TERTIARY TECTONIC HISTORY OF THE CASTLE MOUNTAIN-CARIBOU FAULT SYSTEM IN THE TALKEETNA MOUNTAINS, ALASKA

WILLIAM A. FUCHS

TERTIARY TECTONIC HISTORY OF THE CASTLE MOUNTAIN - CARIBOU FAULT SYSTEM IN THE TALKEETNA MOUNTAINS, ALASKA

by

William A. Fuchs

A dissertation submitted to the faculty of The University of Utah in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Geology

Department of Geology and Geophysics

The University of Utah

June 1980

THE UNIVERSITY OF UTAH GRADUATE SCHOOL

SUPERVISORY COMMITTEE APPROVAL

of a dissertation submitted by

William A. Fuchs

I have read this dissertation and have found it to be of satisfactory quality for a doctoral degree.

May 6, 1980 — Date

Ronald L. Bruhn
Chairman, Supervisory Committee

I have read this dissertation and have found it to be of satisfactory quality for a doctoral degree.

May 7, 1980 — Date

David S. Chapman
Member, Supervisory Committee

I have read this dissertation and have found it to be of satisfactory quality for a doctoral degree.

8 May, 1980 — Date

Francis H. Brown
Member, Supervisory Committee

I have read this dissertation and have found it to be of satisfactory quality for a doctoral degree.

May 8, 1980 — Date

Donald R. Currey
Member, Supervisory Committee

I have read this dissertation and have found it to be of satisfactory quality for a doctoral degree.

5/7/80 — Date

Laurence H. Lattman
Member, Supervisory Committee

ABSTRACT

Mapping on a scale of 1:24,000 of 264 square kilometers along 39 kilometers of the Castle Mountain - Caribou fault system has revealed four Tertiary tectonic events. (1) Faulting with an oblique net slip (right-lateral, north side) initiated uplift on the Castle Mountain - Caribou fault in the late Paleocene. At this time the Castle Mountain splay fault was either nonexistent or inactive. (2) In Eocene time, uplift occurred along both the Castle Mountain splay and Caribou faults when the block between the two faults was raised as a rotational fault block with a pivot at the splay. The uplift of the splay block, which resulted in north-northwesterly tilting, was probably in response to thermal expansion caused by intense magmatic activity. Paleomagnetic data indicate that the tilting occurred (immediately ?) prior to the injection of high-level intrusives of quartz latite domes. Northward thrust faulting near the splay and intrusion of albite granite porphyry in the fault zone immediately west of the splay may have occurred at the time of uplift of the splay block. (3) A period of extension was accompanied by intrusion within the splay block of diabase dikes and dike swarms trending 116°. (4) In a late tectonic phase, reactivation of the Caribou fault alternated with strike-slip motion on north-trending cross faults, producing a "meat-slicer" effect. Motion was then transferred from the Caribou fault to a parallel subsidiary fault

just to the south, the Boulder Creek fault, which may still be active.

Overall post-Eocene vertical motion across the Castle Mountain - Caribou fault system has been estimated by other workers to be 3 to 3 1/2 km (north side up). This author estimates post-Paleocene strike slip (right-lateral) on the Caribou fault to be 14 1/2 km. Total post-Paleocene strike slip on the Castle Mountain fault may be somewhat larger by addition of the partitioned component on the Castle Mountain splay fault, giving a total post-Paleocene strike slip of perhaps 20 km. Post-Eocene strike slip (right-lateral) on the Castle Mountain splay fault has been determined as five km based on an offset volcanic dome.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

The author thanks Dr. Ronald L. Bruhn, academic advisor, for his support and guidance, and Dr. F. Brown, Dr. D. Chapman, Dr. D. Currey, and Dr. L. Lattman for their help and support as members of the supervisory committee. Dr. G. Plafker is thanked for suggesting the topic of this dissertation. The project would not have been possible without the financial support for three field seasons by Amoco Production Company, Atlantic Richfield Company, and Union Oil Company of California, and the initial material support of the U.S. Geological Survey - Alaska Branch. Occasional helicopter support by Amoco Production Company and Atlantic Richfield Company made possible the impossible on several occasions.

Miriam Hill, Steve McMillin, Donna Hewitt, and Victoria Schurer deserve special recognition as field assistants. Dr. William Long often helped the author gain access to the field area.

Dr. D. Stone and B. Panuska were responsible for running some of the paleomagnetic samples on the equipment of Woodward-Clyde & Associates.

Other people who have helped the author in some manner are too numerous to mention all of them, but include Dr. J. Helwig, Dr. B. Csejtey, L. Fay, Dr. W. Connelly, C. White, T. Pavlis, and M. Jennison. The author apologizes to the many he has not mentioned.

INTRODUCTION

The purpose of this study was to investigate the structure and Tertiary tectonic history of a portion of the Castle Mountain - Caribou fault system in the Talkeetna Mountains of south-central Alaska. The focal point of the investigation was a major splay in the Castle Mountain fault where it splits into two major segments, the more northerly one being called the Caribou fault, and the southerly one being herein referred to as the Castle Mountain splay fault (formerly referred to by others as just the Castle Mountain fault). The study area is shown in Figure 1. Figure 2 is a sketch showing the major fault segments. The fault system was investigated at the suggestion of G. Plafker of the U.S. Geological Survey. The major reasons for initiating this project were the prior work in the area, which had delineated the basic geologic framework, reasonable accessibility, and controversy over certain aspects of the fault, such as the timing and magnitude of offsets.

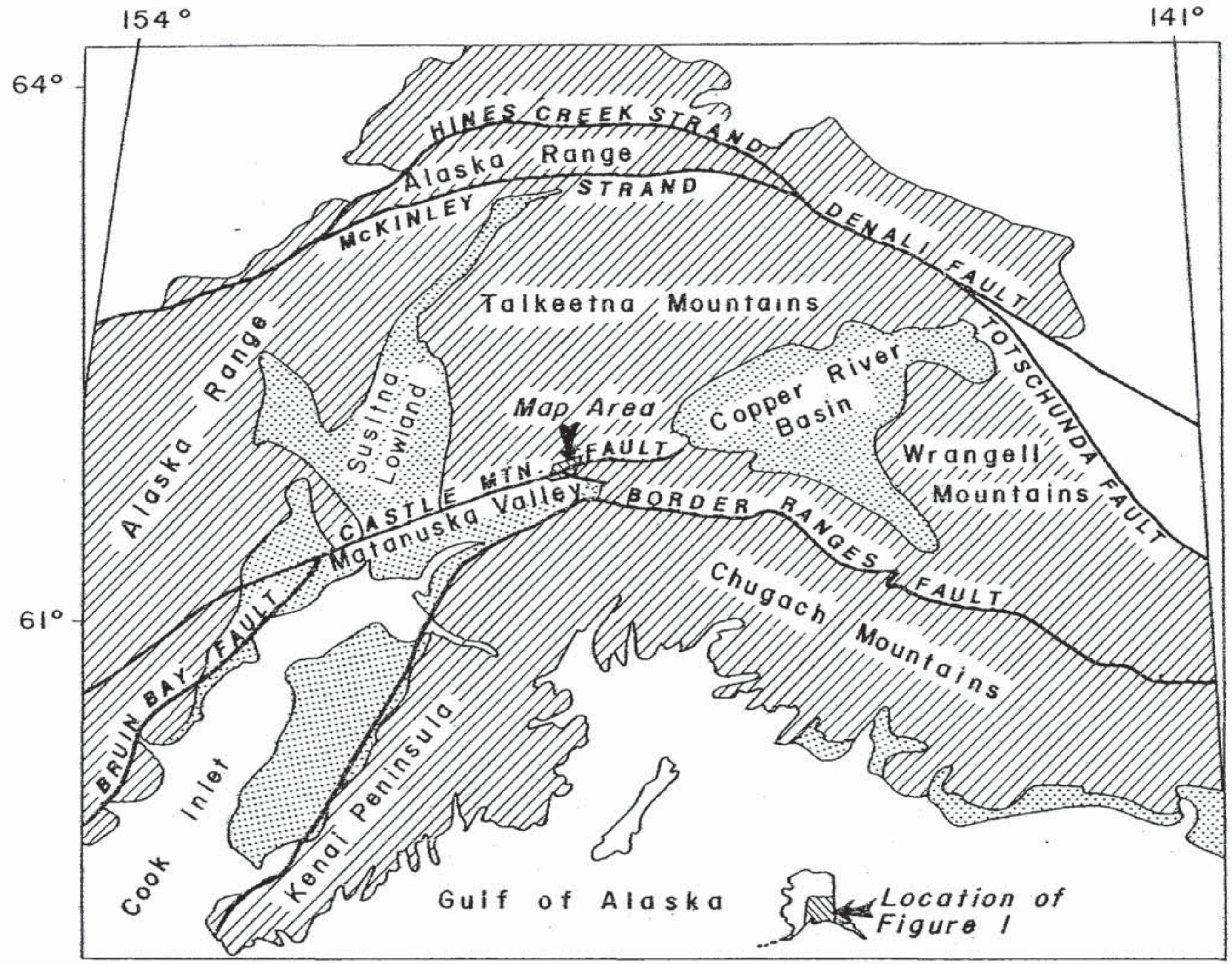


Figure 1. Locality map.

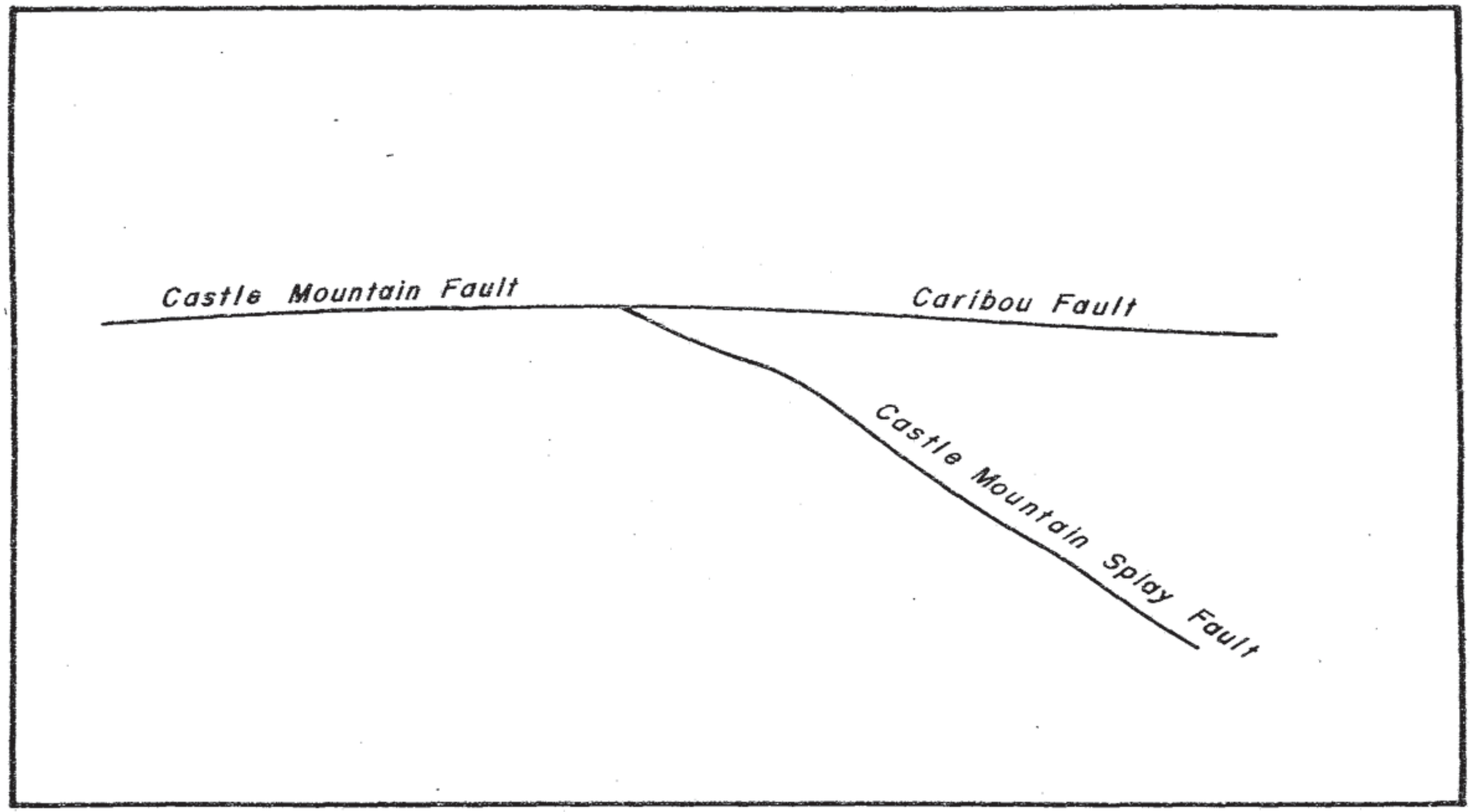


Figure 2. Fault segment names.

ACCESS

Access to the field area was gained by a variety of means. In most cases a base camp was established and as much area as possible was worked from the base camp. Then backpack camps were established to increase accessibility of more remote areas. All mapping was done on foot.

The first base camp was established northwest of Castle Mountain. This was the only base camp accessible by four-wheel drive vehicle. Camps on the Chickaloon River were established by means of packhorse, helicopter, and airplane (Supercub). Camps on Boulder Creek were established by means of packhorse and airplane. A camp was established on East Boulder Creek by helicopter. An efficient means of food supply was found to be air drops from an airplane.

GEOLOGIC AND TECTONIC SETTING

The Castle Mountain - Caribou fault system (more generally known as the Castle Mountain fault) is a major fault system which is known to have had both dextral and reverse (north side up) slip. The fault system trends approximately 073° (revised) for a distance of at least 200 km across south-central Alaska (Grantz, 1966). The fault is considered to be the northern boundary of the Matanuska Valley, a feature which separates the Talkeetna Mountains from the Chugach Mountains to the south. In the Susitna Lowland to the west, there has been recent movement producing a south-facing scarp approximately three meters in height in recent alluvium, indicating that the northern block is faulted up. Radiocarbon and tree ring dates indicate that the last motion on the fault took place from 222 to 1860 ± 250 years ago (Detterman et al., 1974). In the mountainous area to the east of the Susitna Lowland, the area of this study, definite evidence for recent movement is thus far lacking. The rock units present include sedimentary, volcanic, and intrusive rocks, and range in age from early Jurassic to Miocene.

The Castle Mountain fault has important but poorly understood relationships with the plate tectonics of the region. A major north-westerly dipping Benioff zone occurs where the North American plate is overriding the Pacific plate and extends from the Aleutian Islands to the vicinity of Mt. McKinley, crossing the Castle

Mountain fault. The right-lateral movement on the Castle Mountain fault is similar in sense, but less in magnitude, to that of the Denali fault (see Figure 1), a major transform fault and plate boundary to the north. The southern Alaska block (south of the Denali fault) is partially coupled to the Pacific plate and stresses built up between the Castle Mountain and Denali faults may have given rise to Mt. McKinley.

Cook Inlet is a major tectonic basin that contains up to 9,000 meters of Tertiary sediment (Krischner and Lyon, 1973). It lies above the point of greatest curvature in the Benioff zone, where the dip of the zone changes from very shallow to steep. The Castle Mountain fault crosses the Cook Inlet - Susitna Lowland basins with impunity, and then appears to link up with the Lake Clark fault to the west, into which it projects without significant change in trend. In the geologic past the Castle Mountain fault may also have been connected with the presently inactive Bruin Bay fault on the west side of Cook Inlet. The Caribou fault, the eastern extension of the Castle Mountain fault, takes on a splaying character in an eastward direction until it is lost beneath the alluvium of the Copper River Basin. Whether or not the fault continues across the Copper River Basin is conjectural.

PREVIOUS INVESTIGATIONS

In addition to the broader scale investigations noted in the previous section, the Castle Mountain - Caribou fault system has been investigated on a more detailed scale by numerous investigators. First mention of the Castle Mountain fault is by Martin and Katz (1912), who describe a "great fault or zone of faulting," which forms "a remarkably straight line parallel to the general course of the Matanuska and about five or six miles north of it." The work of Martin and Katz in the lower Matanuska Valley was quite good, and in fact, some of their mapping and interpretations are more correct on certain points than are more recent reinterpretations. Martin's (1926) report on the Mesozoic stratigraphy of Alaska contains numerous useful stratigraphic descriptions not available elsewhere. Capps (1927) published a paper on the geology of the upper Matanuska Valley. Waring (1936) has done detailed mapping in the region immediately south of the project area.

Barnes and Payne (1956) have done detailed work in the Wishbone Hill coal district. Their report includes the first reasonable attempt at summarizing the geologic history of the lower Matanuska Valley and southern Talkeetna Mountains area. They also gave the Castle Mountain fault its name based on the fact that it was best described on Castle Mountain. Clarady's (1974) study resulted in a much better understanding of the sedimentological aspects of the

Wishbone Formation, a key unit to interpretation of the tectonics of this region.

Detterman, Plafker et al. (1976) established the basic stratigraphic and structural framework of the Castle Mountain fault from the Susitna Lowland eastward to the western margin of mapping by Grantz in the southeastern Talkeetna Mountains (Grantz, 1960, 1961). The work of Detterman, Plafker et al., and Grantz showed the splaying nature of the fault on its eastward end and indicated that the magnitude of strike slip faulting was on the order of tens of kilometers (based on drainage offsets and a possible offset Cretaceous and Tertiary lithologic sequence). Boss et al. (1976) argue for 240 km of Tertiary strike slip motion by considering the Copper River Basin to be the original northern extension of Cook Inlet, and Hackett (1976) argues for about 100 km of strike-slip motion on the basis of offset gravity anomalies and offset Mesozoic rock trends. The most recent structural work on the Castle Mountain fault has been done by Bruhn (1978), and Bruhn and Pavlis (1978). Grantz (personal communication, 1979) is continuing his noted investigations of this fault system.

METHODS OF INVESTIGATION

It is obvious from a review of work by many investigators of other large fault systems that there is no established method for studying a fault system. This author is impressed by the large variety of techniques which have been used with varying degrees of success on the San Andreas fault system (Dickinson and Grantz, 1968), the most intensely studied fault system in the world. Likewise, this author used a large variety of techniques with diverse degrees of success.

Several of the techniques used initially in this investigation were abandoned because they did not yield interpretable results. Most notable of these abandoned techniques was the use of fracture analysis, both from data gathered in the field and from lineament data derived from the study of air photos on a scale of 1:24,000. Distinct fracture trends were, in fact, noted. However, this author did not feel he could interpret the meaning of the trends. This was partly due to complexity, introduced by proximity to the fault splay and partly because of the diverse ages of rock represented. Near the end of the project the author was introduced to a new technique of fracture analysis that treats brittle failure as a bulk strain phenomenon rather than directly relating it to the orientation of the principle stress axes (Arthaud, 1969). The limited application of this technique by R. Bruhn and the author in the study area, as well as its successful application in an area to the west studied by R. Bruhn (personal communication, 1979) suggests that this method could yield interpretable results.

The basic data from which the conclusions of this dissertation are derived come from semi-detailed geologic mapping on a scale of 1:24,000. A final copy of this map has been made. Figure 3 is a reduced and redrafted version of this map. The total area mapped was approximately 264 square kilometers along 39 kilmoters of the fault system. Figure 4 contains four geologic cross sections, as well as a more detailed map of a complicated portion of the Caribou fault.

The key to unravelling the tectonic history of the Castle Mountain - Caribou fault system was found through a comparative study of the stratigraphy across the various fault segments as well as a study of the igneous intrusive bodies of the area. The latter involved an analysis of dike trends and geochemical analysis of an offset volcanic dome. Morphology and attitude data on faults, bedding, and folds constitute the essential elements of the structural analysis. As would be expected, the structural style contributes very much to arguments concerning the tectonic history. Finally, limited paleomagnetic work was used to refine the conclusion.

Figure 3. Geologic map of the Castle Mountain - Caribou fault system. 3a-b are the legend. 3c is the west half of the map. 3d is the east half of the map.

3a.

SEDIMENTARY ROCK UNITS

SURFICIAL DEPOSITS, Qal, (Quaternary) Alluvium, colluvium, terrace gravels, glacial moraine, outwash, landslides; only large areas of this unit are mapped.

WISHBONE FORMATION, Tw, (Paleocene and Eocene) Well-indurated boulder-cobble-pebble conglomerate with thick interbeds of sandstone siltstone, and claystone; 600 to 900 m thick.

CHICKALOON FORMATION, Tc, (Paleocene) Well-indurated, massive feldspathic sandstone, siltstone, claystone, and conglomerate with numerous beds of bituminous coal; at least 1500 m thick.

MATANUSKA FORMATION, Km, (Cretaceous) Predominantly dark shale and siltstone in lower part with interbedded dark shale and sandstone, locally conglomeratic, in upper part; about 1200 m thick.

CHINITNA FORMATION, Jc, (Upper Jurassic), Dark gray shale and siltstone with interbeds of graywacke and numerous large limestone concretions; 260 m exposed thickness.

TUXEDNI GROUP, Jt, (Middle Jurassic) Well-indurated graywacke sandstone, and conglomerate in lower part, and dark siltstone and shale that weathers brown in upper part; 140 to 350 m thick.

TUFF, Jtf, (Lower Jurassic) Tuff and tuffaceous sandstone, white with variable mottled limonite, well-bedded in places, may be the uppermost member of the Talkeetna Formation (Horn Mountain Tuff); 245 m thick.

TALKEETNA LIMESTONE, Jl, (Lower Jurassic) Light to dark gray, fine-to-medium grained; marble in part; up to 75 m thick.

TALKEETNA FORMATION, Jtk, (Lower Jurassic) Andesitic flows, flow breccia, tuff, and agglomerate interbedded with sandstone and siltstone; locally altered to greenstone; occasional porphyry stocks, about 1000 to 2000 m thick.

3b.

IGNEOUS ROCK UNITS

ALBITE GRANITE PORPHYRY, Tp, (Eocene?), Intrusive quartz-plagioclase porphyry albite granite; localized in Castle Mountain - Caribou fault zone.

VOLCANIC ROCKS, Tv, (Eocene and younger) Mafic to felsic volcanic rocks; flows with interbeds of tuff, ash, and breccia; minimum several hundred meters thick.

QUARTZ LATITE, Tf, (Eocene) Volcanic domes of quartz latite porphyry, probably equivalent to lower units of Tertiary volcanic rocks.

GABBRO, Tm, (Eocene or younger) Probably equivalent to diabase dikes.

xxxxxxxx DIABASE DIKE (Eocene or younger)

QUARTZ DIORITE, Ji, (Early to Middle Jurassic) Medium-grained hornblende quartz diorite and subordinate diorite and tonalite.

SYMBOLS

Contact

Solid line where certain,
dashed line where uncertain

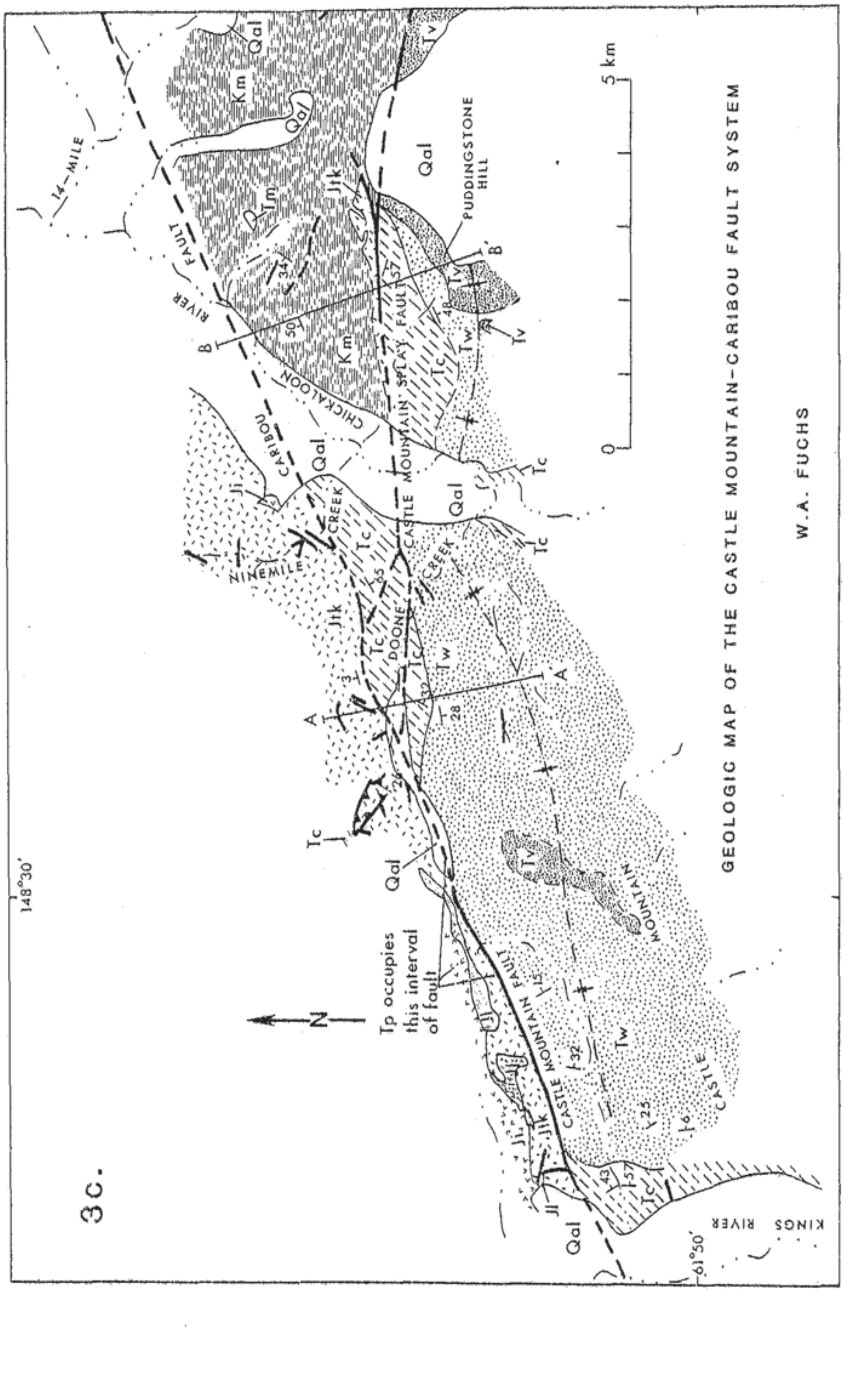
Fault

Solid line where certain,
dashed line where uncertain

Syncline

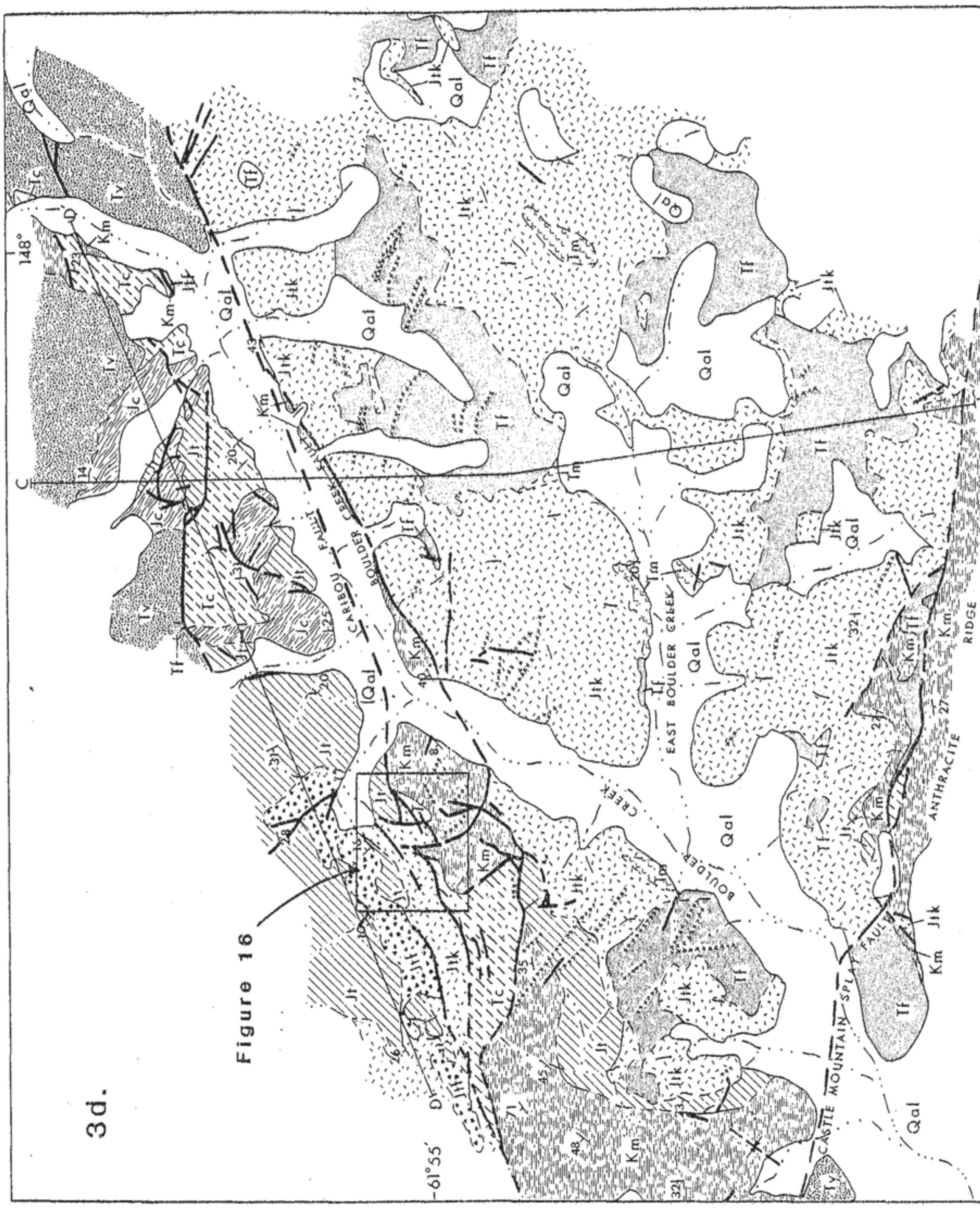
Showing trace of axial plane,
solid line where certain,
dashed line where uncertain

Strike and dip 45



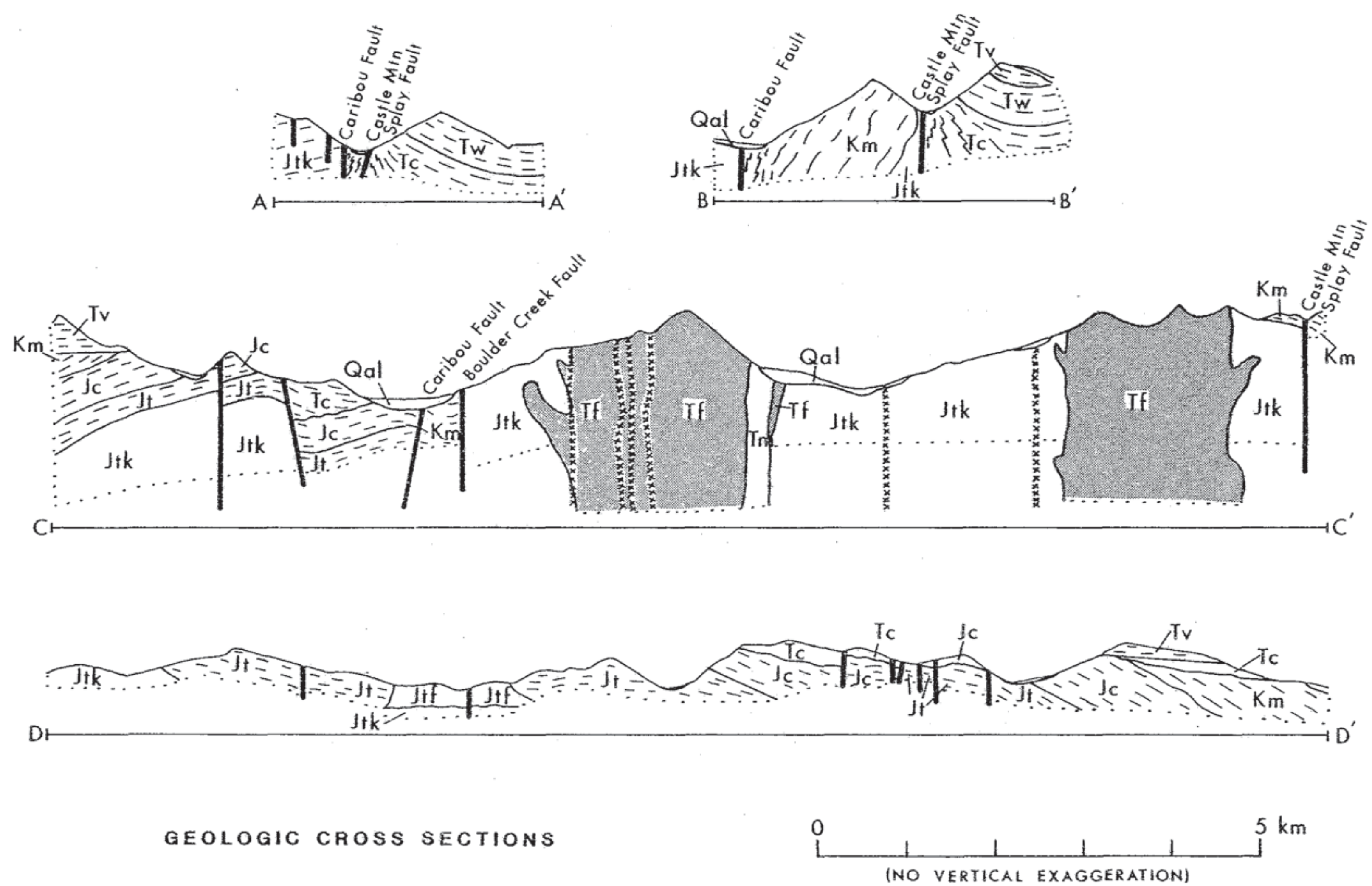
GEOLOGIC MAP OF THE CASTLE MOUNTAIN-CARIBOU FAULT SYSTEM

W.A. FUCHS



3d.
Figure 16
148°
-61°55'
C
D
CARIBOU FAULT
BOULDER CREEK
EAST BOULDER CREEK
BOULDER CREEK
CASTLE MOUNTAIN SPLAY FAULT
ANTHRACITE RIDGE
Qal
Jtk
Tf
Km
Tv
Jc
Jt
Tm

Figure 4. Geologic cross sections. See Figure 3 for locations and legend.



GEOLOGIC CROSS SECTIONS

ROCK UNITS

The rock units descriptions below include the work of others as well as the work of this author. Unless otherwise referenced, the conclusions and descriptions are those of this author.

Sedimentary and Volcanic Rock Units

Talkeetna Formation (Lower Jurassic)

This is the oldest rock unit in the study area, and it is characterized by a 1,000- to 2,000-meter-thick sequence of volcanic flows, flow breccia, agglomerate, and tuff interbedded with marine sedimentary rock, mainly volcaniclastic sandstone and siltstone. The volcanic rocks appear to be dominantly andesite with subordinate basalt and dacite, but the relative proportions have not been established. Pyroclastic rocks are abundant, the most common rock type being andesitic flow breccia. Marine sedimentary rocks are sporadic and constitute roughly 10 to 15% of the section. Nowhere is the lower contact of the Talkeetna Formation observed within the area of investigation. This author believes that the Talkeetna Formation represents the remnants of a classical island arc.

Undoubtedly, the most complete survey of the Talkeetna Formation was done by Detterman and Hartsock (1966). Their study concentrated on a region immediately west of Cook Inlet, 300 km southwest of the study area of this dissertation. Detterman and Hartsock have divided the Talkeetna Formation into three members and claim good correlation between the rocks of their area and those in the Talkeetna Mountains. Having seen a large amount of this formation in the Talkeetna Mountains, this author does not believe that the correlation is that good on a detailed scale, at least not by a mere comparison with the published sections. However, because of lithologic similarities, there is little doubt that the rocks in both areas should be assigned to the same formation. It is interesting to note that according to Detterman and Hartsock, the Talkeetna Formation on the west side of Cook Inlet yielded no fossils, whereas the Talkeetna Formation in the Talkeetna Mountains contains abundant marine fossils in places. This implies that the rocks in the Talkeetna Mountains may have originally been located seaward from a central arc massif represented by the Talkeetna Formation rocks on the west side of Cook Inlet.

The stratigraphy of the Talkeetna Formation is complex in the study area and will only be discussed in the most general terms. A most important observation is that of an abrupt change in the stratigraphy of the formation as one crosses the Caribou fault and its westward extension, the Castle Mountain fault. There are essentially no units within the formation that can be correlated across this boundary, with the exception of some rocks in the vicinity of the major splay behind Castle Mountain; these rocks were clearly thrust northward across the fault and have been isolated by subsequent movement on the Castle Mountain fault. This is discussed further in a later section.

There are several distinctive units of the formation north of the Caribou - Castle Mountain fault. The first of these, a light- to dark-green greenstone, comprises most of the Talkeetna Formation in a narrow strip between the fault north of Castle Mountain and an intruding batholith to the north. Metamorphism, which is probably greenschist facies in this area, was the most intense observed within the study area. The reason for this is probably the close proximity to the intruding batholith. Also distinctive within the Talkeetna Formation is a limestone unit, which was found to be a mappable unit. The unit consists of light- to dark-gray, fine- to medium-grained limestone, which has been recrystallized to marble in places (particularly just east of Kings River). Detterman et al. (1976) indicate a thickness for the limestone of 25 to 30 meters, but the unit was observed to be 75 meters thick by this author in one locality. No fossils were found, and indisputable bedding was not common. Chert beds are evident in places. It was not possible to determine facing directions. Scattered, thin remnants of marble in two localities south of the Caribou fault may correlate with the limestone unit north of the fault, but the correlation is uncertain. Furthermore, in several areas north of the Caribou fault thick sections of well-bedded tuffs and tuffaceous sandstones are present. Correlative units south of the fault could not be found. Another mapped unit, found north of the Caribou fault, at the top of the Talkeetna Formation was a tuff unit. This unit was mapped in part as Tertiary volcanics by Detterman et al. (1976), but is herein assigned to the Talkeetna Formation based on relationships observed in outcrop at a locality 4 1/2 km west of Boulder Creek. At this locality, the tuff is in contact with indisputable Talkeetna Formation. It is fairly certain that the contact is gradational, although some slickensided shear fractures are evident. The unit includes white tuffaceous sandstone and tuff, which is generally white with variable mottled limonite. The unit is well-bedded in places and is possibly equivalent to the Horn Mountain tuff member of the Talkeetna Formation.

South of the Caribou fault there are also several distinctive units of the Talkeetna Formation. One of these units, which was mapped on the original 1:24,000-scale map, is a large, pale orange (on weathered surface), altered (often pyritic) tuff. This tuff unit is found on both sides of Boulder Creek and appears to have been deposited on an irregular surface. Another somewhat distinctive rock style in the area south of the Caribou fault is a maroon flow breccia with subordinate flows and agglomerate. However, the flow breccia is not unique because maroon-colored rocks occur at several stratigraphic levels. A light green agglomerate with large, black fossilized tree fragments (also found south of the Caribou fault) would probably be a mappable unit if more detailed mapping were to be conducted. Several intrusive stocks of porphyry were mapped on the original 1:24,000 map. These may be the youngest rocks of the Talkeetna Formation represented in the study area.

Thin, highly fossiliferous marine sedimentary beds are occationally found both north and south of the Caribou fault. The fossils are dominantly mollusks. One large ammonite was found in float.

Preliminary paleomagnetic results (D.B. Stone, personal communication, 1979) indicate that the rocks of the Talkeetna Formation were formed in more southerly latitudes. This is consistent with results obtained from a study of this formation in the Alaska Peninsula (Stone and Packer, 1979) which show that overlying Middle Jurassic rocks were formed in latitudes approximately 20 degrees south of their present position.

Tuxedni Group (Middle Jurassic)

Group status was given to the Tuxedni Formation by Detterman and Hartsock (1966). West of Cook Inlet the group is up to three kilometers thick and includes six formations. From bottom to top these are the Red Glacier Formation, Gaikema Sandstone, Fitz Creek Siltstone, Cynthia Falls Sandstone, Twist Creek Siltstone, and Bowser Formation.

The six formations of the Tuxedni Group are not mappable within the region of this study. The reason for this is simply because the maximum thickness attained by the Tuxedni Group in the map area is 350 meters, which is 1/9 the thickness described for the section west of Cook Inlet.

A statement by Imlay (1962) is particularly relevant: "The above remarks concerning thickness, lithologic features, and unconformable relations may not apply in the Boulder Creek area of the Talkeetna Mountains which has not been studied in recent years. In that area one collection (Mesozoic loc., 8567) contains species of Normannites and Chondrocerus identical with species of the Fitz Creek Siltstone, and another collection (Mesozoic loc. 8572) contains ammonites identical with species in beds directly overlying the Cynthia

Falls Sandstone northwest of Cook Inlet." Sample locality 8572 is north of the Caribou fault and northwest of Boulder Creek, and from this author's mapping and the above statement by Imlay, it is apparent that the Red Glacier Formation, Gaikema Sandstone, Fitz Creek Siltstone, Cynthia Falls Sandstone, and Twist Creek Siltstone (all from the Tuxedni Group) are present. The Bowser Formation may or may not be present. The lowermost formation of the Tuxedni Group, the Red Glacier Formation, appears to be present because of coquina beds found by this author north of the Caribou fault which resemble those described by Detterman and Hartsock (1966) for this formation. Fossilized wood fragments found north of the fault may be indicative of the Gaikema Sandstone, the formation which overlies the Red Glacier Formation. Detterman and Hartsock (1966) claim that the Fitz Creek Siltstone is abundantly fossiliferous in the Cook Inlet area, and they state, "Many pelecypods are found, but for the first time in the Jurassic of this region the pelecypods are less numerous than are the ammonites." Indeed, such a unit was found north of the Caribou fault. The ammonites found were so numerous and of such quality as to make it a true collector's locality. Sample locality 8567 is south of the Caribou fault and is near the top of the Tuxedni Group represented in this area. Thus, it would appear that south of the Caribou fault the Bowser Formation, the Twist Creek Siltstone, and possibly the Cynthia Falls Sandstone are missing.

North of the Caribou fault the overlying Naknek Formation has been removed, probably by erosion, and south of the fault both the Chinitna and Naknek formations have been removed. It then seems reasonable to assume that south of the Caribou fault the upper part of the Tuxedni Group has also been removed by erosion. Nevertheless, a large amount of thinning must be called upon, and this is consistent with Detterman and Hartsock's conclusion that, at least for the Red Glacier Formation, thinning occurs to the northeast (in the direction of the Talkeetna Mountains). This author estimates the group thickness north of the Caribou fault to be 350 meters. South of the fault, thickness in one locality was estimated to be 140 meters and measured as 370 meters at another locality. Further south, just north of Anthracite Ridge, there is a small nine-meter-thick section of Tuxedni Group. Southward stratigraphic thinning is not necessarily indicated since the upper contact is an erosional unconformity.

The description of Detterman et al. (1976) probably best describes the overall lithologic character of the Tuxedni Group in the map area: "well-indurated graywacke, sandstone, and conglomerate in the lower part, and dark siltstone and shale that weathers brown (to orange-brown) in the upper part." Some limestone beds are also present.

Fossils found by the author to be indicative of the Tuxedni Group in this area (both north and south of the Caribou fault) include extremely abundant ammonites, belemnites, trigonia (particularly diagnostic), and unidentified mollusks. Fossil wood fragments, sometimes quite large, are also indicative. Distinctive brachiopods are present but much less abundant.

The unconformity which separates the Talkeetna Formation from the Tuxedni Group is of great interest. At one locality in the canyon immediately north of the west end of Anthracite Ridge, it is apparent that the relief on this unconformity is a minimum of 200 meters. It is quite possible that the actual relief is on the order of 300 meters. Apparently, the surface on top of the Talkeetna Formation was quite hilly at the time it was submerged. The nature of this unconformity is consistent with rapid subsidence.

The source of most of the sediments of the Tuxedni Group is a volcanic terrain, and previous studies indicate that much of the material is clearly derived from the Talkeetna Formation, although a minor amount of granitic material is present.

Chinitna Formation (Upper Jurassic)

A general lithologic description of the Chinitna Formation is that it consists of dark-gray shale and siltstone with interbeds of graywacke, and numerous large limestone concretions. In the Cook Inlet area the formation is abundantly fossiliferous, but this author found the formation within the map area to be sparse in macrofossils.

Detterman et al. (1976) have mapped Chinitna Formation in the map area both north and south of the Caribou fault. This investigator questioned both of these mapped occurrences, particularly the occurrence south of the fault, and felt the matter to be worthy of further investigation. Original fossil data was scanty and was obtained in 1913 and re-examined by Imlay (1953). For various reasons, not the least of which was a difference in mapping interpretations, this author felt that all the fossil data (all obtained north of the Caribou fault) was suspect. South of the fault the author found beds lithologically identical to, and apparently continuous with, beds mapped as Chinitna Formation by Detterman et al. (1976); these beds lay stratigraphically above beds that contained an obvious Matanuska Formation fauna. There was no apparent tectonic boundary between the two sets of beds.

In order to further test the validity of the author's claim that no Chinitna is present, James Helwig of Atlantic Richfield Company and the author collected three samples for micropaleontological analysis, two samples north of the Caribou fault and one sample south of the fault. The results of the analysis by John Bennett of Atlantic Richfield Company are given in Appendix D. They show that the beds north of the fault are actually Upper Jurassic, and hence Chinitna Formation. However, the beds south of the fault are Upper Cretaceous, and hence Matanuska Formation. This leads to the conclusion that while Chinitna Formation is present north of the Caribou fault, it is missing directly across the fault on the south side, a fact of considerable tectonic importance.

North of the Caribou fault the Chinitna Formation concordantly overlies the Middle Jurassic Tuxedni Formation. The lower contact is marked by a dark-brown, medium-grained sandstone, perhaps 15 to 30 meters thick. Above this lies a brown (weathered color) siltstone, perhaps 30 to 60 meters thick, which is nonresistant and slightly less orange than the upper Tuxedni Group rocks. Limestone concretionary beds are common. Finally, there is very thick sequence (2/3 to 3/4 of the thickness of the entire unit) of resistant, cliff-forming, monotonous, alternating black and white (weathering color) rocks which are predominantly siltstone with thin interbeds of sandstone. The uppermost rocks of the Chinitna Formation are mostly gray siltstone with one distinctive orange sandstone bed. This section is approximately 260 meters thick in exposure. Belemites are fairly common in these rocks, pelecypods less common, and ammonites even less common. In isolated outcrops, the Chinitna Formation is difficult to distinguish from the Tuxedni Group.

Naknek Formation (Upper Jurassic)

Although reported to be present by most previous investigators, the Naknek Formation is not present in the map area. This author contends that the Naknek Formation indicated on the map of Detterman et al. (1976) is in an area which was mismapped. Part of their problem was that a major fault which repeats part of the stratigraphic section had been overlooked. Fossil evidence which favors the presence of Naknek Formation (Martin, 1926) in the map area is scanty and in need of review.

Matanuska Formation (Upper Cretaceous)

Detterman et al. (1976) estimate that the Matanuska Formation is 1,200 meters thick. This author believes that 1,200 meters represents a minimum value. The formation consists predominantly of dark shale and siltstone in the lower part, while the upper part is comprised of interbedded dark shale and sandstone (sandstone predominating) and is locally conglomeratic. Inoceramus is a widespread indicator of this marine formation. Much of the formation consists of turbidites, and its overall character is similar to that found in classical forearc basins (Dickinson and Seely, 1979).

The base of the Matanuska Formation appears to be an unconformity that is represented by a surface of profound erosion cutting across rocks ranging in age from Early Jurassic to Early Cretaceious (Martin, 1926). This is indicated by the fact that this author found Matanuska Formation resting on top of Lower Jurassic Talkeetna Formation (with no apparent tectonic contact) north of Puddingstone Hill, whereas, 3 1/2 km to the east Upper Cretaceous Matanuska Formation rests on top of Middle Jurassic Tuxedni Formation. However, in places, notably along the west side of Boulder Creek, the Matanuska - Tuxedni contact is a surface of such little relief as to appear to be a conformable contact. (Stratigraphically, it cannot be conformable.) This fact leads the author to suggest that the pre-Matanuska Formation physiography was one of buttes and mesas. This hypothesis is made more tenable by preliminary paleomagnetic data (Stone, personal communication, 1979), which indicate that the Matanuska Formation was originally formed in more southerly (and more arid?) latitudes. Stone (1979) has shown that Upper Cretaceous rocks of the Alaska Peninsula were formed in latitudes 40 degrees south of their present position.

Grantz (1964) has shown that fauna collected from two localities within the area of Figure 3 are Upper Campanian and Maestrichtian (?) in age. One of these localities includes the most northeasterly exposure of Matanuska Formation on the geologic map, while the other locality contains the Matanuska Formation along Anthracite Ridge.

Distinction between shales of the Matanuska Formation and those of the overlying Chickaloon Formation can be difficult. The shales of the Matanuska Formation are generally considered to be of darker color, greater hardness, and platy fracture, but these were found to be very misleading criteria. This is particularly true in areas of tectonic activity, where the distinction can become almost impossible. In these areas only the presence of marine fossils in the Matanuska Formation versus the presence of terrestrial plant fossils or coal in the Chickaloon Formation are acceptable criteria for distinction between the two units.

In proximity to faults or other areas of tectonic disturbance, the Matanuska Formation rocks often have undergone a change to argillite with a distinct cleavage. At several localities large slivers of argillite are found within major fault zones, where they appear to have behaved as incompetent concentrators of strain within the zone. The distinction between argillite and Talkeetna Formation greenstone can be difficult, particularly in the area north of Puddingstone Hill.

The upper contact of the Matanuska Formation has not been previously described in the literature. According to L. Fay (personal communication, 1972), there is only one locality in the Matanuska Valley where this contact can be seen, and it is uncertain whether or not that contact is tectonic. The author has not observed the locality in the Matanuska Valley. However, he did observe the contact in two localities within the map area. The first locality is just west of the area of complex offsets in the Caribou fault, west of Boulder Creek. Here, the actual contact is occupied by a dike or sill of diabase. It seems clear, however, from the geometry of the boundary at this locality that the contact was probably erosional, with the overlying unit, the Chickaloon Formation (consisting here of pebble and pebble-cobble conglomerate), occurring as stream channel deposits. The Matanuska is a dark argillite with some sandstone beds and no fossils at this locality. The second locality is west of Boulder Creek in the northeast corner of the map area, where the Matanuska - Chickaloon contact is spectacularly displayed at a waterfall. Fine- to medium-grained, occasionally biotitic (very characteristic of parts of the Matanuska Formation), greenish-gray graywacke with a typical Matanuska fossil assemblage (Inoceramus, belemnites, worm burrows) underlies a 30-meter-thick boulder-cobble-pebble conglomerate (upper Chickaloon Formation) which contains abundant volcanic material. Above this conglomerate is typical whitish, coarse-grained Chickaloon Formation sandstone with coal beds. The two contacts described above are on opposite sides of the Caribou fault, an important distinction, since strike-slip fault movement has juxtaposed two areas which were paleogeographically separated.

Chickaloon Formation (Paleocene)

The Chickaloon Formation is at least 1,500 meters thick and consists of well-indurated, massive, feldspathic sandstone, siltstone, claystone, and conglomerate, along with numerous beds of coal. Iron or iron carbonate concretions commonly occur in thin layers or as nodules.

Mineable coal beds are found in the Wishbone Hill District to the west, mainly in the upper 425 meters of the section, where they occur in several more or less well-defined groups separated by comparatively thick sections of strata containing no coal (Barnes and Payne, 1956). The old Kings River coal camp district is in part included in the map area, and the Chickaloon coal district is several miles south of the map area. This author saw two coal beds of good quality (five feet and six feet thick), east of Kings River.

Plant fossils, mainly wood fragments and leaf impressions, occur sporadically throughout the section. The entire section is essentially of continental origin and represents deposition on "a low fluvial plain with coal-forming marshes standing but slightly above sea level" (Barnes and Payne, 1956). A northerly high grade metamorphic source terrain is postulated because of the abundance of garnet (Kirshcner and Lyon, 1973).

The lower contact of the Chickaloon Formation is an erosional unconformity. The upper contact is gradational and poorly defined. There is an increase in conglomeratic beds, which occasionally are resistant ridge-formers, as the upper contact is approached. However, tremendous lateral variations in the uppermost section are evident. There are five or more pebble conglomerate beds in the upper Chickaloon Formation on the north slope of Puddingstone Hill, two of which are 12 meters thick. Along the side stream east of Kings River there may be only two or three conglomerate beds, one of which is a pebble-cobble conglomerate 27 meters thick, and the conglomerate beds are stratigraphically separated by a larger interval. The 27-meter pebble-cobble conglomerate contains cobbles no larger than a fist. The pebbles and cobbles consist of white and black chert, silicified volcanic and intrusive rock, and silicified siltstone (?). The matrix consists of "dirty" micaceous sandstone with abundant rock fragments. Diabase dikes and sills, which cut all the sedimentary units, are particularly common in the Chickaloon Formation.

Wishbone Formation (Upper Paleocene and Eocene)

The Wishbone Formation is 600 to 900 meters thick and consists of well-indurated pebble-cobble and pebble-cobble-boulder conglomerate with thick interbeds of sandstone, siltstone, and claystone. The pebbles and cobbles (and boulders in places) are composed predominantly of fine-grained igneous and metamorphic rocks, chert, vein quartz, and jasper. The subordinate jasper is clearly derived from the Talkeetna Formation, as is much of the volcanic material.

The source of the abundant chert and quartz is a bothersome and unresolved question. It seems likely that the Wishbone Formation is derived from a mixture of orthoquartzitic conglomerate (represented by a mature component of chert and quartz) and petromict conglomerate (represented by an immature component of volcanic material) (nomenclature of Pettijohn, 1975). The Wishbone Formation, for the most part, consists of a monotonous, thick sequence of conglomerate. However, also present are numerous lenticular sandstone beds ranging in thickness from several centimeters to 12 meters or more, which are often crossbedded. These lenses were used to obtain crude bedding measurements. Siltstone is found at the bottom of the section. A 2- to 5-meter-thick vesicular basalt flow as found by the author within the upper middle part of the formation on Castle Mountain. Although the particular samples obtained by the author did not seem suitable for age dating, less altered samples could potentially yield a more definitive age for the formation.

Clarady (1974) obtained paleocurrent measurements on the Wishbone formation at two localities. At Wishbone Hill, preferred current direction was south and southwest. To the west and southwest of Castle Mountain, paleocurrent directions had a westerly trend. Clarady suggests that the Wishbone Formation was deposited in an alluvial fan environment, and he confirms previous interpretations that correlated this formation with the West Foreland Formation, which underlies Cook Inlet. Clarady has evidence for an Eocene age for the Wishbone Formation, but this author believes that the

Paleocene is also represented. This is based on relations described below which show that the lower Wishbone Formation is in part a facies equivalent of the upper Chickaloon Formation. Admittedly, this is an argument based on rock unit correlations and thus cannot be considered as strongly establishing an absolute time position.

Placing the lower contact of the Wishbone Formation was a difficult task, but rarely was it critical to the structural interpretation. Figure 5 is a schematic diagram showing the larger lateral variations in the lower section. None of these sections are actually measured. However, the following is a general description (thicknesses are approximate) of the lowest Wishbone Formation south of Doone Creek. The description is from top to bottom.

Formation	Thickness	Description
Wishbone	--	Pebble-cobble conglomerate
Wishbone	12	Interlayered siltstone or shale and coarse sandstone
Wishbone	15	Black, highly carbonaceous, fissile shale with concretions
Wishbone	53	Sandstone, fine-grained, well-bedded
Wishbone	9	Pebble conglomerate, pebbles predominantly black chert, white quartz, minor jasper, little or no Talkeetna Formation rocks or siltstone
Chickaloon	335	Interbedded, highly carbonaceous black shale, siltstone, sandstone (with pebbles occasionally) with abundant plant fossils.

Aside from the lateral variations described above, it was necessary to develop a practical working method for locating the conformable contact in any given vertical section. The convention

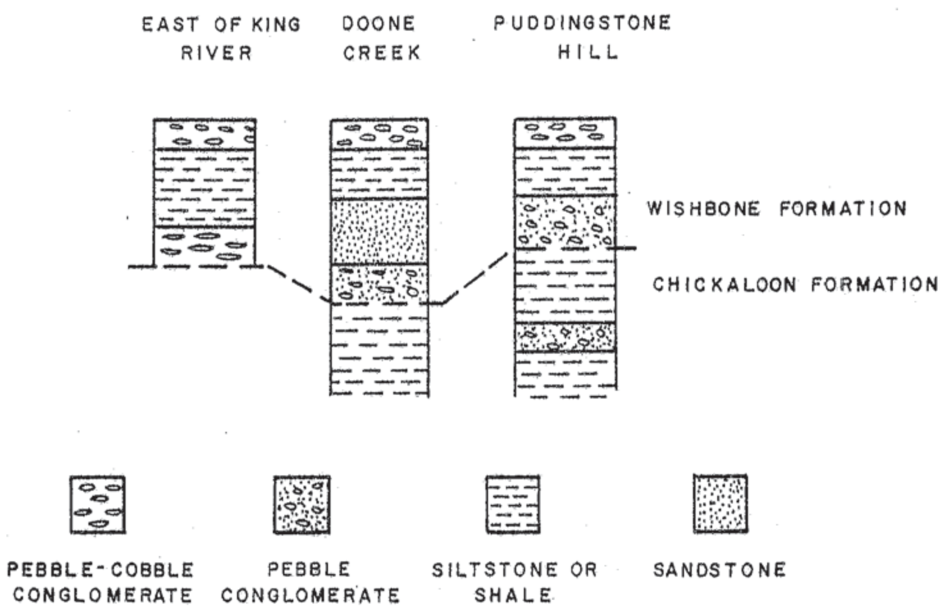


Figure 5. Schematic sections of the base of the Wishbone Formation.

adopted was to work from the top down. In every area investigated there is a huge sequence of essentially uninterrupted pebble-cobble and pebble-cobble-boulder conglomerate which is "definite" Wishbone Formation. Below the "definite" sequence is a series of siltstones, shales, sandstones, and pebble conglomerates. (In the area east of Kings River, it is pebble-cobble conglomerate.) Included in the Wishbone Formation is the siltstone and shale below the "definite" Wishbone Formation and the next pebble (or pebble-cobble) conglomerate below this. The lower contact of this conglomerate is the formational contact, and below it is Chickaloon Formation, which usually contains a dark, highly carbonaceous shale unit as the first or second siltstone/shale unit below the contact. Note that this is a considerable different contact than that used by Barnes and Payne (1956, p. 18) in the Wishbone Hill district, the contact being "arbitrarily taken as the top of coal bed No. 4, the uppermost coal in the Chickaloon Formation."

The upper contact of the Wishbone Formation in the area of this study can be seen north of Castle Mountain, where Tertiary basaltic tuffs and lavas unconformably overlie Wishbone Formation.

Field relations make it apparent that the upper Chickaloon Formation and lower Wishbone Formation are facies equivalents in some areas. This author is convinced that the two formations represent a continuous, basically uninterrupted period of deposition. As a practical measure, the two units are still mapped separately on a lithologic basis. In the Fourteen-mile area, east of the Chickaloon

River, there is a large mass of Wishbone Formation (not on the map) with the typical massive boulder-cobble-pebble lithology. This grades laterally into a Chickaloon Formation lithology north of Boulder Creek. This latter location is mapped as Wishbone by Detterman et al. (1976), but the existence of numerous coal beds, one of them three meters thick (of poor quality), establishes that the unit is Chickaloon Formation. There are boulder-cobble-pebble conglomerates up to 30 meters thick in the unit that indicates its transitional nature. For this reason the author refers to this important unit as upper Chickaloon - lower Wishbone in this dissertation, although the two formations have been mapped separately.

The author regards the Wishbone Formation (including what is referred to above as upper Chickaloon - lower Wishbone) as a unit not of large lateral extent; rather, it was probably confined to a narrow alluvial fan wedge thinning outward from its dominant source, the Talkeetna Mountains. This somewhat restricted environment seems necessary to explain the spectacular accumulation of over 600 meters of boulder-cobble-pebble conglomerate. The trend of the wedge was probably similar to the present-day distribution of Wishbone rocks, which, according to the map of Csejtey et al. (1978), wraps northeasterly around the western margin of the Talkeetna Mountains. It seems clear that the Wishbone Formation delineates the initial uplift in the late Paleocene of the present-day Talkeetna Mountain block.

To the west and southwest, under Cook Inlet and in outcrop in the Susitna Lowland, the Wishbone Formation is represented by the

West Foreland Formation. This investigator would also venture a speculation that it will someday be shown that the Paleocene Arkose Ridge Formation, which is found to the northwest and west of the map area, is a facies equivalent of the Wishbone Formation. It should be noted, however, that this is an extremely controversial suggestion, as, reportedly, Grantz would correlate the Arkose Ridge Formation with the Chickaloon Formation (Magoon, personal communication, 1979).

Mafic and Felsic Tuff and Lavas
(Eocene - Oligocene (?))

Volcanic rocks cap Castle Mountain, Puddingstone Hill, and the mountains north of Boulder Creek. An age of Eocene has been assigned to the base of this unit based on plant fossils found by Grantz (1960a) in interbedded sediments. This is reasonable since the volcanic rocks lie above the Eocene Wishbone Formation. Csejtey et al. (1978) have obtained K-Ar dates (50.4 $\pm$ 2.0, 51.3 $\pm$ 2.5, and 56.3 $\pm$ 2.5 million years) on three samples of andesite flows near the middle of the volcanic section in the northern Talkeetna Mountains. It is evident that volcanism began somewhat earlier in the north as compared to the south in the Talkeetna Mountains. Csejtey et al. (1978) claim that rocks of the sequence range in age from Paleocene to Miocene and that the uppermost part may be as young as Pleistocene. The upper age limits are not well-established and appear to be based primarily upon correlations with dated rocks in the Wrangell Mountains of Eastern Alaska. Until otherwise demonstrated, this author will assume that the Tertiary volcanic rocks in the map area are Eocene and Oligocene in age. The unit is several hundred meters thick. Greater thicknesses of volcanics (up to 1,500 meters) are present in the central and northern Talkeetnas than in the southern region. This may be largely a function of erosion.

The overall composition of the volcanic rocks is not well-known, but Csejtey et al. (1978), from mapping in the central and northern Talkeetna Mountains, believe that the volcanics are more acidic at the base and more basic higher in the section. This author agrees. This conclusion is also apparent from two kinds of likely feeders to the volcanic unit, quartz latite domes and diabase dikes and sills. The fact that diabase dikes cut the quartz latite domes supports the contention that the volcanics are more acidic at their base.

Many of the rocks are flow breccias and porphyritic flows that are very similar in appearance to andesites of the Talkeetna Formation. Probably the bulk of the Tertiary volcanics are andesitic in composition, although this hypothesis will require extensive chemical analyses for confirmation.

It is apparent in the field that the basal flows and tuffs of this unit have been laid down on a very irregular topography. Thickening of flows in the valleys of that time is evident. The extreme lateral changes in the basal units suggest mountainous terrain at the time of extrusion. In one area, which was obviously a valley, fluvial sediments containing woody plant fragments were deposited. In general, the Tertiary volcanic rocks have a fairly flat to gently-dipping attitude. This, however, was not found to be a very good criterion, when used alone, to distinguish these rocks from those of the Talkeetna Formation.

A distinctive glassy flow lies near the base of the volcanic section on Castle Mountain, Puddingstone Hill, and in places north of the Caribou fault. Sometimes the glassy flow occurs right at the base, but often there is a tuff unit (averaging six meters thick) which lies below the flow. Of particular interest is the fact that in the exposure of Tertiary volcanic rocks four kilometers east of Puddingstone Hill, this same glassy flow is found at least 120 meters above the base of the volcanic section. Below the glassy flow, here, lie other flows and flow breccias. Clearly, this was a topographic low at the time of extrusion.

Intrusive Rock Units

Quartz Diorite (Early to Middle Jurassic)

Rocks mapped by this investigator north of the Castle Mountain fault in the Kings River area were dominantly medium-grained hornblende quartz diorite. According to Csejtey et al. (1978), this intrusive is part of the large Talkeetna Mountains batholith, which includes diorite and tonalite. Furthermore, Csejtey et al., contend that, "The age of the quartz diorite is probably late Early Jurassic or early Middle Jurassic because it intrudes the Talkeetna Formation and is intruded by a Middle to Upper Jurassic granodiorite. . . ." Where the quartz diorite intrudes Talkeetna Formation limestone and greenstone north of Castle Mountain stoping is exhibited, and it is evident that replacement was passive. Pyritic hydrothermal alteration is observed within the intrusive, and areas of skarn mineralization are common where the intrusive is in contact with limestone. The author speculates that this intrusive is part of the same magmatic system that produced the Talkeetna Formation volcanics. Thus, because the ages are so similar it would appear to be an example of a magma intruded into its own volcanic pile.

Diabase Dikes and Gabbro (Eocene and Oligocene (?))

Diabase dikes and gabbro are apparently confined to the area south of the Caribou fault. Curiously, the Caribou fault and its extension westward have either acted as barriers to northward intrusion of these bodies, or strike-slip motion has juxtaposed a dike-barren region to the north. The latter is more likely since to the west (as far as the Susitna Lowland) dikes are not abundant north of the fault, while to the east Tertiary volcanic rocks (which are probably fed by dikes) are found north of the fault.

Appendix B contains a petrographic description of a sample of diabase. Small gabbro bodies occur sporadically in the map area. In some cases, dikes were seen emanating out of these bodies, and the two were considered to be completely equivalent. The large gabbro sills of the Matanuska Valley to the south are, with little doubt, equivalent also. There are, however, several mapped gabbro bodies along Boulder Creek and East Boulder Creek which may represent a somewhat earlier Tertiary intrusive, or possibly even a Jurassic intrusive. One of these intrusives north of East Boulder Creek is clearly cut by diabase dikes. It is possible that the dikes were injected only a short time after the gabbro, and that is the interpretation favored by the author.

An attempt was made to obtain a K-Ar date on a plagioclase separate from a sample of diabase dike. Unfortunately, the potassium content was 0.04%, too low to obtain a date (Stan Evans, personal communication). Clarady (1974) found on Wishbone Hill a diabase dike which cut Tsdaka Formation, making this particular dike no older than Miocene. However, it is likely that there is a spectrum of ages. It is probable (based on limited dating of the Tertiary volcanic rocks by others) that the bulk of the dikes are Eocene or Oligocene in age.

The total amount of dike material in the map area far exceeds that which has been mapped. Dikes range in thickness from 0.3 to 60 meters, have dips generally in the range of 77° to 90° (both north and south, and have very consistent trends averaging 116°, the tectonic implications of which are discussed later. Both single dikes and dike swarms of five to eight separate dikes are common. The dikes often occupy both major and minor fault zones.

Quartz Latite (Eocene)

Numerous stock-like intrusives of quartz latite occur within the map area, mainly in the splay block between the Caribou fault and the Castle Mountain splay fault. Mapping indicates that there is a far greater volume of quartz latite intrusive than was previously suspected. This large zone of intrusives extends southeastward into the Matanuska Valley and the foothills of the Chugach Mountains.

Appendix A contains a whole rock chemical and normative analysis of this rock, and Appendix B contains a petrographic description. The petrographic description indicates that the rock is a quartz latite (this author follows the suggestion of Streckeisen (1979) that the division between latite and quartz latite be placed at 5% quartz rather than 10% qaurtz). When the normative analysis (obtained from whole rock chemical analysis) of sample 79-24 (see Figure 19 for location) is applied to Streckeisen's (1979) IUGS classification of volcanic rocks the sample plots in the dacite field of the QAPF diagram. Thus, there is a discrepancy between classification based on petrography and that based on whole rock chemical analysis. Streckeisen points out that this commonly happens. It should also be noted that the appearance of corundum in the norm of sample 79-24 indicates that this particular sample is peraluminous. Corundum probably does not occur in the mode of the rock; more likely candidates for the excess alumina are muscovite (seen as a deuteric alteration product in plagioclase) and garnet (spessartite ?) which was obtained from a heavy mineral separate.

Examination of these quartz latite bodies indicates that they are very shallow-level intrusives, which are perhaps best described as volcanic domes. Where the quartz latite is not altered, it frequently forms spectacular columnar cooling joints. On Anthracite Ridge, a volcanic dome clearly cuts Late Cretaceous Matanuska Formation. The argument given previously that these domes fed the Eocene basal volcanics leads this author to assign an Eocene age to the latite. The volcanic dome on Anthracite Ridge assumes great importance in this dissertation because the dome is cut and offset by the Castle Mountain splay fault. The volcanic dome north of the west end of Anthracite Ridge includes an area of intrusive breccia, not a common phenomenon in these bodies.

In a few areas, particularly at the east end of the map, there is a coarser-grained variety of the quartz latite, coarse enough to be classified as a quartz monzonite. The quartz latite is commonly bleached and pyritically altered along stock margins, and altered quartz latite can be difficult to distinguish from altered tuff of the Talkeetna formation. There is some magnetic expression (as magnetic highs) to the volcanic domes on the aeromagnetic map of the area (aeromagnetic survey, Anchorage (D-3), Alaska, 1972). This is curious because thin section analyses indicates that mafic minerals in the quartz latite are generally destroyed (but not always), and paleomagnetic intensities of collected samples in one locality are very low, on the order of 10^{-8} emu/cm^3. The implication is that the coarse-grained phase described above, in which fresh hornblende (and hence, presumably also magnetite) was observed, exists at depth in most of the volcanic domes.

Barium, rubidium, and strontium analyses were obtained for 31 samples of quartz latite, the results and purpose of which are detailed later.

Albite Granite Porphyry (Eocene (?))

Appendix B contains a petrographic description by Dr. John Payne of an albite granite porphyry found in the map area. This rock was originally designated as a quartz-plagioclase porphyry quartz diorite. Subsequent communication with Dr. Payne (1977) indicates that since the more modern igneous rock classification scheme places albite in the category of alkali feldspar rather than plagioclase, a better name for the rock would be quartz-albite porphyry granite, which is herein referred to as albite granite porphyry.

The albite granite porphyry is a unique intrusive that is localized in the Castle Mountain fault zone north of Castle Mountain. The distinct magnetic expression of this intrusive on the aeromagnetic map of the region (aeromagnetic survey, Anchorage (D-4), Alaska, 1972) indicates that the unit's localization in the fault zone is not just a surface phenomenon.

In hand specimen, the albite granite porphyry appears slightly hematitic as well as chloritic. Large quartz phenocysts make the rock unique and easy to distinguish in the field. Calcitic alteration of plagioclase and calcite in veinlets, seen in thin section, was probably caused by reaction of the magma with nearby limestone.

Pink zircons were separated from the rock in an attempt to obtain a fission track date, but after polishing and etching, the useable zircons were deemed to not be of sufficient quantity to obtain a significant age date (Duncan Foley, personal communication, 1979).

STRUCTURAL GEOLOGY

Kings River to Drainage Divide North of Castle Mountain

The well-defined trace of the Castle Mountain fault in this area neatly divides intrusive and Lower Jurassic rocks on the north from Tertiary rocks on the south.

Considering first the Lower Jurassic Talkeetna Formation, this formation consists entirely of metamorphosed and altered greenstone. Highly slickensided shear fractures are in great abundance even 400 meters north of the main fault. Bedding, if it was there originally, has been destroyed, but no well-defined foliation was discerned. The area has a very strong fracture trend of 90° to 100° and two smaller conjugate trends of 030° to 040° and 330° to 350°. The strong easterly (90° to 100°) fracture trend agrees well with the trend of a right-lateral strike-slip fault which cuts Talkeetna Formation and Talkeetna limestone and also truncates a north-trending fault. The average trend on this fault, which is located at the northwesternmost exposure of Talkeetna Formation, is 098°. Numerous small folds were found in the fault gouge. Since the fault deformation is essentially a brittle style of deformation, it is probable that the fold axes are perpendicular to the movement direction on the fault. A stereographic plot (see Appendix C) of the fold axes at a point on the fault where the measured fault surface has a strike and dip of 090°/75°S indicates that the probable movement direction had a bearing and plunge of 264°/15°. Thus, movement along the fault was essentially strike slip. In the field it could be seen that the offset was about 30 meters in a right-lateral sense. This small fault was only detected because it cut through limestone. Easterly trending faults such as this one are common, though not abundant, within the Talkeetna Formation throughout the map area. They probably represent Mesozoic structures because easterly trending structures, with one major exception (north of the Caribou fault), are rare within the Tertiary rocks.

Interesting but complicated structure was encountered in the Talkeetna limestone. This is immediately suggested by the erratic outcrop pattern on the geologic map. It is clear that where the limestone is near quartz diorite intrusive, it is the intrusive activity that has had the dominant influence upon the structure of the limestone. Magmatic stoping is quite evident, particularly at one locality where large blocks of limestone appear to have sunk into the magma chamber. The map of Detterman et al. (1976) shows a large fault at the limestone-quartz diorite contact. However, lack of shearing indicates that the contact is merely an intrusive contact. Intrusive activity could also have produced some of the folds in the limestone; these folds range in character from an open style to a tightly compressed style and sometimes include Talkeetna Formation greenstone in their cores. In some cases, bedding was observed. However, in most places folds were clearly observed, but it was not clear whether bedding or fracture surfaces were folded. In general, there is a lack of consistency in orientation and style among the various folds in the limestone.

The Chickaloon Formation contains numerous coal beds, and these are normally the most complexly deformed units, whereas the overlying Wishbone Formation is a highly competent, massive pebble-cobble-boulder conglomerate. The overall synclinal nature of the Wishbone Formation suggests that it may have been deformed in a north-south to northwest-southeast compressive stress field. This large syncline, which extends from Castle Mountain, across the Chickaloon river, and onto Puddingstone Hill, is fairly open in style and has a slight southward vergence. It is probably a manifestation of the lateral structural collapse of the Matanuska Valley, an idea which will be elaborated on in a later section. On Wishbone Hill, an area west of the mapped area and the type locality of the Wishbone Formation, the formation is deformed into a syncline of similar style to that of Castle Mountain and Puddingstone Hill.

The more intense deformation in the Chickaloon Formation as compared to the Wishbone Formation is certainly due in part to deformation concomitant with the development of the uplift to the north which served as a source for the Wishbone Formation sediments. Nevertheless, this author contends that much of the more intense Chickaloon deformation occurred within the same stress field that formed the large syncline in the Wishbone Formation, the difference in intensity of deformation then being due partly to an extreme difference in the competence of the two units.

Deformation in the coal-bearing units of the Chickaloon Formation seems to be enhanced to the point that it appears more significant than it really is. Deformation is more intense along the lower part of the tributary which flows north of Castle Mountain into Kings River than it is farther south. Northerly trending high-angle faults and bedding dipping 50° to 80° eastward seems to be the norm. Because much of the area is covered with dense vegetation it is often difficult to determine the sense of displacement on faults. Other typical structures which were found include a small, easterly plunging open anticline, a spectacularly-displayed north-trending normal fault with a minimum displacement of 60 meters (west side up) (see Figure 6), a very low-angle fault cutting across the crest of an asymmetrical, eastward-verging fold, numerous small tight folds, and bedding-plane faults. Clearly, the coal-bearing units in this area have undergone complex deformation with a great diversity in style.

North of Castle Mountain drag folding has clearly been caused by motion on the Castle Mountain fault. Bedding strikes in both the Chickaloon and Wishbone formations swing more easterly as the Castle Mountain fault is approached, and beds near the fault stand on end and are overturned to the east in some places. (Facing directions can commonly be determined from cross-bedding.) The drag effect is observed up to 365 meters south of the fault. Because of the original orientation of the bedding, the sense of drag is consistent with either dip slip (north side up), dextral slip, or combined dip slip-dextral slip on the fault.

The saddle or drainage divide north of Castle Mountain is considered to be the "type locality" of the Castle Mountain fault.

Figure 6. Photograph (looking north) of a normal fault in the Chickaloon. Located in stream cut north of Castle Mountain.

Here, the main fault zone is 45 to 60 meters wide, and measurements of 055°/76°N for the strike and dip of the fault plane were obtained by this author and also, apparently, by previous investigators (Detterman et al. 1976). This is an often quoted overall trend and dip for the Castle Mountain fault, but it is merely an individual measurement and is quite inaccurate as a determination for the entire fault. The overall trend of the fault in the map area is 073° and the dip is variable, but often close to vertical. The rock sequence in the fault zone from south to north is Wishbone Formation, Chickaloon Formation, albite granite porphyry, and Talkeetna Formation. All of these rocks are highly sheared except for the intrusive, which is only mildly sheared.

The outcrop of the albite granite porphyry intrusive continues some distance east and west of the saddle (see Figure 3), and the intrusive is definitely fault-localized, being found only in or immediately adjacent to the fault. As will be discussed later, this small porphyry occurrence is believed to have been intruded at the time the splay block to the east was uplifted.

Numerous small faults extend out into the Wishbone Formation adjacent to the main fault. Upon measuring attitudes on seven of these faults adjacent to the "type locality" of the Castle Mountain fault, it was found that the only general trend not represented was north to northeast. An analysis of fracture measurements taken in the area north of Castle Mountain but south of the Castle Mountain fault indicated no significant regional trends, although there are certainly very localized trends. Figure 7 is a sketch drawn at a locality north of Castle Mountain showing a well-exposed fracture pattern extending outward from the Castle Mountain fault. The diverse and curved (concave upward) nature of the fractures is evident.

Drainage Divide North of Castle Mountain to the Chickaloon River

This area is of great significance because it contains the major splay of the Castle Mountain - Caribou fault system. The actual location of the splay is placed by this author about 1.2 km northeast of the location indicated on the map of Detterman et al. (1976). The splay point is concealed, but it is reasonably inferred from the projection of fault trends.

In this area, the Talkeetna Formation north of the Castle Mountain fault is generally less metamorphosed than in the area to the west (discussed in previous section), and cataclastic zones appear to have a strong correlation with fault zones. Northeasterly trends on vertical to high-angle faults are common. Other fault trends are also present. At least one fault in the Talkeetna Formation west of the Chickaloon River appeared to have a large amount of displacement. Strike-slip motion was not detected on any of the subsidiary faults of this area, but it may have occurred. In the region 2 1/2 to 3 km upstream from the Chickaloon River along Ninemile Creek, the Talkeetna Formation has moderate dips in a direction of east to slightly south of east. This appears to be a regional dip direction applicable to a large amount of the surrounding area. A small sliver of limestone

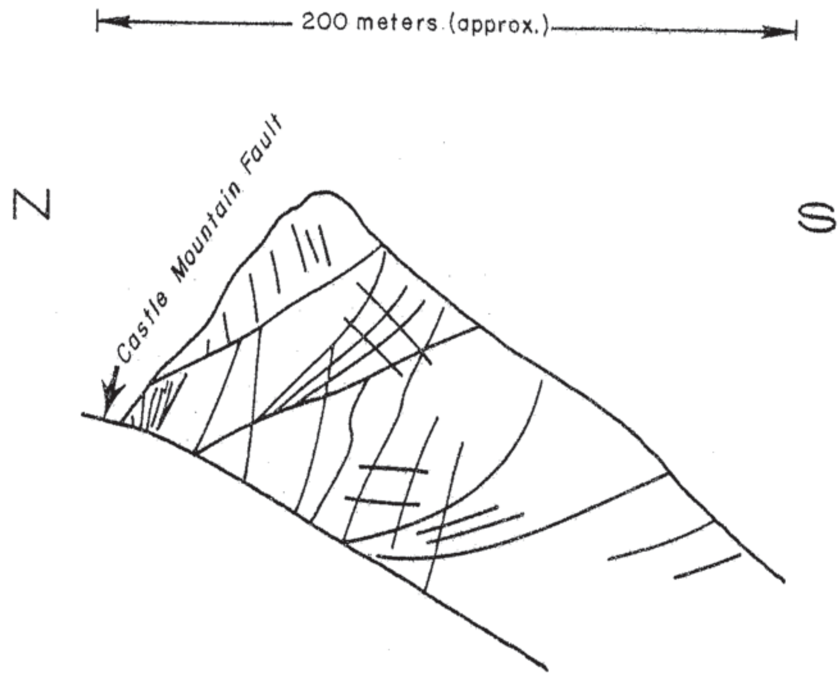


Figure 7. Sketch of fracture pattern adjacent to Castle Mountain fault. Profile view looking N 75° E.

(not on map) just north of the Caribou fault on Ninemile Creek indicates that the rock units of the Talkeetna Formation are much the same here as they are east of Kings River.

Of great interest is the area of thrust faulting discovered northwest of the major splay. This superbly displayed faulting was extensively studied. In one canyon a listric (concave-upward) cataclastic fault zone was observed with dips starting at 35° in the bottom of the canyon and ending at vertical where the fault cut the surface, all within a lateral distance of 150 meters. The fault plane is exposed in two adjacent canyons. Other nearby cataclasites in the area gave the author the impression that imbricate faulting is common. Thrusting was northward to slightly east of north. This is based on a strike of 300° obtained on the high-angle portion of the fault, the distinct drag folding of adjacent rocks, and the sense of imbrication, which in most thrust faults is in the direction of transport of the upper plate. In one canyon, pinkish, upper-plate Talkeetna Formation volcanics have been thrust over Chickaloon Formation, which demonstrates that older rocks have been thrust over younger rocks. However, where volcanics are thrust over volcanics, faulting of younger over older rocks cannot be ruled out and would actually be the case if the thrust model presented below is true.

Figure 8 displays the possible sequence of events for the thrust faulting which could give rise to the present geological configuration observed on the geologic map in the vicinity of the thrust fault. The geology in this area is actually quite complex, although it is not obvious on the map because different units of Talkeetna Formation are not differentiated. One stratigraphic problem is whether the Middle Jurassic section is missing, as is indicated in the area just east of the Chickaloon River. Figure 8 is a hypothetical series of north-south cross-sectional views looking westward. The first step in this model involves high-angle reverse faulting along the Castle Mountain - Caribou fault, resulting in the configuration shown in the first diagram. The second step involves low-angle northward thrusting, which places Wishbone and Chicakloon formations north of the Castle Mountain - Caribou fault. The thrusting may actually have been a result of strike slip along the abruptly changing trend of the Castle Mountain - Castle Mountain splay fault in this area, thrusting being a manifestation of disruption of the strike-slip fault boundary. In the third step, a second northward thrust fault places a chunk containing Wishbone through Talkeetna formations to the north of the Castle Mountain - Caribou fault. This event also leaves a small slice of Chickaloon Formation, which could have wedged out laterally beneath the thrusted Talkeetna Formation. In the fourth step, reactivation along the Castle Mountain fault, and then erosion, obscures evidence of the thrusting except for a small slice of Chickaloon Formation south of the Castle Mountain fault. This model is only one possibility.

Even though the thrust model presented above indicates two thrusting stages, the author considers these to represent essentially one thrusting event. The field investigation indicates that this

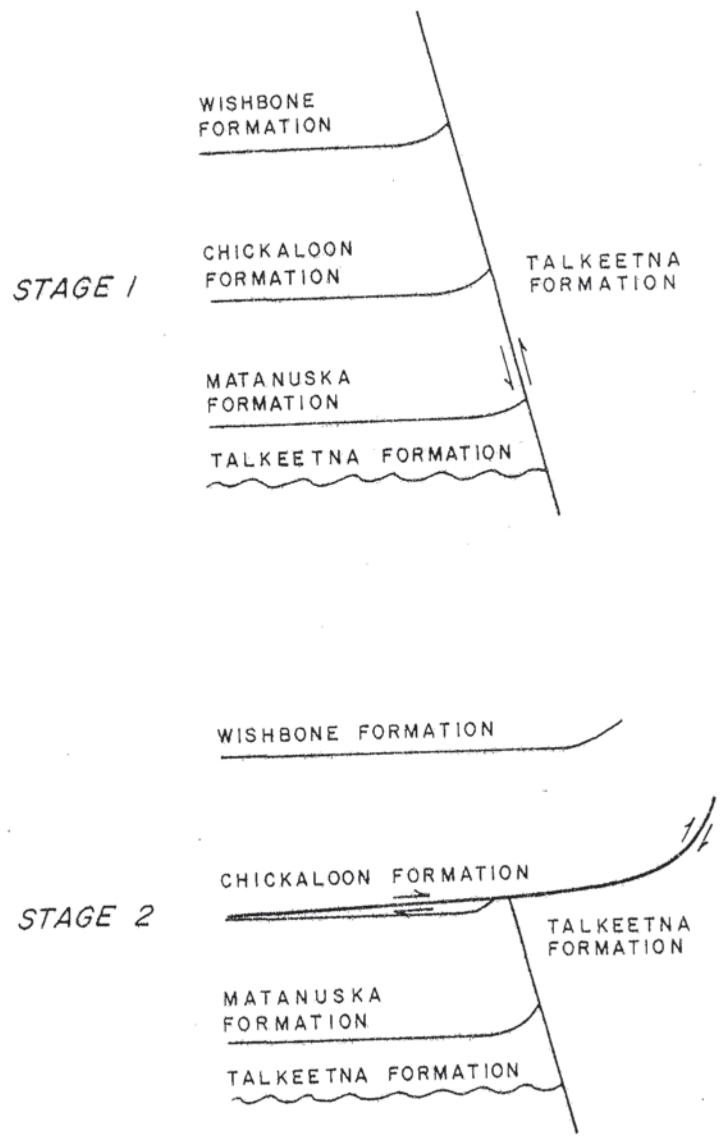
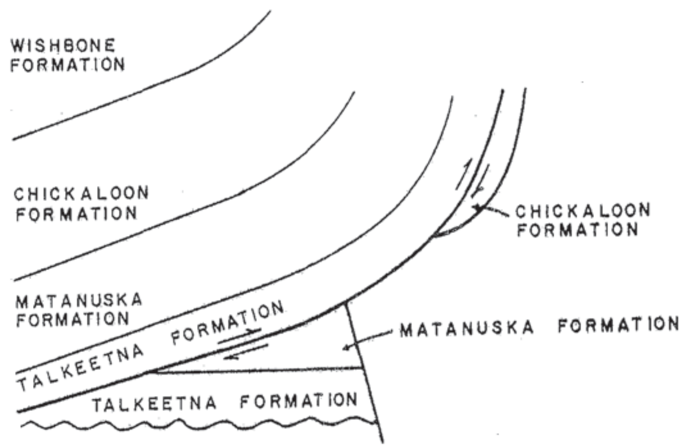


Figure 8. Thrust fault model: possible sequence of events.

STAGE 3



STAGE 4

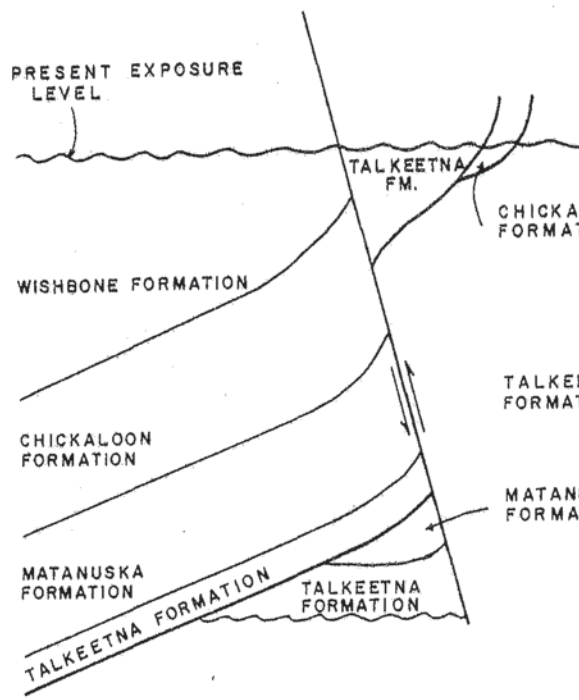


Figure 8. Thrust fault model (continued).

thrusting event is local and, hence, is related to the formation of the splay and the abrupt change in trend of the Castle Mountain - Castle Mountain splay fault. The timing of the event can only be placed as post-Paleocene.

One significant difference between the author's map and that of Detterman et al. (1976) is in the block between the Castle Mountain splay and Caribou faults west of the Chickaloon River. Whereas, Detterman et al. have mapped Matanuska Formation and a sliver of Chickaloon Formation in this block the author found only Chickaloon Formation, as evidenced by the abundant plant fossils in most rocks. The distinction has important tectonic implications as will be shown later. It is noteworthy that Martin and Katz (1912) mapped Tertiary sediments in this area and Barnes (1962) mapped Arkose Ridge Formation (Paleocene) within the block. Obviously, there is disagreement as to which formation these rocks represent; this is because of the limited outcrop exposure and the considerable degree of tectonic induration. The strikes of beds within the block are generally northeasterly with steep north and south dips. Northerly dips dominate near the splay. There may be a fair amount of contortion in the beds within the splay block near the splay point; outcrop is very poor, here. Near the Caribou fault, beds are vertical, while this is generally not the case near the Castle Mountain segment of the splay. The Caribou fault zone is spectacularly exposed in a canyon one kilometer northeast of the splay. The zone of most intense faulting and cataclastic deformation is 25 meters wide and may continue under cover to the south. A cataclastic zone of less intense faulting continues another 30 meters to the north. The dip on the fault zone is nearly vertical. It should be noted that a vertical dip for the Castle Mountain - Caribou fault in general within the map area is indicated by the fact that the fault cuts across topography with little or no change in trend. The Castle Mountain splay fault, although well-exposed to a stream-cut 1.8 km east of the splay point, does not display nearly the intensity of faulting at this spot as does the Caribou fault. The Castle Mountain splay fault occurs as a fairly sharp break, which places lower Chickaloon Formation on the north against upper Chickaloon Formation on the south. The relationship of older on the north and younger on the south is more apparent further east along the Castle Mountain splay fault.

There appears to be considerable indirect evidence for the questioned northwesterly trending fault which cuts across the block between the splays west of the Chickaloon River. There is a subtle lineament on the air photos. (Unfortunately, none of the area is in outcrop.) Moreover, projection of conglomerate units found up Ninemile Creek is incompatible with the geology along Doone Creek. The northwesterly trending fault, if projected to the Chickaloon River, might explain the abrupt offsets in the course of that river. Finally, there is a strange deflection in the trend of the Castle Mountain splay and Caribou faults which might only be an effect of topography or might be caused by this cross-cutting fault. It is quite possible that this fault pre-dates most of the motion on the splay. If it post-dates motion on the splay, motion must have been dominantly vertical or rotational; otherwise (if it were strike slip) there would be evidence of disruption in the trends of the Castle Mountain splay and Caribou faults.

South of the Castle Mountain fault, Chickaloon Formation and overlying Wishbone Formation dip southward and are part of the large syncline which makes up Castle Mountain.

There is a strong fracture trend of 340° to 350° on both sides of Doone Creek and the Caribou fault. South of the Caribou fault, along Doone Creek, there is also a strong fracture trend of 290° to 300°. The proper interpretation of these and other lesser trends is not evident to the author. Theoretically, since the stress pattern near a fault splay is complicated (Chinnery, 1965), so should the fracture pattern also be complicated.

Area South of the Caribou Fault Between the Chickaloon River and Boulder Creek

Within the splay block east of the Chickaloon River, there is a general eastward increase in the age of the rocks. Paleocene Chickaloon Formation is found west of the Chickaloon River, whereas, Cretaceous Matanuska Formation and then successively Middle Jurassic Tuxedni Group and Lower Jurassic Talkeenta Formation are found going eastward. The structural style is most definitely that of a tilted fault block. In general, the Matanuska Formation dips 30° to 70° in a direction west of north. The author proposes that the splay block is best described as a rotational fault block with a pivot located at the splay, where the Castle Mountain splay and Caribou faults join. This model simultaneously explains the observed bedding attitudes, and, going eastward from the splay or pivot point, the increasing age of exposed rocks and the increased fault deformation and apparent displacement along the Castle Mountain splay fault. Figure 9 is a sketch of this model.

The average strike and dip of the splay block was determined by two different methods using measurements within Matanuska Formation. The first method was a subjective evaluation of the data in which the author attempted to remove the effect of an open, undulatory folding of large wavelength which was superimposed upon the primary block tilt. It is the primary block tilt which is of greatest interest to the author. This subjective evaluation resulted in an estimate of the average strike and dip for the splay block of 063°/45° W. The second method involved finding the vector mean of 12 strike and dip measurements (in Matanuska Formation). This method (method of Wilson as described in Irving, 1964) yielded a strike and dip of 058°/50° W and an angular standard deviation of the mean of 8°.

North of Puddingstone Hill and the Castle Mountain splay fault, Matanuska Formation rests on top of Talkeetna Formation. The Talkeetna Formation here is a greenstone, which is probably juxtaposed at a steep dip against the fault. There is a locality in this region, just north of the main Castle Mountain splay fault, where a series of vertical faults or dikes (seen from a distance) are all offset about six meters in a right-lateral sense by what appears to be a

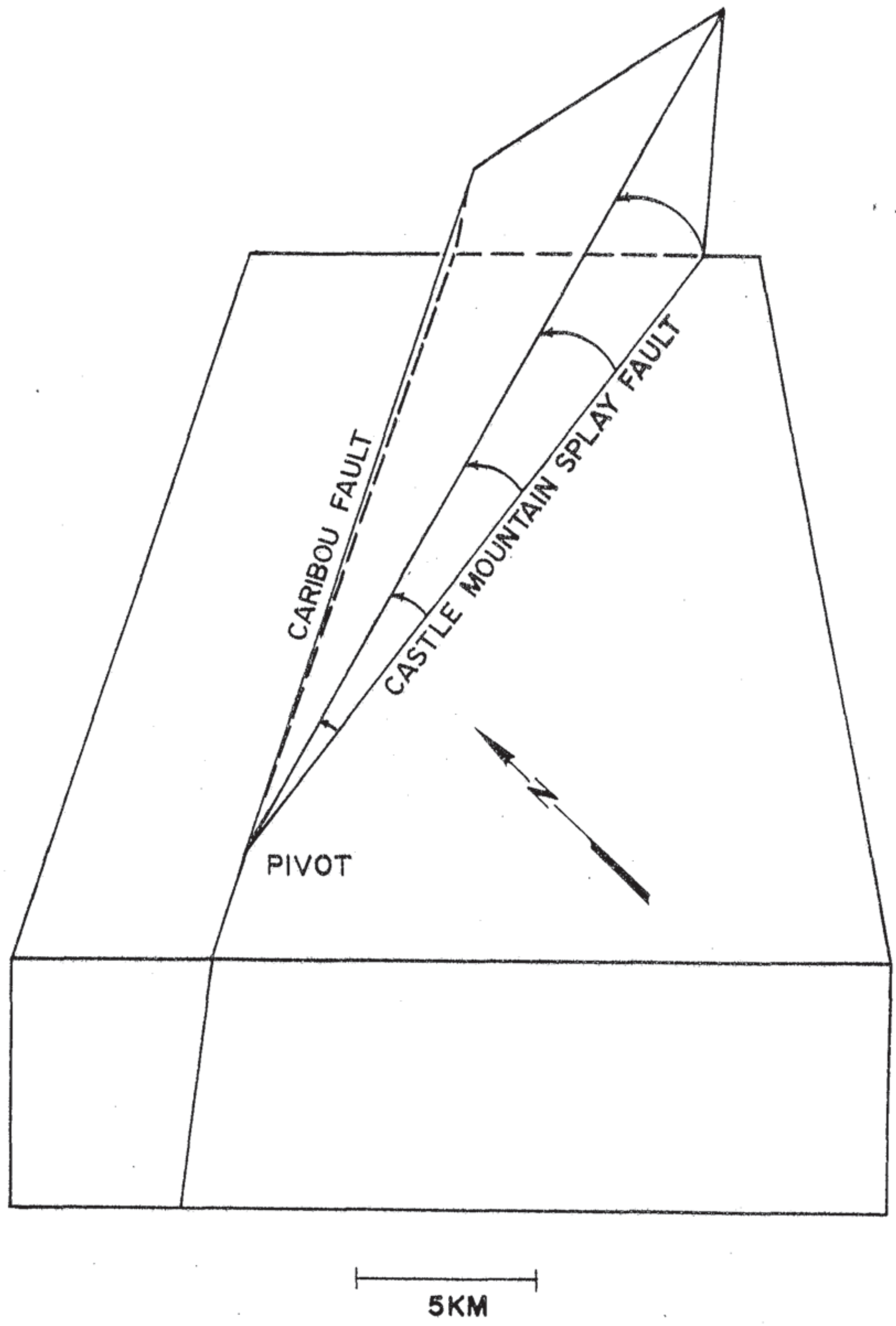


Figure 9. Rotational fault block model. A right-lateral strike-slip component on both faults may have been superimposed on this model or may have come later.

subsidiary low-angle fault.

Due north of Puddingstone Hill there is a very significant structure which is illustrated in Figures 10 and 11 (photos taken looking eastward). Here, there is a diabase dike swarm of 8 to 10 dikes located within (not adjacent to) both the Castle Mountain fault and an adjacent fault zone, the latter of which splays off to the northeast, leaving a wedge of Matanuska Formation between the two faults. In the Castle Mountain splay fault zone, several dikes are folded into a tight chevron-like fold as shown in Figures 10 and 11. The dikes, which are fairly fresh, have clearly been folded by movement of the fault rather than by injection in that form. This is demonstrated by the fact that two, and possibly three, dikes are concordantly folded. Also, the surrounding Chickaloon Formation fault gouge is generally concordant with the fold, and where it is not, it is folded into small folds including chevron folds. Appendix C contains a stereographic plot of poles to the folded dike. The fold axis has a rough bearing of 094° and a plunge of 10° to 34°. Later fault movement has probably caused the dispersion of the plotted data. This fold axis would tend to support an argument of northerly compression and vertical fault movement. However, such an argument may no longer be tenable in light of work by Bryant and Reed (1969) indicating that in zones of progressive simple shear fold axes may rotate toward the extension direction within the plane of cleavage. The Matanuska Formation certainly has a folded cleavage within the fault zone. The observed folding of the dikes indicates that fault movement

Figure 10. Folded diabase dikes in the Castle Mountain fault zone.

Figure 11. Close up of folded diabase dikes in the Castle Mountain fault zone.

must have occurred since the time of injection of the dikes.

South of the Castle Mountain splay fault, structure is once again dominated by a large syncline. This large syncline appears on the map to be two different synclines on opposite sides of the Chickaloon River, because the axes curve northward and a connection between the two is not seen. This is merely a reflection of the combined effect of the northward dip of the axial plane and topography. This could be seen on the original 1:24,000-scale map by placing a straightedge across the intersection of the axes with the 3,500-foot contour lines. The trend is seen to be continuous.

A large subsidiary fault (herein named the Boulder Creek fault) of the Caribou Fault, which is noted on the map of Detterman et al. (1976), was found to have more continuity west of Boulder Creek than previously thought. The Boulder Creek fault is shown in Figure 12, where it places Tuxedni Group (brown rocks) on the south against Chickaloon Formation on the north. The undulatory fault plane has an overall dip of 58° to the south in this area, although further to the east, where the fault is south of and subparallel to Boulder Creek, the fault is more nearly vertical. A large sliver of Matanuska Formation argillite occurs within the fault zone itself and appears to have behaved as a concentrator of strain within the fault. This phenomenon is not uncommon along all the major fault zones of the map area. Commonly, the extraneous rock within the fault zone is coal from the Chickaloon Formation rather than Matanuska Formation argillite. The

Figure 12. Photograph of the Boulder Creek fault. View looking westward from a locality west of Boulder Creek.

Boulder Creek fault begins by diverging in the west from the Caribou fault; it then rejoins the Caribou fault to the east. It is clear to this author that the function of the Boulder Creek fault is to bypass the most complicated segment of the Caribou fault, where the Caribou fault zone has itself been offset by north-trending faults and appears to have locked up (Figure 16). This locked-up portion of the Caribou fault is discussed further in a later section. This author can offer little substantial information with respect to offsets on the Boulder Creek fault. The consistent occurrence of older rocks to the south indicates some component of south side up. More speculative is the argument that offsets the Caribou fault would probably offer more resistance to strike slip than to dip slip, which would suggest a substantial component of strike slip on the Boulder Creek fault. This fault is of particular interest because there appears to be an offset moraine along its trend east of Boulder Creek, as noted by Detterman et al. (1976). As they indicated, however, it is not possible to rule out landsliding as the cause of offset. Contrary to the conclusion of Detterman, et al., this author found only one offset moraine and not two which are aligned along the fault's trend. Also, it would be easier to accept the offset as being fault-related if there were some lateral as well as vertical offset, but only vertical offset is present. Nevertheless, the Boulder Creek fault is the best candidate in the entire area for an active fault. The fact that north-trending faults, which offset the Caribou fault but not the Boulder Creek fault are similar to faults found by R. Bruhn and Paulis (1978) in the Wishbone Hill area (west of the map area) is one of the reasons for this conclusion. Bruhn (personal communication, 1979) claims that faults with northerly trends and demonstrated strike slip are among the most youthful structures of the region.

Particularly significant to the structural interpretations of this investigation are trends of diabase dikes and dike swarms, both of which become particularly abundant three kilometers west of Boulder Creek. These dikes occupy extension fractures and in many cases demonstrably occupy faults. Where the dikes occupy faults, these faults often have normal dip slip on the order of 30 meters. Figure 13 is a rose diagram of dike trends. A strong average trend of 116.1° (standard deviation = 17.3°) is evident. Actually, the distribution is biomodal, with an average trend of 122° west of Boulder Creek and 110° east of Boulder Creek. These dikes have dips generally varying from 77° S to 77° N. It is worth noting that in an area 15 to 20 km east of the northeast corner of the mapped area, Grantz (1960a) found a strong dike trend with a maximum at 103°. This included dikes both north and south of the Caribou fault. This trend is only 7° different from the trend this author found east of Boulder Creek.

Of considerable importance is the drag on dikes as they approach the Caribou fault. The drag is well-displayed just south of the complicated area of offsets in the Caribou fault. Because the dikes are vertical, the drag is clearly right-lateral in sense. The drag effect is seen up to 365 meters away from the fault, which is essentially the same distance from the fault that such an effect

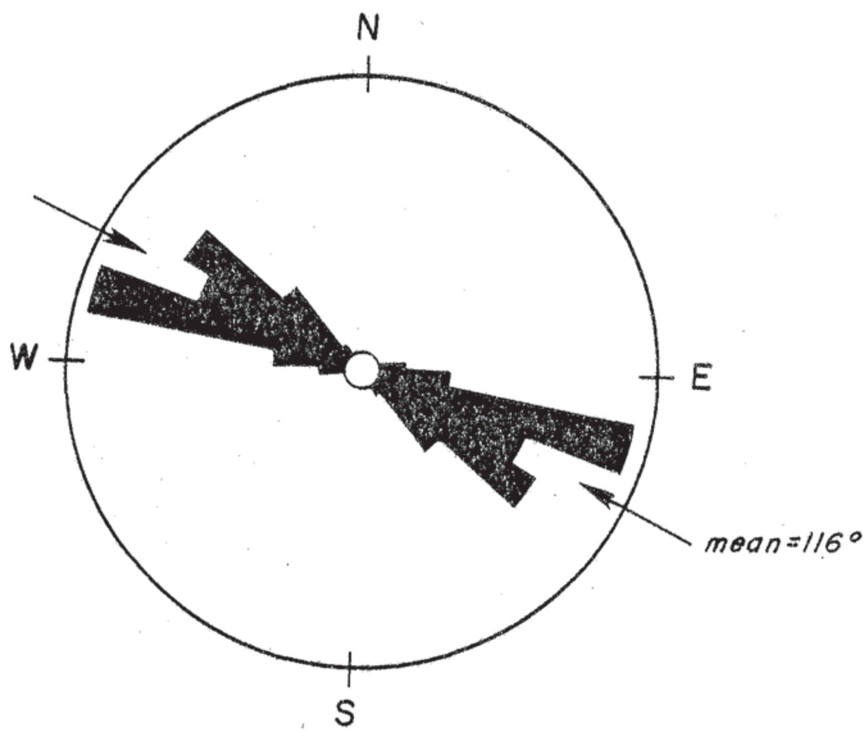


Figure 13. Rose diagram of dike trends.

(previously described) was seen in bedding attitudes in the Wishbone Formation in the area to the west. There is some possibility that the dikes were not actually drag-folded, but rather that their curved trend represents injection into a distorted stress field in the vicinity of the fault.

One large quartz latite dome is found west of Boulder Creek. It has been emplaced passively and contains a large piece of Talkeetna Formation that is nearly surrounded by quartz latite and looks very much like a roof pendant. This volcanic dome is only one of many similar domes which are seen to the east and southeast.

Area North of Boulder Creek and North of the Caribou Fault

Bedding in Cretaceous and younger formations within the block north of Boulder Creek and the Caribou fault generally has easterly to northeasterly dips. This author contends that this block represents a broad anticlinal arch, the crest of which lies somewhere to the west of the drainage divide between the Chickaloon River and Boulder Creek. Wavy, open folding has been superposed upon this anticlinal arch. The exposed stratigraphic section is consistent with this interpretation. Going eastward from the Chickaloon River one finds successively Talkeetna Formation, Tuxedni Group, and Chinitna Formation. The section is then repeated in part by a large fault with one additional formation, the Matanuska Formation, lying above Chinitna Formation. Chickaloon Formation and, in the western area (not on map), Wishbone Formation lie unconformably above this entire Jurassic through

Cretaceous section (see cross section D-D' on Figure 4). Hence, it appears that uplift took place along the Caribou fault sometime in the Late Cretaceous or Paleocene. The fine-grained nature of much of the Matanuska Formation (even in the upper section) and the lower section of the Chickaloon Formation suggests that orogenic uplift was not initiated on the Caribou fault prior to the middle or late Paleocene. Increasing coarseness of sedimentary rocks in the upper section of the Chickaloon Formation south of the Caribou fault suggests that uplift was initiated in the middle or late Paleocene. Figure 14 is a sketch portraying the author's model of this tectonic event. Folding occurred in the northern block with concomitant tear faulting. The synclinal portion of this model is purely speculative, but has the advantage of allowing for deposition of the Arkose Ridge Formation (a Paleocene formation found west of the map area) in a basin north of the fault. No major folding with a style such as that occurring on the northern block was detected on the southern block, but it may be present outside the mapping boundaries. This tear faulting model is similar to that shown by Hills (1963, p. 208, after J. Goguel) for the Jura folds in the Alps. Figure 15 is a sketch portraying an alternate model for this tectonic event suggested by R. Bruhn (personal communication, 1980). In this model arching and tear faulting are more directly linked to magmatic activity associated with intrusion of the large batholith which makes up the southwestern portion of the Talkeetna Mountains. No adjacent syncline is postulated. The only difficulty with this model is that it implies deposition of the Arkose Ridge Formation both north and south of the

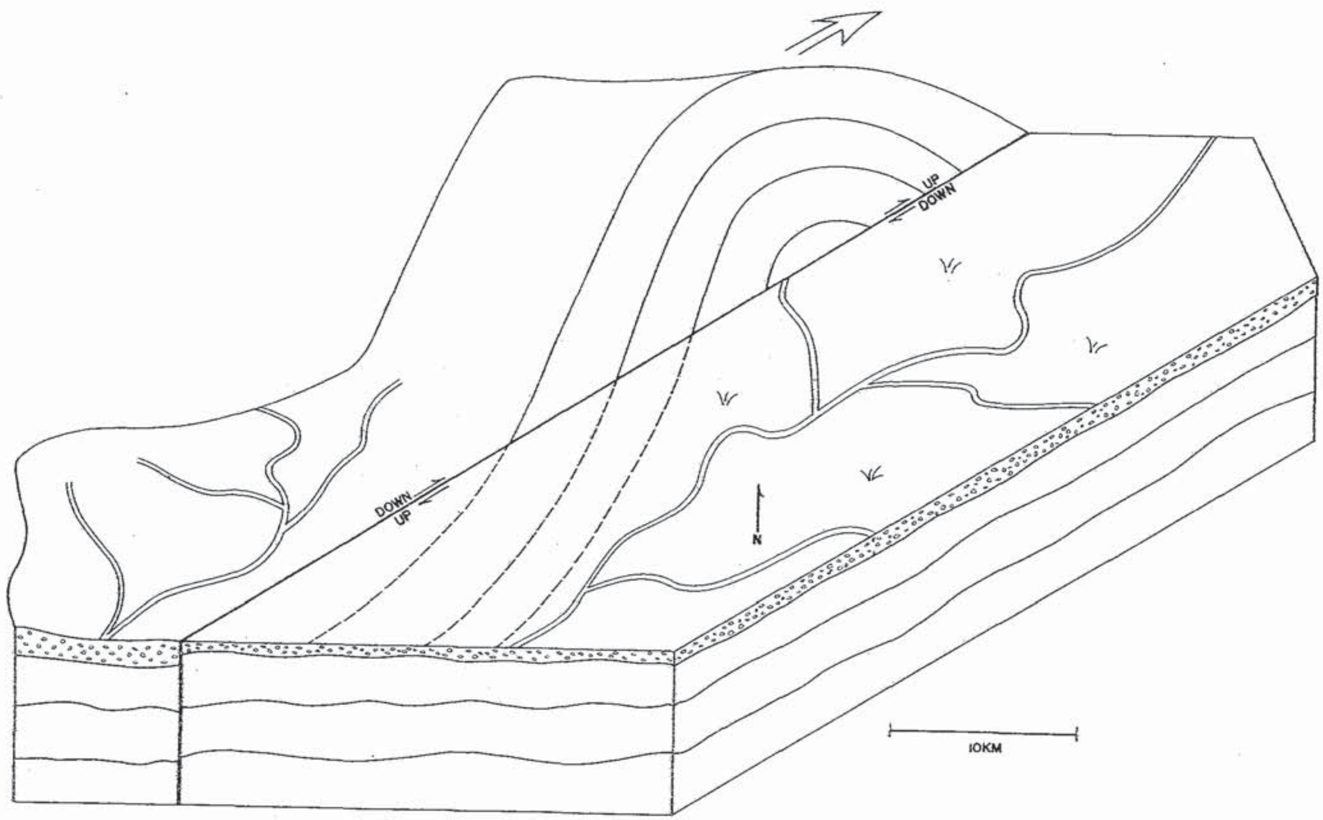


Figure 14. Sketch of tear faulting along the Castle Mountain - Caribou fault. There is a 3 X vertical exaggeration.

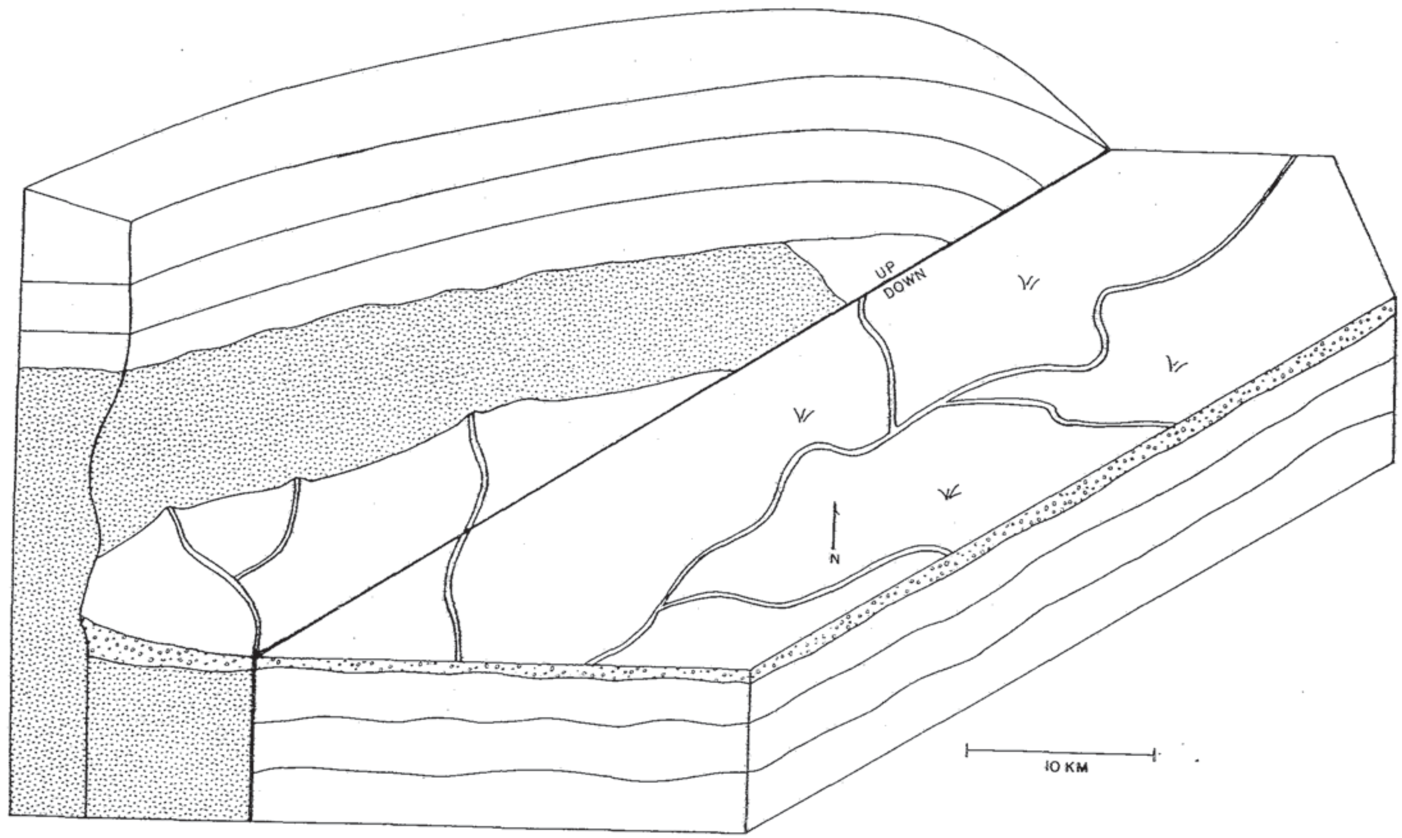


Figure 15. Sketch of alternate model for tear faulting along the Castle-Mountain - Caribou fault. There is a 4 X vertical exaggeration.

Castle Mountain Fault. Hence, one would predict the existence of Arkose Ridge Formation beneath Cook Inlet. This has not been documented, although the data are scanty. Rock similar to Arkose Ridge Formation has been found south of the Castle Mountain fault on the west side of Cook Inlet; the implications of this are discussed later.

The large unnamed fault north of Boulder Creek which repeats the stratigraphic sequence of Tuxedni Group, Chinitna Formation is high-angle, east-west-trending, and southward dipping (from topographic considerations). The author does not know whether motion on this fault was dominantly strike-slip or dominantly dip-slip. Assuming that the fault plane is vertical (it actually has a steep southward dip), and that movement was entirely vertical (south side down), a graphical solution indicates that displacement would be approximately 2,350 meters. If motion were entirely strike-slip, displacement would be roughly 3,385 meters. The fault is probably oblique with vertical and horizontal displacements of less than these values, but net displacement was certainly large. The fault has had Eocene or younger movement because it cuts off Eocene volcanic rocks, and it is probably a subsidiary fault of the Caribou fault.

Numerous high-angle normal faults which give rise to small grabens exist in the area, commonly with trends varying from north-northwesterly to northeasterly and with displacements ranging from 30 to 150 meters. There is a significant fault in the northwest corner of the map (west of Boulder Creek), which trends east-northeast and places Cretaceous Matanuska Formation on the north against Paleocene

Chickaloon Formation on the south. This fault is of interest because it does not cut the Tertiary volcanics, thus placing an upper limit on its age of Eocene.

One problem which has not been completely solved is the fact that on the eastern edge of the map, east of Boulder Creek, Tertiary volcanics north of the Caribou fault are placed against Talkeetna Formation on the south. Everywhere to the west of this area the Caribou fault separates older rocks on the north from younger rocks on the south. Why are the age relations across the fault suddenly reversed at this point? One possible reason is that the Caribou fault may have existed as a large fault scarp at the time the volcanic flows were extruded. The topography might thus have prevented all but a thin cover of flows to be deposited south of the fault in this area, and this cover has since been eroded away.

The Caribou fault zone just west of Boulder Creek is unique in that it was found to be offset by north-trending faults (Figure 16). The sense of slip on these faults is not known for certain, but limited use of bulk strain analysis on slickensided shear fractures by R. Bruhn (personal communication, 1979) suggests that they are strike-slip faults. These faults are similar to those found by Bruhn and Pavlis (1978) which cut the Castle Mountain fault in the Wishbone Hill area and are considered to be Miocene or younger. The presence of slices of different formations just north of the Caribou fault also suggests strike-slip faulting. This investigator visualizes a process of alternating activation of the Caribou fault and strike slip faulting on north-trending faults producing a "meat-slicer" effect. Figure

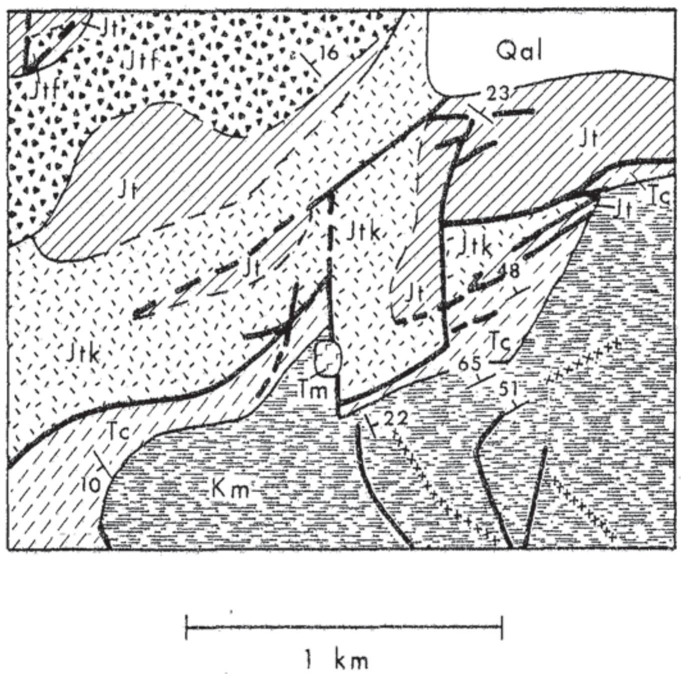


Figure 16. Detailed map of offset portion of the Caribou fault. See Figure 3 for location and legend.

17 is a sketch of a probable configuration after offset on two north-trending faults and before reactivation of the Caribou fault. The reason that the offset of the main Caribou fault zone is preserved is undoubtedly because more recent motion was shifted to a major subsidiary fault 1,200 meters to the south, the Boulder Creek fault.

Area Between the Castle Mountain Splay and Caribou Faults East of Boulder Creek

East of Boulder Creek the splay block is primarily composed of Talkeetna Formation and a large amount of intruding quartz latite in the form of volcanic domes. The domes have mainly been passively emplaced, but there are notable exceptions where updoming of surrounding layered volcanic rocks of the Talkeetna Formation has occurred.

Deformation within the Talkeetna Formation is difficult to interpret becuase it is not certain whether specific structures are Tertiary or Mesozoic in age. An easterly trending fault, just south of the Boulder Creek fault, was traced for two kilometers and is suspected of being a Mesozoic structure. This is because easterly-trending faults are more common within the Talkeetna Formation. The sense and amount of displacement on this fault is unknown.

South of East Boulder Creek there are numerous enigmatic, unmapped, generally flat-lying cataclasite zones with white talcose (?) veining. The author found these structures to be the most confusing in the entire map area. Significant offset could not be documented on these structures, and thrust faulting did not seem to be indicated. Although the author lacks substantial proof, he suggests that the deformation may be a hydrothermal syndepositional phenomenon.

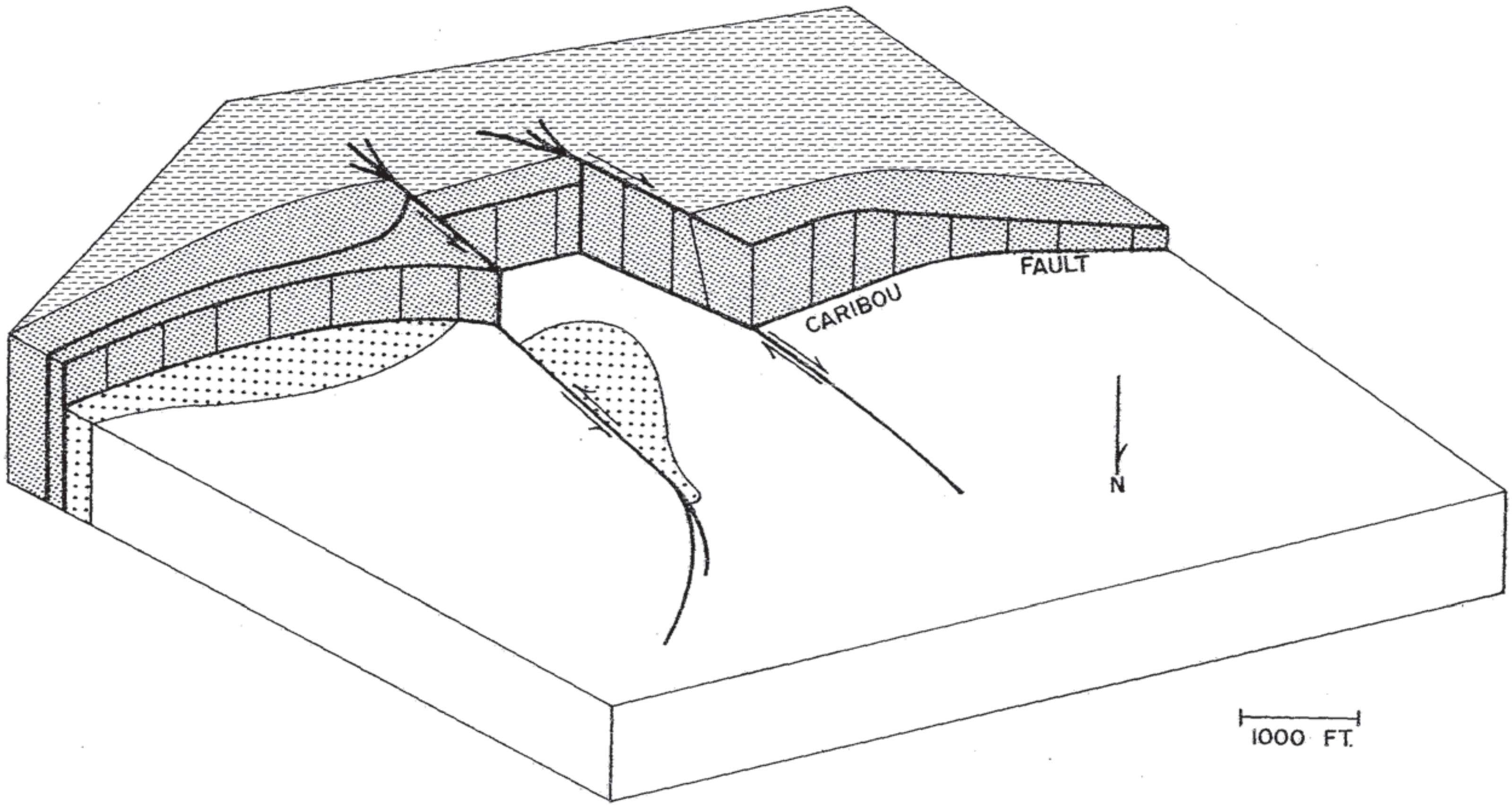


Figure 17. Sketch of offset of the Caribou fault zone by north-trending strike-slip faults.

Along Anthracite Ridge, the Castle Mountain splay fault has displaced a quartz latite dome in a right-lateral sense. This offset dome is discussed further in a later section.

A large northeasterly trending step-down fault (down to the east), which was mapped by Detterman et al. (1976) south of East Boulder Creek, was found to be nonexistent. Nevertheless, although not studied by this author, two other step-down faults further to the east on their map (such as the one along Hicks Creek) probably do exist. This is apparent on the map of Csejtey et al. (1978) where it can be seen that the blocks bounded by these step-down faults contain rocks of decreasing age in an eastward direction. These faults may be manifestations of the tectonic influence of the Copper River Basin.

Major Fault Offsets

Well-documented offsets on the Castle Mountain - Caribou fault system (including the Castle Mountain splay fault) are few and far between in spite of the large amount of attention this fault system has received. Detterman et al. (1976) postulate 3 km of vertical offset along the Talkeetna Mountains' portion of the Castle Mountain fault based on stratigraphic separation just west of the major splay, where Talkeetna Formation on the north is juxtaposed against Wishbone Formation on the south. This must probably be considered an estimate of post-Eocene vertical displacement. Although stratigraphic separation is a dangerous criterion for inferring slip on any fault, particularly one such as this with a complicated history, this estimate is probably the best one presently available, since no net slip information is available.

A dextral offset of 14 1/2 km (less some small amount due to dip slip) is estimated for the Caribou fault on the basis of a sequence of Chickaloon and Matanuska formation rocks found south of the fault (located just west of Boulder Creek where the Caribou fault is offset by north-trending faults) and north of the fault (located off the map 14 1/2 km east along the Caribou fault) (see Figure 18). The correlation of this sequence across the fault was first suggested by Detterman et al. (1976), and a vist was made to both localities by this author. In the field both the Chickaloon Formation and Matanuska Formation rocks on both sides of the fault look identical. Thus, because rapid lateral facies changes are characteristic of both the Chickaloon and Matanuska formations, it would appear that the sequence of rocks could be considered as a "pseudo-piercing point." There are, however, some difficulties with the correlation. Firstly, the Chickaloon and Matanuska Formations are separated by a subsidiary fault in the sequence north of the Caribou fault, but the two formations are not separated by a subsidiary fault in the sequence south of the Caribou fault. This is not considered a very significant difference. Secondly, two samples of Chickaloon Formation rocks, one from north of the fault (sample HEL), and one from south of the fault (sample B-5) were examined petrographically. Sample B-5 is a conglomeratic lithic greywacke, while sample HEL is a conglomerate lithic arenite (classification of Pettijohn, Potter, and Siever, 1973). Appendix B shows the results of point-counting (355 points) each sample. There are significant differences between the samples. Sample HEL contains significantly more metamorphic material than does B-5. Sample B-5 contains

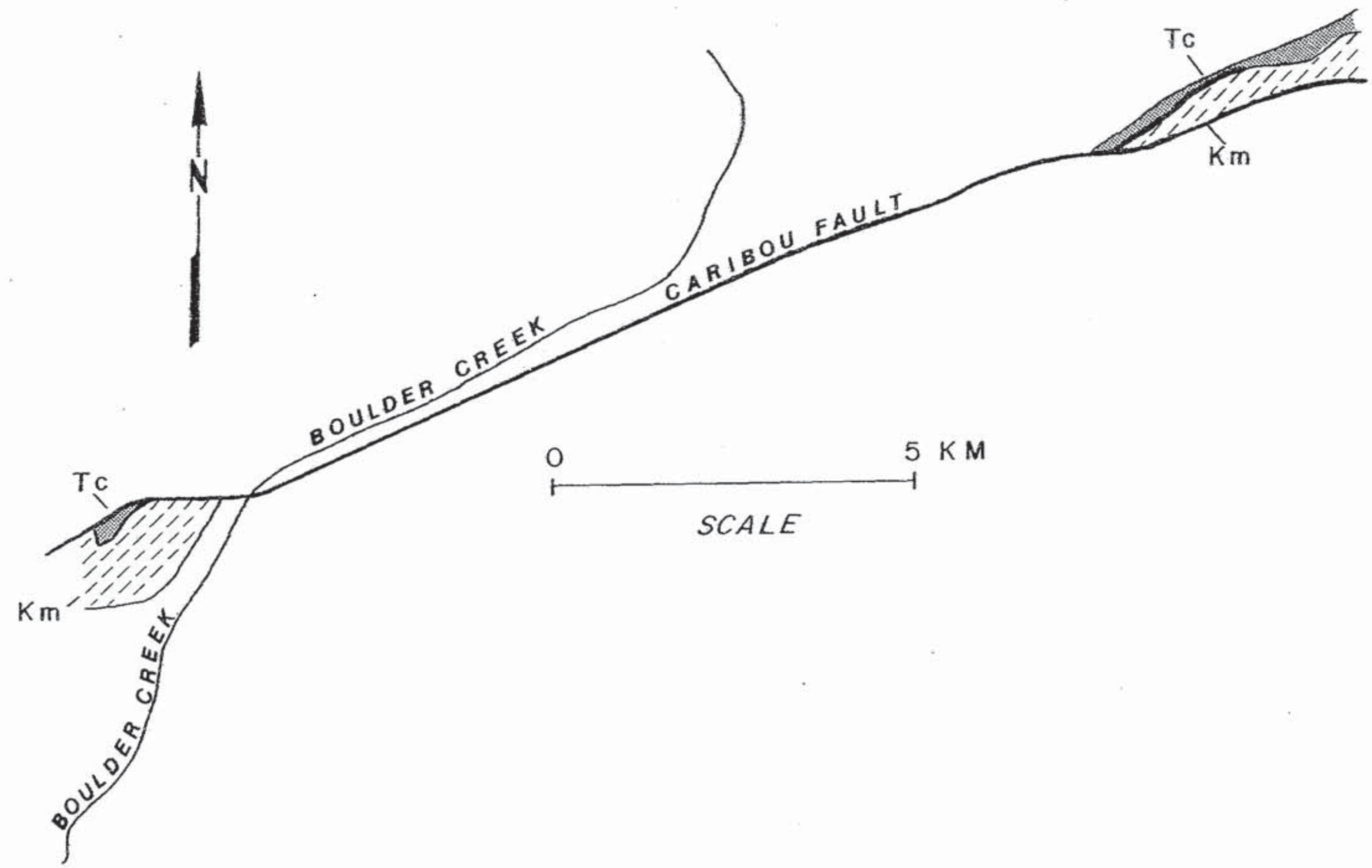


Figure 18. Location of offset sequence of rocks along Caribou fault.

21.4% carbonate cement and 7.0% intermediate plutonic material, both of which are either in very low abundance or absent from HEL. Although the cement differences may not be important, the differences in metamorphic and plutonic material cannot be dismissed. The large chert contents of both samples are indicative of some degree of similarity between the samples, but the petrographic data cannot be considered as highly supportive of a correlation between samples. Nevertheless, consideration of the fluvial environment of these Chickaloon Formation conglomerates leads one to believe that different proportions of material transported laterally versus material transported downstream could readily result in the petrographic differences which are observed. Such variation is readily apparent in point-counting done by Clarady (1974) on samples of Wishbone Formation. This author considers the correlation to be valid and the estimated dextral offset of 14 1/2 km (the author has modified Detterman's estimate of 16 km) to be the best available for the Caribou fault. The 14 1/2 km dextral offset is post-Paleocene (Paleocene being the age of the Chickaloon formation). To obtain an estimate on the post-Paleocene strike slip on the Castle Mountain fault (as opposed to the Caribou fault), it may be necessary to add an additional component that is partitioned onto the Castle Mountain splay fault. This leads to an estimate of 20 km of strike slip.

It should be noted that there is a potential argument favoring larger amounts of Tertiary strike slip, which involves matching up the Arkose Ridge Formation (Paleocene) north of the Castle Mountain fault and Wishbone Hill (west of the map area) with a similar arkosic unit that was encountered in several wells on the west side of Cook Inlet south of the Castle Mountain fault. Specifically, the author learned from C. White of Union Oil Company (personal communication, 1980) that a well drilled 15 km northwest of Tyonek (Pan Am Chuitna State 03193) and definitely south of the Castle Mountain fault penetrated over 1,250 meters of rock which was lithologically similar to Arkose Ridge Formation. The section lay below Kenai Group rocks. Palynological data were confidential, but presumably not inconsistent with the age of Arkose Ridge Formation. Furthermore, two wells were drilled in the Susitna Lowland (north of the Castle Mountain fault) into granodiorite basement and Arkose Ridge Formation was definitely not hit in these holes. It would appear that an argument could be developed involving up to 100 km of dextral slip on the fault system, which would be inconsistent with results obtained by this author in the Talkeetna Mountains. The Arkose Ridge argument is, however, far from substantiated in that the eastern boundary of the arkosic unit near Tyonek is not known. Additionally, there is a potential local plutonic source for this arkosic unit directly to the north across the fault, so that the unit may not be a displaced segment of Arkose Ridge Formation. Thus, this author contends that the Arkose Ridge Formation argument is more conjectural than are the arguments presented in this dissertation which favor smaller amounts of post-Paleocene strike slip.

In the southern part of the map area there is a quartz latite dome that appears to have been offset five kilometers by the Castle

Mountain splay fault (domes A and B on Figure 19). Since the field observations made it clear that all of the quartz latite domes were emplaced essentially vertically, all of the five kilometers of offset could be attributed to a dextral component of slip (the vertical component remaining unknown). Proof that the two offset portions of the dome were indeed due to offset and were not merely two different intrusions was deemed important enough that considerable effort was expended to validate this claim. The approach was geochemical. An initial test batch of seven quartz latite samples were analyzed for rubidium, barium, and strontium. These elements were three of several suggested by W. Nash (personal communication, 1978) as being useful for discriminating igneous bodies. The seven samples showed that the two halves of the offset quartz latite dome were nearly identical when the Rb, Sr, and Ba ratios were plotted on a ternary diagram and different from surrounding quartz latite bodies. During the next summer, 24 more quartz latite samples were collected from various intrusive bodies for Rb, Sr, Ba analyses in order to make the geochemical evidence more conclusive. The results definitely support the contention that the quartz latite dome has been offset by the Castle Mountain splay fault. Figure 19 shows the location of the samples. Figure 20 is a ternary plot of Rb, Sr, and Ba ratios. The field for each quartz latite body was defined by merely connecting up outlying points. Each point is given a letter designation (A through G) to indicate the quartz latite body from which that sample was collected. A and B are the two halves of the offset dome. Several miscellaneous quartz latite domes did not have

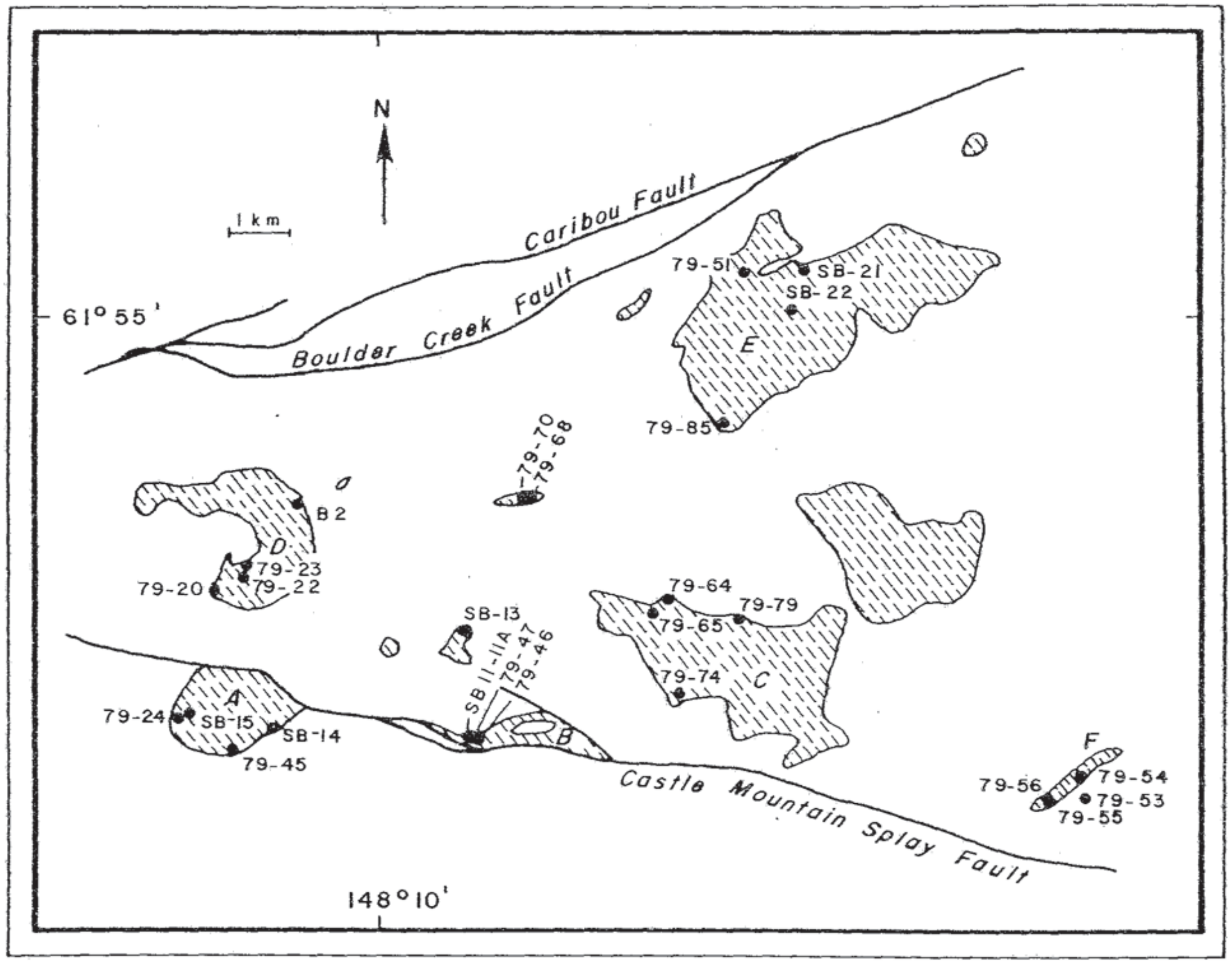


Figure 19. Location of samples analyzed for Rb, Sr, and Ba.

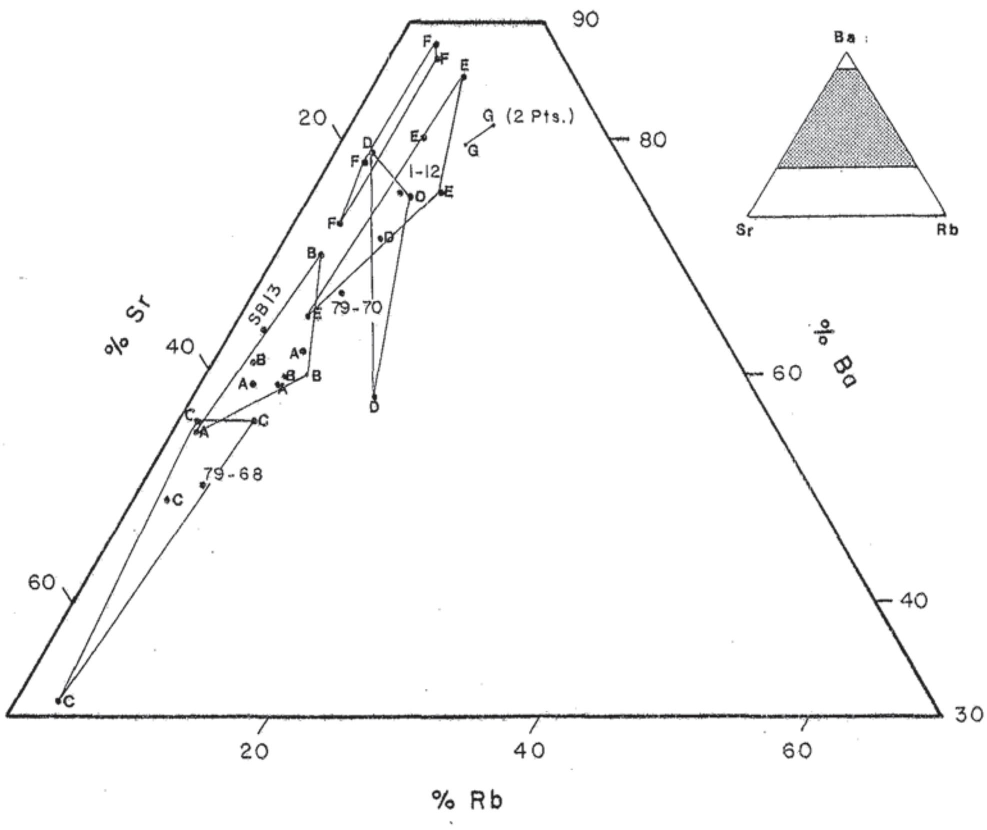


Figure 20. Ternary plot of Rb, Sr, and Ba ratios.

sufficient samples collected from them to define fields. Appendix A gives the actual Rb, Sr, Ba concentrations as well as averages for each quartz latite body. Four samples each were obtained from six quartz latite domes (and three samples from one other dome), including the offset dome. This was done because it was necessary to show that not only were the two offset halves of the quartz latite dome geochemically similar, but also that they were different from surrounding domes. It was also hoped that each of the domes would be characterized on the ternary plot by a well-defined field and that none of the fields would overlap (except, of course, the fields for the two halves of the offset dome). Figure 20 shows that both halves of the offset quartz latite dome do indeed plot in the same field and that this field does not significantly overlap any other fields. Fields D and E do significantly overlap and it is quite possible that these two large domes tapped a single magma chamber at depth and were intruded at the same time. Field evidence does not allow for them to have once been connected at their present exposure level and then displaced by a fault.

The fact that the Rb, Sr, Ba ratio fields overlap for quartz latite domes D and E, which are clearly not offset by a fault, might lead to the suggestion that the geochemical data for the offset dome are merely permissive of it being offset by a fault rather than injected as separate bodies. However, the following is a list of four arguments, which when considered in total, demonstrate that the quartz latite dome is offset by the Castle Mountain splay fault:

1. Rb, Sr, Ba analyses, when plotted on a ternary diagram, show that the offset halves of the quartz latite dome lie in the same field and are essentially outside the fields for all other domes in the area.

2. Although two quartz latite domes north of the offset dome have overlapping Rb, Sr, Ba fields, the fields of three other domes (not including the two halves of the offset dome) have no significant overlap.

3. It was seen in the field that both halves of the offset dome are clearly fault-bounded, at least in part.

4. The northern offset portion of quartz latite dome was intruded into and, for the most part, is surrounded by Matanuska Formation, even though most of the splay block east of Boulder Creek is devoid of Matanuska Formation. Similarly, the southern offset portion of the quartz latite dome clearly intrudes Matanuska Formation.

Since the quartz latite domes are considered to be Eocene in age, the conclusion is that the Castle Mountain splay fault has undergone five kilometers of displacement since Eocene time. Drag folding near the fault and age relations across the fault suggest an unknown component of dip slip (north side up).

LATE MESOZOIC TECTONIC EVENTS AND PLATE

TECTONIC SPECULATIONS

This study has shed only a little light on the Mesozoic tectonic history of the Castle Mountain - Caribou fault system. More detailed mapping over large areas will be necessary for a fuller understanding of this history. It seems likely, however, that the Castle Mountain and Caribou faults were active sometime in the Mesozoic because of the large facies differences in Talkettna Formation on opposite sides of the faults (as described in the section on rock units), and the fact that while Chinitna Formation is sandwiched between the Matanuska and Tuxedni Formations north of the Caribou fault, the Chinitna Formation is absent south of the fault, where Matanuska Formation directly overlies Tuxedni Formation. The absence of Chinitna Formation south of the fault could be attributed either to Mesozoic uplift or strike slip on the Caribou and Castle Mountain faults. However, the large facies differences in the Talkeetna Formation across the faults would apparently call for a substantial component of strike slip on this fault (larger than has been established for the Tertiary). This author can deduce very little other information on this subject. Relevant to the discussion is the hypothesis of Csejtey et al. (1978) that all pre-middle Cretaceous rocks in the northern Talkeetna Mountains) are allochthonous and were emplaced by collision and obduction of a continental microplate which came from the south. Csejtey claims that this event took place in the Middle to Late Cretaceous. This author believes that this hypothesis is the best one currently available. Given that this collision did occur, all previous arguments by other workers, which demonstrate Mesozoic activity on the Castle Mountain - Caribou fault system, must be re-evaluated. For example, it has been argued that the Jurassic Alaska Range - Talkeetna Mountains batholith is offset 100 km or more by the Castle Mountain fault (Hackett, 1976). However, since a collisional microplate is involved, it is quite possible that the microplate did not come in as a coherent block, but rather that it came in as two or more pieces. Hence, the "offset" may actually represent only the original docking configuration. This author emphasizes that the offset may in fact be real, but it will take additional evidence (i.e., paleomagnetic data) to substantiate the claim.

The collision event hypothesized by Csejtey et al. (1978) is not readily apparent as an orogenic event in the area of this study. This is perhaps to be expected since the area would be located on the trailing edge of the colliding microplate. The first event thereafter was the formation of the forearc basin, represented by the Matanuska Formation. This would imply the onset of a new subduction event. The Matanuska Formation contains rocks which range in age from Albian (late middle Cretaceous) through Maestrichtian (latest Cretaceous), with some notable gaps in the record (particularly the Santonian). All of the Matanuska Formation rocks in the study area are Campanian and Maestrichtian in age according to micropaleontological results obtained by this author (Appendix D), and according to Grantz (1964). The associated magmatic-arc rocks for the Campanian and Maestrichtian forearc basin are well represented by the batholith which makes up most of the southwest corner of the Talkeetna Mountains. K-Ar dates ranging from 74 to 61 million years have been obtained on samples of this batholith (Csejtey et al., 1978). The older rocks of the Matanuska Formation (106 to 82 million years) do not have an associated magmatic arc, but these rocks were formed during the period of collision and obduction, when one might expect an interruption of normal magmatic activities.

TERTIARY TECTONIC EVENTS AND PLATE TECTONIC SPECULATIONS

The Tertiary begins with the demise or seaward shift of the Late Cretaceous forearc basin. A change from marine to continental sedimentation took place. The Chickaloon Formation represents deposition on a low fluvial plain standing only slightly above sea level. There is no evidence to suggest a significant hiatus between deposition of the Matanuska and Chickaloon Formations. Because of the fine-grained nature of most of the lower Chickaloon Formation sedimentary rocks, even near the Castle Mountain and Caribou faults, it is not likely that the two faults were highly active at this time. Large amounts of vertical motion on the faults would certainly have increased the coarseness of the sediments. Large amounts of strike-slip motion would have led to the formation of associated folding and pull-apart grabens, as is seen along the San Andreas fault, and would also have drastically disrupted the sedimentation pattern.

A major orogeny began in the Late Paleocene. In the Talkeetna Mountains, at 60 m.y., magmatic activity was suddenly disrupted such that the axis of the magmatic activity was shifted at least 60 kilometers to the northwest of the previous magmatic center. It was during this orogeny that uplift was initiated on the Caribou fault. Counter to claims by Detterman et al. (1976), that the Castle Mountain splay fault is the older, more fundamental break while the Caribou fault is of more recent origin, the author contends that with respect to uplift the reverse is actually true. Uplift occurred first on the Caribou fault during the Paleocene, and the Castle Mountain splay was either nonexistent or inactive at this time. Figure 21 is a sketch showing the stratigraphic argument which favors this interpretation. If the three blocks which are delineated by the Castle Mountain splay and Caribou faults are considered, it is clear that in the time period Upper Cretaceous through early Eocene the middle splay block and the southern block (the Matanuska Valley) have an identical overall stratigraphy. On the other hand, the northern block is missing the entire lower Chickaloon Formation, over 1,000 meters of strata. Clearly then, the uplift that occurred in the Paleocene on the Caribou fault was not present on the Castle Mountain splay fault. Some of the Tertiary strike slip on the Caribou fault may have occurred during this Paleocene tectonic event.

Following this event, or quite possibly concurrent with it, was the deposition of the spectacular boulder-cobble-pebble conglomerate of the Wishbone Formation. Because Wishbone Formation is found on both sides of the Caribou fault, the fault itself could not have been the dominant source of the conglomerate. Since Wishbone Formation rims the present-day Talkeetna Mountains block on the south and east sides, this wedge of sedimentary rocks is probably a manifestation of the initial blocking out of the Talkeetna Mountains as we know them today.

Following deposition of the Wishbone Formation, several events

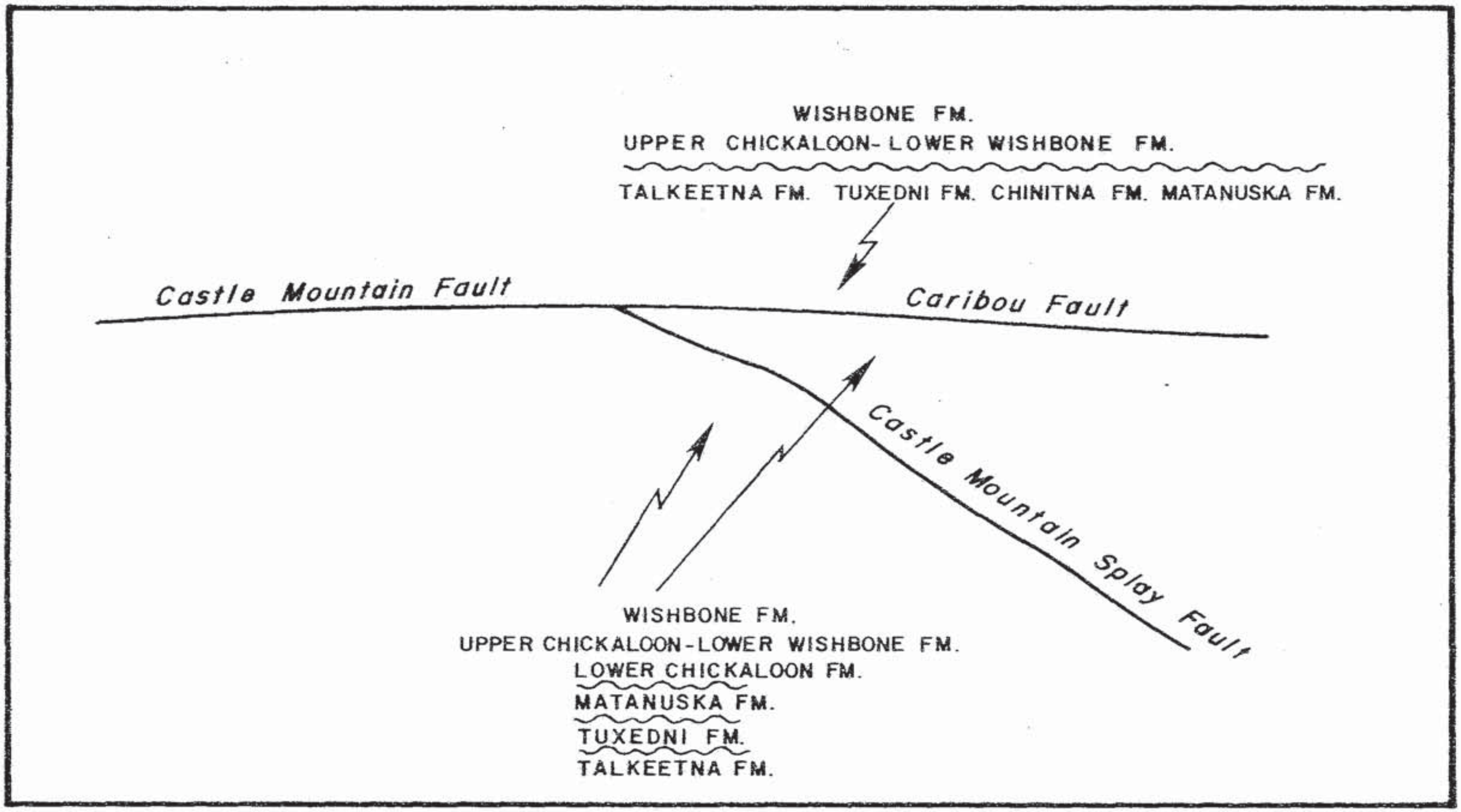


Figure 21. Sketch showing comparative stratigraphy of the three fault-bounded blocks.

occurred. It is only possible to speculate on the exact order in which most of them occurred. As mentioned previously, open synclinal folding of the Wishbone Formation may have been, at least in part, contemporaneous with more complex deformation of the underlying Chickaloon Formation. Indeed, the synclinal folding may have been taking place even as the Wishbone Formation was being deposited.

Volcanic activity which was ongoing in the northern Talkeetna Mountains throughout the period of deposition of the Wishbone Formation eventually reached the southern Talkeetna Mountains in the Eocene and brought to a close the deposition of this unit. The volcanic activity occurred along a very obvious northwest-trending axis through the central Talkeetna Mountains. This volcanic axis appears to represent a perpendicular outlier to the main magmatic arc and is a curious feature, but it has analogs in present-day volcanic arcs around the world (i.e. Talasea, New Britain and the Shumagin Islands, Alaska). Also, curious is the fact that felsic volcanic rocks lie at the base of the volcanic section, and andesites and basalts lie higher in the section; whereas, the reverse is true in most magmatic arcs. The author knows of no good explanation for this. This area lies only roughly 50 km above the present-day Benioff zone, too shallow to give rise to the observed magmatism. Hence, throughout most of the Tertiary the Benioff zone must have had a steeper dip than it does now. An alternative possibility is to attribute the formation of the felsic volcanic rocks to anatexis, as Hudson et al. (1979) have for rocks of similar age and composition along the margin of the Gulf of Alaska. The difficulty with this hypothesis is that Hudson's model is for anatexis within the accretionary prism of the Paleogene subduction zone; whereas, the quartz latite domes of the study area were certainly not part of the accretionary prism.

Also in the Eocene the block between the Castle Mountain splay and Caribou faults was uplifted as a rotational fault block with a pivot at the splay point. Paleomagnetic evidence indicates that the splay block was tilted prior to intrusion of the diabase dikes and the quartz latite domes. This can be seen in Figure 22 which is a northern hemisphere Wulff Stereonet plot of the paleomagnetic poles for samples of quartz latite and diabase collected near locality B-2 (see Figure 19), as well as the Eocene pole for North America (Irving, 1979). Appendix E contains the paleomagnetic data analysis which resulted in the poles plotted in Figure 22. Since all three poles plot within 8° of each other (before bedding correction), it is clear that a bedding correction of 50° for the tilt of the splay block should not be applied. Hence, tilting was prior to intrusion of either the quartz latite or diabase. It should be noted that the quartz latite samples have a low Fisher precision of 6.7 and a high $alpha_{95}$ of 31.7° (standard deviation of the mean is 13.2°.) The diabase samples have a much better Fisher precision of 31.9 and $alpha_{95}$ of 13.7°. Also, of unknown relevance is the conclusion of Stone (personal communication, 1979) that in the Alaska Peninsula Eocene rocks were not firmly attached to North America and were actually displaced 10° of latitude to the south. The author favors an Eocene age for this event because he would

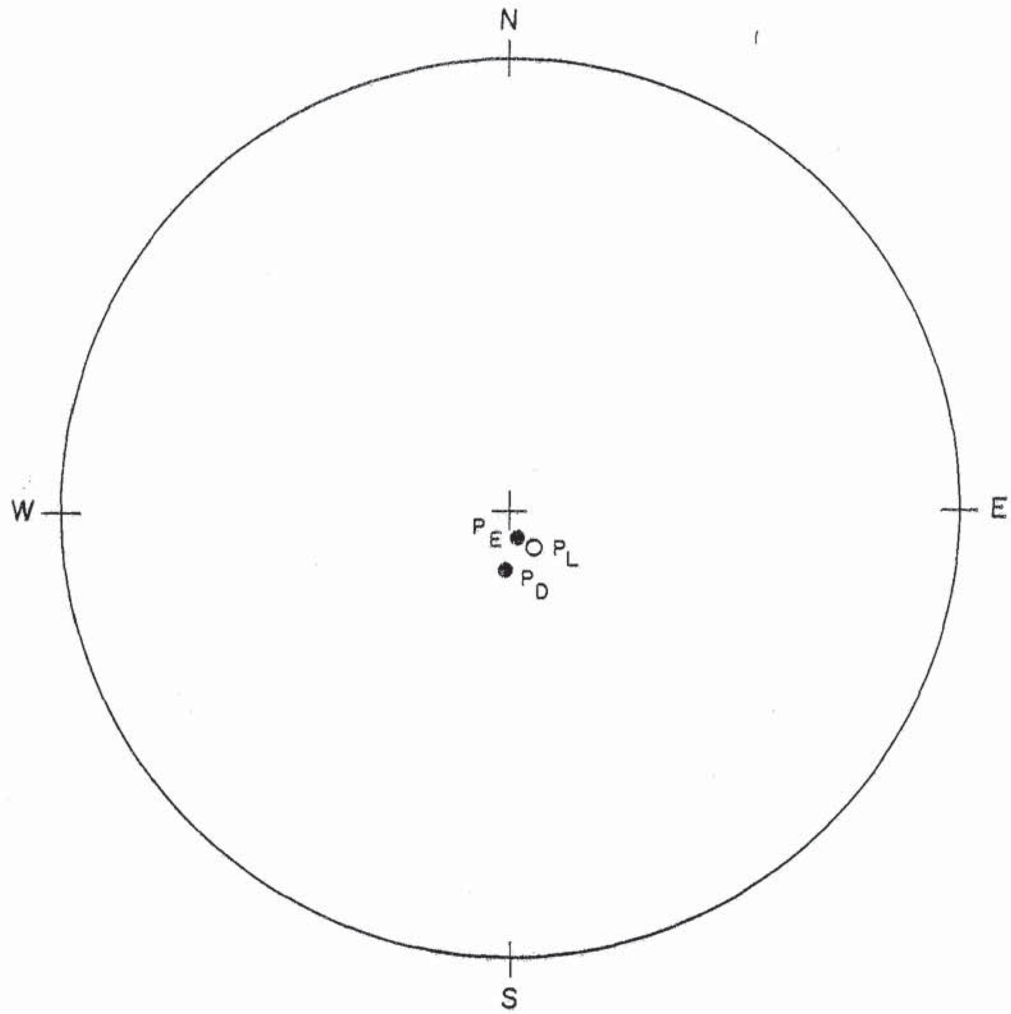


Figure 22. Northern hemisphere stereonet projection of paleomagnetic poles for diabase (P_D), quartz latite (P_L), and North America in the Eocene (P_E). Open circle represents a reversed pole.

attribute the uplift in the splay block to thermal expansion caused by the tremendous intrusive activity at this time (as manifested by the abundant quartz latite domes). Thus, uplift of the splay block was probably concurrent with the initial intrusion of magma at deeper levels and prior to the injection of the higher level volcanic domes. Quartz latite domes are very abundant within the splay block and less so to the southwest of the Castle Mountain splay fault (a view supported by the study of aeromagnetic maps), so that there was certainly a thermal differential across this fault. The thermal differential across the Caribou fault would be less than that across the Castle Mountain splay fault because there was abundant igneous activity north of the Caribou fault also. This is compatible with the model shown in Figure 9, which indicates that greater uplift of the splay block along the Castle Mountain splay fault than along the Caribou fault is necessary in order to explain the observed tilt of the splay block. The formation of the splay block may also have been accompanied by intrusion of the unique albite granite porphyry which is localized in the fault zone just west of the splay point. Presumably a complex pattern of stress trajectories would obtain in this area during uplift of the splay block. If this area was in an extensional regime, intrusion of the albite granite prophyry could easily have been facilitated.

The localized thrust faulting near the splay may also have occurred at about the time the splay block was uplifted. Northeast-trending step-down faults (down to the east) which occur at Hicks Creek (east of the map area) and further east delimit the eastern edge of the splay block and are probably a manifestation of the influence of the Copper River Basin. It seems probable that both the Castle Mountain splay and Caribou faults have been active throughout the Tertiary since the time of the inception of uplift along them. This would call for partitioning of movement onto both faults, maintaining a right-lateral sense of displacement on both faults. This is best visualized by assuming the splay block to be stationary while the northernmost block moves eastward and the southernmost block moves westward. The model is not unique, of course, since the splay point could also migrate laterally along the Caribou fault, in which case the splay block could no longer be assumed to remain stationary. It takes very little modification to impose a vertical component into this picture.

Another hypothesized event which may have taken place over a long period of time is the lateral collapse of the Matanuska Valley (south of the map area). In this case, the term Matanuska Valley is nearly synonymous with Matanuska Formation forearc basin because the formation's areal extent corresponds so closely with that of the valley. Collapse of the valley seems likely because the width of the valley (perpendicular to the general trend of known Matanuska Formation outcrop) is approximately 25 kilometers. By comparison, most present-day forearc basins are a minimum of 50 kilometers in width. A minimum of 50% shortening across the valley would be indicated by this line of reasoning, and this would be consistent with the structural style of the Matanuska Valley, which in addition to poorly understood valley-parallel faulting contains moderate to strong folding with valley-parallel axes (Barnes, 1962).

In the Late Eocene or Oligocene, continued uplift, magmatic activity, and northeast-southwest extension led to the intrusion of diabase dikes with an average trend of 116° in the map area and 103° to the east in the Caribou Creek area. These trends represent the regional direction of maximum horizontal compression of that time. This would represent either σ_1, the maximum stress axis, or σ_2, the intermediate stress axis, depending upon whether σ_1 was vertical or horizontal.

A regional hiatus throughout most of southern Alaska is recorded in the early (?) Oligocene. Large vertical offset on the Castle Mountain - Caribou fault during the Miocene (and also the Oliocene ?) is best described by Clarady (1974), where he states, "There is a minimum of several thousand feet of vertical separation (up to the north) of Miocene and Oligocene (?) sediments between the Anchorage Oil and Gas, Rosetta well (Section 20 and 21, T 18 N, R 3 W, S.M.) and the Lum Lovely, Beaver Lakes State No. 1 well (Section 32, T 18 N, R 3 W, S.M.)." These wells are located in upper Cook Inlet on opposite sides of the Castle Mountain fault. Continued motion on the Castle Mountain fault in the Miocene is indicated by the fact that some faults which cut the Tsdaka Formation (late Oligocene or early Miocene in age) to the west of the map area are cut by the Castle Mountain fault (R. Bruhn, personal communication, 1980).

The offset of the Caribou fault zone along north-trending strike-slip faults and the transfer of motion onto the Boulder Creek fault referred to earlier probably represent late tectonic events.

SPECULATION ON THE TECTONIC EFFECTS OF THE SUBDUCTION OF THE KULA RIDGE

It would seem appropriate to attempt to relate the events associated with the postulated subduction of the Kula Ridge, the spreading center separating the Kula and North American plates, to the tectonic events herein described for the southern Talkeetna Mountains. This is very much in the realm of speculation because the offshore subduction events are presently a subject of great controversy, as they have been for the past ten years. Various models would have the Kula Ridge subducted at times ranging from 60 m.y. to 30 m.y. At present, the two models being given the greatest consideration (at least by this author) are those of DeLong et al. (1978) and Byrne (1979). Without going into all of the various arguments, for the purposes of this dissertation the author accepts DeLong's model, which claims that the ridge was subducted between 45 and 30 million years ago, and the author rejects Byrne's model which calls for subduction of the ridge between 56 and 59 million years ago. The reason for this is that DeLong's evidence is more direct and was obtained from the Aleutian Islands, near where the actual subduction event occurred, while Byrne's evidence is less direct and was obtained from a portion of the North Pacific not directly involved in the subduction event. Byrne's paper is important, however, because, based on an analysis of magnetic lineations in the North Pacific, it shows that there was a massive plate reorganization 56 to 59 million years ago, Byrne then takes the unjustified jump to concluding that this plate reorganization was caused by subduction of the Kula Ridge (DeLong, personal communication, 1980). The plate reorganization may have been the cause of the northwestward shift in the magmatic arc at 60 m.y. noted above.

DeLong et al. test, against geological and geochronological data from the Aleutians, a model of what should happen when a ridge subducts. Their complicated model calls for:

1. diminution of magmatism as the ridge approaches the trench, followed by

2. shoaling and emergence of the crest of the arc, followed by

3. subduction of the ridge and concurrent greenschist metamorphism, followed by

4. subsidence of the arc, followed by

5. resumption of magmatic activity.

In their paper, DeLong et al., claim that Event 1 occurred at 45 m.y. and Event 3 at 30 m.y. (in the Aleutians). However, recent discussion with DeLong (personal communication, 1980) indicates that he would not be as specific on the dates, and he talks about "a window of 45 to 30 m.y." for subduction of the ridge. It should be noted that DeLong belongs to the school (which includes people such as Grow and Atwater (1970) and Francheteau et al. (1970)) that holds to subduction of 900 to 1,000 km of Pacific plate since 30 to 35 m.y. ago. This is based on paleomagnetic studies and studies of the evolution of the San Andreas fault system. Others, such as Marlow et al. (1973) claim that the amount of Pacific plate subducted is much less (perhaps 500 to 600 km). Most of these people base their conclusions upon sedimentological arguments derived from Deep Sea Drilling Project data. DeLong also believes (and this author agrees) that the east-west ridge that was subducted beneath the Aleutians was not immediately stifled, but rather its offshore easterly segment continued to be subducted obliquely along the margin of the Alaska Peninsula and finally beneath Cook Inlet. Some extrapolation is necessary to obtain an arrival time for the Kula Ridge beneath Cook Inlet, but 10 m.y. after arrival in the Aleutians is probably a reasonable estimate.

This author is unable to completely reconcile the tectonic events in the southern Talkeetna Mountains with DeLong's model of the five events which should occur upon the subduction of a ridge. This author suggests that two regional events which are most likely to correlate with subduction of the Kula Ridge are found in the sedimentary record of Cook Inlet. The first is the widespread early (?) Oligocene hiatus. In fact, early (?) Oligocene rocks are rare in all of Southern Alaska (W. Connelly, personal communication, 1978). This may correlate with the shoaling of the crest of the arc, DeLong's Event 2. Subsidence, or Event 4, may be represented by deposition of the Hemlock Conglomerate and the Tyonek Formation in Cook Inlet, which have a combined thickness of over 2,100 meters (Kirschner and

Lyon, 1973). To this author, the other events of DeLong are not readily apparent in the Cook Inlet area. Along the Castle Mountain - Caribou fault system in the Talkeetna Mountains, Oligocene uplift probably occurred, but significant subsidence at any time since the Oligocene did not. It is possible that uplift ceased periodically along the fault system in the Neogene, but subsidence does not fit the picture. Little can be said about possible cessation of magmatic activity in the southern Talkeetna Mountains with the approach of the Kula Ridge. More age dates are needed, but magmatic activity may not have completely ceased until the Pliocene. Certainly, there was much igneous activity in the Eocene, although DeLong's model would suggest that it should have diminished at this time. In the final analysis, the author suggests that while subduction of the Kula Ridge affected Cook Inlet to some extent, its effect in the southern Talkeetna Mountains, other than as a possible boost to the ongoing uplift, was minimal.

SUMMARY OF TERTIARY TECTONIC EVENTS

An important conclusion of this study is that the Castle Mountain - Caribou fault system has had a very episodic history, which has its vague origins sometime in the Mesozoic. Fortuitously, the existence of a comparable stratigraphy and igneous history across the three main faults in the study area (the Castle Mountain, Castle Mountain splay, and Caribou faults) allows a fairly clear picture of the major Tertiary tectonic events to be formulated. There is great potential for future studies to make this fault system as well understood as any in the world.

This study and an integration of the results of numerous other workers leads to the following chronology of Tertiary tectonic events that occurred on or affected in some manner the Castle Mountain - Caribou fault system:

1. At the end of the Cretaceous and the beginning of the Paleocene, uplift caused the demise or seward shift of the late Mesozoic forearc basin, and continental sedimentation began. The Castle Mountain - Caribou fault, which was in prior existence, does not show detectable motion at this time.

2. At 60 million years the axis of magmatic activity shifted at least 60 km northwest from its former position in the southwest corner of the present Talkeetna Mountains.

3. A major orogeny began in the late Paleocene. At this time uplift was initiated on the Castle Mountain - Caribou fault. Anticlinal arching in the block north of the fault (and synclinal downwarping to the west ?) was accompanied by tearing along the fault.

4. In the late Paleocene and Eocene, the Wishbone Formation, a thick boulder-cobble-pebble conglomerate, was deposited as an alluvial fan wedge along the southern and eastern margin of the Talkeetna Mountains. The Wishbone Formation was folded into a large open syncline, and the underlying, less competent Chickaloon Formation was more complexly deformed by a variety of styles of folding and faulting (including thrust faulting). The collapse of the forearc basin in which the Matanuska Formation had been deposited may have begun at this time, and is probably still in progress today.

5. Intense magmatic activity, as evidenced by the presence of quartz latite domes in the map area, brought about uplift of the splay block as a rotational fault block with a pivot at the splay point. Tilting was north-northwesterly. This initiated uplift on the Castle Mountain splay fault. Paleomagnetic data indicate that tilting occurred (immediately ?) prior to actual injection of the high level quartz latite domes. Intrusion of albite granite porphyry in the fault zone, just west of the splay point, and local northward

thrusting in the vicinity of the splay point may have occurred at about this time. Block uplift and splaying became even more manifest further east on the Caribou fault, in the area along the western margin of the Copper Basin. The magmatic activity was part of a northwesterly trending volcanic system that was a perpendicular outlier of the main magmatic arc to the north. Volcanism began earlier (in the Paleocene) to the north and migrated to the southern Talkeetna Mountains in the Eocene.

6. In either the Eocene or the Oligocene, diabase dikes, which fed the abovementioned volcanic system, were intruded with strong regional trends of 116° to 103°. The plane of the dikes would be perpendicular to the σ_3 orientation (minimum stress axis) of that time. Southwest - northeast extension is indicated.

7. Faulting must have continued after the intrusion of the dikes since dikes in the Castle Mountain splay fault are folded by later faulting.

8. Throughout Southern Alaska uplift in the early (?) Oligocene is apparent because of a hiatus in the stratigraphic record. Subduction of the Kula Ridge may have occurred at this time.

9. Uplift along the Castle Mountain fault (north side up) continued into the Miocene. There is no direct evidence concerning the events of the Pliocene.

10. In a late tectonic phase, reactivation of the Caribou fault alternating with strike-slip motion on north-trending cross faults produced a "meat-slicer" effect along the fault. Motion was then transferred from a portion of the Caribou fault to a parallel subsidiary fault just to the south, the Boulder Creek fault.

11. Volcanic activity in the southern Talkeetna Mountains ceased altogether in the Neogene, quite possibly in Pliocene time. The reason for this cessation of volcanic activity is not known.

Overall post-Eocene vertical motion across the Castle Mountain - Caribou fault system has been estimated by other workers to be 3 to 3 1/2 km (north side up). This author estimates post-Paleocene strike slip (right-lateral) on the Caribou fault to be 14 1/2 km. Total post-Paleocene strike slip on the Castle Mountain fault may be somewhat larger by addition of the partitioned component on the Castle Mountain splay fault, giving a total post-Paleocene strike slip of perhaps 20 km. Post-Eocene strike slip (right-lateral) on the Castle Mountain splay fault has been determined as (not estimated as) five kilometers based on an offset volcanic dome. Since the Castle Mountain splay fault was probably not in existence prior to the Eocene, five kilometers may represent the total Tertiary strike slip on this fault. The very small amount of strike slip on the Castle Mountain splay fault is probably due to its being roughly parallel to the regional direction of maximum horizontal compression throughout its existence.

APPENDIX A

CHEMICAL ANALYSES

Whole Rock Analysis and Norm of Quartz Latite

Sample 79-24

Whole Rock Analysis		Norm		
Species	Wt. %	Mineral	Mole %	Wt. %
SiO_2	67.30	Quartz	32.01	34.06
Al_2O_3	13.50	Corundum	4.76	4.30
Fe_2O_3	1.10	Orthoclase	3.90	3.84
FeO	2.40	Plagioclase	45.86	42.66
MgO	0.21	(Albite)	44.65	41.46
MnO	0.11	(Anorthite)	1.21	1.19
CaO	4.50	Hypersthene	3.26	3.65
Na_2O	4.90	(Enstatite)	0.59	0.52
K_2O	0.65	(Ferrosilite)	2.68	3.12
TiO_2	0.35	Magnetite	1.17	1.59
P_2O_5	0.02	Ilmenite	0.49	0.66
H_2O^+	1.70	Apatite	0.04	0.05
F	0.02	Fluorite	0.03	0.04
CO_2	3.30	Calcite	8.47	7.51
TOTAL	100.06		100.00	98.35

The whole rock analysis was performed by Skyline Labs, Inc. The normative analysis was calculated using a computer program of W. Nash, The University of Utah.

Rb, Sr, Ba Analyses of Quartz Latite Domes

Qtz. Latite Body		ppm Rb	ppm Sr	ppm Ba	Aver.	ppm Rb	ppm Sr	ppm Ba
A	79-45	20	190	300				
	79-24	10	240	300	A:	20	177	275
	SB-14	25	150	250				
	SB-15	25	130	250				
B	79-47	10	120	200				
	79-46	20	150	400	B:	20	131	262
	SB-11	25	110	200				
	SB-11 alt.	25	145	250				
C	79-64	10	210	100				
	79-65	10	200	200	C:	10	197	200
	79-74	10	70	100				
	79-79	10	310	400				
D	79-20	30	70	300				
	79-22	20	140	600	D:	26	86	312
	79-23	20	60	200				
	B2	35	75	150				
E	79-51	60	110	700				
	79-85	50	80	400	E:	54	122	625
	SB-21	70	90	950				
	SB-22	35	210	450				
F	79-53	40	120	1200				
	79-54	20	150	600	F:	30	127	800
	79-55	20	130	400				
	79-56	40	110	1000				
G	79- 2	60	70	500				
	79- 3	80	60	600	G:	73	63	567
	79- 4	80	60	600				
	SB-13	30	430	800				
	79-68	10	110	100				
	79-70	20	80	200				
	1-12	60	170	700				

Note: Samples 79-2, 79-3, and 79-4 were collected from a latite dome called the Lion Head, Mile 106 Glenn Highway at elevations between 2,370' and 2,460'.

Sample 1-12 was collected from a dike between Mile 74 and 75 of the Glenn Highway. Analyses performed by Skyline Labs, Denver, Colorado.

APPENDIX B

PETROGRAPHIC DESCRIPTIONS

Petrographic Description of Diabase Sample P-2

Sample P-2	Altered Diabase
Plagioclase Laths (0.3 - 2.0 mm long)	60 - 65%
Calcite	20 - 25%
Chlorite: patches (0.3 - 0.5 mm)	5%
intergrown with calcite	5%
Ti-oxide	2%
Opaque (nonmagnetic)	1%
Veins: calcite, quartz, chlorite (?), zeolite	1 - 2%

The rock is composed of intergrown elongate plagioclase laths which have a characteristic random orientation of basic hypabyssal intrusions. Crystals are strongly zoned from more-calcic cores to more-sodic rims, but no accurate composition could be determined. Grains are fresh.

Calcite forms very fine grained interstitial patches among plagioclase grains, and contains lesser chlorite and minor Ti-oxide. It is probably an alteration product of mafic minerals.

Chlorite also forms patches scattered through the rock, these may represent altered mafic phenocrysts.

Ti-oxide and opaque form scattered grains through the rock.

Veins are mainly calcite with lesser quartz and two minerals tentatively identified as chlorite and zeolite. Zeolite forms radiating fine grained aggregates, and chlorite occurs in parallel growths perpendicular to vein borders. Both are intergrown with calcite and lesser quartz.

Note: This thin section description was performed by Dr. John Payne, University of British Columbia, 1977.

Petrographic Description of Albite Granite Porphyry

Samples T-2, T-4

Samples T-2, T-4 Quartz-Plagioclase Porphyry Granite

Compositions: (in percent)	T-2	T-4
Phenocrysts		
Plagioclase*	20-25	15-20
Quartz	10-15	10
Mafic minerals**		
epidote	4	5- 7
chlorite	1	3- 5
muscovite	2	0
Ti-oxide	0.5	0.5
Opaque (nonmagnetic)	2	2- 3
Groundmass		
Plagioclase laths	3	1
Quartz patches (0.15 mm)	2	0
Fine-grained intergrowth feldspar-quartz (no K-feldspar stained)	35-40	35-40
Chlorite	5- 7	5
Calcite	1	3
Sericite	3	5
Apatite	0.2-0.5	0.5-0.5
Veins		
Calcite		5
Epidote		1

*Plagioclase phenocyrsts (and laths in groundmass) altered as follows:

T-2: Flakes and patches of sericite (5-7% of total plagioclase = 1-1.7% of total rock), and patches of epidote (2% of plag.)

T-4: Flakes and patches of sericite (7-10% of plag.), patches of calcite (3-5% of plag.).

**Mafic phenocrysts probably biotite and hornblende. Biotite altered to pseudomorphs of muscovite or chlorite with irregular patches of other minerals; hornblende altered to irregular patches dominated by epidote.

The samples are similar, with minor differences in distribution of alteration minerals (especially calcite, which is abundant in T-4 and rare in T-2).

Plagioclase and quartz phenocrysts are up to several mm across. Many are fractured and cut by calcite veins in T-4, and some quartz phenocrysts are partly replaced by fine grained quartz. Plagioclase gives a Michel-Levy composition of An_7. The groundmass in T-4 is finer grained (0.02 - 0.04 mm) and more uniform than that of T-2 (0.03 - 0.05 mm, locally up to 0.10 mm).

Note: This thin section description was performed by Dr. John Payne, University of British Columbia, 1977.

Petrographic Description of Quartz Latite

Sample SB-22 II

Sample Number:	SB-22 II	
Mineralogy (%):	Plagioclase phenocrysts	3
	Na-K spar (groundmass)	88
	Quartz (groundmass)	4- 5
	Chlorite	2- 3
	Sericite/clay	tr- 1
	Opaques	1- 2
	Zircon	tr
Rock Type:	Trachyandesite (latite)-rhyodacite (quartz latite)	
Texture:	Fine-grained porphyritic, holocrystalline, hypidiomorphic-granular, felsophyric	

Plagioclase phenocrysts: Euhedral phenocrysts of plagioclase 1 to 3 mm in diameter are suspended in a felsophyric groundmass. Simple twins consisting of two individuals (Carlsbad) are frequent, with few phenocrysts showing well-developed ablite twinning. Phenocryst cores are often clear, with alteration only along fractures, whereas the outer zones are slightly turbid with minor sericite and/or clay alteration. Carbonate replacement as in SB 15 is not visible. The margins of the phenocrysts are delicately embayed and intergrown with the groundmass, suggesting partial dis-equilibrium. The clear cores are optically negative and do not show twinning; however, K-spar staining does not indicate the presence of

K-spar in the phenocrysts. Replacement of orthoclase and/or sanidine is not supported. The average phenocryst composition, determined by the Michel-Levy technique, is calcic andesine (An_{42}). Several of the phenocrysts show well-defined normal zonation.

Na-K spar (groundmass): The matrix which serves as host to the phenocrysts consists of a felted fabric of subparallel feldspar laths less than 1 mm in length. A few are large enough to show albite twinning. The average plagioclase composition is sodic andesine (An_{32}), determined by the Michel-Levy technique. The groundmass plagioclase therefore appears to be slightly more sodic than the phenocrysts. The great majority of the groundmass feldspar shows twins which consist of two individuals and may be either albite or carlsbad twinning of orthoclase or oligoclase-andesine. No distinction has therefore been made between these constituents, grouping both as Na-K spar as suggested. Alteration of the groundmass feldspar consists of weak clouding by clay and dusting by sericite.

Quartz: Anhedral grains of quartz occupy intersticies among the groundmass feldspars. No graphic or myrmekitic intergrowths are visible; the quartz is late in the paragenetic sequence of a melt which did not approach the eutectic composition. The rock classification (latite transitional to quartz latite) is based upon the estimated quartz mode. With increase in quartz the rock passes into a true rhyodacite, and with decrease to a trachyandesite.

Accessories: Granular opaques less than 1 mm in diameter are randomly disseminated throughout. Larger (1-2 mm) opaques are also locally present. Green chloritic material fills intersticies among the groundmass feldspar laths. It is restricted to the interstitial fillings, and presumably replaces ferromagnesian minerals. The original composition of these minerals, while assumed to be either hornblende or biotite, could not be determined due to the pervasive nature of the alteration. Some areas appear to have concentrations of the chloritic material. Granular zircon (?) is often associated with these concentrations. The exceedingly fine grain size does not allow positive identification.

<u>Note</u>: Thin section analysis was performed by Mark S. Bloom, University of British Columbia, 1978.

Point Counting of Two Samples of Chickaloon Formation Sandstone

Component	Percent Component in Sample B-5	Percent Component in Sample HEL
Carbonate cement	21.41	0
Hematite	5.07	4.79
Quartz (single grain)	16.90	16.34
Metaquartz	1.69	10.70
Quartz (polycrystalline)	21.97	27.32
Chert	23.66	16.34
K-feldspar	0	0
Plagioclase	0.28	0
Volcanic - felsic	1.13	0.28
Volcanic - intermediate	0.56	3.38
Volcanic - basic	0.28	2.82
Plutonic - felsic	0	0.28
Plutonic - intermediate	7.04	0.28
Plutonic - basic	0	0
Cherty matrix	0	5.35
Holes	0	2.25
Muscovite	0	0.28
Opaques	0	0.28
Clay	0	0.28
Metamorphic	0	9.01

355 points were counting in each of the samples B-5 and HEL.

Sample B-5 is a lithic graywacke.
Sample HEL is a lithic arenite.

APPENDIX C

STEREONET PLOTS

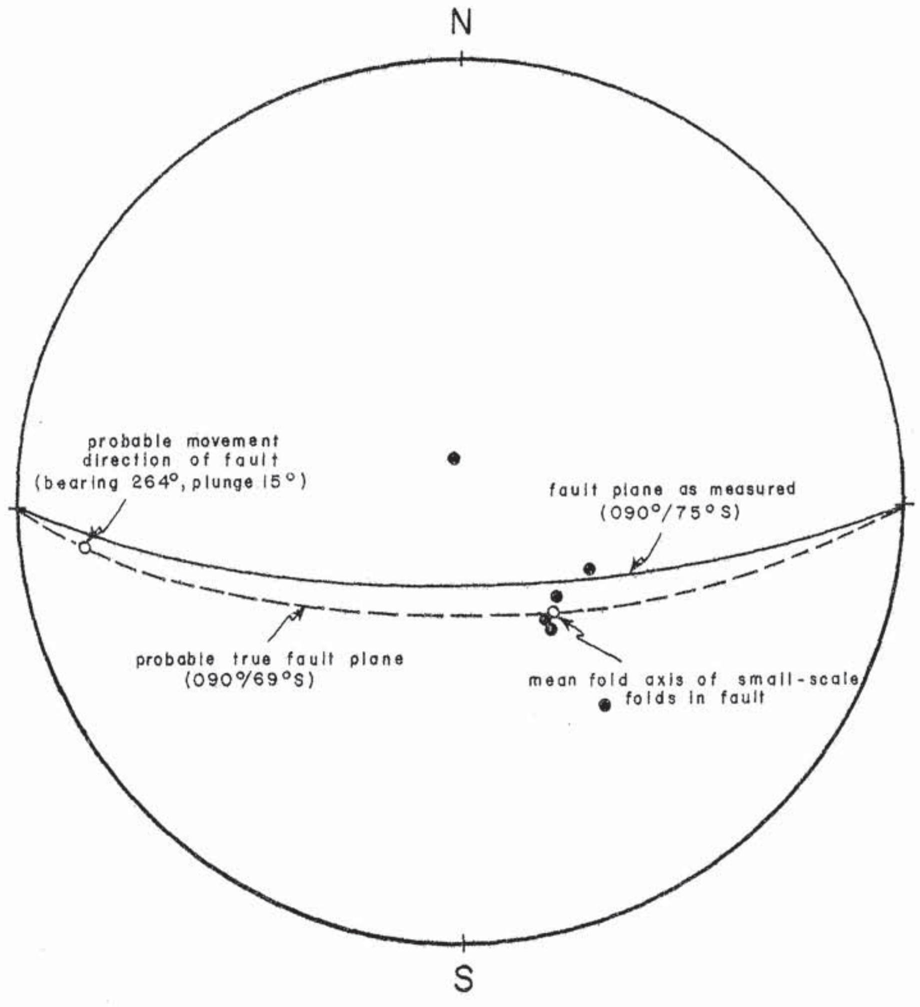


Figure 23. Stereonet solution of the movement direction on a fault using small-scale folds within the fault zone.

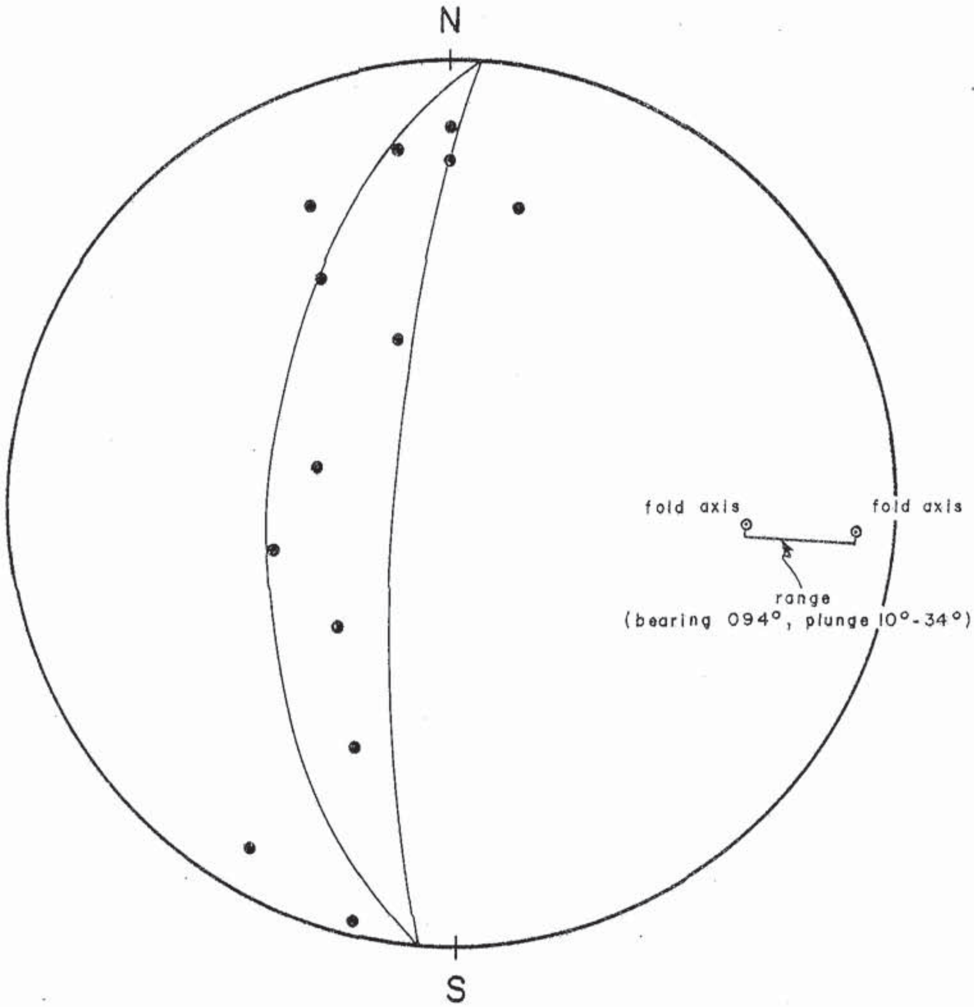


Figure 24. Stereonet solution of fold axis of folded diabase dikes. Black points represent poles to the dike surface.

APPENDIX D

PALYNOLOGICAL ANALYSES

Field No.	Palynology No.	Remarks
F-79-48	32393	Upper Jurassic: Sample contains a poor to fair spore/pollen assemblage as well as a few age diagnostic dinoflagellate cysts. The dinoflagellate assemblage includes *Pareodinia osmingtonense* and *Gonyaulacysta* cf. *longicornis*.
F-79-49	32394	Upper Jurassic: Assemblage similar to sample F-79-48 including a few specimens of *Pareodinia osmingtonense*.
F-79-50	32395	Upper Cretaceous (Campanian/Maestrichtian): Sample contains an excellent dinoflagellate assemblage including *Deflandrea diebeli*, *Amphidiadema nucula*, *Laciniadinium* sp, and *Spinferites* sp. There are also several occurrences of the age diagnostic pollen genus *Aquilapollenites*.

Note: Samples were analyzed by J. E. Bennett of Atlantic Richfield Company.

APPENDIX E

PALEOMAGNETIC ANALYSES

Paleomagnetic Analysis--Diabase Dike

Locality: Latitude = 61.89

Longitude = -149.19

This is near the center of the splay block, west of Boulder Creek.

Number of oriented samples collected: 9 (1 sample later destroyed by drilling). Type of spinner magnetometer: Digico (at The University of Utah).

Method of cleaning: Alternating field demagnetization.

Resulting mean pole: Latitude = 75.1°

Longitude = 183.7°

Fisher precision = 31.9

$Alpha_{95}$ cone of confidence = 13.7°

Discussion: Figure 25 is a southern hemisphere Wulff stereonet plot of the magnetic vectors before cleaning. Figure 26 is a plot of vectors obtained after cleaning. Table 1 gives the results of the demagnetization procedure. Zijderveld (1967) diagrams were plotted to help in deciding when (and if) a stable primary magnetization was obtained. Figure 27 is an example of one of these plots where a stable primary magnetic vector was obtained. Figure 28 is an example of one of these plots where a stable primary magnetic vector was not obtained. Three sample results were discarded after cleaning. Samples 2-II-1 and 2-II-3 were rejected because of lack of stable primary magnetic vectors. Sample 2-II-1 was rejected because it had a normal inclination, but a reversed declination.

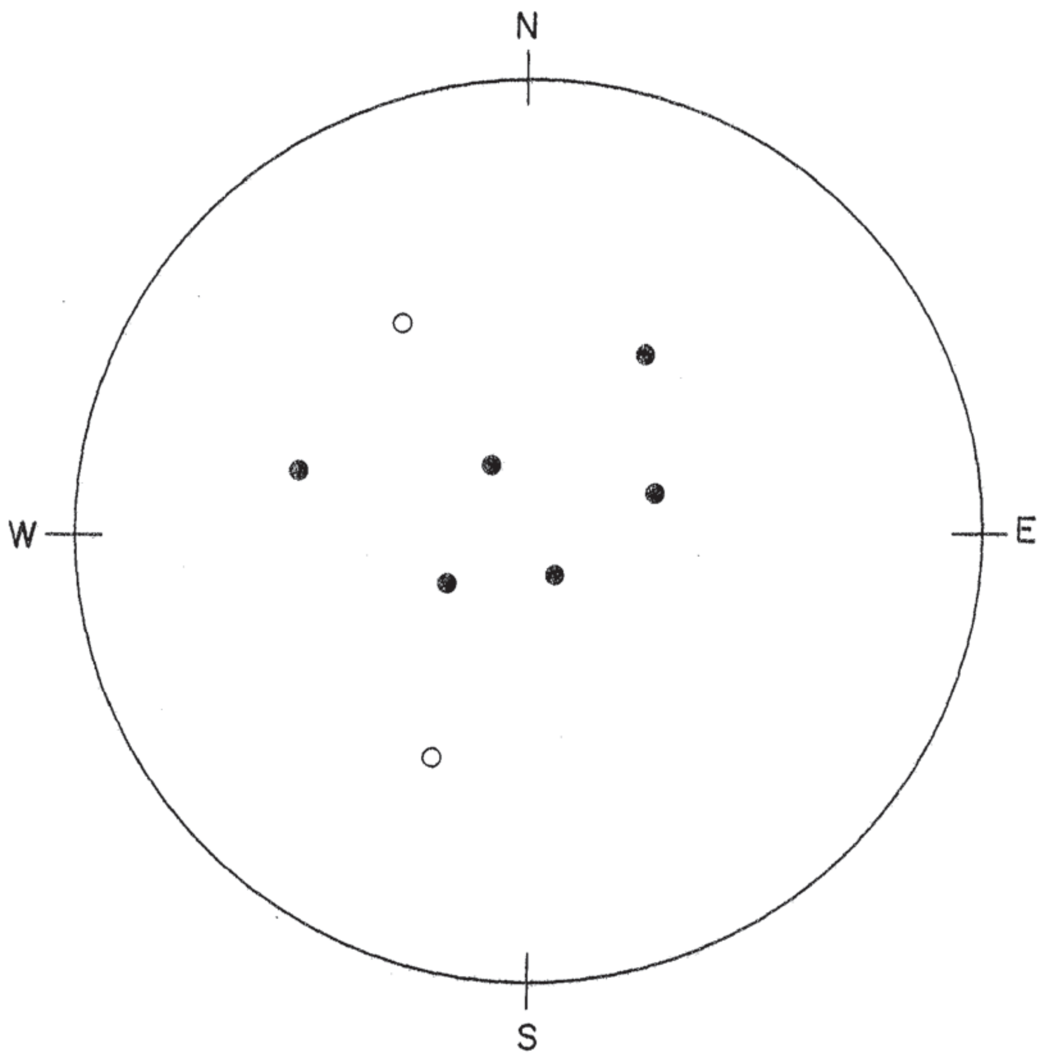


Figure 25. Southern hemisphere Wulff stereonet plot of magnetic vectors for diabase before cleaning. Open circles represent reversed samples.

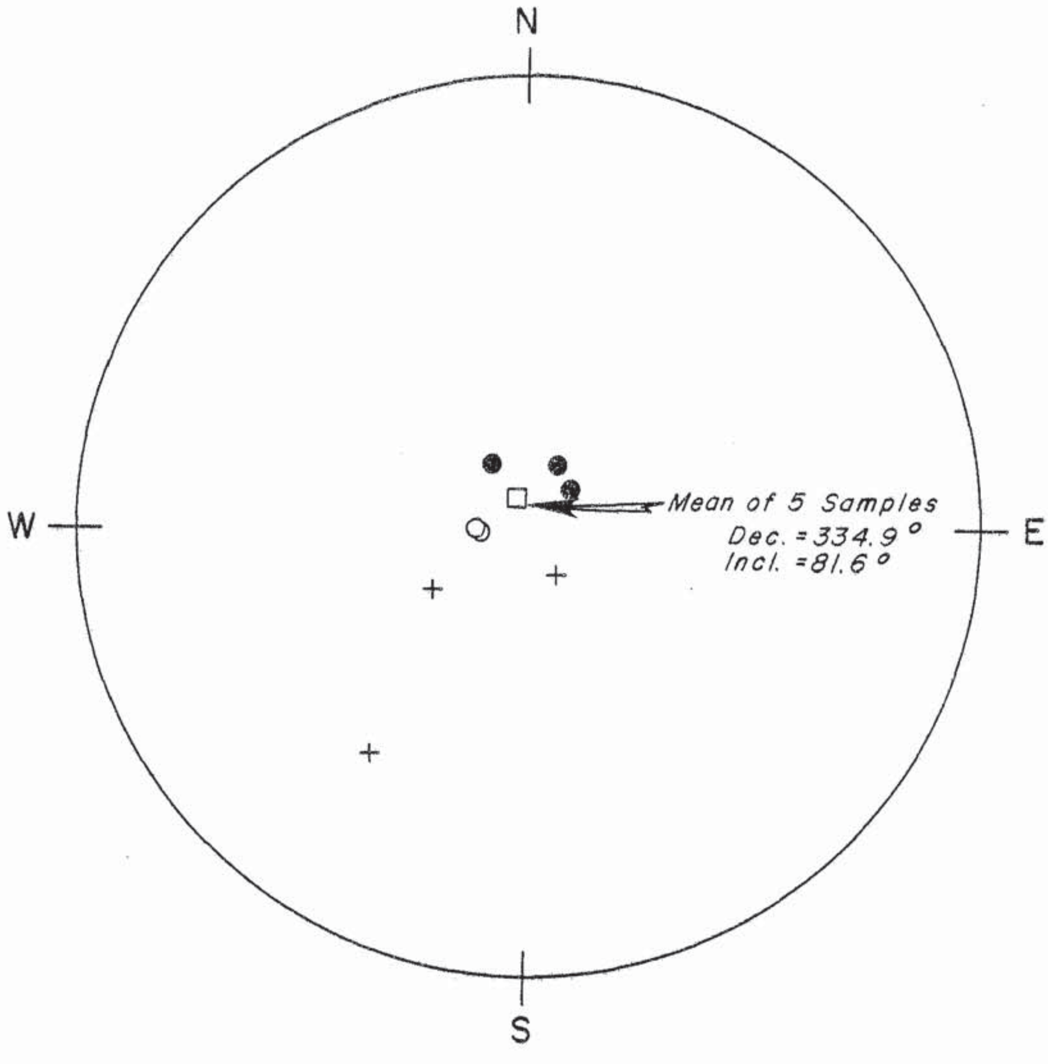


Figure 26. Southern hemisphere Wulff stereonet plot of magnetic vectors for diabase after cleaning. Open circles represent reversed samples. Plus signs are rejected samples.

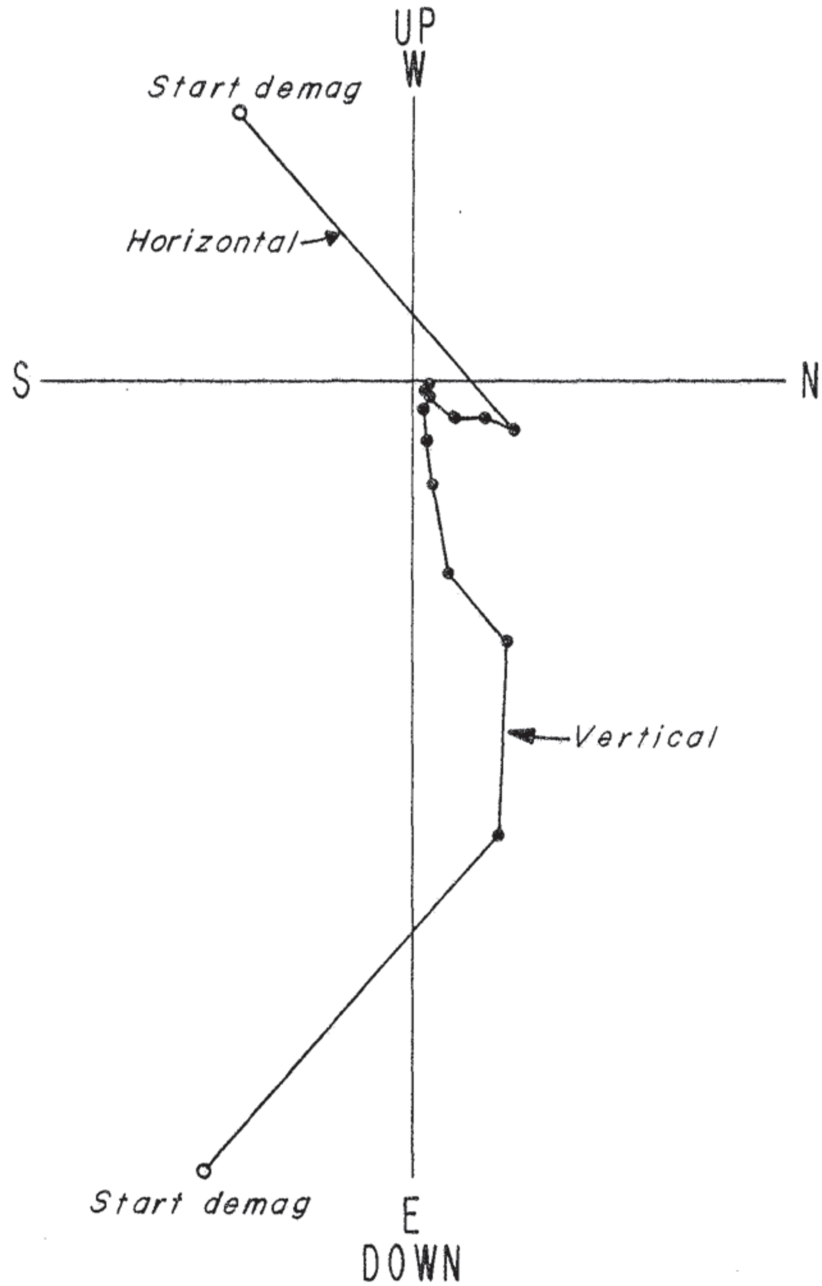


Figure 27. Zijderveld diagram of sample 2-III-3 upon cleaning. A stable primary magnetic vector is obtained.

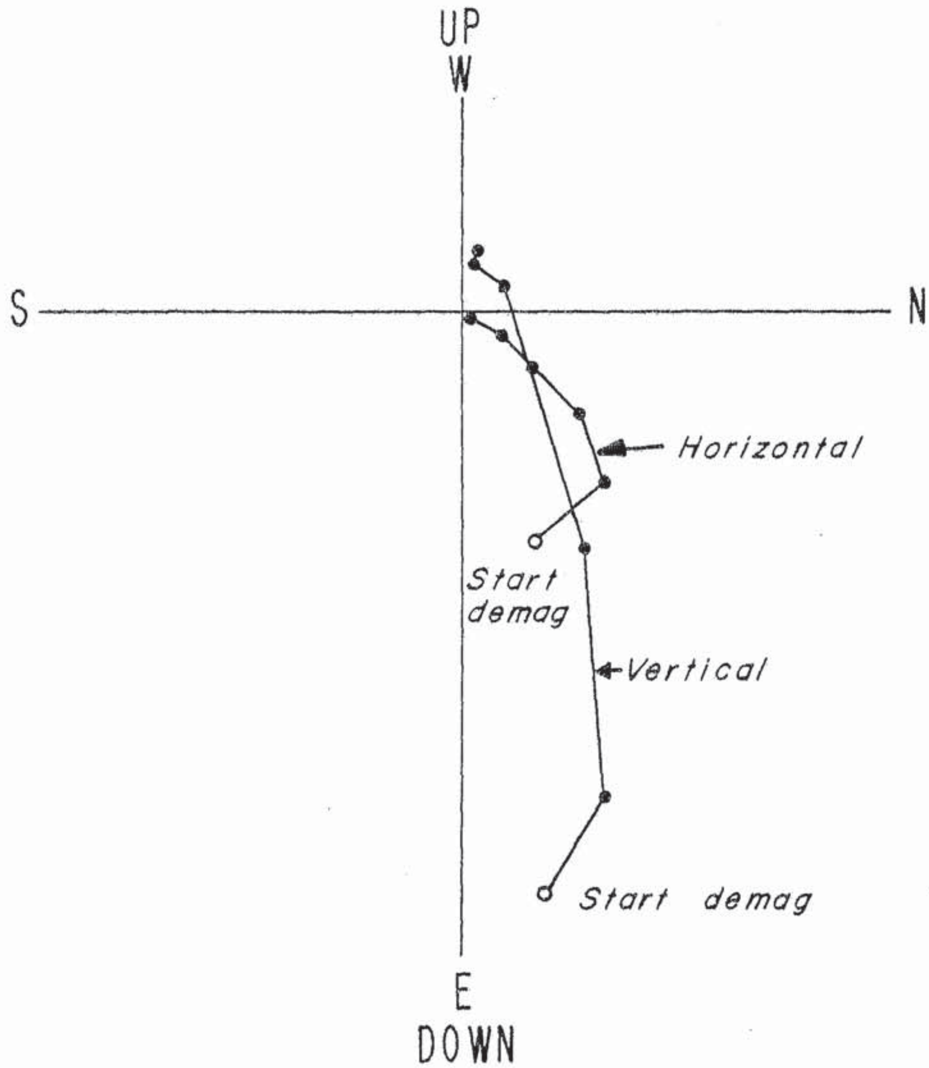


Figure 28. Zijderveld diagram of samples 2-II-3 upon cleaning. No stable primary magnetic vector.

Paleomagnetic Analysis--Quartz Latite Dome

Locality: Same as for diabase dike (120 meters away).

Number of oriented samples collected: 9 (1 sampled later destroyed by drilling).

Type of spinner magnetometer: Schonstedt SM-1 (measurements made by Bruce Panuska, University of Alaska).

Method of cleaning: Alternating field demagnetization.

Resulting mean pole: Latitude = -79.6° (reversed pole)
Longitude = -35.7°
Fisher precision = 6.7
$Alpha_{95}$ cone of confidence = 31.7°

Discussion: Figure 29 is a southern hemisphere Wulff stereonet plot of the magnetic vectors before cleaning. Figure 30 is a plot of vectors obtained after cleaning. Table 2 gives the results of the demagnetization procedure. Zijderveld (1967) diagrams plotted by computer were used to help in deciding when (and if) a stable primary magnetization was obtained. Figure 31 is an example of one of these plots where a stable primary magnetic vector was obtained. Figure 32 is an example of one of these plots where a stable primary magnetic vector was not obtained. The large scatter, as evidenced by the $alpha_{95}$ of 31.7°, is attributed mainly to the very low magnetic intensities (10^{-8} emu/cm^3) of these samples. Three sample results were discarded after cleaning. Samples WF-1, WF-5, and WF-6 were rejected because of lack of stable primary magnetic vectors.

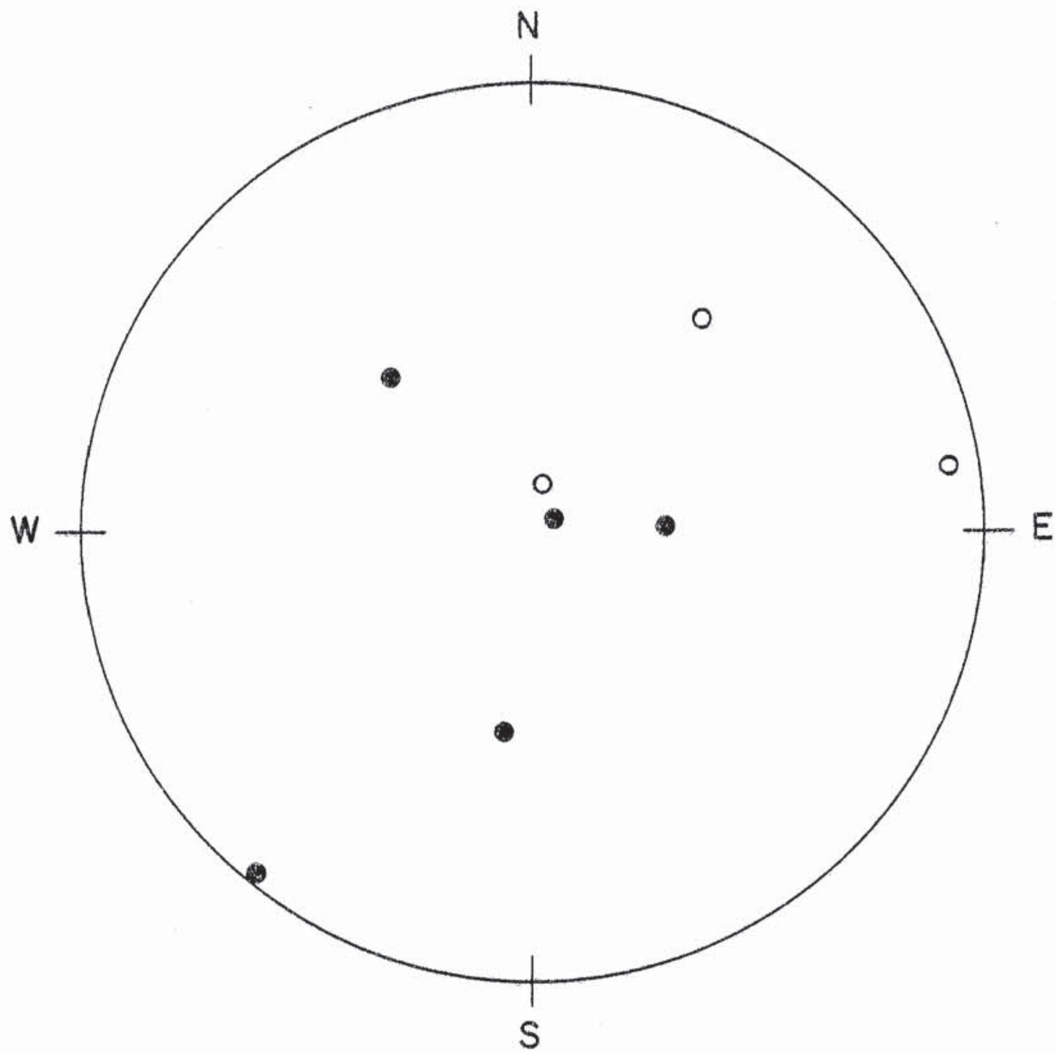


Figure 29. Southern hemisphere Wulff stereonet plot of magnetic vectors for quartz latite before cleaning. Open circles represent reversed samples.

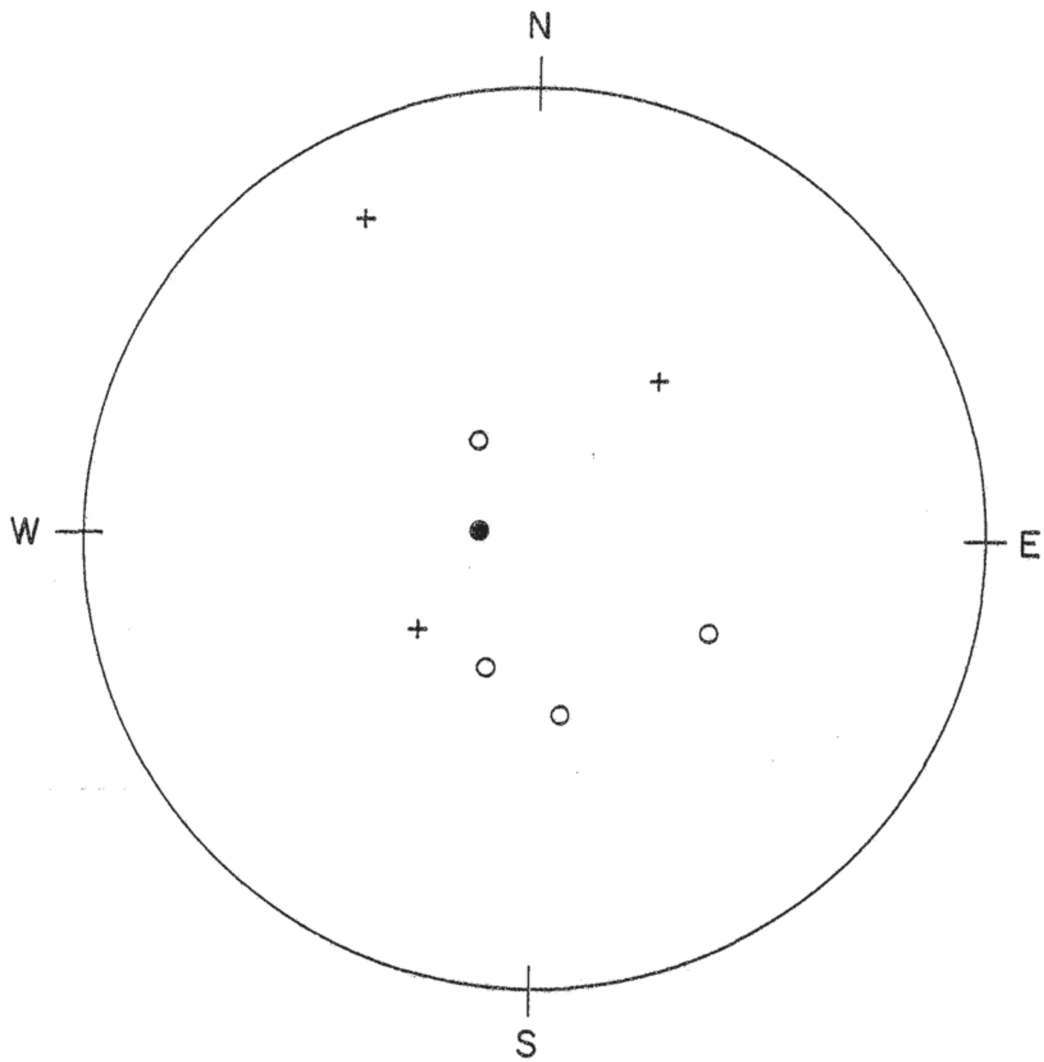


Figure 30. Southern hemisphere Wulff stereonet plot of magnetic vectors for quartz latite after cleaning. Open circles represent reversed samples. Plus signs represent rejected samples.

Table 2. Paleomagnetic Data--Quartz Latite.

Demag Level (oe)		Sample WF-1	WF-2	WF-3	WF-4
0	Intens.*	4.92	27.2	57.9	208
	Dec.	188	219	81	10
	Inc.	42	1	- 5	- 76
15	Intens.	4.32	27.1	54.4	204
	Dec.	177	218	82	12
	Inc.	- 6	- 1	- 6	- 78
25	Intens.	5.42	20.2	45.1	191
	Dec.	172	213	83	11
	Inc.	- 15	- 5	- 9	- 79
50	Intens.	6.92	10.0	25.4	99.5
	Dec.	149	215	81	338
	Inc.	- 43	- 22	- 22	- 75
75	Intens.	--	6.47	17.7	57.0
	Dec.	--	217	83	330
	Inc.	--	- 36	- 32	- 68
100	Intens.	7.35	5.12	13.0	33.8]
	Dec.	158	205	84	328]
	Inc.	- 48	- 46	- 47	- 62]
150	Intens.	--	3.84	8.52	14.6
	Dec.	--	206	93	337
	Inc.	--	- 61	- 68	- 51
200	Intens.	6.59	3.22	5.89	6.67
	Dec.	158	198	114	329
	Inc.	- 58	- 69	- 68	- 18
300	Intens.	3.42	1.33]	2.59]	--
	Dec.	191	198]	171]	--
	Inc.	- 31	- 56]	- 47]	--
400	Intens.	1.29	--	--	--
	Dec.	231	--	--	--
	Inc.	54	--	--	--

Table 2.--Continued.

Demag Level (oe)		Sample WF-5	WF-6
0	Intens.*	6.37	8.98
	Dec.	318	88
	Inc.	40	57
15	Intens.	5.65	5.52
	Dec.	321	81
	Inc.	32	42
25	Intens.	6.48	2.60
	Dec.	319	88
	Inc.	20	16
40	Intens.	--	3.49
	Dec.	--	105
	Inc.	--	- 17
50	Intens.	5.95	3.55
	Dec.	312	108
	Inc.	- 8	- 34
75	Intens.	--	4.05
	Dec.	--	126
	Inc.	--	- 43
100	Intens.	5.51	3.71
	Dec.	307	129
	Inc.	- 30	- 57
150	Intens.	--	3.14
	Dec.	--	112
	Inc.	--	- 34
200	Intens.	3.56	2.07
	Dec.	304	39
	Inc.	- 16	- 42
300	Intens.	3.74	--
	Dec.	332	--
	Inc.	13	

Table 2.--Continued.

Demag Level (oe)		Sample WF-7	Sample WF-8
0	Intens.*	19.5	32.0
	Dec.	39	56
	Inc.	- 27	84
15	Intens.	15.5	30.4
	Dec.	51	45
	Inc.	- 38	83
25	Intens.	12.3	27.5
	Dec.	61	51
	Inc.	- 44	82
50	Intens.	7.63	23.9
	Dec.	93	58
	Inc.	- 49	80
75	Intens.	6.51	--
	Dec.	108	--
	Inc.	- 45	--
100	Intens.	6.29	20.6
	Dec.	118	54
	Inc.	- 43	78
200	Intens.	3.26	18.9
	Dec.	102	53
	Inc.	- 60	81
300	Intens.	[2.18	--
	Dec.	104	--
	Inc.	- 60]	
400	Intens.	2.31	14.1
	Dec.	199	48
	Inc.	- 49	84
800	Intens.	--	10.0
	Dec.	--	357
	Inc.	--	74
1200	Intens.	--	[5.78
	Dec.	--	277
	Inc.	--	77]

*($X10^{-8}$ emu/cc)
Brackets indicate chosen primary vector.

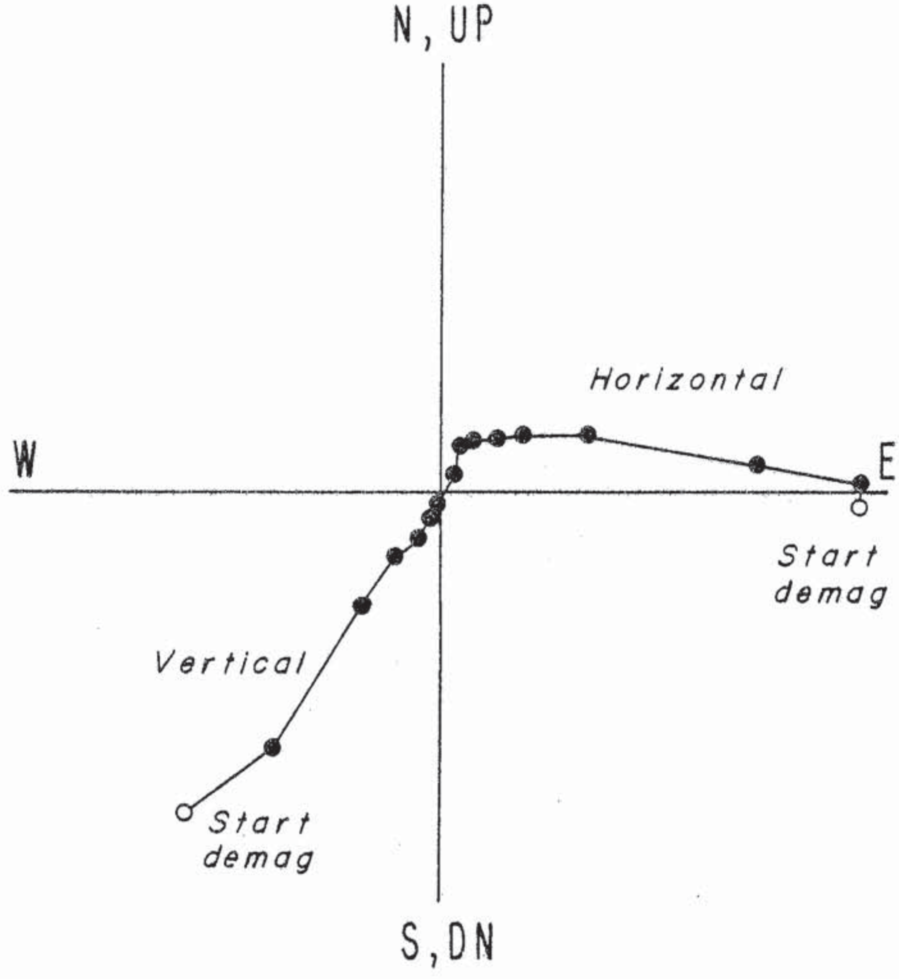


Figure 31. Zijderveld diagram of sample WF-2 upon cleaning. A stable primary magnetic vector is obtained.

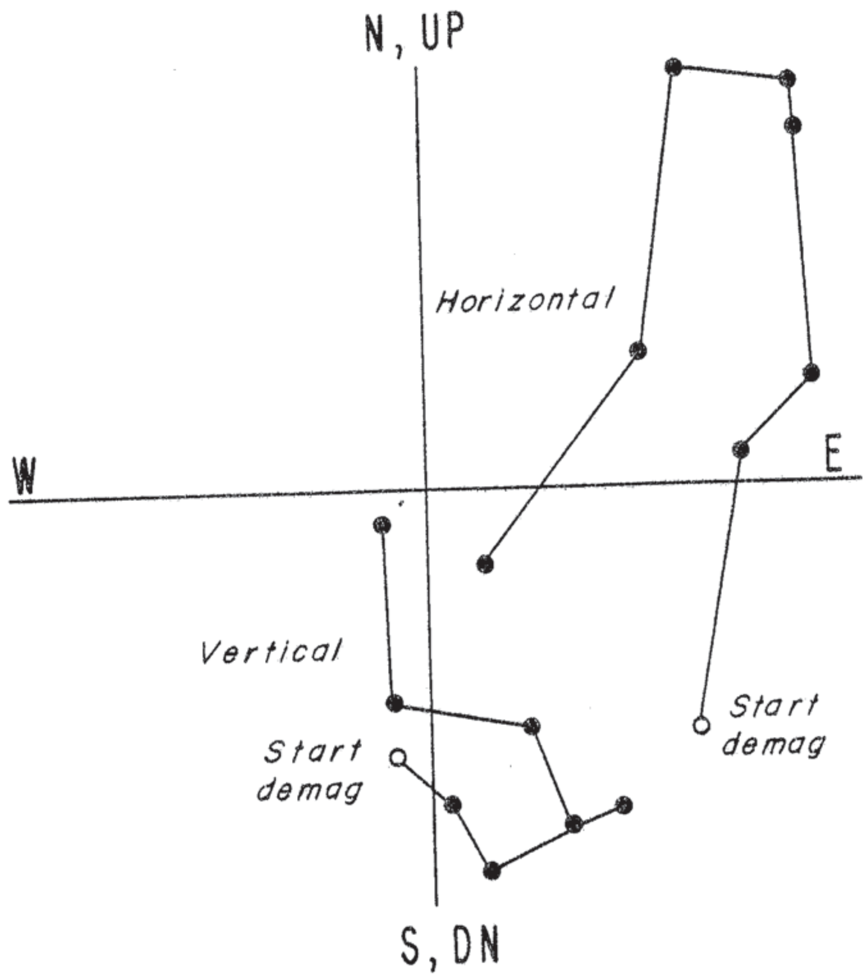


Figure 32. Zijderveld diagram of sample WF-1 upon cleaning. No stable primary magnetic vector.

REFERENCES

Arthaud, F., 1969, A graphic method of determination of the shortening, elongation, and intermediate directions from a population of faults, Bulletin de la Societe Geologique de France, 7th Series, t. XI, p. 720-737.

Barnes, F. F., and Payne, T. G., 1956, The Wishbone Hill District, Matanuska Coal Field, Alaska, U.S. Geol. Survey Bull. 1016, p. 88.

Boss, R. F., Lennon, R. B., and Wilson, B. W., 1976, Middle Ground Shoal oil field, Alaska, in: North American oil and gas fields, (ed.) Braunstein, J., Memoir 24, Amer. Assoc. Petroleum Geologists.

Bruhn, R. L., 1978, Holocene displacements measured by trenching the Castle Mountain fault near Houston, Alaska: Short Notes on Alaskan Geology, 1978.

Bruhn, R. L., and Pavlis, T. L., 1978, Tertiary stress orientation near the eastern end of the Alaska-Aleutian volcanic arc, [abs], Transactions American Geophysical Union, v. 59, no. 12, p. 1184-1185.

Bryant, B., and Reed, J. C., 1969, Significance of lineation and minor folds near major thrust faults in the southern Appalachians and the British and Norwegian Caledonides, Geol. Mag., v. 106, no. 5, p. 412-429.

Byrne, T., 1979, Late Paleocene demise of the Kula-Pacific spreading center, Geology, v. 7, p. 341-344.

Capps, S. R., 1927, Geology of the upper Matanuska Valley, Alaska, U.S. Geol. Survey Bull. 791.

Chinnery, M. A., 1966, Secondary faulting, Canadian Jour. of Earth Sci., v. 3, p. 163-190.

Clarady, B. I., 1974, Origin of the lower and middle Tertiary Wishbone and Tsdaka formations, Matanuska Valley, Alaska, M.S. Thesis, University of Alaska, p. 50.

Csejtey, B., Nelson, W. H., Jones, D. L., Silberling, N. J., Dean, R. M., Morris, M. S., Lanphers, M. A., Smith, J. G., and Silberman, M. L., 1978, Reconnaissance geologic map and geochronology, Talkeetna Mountains quadrangle, northern part of Anchorage quadrangle, and southwest corner of Healy quadrangle, Alaska, U.S. Geol. Survey open-file report 78-558-A, p. 60.

DeLong, S., Fox, P., and McDowell, F., 1978, Subduction of the Kula Ridge at the Aleutian, Geol. Soc. Amer. Bull., v. 89, p. 83-95.

Detterman, R. L., and Hartsock, J. K., 1966, Geology of the Iniskin-Tuxedni region, Alaska, U.S. Geol. Survey Prof. Paper 512, p. 78.

Detterman, R. L., Plafker, G., Hudson, T., Tysdal, R. G., and Pavoni, N., 1974, Surface geology and Holocene breaks along the Susitna segment of the Castle Mountain fault, Alaska, U.S. Geol. Survey Misc. Field Studies Map MF-618, scale 1:24,000.

Detterman, R. L., Plafker, G., Tysdal, R. B., and Hudson, T., 1976, Geology and surface features along the Castle Mountain fault system, Alaska, U.S. Geol. Survey Misc. Field Studies Map MF-738, scale 1:63,360.

Dickinson, W. R., and Grantz, A., 1968, Proceedings of Conference on Geologic Problems of San Andreas Fault System, Stanford University Publications, p. 377.

Dickinson, W. R., and Seely, D. R., 1979, Structure and Stratigraphy of forearc regions, Amer. Assoc. Petrol. Geol. Bull., v. 63, p. 2-31.

Francheteau, J., Harrison, C. G. A., Sclater, J. G., and Richards, M. L., 1970, Magnetization of Pacific seamounts: A preliminary polar curve for the northeastern Pacific, Jour. Geophys. Research, v. 75, p. 2035-2061.

Grantz, A., 1960a, Generalized geologic map of the Nelchina area, Alaska, showing igneous rocks and larger faults, U.S. Geol. Survey Misc. Inv. Map. I-312, scale 1:48,000.

--- 1960b, Geologic map of the Talkeetna Mountains A-2 quadrangle, Alaska and the contiguous area to the north and northwest, U.S. Geol. Survey Misc. Geol. Inv. Map I-313, scale 1:48,000.

--- 1960c, Geologic map of the Talkeetna Mountains A-1 quadrangle and the south third of the Talkeetna Mountains B-1 quadrangle, Alaska, U.S. Geol. Survey Misc. Geol. Inv. Map I-314, scale 1: 48,000.

--- 1961a, Geologic map and cross sections of the Anchorage D-2 quadrangle and northernmost part of the Anchorage D-3 quadrangle, Alaska, U.S. Geol. Survey Misc. Geol. Inv. Map I-342, scale 1: 48,000.

--- 1961b, Geologic map of the north two-thirds of Anchorage D-1 quadrangle, Alaska, U.S. Geol. Survey Misc. Geol. Inv. Map I-343, scale 1:48,000.

--- 1964, Stratigraphic reconnaissance of the Matanuska Formation in the Matanuska Valley, Alaska, U.S. Geol. Survey Bull. 1181-I, p. 33.

--- 1966, Strike-slip faults in Alaska, U.S. Geol. Survey open-file report, p. 82.

Grow, J. A., and Atwater, T., 1970, Mid-Tertiary tectonic transition in the Aleutian arc, Geol. Soc. America Bull., v. 81, p. 3715-3722.

Hackett, S. W., 1976, Speculative tectonic evolution of the Cenozoic Shelikoff Trough, south-central Alaska, in: Short Notes in Alaskan Geology, 1976, Geologic Report 51, Alaska Div. of Geol. and Geophys. Surveys, p. 13-17.

Hills, E. S., 1963, Elements of Structural Geology, John Wiley & Sons, Inc., p. 483.

Hudson, T., Plafker, G., and Peterman, Z. E., 1979, Paleogene anatexis along the Gulf of Alaska margin, Geology, v. 7, p. 573-577.

Imlay, R. W., 1953, Alaska Peninsula and Cook Inlet regions, pt. 2 of Callovian (Jurassic) ammonites from the United States and Alaska: U.S. Geol. Survey Prof. Paper 249-B, p. 41-108.

--- 1962, Middle Bajocian ammonites from the Cook Inlet region, Alaska, U.S. Geol. Survey Prof. Paper 418-B, p. 14.

Irving, E., 1964, Paleomagnetism and Its Application to Geological and Geophysical Problems, John Wiley & Sons, Inc., p. 399.

--- 1979, Paleopoles and paleolatitudes of North America and speculations about displaced terrains, Canadian Jour. Earth Sci., v. 16, p. 669-694.

Kirschner, C. E., and Lyon, C. A., 1973, Stratigraphic and tectonic development of Cook Inlet petroleum province, in: Arctic Geology, Amer. Assoc. Petrol. Geol. Memoir, 19, p. 397-407.

Marlow, M. S., Scholl, D. W., Buffington, E. C., and Alpha, T. R., 1973, Tectonic history of the central Aleutian Arc., Geol. Soc. America Bull., v. 84, p. 1555-1574.

Martin, G. C., 1926, The Mesozoic stratigraphy of Alaska, U.S. Geol. Survey Bull. 776, p. 493.

Martin, G. C., and Katz, F. J., 1912, Geology and coal fields of the lower Matanuska Valley, Alaska, U.S. Geol. Survey Bull. 500, p. 98.

Packer, D. R., Brogan, G. E., and Stone, D. B., 1975, New data on plate tectonics of Alaska, in: Pavoni, N., and Green, R. (editors), Recent crustal movements, Tectonophysics, 29(1-4), p. 87-102.

Pettijohn, F. J., 1975, Sedimentary Rocks, Harper and Row Publishers.

Pettijohn, F. J., Potter, P. E., Siever, R., 1973, Sand and Sandstone, Springer-Verlag, p. 618.

Stone, D. B., and Packer, D. R., 1979, Paleomagnetic data from the Alaska Peninsula, Geol. Soc. Amer. Bull., part I, v. 90, p. 545-560.

Streckeisen, A., 1979, Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melilitic rocks: Recommendations and suggestions of the IUGS Subcommission on the Systematics of Igneous Rocks, Geology, v. 7, p. 331-335.

Waring, G. A., 1936, Geology of the Anthracite Ridge coal district, Alaska, v. 5, U.S. Survey Bull. 861.

Zijderveld, J. D. A., 1967, A. c. demagnetization of rocks: analysis of results, in: Developments in Solid Earth Geophysics 3, Methods of Paleomagnetism, Elsevier Pub. Co., p. 254-287.

VITA

Name	William A. Fuchs
Birthdate	February 21, 1948
Birthplace	Dayton, Ohio
Degrees	B.S. Geology, 1970, Pennsylvania State University. M.S. Geochemistry, 1972, Pennsylvania State University.
Professional Organizations	Society of Economic Geologist (associate) Geochemical Society Utah Geological Association Alaska Geological Society
Professional Positions	Associate Instructor Department of Geology & Geophysics The University of Utah September 1979 - December 1979
	Geologist Freeport Exploration Company Reno, Nevada January 1974 - July 1976
	Field Geologist Exxon Company Reno, Nevada Summer, 1972
	Field Geologist Cerro Corporation Salt Lake City, Utah Summer, 1971
	Field Geologist Johns-Manville Corporation Montana Summer, 1970

Professional Positions (Continued)

Geological Field Assistant
Amax Exploration Company
Helena, Montana
Summer, 1969

Geological Field Assistant
Precambrian Mining Services, Ltd.
Yellowknife, N.W.T., Canada
Summer, 1968

Publications

Fuchs, W. A., and Rose, A. W., The geochemical behavior of platinum and palladium in the weathering cycle in the Stillwater Complex, Montana: Economic Geology, v. 69, 1974, pp. 332-346.

Fuchs, W. A., Tertiary tectonic history of the Castle Mountain - Caribou fault system in the Talkeetna Mountains, Alaska [Abst.], Geological Society of America Abstracts, 1979 Annual Meeting, San Diego, CA, 1979, p. 429.