somewhat to their size. However, almost equally intense anomalies (as much as 800 gammas) were recorded over the lowland west of the mountain (profiles 79 to 87). The large anomalies in this entire area, therefore, are interpreted to reflect primarily the presence of magnetic rocks rather than the effects of topography. If, as reported, Mount Susitna is composed of dioritic plutonic rocks, most of the area of large anomalies of shallow origin may be underlain by similar rocks. Such areas near Mount Susitna are partly outlined and marked 3A on plates 18, 19, and 20. Profiles 212 and 213 also display anomalies of high magnetic intensity over the dioritic plutonic rocks of the southern Alaska Range west of Iniskin Bay in the southwest corner of the surveyed area. This area is marked 3B on plates 18 and 21.

Anomalies of lower amplitude than those attributed to the plutonic rocks, and some of large amplitude, occur west of Mount Susitna. Volcanic rocks of Jurassic(?) age and small plutons crop out in this area. These, and possibly magnetically similar rocks are interpreted to underlie this area at shallow depths. Capps (1935, p. 71) reports that many of the plutons in the south flank of the Alaska Range are composed of granite, a type of rock which is generally moderate or low in magnetic susceptibility. Such plutons might produce anomalies of only small magnitude. However, diorite and other rocks which might produce large anomalies also occur in this area.

An area of moderate- and low-amplitude anomalies that were produced by rock masses at shallow and moderate depths lies between Mount Susitna and Houston. (See pls. 18 and 19 (3C).) Some of these anomalies seem large enough to be attributable to plutonic or volcanic rocks. However, some of the anomalies in the eastern and southern parts of this area are low in amplitude and may reflect the metamorphic rocks which crop out near Willow Creek or other weakly magnetic rocks.

Anomalies indicating shallow magnetic rocks were found at the east end of profiles 33, 41, and 65. These occur over the east side of the Susitna Lowland where plutonic and volcanic rocks of the Talkeetna Mountains are at or near the surface. The rocks that produce the anomalies are deeper to the west, beneath the lowland.

Anomalies on many profiles south of profile 50 indicate that magnetic rocks occur at shallow or moderate depths at the west edge of the survey area. Such anomalies occur west of checkpoints 40 and 75 on profiles 120 and 132, west of checkpoints 55 and 78 on profiles 212 and 213, and on the western parts of other profiles. Published information about the rocks in these areas is scanty. However, enough lines cross mapped areas of volcanic, plutonic, and metamorphic rocks in the eastern foothills of the southern Alaska Range to establish the fact that these rocks produced the large anomalies.

POSSIBLE TRANSVERSE STRUCTURE NEAR THE CHAKACHATNA RIVER

Comparison of profile 103 west of checkpoint 37 and profile 105 west of checkpoint 91 reveals a difference in magnetic character that suggests a possible structure striking at a large angle to the major structures of the Cook Inlet area. (See pls. 18 and 20 (3D).) Both profiles decline steadily in magnetic intensity in this area, but where the profile 105 has numerous steep-gradient anomalies indicating that magnetic rocks occur beneath it at shallow depths, profile 103 is smooth—indicating that magnetic rocks beneath it are at considerable depth. If these relations reflect a fault or flexure, it strikes westward and possibly separates an area to the north, where magnetic rocks are deeply buried, from the area to the south where they are at shallow depths. The possible structure may cross flight line 105 between checkpoints 87 and 88 and trend west through Chakachamna Lake. If the structure exists, the nearly flat character of the extreme west end of profile 105 might indicate that a relatively thick but narrow body of sedimentary rocks (perhaps Tertiary) occurs on the north side of the structure and is overlain by thin or slightly magnetic late Cenozoic lavas from Mount Spurr. This flat segment of profile 105 may be part of the area of low-gradient magnetic profiles near the west end of flight lines 99 to 103, which is marked 3E on plates 18 and 20 and discussed below. Magnetic rocks occur at shallow depths north and probably south of the west end of flight line 105.

SUSITNA LOWLAND

Tertiary strata of nonmarine origin crop out at many places in the Susitna Lowland and by inference underlie much of it (see fig. 44 and pl. 18). However, pre-Tertiary rocks also crop out at many places in the lowland. Slate and graywacke deposited in the Alaska Range geosyncline crop out in the northwest part of the lowland and Mesozoic and older volcanic, plutonic, and metamorphic rocks of the Talkeetna geanticline crop out in the southeastern part of the lowland. Marine sedimentary rocks of the Matanuska geosyncline are thought to be absent from the Susitna Lowland north of the Castle Mountain fault, but the nonmarine Arkose Ridge formation of mid-Cretaceous age forms a narrow wedge against the north side of this fault near the Little Susitna River.

The magnetic data suggest that the part of the Susitna Lowland beneath which the Talkeetna geanticline trends is in most places underlain by not more than several hundred feet of nonmagnetic (sedimentary) rocks. Magnetic anomalies that were produced at shallow depths occur many miles from the margins of the lowland in this area. However, greater thicknesses of nonmagnetic rocks may underlie parts of this area, particularly where the aeromagnetic profiles are widely spaced. About 2,000 feet of nonmagnetic rocks are estimated to overlie the rocks that produced the magnetic anomalies at checkpoint 8 on flight line 77 and 12 miles west of checkpoint 33 on flight line 81, in the southeastern part of the lowland.

BELUGA LOWLAND

Quaternary deposits mantle most of the Beluga Lowland (see fig. 44). Coal-bearing rocks of Tertiary age crop out at several places within the lowland suggesting that much of the intervening area is also underlain by these rocks. If Mesozoic sedimentary rocks occur beneath the Tertiary rocks, they cannot be distinguished with the magnetometer.

The large steep-gradient anomalies over and west of Mount Susitna broaden and develop gentler gradients as they trend southwest over the Beluga Lowland, indicating that magnetic rocks are deeper or change in magnetic character in that direction. Thus these anomalies are much subdued on profile 97, obscure on 99, and unrecognizable on profiles 101 and 103, where the magnetic profiles are very smooth. This area of smooth profiles (3E) and its approximate northern limit (3F) are marked on plates 18 and 20. The area is terminated on the south by the inferred structure (3D) between flight lines 103 and 105, beyond which magnetic rocks are again near the surface. On the west it is terminated by a zone of steepening magnetic gradient (3G) near the west end of flight lines 97 through 103. On the east the area with smooth magnetic profiles merges with the low-gradient magnetic pattern over Cook Inlet. It may be significant that the Moquawkie contact (4), which bounds the Mount Susitna anomaly group on the southeast, is obscure where these areas with smooth profiles merge south of Mount Susitna.

The area with smooth profiles (3E) may be underlain by a thick section of Tertiary and possibly Mesozoic sedimentary rocks, or merely by nonmagnetic basement. The area with smooth profiles lies immediately north of the inferred transverse structure near the Chakachatna River and perhaps these features are related. For example, the area with smooth profiles could reflect a tilted fault block or asymmetric syncline containing nonmagnetic rocks that is terminated on the south by the possible transverse structure.

MOQUAWKIE MAGNETIC CONTACT

The Mount Susitna anomaly group is bounded on the southeast by the Moquawkie magnetic contact (4) shown on plates 18 to 21, which separates it from the low-gradient magnetic pattern over Cook Inlet. The Moquawkie contact is manifested by a steepening in gradient and (or) a change in magnetic character at the western edge of the low-gradient magnetic pattern over Cook Inlet. The change in magnetic character is not necessarily accompanied by a large increase in amplitude of the anomalies, for some of the rocks on the north side of the contact are only weakly magnetic.

The Moquawkie contact is clearly defined across the Susitna Lowland and west of Cook Inlet. It can be recognized on profiles 77 to 91, but its position is obscured by the converging Ivan River anomaly (7A) on profiles 93 to 97. It is not recognizable on profiles 99 and 101, where the magnetically smooth area (3E) south of Beluga Lake merges with the low-gradient magnetic pattern over Cook Inlet. The contact is again seen on most profiles from 103 to 175 and on profiles 212 and 213.

The Moquawkie contact reflects the boundary between generally nonmagnetic sedimentary rocks of the Matanuska geosyncline and predominantly magnetic igneous rocks exposed in the Talkeetna geanticline. Where the contact is overlain by Tertiary sedimentary rocks or where metamorphic or sedimentary rocks occur against it in the Talkeetna geanticline, its magnetic expression is subdued. Where Tertiary rocks overlie only the sedimentary rocks of the Matanuska geosyncline and not the magnetic rocks of the Talkeetna geanticline, the magnetic contrast along the Moquawkie contact is enhanced. At checkpoint 8 on flight line 77 and 10 miles west of checkpoint 33 on flight line 81, in the southeastern part of the Susitna Lowland, magnetic rocks immediately north of the contact are about 2,000 feet deep. It is inferred that the magnetic rocks at the contact are overlain by Quaternary deposits and Tertiary nonmarine sedimentary rocks in this area.

Several profiles between flight lines 175 and 212 extend a few miles west of the boundary between the Matanuska geosyncline and the Talkeetna geanticline, which produces the Moquawkie magnetic contact. However, these profiles terminate over weakly magnetic rocks (predominantly sedimentary and pyroclastic rocks) in the upper part of the Lower Jurassic series west of Cook Inlet. None of these profiles reach the rocks in the southern Alaska Range which elsewhere produce the large anomalies of the Mount Susitna anomaly group (3). Anomalies over the Lower Jurassic rocks are not greatly different from some of those over the adjacent rocks of the Matanuska geosyncline. (See the section "Iniskin magnetic pattern," p. 127.) In the absence of the large anomalies of the Mount Susitna anomaly group it is not possible to determine with confidence whether the change in magnetic pattern which marks the Moquawkie magnetic contact occurs on these profiles. Small changes in magnetic character which may mark the Moquawkie contact occur at the extreme west end of profiles 178, 200, and especially 209, 210, and 211.

The Moquawkie contact trends into the Castle Mountain fault, which is the northern limit of the sedimentary rocks of the Matanuska geosyncline in the Matanuska Valley. It is also less than a mile north of a probably related fault that displaces the Quaternary deposits southwest of Houston. The Moquawkie contact is inferred to mark the southwestern extension of the Castle Mountain fault beneath the Susitna Lowland. Near Iniskin Bay, in the southwest part of the survey area, the Moquawkie contact reflects the Bruin Bay fault. Between Tuxedni Bay and the Susitna Lowland geologic information is meager. Most of this area is covered by surficial deposits and the geologic situation that produced the magnetic contact here is not known.

The Moquawkie contact follows the arcuate trend of the Mesozoic tectonic elements in the Cook Inlet area, and is oblique to the trend of the Shelikof trough. Tertiary sedimentary rocks occur on both sides of the contact but are thickest southeast of it. The Mesozoic sedimentary rocks occur almost exclusively southeast of the contact. The faults and related homoclines that are interpreted to have produced the Moquawkie contact are thought to be primarily latest Mesozoic or early Tertiary structures. However, these have been reactivated by major displacement during Tertiary and Quaternary time and in places these structures separate Tertiary from pre-Tertiary rocks.

MAGNETIC PATTERNS OVER THE COOK INLET AND KENAI LOWLANDS

MAJOR MAGNETIC FEATURES

Sedimentary rocks of Mesozoic and Tertiary age crop out at several places on the margins of the Cook Inlet Lowland and in the south half of the Kenai Lowland (see pl. 18, fig. 44). This area is characterized by broad low-amplitude anomalies of low and moderate gradient. However, steep gradients and moderately large anomalies occur over the western part of this area between Ursus Cove and Tuxedni Bay. These anomolies are part of the Iniskin magnetic pattern (5) and the Chinitna magnetic gradient (6). The low-gradient area is limited on the northwest by the Moquawkie contact and on the southeast by the Knik Arm anomaly (8). A conspicuous feature of the profiles across Cook Inlet is their broadly arched character.

INISKIN MAGNETIC PATTERN

The level of magnetic intensity over the Jurassic marine sedimentary rocks west of lower Cook Inlet is about 200 to 400 gammas lower than the magnetic intensity over Cook Inlet. However, several narrow steep-gradient anomalies are superimposed on the magnetic profiles in the Iniskin area which are absent over Cook Inlet. The superimposed anomalies characterize the Iniskin magnetic pattern. (See pls. 18 and 21 (5).) The Iniskin pattern is bounded on the east by the Chinitna magnetic gradient (6).

The Jurassic sedimentary rocks in the Iniskin area rest on Lower Jurassic volcanic rocks. Geologic evidence indicates that the top of the volcanic rocks is 1½ or 2 miles deep at the center of the Iniskin Peninsula and 3 to 4 miles deep at the coast, and thus dips east. The westerly slope of the Iniskin magnetic pattern is related to the regional magnetic gradient and the arching of the profiles over Cook Inlet, rather than to the slope of the upper surface of the volcanic rocks.

The steep-gradient anomalies superimposed on the low-gradient anomalies in the Iniskin area are produced by thin or narrow bodies of magnetic rock at or near the surface. Dikes or steeply dipping magnetic layers, if sufficiently thick and permanently magnetized, might produce such anomalies. Kirschner and Minard (1949) report several basalt bodies in the Iniskin Peninsula that range from 6 inches to 6 feet in thickness, but these are too thin to produce the recorded anomalies. If they are representative in size of the intrusive bodies in the Iniskin area, some other features must have produced the anomalies. The anomalies seem too great to be caused by sedimentary rocks but no other rock masses of sufficient size are known in the area. Perhaps intrusive rocks that are magnetic underlie the anomalies at shallow depths, or possibly such rocks crop out beneath the anomalies but have not as yet been recorded. Another possible, although perhaps less likely, cause of the anomalies are the massive beds of arkosic sandstone and conglomerate which occur at several levels in the Jurassic section in units several hundred feet thick. These sediments are composed of coarse, fresh detritus derived from the plutonic and volcanic terrains immediately to the west which are strongly magnetic where crossed by the aeromagnetic lines.

The Iniskin magnetic pattern seems to narrow on the southernmost lines, apparently wedging out between the Moquawkie contact and the Chinitna gradient on profiles 212 and 213. It maintains its lower magnetic level as far south as profile 212 and may occur at a higher level and be narrower on profile 213. The Iniskin pattern may extend north to flight line 175 where, if present, it is at the same level as the magnetic pattern over Cook Inlet and the superimposed anomalies are small and have gentle slopes. The rocks that produce the superimposed anomalies in this area are overlain by a thin cover of nonmagnetic rocks in contrast to the Iniskin area, where they are at the surface. The next few flight lines north of 175 may not cross the rocks which produce the Iniskin pattern, but if they do these rocks must be deeply buried or change in magnetic character in this area.

CHINITNA MAGNETIC GRADIENT

The 200- to 400-gamma drop in magnetic intensity near the west shore of Cook Inlet on flight lines south of 175 is called the Chinitna magnetic gradient. (See pls. 18 and 21 (6).) It separates the low-gradient high-intensity magnetic field over Cook Inlet (7) from the field of lower intensity having superimposed steep-gradient anomalies in the Iniskin area (5).

The position of the Chinitna gradient is obscured on many profiles by the steep-gradient anomalies associated with the Iniskin magnetic pattern. The gradient can be plotted on profiles 178, 185, and 213, although on some of these its position may have been shifted by superimposed anomalies which are not separately distinguishable. On profiles 200, 205, 207, 209, 210, 211, and 212, the gradient has been shifted westward by the superimposed anomalies. An attempt to reconstruct the actual gradient on these lines by removing the effects of the superimposed anomalies is shown on plate 21. The position of the gradient thus obtained is shown by a dashed line on profiles 200, 205, 209, 210, 211, and 212. Between lines 185 and 200 the Chinitna gradient cannot be located with the available data and it was placed at the base of the hills fronting Cook Inlet. This is the approximate position it occupies in the adjacent area.

The rocks with contrasting magnetic character which produce the Chinitna gradient are estimated to be buried about a mile below sea level. This estimate is based on analysis of the reconstructed gradients on profiles 200 to 212 on plate 21, rather than on observed profiles. Thus the depth estimated may be greatly in error and is offered only tentatively as the best estimate that can be made with the available data.

The Chinitna gradient could be explained by the presence of magnetic rocks (Lower Jurassic volcanic rocks?) beneath 1 mile of nonmagnetic rocks under Cook inlet and 3 or more miles of weakly magnetic rocks under the Iniskin area. A possible geologic situation with this configuration is illustrated on figure 46. It

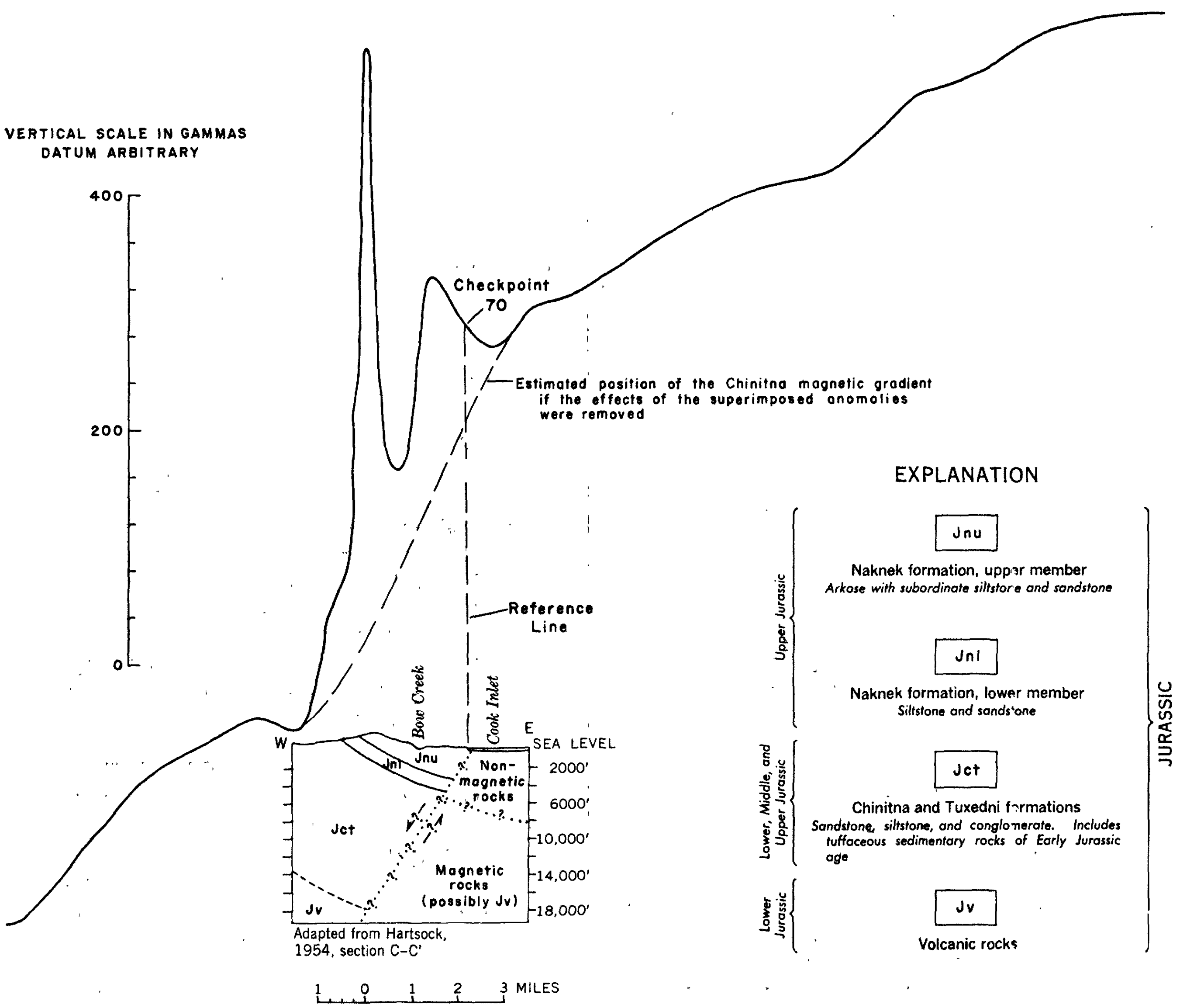

FIGURE 46.—Hypothetical structure section across the Chinitna magnetic gradient. The structure section crosses the Chinitna magnetic gradient at Bow Creek on the west shore of the Cook Inlet, and near checkpoint 70, flight line 210. The section shows a possible geologic interpretation of the Chinitna gradient. A part of profile 210 is drawn above the hypothetical section for reference. The relation of the sharp anomalies that are superimposed upon the Chinitna gradient to outcrops of the Naknek formation is also shown.

requires a fault, upthrown on the east, with a large vertical displacement. The postulated depth to magnetic rocks immediately west of the Chinitna gradient in the Iniskin area is indicated by geologic evidence.

The upper surface of rocks of higher susceptibility appears to be buried not more than a mile below sea level under western Cook Inlet. This is based on the interpretation of two small anomalies just east of the coast on profile 200. However, if these anomalies are produced by magnetic masses within nonmagnetic (sedimentary) rocks, rather than by features within magnetic basement, the interpreted depths indicate only the minimum thickness of nonmagnetic rocks in this area.

The trend of the Chinitna gradient is indicated by short straight segments which approximately parallel the west shore of Cook Inlet. This suggests the coast may be fault controlled, with softer rocks, possibly Cenozoic, under the inlet. In places the trace of the gradient falls several thousand feet inland from the shore of the inlet. If the gradient indeed reflects the position at depth of a fault which reaches the surface under Cook Inlet, such a fault would have a moderate dip to the west (fig. 46).

The possibility exists that the Chinitna gradient is caused by the termination or displacement at the gradient of an unknown unit of magnetic rocks that might underlie Cook Inlet, rather than the postulated displacement of the Lower Jurassic volcanic rocks. Such a possibility does not seem strong, but cannot be dismissed with the evidence at hand.

COOK INLET MAGNETIC PATTERN

A large area of only low-gradient magnetic features, the Cook Inlet magnetic pattern (7), extends from flight line 77, north of Palmer, to line 213 at the mouth of Cook Inlet. This area is 50 miles wide in places and over 190 miles long, and within it magnetic rocks are deeply buried. The pattern is limited on the northwest by the Moquawkie magnetic contact (4) and the Chinitna magnetic gradient (6), and on the southeast by the Knik Arm anomaly (8). The southeast boundary of the Cook Inlet pattern cannot be determined where the Knik Arm anomaly is absent. In general the pattern is interpreted to reflect the presence of sedimentary rocks of the Matanuska geosyncline and the superimposed Shelikof trough.

The sedimentary rocks of the Matanuska geosyncline are inferred to be bounded on the northwest by the Moquawkie contact and to not extend southeast of the Knik Arm anomaly. The nonmarine sedimentary rocks of the Shelikof trough may be thickest between these magnetic features, but they extend east of the Knik Arm anomaly to the structural front of the Chugach Mountains and northwest of the Moquawkie contact in the Beluga and Susitna Lowlands.

The basement rocks upon which the sedimentary rocks of the Matanuska geosyncline and Shelikof trough were deposited are Permian to Early Jurassic in age. Where these basement rocks are exposed in the Seldovia geanticline as near Seldovia they include sedimentary rocks as well as lavas, and as a whole are not highly magnetic. However, both west of Cook Inlet and south of the Matanuska River the basement rocks of Permian to Early Jurassic age produce strong magnetic anomalies. Anomalies that are thought to be produced by these rocks beneath the Cook Inlet-Kenai Lowland provide a means of estimating the thickness of sedimentary rocks in this area. In places, however, these estimated depths may include an unknown thickness of nonmagnetic rocks older than those of the Shelikof trough and Matanuska geosyncline. The anomaly which arched the profiles across the Cook Inlet Lowland is larger, and is produced at greater depth than the anomalies thought to originate in the Permian to Lower Jurassic rocks.

COOK INLET MAGNETIC ANOMALY

The profiles across Cook Inlet are broadly arched. The arch has a maximum amplitude of about 500 gammas and is more apparent on many profiles if the regional magnetic gradient is removed. The arching forms a broad elongate magnetic high, the Cook Inlet magnetic anomaly, which produces a high magnetic datum over a large area. This anomaly is obscure on the northern profiles where the Matanuska geosyncline is narrow and anomalies produced at shallower depths in the adjacent geanticlines are superimposed upon it.

The axis of the anomaly cannot be located exactly but follows roughly the trend of the Matanuska geosyncline along the middle part of the Cook Inlet-Kenai Lowland. The size and gradient of the anomaly indicate that it is produced by a large and thick rock mass with higher magnetic susceptibility than the surrounding rocks. The rock mass may be as much as 5 or 10 miles deep. Such a mass would probably be igneous and would constitute a major feature of the upper crust.

A similar anomaly, with an amplitude of about 400 gammas, has been observed in the southern Copper River Lowland (Andreasen and others, 1958). There the crest occurs over the northern, more stable side of the Matanuska geosyncline. Another broad anomaly with an amplitude which ranges from a few hundred to more than 1,000 gammas was observed over the Great Valley of California (Grantz and Zietz, 1960). This anomaly trends north-northwest from south of Turlock to north of Redding. Its crest is close to the San Joaquin and Sacramento Rivers and occurs over the more stable side of the late Mesozoic trough in this area. This magnetic high is produced at great depth. However, where its amplitude is greatest it includes superimposed anomalies produced at higher levels which yield depth estimates that approximate the top of the basement upon which the upper Mesozoic and Tertiary sedimentary rocks of the Great Valley were deposited. Representative profiles from these areas that are normal to the regional magnetic and geologic grain are compared with profiles from the Cook Inlet area on plate 22.

All three of the broad magnetic highs under discussion occur over belts of upper Mesozoic sedimentary rocks deposited in troughs or areas that were tectonically only moderately unstable (the Matanuska geosyncline and the Great Valley area). These rocks are, in a general way, characterized by sandstones that are intermediate in lithology between graywacke and arenite and are only moderately deformed. The magnetic highs appear to be absent over the adjacent and parallel belts of sedimentary rocks of similar age that were deposited in tectonically very unstable troughs—the Alaska Range and Chugach Mountains geosynclines and the area of the Coast Ranges of California (see pl. 22). These rocks are characterized by graywacke-type lithologies and were severely deformed early in their history.

If the associations outlined above are not accidental, the troughs that were only moderately unstable may be related in origin to the features which produced the broad magnetic highs. For example, the magnetic highs could represent structurally competent rocks which, in late Mesozoic time, exerted a stabilizing influence on the crust beneath the Matanuska geosyncline and Great Valley. The absence of such competent rocks beneath the Alaska Range and Chugach Mountains geosynclines and the Coast Ranges in late Mesozoic time may explain why these areas were less stable at that time and subjected to much greater deformation. However, on the basis of evidence at hand, it is not possible to distinguish between the many ways the magnetic highs and the less deformed areas might be related, if indeed they are.

The magnetic data cannot discount the possibility that the tectonically unstable geosynclines or depositional areas are underlain by nonmagnetic but nevertheless structurally competent rocks similar to those suggested to underlie the Matanuska geosyncline and Great Valley. The contrasts tentatively suggested must be checked by other geophysical methods. Magnetic studies of other areas with analogous structural and stratigraphic conditions will be necessary to test whether the occurence of the magnetic highs over the tectonically more stable geosynclines or depositional areas is more than fortuitous.

ANOMALIES WITHIN THE COOK INLET MAGNETIC PATTERN

Several broad anomalies with low gradients (7A, 7B, 7D, 7E, 7F, and 7L), two narrower anomalies with moderate gradients (7C, 7K) and many smaller or indistinct anomalies occur within the Cook Inlet magnetic pattern. Anomalies at 7G, 7H, 7I, and 7J, which are part of the Cook Inlet magnetic pattern, are obscured by the large Knik Arm anomaly (8). For convenience in discussion, the apparent crestlines and, where possible, the outlines of the larger anomalies are plotted and designated by numbers and letters on plate 18 and by numbers, letters, and geographic names on plates 18 to 21.

Most of the anomalies within the Cook Inlet magnetic pattern appear to be circular or subcircular in outline. However, the North Foreland anomaly (7C), the Mystery Creek anomaly (7J), and possibly the Ivan River anomaly (7A) appear to be elongated in a northern or northeastern direction, and the Wasilla anomaly (7G) is possibly elongated in an eastern direction.

A few slopes on the broad anomalies are suitable for depth estimates. These were made only on the steepest slopes recorded for each anomaly and a fairly conservative estimate of the depth to magnetic rocks was obtained. The depths estimated from the steepest slopes are approximately correct only if the generalizing assumptions discussed on page 120 are valid. One of these assumptions is that the thickness of the magnetic mass is at least as great as the depth of the magnetic mass below the magnetometer. Magnetic basement beneath the Cook Inlet magnetic pattern is interpreted to lie within Lower Jurassic volcanic rocks and these are thought to be underlain by nonmagnetic rocks at many places. Where this is the case, and the magnetic rocks are thinner than their depth below the airborne magnetometer, the anomaly slopes will indicate depths that are too shallow. This possible limitation does not apply to an anomaly like the Knik Arm anomaly (see (8) on pls. 18 to 21) which, if correctly interpreted, is produced by a magnetic mass of great vertical extent.

Depths were estimated at two places on each of three broad anomalies. These depths were about 1 to 1½ miles below land surface on the Ivan River anomaly (7A), about 1½ to 2 miles below land surface on the Race Point anomaly (7B), and about 2½ to 3 miles below land surface on the Swanson River anomaly (7D). South of flight line 150 in the eastern and central parts of the Cook Inlet magnetic pattern (7), slopes are too low to permit depth estimates. If the basement beneath this area is magnetic, it may be very deep.

The nonmagnetic section above the anomaly-producing rocks consists of surficial deposits and Tertiary nonmarine sedimentary rocks to an unknown depth. Beneath these, Cretaceous and (or) Jurassic marine sedimentary rocks of the Matanuska geosyncline are present at many places. If the Cretaceous and Jurassic rocks in the geosyncline are distributed in the Cook Inlet area as they are where they crop out to the northeast, either or both systems may locally be absent.

Objective data for evaluating the depth estimates is being obtained from test wells in the Cook Inlet area. Lithologic logs of these wells are not yet available, but it can be presumed that the wells are mainly or entirely in sedimentary rocks. The location and depth of some of the test wells as of 1959 are given on plate 18. Test wells in the Swanson River area (1959) range in depth from about 11,100 to about 12,300 feet below sea level. If the estimated depths to the rocks that produce the Swanson River anomaly are representative of the entire feature, the Swanson River test wells may have penetrated most of the section above the magnetic basement in that area. However, the depth estimates were made between 5 and 10 miles northeast and between 10 and 15 miles southeast of the test wells, and the magnetic basement may slope westward and lie at greater depth where the wells were drilled. This may be indicated by the magnetic gradients, which are more gentle on the west side than on the east side of the Swanson River anomaly, particularly if the effect of the westward regional magnetic gradient is removed from the profiles. A test well drilled to about 15,000 feet below sea level near the east shore of Cook Inlet between Kenai and Kasilof is at the margin of the Kasilof anomaly (7E). This anomaly indicates that if the basement in this area is magnetic, it may be very deep. The magnetic profiles are very smooth, and the magnetic basement may lie at great depth in the Deep Creek area, where a test well was drilled to about 13,500 feet below sea level.

It is interesting that the productive wells near Swanson River (as of 1959) were drilled to depths ranging from about 11,100 to about 12,000 feet below sea level over the Swanson River anomaly (7D). However, this association is neither known nor inferred to be more than accidental. It cannot be evaluated with the data at hand.

The magnitude of the broad anomalies and the depth at which they are produced preclude the possibility that they represent topography on the magnetic basement. That is, the anomalies cannot reflect buried hills or the cores of anticlines with gently or even moderately dipping flanks. Such structures may well be present but the anomalies they might produce would be too small to observe in the presence of the much greater anomalies produced by lateral contrasts in magnetic properties within magnetic basement rocks (see Vacquier and others, 1951). Fault blocks of magnetic rocks that have been emplaced between nonmagnetic rocks might produce large anomalies if the vertical displacement was large and the bounding faults were steep.

An anomaly of low gradient and amplitude (7L) occurs near the west ends of profiles 150 and 158 (see pls. 18 and 20). However, these profiles are 10 miles apart and the character of the anomaly may be much different in the interval between them. Therefore, although removal of the westward regional magnetic gradient would emphasize this anomaly, a depth to the rocks which produce it was not estimated.

Four anomalies are superimposed on the west flank of the Knik Arm anomaly (8). These are the Wasilla (7G), Goose Bay (7H), Point Mackenzie (7I) and Mystery Creek (7J) anomalies, and they are shown on plates 18, 19, and 20. The east side of most of these anomalies is marked by a flattening rather than by a reversal in slope because they are modified by the westward slope of the regional magnetic gradient and the west side of the Knik Arm anomaly. Thus it is not possible to estimate their depth. They may be produced by the same types of features that produce the broad anomalies to the west. A dry hole was drilled in 1955 near the crest of the Goose Bay anomaly (7H) between the settlement of Knik and Goose Bay. It penetrated sedimentary rock to a depth of almost 4,000 feet below sea level.

The North Foreland anomaly (7C) appears to be a two-dimensional feature and may represent a fault block of magnetic rock in nonmagnetic rock or an elongate, narrow intrusive. The slopes indicate that the south end of the feature may be buried about half a mile below sea level. The west slope of the anomaly extends farther north than the east slope, and perhaps it can be more readily attributed to magnetic rocks that have been uplifted between parallel faults than to a narrow intrusive.

The moderate-gradient anomaly (7K) over Cook Inlet on flight line 213 is 15 miles northeast of Augustine Volcano and could reflect a volcanic or intrusive feature. However, it is not on the line which connects the Iliamna and Augustine Volcanoes and the volcano of Mount Douglas (fig. 44) and there is no basis upon which to interpret this feature.

The small anomalies on flight line 200 over western Cook Inlet are estimated to originate at most about 1 mile below sea level. They are discussed on page 129.

KNIK ARM ANOMALY

A conspicuous large-amplitude two-dimensional magnetic high, the Knik Arm anomaly, trends southeastward under the east side of the Cook Inlet–Kenai Lowland from line 81 to line 175. It is marked 8 on plates 18 to 21. It may continue in subdued form to flight line 205 but cannot be recognized on line 210. A similar magnetic feature, which may be related, occurs on lines 212 and 213 and is marked (9) on plates 18 and 21. The Knik Arm anomaly occurs above the rocks that are exposed in the Seldovia geanticline near Eklutna in the north part of the survey area and trends toward exposures of the geanticline near Seldovia in the southern part.

The size and location of the anomaly, the apparent depth of the magnetic rock that produces it, and its discontinuous nature suggest it is produced by a commonly, but not universally, occurring narrow band of magnetic rock in the Seldovia geanticline. It does not seem to be produced by the rocks that crop out in the geanticline at most places. Elongate narrow discontinuous but widely distributed intrusive bodies occur along the axis of the Seldovia geanticline where it is exposed from the Copper River to the northwest side of Kodiak Island. These axial plutons are inferred to produce the Knik Arm anomaly.

Where the Knik Arm anomaly is absent or subdued the Seldovia geanticline may not have magnetic expression, for the rocks exposed in this structure are in places weakly magnetic. For example, the magnetic profiles cross outcrops of rocks exposed in the geanticline without recording large anomalies on profile 210 near checkpoint 2000, on profile 212 near checkpoint 62, and on profile 213 near checkpoint 76. Elsewhere, as on the eastern ends of profiles 83 to 87, these rocks seem to produce sizeable anomalies. The variable magnetic character of the Permian to Lower Jurassic rocks exposed in the geanticline is due to their lithology, which consists of sedimentary and pyroclastic rocks as well as lava.

Depth estimates to the rocks that produce the Knik Arm anomaly range from near the surface to a few thousand feet below sea level near Knik Arm. Near Anchorage the eastern contact of the rock mass that produces the anomaly is estimated to be buried about three-fourths of a mile below land surface beneath flight line 103 and about half a mile below land surface beneath line 109. The contact is about three-fourths of a mile below land surface on flight line 141 and about 1½ miles below land surface on line 175. The Knik Arm anomaly decreases greatly in amplitude from profile 175 to profile 185. The disturbing rocks may be very deep (about 2 to 4 miles) or lower in magnetic susceptibility beneath profiles 185, 195, 200, and 205. They appear to be absent beneath profile 210.

The estimated depths to the rocks which produce the Knik Arm anomaly indicate the maximum possible thickness of the overlying sedimentary rocks, which in many places are of Tertiary age. However, if the plutons that are interpreted to produce the anomaly were not exposed by erosion before the Tertiary rocks were deposited, the estimated depths will include thicknesses of pre-Tertiary rocks. The Mesozoic rocks of the Matanuska and Chugach Mountains geosynclines are in part contemporaneous and local field evidence suggests that the Seldovia geanticline was a positive feature during part of Cretaceous time. Mesozoic sedimentary strata are probably thin or absent over the geanticline. Thus the estimated depths to the rocks that produce the Knik Arm anomaly indicate primarily the thickness of any Tertiary sedimentary rocks which may overlie them and an unknown thickness of Lower Jurassic or older rocks.

If the anomaly at the mouth of Kachemak Bay (see (9) on pls. 18 and 21) is the southward continuation of the Knik Arm anomaly it may be offset by a swing in trend of the anomaly-producing rocks, or by a fault. The profiles are too widely spaced here to discriminate between possible explanations of the offset. One possibility is that the belt of crystalline limestone and schist of Triassic(?) age (pl. 18) that strikes a little east of north through the entrance to Seldovia Bay reflects a fault zone along which the rocks producing the Knik Arm anomaly were offset in a left-lateral sense.

SKILAK MAGNETIC PATTERN

The east ends of flight lines 158 and 165 are almost flat and slope westward at a uniform rate that reflects the regional magnetic gradient. This is called the Skilak magnetic pattern and is marked 11A on plates 18 and 20. The profiles show several small anomalies that indicate the presence of small bodies of magnetic rocks, perhaps igneous, at or near the surface in a predominantly nonmagnetic terrain. The Skilak pattern occurs over slate and graywacke in the Chugach Mountains geosyncline. It closely resembles the Kahiltna pattern (1), which occurs over similar rocks.

The Skilak pattern is bounded on the west by a reversal in magnetic gradient at the line marked 10 on plates 18 and 20. The eastward slope of the profiles just west of this line is caused by the Knik Arm and Cook Inlet anomalies, which are produced at depth by rock masses that are not in contact with the slate and graywacke. Thus, any correspondence of the line marked 10 with the west boundary of the slate and graywacke is coincidental.

A magnetic pattern similar to the Skilak pattern can be observed as far south as flight line 212 and is marked 11B on plates 18 and 21. Here the pattern occurs over some of the rocks that are exposed in the Seldovia geanticline, which locally are not highly magnetic, as well as over the slate and graywacke of the Chugach Mountains geosyncline. In such places the rocks that are exposed in the Seldovia geanticline and those of the Chugach Mountains geosyncline are aeromagnetically indistinguishable, and the Knik Arm anomaly affords the only means of magnetically identifying the geanticline and separating the areas underlain by the rocks of the Matanuska and Chugach Mountains geosynclines.

SUMMARY

A reconnaissance aeromagnetic survey of the Cook Inlet area has permitted the delineation of many major and some minor geologic structures. The extent of areas that have significant thicknesses of nonmagnetic rocks (assumed to represent sedimentary rocks) and in places the estimated depth to the magnetic basement beneath the nonmagnetic rocks have been determined. Large areas where sedimentary rocks form only a thin or sporadic cover have also been outlined.

Mesozoic slate and graywacke crop out in large areas of the Alaska Range and Chugach Mountains. These rocks are in the Alaska Range and Chugach Mountains geosynclines. They are characterized by flat magnetic patterns that slope gently and uniformly westward with a component of the regional magnetic gradient. The flat magnetic patterns are interrupted only by small but often steep-gradient anomalies. If large masses of magnetic rocks are present beneath these areas they are at great depth. The magnetic pattern over these rocks in the Alaska Range is referred to as the Kahiltna magnetic pattern (1), and in the Chugach Mountains as the Skilak magnetic pattern (11A).

A large area of volcanic rocks with many plutons occurs in the Talkeetna Mountains, the southern Alaska Range, and under the Susitna Lowland. These rocks, exposed in the Talkeetna geanticline, produce the steep-gradient and high-amplitude magnetic anomalies of the Mount Susitna anomaly group (3). Locally these rocks are covered by Tertiary and Quaternary sedimentary rocks, but their magnetic expression can in most places be recognized through the cover. The sedimentary cover is most extensive in the Susitna and Beluga Lowlands, and in parts of these areas sedimentary rocks may be thick.

The Mount Susitna anomaly group is bounded on the southeast by the Moquawkie magnetic contact (4). The contact is a definite line or zone southeast of which magnetic gradients are distinctly lower. It is interpreted to reflect the boundary between the Jurassic and Cretaceous sedimentary rocks of the Matanuska geosyncline, which mainly occur beneath the Cook Inlet Lowland, and the rocks of the Talkeetna geanticline. Locally this contact is obscured by overlying sedimentary deposits of Cenozoic age, but in most places the Cenozoic deposits are thickest south of the contact and contribute to the difference in magnetic relief across it.

The magnetic profiles across Cook Inlet are smooth but broadly arched. The arching reflects the large but broad positive Cook Inlet anomaly which is interpreted to indicate the presence at great depth of an elongate mass of magnetic and presumably igneous rock. This mass may somehow have affected the nature of the Matanuska geosyncline and controlled the degree of deformation to which it has been subjected. Large anomalies of this nature seem, on the basis of as yet incomplete data, to be absent over the adjoining geosynclines of late Mesozoic age which were tectonically unstable during sedimentation and which were intensely deformed early in their history.

Superimposed on the broad Cook Inlet anomaly are several low- and moderate-gradient anomalies which are produced by magnetic rocks estimated to be buried about ½ to 4 miles below sea level. Estimated depths to the disturbing rock masses may reflect the depth to the magnetic basement and thus may approximate the local thickness of sedimentary rocks. However, if the magnetic rocks are thinner than their depth beneath the magnetometer, they may actually be deeper than estimated from the anomalies. The oil wells at Swanson River are within the area of the Swanson River anomaly (7D).

West of southern Cook Inlet a distinctive magnetic pattern occurs between the Cook Inlet pattern and the Mount Susitna anomaly group. Called the Iniskin magnetic pattern (5), it is interpreted to represent an area of dominantly nonmagnetic Jurassic marine rocks containing some thick magnetic beds or intrusive bodies. This pattern is about 200 to 400 gammas lower than the magnetic pattern over Cook Inlet. The change in magnetic level occurs along the steep Chinitna magnetic gradient (6), which may represent a fault. East of this gradient, magnetic rocks may be buried about 1 mile below sea level, whereas west of it, they are more than 3 miles below sea level.

The Cook Inlet magnetic pattern (7) is bounded on the east by the large-amplitude low- to moderately steep-gradient two-dimensional Knik Arm anomaly (8). This anomaly may be produced by a narrow belt of plutons that crop out in the axial part of the Seldovia geanticline at many places in the northern foothills of the Chugach-Kenai Mountains and on Kodiak

Island. The Knik Arm anomaly may therefore indicate the position of the Seldovia geanticline. Locally much weakly magnetic sedimentary and pyroclastic material occurs in the rocks exposed in the Seldovia geanticline, and its magnetic expression in these places is poor. Where this occurs, and the Knik Arm anomaly is absent, the Seldovia geanticline may be magnetically indiscernible.

The Mesozoic sedimentary rocks of the Matanuska geosyncline are inferred to be restricted to the area northwest of the Knik Arm anomaly, and to be thin or absent over and east of it. However, the Tertiary nonmarine sedimentary rocks of the Shelikof trough occur not only northwest of the Knik Arm anomaly, but in many places they extend across it to the front of the Chugach Mountains. It is estimated that the magnetic basement is deepest, and hence sedimentary rocks are thickest, within the large area between the Knik Arm anomaly and the Moquawkie magnetic contact.

SELECTED REFERENCES

Andreasen, G. E., and others, 1958, Aeromagnetic map of the Copper River basin, Alaska: U.S. Geol. Survey Geophys. Inv. Map GP-156.

Barnes, F. F., and Payne, T. G., 1956, The Wishbone Hill district, Matanuska coal field, Alaska: U.S. Geol. Survey Bull. 1016, 88 p.

Brooks, A. H., 1911, The Mount McKinley region, Alaska: U.S. Geol. Survey Prof. Paper 70, 234 p.

Capps, S.R., 1913, The Yentna district, Alaska: U.S. Geol. Survey Bull. 534, 75 p.

———1916, The Turnagain-Knik region: U.S. Geol. Survey Bull. 642-E, p. 147-194.

———1927, Geology of the upper Matanuska Valley, Alaska: U.S. Geol. Survey Bull. 791, 92 p.

———1929, The Skwentna region [Alaska]: U.S. Geol. Survey Bull. 797-B, p. 67-98.

———1935, The southern Alaska Range: U.S. Geol. Survey Bull. 862, 101 p.

———1940, Geology of the Alaska Railroad region: U.S. Geol. Survey Bull. 907, 201 p.

Cobb, E. H., 1952, Coal investigations in the Homer district, Kenai coal field, Alaska, in 1950 and 1951: U.S. Geol. Survey open-file rept.

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

Grantz, Arthur, and Zietz, Isidore, 1960, Possible significance of broad magnetic highs over belts of moderately deformed sedimentary rocks in Alaska and California, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400-B, p. B342-B347.

Hartsock, J. K., 1954, Geologic map and structure sections, Iniskin Peninsula, Alaska: U.S. Geol. Survey open-file rept.

Imlay, R. W., and Reeside, J. B., 1954, Correlation of the Cretaceous formations of Greenland and Alaska: Geol. Soc. America Bull., v. 65, p. 235-236.

Irwin, W. P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California: California Div. Mines Bull. 179.

Juhle, R. W., 1955, Iliamna volcano and its basement: U.S. Geol. Survey open-file rept.

Kirschner, C. E., and Minard, D. L., 1949, Geology of the Iniskin Peninsula, Alaska: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 95.

Martin, G. C., Johnson, B. L., and Grant, U. S., 1915, Geology and mineral deposits of Kenai Peninsula, Alaska: U.S. Geol. Survey Bull. 587, 243 p.

Martin, G. C., and Katz, F. J., 1912a, A geologic reconnaissance of the Iliamna region, Alaska: U.S. Geol. Survey Bull. 485, 138 p.

——— 1912b, Geology and coal fields of the lower Matanuska Valley, Alaska: U.S. Geol. Survey Bull. 500, 98 p.

Mather, K. F., 1925, Petroleum on Alaska Peninsula—Mineral resources of the Kamishak Bay region: U.S. Geol. Survey Bull. 773-D, p. 159-181.

Paige, Sidney, and Knopf, Adolph, 1907, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U.S. Geol. Survey Bull. 327, 71 p.

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

Trainer, F. W., 1953, Preliminary report on the geology and ground-water resources of the Matanuska Valley agricultural area, Alaska: U.S. Geol. Survey Circ. 268, 43 p.

Vacquier, Victor, Steenland, N. C., Henderson, R. G., and Zietz, Isidore, 1951, Interpretation of aeromagnetic maps: Geol. Soc. America Mem. 47, 151 p.

Vestine, E. H., and others, 1947, Description of the earth's main magnetic field and its secular change, 1905-1945: Carnegie Inst. Wash., Pub. 578, 532 p.

Zietz, Isidore, and Henderson, R. G., 1955, The Sudbury aeromagnetic map as a test of interpretation methods: Geophysics, v. 20, p. 307-317.