

A GEOLOGIC GUIDE TO MOUNT MCKINLEY NATIONAL PARK

By
Wyatt G. Gilbert



Front Cover: Looking west toward Mount McKinley along the McKinley strand of the Denali fault system (black line). Rocks south of the fault are moving west relative to those to the north of the fault. Photo by R. Wilson.

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Alaska Natural History Association
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1979

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For my family

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PREFACE

Alaska is an exciting place for geologists. New concepts about how the continents and ocean basins evolved are now being tested against the slowly emerging record of the rocks in northwestern North America and northeastern Asia. It is the aim of this book to transmit some of this excitement to those who would like to learn a little more about the history of our planet.

Most visitors to Mount McKinley National Park are initially attracted by the park's rich and varied wildlife and the panorama of North America's highest mountain. As one comes to know the park, however, it becomes apparent that the rocks have a complex story of their own to tell. This story includes both ongoing processes which are modifying the earth we live on today and the results of similar processes which took place earlier in the earth's history.

Mount McKinley National Park is part of the Alaska Range, but the Alaska Range is only one segment of an extensive series of mountains, called the North American Cordillera, that covers the western North American continent from Mexico to Alaska (fig. 1). This series of mountains was formed by many geologic processes including plate collision, volcanism, folding, faulting, and uplift. The geologic history of the North American Cordillera is, in fact, the story of the geologic growth of the western part of the continent. The Alaska Range participated in the geologic evolution of the Cordillera, and in the Mount McKinley area the record of this evolution is abundant and strikingly displayed, a condition which makes Mount McKinley National Park an outstanding geologic park.

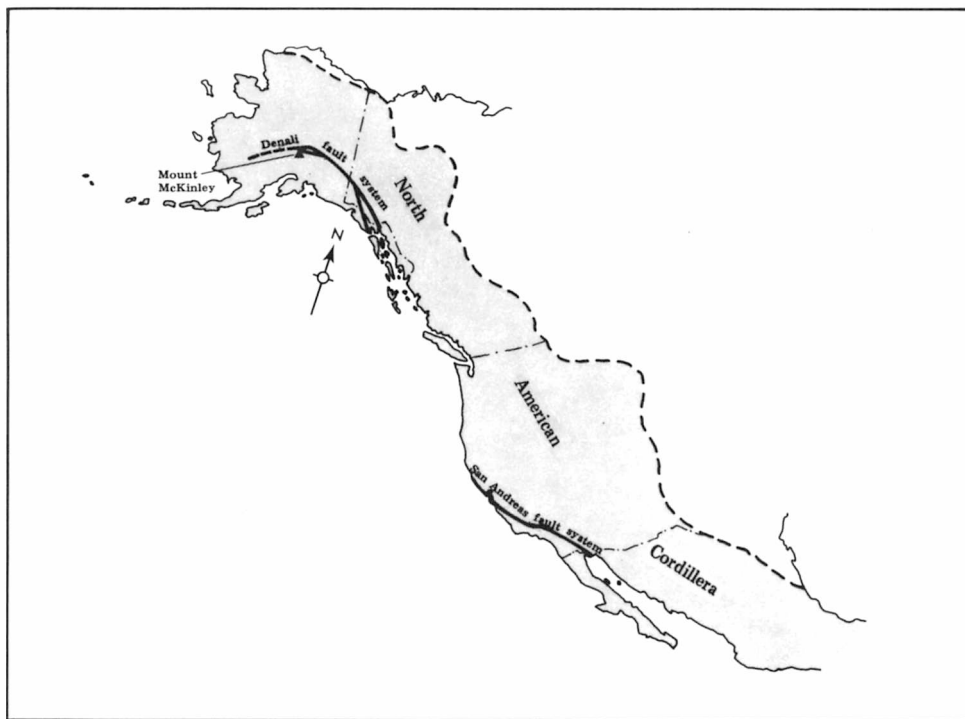


Figure 1. Map of North American Cordillera.

A book such as this, which summarizes information collected during the last three quarters of a century, is necessarily the work of many people. However, special thanks are due the students and faculty of the Geology Department at the University of Alaska. Graduate students and members of the 1972, 1973, and 1974 University of Alaska geology field camps, while adding to their own knowledge of geology, have greatly advanced our understanding of the geologic history of the Mount McKinley region. Likewise, the support and encouragement from my colleagues in the State of Alaska Division of Geological and Geophysical Surveys and the information provided by the Division's geologic programs in recent years have been critical to the ideas contained in this book.

I am grateful to John Decker, Earl Redman, Thomas Bundtzen, Donald Triplehorn, Bruce Reed, Virginia Ferrell, Thomas Smith, Steve Hackett, and Richard Reger, who have added to recent knowledge of the geology of the central Alaska Range and who have taken part in many stimulating discussions of Alaska Range geology over the years.

The staff at Mount McKinley National Park have all been extremely helpful during our geologic studies in the park, and I especially appreciate the assistance of Henry C. Warren, who shared my initial enthusiasm for this guide.

I also thank Marvin A. Pistrang, who reviewed and edited the manuscript, and Roberta Mann and Greg Laird, who assisted in typing and drafting.

Wyatt G. Gilbert
Fairbanks, Alaska
May, 1979

INTRODUCTION

Pioneer Geologists

Today's understanding of the geology of the Mount McKinley region results from the work of numerous geologists who have attempted to puzzle out the area's geologic history. The first major attempt to learn about the geology of the park area was the pioneer effort of Alfred H. Brooks during the summer of 1902. Brooks' party included seven men, one of whom was another geologist, L.M. Prindle. The party landed at Tyonek on the western shore of Cook Inlet on the second of June, and then, with many difficulties, ascended the Yentna River and its tributary, the Kichatna River, and crossed the Alaska Range through Rainy Pass on July 15. On July 29 the party reached the Tonzona River, and on August 3 and 4 it camped at Slippery Creek, 24 kilometers northwest of the summit of Mount McKinley. The party reached the Nenana River on August 16. The present park road between the Nenana and Teklanika rivers parallels part of the expedition's route, but most of the country through which the expedition passed is nearly as wild today as it was 75 years ago. (Part of the route of the Brooks party through Mount McKinley National Park is shown on the geologic map.)

Another U.S. Geological Survey geologist, Stephen R. Capps, made perhaps the largest contribution to the geologic understanding of the Mount McKinley area until recently. Parties under Capps' direction mapped the geology between the Nenana River and Kantishna Hills during the summers of 1916 and 1926. Reports based on this work served as the basis of geologic knowledge in the Mount McKinley region for many years. Since Capps' investigations, work by U.S. Geological Survey geologists John C. Reed, John C. Reed, Jr., Clyde Wahrhaftig, and Bruce Reed, and recent studies by myself, Robert Hickman, and Thomas K. Bundtzen, among others, have contributed substantial new knowledge about the geology of the Mount McKinley National Park area.

No mention of early geologic studies of the park can ignore the role played by the prospectors and miners of the Kantishna mining district. George Wickersham first discovered gold in Chitsia Creek in the northern Kantishna Hills during his 1903 expedition to Mount McKinley, and in 1904 and 1905 rich placer gold deposits were found by Joe Quigley and Joe Dalton in the southern Kantishna Hills. During the summer of 1905 there was a gold rush to the Kantishna Hills, and in 1906, L.M. Prindle, who had accompanied Brooks, carried out geologic studies of the Kantishna district. Small-scale mining in the Kantishna district continues today.¹

Some General Concepts

The non-geologist is often confused by the multitude of terms used by earth scientists to describe rocks and geologic processes, and the central Alaska Range has such geologic variety that we can only touch on a few of them. But some understanding of the rocks that are all around us and of the general geologic conditions that build up, deform, or wear

¹ A good summary by T.K. Bundtzen of mining in the Kantishna district is listed in the references on p. 47.

away the land is important. Many kinds of rocks are present in Mount McKinley National Park, but geologists generally group them into three main categories: *igneous* rocks, *sedimentary* rocks, and *metamorphic* rocks. These categories are based on the main processes that cause rocks to form. Igneous rocks are formed by cooling and crystallization of molten material called *magma* both above and below the earth's surface. Igneous rocks are found in many places in the Alaska Range and include both *volcanic* rocks, such as basalt, which occur when magma rapidly cools and solidifies into rock on the earth's surface, and *plutonic* rocks, such as granite, which are formed by slow cooling and gradual solidification of magma insulated deep within the earth. Sedimentary rocks largely result from the consolidation of loose rock material on the earth's surface. There are many types of sedimentary rocks, including *conglomerate*, *sandstone*, and *shale*, which are the result of the burial and compaction of gravel, sand, and mud, respectively. *Limestone*, another sedimentary rock, can form either by the consolidation of the hard parts of marine organisms, or by chemical precipitation. Metamorphic rocks are made from pre-existing rocks that have been affected by high temperatures and pressures deep within the earth. The Mount McKinley area contains several kinds of metamorphic rocks such as *schist*, *slate*, *quartzite*, and *marble*, all produced by transformation of older rocks.

When we look at rocks in the Alaska Range, we can see that some are tilted, broken, or bent. *Faults*, which are fractures of the earth along which opposite sides have moved relative to one another, and *folds*, which occur when rocks are bent but not broken, are the result of such deformation. *Uplift* of the earth's crust is a process that sometimes accompanies faulting and folding. Thus, rocks commonly move from the places where they originated, and many rocks which were once deep below the surface of earth are seen at the surface today. As segments of the crust rise, however, land is simultaneously worn away by *erosion*. Running water is the dominant agent of the erosion, but it is assisted by downslope movement of rocks and soil by gravity and, in some areas, by the action of glaciers. Erosion is rapid, and we have high mountains today only because forces within the earth have raised segments of the earth's crust within the last ten or fifteen million years.

Ten or fifteen million years may seem like a long time, but the last ten or fifteen million years is only a brief episode in the earth's 4.5 billion (4,500 million) year history. Geologists have devised their own way to measure this long period of time (fig. 2). When speaking of age, however, we should always remember that whereas the age of high mountains is generally very young, the age of formation of the rocks that comprise those same mountains may be very much older.

How To Use This Book ---

This book is divided into two parts. Part I outlines the geologic history of Mount McKinley National Park. You should study the geologic map in the folder at the back of the book while reading this section.

Part II includes guides to help you enjoy points of geologic interest at close range. There is a road guide which will help you understand what you are seeing from your car or the park transportation system. But even more important are several geologic hikes that you can make away from the park road. Please note that although you will see much interesting geology in the park, you must not collect any rocks or specimens. Collecting is prohibited without a special permit, in order to preserve the park's geologic features for everyone.

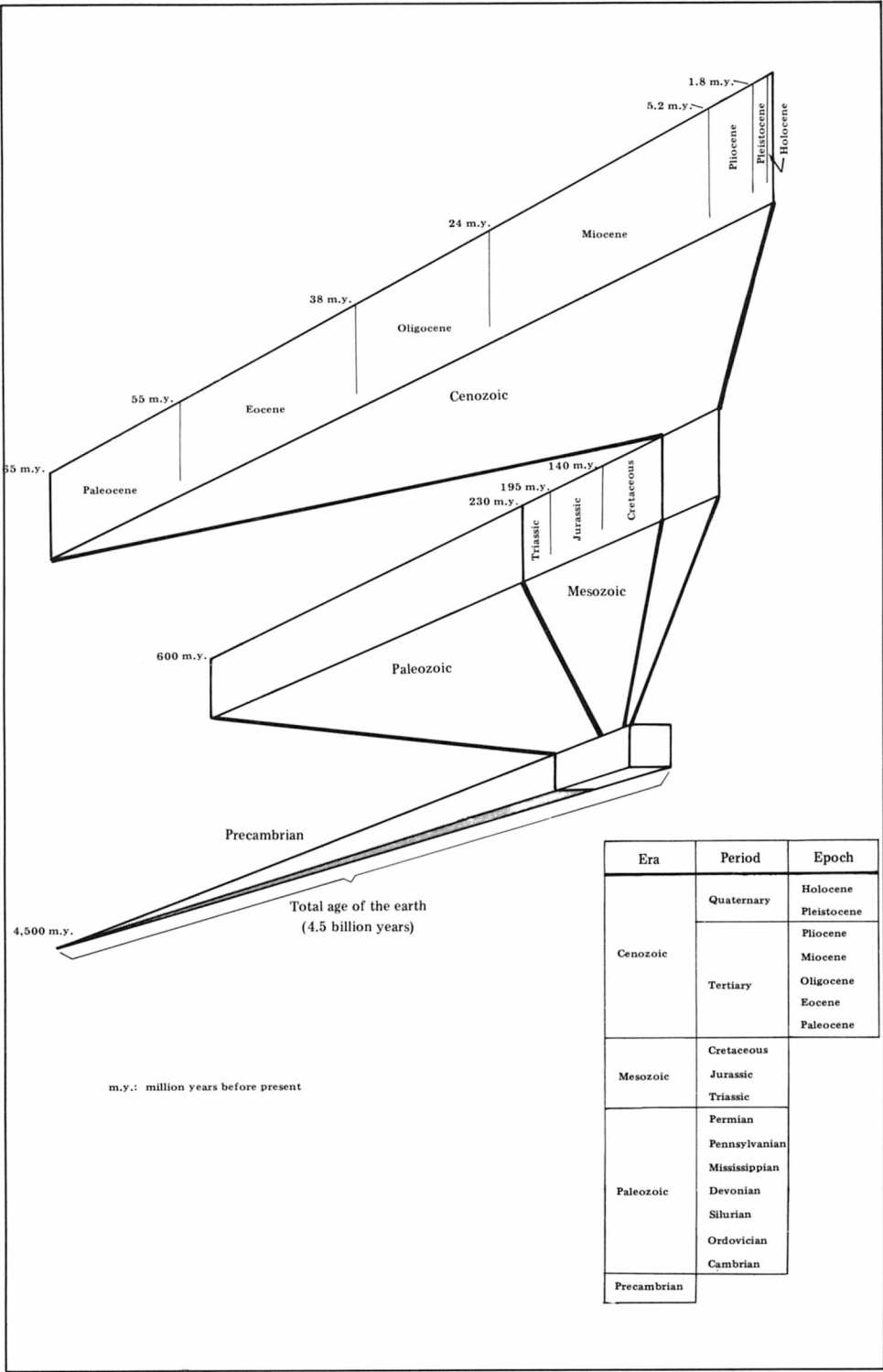


Figure 2. The geologic scale of time.

NOTES

PART I

GEOLOGIC EVOLUTION OF MOUNT MCKINLEY NATIONAL PARK

Metamorphic Rocks — Clues To Ancient Ages _____

The geology of Mount McKinley National Park is divided into two parts by the *Hines Creek fault*. Within the park this major fault can be traced westward from the Nenana River, near park headquarters, to just south of the Kantishna Hills, where its trace south-westward is uncertain (fig. 3 and geologic map). The rocks north of the fault are a part of the ancient northwestern North American continent, but, as we shall see later, the rocks south of the fault may have moved great distances before arriving at their present location.



Figure 3. View west across the Teklanika River. YCT = Yukon Crystalline Terrane, HCF = Hines Creek fault, F = fault, ms = Triassic marble and slate, ss = Cretaceous sandstone and shale.

The oldest rocks in the Mount McKinley region are found north of the Hines Creek fault. These rocks are predominantly mica-quartz schist, quartzite, metamorphosed volcanic rocks, and marble which were formed from sedimentary and volcanic rocks deposited 350 million to 1.0 billion years ago. They make up most of the outer ranges of the park and are clearly displayed on Mount Healy, Mount Wright, and in the Wyoming Hills and the Kantishna Hills. If you examine these old rocks carefully, in many places you will observe both early-formed metamorphic layering and later-formed folds with closely-spaced dislocations (*cleavage*) (fig. 4). A good place to see these metamorphic features is on Mount Healy or in the canyon north of the Savage River bridge.

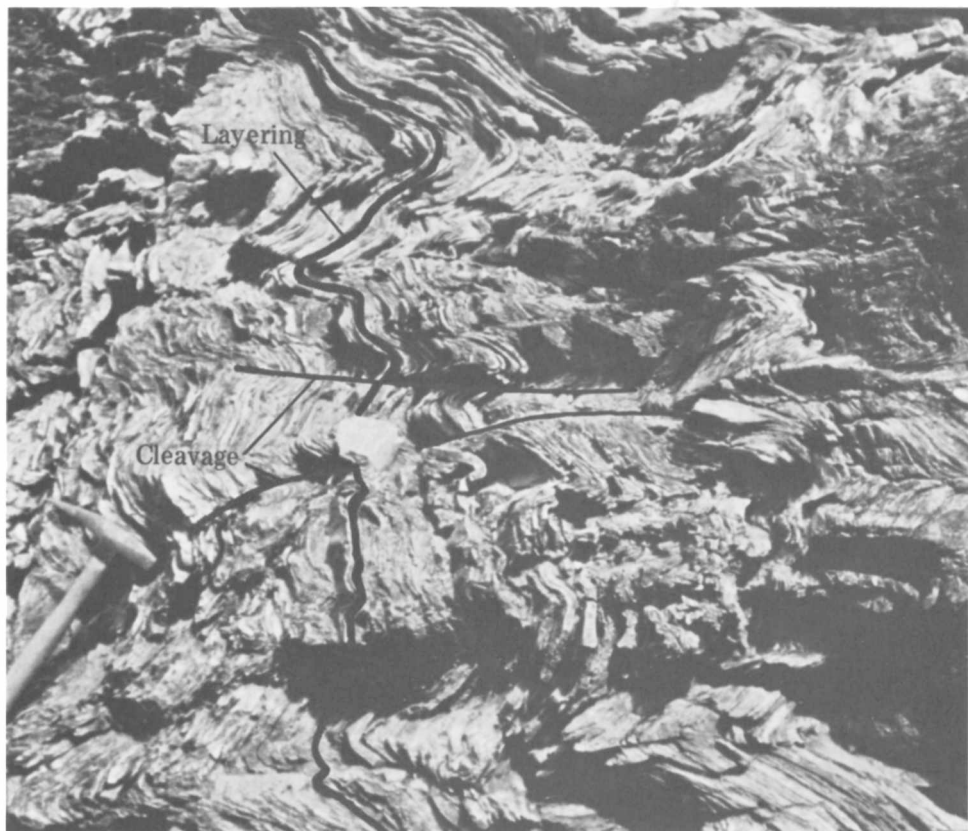


Figure 4. Mica-quartz schist of Yukon Crystalline Terrane. Earlier metamorphic layering (vertical) is folded, and cut by cleavage (horizontal).

These ancient rocks are not unique to Mount McKinley National Park. In fact, they are the southernmost edge of an area of similar rocks, the *Yukon Crystalline Terrane*, which extends north to the Brooks Range and east into Canada. The hills around the city of Fairbanks, 140 kilometers northeast of the park, are also made up of the same kind of rocks.

What do these very old rocks tell us about the geologic history of Alaska? First, they indicate that beginning about one billion years ago quartz-rich sand and mud began to be eroded from the ancient North American continent and deposited in a shallow sea. Later, during the Devonian Period (395-345 million years ago) volcanoes erupted on the sea floor and poured out lava which mixed with the quartz-rich sediments. In shallow

areas marine animals, such as corals, grew abundantly and contributed their shells to deposits of limy mud, which became limestone. After the Devonian Period high temperatures, pressures, and folding deformed and metamorphosed these sediments and volcanic rocks at least two times (fig.4). The original quartz-rich sands were altered to very hard *quartzite*, and the quartz-rich mud and volcanic rocks were converted to mica-quartz schists. Former beds of limestone were metamorphosed into marble, within which paleontologists can still identify the *fossil* remains of the marine animals which lived 350 to 400 million years ago. These old rocks became part of the ancient northwestern North American continent against which other groups of rocks were faulted and on which many younger rocks were deposited.

South of the Hines Creek fault is another belt of old metamorphic rocks, ranging in age from 80 to 400 million years old. These rocks were probably not originally part of the northwestern North American continent but were derived from material deposited elsewhere in deep ocean basins. Indeed, it is possible that some of the rocks in the major metamorphic belt south of the Hines Creek fault originated thousands of kilometers away from their present location. The southern belt of the metamorphic rocks contains three major groups of rocks, but the original location of the ocean basins where these groups formed and the relationship of the three groups of rocks to each other is unclear. They may have originally been part of the same ocean basin, or they may have formed in three separate ocean basins.



Figure 5. View west across Toklat River. Park road at right. Triassic basalt (**Rv**) rests on top of upper Paleozoic slate (**Pzs**).

One group of metamorphic rocks south of the Hines Creek fault contains gray slate, marble, dark, iron-rich plutonic rocks (*gabbro*), and dark, iron-rich volcanic rocks (*basalt*). This group of rocks is present along the crest of the Alaska Range between Windy Pass and Mount McKinley, but can also be observed near the park road between the Toklat River and Eielson Visitor Center (fig. 5). From these rocks we know that during the last half of the Paleozoic Era mud, sand, and fossil debris collected in a deep ocean basin. Then, during the Permian and Triassic periods, deformation of this basin generated



Figure 6. Bulbous pillow basalt south of park road between Toklat River and Stony Creek. Photo by J. Buza.

fissures which allowed molten magma to rise. This magma crystallized into gabbro at depth, or flowed out over the ocean floor where it formed basalt (fig. 6). Both the sediments and igneous rocks were later buried, and a slight increase in temperature and pressure converted the sediments to *slate* and fossiliferous marble.

The second group of metamorphic rocks south of the Hines Creek fault consists of interbedded marble and slate 195 to 230 million years old. These rocks are present in a narrow band that extends from the Savage River to Stony Creek (fig. 3). The alternating beds of marble and slate are due to sea level changes in a broad ocean basin. These changes resulted in the interfingering of shallow-sea deposits of limestone and deeper-sea deposits of silt and mud. These deposits were buried and weakly metamorphosed, converting the silt and mud to slate and the limestone to marble (fig. 7), and in some areas they have been intruded by gabbro.

A third group of metamorphic rocks south of the Hines Creek fault is made up of very weakly metamorphosed marine sandstone and shale and is now present in a band lying geographically between the two groups of metamorphic rocks just described. Although the age of the sandstone and shale is uncertain, they were probably deposited in a deep ocean basin, buried, and then weakly metamorphosed and locally intruded by gabbro during the Cretaceous Period (140-65 million years ago). Similar rocks are also present in the Alaska Range just south and east of Mount McKinley.

The origin and history of each of the three groups of metamorphic rocks outlined above are puzzling problems now being studied by Alaskan geologists. However, the importance of the Hines Creek fault as a boundary between two metamorphic belts with very different geology is now widely recognized.

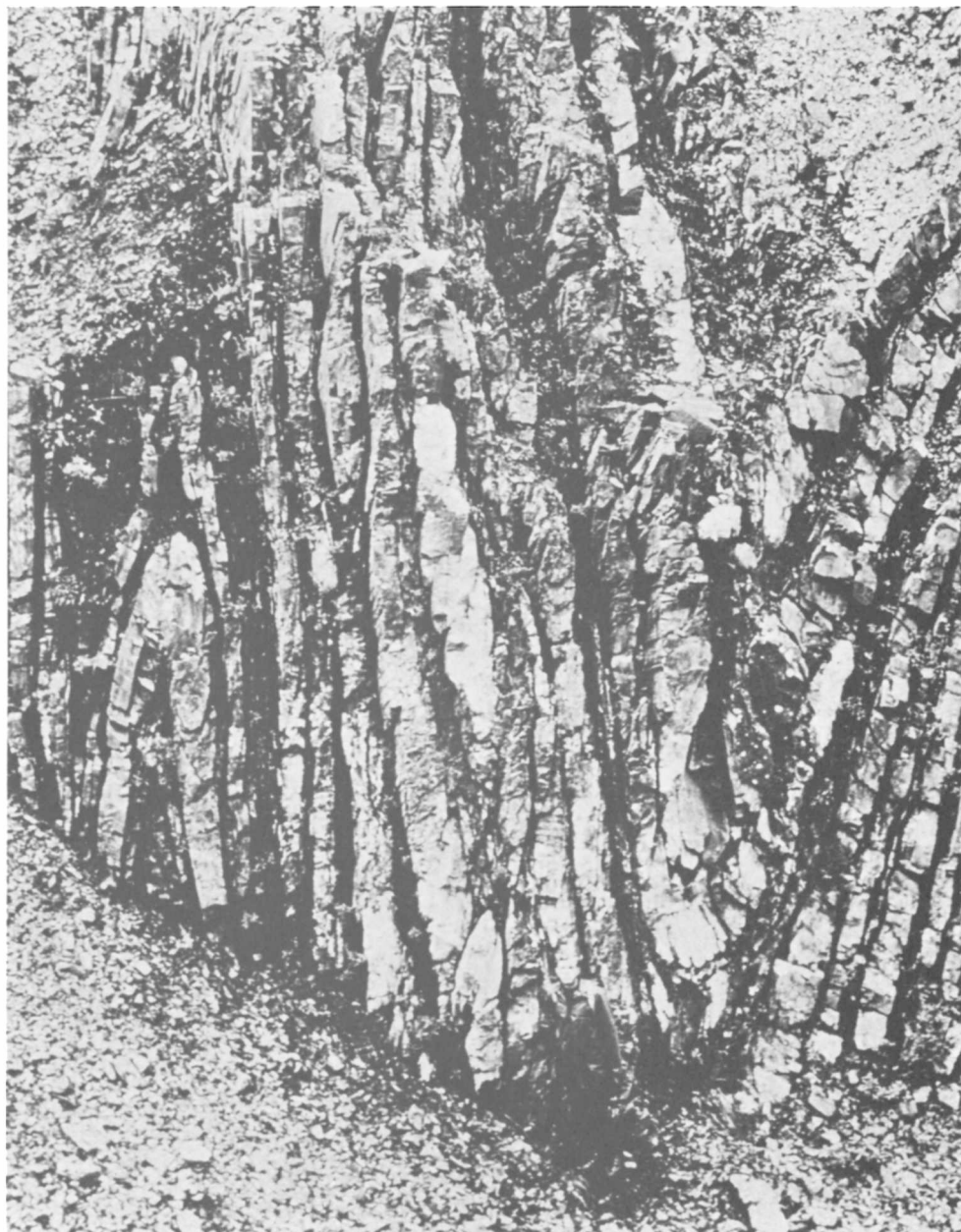
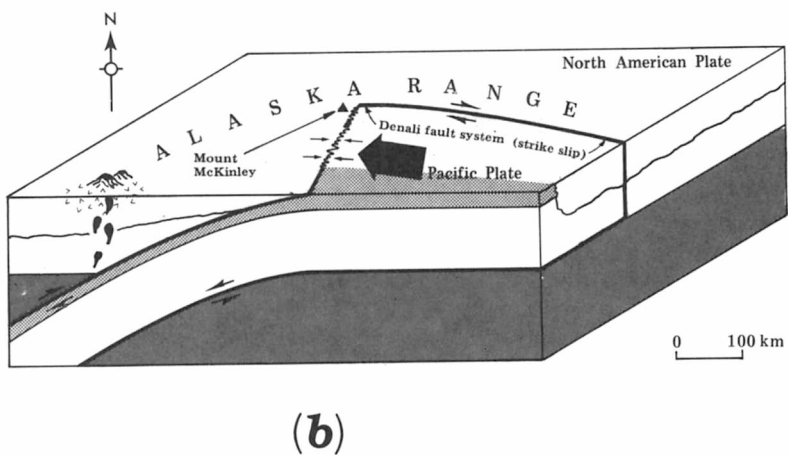
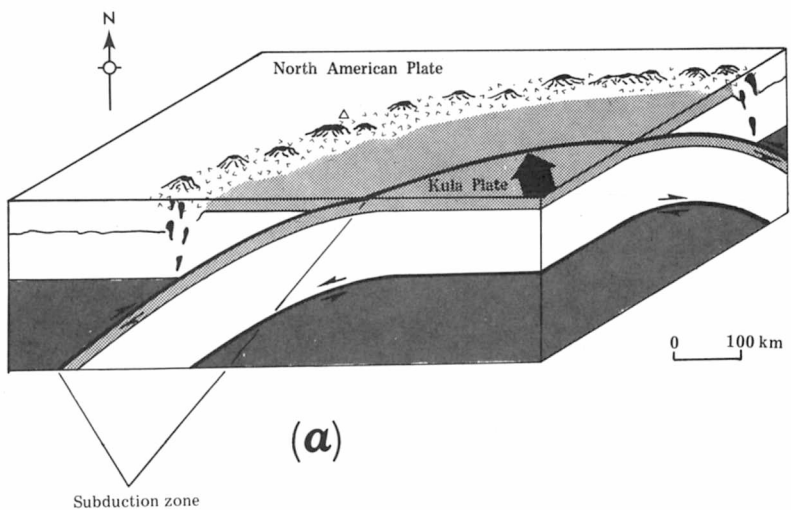


Figure 7. Folded slate (dark) and marble (light) in Wyoming Hills. Photo by E. Redman.



Continental crust (granitic)

Volcanic-plutonic arc
(and metamorphism)

Magma

Oceanic crust (basaltic)

Upper mantle

Lower mantle

Plate boundary

Figure 8. Plate movements during a) late Mesozoic-early Cenozoic (Δ = future site of Mount McKinley), b) late Cenozoic.

Late Mesozoic-Early Cenozoic

Orogeny: The Meeting Of Plates

The previous section characterized the two dissimilar belts of old metamorphic rocks presently lying next to one another on either side of the Hines Creek fault. Yet these two belts may have originated far apart. How do such large masses of rock move about? Today we know that about the upper 100 kilometers of the earth, including the crust and upper mantle, are partially decoupled from the lower mantle and core. This outer "rind" of the earth is broken into a number of separate *plates*, which may move toward, away from, or parallel to other plates (fig. 8). Geologists call the processes involved in such plate movements *plate tectonics*. In some areas plates are separating and molten material is rising up between them (some of the Paleozoic and Mesozoic basalt and gabbro mentioned earlier may be the result of such a separation). In other areas plates are sliding past one another parallel to the earth's surface along long, *strike-slip faults*. In some places plates are moving toward one another. Where plates are converging, one plate generally dives under the other along a *subduction zone* and is destroyed (fig. 8). The two dissimilar metamorphic belts in the central Alaska Range were probably brought together by a combination of plate movements, and the Hines Creek fault may represent a boundary where two plates met.

The convergence of two plates generally causes the overriding plate to be deformed by folding, metamorphism, faulting, plutonism, volcanism, and uplift. The sum total of all of these deforming actions is called *orogeny*. Central and southern Alaska were affected by extensive orogeny during the late Mesozoic Era (Cretaceous Period) and the early part of the Cenozoic Era as the *Kula Plate* collided with the *North American plate* (fig. 8a).



Figure 9. Contact between 60 million year old granite (gr) and Cretaceous sedimentary rocks on north peak of Mount McKinley. Photo by R. Wilson.

As one plate descends beneath another, heating often causes the more volatile part of the crust and mantle to melt and rise through the overriding plate (fig.8). In the Mount McKinley region, great volumes of igneous rocks were produced about 60 and 38 million years ago. Mount McKinley is partly made up of light-colored plutonic rock called *granite*, about 60 million years old (fig. 9). Mount Foraker and Mount Eielson (fig. 10) are made up of granite about 38 million years old.² These plutonic rocks were probably formed in

²The age of igneous and metamorphic rocks is determined by studying the trace amounts radioactive isotopes present in these rocks, in particular, the ratio of parent isotopes to daughter isotopes.



Figure 10. Mount Eielson, composed of granite 38 million years old.

the overriding plate above subduction zones during late Mesozoic-early Cenozoic time and during the middle of the Cenozoic Era. In addition, some igneous material reached the earth's surface. *Rhyolite*, a volcanic rock with the same composition as granite, together with basalt poured out over the landscape about 60 million years ago. These volcanic rocks now make up the striking volcanic flows of the *Teklanika Formation* along Calico Creek, at Polychrome Pass (fig. 11), and on Cathedral and Igloo Mountains. *Andesite* (volcanic rock intermediate in composition between rhyolite and basalt) of the *Mount Galen Volcanics* (about 38 million years old) is still preserved along the upper part of

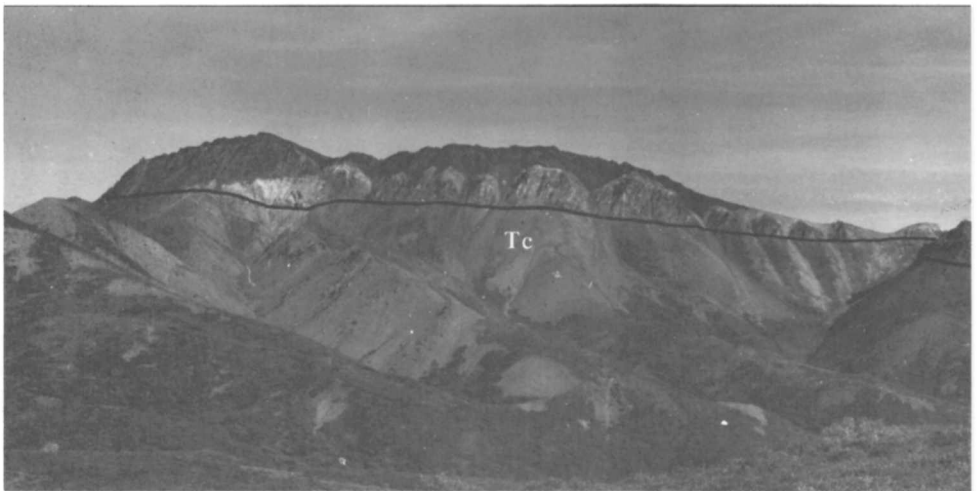


Figure 11. East end of Polychrome Mountain with basalt (dark) and rhyolite (light) of the Teklanika Formation (60 million years old) resting on sandstone and conglomerate of the Cantwell Formation (Tc) (65-60 million years old).

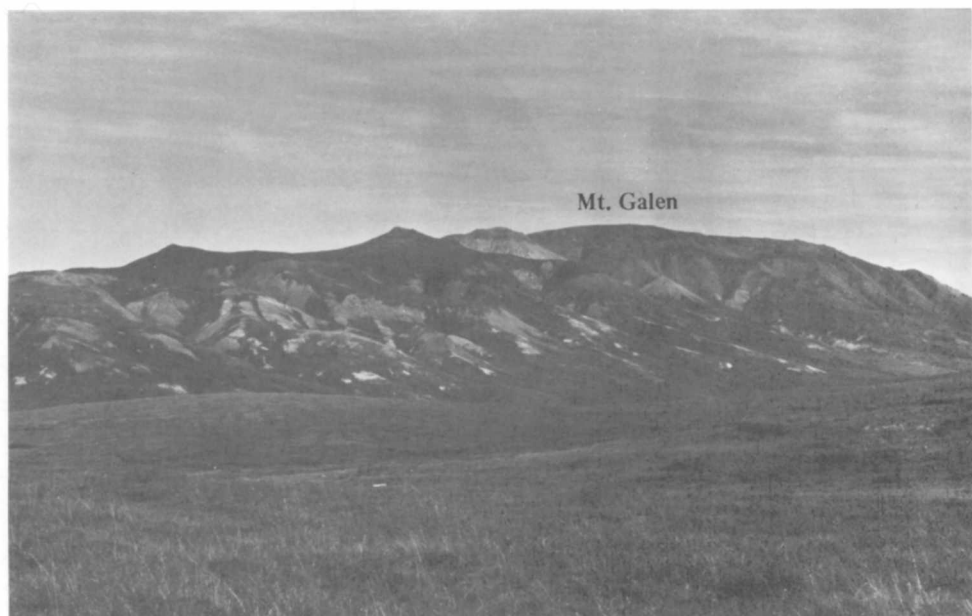


Figure 12. Looking north across upper Moose Creek with andesites of the Mount Galen Volcanics (38 million years old) forming the ridge and summit of Mount Galen.

Moose Creek and Stony Creek (fig. 12), and south of Thorofare Pass. Metamorphism generally accompanies widespread, igneous activity, and the metamorphism of the major metamorphic belts north and south of the Hines Creek fault probably occurred in response to the heating and deformation accompanying the convergence of plates (fig. 8).

During orogeny the earth's crust may be uplifted. About 65 million years ago, the land began to rise in the northern part of the Mount McKinley region. Much of the rest of the park area was a large continental lowland, similar to the area north of the Alaska Range today. South-flowing rivers and streams meandered across this lowland depositing gravel, sand, and silt (fig. 13a). As the earth slowly rose further south, streams began to flow northward (fig. 13b). During the final stages of the uplift, volcanic lava hardening to rocks of the Teklanika Formation poured out from fissures and volcanoes, burying the gravel, sand, and silt and turning them into the conglomerate, sandstone, and shale of the *Cantwell Formation*. But that was not all. Compressive forces as the result of continued plate convergence severely tilted and folded these rocks so that today folded conglomerate, sandstone, and shale of the Cantwell Formation are preserved along and near the park road between park headquarters and the Kantishna Hills (fig. 14).

The collision of plates probably brought together the main elements of northern and southern Alaska, and Mount McKinley National Park has certainly had a very different geologic history than areas such as Grand Canyon National Park and Dinosaur National Monument with their relatively undisturbed, "layer cake" geology. During a geologically short period of time at the end of the Mesozoic Era and the beginning of the Cenozoic Era, intense geologic activity associated with plate convergence produced the many different kinds of rocks and geologic structures which are seen today throughout Mount McKinley National Park.

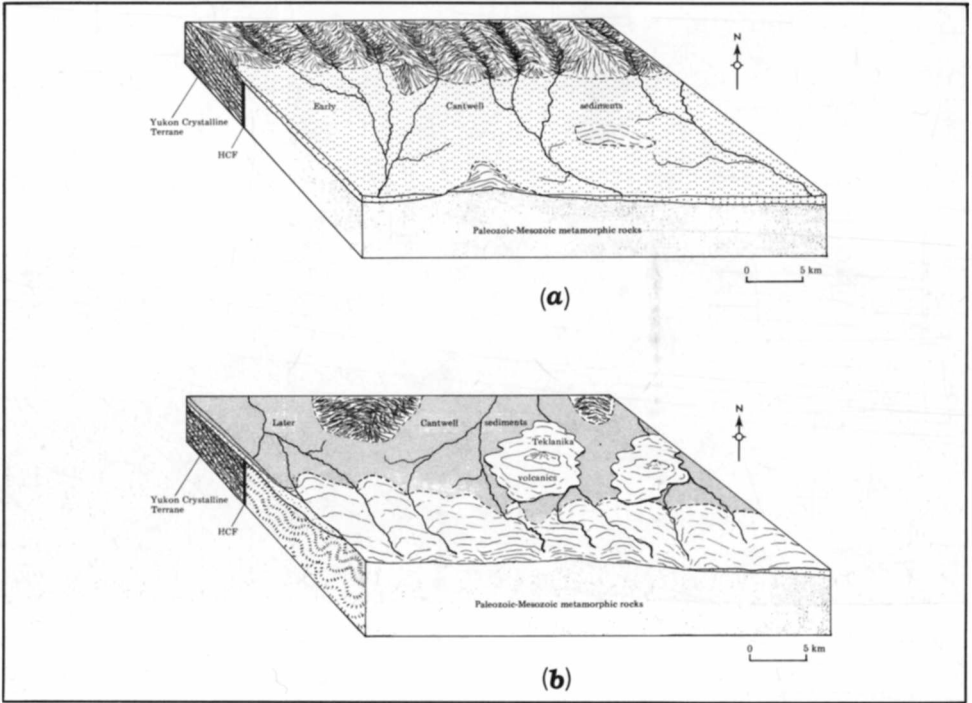


Figure 13. Early Cenozoic continental sedimentation, volcanism, and folding in north-eastern Mount McKinley National Park between 60 and 65 million years ago. (a) Early uplift to the north shed quartz-rich sand and gravel to the south. (b) Later uplift and folding to the south shed sand and gravel to the north. HCF = Hines Creek fault.



Figure 14. Anticline in Cantwell Formation along East Fork River.

Late Cenozoic —

Blocking Out Today's Ranges

By the middle of the Cenozoic Era, the Kula Plate had disappeared and the movement between the plates which make up southern and northern Alaska shifted direction from approximately north-south to approximately east-west (fig. 8). As a consequence, compressive forces waned in the central Alaska Range northeast of Mount McKinley, and during the last half of the Cenozoic Era (the last 30 million years) this area has been broken into many segments along steeply-inclined faults (fig. 15). Many segments have been tilted, some segments have subsided, and other segments have risen. This *block faulting* has continued to the present day.



Figure 15. South side of Sable Mountain and late Cenozoic fault dividing sandstone and shale of the Cantwell Formation (dark) from rhyolite of the Teklanika Formation (light). The Teklanika Formation has been faulted down relative to the Cantwell Formation.

A further consequence of the change in relative plate motion between northern and southern Alaska is that the boundary between the two plates has shifted south from the Hines Creek fault to form the *McKinley strand* of the *Denali fault system* (The Hines Creek fault is the presently inactive, northern strand of the Denali fault system). The McKinley strand exhibits strike-slip movement, similar to the San Andreas fault in California, and is only part of the larger Denali fault system, which extends from southeastern Alaska to Mount McKinley and, perhaps, to the Bering Sea (fig. 1). The McKinley strand enters Mount McKinley National Park near Cantwell and trends eastward to Anderson Pass (front cover). West of Anderson Pass its trace is marked by the middle part of the Muldrow Glacier (see geologic map). The fault then crosses Gunsight Pass and continues along the north side of Mount McKinley. Although the McKinley strand primarily has had a strike-slip history, it locally displays vertical offset. (The Wickersham Wall on the northwest side of Mount McKinley reflects recent movement upward on the south side of the McKinley strand.) The fault is active today, and because the rocks in the fault zone are crushed, pulverized, and easily eroded, the trace of the McKinley strand is generally marked by an easily recognizable, linear, topographic depression.

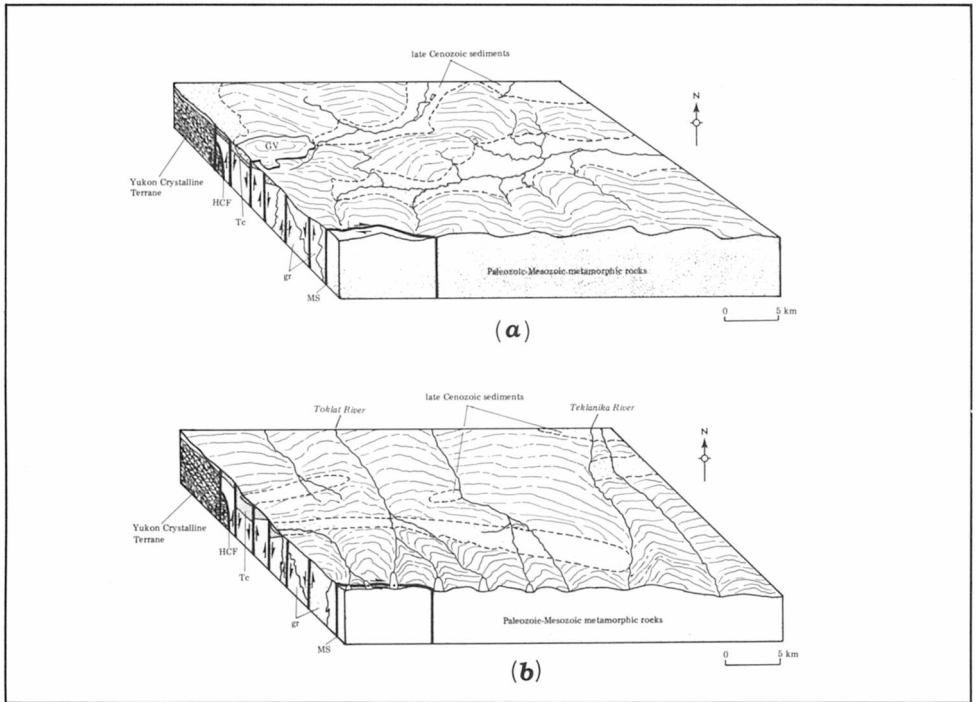


Figure 16. Late Cenozoic block faulting and uplift in northeastern Mount McKinley National Park. (a) Mud, sand, gravel, and plant material accumulate in down-faulted continental basins. (b) Continued uplift and modern streams now flow north at right angle to block faulted lowlands. HCF = Hines Creek fault. MS = McKinley Strand; GV = Mount Galen Volcanics; TC = Cantwell Formation; gr = granite rocks.

As the Alaska Range rose and broke into a series of blocks, erosion of older rocks shed sediments into several downfaulted inland basins (fig. 16). The record of this sedimentation is preserved in the *Coal-bearing Group* of late Oligocene-Miocene age (30 to 5 million years ago). The Coal-bearing Group contains evidence of prolific forests and is the result of the deposition of sand and gravel by streams, of mud in lakes, and of plant material in swamps. Burial and compaction have transformed these sediments into easily eroded conglomerate, sandstone, shale, and coal (fig. 17). The large coal field near Healy is part of the Coal-bearing Group, and coal was once mined from a coal seam in similar rocks between Sable Pass and the East Fork River. During the Pliocene Epoch (5 to 2 million years ago) further uplift of the Alaska Range shed sand and gravel into downfaulted basins within the range and out onto the lowland to the north, producing the poorly consolidated sandstone and conglomerate of the *Nenana Gravel* (fig. 18).

There is a break in the rock record of many millions of years between the late Cenozoic sedimentary rocks and the metamorphic rocks and folded Cantwell Formation on which they were deposited. The eroded surface of older rocks on which much younger rocks are deposited is called an *unconformity*. The smooth, flat-topped summits of Mount Wright and Mount Margaret near the Sanctuary River may mark the unconformity, from which the younger sedimentary rocks recently have been removed by erosion.

By the end of the Pliocene Epoch, erosion had reduced the Alaska Range to a series



Figure 17. Conglomerate of late Cenozoic Coal-bearing Group near Sable Pass containing fossil tree trunk.



Figure 18. Easily-eroded Pliocene Nenana Gravel (light) underlying the lowland near Highway Pass has been faulted down relative to the Paleozoic slate and Triassic basalt on the high ridge to the north.

of low hills containing a few high mountains, such as Mount McKinley, which may have been about 3,000 meters (10,000 feet) high. However, the present course of the Nenana River, which now originates on the south side of the range and flows through it to the north, was probably already established. During the Pleistocene Epoch (beginning about 2 million years ago) the Alaska Range again began to rise, especially in the south, causing most major streams of the central Alaska Range to flow northward. The Nenana River apparently was able to keep cutting its channel through the range at a rate which was at least equal to the rate of uplift. Uplift and wearing down of the Alaska Range is continuing today, and it is possible that the sand and gravel you see along the rivers in Mount McKinley National Park may someday be converted into sandstone and conglomerate.

Why Is Mount McKinley So High? _____

This question intrigues geologists as well as most visitors to Mount McKinley National Park. Part of the answer lies in the normal uplift of areas that have experienced orogeny and have been intruded by relatively lightweight granitic rocks. But part of the answer to this question may involve a change in the direction of the plate boundary near Mount McKinley. From studies of earthquakes many geologists now believe that east of Mount McKinley the main plate boundary between northern (and western) Alaska and southern Alaska is marked by the McKinley strand of the Denali fault system, but that near Mount McKinley this boundary turns southward (fig. 8b). If the rocks southeast of Mount McKinley (*Pacific plate*) are now moving west along the McKinley strand relative to northern and western Alaska (*North American plate*) they must be pushed against or under western Alaska. Because the Alaska Range just south of the McKinley strand is composed of a thick series of relatively lightweight igneous and metamorphic rocks, the Pacific plate is unable to sink beneath the North American plate. Instead, its movement tends to shove the region of Mount McKinley upward (fig. 8).

Glaciers — The Mighty Sculptors _____

The visitor to Mount McKinley National Park is often impressed by the sight of *glaciers* partially filling valleys in the heart of the central Alaska Range. At high elevations the accumulation of winter snow exceeds the amount that melts in the summer, and permanent snowfields develop. As the snow thickens it is converted to glacier ice, which deforms plastically and flows downhill. Glaciers now occupy the uppermost parts of most of the major river drainages, and since the Alaska Range intercepts moisture-laden air moving north from the Gulf of Alaska, the most extensive glacier systems lie south of the crest of the range. For example, the Kahiltna Glacier system on the south side of the range is nearly 64 kilometers long.

The park visitor, however, may not realize that the place where he views glaciers at a distance was probably once buried by ice, possibly several times. During the late 1940's and early 1950's a U.S. Geological Survey geologist, Clyde Wahrhaftig, first unravelled the glacial history of the Mount McKinley area. His studies show that there were at least four major episodes of glaciation in the Mount McKinley region, the oldest taking place two to three million years ago. At that time the Alaska Range was a series of low, rolling hills with a group of moderate-sized mountains near Mount McKinley and also near Mount Hayes, 110 kilometers east of the park. Climatic changes during the late Pliocene

The evidence for glaciation in Mount McKinley National Park is visible if you look for it. One sign of glacial activity is the shape of the mountain valleys. As streams cut down they often erode a **V-shaped valley** (fig. 20a). When ice flows down such a valley, it carries a great amount of rock debris with it and scours the valley sides and floor, forming a **U-shaped valley** (fig. 20b). The upper valleys of the Savage, Sanctuary, and Teklanika rivers are **U-shaped**, and the rivers flowing in them seem too small, or *underfit*, compared to the width of the valley. In contrast the lower valleys of these streams are **V-shaped**, indicating that during the last two glaciations, when the Alaska Range was rising to near its present height, glaciers did not extend farther north than the approximate location of the park road.

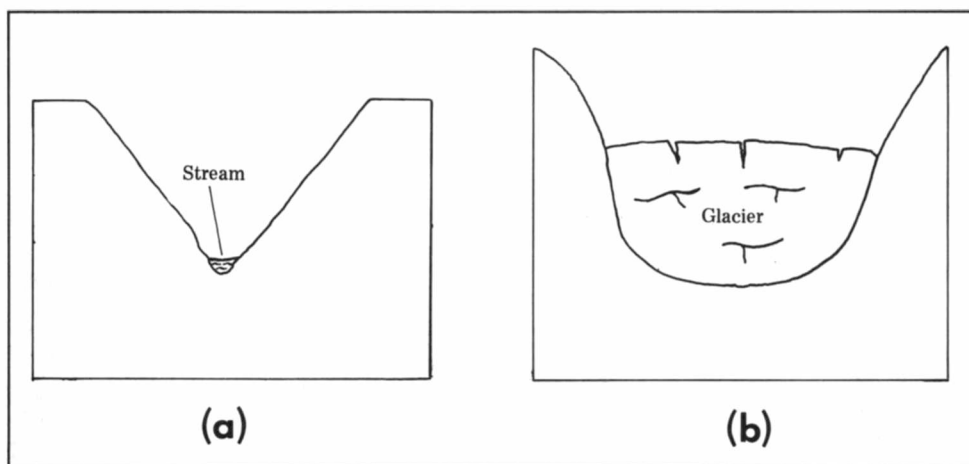


Figure 20. **V-shaped valleys** cut by streams (a) became **U-shaped** from scouring by glaciers (b).



Figure 21. Looking south along Fairbanks-Anchorage highway from park entrance. Light-colored roadcuts are glacial moraines deposited by the Riley Creek Glaciation.

Another indication of glacial activity is the presence of *glacial till*, or the deposits left by glaciers after they have retreated. By mapping the location of glacial till, it may be possible to reconstruct the shape of *glacial moraines*, the mounds of glacial material deposited at the front or along the sides of the glaciers (fig. 21). The glacial moraines just south of the park road along the Savage, Sanctuary, and Teklanika rivers are further evidence that glaciers did not extend farther north during the last two glaciations (fig. 19). Three kilometers south of park headquarters a remnant boulder (*glacial erratic*) left by the Browne Glaciation rests on a hillside at an elevation of 1,040 meters (3,400 feet). A similar erratic rests at 1,280 meters (4,200 feet) on the summit of Mount Fellows (fig. 22).



Figure 22. Granitic glacial erratic on summit of Mount Fellows, 3 kilometers east of park entrance.

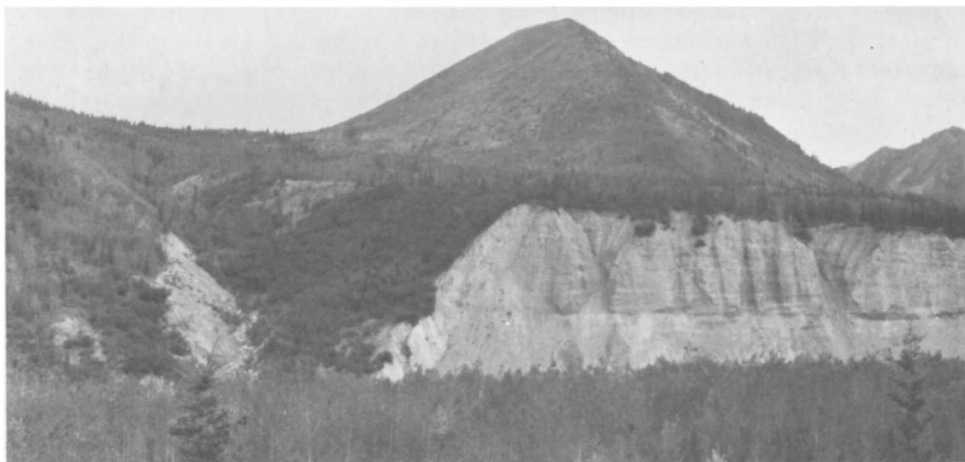


Figure 23. Bluffs along east side of the Nenana River near the park entrance exposing glacial outwash deposited by Nenana River during the Riley Creek Glaciation.

The streams that flowed from the glaciers during the Pleistocene Epoch carried enormous amounts of silt, sand, and gravel and deposited this material as *glacial outwash* downstream from the glaciers. Today this glacial outwash forms terraces and bluffs along the lower portions of many of the park's river valleys (fig. 23). Now that glaciers have withdrawn to the heads of many of the valleys, sediment carried by today's underfit streams is being deposited in the upper parts of the valleys, which are slowly filling up with sand and gravel.

A further consequence of glaciation is the formation of glacial lakes. When glaciers recede, glacial deposits may partially dam river valleys, forming lakes upstream. Such a lake, called *Lake Moody*, once existed in the Nenana River Canyon between the park entrance and Healy following the Healy Glaciation and during the Riley Creek Glaciation (fig. 19). Thus, today's Alaska Range glaciers are but the latest stage of a complex glacial history which has helped shape the central Alaska Range during the last three million years.

PART II

ROAD GUIDE AND GEOLOGIC HIKEs

Guide To The Geology Along The Park Road

This geologic guide is designed to be used while traveling on the park road by bus or in your own car. To understand the geologic terminology, it will be necessary to read first the Introduction and Part I of this book. The sections of the road guide are keyed to major rivers, passes, and buildings and describe in a general way the main geologic features along the road. You may find it convenient to refer to Part I and to the geologic map in the back of this book as you are using this guide.

Highway Turnoff — Railroad Depot (0.0-2.4 km or 0.0-1.5 mi.)

The park road is built on sand and gravel deposited by the Nenana River and its tributaries during the Riley Creek Glaciation (fig. 23), but Horseshoe Lake near the railroad depot is the result of changes in modern stream drainages. The lake is the remnant of a former bend in the Nenana River, left isolated when the river recently shifted position.

Railroad Depot — Park Headquarters (2.4-5.5 km or 1.5-3.4 mi.)

The park road follows the lower part of Hines Creek and is mainly built across rubble of metamorphic rocks derived from the Yukon Crystalline Terrane to the north. South of Hines Creek the mountains are composed of shale, sandstone, and conglomerate of the Cantwell Formation, about 65 million years old (p. 15). Looking south from the park road about three kilometers away, you can see a large glacial erratic left by the Browne Glaciation about three million years ago on a broad surface once scoured by the passage of glacial ice.

Park Headquarters — Savage River

(5.5-23.5 km or 3.4-14.6 mi)_____

The road parallels the trace of the Hines Creek fault (p. 7), which is an old plate boundary and separates the geology of northern Alaska from that of southern Alaska. In this area it is also the contact between mountains made up of sedimentary rocks to the south and the Yukon Crystalline Terrane — the oldest rocks in Mount McKinley National Park — to the north. Mountain slopes on both sides of the road are marked by lobe-shaped masses called *solifluction lobes*, which result from downslope flow of water-saturated soil.

Savage River — Sanctuary River

(23.5-36.2 km or 14.6-22.5 mi)_____

The park road continues along the north side of a broad lowland between old metamorphic rocks of the Yukon Crystalline Terrane to the north and sedimentary rocks of the Cantwell Formation in the main part of the Alaska Range to the south (fig. 24). This low region resulted from faulting along the north and south sides of the lowland; the Hines Creek Fault trends along the north side near the road.

The lowland contains easily-eroded sandstone and conglomerate of the Coal-bearing Group and Nenana Gravel (exposed in roadcuts), which once may have been eroded away from the flat-topped summits of the ranges north and south of the road (p. 18). Along the Savage and Sanctuary rivers there is a contrast between the glacier-scoured, **U**-shaped valleys in the headwater regions to the south and the **V**-shaped valleys which the rivers have cut into the ranges north of the road (figs. 25 and 26).



Figure 24. Looking east across the lowland near the Savage River. The Yukon Crystalline Terrane is present in mountains to the north, and the Cantwell Formation is found in mountains to the south.



Figure 25. Looking south at the **U**-shaped entrance to the upper valley of the Savage River.



Figure 26. Looking north along the **V**-shaped lower valley of Savage River north of park road. Quartzite and mica-quartz schist of the Yukon Crystalline Terrane form rugged outcrops.

Sanctuary River — Teklanika Campground

(36.2-46.3 km or 22.5-28.8 mi)

The prominent peak to the south is Double Mountain. Chocolate-colored volcanic flows of the Teklanika Formation (60 million years old) on its upper slopes overlie the dark gray sandstone, shale, and conglomerate of the Cantwell Formation (65 million years old) on its lower slope (fig. 27). The broad, east-west depression extending westward from the Nenana River ends at the Teklanika River. West of the Teklanika River, metamorphic rocks along the Hines Creek fault make up prominent ridges (fig. 3). Just north of Teklanika Campground, glacial moraines of the most recent glaciation contain numerous lakes and ponds formed by the melting of blocks of ice.



Figure 27. Looking southeast across the Teklanika River toward Double Mountain. Volcanic rocks of the Teklanika Formation (Ttv) rest on sandstone and shale of the Cantwell Formation (Tc).

Teklanika Campground — Igloo Creek

(46.3-54.0 km or 28.8-33.6 mi)

Between Teklanika Campground and Igloo Creek a wide variety of geologic features can be seen. The ridges both east and west of Teklanika Campground are composed of metamorphic rocks — primarily gray slate about 100 million years old. In the hills east and west of the Teklanika River bridge, light-colored conglomerate of the Cantwell For-

mation rests on the dark gray metamorphic rocks (see Geologic Hike no. 3). South of the Teklanika River bridge, however, sandstone and shale of the Cantwell Formation is also dark gray. In the bluffs along Igloo Creek on the east side of the road between the Teklanika River bridge and Igloo Campground, dark brown *dikes* of basalt cut through gray sandstone and shale. These dikes may represent the conduits along which rose the basalt that caps Igloo Mountain to the southwest and Double Mountain to the southeast. The basalt flows on Igloo Mountain have been folded and tilted northeast toward the road (see Geologic Hike no. 4). The park road itself generally is built on glacial deposits that cover low areas along the Teklanika River.

Igloo Campground — Sable Pass

(54.0-61.7 km or 33.6-38.3 mi)_____

The park road runs along Igloo Creek between Igloo Mountain to the north and Cathedral Mountain to the south. On both mountains volcanic flows of the Teklanika Formation, which erupted about 60 million years ago, overlie folded sandstone, shale, and conglomerate of the Cantwell Formation (fig. 28). Dark-colored volcanic rocks are mainly flows of basalt, and the light-colored rocks are primarily layers of rhyolite (see Geologic Hike no. 5). Bluffs along Igloo Creek and in the hills to the north display gray beds of steeply-inclined sandstone, shale, and conglomerate which are cut by dark brown basalt dikes. Sable Pass marks the east end of another east-west lowland containing easily-eroded sedimentary rocks.



Figure 28. Looking southwest toward Igloo Mountain from the park road. Tilted basalt flows of the Teklanika Formation (Ttv) rest on sandstone, shale, and conglomerate of the Cantwell Formation (Tc).

Sable Pass — East Fork

(61.7-68.3 km or 38.3-42.4 mi)_____

The park road is built on light-tan sedimentary rocks of the Coal-bearing Group (exposed in roadcuts; figs. 17 and 29), and the low, flat-topped hill just south of Sable Pass is composed mainly of conglomerate of the Nenana Gravel. Near the mouth of the creek that runs along the road, a coal seam was mined for local use in the early years of the park. North of the road a major fault along the front of Sable Mountain has raised dark sedimentary rocks (Cantwell Formation) above the light-colored volcanic rocks (Teklanika Formation) at the base of the mountain (fig. 15).



Figure 29. Bluffs of late Cenozoic Coal-bearing Group between Sable Pass and the East Fork River.

East Fork River — Polychrome Overlook

(68.3-72.3 km or 42.4-44.9 mi)_____

The road is cut into steeply-inclined, light-colored rhyolite beds of the Teklanika Formation. Dark basalt flows contrast with the rhyolite. South of the road you can see the wide, downfaulted lowland where the upper East Fork drainage has largely removed easily-eroded sedimentary rocks of the Coal-bearing Group and Nenana Gravel. The upper portions of streams that once flowed north across this lowland through the hills near Polychrome Overlook have been captured by the East Fork River as it removed the sedimentary rocks and extended branches of its headwaters west toward the Toklat River. On the valley floor south of the overlook you can see several lakes caused by the melting of ice in glacial deposits. A large, isolated block of limestone on the valley floor is a glacial erratic that was carried by glaciers from near the crest of the Alaska Range. Across the lowland you can see more light-colored rhyolite of the Teklanika Formation.

Polychrome Overlook — Toklat River

(72.3-83.7 km or 44.9-52.0 mi)_____

A short distance west of Polychrome Overlook the road cuts through tan and gray sandstone and conglomerate of the Cantwell Formation. North of the road Polychrome Mountain is generally composed of similar sedimentary rocks. It is capped on the east by flows of dark basalt and white rhyolite (fig. 11) and is cut by dikes of andesite on its west end. Across the low area to the south, the ridges contain colorful volcanic rocks. Near the Toklat River an unconformity can be seen north of the road where sedimentary rocks of the Cantwell Formation, about 65 million years old, rest on dark, metamorphosed basalt, about 200 million years old (fig. 30). Like most of the major rivers in the park, the Toklat River is a braided, underfit stream flowing in a wide, glacially eroded valley.

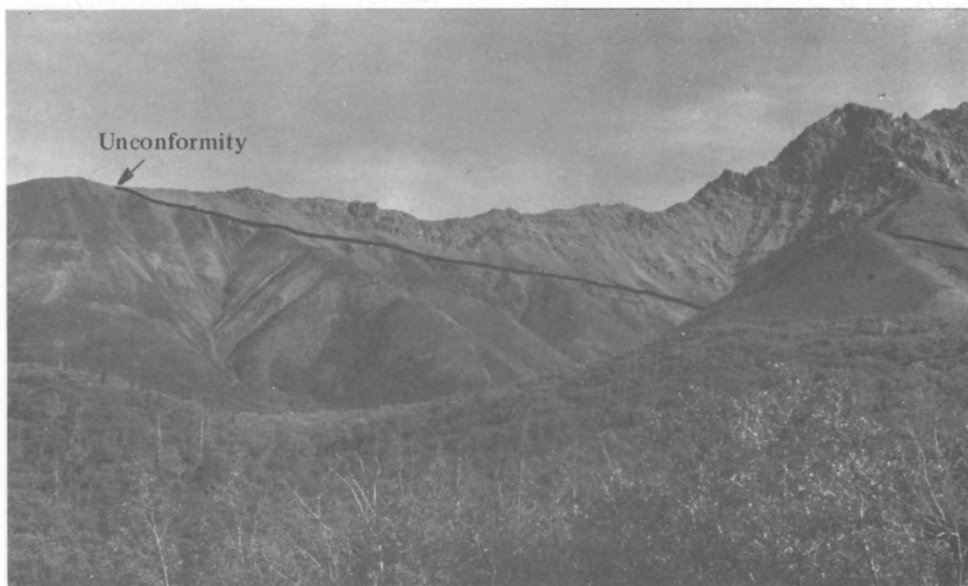


Figure 30. Unconformity between Triassic basalt (200 million years old) below and conglomerate and sandstone of the Cantwell Formation (65 million years old) above.

Toklat River — Stony Overlook

(83.7-97.7 km or 52.0-60.7 mi)_____

The park road follows a downfaulted depression (fig. 31) containing easily eroded conglomerate of the Nenana Gravel, which is exposed in roadcuts. The upper parts of the mountains north and south of the road are composed of dark basalt which erupted on the ocean floor about 200 million years ago (see Geologic Hike no. 8). Light gray, metamorphosed sedimentary rocks underlie the basalts. Near Stony Creek intermittent streams flowing from the ranges to the south have deposited large fans of gravel across which the road is built.



Figure 31. Looking east toward Stony Overlook. Nenana Gravel lies in downfaulted lowland between ridges of Triassic basalt to north and south.

Stony Overlook — Eielson Visitor Center **(97.7-104.0 km or 60.7-64.6 mi)**_____

The park road affords a good view of the heart of the Alaska Range and some of its most active glaciers. Below the visitor center the broad, flat valley of the Thorofare River is now filling up with gravel. Mount Eielson, 4.0 kilometers south of the visitor center, is composed of granite about 38 million years old (fig.10). The dark metamorphic rocks along the crest of the Alaska Range beyond Mount Eielson were originally sedimentary and igneous rocks that formed during the Paleozoic Era. The ridge above the visitor center to the north is mainly composed of basalt about 200 million years old.

Eielson Visitor Center — **Wonder Lake Ranger Station** **(104.0-136.5 km or 64.6-84.8 mi)**_____

Just west of Eielson Visitor Center, the park road cuts through older volcanic rocks (200 million years old) and younger volcanic rocks (38 million years old) (see Geologic Hike no. 10). For the most part, however, the road crosses glacial deposits left by an earlier, much larger Muldrow Glacier. Small lakes are abundant and were formed by the melting of the ice left in these deposits after the glacier receded. The

modern Muldrow Glacier makes several sharp turns. Near the last turn (to the west), a short distance south of the road, you can see the dark, rough, debris-covered surface of the glacier (back cover photo). Here the glacier has also pushed the Thorofare River into a narrow canyon. Below this canyon melting water from the Muldrow Glacier joins with the Thorofare River to form the wide, braided McKinley River. The Muldrow Glacier has rapidly advanced several times, with the last major surge occurring during 1956-1957. These surges are thought to be caused by periodic buildup of water beneath the glacier, permitting rapid or catastrophic movement of the ice.

The McKinley Strand of the Denali fault system passes along the base of the steep, north side of Mount McKinley. The fault is active and has raised rocks south of the fault many thousands of meters.

The prominent, light-colored ridge north of the road (fig. 12) is made up of volcanic rocks of the Mount Galen Volcanics, which erupted 37 million years ago. The Kantishna Hills near Wonder Lake Ranger Station are composed of the same, old metamorphic rocks, the Yukon Crystalline Terrane, that you first saw near park headquarters.

Geologic Hikes In — Mount McKinley National Park —

Mount McKinley National Park is a superb area both for short walks and lengthy expeditions. Your own enjoyment of the park's attractions will be greatly increased if you spend a few minutes or hours studying the park's natural features away from the road. There is a good chance that you will encounter wildlife, impressive scenery, and fascinating geology. These geologic hikes describe features which by and large have been discussed in Part I. All of the hikes can be completed in a few hours or within one day. Of course, if you study the geologic map you will see that there are a great many other areas containing geologic features worth visiting.

Geologic Hike No. 1: Triple Lakes ↗

This pleasant hike (8 km, 4 hours) takes you across a glacial moraine and will show you several large landslides, as well as a basalt dike cutting the Cantwell Formation. First, find the trail leaving the Anchorage-Fairbanks highway a short distance north of the bridge over the Nenana River (fig. 32). For much of the first two kilometers of the trail you will be walking on a glacial moraine deposited during the Riley Creek Glaciation. As you climb up the hill away from the railroad tracks, you will see rounded boulders of

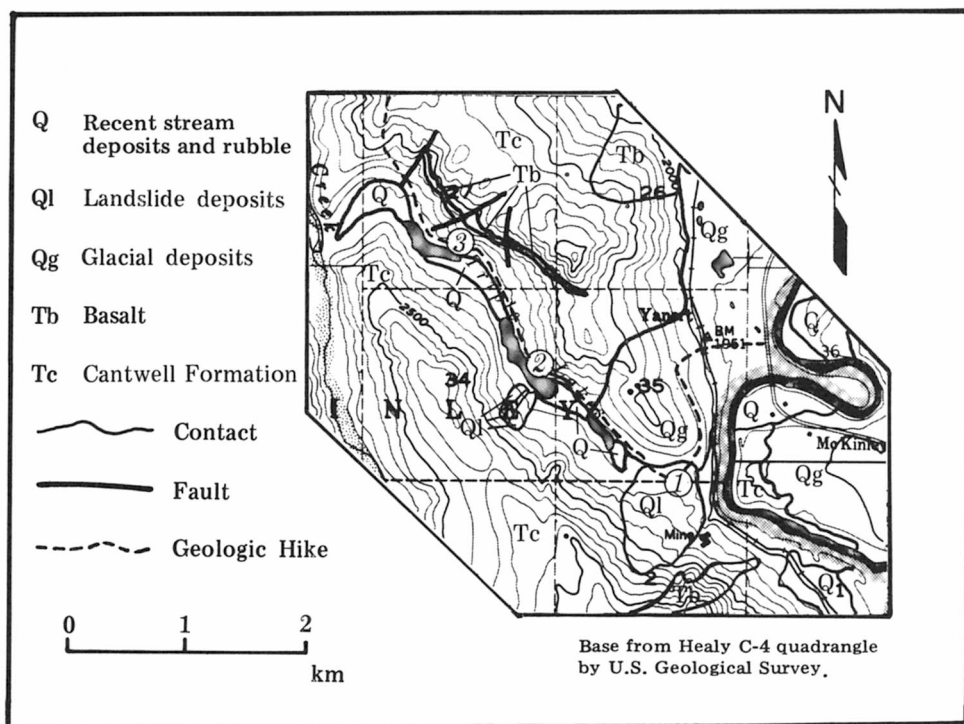


Figure 32. Geologic map of Triple Lakes area.

granite carried by glaciers from the crest of the Alaska Range. After you have walked south about one kilometer, the trail turns west. At this point ⑦ you will be walking across the hummocky surface of a large landslide which came from the large bowl on the canyon wall to the south. This landslide contains blocks of sandstone and conglomerate of the Cantwell Formation and is many decades old. It supports large trees and can be seen clearly on aerial photographs of the area taken in 1949. From here the trail turns northwest into the valley of Triple Lakes. When ice filled the Nenana River and Yanert Fork valleys during the Riley Creek Glaciation, a lobe of ice extended northwest through the Triple Lakes valley (fig. 19). The trail continues northwest past three small lakes. When you reach the southeast end of the middle lake ②, look across to the far side of the valley. There you will see three young landslides that do not appear on aerial photographs taken in 1949. You can easily see which landslide is the youngest, for it supports no vegetation. Continue walking from the middle lake to the lake to the northwest. If you look at the northeast wall of the valley, you can see where a basalt dike has intruded into sandstone and conglomerate of the Cantwell Formation ③. If you look carefully you can observe where the dike has been offset along several small faults. From this point you can return to the Anchorage-Fairbanks Highway, or follow the trail north seven kilometers to the park headquarters area along a ridge underlain by more sandstone and conglomerate.

Geologic Hike No. 2: Savage River ➤

This short walk (2 km, 1 hour) north from the Savage River bridge will show you the oldest rocks in Mount McKinley National Park, as well as the erosive power of running water. Walk a short distance west of the bridge and look south across the broad valley formed by removal of the easily-eroded Coal-bearing Group and Nenana Gravel (fig. 33). You will see the mouth of the U-shaped valley of the upper Savage River (fig. 25). Glaciers once occupied this valley and reached within 1.0 kilometer of the bridge during the Dry Creek Glaciation. Now walk north into the Savage River canyon. The river flows between interlocking spurs of metamorphic rocks in a narrow gorge cut through the outer ranges by the Savage River (fig. 26). These metamorphic rocks are part of the Yukon Crystalline Terrane and may be as much as one billion years old (p. 7). They form conspicuous *tors* (spires) due to weathering along fractures. The very hard, light-colored layers are quartzite, quartz-rich sandstone that has been metamorphosed. These rocks grade into gray, shiny, mica-quartz schist. The mica is mainly *muscovite*, a white mica which formed from metamorphism of fine-grained sediments. The plate-like alignment of mica layers is due to the growth of muscovite parallel to the direction of movement during metamorphism. The discontinuous, white layers are quartz veins. The quartzite, schist, and quartz veins are now severely folded and cut by a prominent cleavage (fig. 4), indicating that they have been deformed at least once since earlier metamorphism. Downstream the upper slopes of the canyon have weathered to a conspicuous orange color. This zone of weathering represents the unconformity from which sedimentary rocks of the Coal-bearing Group have more recently been removed by erosion.

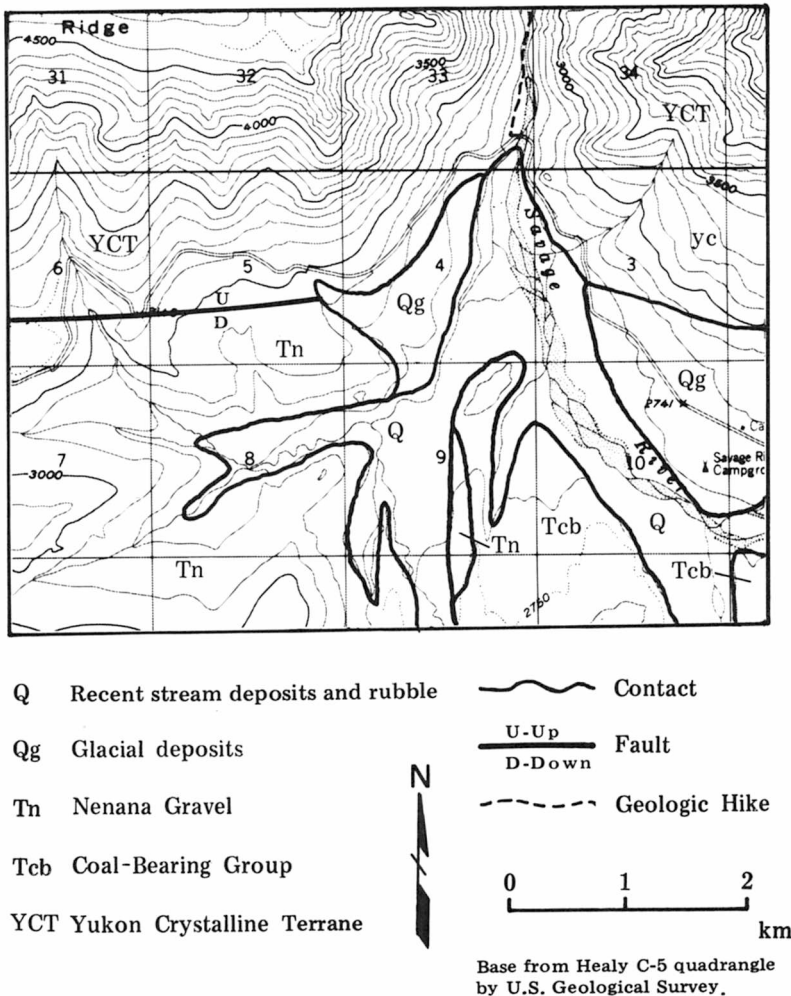


Figure 33. Geologic map of Savage River area.

Geologic Hike No. 3: Teklanika Campground

Teklanika Campground makes a good base for several geological hikes. One of the most interesting walks (9 km, 5 hours) takes you east of the campground to look at metamorphic rocks 200 and 100 million years old, which are overlain by conglomerate of the Cantwell Formation about 65 million years old. First walk to the top of the hill ① just east of the park road near the campground (fig. 34). This hill is made up of light-colored marble and slate about 200 million years old, which has been intruded by dark-colored

gabbro (p. 9). Similar rocks are present on the ridge across the Teklanika River west of the campground. The low-lying areas surrounding the hill and along the Teklanika River near the campground are covered by glacial deposits containing numerous lakes. These lakes fill hollows that were formed by the melting of buried ice blocks after the last glaciers receded. Next set off across the tundra for the gray ridge ② about 1.5 kilometers southeast of the hill near the campground. Most of this ridge is underlain by weakly-metamorphosed sandstone and slate about 100 million years old (p. 10). Follow this ridge south and cross the low saddle separating the ridge from the light-colored hills to the south. You should be able to find the contact ③ where quartz-rich conglomerate of the Cantwell Formation rests on the metamorphic rocks. This contact is an unconformity, and marks a break in the geologic record between 100 million and 65 million years ago. The rounded pebbles, cobbles, and boulders of the Cantwell Formation were probably eroded from quartz-rich metamorphic rocks to the north. From these hills you can reach the park road by walking due west about 2.0 kilometers.

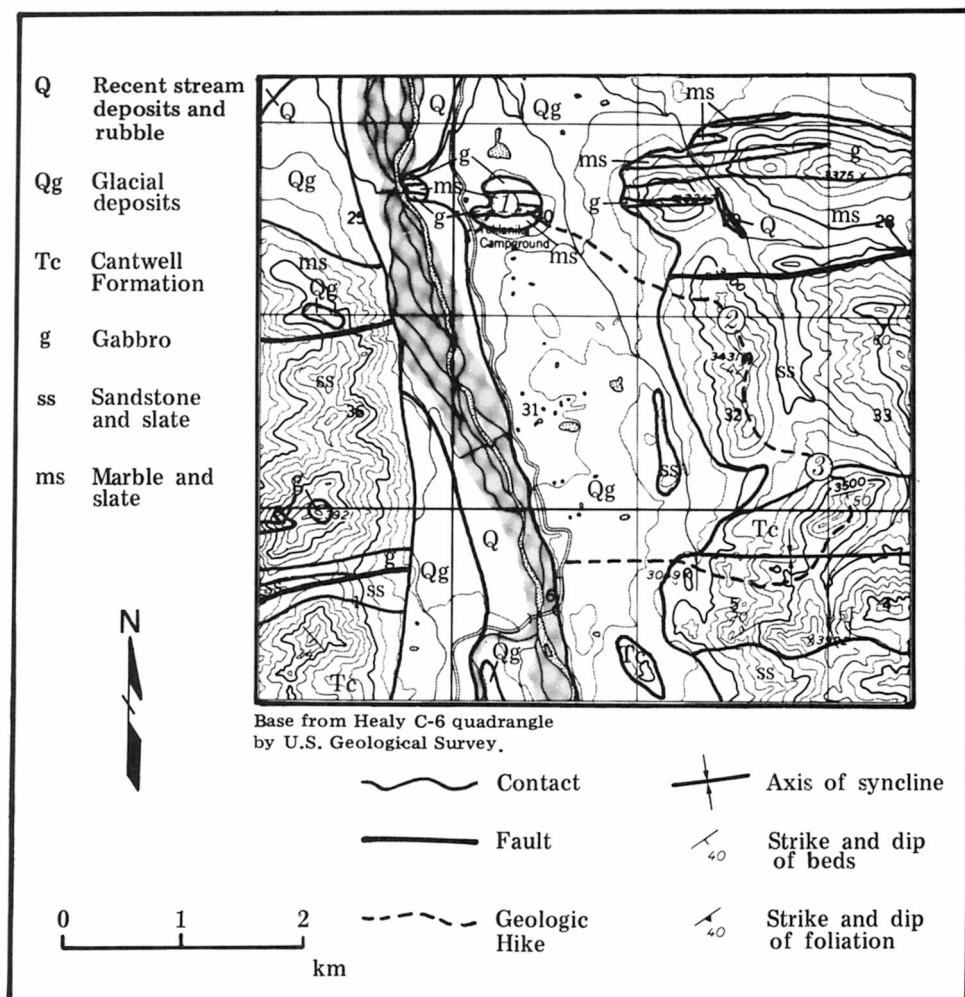


Figure 34. Geologic map of Teklanika Campground area.

Geologic Hike No. 4: Igloo Mountain ↗

The popular ascent of Igloo Mountain (4 km, 4 hours) is almost entirely across folded basalt flows of the Teklanika Formation (p. 14). Leave Igloo Campground and walk north across vegetated glacial till until you are opposite the grassy slope leading to the top of Igloo Mountain (fig. 35). Climb this slope to the summit ridge. As you climb you will be walking along volcanic rocks folded into a large *syncline*, which is tilted north-east. Flows to the northwest are inclined to the southeast, and flows to the southeast are inclined northwest. On the summit you may see *geodes*, formed about 60 million years ago when quartz or calcite crystallized in cavities in the cooling basalt flows. From the top of the mountain you can view to the west the dark-colored shale, sandstone, and conglomerate of the Cantwell Formation, which lies beneath the volcanic rocks of the Teklanika Formation. To the south you can clearly see colorful volcanic rocks on the Cathedral Mountain.

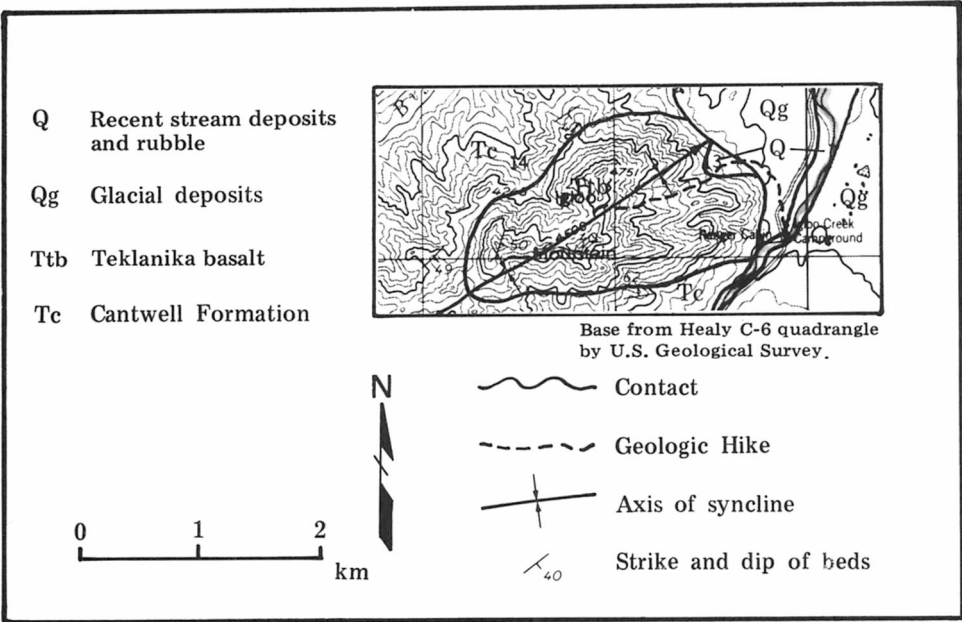


Figure 35. Geologic map of Igloo Mountain.

Geologic Hike No. 5: Cathedral Mountain ↗

A hike to the summit of Cathedral Mountain (9 km, 5 hours) crosses sedimentary and volcanic rocks, and will show you the trace of a fault. Begin your hike at the canyon which crosses the park road about 3.0 kilometers southwest of Igloo Creek bridge (fig. 36). Walk southeast up the canyon. For the first kilometer the canyon cuts through steeply-inclined shale, sandstone, and conglomerate of the Cantwell formation ① (p. 15). Then the canyon is cut into dark-colored basalt flows in the lower part of the Teklanika

Formation ② (p. 14). The upper part of the canyon, however, crosses light-colored volcanic rocks, which are primarily rhyolite tuff ③ . This tuff contains considerably more silica than the basalt and was formed by the explosive eruption of a volcano. The fragments of the volcanic ash blown into the air settled on the ground in layers. At the head of the canyon you will suddenly find yourself in conglomerate and sandstone again. The contact between the volcanic and sedimentary rocks is a fault ④ along which the Cantwell Formation has been uplifted.

Follow the crest of Cathedral Mountain southwest about 1.0 kilometer along sheep trails worn into rhyolite. You will have an excellent view of the upper Teklanika River drainage where more volcanic rocks of the Teklanika Formation and glaciers are well displayed. Return to the park road by descending the canyon which meets the park road 3.0 kilometers south of the Igloo Creek bridge. Enroute you will again cross rhyolite, basalt, and plutonic rocks of the Teklanika Formation.

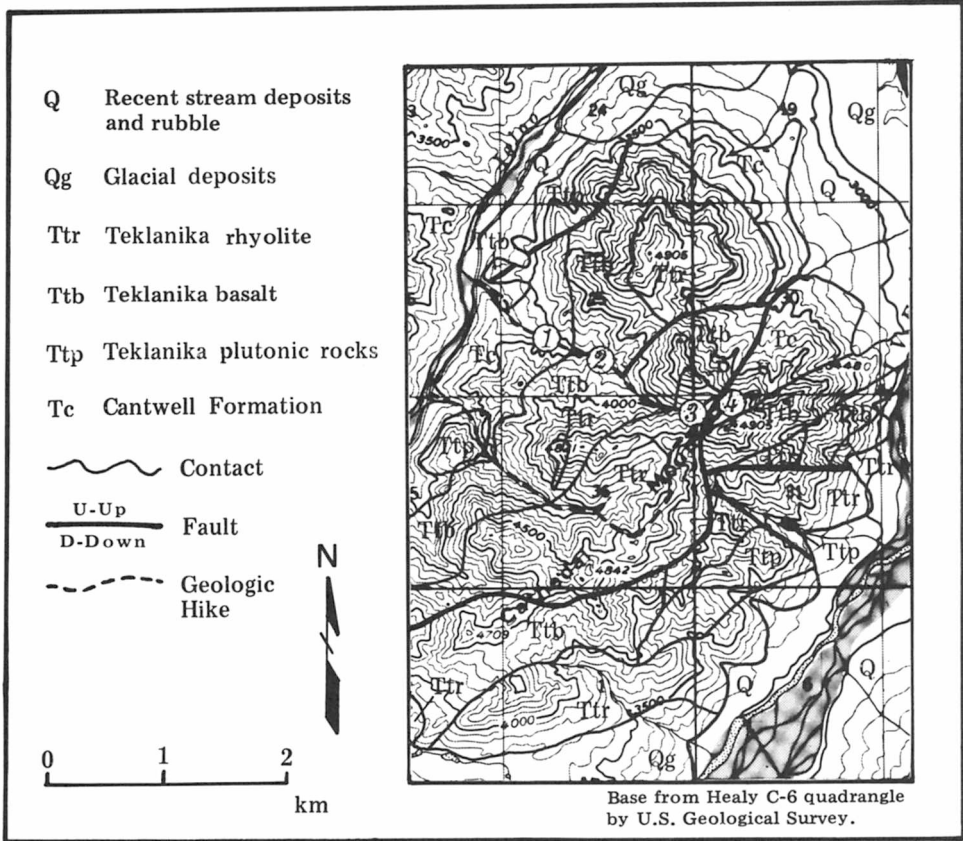


Figure 36. Geologic map of Cathedral Mountain.

Geologic Hike No. 6: Tattler Creek ↗

A hike along Tattler Creek (4 km, 2 hours) crosses volcanic and sedimentary rocks and a fault. Begin your hike where the park road crosses Tattler Creek (fig. 37). The

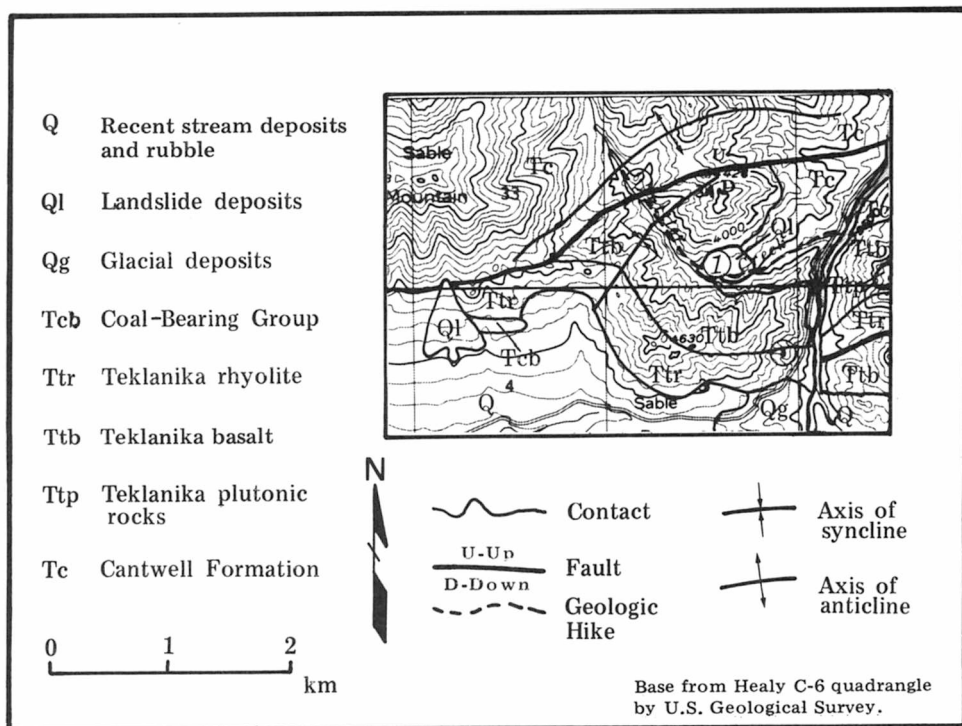


Figure 37. Geologic map of Tattler Creek area.

lower part of Tattler Creek flows through shale and sandstone of the Cantwell Formation, although you can see the lowermost volcanic rocks of the Teklanika Formation on the south canyon wall. About 1.0 kilometer above the road a landslide ① has pushed the creek to the south and has covered the contact between the sedimentary and volcanic rocks. Above the landslide the creek cuts through basalt flows, which are inclined upstream toward the northwest. These flows suddenly become inclined downstream toward

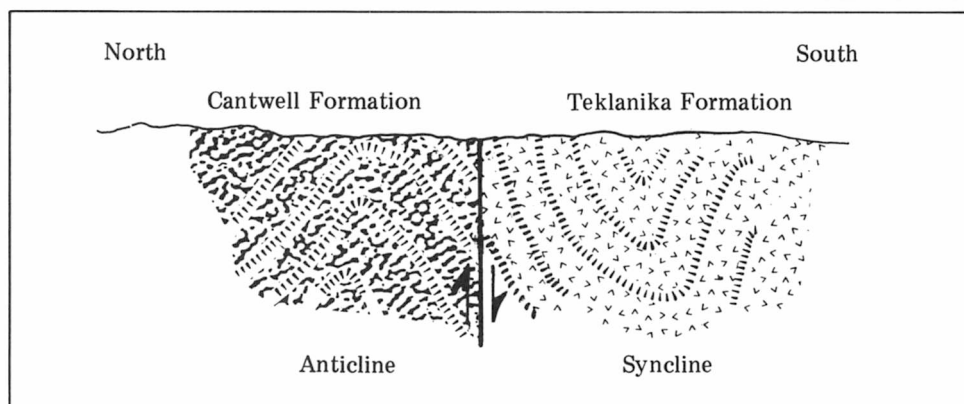


Figure 38. Folds along Tattler Creek caused by resistance (drag) as the Cantwell Formation moved up relative to the Teklanika Formation. An *anticline* (arched upward in the middle) and *syncline* (folded down in the middle) were formed.

the southeast as you approach the fault ② separating volcanic and sedimentary rocks. This change in orientation was caused by “drag” along the fault as dark-colored shale and sandstone of the Cantwell Formation were uplifted at least 450 meters. A similar fold is seen in the change in inclination of beds of the Cantwell Formation on the north side of the fault (fig. 38). From where the fault crosses Tattler Creek you can return to the park road by following the fault due east or by returning downstream.

Geologic Hike No. 7: Polychrome — East Fork River ↗

This hike (6 km, 4 hours) will take you to some of the most dramatic geologic features in Mount McKinley National Park. Hike north along the creek that heads near Polychrome Overlook (fig. 39). After walking downstream a short distance you will

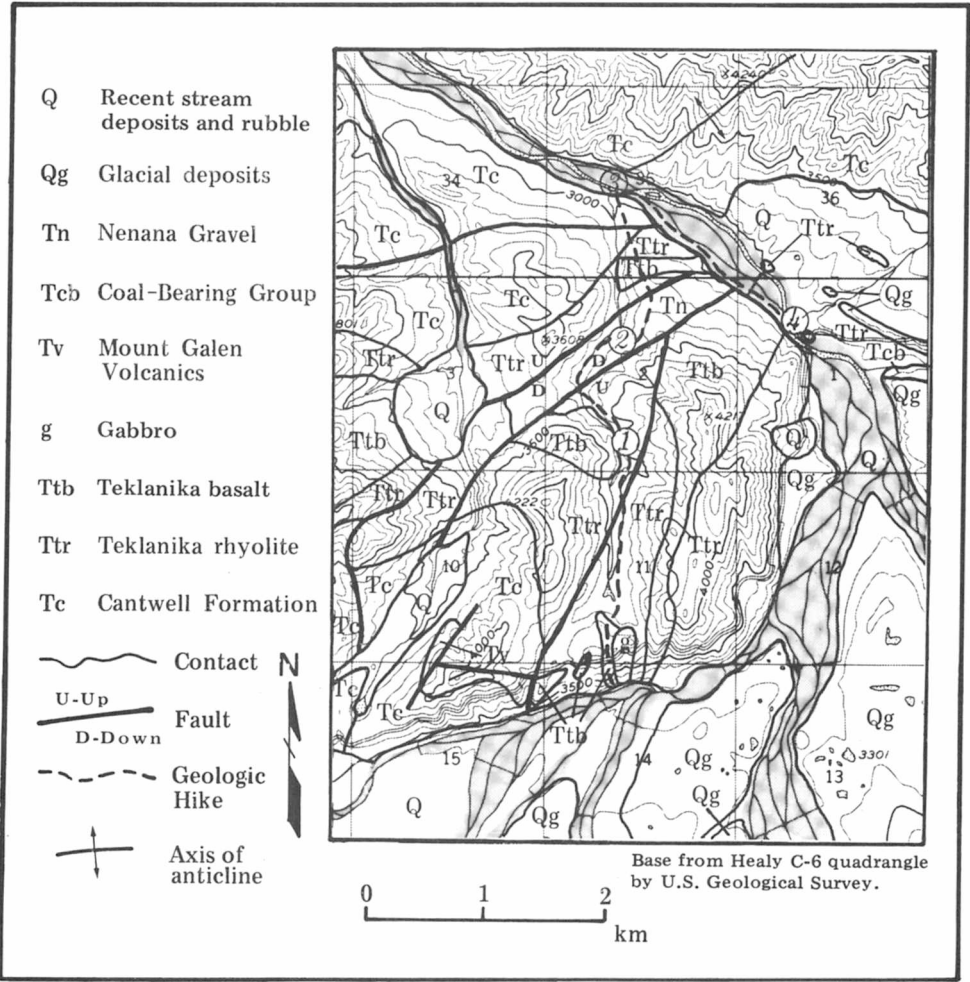


Figure 39. Geologic map of Polychrome-East Fork area.

eventually pass through a narrow canyon ① cut in rhyolite and basalt flows (Teklanika Formation) which erupted about 60 million years ago. After the canyon widens from the narrow gorge turn east and climb onto the poorly consolidated sandstone and conglomerate of the Nenana Gravel ② (p.18) which exhibits colorful “badlands” topography similar to that seen in the Painted Desert of the American Southwest. Most of the pebbles in the conglomerate are rhyolite, indicating that they were deposited by streams eroding nearby volcanic rocks. These sedimentary rocks are preserved in a downfaulted block between areas of volcanic rocks to the north and south.

Continue north along the ridge west of the East Fork River for about 2.0 kilometers. You will then see a spectacular *anticline* (fold arched upward in middle) ③ in sandstone and shale of the Cantwell Formation on the canyon wall across the river (fig. 14). This folding took place between 65 and 40 million years ago. Now turn upstream (southeast) toward the East Fork bridge. Just before you reach the bridge, there is a layer of green volcanic tuff in the canyon wall on the southwest side of the river ④ . This tuff is a record of one of the explosive events that occurred frequently during the eruption of the Teklanika Formation. The bridge itself spans a narrow gap cut into rhyolite by the river.

Geologic Hike No. 8: Toklat

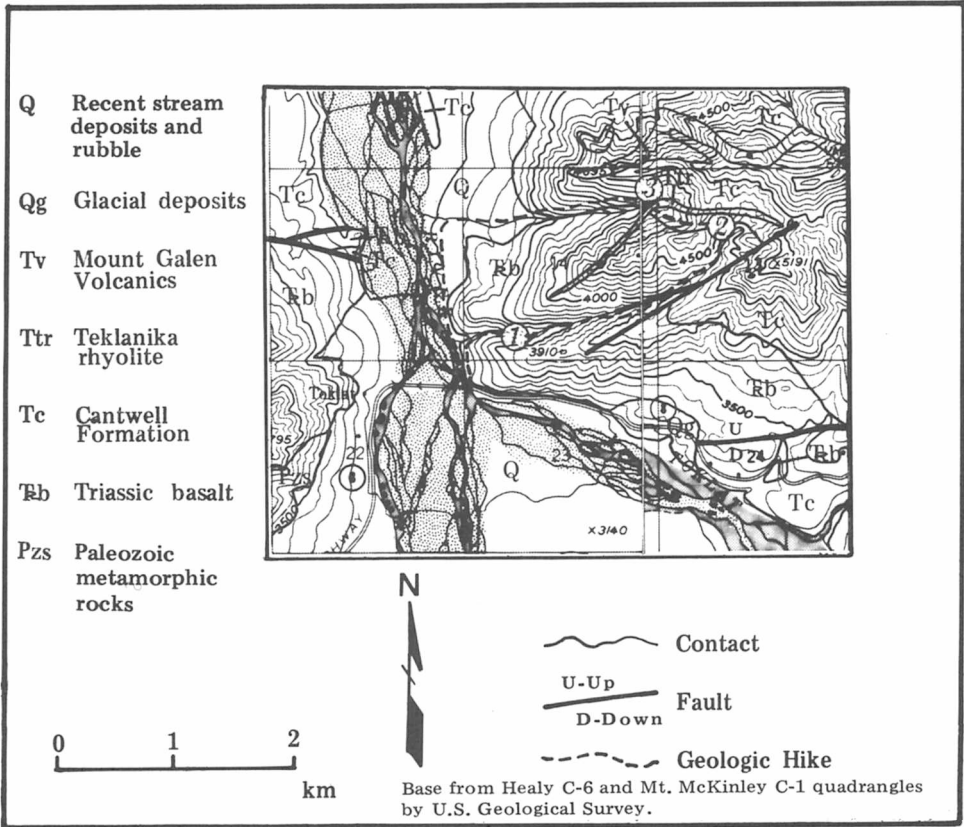


Figure 40. Geologic map of Toklat area.

This hike (4 km, 5 hours) will show you both basalts which erupted on an ocean floor about 200 million years ago, and sandstone and conglomerate which rest on top of them (p. 9-10 and p. 15). Leave the park road at the east end of the Toklat River bridge and walk downstream about 0.3 kilometer (fig. 40). Turn east into the dark, narrow canyon draining into the river. As you ascend the canyon you will see many examples of the bulbous, tubular-shaped lava flows which geologists call *pillow basalt* ① (fig. 6). These shapes formed as basalt erupted under water. The lava quickly chilled, and new material covered older flows. You may also see an occasional bright green stain on these basalts, caused by the oxidation of copper-bearing minerals. The basalts have been affected by orogeny during the past 200 million years, and are thus sheared and slightly metamorphosed. At the head of the canyon tan-weathering sandstone and conglomerate of the Cantwell Formation lie on top of the older basalts along an unconformity ② (fig. 30). This unconformity marks a break in the rock record of 135 million years. The lower few meters of the Cantwell Formation contain pebbles and boulders eroded from the underlying pillow basalt. As you cross the drainage divide between the canyon you just ascended and its neighbor to the north, you will see a dike ③ of white rhyolite which cuts both the pillow basalt and the Cantwell Formation. This dike probably fed some of the rhyolite flows of the Teklanika Formation. Your descent along the canyon to the north follows the contact between sandstone and conglomerate to the north and pillow basalt to the south.

Geologic Hike No. 9: Bergh Lake

The walk to Bergh Lake (1 km) takes only a few minutes, but it illustrates the effects of massive landslides. Leave the park road near the divide between Stony and Little Stony Creeks (fig. 41). Walk either to the top of the hill to the north or to Bergh Lake

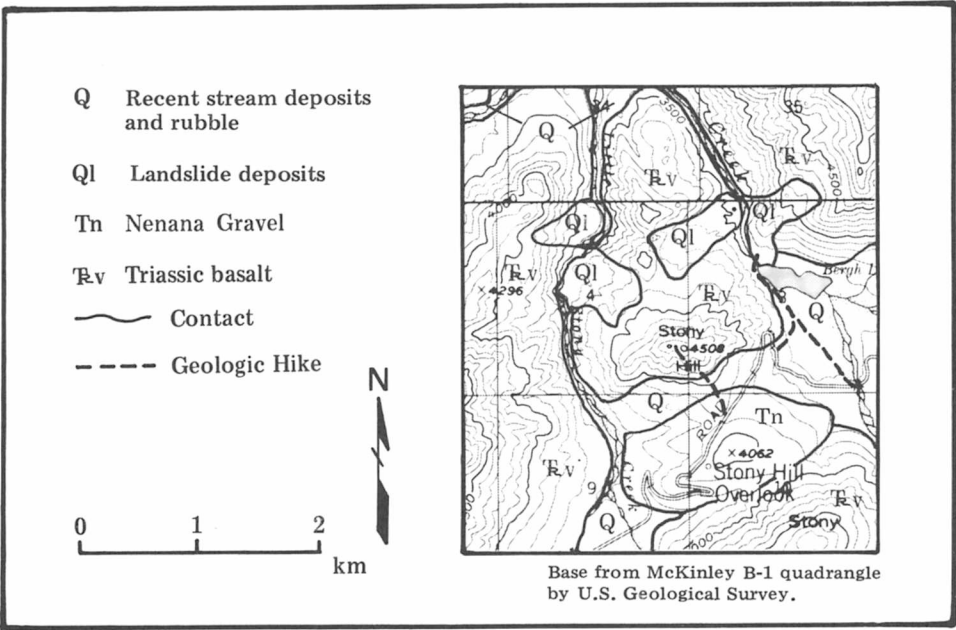


Figure 41. Geologic map of Stony Hill area.

itself. Portions of the highly sheared pillow basalt (p. 43) forming the mountains north of the park road have broken loose and slid into the valleys of both creeks. One landslide occurred in 1953 and dammed Stony Creek, forming Bergh Lake (fig. 42). The lake is much smaller than it was immediately after the landslide, because the creek has partially cut through the blocking material.



Figure 42. Landslide blocking Stony Creek forming Bergh Lake.

Geologic Hike No. 10: Thorofare Hill

This hike (6 km, 5 hours) will show you some of the oldest and youngest volcanic rocks in Mount McKinley National Park. First climb the canyon that drains Thorofare

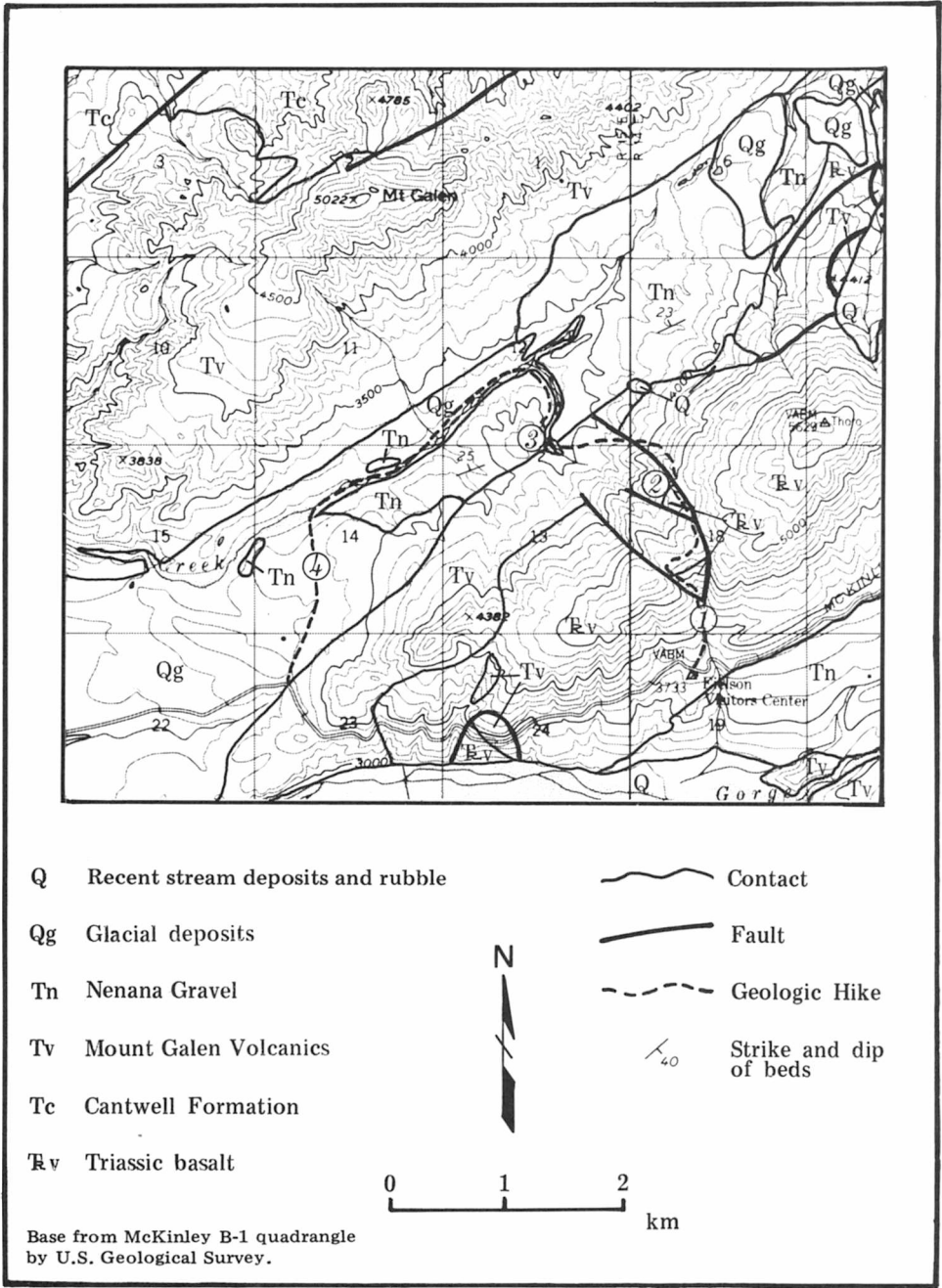


Figure 43. Geologic map of upper Moose Creek area.

Hill behind Eielson Visitor Center (fig. 43). On your way to the top of the hill you will cross pillow basalts ① like those which make up the mountains along the park road west of the Toklat River (fig. 6; Geologic Hike 8). Four kilometers south of Eielson Visitor Center stands the gray mass of Mount Eielson. This mountain is composed of granite, which solidified below the earth's surface about 38 million years ago. From the top of Thorofare Hill look northwest at the light-colored ridge containing Mount Galen (fig. 14). This ridge is made up of the Mount Galen Volcanics which erupted onto the earth's surface during the same magmatic episode that formed Mount Eielson (p. 13). These volcanic rocks are composed mainly of andesite (intermediate in composition between basalt and rhyolite) and generally erupted explosively, producing large amounts of *volcanic breccia* (coarse fragments) and tuff (fine-grained fragments). Descend the northwest side of Thorofare Hill. You will pass rugged cliffs of volcanic breccia ② at the site from which some of the Mount Galen Volcanics may have erupted. In the valley of Moose Creek between Thorofare Hill and Mount Galen, easily-eroded conglomerate and sandstone of the Nenana Gravel ③ (p. 18) rest on top of the Mount Galen Volcanics.

Return to the park road by walking down the valley of Moose Creek 3.0 kilometers before crossing to the park road. Between Moose Creek and the road you will be walking on glacial till ④ deposited by an early advance of the Muldrow Glacier that once nearly filled the valley of Moose Creek.

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USING METRICS

To convert from meters to feet, multiply by 3.2808.

To convert from kilometers to miles, multiply by 0.6214.

1.0 meter equals 3.2808 feet.

1.0 kilometer equals 0.6214 mile.

Mount McKinley is 20,320 feet or 6,913.6 meters above sea level.

ABOUT THE AUTHOR

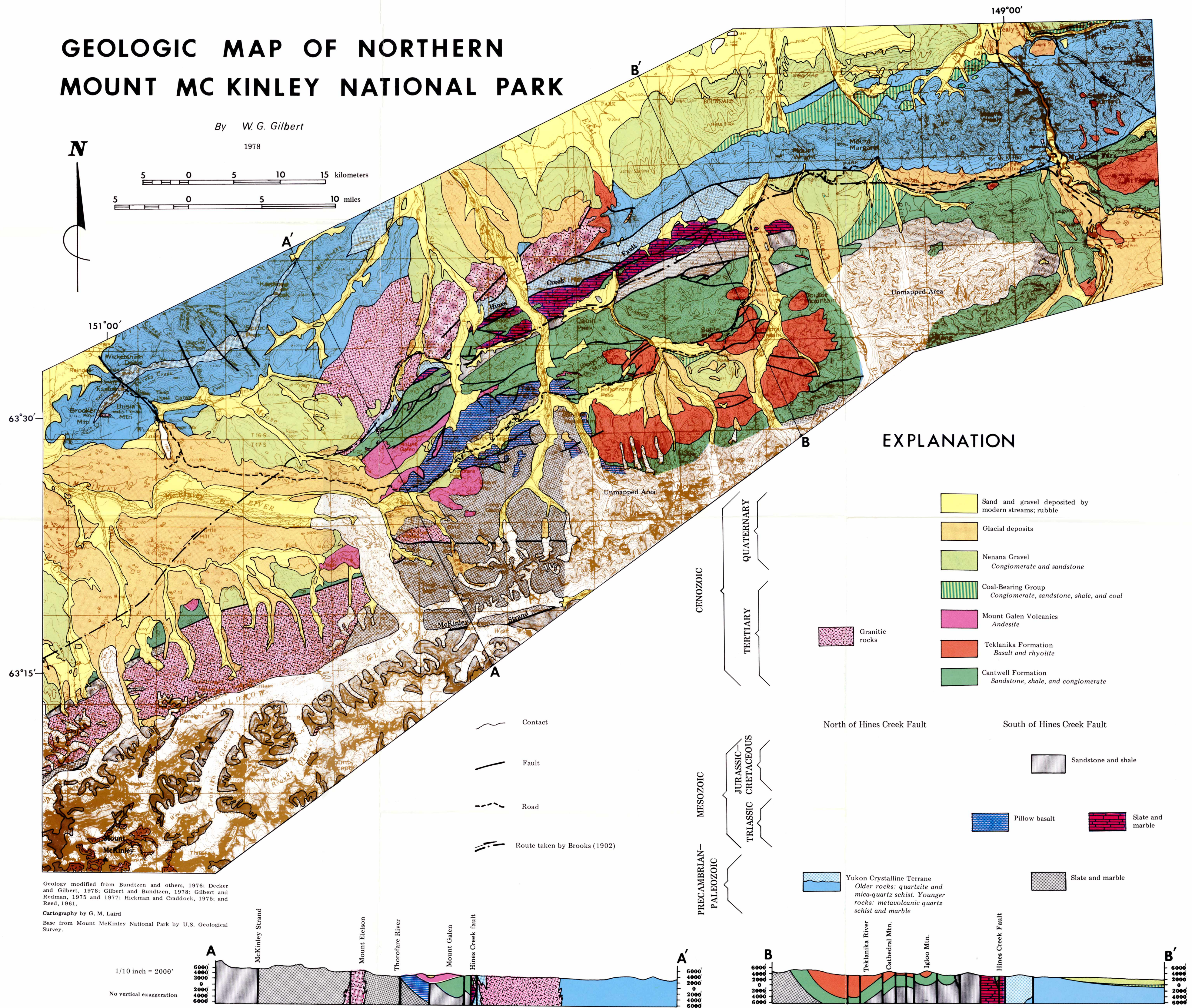
Wyatt G. Gilbert came to Alaska after receiving his doctor of philosophy degree from Stanford University and is currently a professor of geology at the University of Alaska and a geologist with the Alaska Division of Geological and Geophysical Surveys. He has spent many field seasons studying and mapping the geology of the Alaska Range and is the author of numerous scientific publications on the geology of the Mount McKinley region.

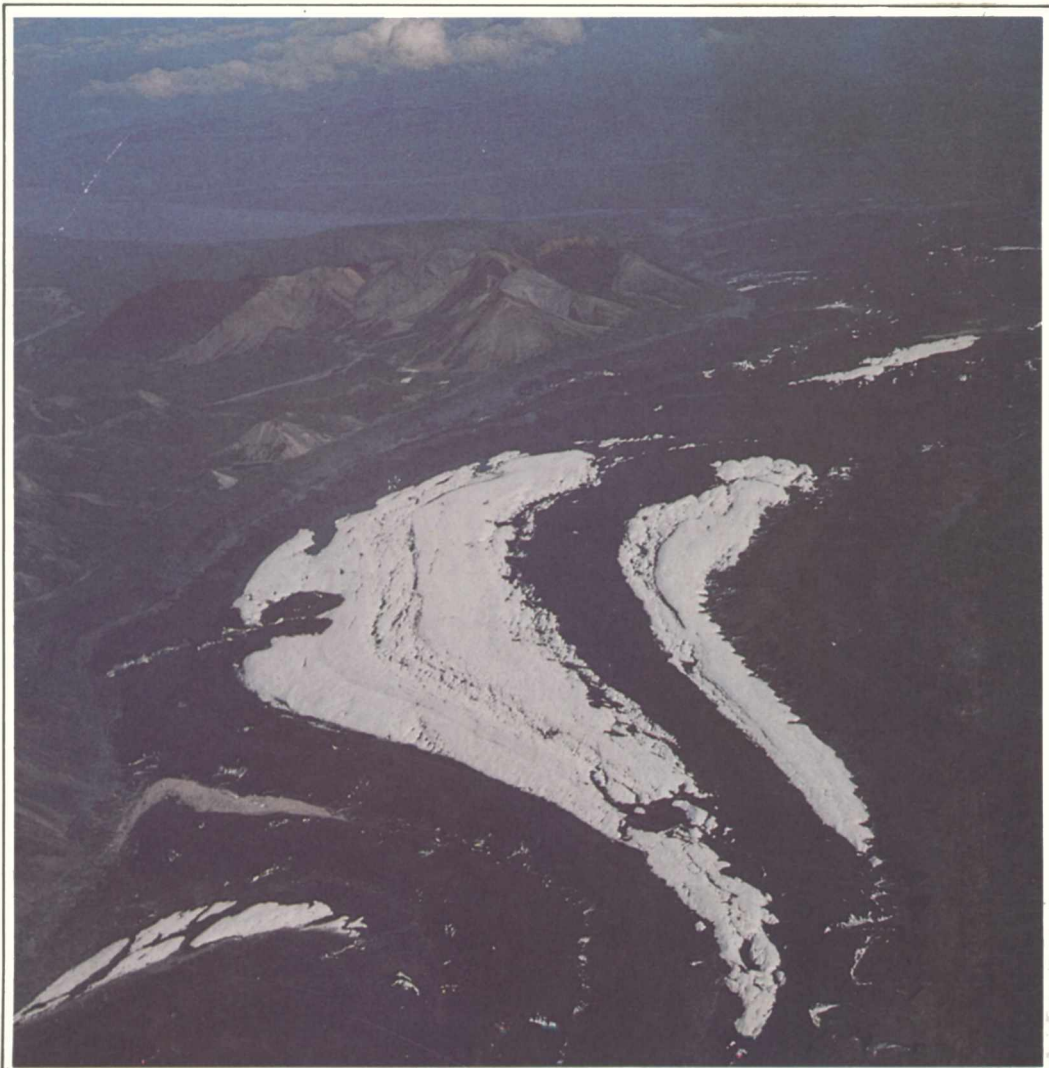
Back Cover: View north over lower Muldrow Glacier. Dark piles of debris on the glacier surface are derived from rubble collected in the upper part of the glacier basin. Photo by R. Wilson.

By *W. G. Gilbert*

1978

The map shows a portion of the Colorado Rockies. The Grand and Front ranges are labeled. Site A' is marked on the Front Range. A dashed line indicates the location of the study area. The map includes contour lines and a scale bar.





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