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ILIAMNA VOLCANO AND ITS BASEMENT

by

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55-77

This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

1955

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ILLUSTRATIONS

* PLATE NO. 2 IS NOT INCLUDED AS IT IS COVERED ON THE GEOLOGIC MAP OF ALASKA, BY DUTRO, PAYNE AND GRYC.

ILIAMNA VOLCANO AND ITS BASEMENT

Abstract

~~Mt.~~ *

~~Mr.~~ Iliamna volcano lies near the continental end of the 1500 mile long belt of Aleutian volcanos. It erupted near the border of the quartz diorite batholith composing the core of the Alaskan Peninsula. Hypersthene-augite andesite and basaltic andesite flows interbedded with coarse tuff breccias comprise this stratovolcano. Blocky lava fused into a slaggy matrix underlies most flows. These basal breccias seem to originate at the encrusting ends of moving flows which are continually overridden by the still advancing fluid lava.

Glass inclusions sealed in plagioclase crystals are oxidized as well as the groundmass glass at the surface of lavas indicating that the hematite producing the red color of the glass may have received its oxygen from the glass rather than from the atmosphere.

Crater fillings of porous andesite tuff have been replaced by hydrous opal. Acid waters, products of the hydration and oxidation of solfataric gases have leached out the metal cations from the silicate minerals leaving only the opaline pseudomorphs.

Propylitized Lower Jurassic andesite and dacite tuffs, tuff breccias, volcanic conglomerates, and mud flows make up a section approximately 8,000 feet thick. They grade conformably into 15,000 feet of Middle and Upper Jurassic siltstones, tuffaceous graywackes

* Iliamna Volcano is usage now approved by Board of Geographic Names

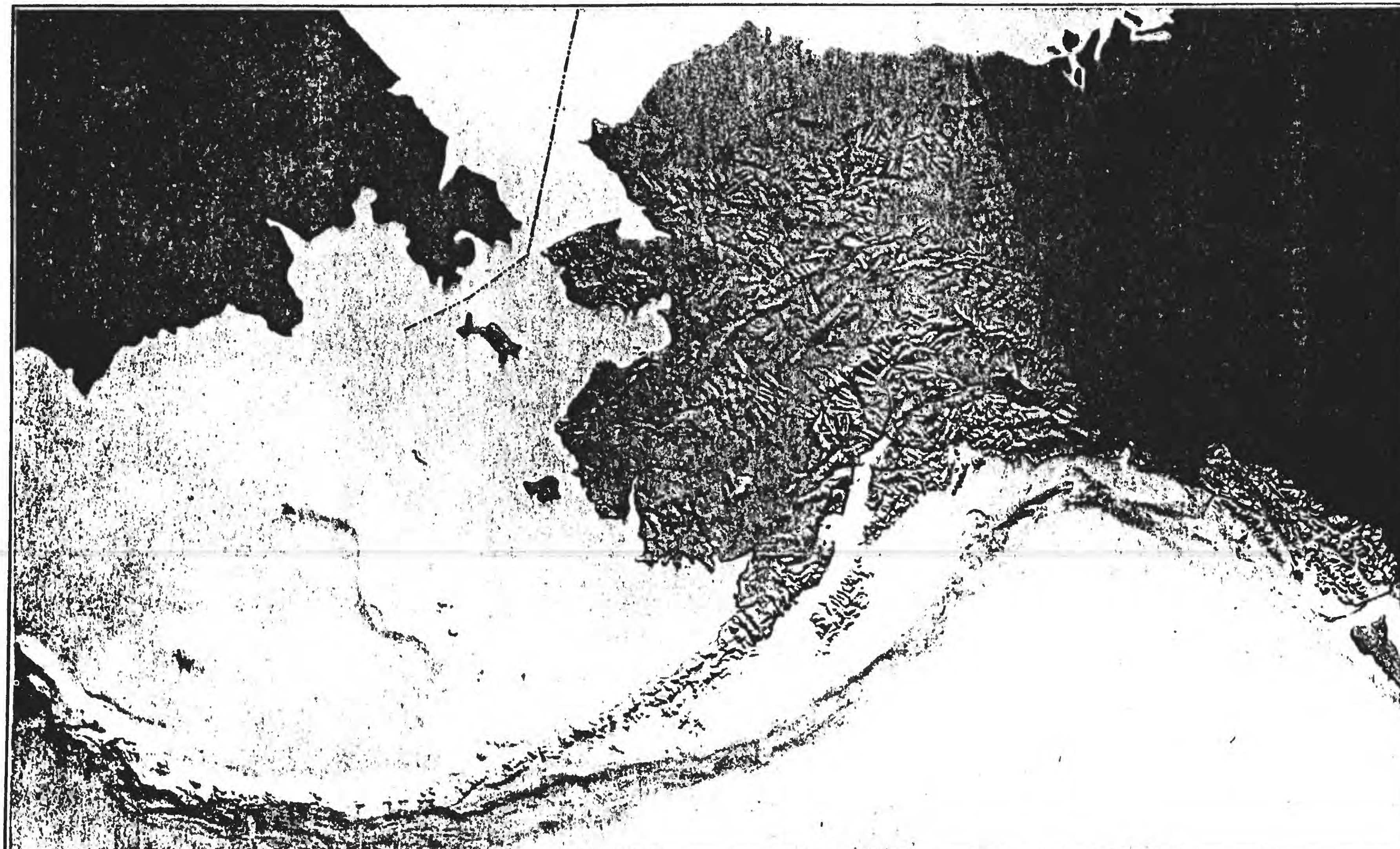
gm 7c

and conglomerates dipping gently toward Cook Inlet. Pink granophyric quartz monzonite stocks occur along the intrusive border of the quartz diorite batholith. They cut both the quartz diorite and the adjacent sedimentary rocks. The hornblende quartz diorite grades into a local muscovite-rich granodiorite in the interior of the batholith. Perhaps this is the deep "root" of a former volcano where escaping fluids altered the andesine to albite and replaced the hornblende first by biotite and secondly by muscovite.

In places along the border of the pluton the quartz diorite has been upthrust over the sedimentary rocks for very short distances along marginal reverse faults add thrust faults.

Plate 4

Index Map of Alaska Showing Location of ~~Mt.~~ Iliamna Volcano. From U.S. Geol. Survey Prof. Paper 45.



RELIEF MODEL OF ALASKA.

By E. E. Howell, from base map by U. S. Geological Survey.

INTRODUCTION

General

~~Mt.~~ Iliamna volcano is one of the 36 historically active and 40 extinct stratovolcanoes extending from Buldir Island in the western Aleutians to Mt. Spurr on the Alaska Peninsula. This volcano lies near the continental end of the 1500 mile long Aleutian belt of volcanoes (Plate 4) and is now in the solfataric condition. In contrast to many Aleutian volcanoes that rest on a relatively low landscape, ~~Mt.~~ Iliamna Volcano erupted in mountainous country. It rises at the approximate contact between the quartz diorite batholith composing the core of the Alaska Peninsula and an older basement of Lower Jurassic flows and pyroclastics.

The Lower Jurassic volcanics dip gently seaward and grade upward into 15,000 feet of Middle and Upper Jurassic siltstones, graywackes, tuffs, and conglomerates. A continuous exposure of these sediments extends from the base of the volcano to the western shore ~~coast~~ of Cook Inlet.

Pleistocene and Recent glaciers have scoured deep valleys into the constructional cone, exposing the quartz diorite and Jurassic sedimentary and volcanic rocks whose structures can be traced almost to the conduit of the volcano. Here is afforded an excellent opportunity to study the relationship of a recently active volcano to the structure of its foundation -- a relationship of particular interest in this transitional orogenic region where the Aleutian belt of volcanoes merges into the continental structure of the Alaska Range.

Topography and Drainage

The Aleutian Range divide, with drainage toward the Bering Sea on the west and toward Cook Inlet and the Pacific on the east marks the western boundary of the area investigated. Frost shattered horns and aretes rise 4,000 to 5,000 feet above the rocky coast of Cook Inlet. A swampy lowland, however, separates this range from the Bering Sea some hundred miles to the wouthwest.

Ten glaciers radiate from the slopes and snowfields of Iliamna Volcano, whose summit rises 10,086 feet above the salt marshes of Chinitna Bay 12 miles south. Of these ice tongues, Tuxedni Glacier, 15 miles long, nearly reaches salt water on Tuxedni Bay. Three bays deeply indent the coast in this area, bringing almost every portion of the interior within 20 miles of tidewater -- a considerable advantage in a region devoid of roads or trails.

Drainage from the northern sector enters Tuxedni Bay. Johnson River and Red Glacier Creek drain the eastern snowfields, flowing directly into Cook Inlet. ~~Chitina~~ Chinitna Bay receives the waters from Marsh Creek, West Glacier Creek, Middle Glacier Creek and East Glacier Creek which carry the meltwater from the southern flanks of

~~Mt.~~ Volcano Iliamna and the Aleutian Range. Iniskin Bay marks the southern boundary of the area studied.

Climate

The subpolar marine climate typical of this coastal region is characterized by strong winds and abundant precipitation (40 - 80 inches per year). A large percentage of the days are overcast, foggy, and rainy. Little time need be lost in the field on account of unfavorable weather, however, if the conditions are anticipated and ~~if~~ one arrives properly equipped. In midsummer the sun is above the horizon 16 - 18 hours per day and the temperature rarely drops below freezing. Snow leaves the lower slopes in early June and can be expected to cover the tidal marshes again by mid October or early November. At higher altitudes snow falls every month of the year.

Vegetation

White and black spruce grow in local groves from sea level to approximately 1000 feet. Cottonwood, balsam poplar, quaking aspen, birch and willows are abundant in the valleys and flood plains of the glacial streams. Below an altitude of 2000 feet dense thickets of alder cover the mountain slopes. Ferns and the ubiquitous devils club thrive under the alders and in the spruce forests. Clearings between alder patches are overgrown by salmonberry tangles, fireweed, and

4 to 5 foot growths of red top grass. Above 2000 feet rock exposures are excellent. Moss and crowberry may continue up to 3000 feet. Above this zone the rock is barren except where hidden by ice and snow.

Accessibility and Settlements

The ~~Mt.~~ Iliamna ~~region~~ Volcano area is accessible by fishing boat or float plane from Homer or Seldovia, the two nearest ~~villages~~ communities. They are 60 miles distant across Cook Inlet, and are serviced by the Alaska Steamship Company and by Pacific Northern Airlines. During the salmon season the Snug Harbor Packing Co. on Chisik Island is in operation. A small sawmill is located near the mouth of Red Glacier Creek.

Present Investigation

During the summers of 1949 and 1950 the writer was geologic field assistant to ~~Mr.~~ ~~John~~ K. Hartsock of the United States Geological Survey, who was engaged in mapping Jurassic sedimentary rocks on Iniskin Peninsula, Cook Inlet, as part of a Southern Alaskan petroleum investigation program. Reports of magnetite on Tuxedni Bay, and chalcocite cobbles found in streams draining the interior volcanic rocks, interested the Alaskan Geology Branch. Hence the writer was asked to undertake a detailed structural and petrographical investigation of Iliamna volcano and its substructure of Triassic limestone, Lower Jurassic pyroclastics, pink granite stocks, and a quartz diorite batholith. Field investigations were carried out from June 24, 1951 to September 16, 1951, and from June 7, 1952 to October 20, 1952.

Reconnaissance observations of the coastal belt of sedimentary rocks between Tuxedni Bay and Chinitna Bay are included in this report. It was thought desirable to incorporate these observations into the report because the evidence regarding the later geologic history of the older volcanic and intrusive rocks lies in these Middle and Upper Jurassic sedimentary rocks (Plate 3).

Previous Work

G. C. Martin and F. J. Katz (1912) made a brief survey of the coastal areas during a more extensive areal exploration in 1904. Fred H. Moffit, (1927) first outlined the approximate distribution of the quartz diorite, Lower Jurassic tuff breccias, and the Middle and Upper Jurassic sediments. His report is the most comprehensive

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one available heretofore, and contains a geologic map at the scale of 1 : 250,000. C.E. Kirschner and D.L. Minard (1949) published U.S.G.S. Oil and Gas Investigation Preliminary Map 95 of the Iniskin Peninsula. J. K. Hartsock with Arthur Grantz from 1948 - 1951 mapped the Iniskin Peninsula sedimentary rocks in further detail and extended their stratigraphic studies north to Tuxedni Bay. During several trips into the area west of Chinitna Bay in 1949 and 1950 they were the first to recognize the presence of quartz monzonite stocks along the border of the batholith. Mr. Hartsock's unpublished preliminary geologic map of the Iniskin Peninsula is reproduced with his permission, to show the structural relationship of the sedimentary rocks of the peninsula to the lower Jurassic volcanic rocks west of Portage Creek, the natural boundary of the peninsula. (Plate 1)

Acknowledgements

It is a pleasure to thank G. O. Gates, P. L. Killeen, and J. K. Hartsock of the Geological Survey, who made possible this geologic study of Iliamna Volcano. The willing aid and perseverance of field assistants Neely H. Bostick from Stanford University and Frank R. Holland from the University of Cincinnati, allowed the work to proceed efficiently. Cordial thanks are due Mr. J. E. Freibrock, owner of the Snug Harbor Packing Co., who extended many courtesies to the writer and made available the facilities of the cannery. R. W. Imlay of the Geological Survey identified all ammonite and pelecypod fossil material. The Triassic fauna were identified by Helen Duncan of the Geological Survey. Chemical analyses used in this report were prepared by the Geological Survey's laboratory at Denver.

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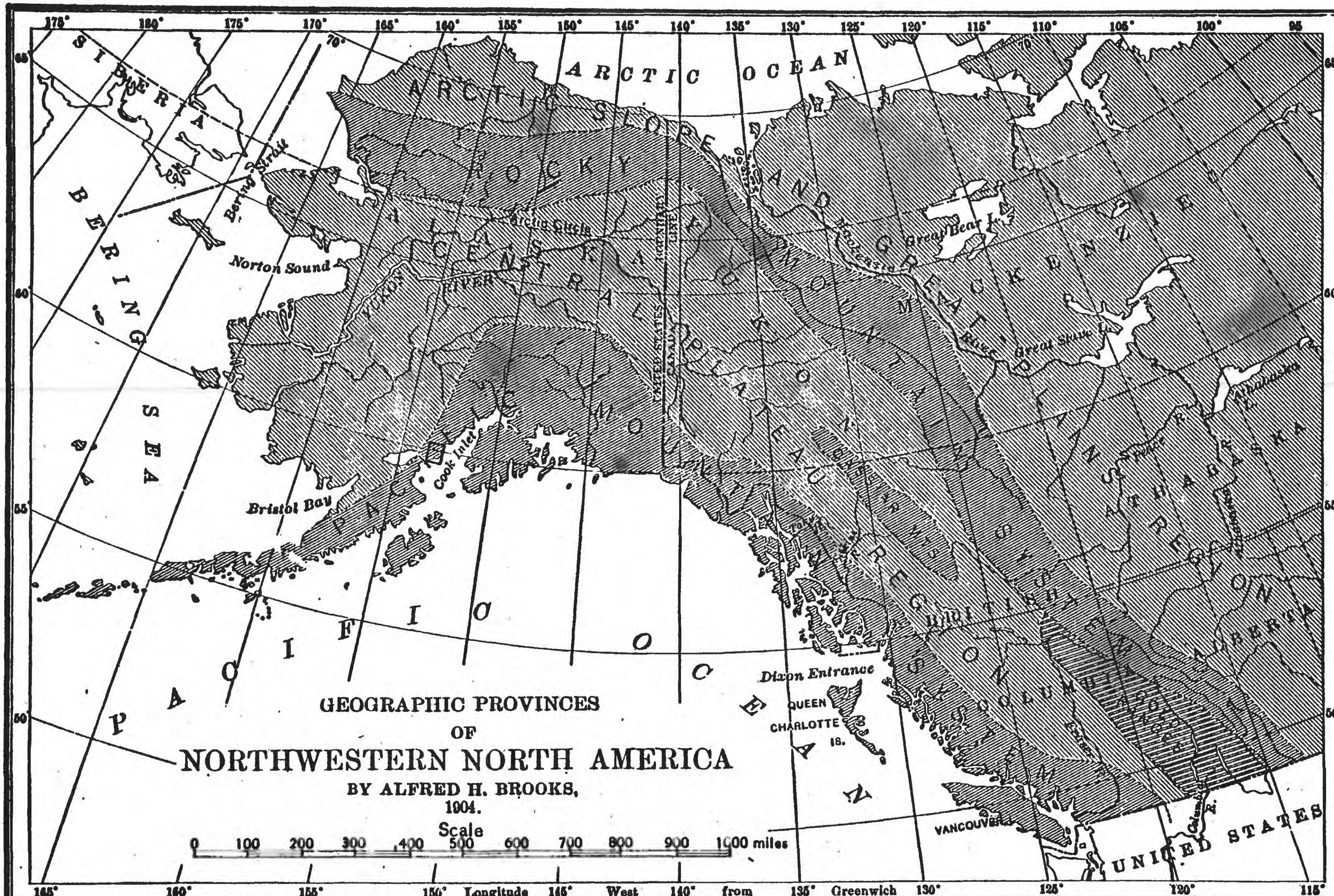
Plate 5

Geographic provinces of northwestern North America.

From U. S. Geol. Survey Prof. Paper 45.



GEOGRAPHIC PROVINCES
OF
NORTHWESTERN NORTH AMERICA
BY ALFRED H. BROOKS,
1904.

Regional Setting

According to Eardley's (1948) paleographic maps, most of Alaska was submerged during the Paleozoic era, it being an extension of the Cordilleran geosyncline. A geanticline, occupying the site of the present central plateau in Alaska (Plate 5) is thought to have separated the Cordilleran basin into an eastern and a western trough by Triassic time. The eastern trough was at the site of the present Rocky Mountains and the Brooks Range of northern Alaska. The Pacific Coast Ranges, the Alaska Range, and the Aleutian Islands are at the locus of the former western trough. Abundant graywackes, volcanic conglomerates, andesitic tuffs and flows in the Pacific coastal region suggest the presence of former volcanic islands further to the west in Paleozoic and Mesozoic time (Eardley, 1948). The Rocky Mountains to the east consist of quartz sandstones, limestones, and shale beds with a notable absence of volcanic detritus. Uplifts that deformed early Pliocene coastal deposits are thought to have elevated the Pacific Coast Range as well as the Alaska Range and the Aleutian Islands during late Pliocene time (Eardley, 1948).

Today's Aleutian volcanoes are the highest peaks of a submarine range standing over 25,000 feet above the Aleutian Deep and some 14,000 feet above the deep embayment of the Bering Basin to the north (Murray, 1945). The continental extension of this submarine range forms the Alaska Peninsula which merges into the high interior land mass culminated by Mt. McKinley.

Older Mesozoic and early Tertiary conglomerates, graywackes, mudstones, cherts, pyroclastic detritus and pillow lavas underlie the Aleutian volcanoes (Coats, 1947). The present volcanoes of Mts. Pavlof, Aniakchak, Katmai, and several others have broken through the eastward dipping sedimentary rocks on the Alaska Peninsula (Plate 2). Toward the northeast the volcanoes erupted nearer the plutonic core of the range, ~~Mt.~~ Iliamna Volcano rises near the contact of the batholith, and Mt. Spurr, the furthest continental outpost of this belt of volcanoes, is entirely surrounded by quartz diorite.

Volcanoes on the Alaska Peninsula reach heights considerably greater than those attained by the Aleutian cones. This does not seem to be caused by a larger volumetric extrusion of lava and fragmental ejecta. Instead, the greater altitudes of the cones on the Alaska Peninsula are an expression of an initially higher basement, as is strikingly borne out on the flanks of Iliamna volcano where Jurassic quartz diorite is exposed at 6,000 feet.

General Geology

The oldest rocks exposed in the substructure of Iliamna volcano are Triassic limestones and argillites. Quartz diorite and associated pink granite stocks invaded the Triassic rocks and overlying Lower Jurassic tuff breccias and flows, probably in early Middle

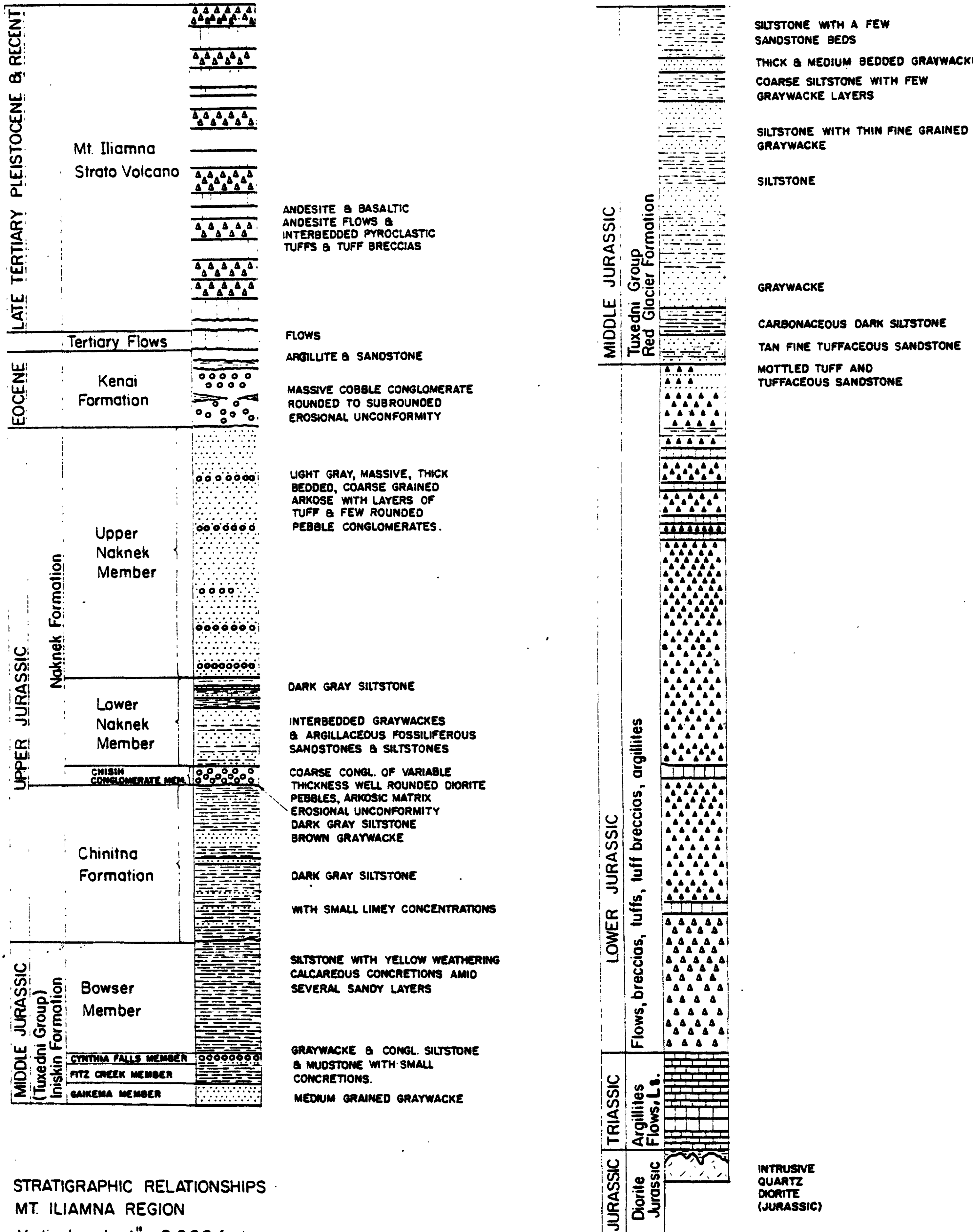
Jurassic time. The volcanic rocks grade upward into a thick section of Middle Jurassic graywackes, siltstones, and conglomerates divided into the Red Glacier formation and the Iniskin formation (Plate 6). In places an erosional unconformity separates the Iniskin formation from the jaunt ? supersecind Chinitna siltstone of Upper Jurassic age. The local Chisik conglomerate member of the Naknek formation unconformably overlies the Chinitna formation. This Chisik conglomerate member grades upward into a massive arkose sequence with several thick siltstone horizons.

No Cretaceous rocks are exposed in the area. The coal bearing Eocene Kenai formation disconformably overlies the Upper Jurassic Naknek formation with a discordance of about 5° to 10°. Its plant fossils and wide distribution suggest that it was deposited in a fresh water environment extensive over much of the Cook Inlet coastal region during Eocene time.

Conglomerate lenses from a few inches thick to several hundred feet thick occur throughout the sedimentary column. Water worn volcanic pebbles and cobbles from the Lower Jurassic volcanic beds make up a large fraction of these conglomerates. Granitic pebbles are rarely seen in the lower part of the sedimentary strata below the Iniskin formation but they become increasingly more abundant in the upper horizons. The Chisik conglomerate member of the Naknek formation contains large cobbles of quartz diorite which resemble the

Plate 6

Stratigraphic relationships, Iliamna Volcano area.



STRATIGRAPHIC RELATIONSHIPS
MT. ILIAMNA REGION
Vertical scale: 1" = 2,000 feet

quartz diorite of the Aleutian Range in every respect. Pink granophyric quartz monzonite cobbles similar in lithology to the smaller stocks are also found in these upper conglomerate layers, indicating increasing exposure of the western basement during Middle and Upper Jurassic time.

Sporadic remnants of hypersthene-augite andesite flows rest unconformably upon the Jurassic sediments. These flows seem to be products of a period of Tertiary volcanism prior to that of Iliamna volcano. No direct dating of these isolated remnants of former flows is possible.

Mt. Iliamna Volcano's andesitic and basaltic andesite flows and interbedded breccias bury the quartz diorite mountains in its immediate vicinity. On the eastern side, facing Cook Inlet, the flows lie upon a late Tertiary or Pleistocene erosional surface cut across the Jurassic sediments and volcanic rocks.

Clouds of vapor issuing from two vents are smouldering remnants of historic activity.

~~MOUNT~~ ILIAMNA VOLCANO

Historical Activity

Records of historical volcanic action at ~~Mt.~~ Iliamna Volcano are meager and may not be too reliable. The following records of former activity have been recorded.

Coats (1950)	Sapper (1927)	Becker (1898)
		1741 grew quiet
1768 smoke	1768 smoke	
	1778 smoke	1778 very active
	1779 smoke	1779 active
1786 smoke	1786 smoke	
	1793 smoke	
	1843 smoke	
March 1867 (minor explosive eruption)		
1876 smoke	1876 smoke	1876 eruption
May 1933 smoke and strong earth-quake)		
1941 steam and rumble		
June, 1947 smoke		

Whether the work "smoke" means the discharge of actual dark ash and dust clouds or whether it simply refers to the columns of water vapor like those which still issue from vents on the precipitous eastern face is not known. If we assume the word "smoke" to indicate the ejecta of actual light ash and dust then we can plot the following record of its historical activity, as far as is known (Plate 7).

According to Dall (1894) the March 1867 eruption produced a light pumice and ash fall on St. Paul, Kodiak Island 165 miles to the southeast.

Plate 7

Recorded volcanic activity, Iliamna Volcano, Alaska.

Recorded volcanic activity, ~~Mt.~~ Iliamna Volcano, Alaska.

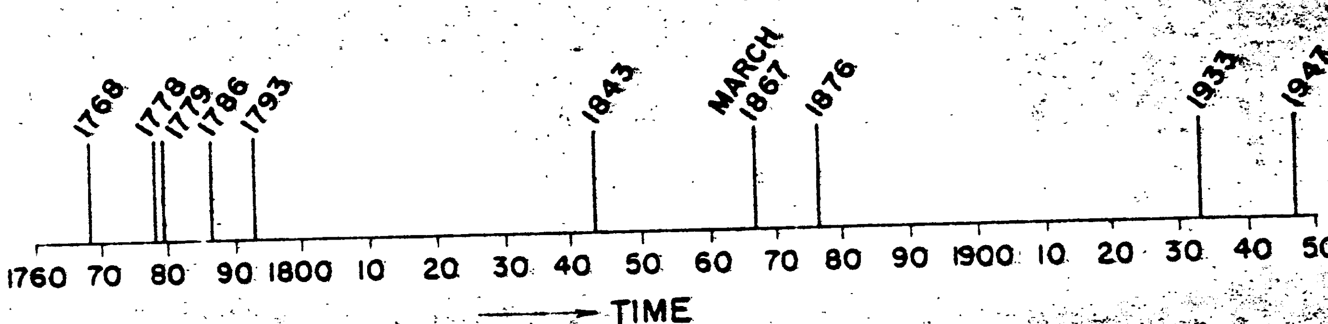


Plate 8

Iliamna Volcano

Figure 1. ~~Mt.~~ Iliamna volcano, showing vapor issuing from two steam vents. Quartz diorite batholith composing the core of the Alaska Peninsula in background.

by permission of U.S. Air Force

Figure 2. Closer view of steam vent on sharp ridge between ~~Mt.~~ Iliamna Volcano and North Twin. This is a detailed view of the foremost vent in figure 1 above.

by permission of U.S. Air Force

15865

28170 A.C

similar to A-28712 AC

Plate 8

I.C. Russell (1897, p211) writes: "In the summer of 1895 it was sending out five or six columns of steam and seemed peaceful enough. A few years ago, however, it was in violent eruption and discharged such a profusion of hot dust and lapilli that the timber over hundreds of square miles of the adjacent tableland was killed." Unfortunately the source of this information is not given. Perhaps this refers to the March 1867 eruption. The magnitude of the eruption seems somewhat exaggerated. Today only a few cinder lapilli, which may be remnants of this ash fall, can be found in protected topographic depressions at high altitudes.

Of the two vents which still send forth clouds of vapor one is located on the very sharp ridge between ~~Mt.~~ Iliamna Volcano and North Twin (Plate 8). The other one overlooks Red Glacier on the precipitous eastern face, and sends its column of vapor billowing over the ice cap of Iliamna Volcano. Both vents are quite inaccessible. Free sulphur and gypsum crystals found on Red Glacier indicate the presence of these sublimates near the vent. A greenish yellow staining is visible around the orifice of the vents and at times sulphurous fumes have been smelled at sea level. The present steam vents are only small openings located in the porous throat filling of the former crater. Occasionally a low rumble can be heard accompanying the emission of an unusually strong steam expulsion.

Geologic Setting

Iliamna volcano erupted in mountainous country topographically like that of the present Aleutian Range, or Chigmit Mountains, as the range is called locally. The lavas and pyroclastics poured out upon a landscape 4,000 to 5,000 feet above sea level. The structure of the basement seems to have been essentially the same at the time of the construction of this stratovolcano as it is today. The seaward dipping Jurassic sedimentary and volcanic rocks were already elevated to their present position and erosion had exposed the quartz diorite batholith. Lavas from Iliamna volcano are completely undeformed. They flow across some large faults in the basement Jurassic rocks but are unaffected -- indicating no renewal of faulting after extrusion.

By projecting the contact between the quartz diorite batholith and the Lower Jurassic volcanics exposures in deep glacial valleys on the flanks of the volcano it seems that the lavas broke forth along several closely spaced vents either actually at the contact of the batholith or as much as 1 1/2 miles within the batholith itself.

The viscous hypersthene augite andesite lava flowed only short distances from its source. Instead of spreading out into a great lateral shield volcano, Iliamna built a steep cone that rose about 5000 feet above its foundation.

On the eastern side of ~~Mt.~~ Iliamna Volcano, overlooking Cook Inlet, the longest single lava flow ends at 1000 feet above sea level. This East

Glacier Flow extends six miles from its source and covers the Jurassic basement as well as the large Horn Creek Fault.

The lavas flowed over the quartz diorite batholith on the western and northern flanks. Boulders of quartz diorite are incorporated into the base of the flows where the lavas moved over talus piles or down bouldery stream beds (Plate 9, figure 1). The western flows dip about 10° in their lower reaches and become steeper toward their source. Thick tuff breccias containing cognate inclusions composed of dark scoriaceous blocks and cinder lapilli embedded in a lapilli tuff matrix are interbedded with the flows. These deposits dip 10° - 15°. Most fragments are quite angular and measure from a few inches to as much as a yard in their greatest dimension. The fragments show no evidence of welding or agglutination. Slight sorting of the interbedded layers of ejectamenta suggest that they may have been erupted as dark Vulcanian clouds of previously solidified ~~c~~volcanic materials.

These pyroclastic deposits are well exposed in mesa like remnants which rise steeply above the surrounding glaciers. Glacial scouring coupled with the heavy precipitation have severely dissected the flows and particularly the porous interbedded pyroclastics and crater fillings. Mt. Nick is a lone quartz diorite peak surrounded by glaciers and capped by a needle of a half dozen tall lava columns -- the last outposts of a once more extensive flow.

Plate 9

Cobbles Incorporated into Base of Flow

Quartz diorite talus boulders and broken fragments of lava incorporated into base of flow from Iliamna volcano where it advanced over quartz diorite basement.

Plate 9

Structure of the Volcano

Iliamna volcano is not a simple symmetrical cone. It is the highest one of four peaks comprising a north-south trending ridge of eruptive andesites approximately three miles long. From south to north the peaks are named South Twin, Middle Twin, North Twin and ~~Mt.~~ Iliamna Volcano (Plate 10). These peaks are separated by low saddles on a sharp treacherous ridge.

~~Mt.~~ Iliamna Volcano is capped by a few flows which cover a massive porous crater filling beneath. Apparently Iliamna Volcano is the remnant of the northwestern edge of the old crater from which the lavas issued. This crater has been breached by Umbrella Glacier which exposes an excellent cross section of the light yellowish gray porous vent filling in a cliff about 2000 feet high. In this exposure the flows and interbeds of fragmental ejectamenta can be seen dipping about 10° - 15° outward from the vent filling with which they interdigitate. These flows can be traced in longitudinal section far down the western slopes of the volcano out to their terminus on the quartz diorite.

North Twin is composed entirely of a yellow-gray vent filling of opalized tuff and lapilli tuff. Flows extend from it to the southeast toward Red Glacier.

Middle Twin is a continuation of the crater filling on North Twin. The two peaks are separated only by a topographic saddle. Gray andesite flows dip steeply to the south from Middle Twin and one of the flows forms a major part of South Twin. The porous crater filling does not extend to this southern peak. South Twin is composed of flows and pyroclastics erupted from an old crater whose locus was at the present site of Middle and North Twin.

Remnants of a small parasitic crater are preserved in a porous opalized throat filling on the ridge between the upper reaches of Umbrella Glacier and Middle Glacier. Fiery red, oxidized scoria is found at the edge of the white opalized vent filling.

The Lavas

The dominant lava flows of ~~Mt.~~ Iliamna volcano are hypersthene-augite andesites. Most of the flows are a light gray color with a pilotoxitic texture. They range in thickness from about 400 feet to 80 feet. Columnar joints are developed, but they are not as well developed as in plateau basalts. Most joints are irregular and are not bounded by sharp clean cut faces. A platy jointing probably due to viscous-shear following planes of laminar flow in the lava is commonly present in the central and lower parts of the flows. On the exposed ridges these platy shingles and slabs accumulate into thick unstable talus heaps which clatter to lower elevations upon the slightest provocation. This platy jointing is generally parallel to the surface of the flows but may also be oriented in several other directions.

[illegible] Iliamna volcano

Plate 10

Structure of ~~Mt~~. Iliamna volcano

and North, Middle, and South Twins

by permission of U.S. Air Force

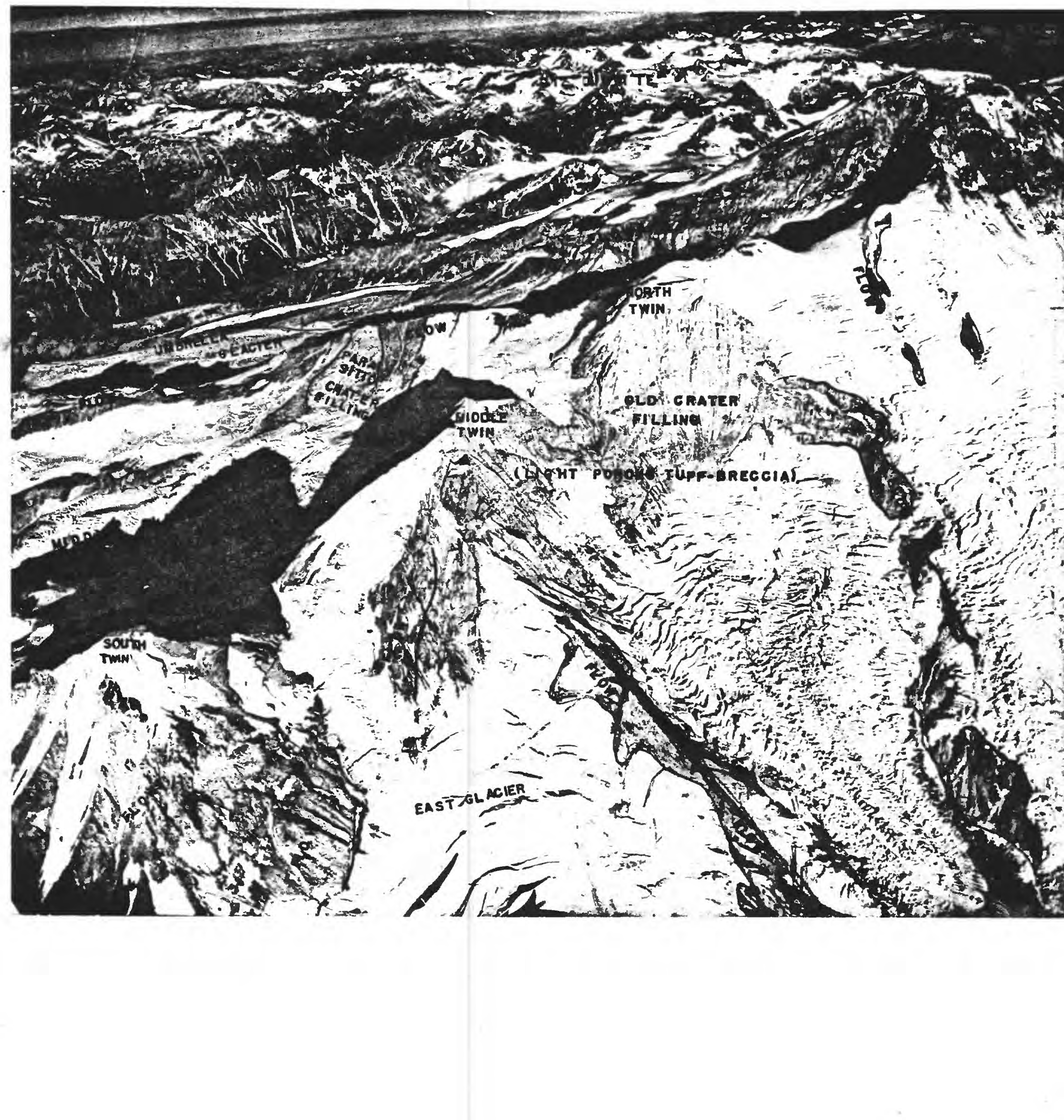

NORTH TWIN
OLD CRATER FILLING
MIDDLE TWIN
SOUTH TWIN
EAST GLACIER
FLOW

Plate 11

Oscillatory Zoned Plagioclase

Oscillatory zoned plagioclase phenocryst in hypersthene augite andesite flow. The zones range in composition from sodic bytownite at the core to andesine at the rims. The rims are of the same composition as the microlites in the surrounding groundmass.

(crossed nicols X75)

Plate 11

These lavas contain phenocrysts of plagioclase seriately ranging in length from large 2 mm intratelluric phenocrysts to the finest microlites, although a slight hiatus in size distribution is often noticeable between the fine microlites of the groundmass and the smallest phenocrysts. Oscillatory zones ranging in composition from sodic bytownite to andesine are clearly displayed in the phenocrysts (Plate 11). The last outer zone of the rim is usually of the same composition as the microlites in the groundmass. Glass inclusions are very abundant in the plagioclase phenocrysts. In many phenocrysts the glass inclusions are arranged concentrically with respect to the oscillatory zones of the crystals. In others they are randomly scattered as large elongate globules. The glass is a very clear pale greenish color in the phenocrysts collected from near the interior of the flows, but if the flow has been oxidized and the groundmass glass is a red translucent color, then the glass inclusions within the phenocrysts invariably are also oxidized to the same red color. Tiny inclusions of augite and magnetite may also be found in the plagioclase crystals.

Phenocrysts of augite and hypersthene range in size from about 1.5 mm to .1 mm. The hypersthene and augite are not present in as large a quantity as the plagioclase phenocrysts.

Small amounts of olivine occur in some of the flows, generally less than one percent. It is common in the red very rapidly chilled scoriaceous lapilli cinders near the vents or at the surfaces and bases

Plate 12

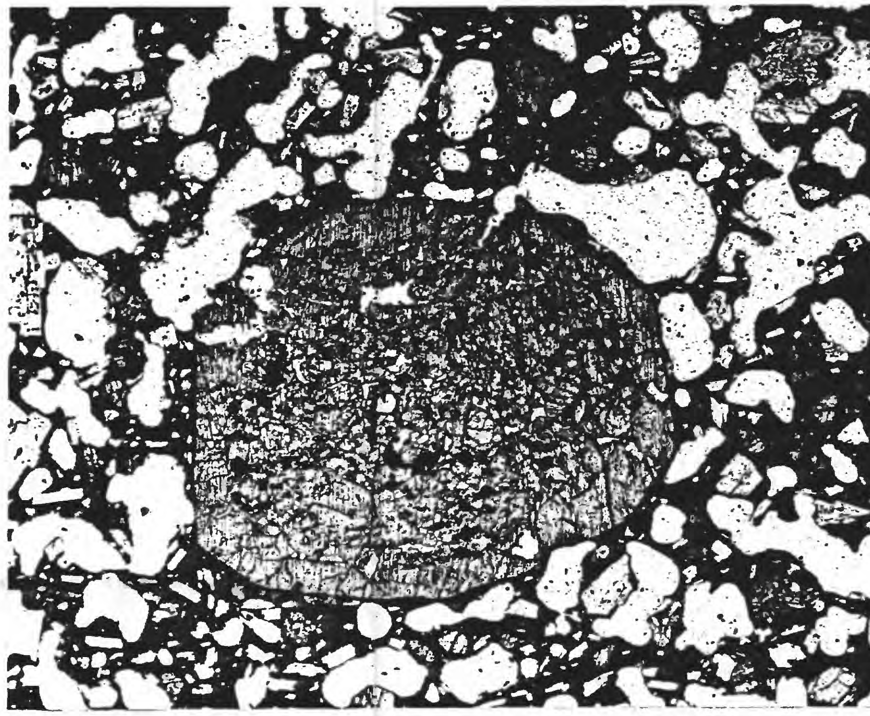
Unstable Ølivine

Figure 1. Large augite phenocryst with small olivine grain at its core which was nearly entirely resorbed. Vesicular oxidized surface of lava.

(plain light X43)

Figure 2. Unstable olivine partially resorbed in vesicular lava near surface of a flow from Iliamna volcano.

(plain light X40)



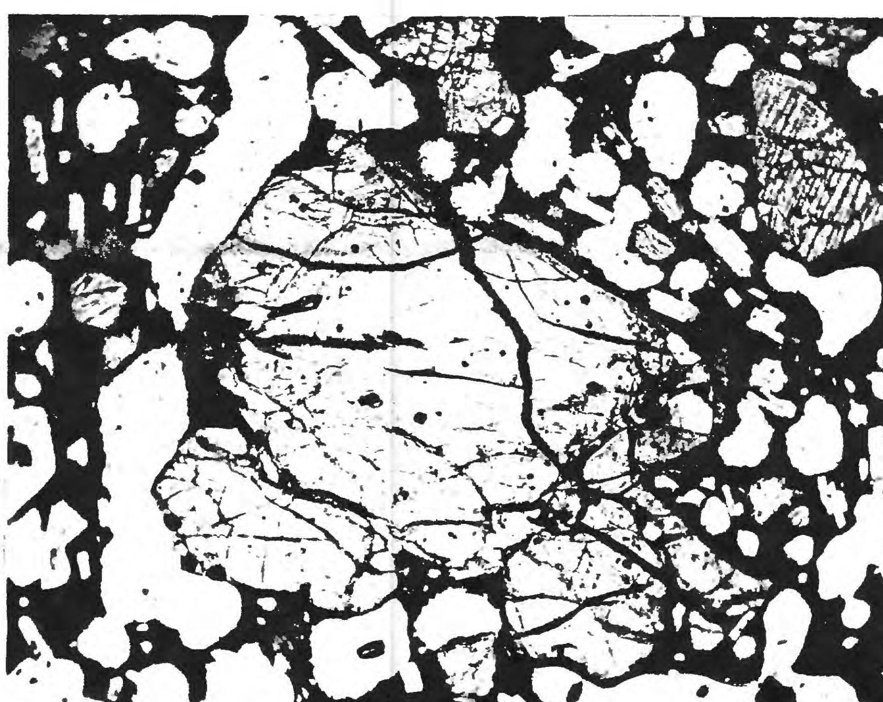


Plate 12

of flows. Deuteric red brown iddingsite replaces some of the olivine along cracks and cleavages. One grain of olivine was found to form the core of a large augite phenocryst (Plate 12, figure 1). More commonly borders of fine augite and hyperathene grains surround larger grains of olivine, indicating an early stage of reaction of olivine with the lava which froze before the reaction could go to completion. This instability and partial resorption of olivine is noticeable in many of the flows (Plate 12, figure 2).

The groundmass of these andesite lavas consists of very fine randomly oriented microlites packed into a dense mesh with relatively little glass -- a typical pilotaxitic texture. Granules of magnetite are scattered throughout the groundmass. In some of the darker flows the groundmass is more glassy. It becomes quite hyalopilitic at the rapidly chilled borders and in the oxidized scoria.

Oxidation of the Lavas

On the western slopes of Iliamna Volcano where the flows can be traced vertically and horizontally in the great cut made by Umbrella Glacier the gray lava of the flows grades down into a fine red vesicular zone. Large blocks and angular fragments of gray lava in a slaggy matrix such as is common in the lower reaches of some flows are rarely seen near the source. Here the basal zone is a fine vesicular scoria usually only a few feet thick, rarely exceeding 15 feet.

Plate 13

Oxidized Lava

Oxidized pyroclastic bed near craters on Ridge between Middle Glacier and Umbrella Glacier. Note fragment of gray lava imbedded in the oxidized matrix.

Plate 13

It may contain some red oxidized lapilli. The columnar joints of the flow continue into this vesicular oxidized base. Nearer the vents all gradations are found from dense lava, frothy slag, disrupted scoria, and airborne cinders which became welded upon deposition or remained unaltered.

The lavas which have vesiculated commonly show a red "burned" color, apparently due to crystallization of hematite from the glass (Plate 13). The complete succession of changes which take place in the conversion of normal gray andesite to the red scoria was traced in a series of samples collected from the inner parts of the flows to their pink basal portion, and from the brightest red scoria found near the vents.

Several mineralogical changes occur successively from the interior of the flows to the red basal zones.

1. The glass of the groundmass is a pale light greenish color and contains scattered magnetite granules. As oxidation proceeds the magnetite becomes more abundant and the glass gradually turns a pale brown. Finally in the red scoria the glass is a translucent fiery red due to the conversion of ferrous iron in the glass to microcrystalline hematite dust.

2. The glass inclusions in the large plagioclase crystals change simultaneously and in like manner with the glass of the groundmass. At first it is a pale green color. As

Plate 14

Oxidized Glass Inclusions

Figures 1 and 2. Glass inclusions sealed in plagioclase crystals. The inclusions are normally a pale green color at the center of the flows. Here in the red oxidized lava they are also a translucent red indicating that high surface temperatures of the flows may have promoted the conversion of ferrous iron into minute hematite specks. Since the glass inclusions are sealed within the crystals of plagioclase oxygen for the oxidation of the iron may have been derived from the glass itself rather than from atmospheric oxygen.

(X75 plain light)

(X75 crossed nicols)

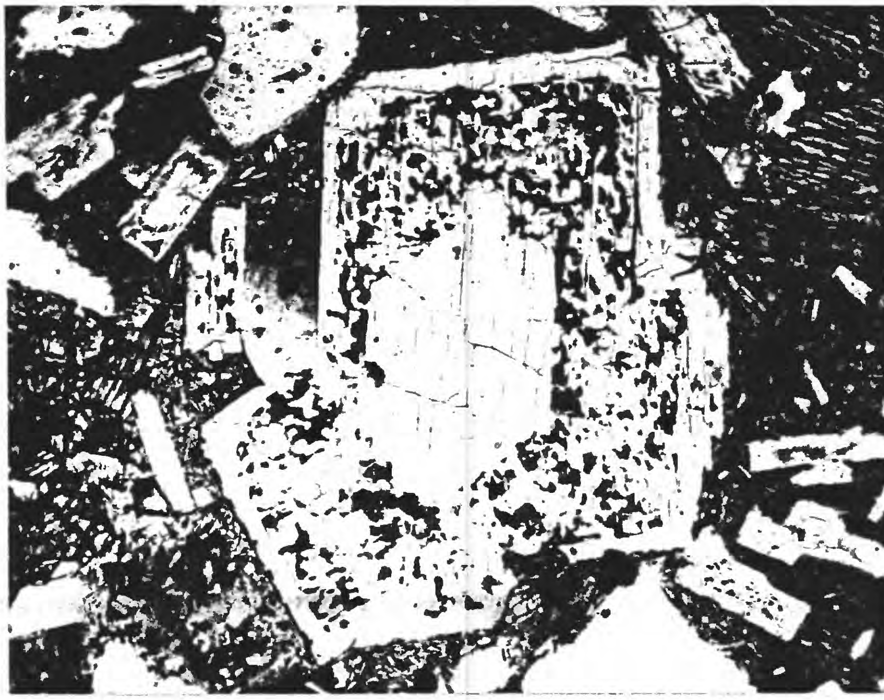


Plate 14

Chemical Analysis of Rocks

1. Normal Gray Andesite from East Glacier Flow (52A Ju 268B)

Oxide	wt.o/o	Atom	wt.o/o
		O	47.06
SiO_2	58.40	Si	27.05
Al_2O	18.02	Al	9.56
Fe_2O_3	2.67	$Fe^{(+++)}$	1.87
FeO	3.59	$Fe^{(++)}$	2.79
MgO	3.59	Mg	2.17
CaO	7.39	Ca	5.31
Na_2O	3.64	Na	2.70
K_2O	1.02	K	.85
H_2O	.35	H	.04
H_2O^+	.39	H	.04
TiO_2	.65	Ti	.39
P_2O_5	.17	P	.08
MnO	.13	Mn	.10
	100.01		100.01

2. Red Vesicular Scoria from Middle Twin (52AJu 531)

Oxide	wt o/o	Atom	wt.o/o
		O	46.60
SiO_2	56.48	Si	26.10
Al_2O_3	18.21	Al	9.75
Fe_2O_2	6.01	$Fe^{(+++)}$	4.20
FeO	1.01	$Fe^{(++)}$	.78
MgO	4.00	Mg	2.41
CaO	7.98	Ca	5.84
Na_2O	3.51	Na	2.60
K_2O	.95	K	.79
H_2O	.06	H	.01
H_2O^+	.64	H	.07
TiO_2	.62	Ti	.37
P_2O	.17	P	.07
MnO	.14	Mn	.11
	99.78		99.78

the lava becomes a pink gray color many magnetite inclusions in the plagioclase are noticeable also. These glass inclusions finally turn a pale brown and are red in the scoriaceous red rock (Plate 14, figures 1 and 2).

3. Hypersthene and augite in the early stages of oxidation have slightly opaque borders and become quite dark in some of the highly oxidized rocks due to the exsolution of magnetite.

If the glassy groundmass became oxidized only around the vesicles one might suspect that the oxygen necessary to oxidize ferrous iron to hematite was derived from the air. Since the glass inclusions inside of the plagioclase crystals, however, are also filled with hematite dust, it seems probable that the oxygen needed to form the crystallic ferric oxide has been supplied from the oxygen atoms of the glass itself. It would be quite difficult for atmospheric oxygen to reach the glass inclusion within the plagioclase phenocrysts.

The chemical analyses as well as the pale green color of the glass in thin section indicate that much of the iron is originally in the ferrous state within the glass. In the red scoria two changes have befallen the ferrous iron.

(1) It has been converted to ferric iron

(2) It has changed from the glassy state into the crystalline structure of hematite.

Analytical errors and inhomogeneities within the lava should always be kept in mind when comparing chemical abundance values. Yet the above analyses indicate that the two lavas have nearly the same oxygen content. In fact the red scoria may have slightly less oxygen than is present in the normal gray flow. This is in harmony with the suggestion that the oxidation of the ferrous iron was largely effected by oxygen derived from the siliciate glass, and that atmospheric oxygen has played only a minor role.

If this is the case then why does the ferrous iron oxidize to ferric iron and combine with oxygen near the outer surface of the lava and not in the interior? A possible explanation may be found in temperature measurements made in Kilauea lavas. Jaggar and others have observed that the surface lavas may be several hundred degrees warmer than the lava at greater depths. This rise in temperature at the surface seems to be produced by exothermic reactions occurring in the escaping volatiles.

Normally ferrous oxide is connected to ferric oxide more readily at a higher temperature than at a lower temperature. Perhaps the same is true when the oxygen is derived from the glassy siliceous melt permitting hematite to crystallize. Unfortunately no direct measurements have been made to detect the change of oxidation potential of iron with increasing temperature in silicious glasses.

The East Glacier Flow

East Glacier flow extends about six miles from South Twin to East Glacier Creek and is the longest lava tongue in the Mt. Iliamna Volcano area. Actually there are two flows -- the long lower one and a short upper one which just protrudes from under the East Glacier snowfield. The upper flow is separated from the lower tongue by a basal block breccia zone similar to the one at the base of the lower flow. This East Glacier flow moved out upon the Jurassic volcanic and sedimentary rocks. It covers the trace of the large Horn Creek fault. Apparently this flow once filled an old valley. Today, however its wide mesa-like top is bounded by two deep gorges on either side, revealing its foundation and exposing a longitudinal section of the flow (Plate 15, figure 1).

This lava is a light gray color. Phenocrysts of oscillatory zoned plagioclase as well as hypersthene and augite are embedded in a pilotaxitic groundmass of andesine microlites with some pale greenish glass. Magnetite granules bespeckle the groundmass. Toward the base the lava is tinted light pinkish gray by minute flecks of hematite in the glass. The upper surface of the flow is vesicular. This porous zone grades downward into a zone of contorted and poorly developed joints. The flow is approximately 200 feet thick and is floored by a 20-40 feet thick basal blocky breccia which thickens toward the end of the flow. This breccia consists of blocky fragments of lava, short broken pieces of columns, and cobbles of the Jurassic volcanics all incorporated into a

Plate 15

East Glacier Flow and Basal Breccias

Figure 1. The East Glacier lava flow is the longest tongue of lava from Iliamna volcano. Streams have cut deep valleys on both sides exposing it in longitudinal section.

Figure 2.

Coarse basal breccia beneath East Glacier flow. Columnar joints do not extend into the coarse breccia under the flow.

Figure 3.

Closer view of basal breccia under East Glacier flow showing blocky lava and a broken column incorporated in the red slaggy matrix which formed at the encrusting end of the flow only to be rolled underfoot by the still advancing fluid lava.

Plate 15

red disrupted matrix of slaggy lava (Plate 15, Figures 2 and 3). The lava apparently continuously overrode its encrusting end which was endlessly being rolled underfoot to form a "road bed" for the advancing viscous tongue.

Variation of Basal Breccias with Distance from the Source of the Flow

The coarse blocky breccia under the East Glacier flow, which is 5 or 6 miles from its source, is of an entirely different nature from the fine vesicular breccia found under the flows that moved down the west slope of ~~Mt.~~ Iliamna volcano where the parent crater is close at hand (Plate 16, figure 1). On the western flank the gray lavas grade into a fiery red oxidized vesicular zone which is only a few feet thick (Plate 16, figure 2). Columns developed in the flows by contraction upon cooling extend into the basal zone. Near the crater the red zone is only a little disrupted, further down the slope the breccias contain larger angular fragments and cinder lapilli. This fine breccia contrasts sharply with the large blocks of solidified cognate lava and fragmentary pieces of columns and foreign boulders all incorporated into a coarse slaggy matrix as is found in the lower reaches of the East Glacier flow. The columnar joints never extend into this blocky basal breccia under the East Glacier flow.

The change in the nature of the basal breccia with distance from the source can best be understood by observing how such a breccia originates. This brings us to the problem of how a lava flow advances --

Plate 16

Flow on High Western Flanks of Volcano

Figure 1. Andesite flow far on high western flanks of ~~Mt.~~ Iliamna Volcano. Columnar joints are not as well developed as in plateau basalts.

Figure 2. Closer view of the base of the flow near its source on the high western flank of ~~Mt.~~ Iliamna Volcano. Note the contrast in texture between the basal breccia of this flow near its source and the basal breccia under the lower reaches of the East Glacier Flow 5-6 miles from its source (Plate 15). Here columnar joints extend into the fine welded oxidised basal portion which is considerably thinner and finer grained than the breccias under the distant end of the East Glacier Flow.

a problem of fluid flow on an open surface or channel in which the moving fluid is continually freezing at its cooling forward end.

The viscosity of lava issuing from its conduit may vary from that of a viscous plug or spine to that of a highly fluid incandescent flow. The distance that a molten flow moves before its cooling end begins to become encrusted will increase with:

1. increase of the initial temperature of the lava
2. increase of the initial gas content of the lava
3. increase of the rate of extrusion of the lava
4. increase of the slope of the land surface
5. increase of the total mass of lava extruded
6. increase of thickness of the flow
7. increase of temperature of the surroundings

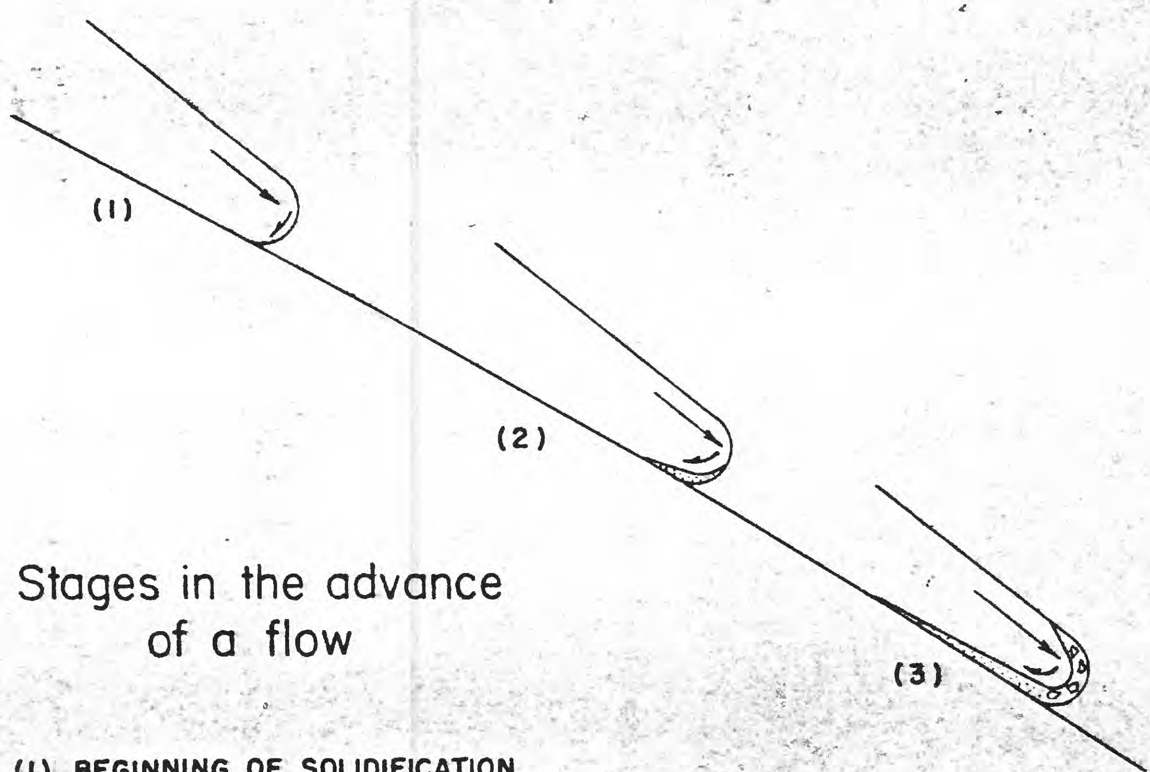
The distance the flow moves before solidifying, however, will decrease with:

1. increase of melting point of the lava
2. increase of heat conductance of the lava
3. increase of initial viscosity of the lava

We need to see what is taking place at the end of an advancing flow to determine the type of basal breccia which will result since it is at the extremity of the moving tongue where the basal breccia seems

Plate 17

Stages in the Advance of a Flow



Stages in the advance
of a flow

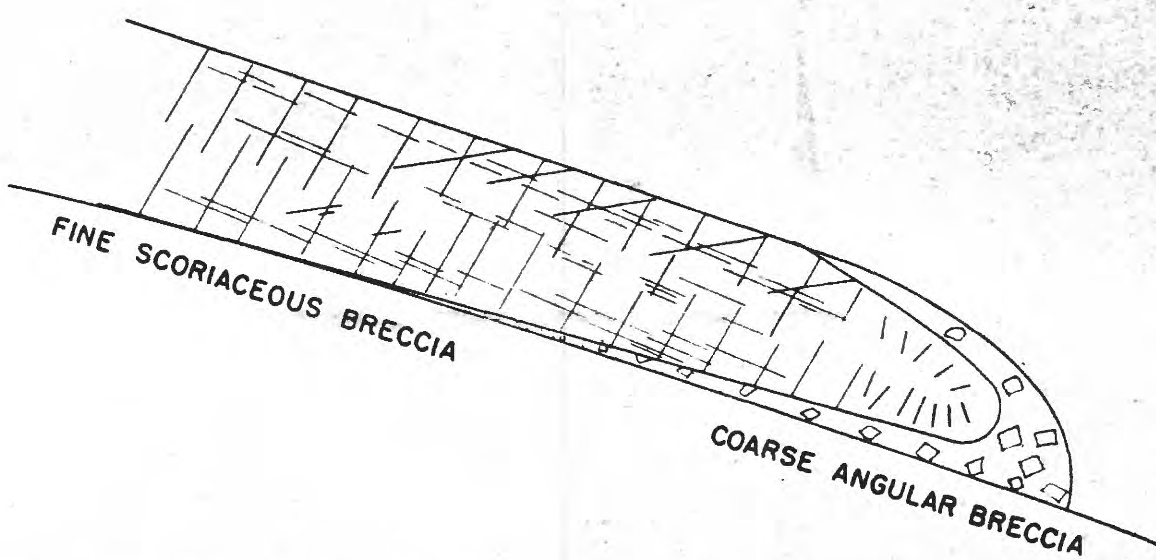
(1) BEGINNING OF SOLIDIFICATION

(2) SLIGHT SCORIACEOUS FROTH ENCRUSTS THE END

(3) BLOCK LAVA BEGINS TO FORM - THE END IS COOLING RAPIDLY

Plate 18

Schematic sketch of lava flow showing variation of basal breccia with distance from source.



Schematic sketch of lava flow showing variation of basal breccia with distance from source.

to originate. This process may perhaps be qualitatively portrayed as follows.

Upon issuing from the conduit, the molten lava may be fountaining and sending up frothy spray which falls back into the glowing flow only to become remelted again. The base of the lava coming into contact with the cool surface may form a dense glassy selvage. If gases are being profusely emitted the selvage may be quite frothy. Rushing down the slope as a glowing ribbon the flow gradually loses its heat and a vesicular scum may form at the cooling end (Plate 17). This scum will be rolled underfoot by the advancing flow and probably forms the granular red cindery breccia underlying the flows on the western flanks of Iliamna Volcano.

The distant forward moving snout of the flow becomes more and more viscous and a blocky slaggy crust develops there while the near vent part of the flow is still a glowing fluid. The slope of the land surface and hydrostatic head of the lava will keep the fluid portion of the flow moving every forward -- continually overriding the viscous end of jostling crumbling blocks and slaggy lava. Finally all motion stops. The blocky end of the flow grades into the basal breccia (Plate 18) and a scoriaceous surface forms on the upper reaches of the flow. As the lava cools, columnar joints begin to grow upward from the base and downward from the surface. They begin in the red scoriaceous welded base at the upper end of the flow but never form in the slaggy breccia underlying the lower end of the flow.

Opalization of the Crater Fillings

Solfataric activity has decomposed the crater fillings of andesite tuff to a white or light yellowish gray opaline mass with a considerable quantity of free sulfur (Plate 19, figure 1). Comparison of the chemical analyses of the opalized vent filling and unaltered andesite from the East Glacier flow sheds some light on the opalization process.

East Glacier Flow normal andesite (52A Ju268B)		*Opalized Vent Filling from North Twin (52A JU 527)	
Oxide	wt. o/o	Oxide	wt. o/o
SiO_2	58.40	SiO_2	54.83
Al_2O_3	18.02	Al_2O_3	2.13
Fe_2O_3	2.67	Fe_2O_3	3.38
FeO	3.54	FeO	.09
MgO	3.59	MgO	1.69
CaO	7.39	CaO	11.24
Na_2O	3.64	Na_2O	.62
K_2O	1.02	K_2O	.09
H_2O	.35	H_2O	6.51
H_2O^+	.39	H_2O^+	1.27
TiO_2	.65	TiO_2	.62
P_2O_5	.17	P_2O_5	.01
MnO	.13	MnO	.02
	100.01		82.50

*Also free sulfur - abundance not precisely determined

Plate 19

Opalized Crater Fillings

Figure 1. Breached Crater of Mt. Iliamna volcano at the head of Umbrella Glacier. The light rock under the summit ~~of Mt. Iliamna~~ is a light yellowish gray opalized vent filling. A considerable quantity of free sulfur has also been introduced by the solfataric gases.

Figure 2. At the edge of opalized throat filling of parasitic crater on the ridge between Umbrella Glacier and Middle Glacier. Red oxidized pyroclastic bed at the edge of the old crater and some dark glassy vesicular lava interbedded with the "burned" breccia.

Figure 3. Opalized plagioclase phenocrysts. Note the preservation of original zoning in these opaline pseudomorphs. (x75, plain light)

?-?1-32

Plate 19

*The analyst had difficulty with the opalized sample. The free sulfur determination did not quite make up for the discrepancy between 82.5 o/o and 100.0 o/o.

These analyses indicate that Al^{+++}, Fe^{++}, Mg^{++}, Na^{+}, K^{+}, P^{++++}, Mn^{++} have been largely removed from the andesite vent filling by the acid solfataric solutions. Note the drastic decrease in the weight per cent of Al_2O_3 from 18.02 o/o to 2.13 o/o by weight. Much of the ferrous iron which was not removed in solution was converted into ferric iron probably in the form of limonite -- which now streaks these light opaline deposits a rusty brown in places (Plate 19, figure 2). The silica remaining from the decomposed silicate minerals was converted into opal by the addition of water. Note the high content of low temperature water of hydration (6.51 o/o by weight) which is present in the opalized rock.

Vestiges of the original zoned plagioclase which the opal completely replaces are exquisitely preserved in minutest detail. Even traces of the original zones in the plagioclase are still visible in ordinary light (Plate 19, figure 3). Under crossed nicols these opal pseudomorphs after plagioclase extinguish completely. Chalcedony is present in many of the pore spaces of the original rocks. It is riddled with minute flakes of white mica. The high CaO content is difficult to account for -- possibly it is present as dispersed gypsum. No gypsum as such was recognized under the microscope, however.

E. T. Allen (1934) has pointed out that replacement of lavas by opal is a common feature in the Lassen Peak and Yellowstone volcanic areas. The juvenile gases H_2S, SO_2 and SO_3, rising through the porous crater filling are oxidized and hydrated to sulfuric acid. HCl and CO_2 are also common volcanic emanations which produce hydrochloric and carbonic acid. These acid waters circulate through the vent filling of the porous andesite selectively removing iron, aluminum and other cations from the silicates and leaving only the insolube silica as a hydrous opal-ine pseudomorph after the former crystals.

Correns (1949) shows the change in solubility of alumina, iron, and silica with varying pH conditions (Plate 20). Silica is quite insoluble in the acidic solutions but the solubility of the amphoteric iron and alumina increases rapidly in an acid environment. The inherent solubility differences of these ions determines their distribution and migration within the volcano.

The process may schematically be depicted as follows:

H_2S, SO_2, SO_3 $\xrightarrow[\text{hydration}]{\text{oxidation}}$ sulfurous and sulfuric acids

HCl, CO_2 $\xrightarrow[]{\text{hydration}}$ hydrochloric and carbonic acid

$Ca_{1-x}\,Na_x\,Al_{2-x}\,Si_{2+x}\,O_8 + H_2O$ Fe, Mg $(SiO_3)_2$ + H_2O

leached out by acid waters — opal $SiO_2(H_2O)_x$ — leached out — opal

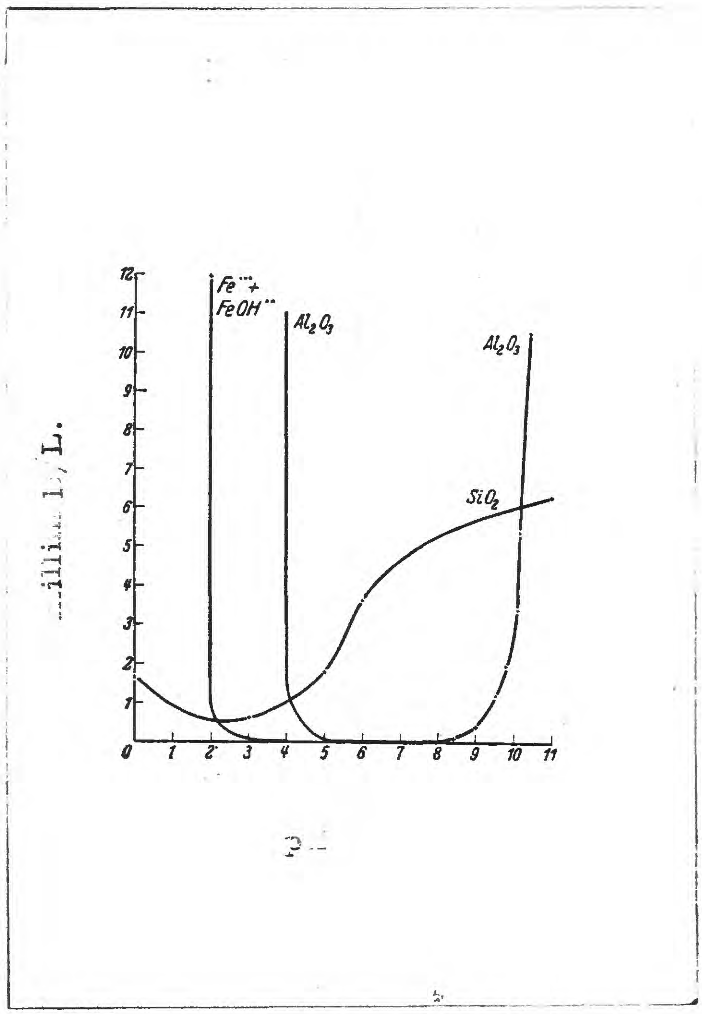
The acid waters remove the acid soluble cations leaving only a residue of hydrous opaline pseudomorphs (Plate 21).

Plate 20

Variation of Solubility of Alumina, Iron and Silicon with pH

Figure 1. Solubility of iron, alumina, and silica under various pH conditions. Iron and alumimum become quite soluble in an acid environment. Silica decreases in solubility in acid solutions, hence, it remains behind as opaline pseudomorphs.

From Correns (1949, p. 210)



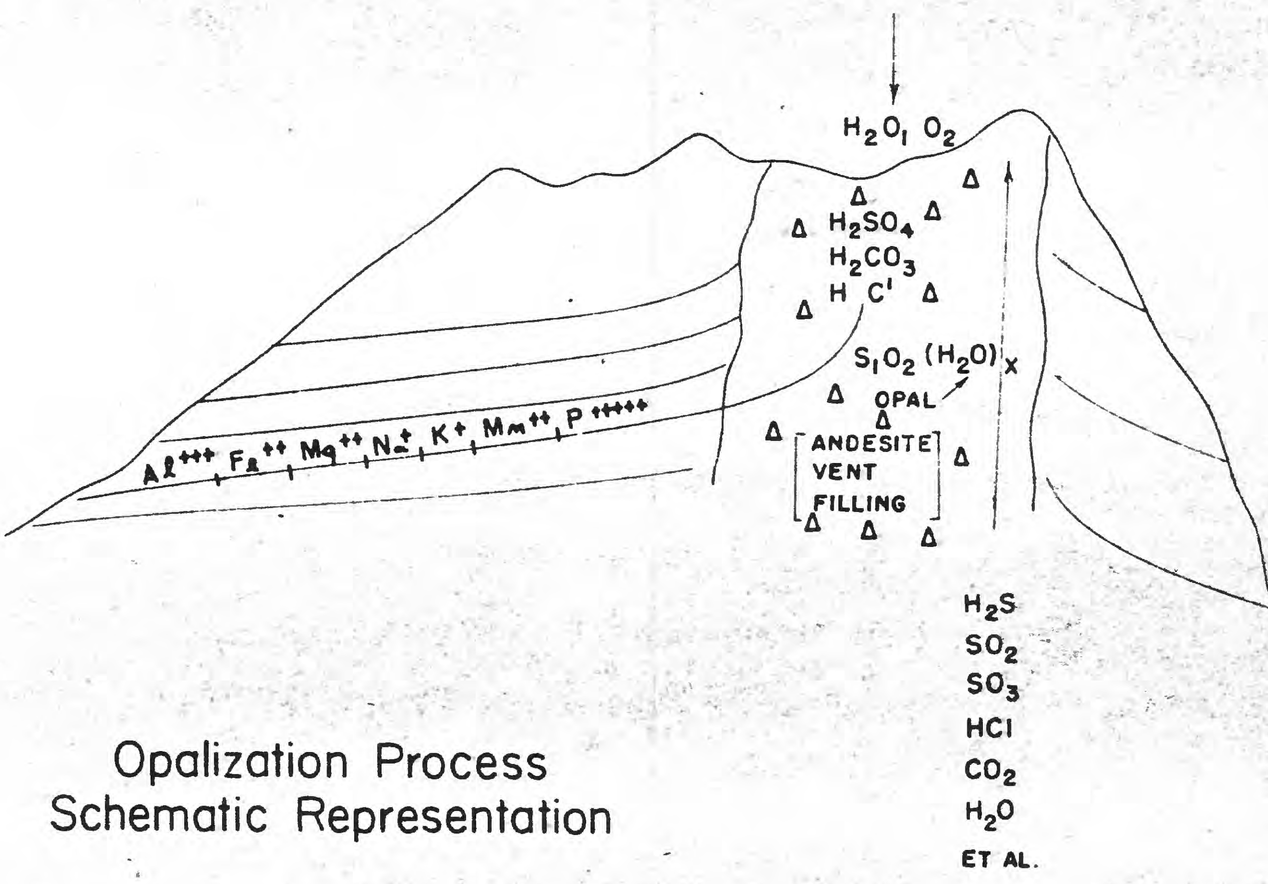
$Fe^{\cdots}$ +
$FeOH^{\cdot\cdot}$
Al_2O_3
Al_2O_3
SiO_2
12
11
10
9
8
7
6
5
4
3
2
1
0 1 2 3 4 5 6 7 8 9 10 11

Plate 20

Plate 21

Opalization Process

Opalization process - schematic representation of solfataric gases rising through the porous throat filling. These are hydrated and oxidised to acidic solutions which in turn leach the metal cations from the silicates leaving the insoluble opaline residue.



Opalization Process
Schematic Representation

Weathering

~~The~~ Iron plays a conspicuous role in the weathering cycle of the rocks in this wet climate. Limonite probably produced from the oxidation and solution of sulfide from the recent volcanic rocks and possibly also from the weathering of ferromagnesium silicates leaves orange brown stains on the rocks, particularly on the morainal debris covering the glaciers (Plate 22, Fig. 1). This morainal covering of the glaciers is always wet and rests in a semi-liquid muddy matrix on the ice. Very yellow iron bearing waters drain from these glacial coverings into the streams (Plate 22, Figure 2). Present gravel beds in the streams are thoroughly cemented by the limonite into tough conglomerates with a dark brown iron cement. These ferrougenously cemented conglomerates are particularly noticeable at the mouth of the streams where the iron hydroxides are flocculated by the salt water (Plate 22, Figure 3). Stagnant swamps along the borders of these streams commonly have red brown flocculated gels on their bottoms. These gels also accumulate on the leaves and stems of the aquatic vegetation.

Plate 22

Role of Iron in the Weathering Cycle

Figure 1. Limonite stained rock debris covering Umbrella Glacier at its lower end.

Figure 2. Iron bearing waters draining from moraines covering lower part of Red Glacier.

Figure 3. Ferruginously cemented gravels at the mouth of Red Glacier Creek exposed at low tide. Sea water flocculates the iron in the stream which forms well cemented hard brown conglomerates in the stream bed.

31-35

Photo 22

STRUCTURAL GEOLOGY OF THE BASEMENT

Regional

In the ~~Mt.~~ Iliamna ~~region~~ Volcano area the Jurassic beds are tilted 10° - 30° toward Cook Inlet and strike about N30E parallel to the axis of the inlet and the Aleutian Range. The Lower Jurassic volcanics and Triassic limestone beds disappear beneath Cook Inlet in this area but emerge again near Seldovia on the Kenai Peninsula, suggesting that Cook Inlet is a low structural depression lying between two elevated peninsular ranges.

The central core of the Alaska Peninsula has been elevated with respect to the Cook Inlet depression; the batholith is exposed at altitudes up to 6000 feet above sea level. The quartz diorite intrudes flanking Lower Jurassic volcanic rocks in both the ~~Mt.~~ Iliamna ~~region~~ Volcano area on the east and the Lake Clark country on the west. Not being stratified like the sediments which it invaded, however, the quartz diorite seems more resistant to deformation and has slightly forced up and faulted the flanking sedimentary beds at its periphery, perhaps during the regional uplift of the central Aleutian Range.

Uplift of the interior of the Alaska Peninsula seems to have been a gradual and recurrent process, perhaps begun in early Middle Jurassic time synchronous with the intrusion of the quartz diorite. Indications of this uplift are preserved in the stratigraphic record as well as in the gentle seaward tilt of the beds. The Jurassic volcanic tuffs, breccias, and mudflows (lahars) grade conformably into overlying Middle Jurassic siltstones, conglomerates and graywackes. Yet pebbles and cobbles of the underlying volcanic rocks are found in these overlying conglomerates, indicating that the older tuffs, tuff breccias, and mudflows were undergoing uplift and erosion in the west probably at the approximate site of the central Alaska Peninsula. Quartz diorite pebbles first appear in the Middle Jurassic Iniskin formation conglomerate beds and become increasingly abundant higher in the section, indicating that uplift and erosion may have already exposed the batholith by Middle Jurassic time. The presense of quartz diorite pebbles alone is not in itself conclusive evidence of their derivation from this batholith, since quartz diorite of several different ages is exposed in the western cordillera. However, above the erosional unconformity at the base of the Upper Jurassic Chisik conglomerate member, the appearance of very large boulders of quartz diorite as well as the appearance of a few cobbles of the characteristic granophyric stocks and Triassic limestone pebbles is cogent evidence that the batholith was exposed at least by early Upper Jurassic time.

The regional eastward dip of the basement swings concentrically around the volcano, becoming nearly due south to the south of ~~Mt.~~

Iliamna Volcano. These strata are severed by both normal and reverse faults. These faults strike NE, approximately parallel to the regional strike of the tilted strata. East west faults, however, relieve the stresses south of the volcano where the beds dip southward.

North of the volcano, quartz diorite has been thrust over Triassic limestone for a short distance, perhaps indicating a slight eastern movement accompanying the vertical uplifts of the Aleutian Range.

Whether these marginal upthrusts along the border of the batholith are the result of regional tectonic uplift which occurred after the intrusion of the quartz diorite magma or whether these marginal faults are the direct result of the intrusion forcing its way upward synchronous with the consolidation of its borders is difficult to determine. The borders of the quartz diorite were certainly consolidated when they were thrust over the limestone. But, had only the marginal rocks solidified at the time of faulting and was it being forced upward and outward by the still upward moving molten magma? Apparently the faulting occurred after the intrusion of the granophyric quartz monzonite stocks. On the north side of the Johnson Glacier the stock lying between the glacier and the thrust fault has been severely sheared and hydrothermally altered. Perhaps the fault plane should have been drawn through this stock on the map, although the magnitude of displacement is probably quite small. Nevertheless the quartz grains are fractured and intensely strained. They are the only grains that withstood the attack of subsequent hydrothermal alterations. Most of the feldspar is so completely altered to serecite ~~so completely~~ that not even vestiges of the original feldspar crystals remain.

Since these granophyric quartz monzonite stocks seem to be the last stage manifestations of the batholith's intrusion as evinced by their discordant relations to the quartz diorite, it seems that the earliest phase of marginal faults occurred not before this very last stage of consolidation of the pluton. Past intrusive tectonic movement is, however, not ruled out by this relationship and the exact age of the faulting must remain undetermined.

Local Structures

Horn Creek Fault:

On the north side of Chinitna Bay in the valley of Horn Creek, Lower Jurassic bedded volcanic tuffs and lapilli tuffs are faulted against the Upper Jurassic Chinitna siltstone; cutting out approximately 6000 - 7000 feet of Middle Jurassic sedimentary rocks. Traced northward the fault disappears under the East Glacier lava flow from Iliamna Volcano. It reappears again on the northern side of the flow and continues to the headwaters of the North Branch of East

Plate 23

Faults

Figure 1. Horn Creek fault north of the East Glacier flow. The Lower Jurassic volcanic tuff and tuff breccias (purple in the left side of the photograph) have been faulted up against the light colored Upper Jurassic Chinitna siltstone, cutting out about 6000 - 7000 feet of middle Jurassic strata.

Figure 2. Jurassic quartz diorite thrust over Triassic limestone, north of Johnson River. The surface of the Triassic limestone in the foreground is approximately parallel to the fault plane. The brown ridge consists of quartz diorite. The hammer is in quartz diorite talus resting on the fault plane.

Plate 23

Glacier Creek where it is covered again by more flows. This reverse fault is clearly exposed north of East Glacier flow (Plate 23, figure 1). The attitude of the fault surface dips 65° west. A gouge zone 4 - 25 feet wide is present. Siltstone and conglomerate beds of the Chinitna formation were drag folded into a close syncline east of the fault. The beds of the synclinal drag fold pass into a gentle anticline east of the fault. This anticline plunges 12° to the north, and is well exposed on the north coast of Chinitna Bay.

Red Glacier Faults

On the south side of Red Glacier, near the upper end, dark carbonaceous slates of the Red Glacier formation are severed by a low angle thrust fault with only minor displacement. The fault surface dips 30° to the west. The incompetent black shale is crumpled and folded on both sides of the fault, but resumes its normal seaward dip about 1/4 of a mile to the east.

North of Red Glacier beds are displaced about 400 feet stratigraphically by a steeply dipping fault. The undisturbed section is exposed in a cliff east of the fault permitting a close estimate of the displacement. The beds are warped into low arches on both sides of the fault, as shown on the map.

A 3 foot quartz vein west of the fault transects the lower Red Glacier formation along this ridge on the north side of the glacier.

This quartz vein is exposed for several hundred yards and contains fragments of wall rock. Well developed euhedral quartz crystals 1 com long line cavities within the vein.

The quartz diorite intrudes the Lower Jurassic volcanic coarse tuff immediately below the Red Glacier formation. The shale of the Red Glacier formation has been somewhat baked by heat from the underlying quartz diorite. These shale beds weather a rusty red due to the alteration of their pyrite content.

Fault South of Johnson Glacier:

Between Johnson Glacier and the long glacier south of it the quartz diorite is faulted against the Lower Jurassic volcanic beds by a 60° reverse fault dipping west. The bedded tuffs and graywackes of the Red Glacier formation as well as the volcanic beds have been steeply upturned and even slightly overturned into a sharp synclinal drag fold produced by the upthrust of the quartz diorite (Plate 24, fig. 1). This entire structure is clearly exposed in the valley wall south of Johnson Glacier. The displacement along this fault seems quite small. Quartz diorite is in intrusive contact with the Lower Jurassic volcanic rocks both on the north side of Johnson Glacier and south of the second long glacier feeding into the Johnson River.

Faults North of Johnson Glacier:

On the divide between the Johnson River and Tuxedni Bay the quartz diorite is thrust over Triassic limestone for a very short distance (Plate 23, fig. 2). The fault is clearly displayed on the divide where a tongue of quartz diorite about 1/4 mile long rests upon the limestone. The limestone directly at the fault plane is covered by talus of quartz diorite that obscures any evidence of brecciation or mylonitization.

Dikes of quartz diorite in the Jurassic volcanic rocks indicate that the fault is quite close to the intrusive contact of the quartz diorite. Traced southward the fault goes into the pink quartz monzonite stock just north of Johnson Glacier. The stock has been severely sheared. The quartz grains are intensely strained and fractured. Hydrothermal alteration has converted all feldspar to sericite, so that hardly any vestiges of the original feldspar are preserved.

Two miles southeast of this margin thrust fault the Jurassic volcanics are severely disrupted by another fault zone dipping about 85° to the west. East of this fault the strata resume their normal dip toward Cook Inlet.

West Glacier Ridge:

On the ridge separating Middle Glacier Creek from West Glacier Creek the strata dip southward toward Chinitna Bay -- swinging concentrically around the volcano. An east-west fault cuts across the Lower Jurassic volcanic tuff and argillite, which are bent into a steep synclinal drag fold on the southern downthrown side of the fault.

Iniskin Peninsula:

On the Iniskin Peninsula a fault is believed to run the length of the valley of Fitz Creek on the basis of stratigraphic measurements made on the two sides of the valley. The Fitz Creek fault seems to be a southward extension of the Horn Creek fault seen on the north shore of Chinitna Bay. The tight Gaikema Creek anticline to the west of this fault, and the close syncline immediately east of the fault were probably produced by drag folding during the development of this fault (J.K. Hartsock, oral communication).

Portage Creek Fault:

The Portage Creek Divide separates the Iniskin Peninsula from the mainland. Moffit (1927) believed that a large fault separated the Jurassic sedimentary rocks from the Lower Jurassic volcanics to the west. Several small outlying ridges of basaltic andesite in the sedimentary rocks were interpreted as infaulted slices of the

Plate 24

Marginal Upthrust of Quartz Diorite

Quartz diorite is upthrust against the lower Jurassic volcanic beds along a reverse fault dipping west 60°. The bedded tuffs and tuffaceous graywackes of the Red Glacier formation as well as the Lower Jurassic volcanic beds have been sharply upturned into a sharp synclined drag fold produced by the upthrust of the quartz diorite.

Plate 24

Lower Jurassic volcanics by Kirschner (1949).

Exposures are poor in Portage Creek valley and their interpretation is based only upon available evidence seen in the valley. On the ridge to the west, however, a later flow is clearly exposed. This flow covered the Lower Jurassic volcanic tuffs and has flowed over their eroded edges down to Iniskin Bay and also toward Portage Creek valley.

Erosion severely dissected parts of the flow, and it seems that the outlying ridges of basaltic andesite in the valley are simply remnants of this probably early Tertiary flow.

Bedded lapilli tuff and tuffaceous sandstone occur on the west side of the fault. Graywackes, tuffaceous sandstones and conglomerates are visible on the eastern side. No fossil material is available to indicate the age of the rocks near the fault, yet the stratigraphic succession seems to be the normal sequence as seen further north near Portage Creek Divide, on Middle Glacier Ridge, on Red Glacier, and on the south shore of Tuxedni Bay. A fault does sever the steeply dipping beds, but the writer believes that the magnitude of displacement is not as large as previous observers suspected. In addition this fault seems to die out northward with ever decreasing displacement.

PLUTONIC ROCKS

General Statement

Quartz diorite forms much of the interior of the Alaska Peninsula. It intrudes Triassic limestones and argillites, and also the Lower Jurassic volcanic breccias and tuff breccias in the western part of the ~~Mt.~~ Iliamna Volcano area ~~region~~. This batholith does not consist of quartz diorite alone. It grades into a muscovite granodiorite that forms the interior of the batholith. In addition, stocks of granyphyric quartz monzonite have invaded the quartz diorite and the sedimentary rocks along the eastern border of the pluton.

Quartz diorite dikes occur in the Jurassic volcanic rocks as much as two miles from the nearest surface exposures of the quartz diorite pluton. Lamprophype dikes cut all three of the intrusive rock types. Pegmatites are rare, but thin aplite dikes appear toward the interior of the quartz diorite. The granophyric quartz monzonite stocks in contrast to the quartz diorite are devoid of any late aplite or pegmatite dikes.

Basalt dikes are present in the quartz diorite, in the granophyric quartz monzonite stocks, and also in the sedimentary rocks.

Plate 25

Zoned Plagioclase in Quartz Diorite

Zoned plagioclase in the quartz diorite indicates a sufficiently rapid drop in temperature to prevent the crystals from attaining equilibrium with their surroundings. This zoning, coupled with the intrusize, discordant contact phenomena at the borders of the quartz diorite, is strong evidence for the magmatic origin of the quartz diorite. (X 43, crossed nicols)

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Plate 25

Quartz Diorite

The western part of the ~~Mt.~~ Iliamna Volcano area ~~district~~ is composed chiefly of medium grained greenish gray quartz diorite. The rock consists of andesine, hornblende, and quartz, with some biotite, and accessory magnetite and apatite. The texture is equigranular hypidiomorphic. Hornblende and quartz are irregularly shaped and anhedral, the andesine is subhedral. Progressive zoning is present in the andesine, ranging from sodic labradorite at the core to andesine at the rims (Plate 25). This compositional zoning, although not conclusive evidence for the igneous origin of the rock, does, however, indicate a rapid drop in temperature which prevented the crystals from attaining equilibrium with their surroundings. This zoning, coupled with the definitely intrusive contact phenomena, is cogent evidence for the magmatic origin of the quartz diorite.

Skarn zones were developed where quartz diorite invaded Triassic limestone north of Tuxedni Bay. On the small rock island at the entrance to the lagoon a thick lens of pyrometasomatic magnetite replaces the limestone. The limestone is completely recrystallized into coarse grains up to a cm in diameter, although most of the recrystallized grains are only 3-5 mm across.

Idocrase is present in the limestone as well as brown garnet -- probably andradite.

Pegmatite and aplite dikes are rare in the quartz diorite --

Plate 26

Aplite Zones Surrounding Contact Breccias

Light aplitic zones developed around the contact breccias on the ridge between Middle Glacier Creek and Umbrella Glacier. Elsewhere, except around the xenoliths, the rock is a normal quartz diorite. Perhaps the ferromagnesium components have been absorbed from the surrounding rock to produce the more basic xenoliths.

Plate 26

the pegmatites being less abundant than the aplite dikes. They are grouped together on the geologic map. The aplite dikes are only a few inches thick. They consist of fine sugary textured quartz and andesine. A small swarm of aplite dikes is present at the head of Marsh Creek. Individual dikelets are offset in places suggesting slight fracture of the quartz diorite after these late aplitic dikes had crystallized.

On the ridge between Middle Glacier Creek and Umbrella Glacier light sugary textured aplite surrounds basic xenoliths (Plate 26). This light aplitic rock is developed only immediately along these xenoliths. Elsewhere the rock is a normal hornblende quartz diorite. The xenoliths are richer in hornblende and plagioclase, whereas the aplite contains chiefly quartz and andesine. The plagioclase is sericitized in the xenoliths, and some epidote and muscovite also appear.

Lamprophyre dikes containing chlorite, augite and oligoclase intrude the quartz diorite. Some of these dikes are slightly offset indicating movement and fracturing of the quartz diorite after the emplacement of these lamprophyres. The fractured surfaces, however, are no longer distinctly discernible, although the dikes are definitely offset. Perhaps this indicates that the quartz diorite was still plastic enough to heal the fractures after the dikes were offset.

Brown basaltic dikes intrude the quartz diorite, the granophyric stocks, and also the Jurassic bedded rocks. These dikes contain brown patches of decomposed chlorophaeite, fresh labradorite, augite, magnetite and apatite. Many of the basaltic dikes are 5 - 8 feet thick, considerably thicker than the lamprophyre dikes. Some of them have well developed joints perpendicular to their walls. Although no conclusive evidence is available, their ubiquitous distribution suggests that they may be offshoots from the magma chamber that fed the volcano.

The contacts of the quartz diorite are sharp and discordant (Plate 27, fig. 1). Brecciated fragments of the argillite, volcanic flows, and pyroclastics were incorporated into the magma as xenoliths. Near the contacts these xenoliths are angular and brecciated. Where inclusions of early lava flows make up part of the contact breccias, remnants of vesicles from the early flows are preserved in a few places (Plate 27, fig. 2).

Near the contact of the pluton the quartz diorite becomes finer grained. Dikes of quartz diorite 1 - 3 feet thick can be traced into the wall rock. Bedded shales along the walls are invaded by sills of quartz diorite. A large slab of Triassic shale about 75 yards long and 30 yards wide lies engulfed in the quartz diorite near the contact on the ridge between Middle Glacier and Umbrella Glacier. This thin bedded

Plate 27

Quartz Diorite Intrusive Effects

Figure 1. Quartz diorite intruding flows on the north side of Johnson Glacier.

Figure 2. Inclusion of volcanic rock in quartz diorite with remnants of vesicles still preserved on the divide between Marsh Creek and Iniskin Bay.

Figure 3. Shale shabs engulfed by quartz diorite. The magma has invaded the rock along the bedding planes and thoroughly soaked it in granitic fluids. The quartz diorite is dispersed throughout the beds.

Figure 4. Gray quartz diorite with included xenoliths. This quartz diorite is in turn cut by a pink dike from one of the quartz monzonite stocks. Divide between Marsh Creek and Iniskin Bay.

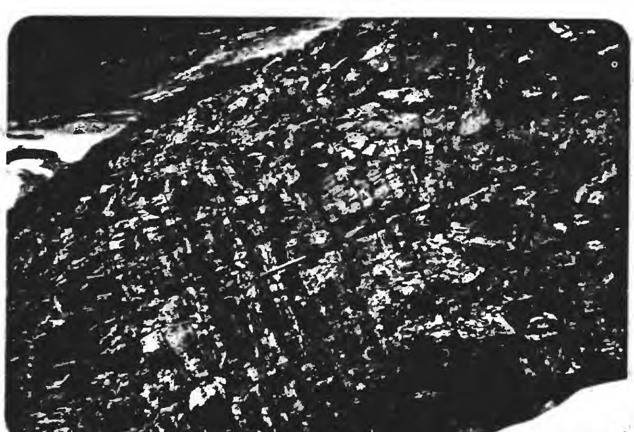

Plate 27

shale inclusion is cut by thin sills of the quartz diorite along the bedding planes and was thoroughly soaked through by the granitic fluids. At the contact the beds normally dip 50°S. but this large xenolith of bedded shale was disengaged from the normal beds and now dips 70°E (Plate 27, fig. 3).

At the head of Tooie Creek the quartz diorite merges into an amphibolitic border consisting primarily of hornblende and sericitized andesine. Basic clots of similar amphitolitic material are irregularly distributed throughout the quartz diorite. This may indicate that the basic clots are partially assimilated xenoliths of wall rock.

Quartz diorite occurs on the north side but not the south side of the lagoon north of Tuxedni Bay. Iron Mountain consists chiefly of bedded breccias, tuffs and interbedded shales. These rocks have been hornfelsized, apparently by heat from the immediately subjacent quartz diorite. The proximity of the quartz diorite is also suggested by the surface outcrop pattern and by the presence of two dikes of quartz diorite 20 - 25 feet thick along the shore of Iron Mountain. Another thick quartz diorite dike is exposed on the south coast of Tuxedni Bay, approximately two miles from the nearest exposure of the batholith.

The presence of a fourth quartz diorite dike at the head of Hickerson Lake just in front of the eastern flows from ~~Mt.~~ Iliamna Volcano suggests the presence of that intrusive body to the east of the volcano.

Plate 28

Muscovite Granodiorite

Typical muscovite granodiorite showing saussuritized plagioclase, and clear muscovite crystal in center. (X40 crossed nicols)

pl 28
48-49

Plate 28

Age of the Quartz Diorite

Determination of the exact time when this batholith was emplaced is difficult. The intrusive rocks of the Aleutian Range and the Alaska Range are unmapped for the most part. There may well be several different intrusions of granitic rocks extending in age perhaps from the Paleozoic to Tertiary time.

For the Mt. Spurr region which lies about 100 miles north of Mt. Iliamna Volcano, Stephen R. Capps (1930) writes:

"No positive evidence of the age of the granitic intrusive rocks was obtained during the investigation, but it is certain that granites have been intruded into this general region during at least two periods in its history, for granitic pebbles were observed in tuffs of probable Lower Jurassic age and these tuffs were later cut by other granites. Most of the granite of the region is believed to be of late Mesozoic Age. In the Upper Skwentna region these granites cut shale from which was collected a fossil leaf that was identified as of Upper Cetaceous or Tertiary age and are directly continuous with the same great intrusion that brought in most of the granite of the Mt. Spurr region and are probably a part of it."

In the Talkeetna Mountains Paige and Knopf (1907) mention that "quartz diorite invades andesitic greenstones of Sheep Mountain which has been shown by fossils to be of lower Middle Jurassic age."

From the abundance of granitic material in the coarse conglomerate of Upper Jurassic age they infer that the intrusion preceded the deposition of the late Jurassic strata. Hence they bracket the age of the Talkeetna quartz diorite at about the Middle Jurassic.

In the ~~Mt.~~ Iliamna Volcano area ~~region~~ quartz diorite pebbles occur in the Middle Jurassic beds, but the genetic relationships of these pebbles to the immediate quartz diorite batholith is not certain. They could have been transported from some other area in which quartz diorite was exposed during Middle Jurassic time.

In the coarse Upper Jurassic Chisik conglomerate deposited above the erosional unconformity at the top of the Chinitna formation, however, the occurrence of a few cobbles from the distinctive stocks of granophyric quartz monzonite, and the presence of Triassic limestone pebbles suggests rather strongly that uplift and erosion had exposed the quartz diorite by Upper Jurassic time and quite possibly by Middle Jurassic time, since quartz diorite pebbles are also found in the Middle Jurassic conglomerate beds. In addition, a dike of quartz diorite cuts the lowest Middle Jurassic beds east of ~~Mt.~~ Iliamna Volcano.

Thus the evidence indicates that the quartz diorite was emplaced at least by early Upper Jurassic time and quite possibly by early Middle Jurassic time.

Muscovite Granodiorite

In the high plateau west of West Glacier Creek the quartz diorite grades into a very light colored muscovite granodiorite (Plate 28) devoid of any primary mineral orientation, bonding or other flow structures. Books of muscovite are randomly oriented in this granodiorite. The normal hornblende quartz diorite grades into this muscovite granodiorite over a distance of about one quarter mile. The grain size remains coarse over the entire transition zone. The hornblende of the quartz diorite becomes replaced by biotite which in turn gives way to pure clear muscovite in the granodiorite. Orthoclase is added and the andesine of the quartz diorite becomes albitized to sodic oligoclase and is in turn saussuritized to clinozoisite, epidote sericite, and albite.

These relations suggest that the muscovite granodiorite is not a separate composite injection into the quartz diorite, but rather that it may have been produced by the streaming of fluids through the hot quartz diorite during and following the last stages of congealing. Such fluids would albitize and saussuritize original andesine of the quartz diorite as noted, and they might well remove the original hornblende and replace it with biotite and the hydrous muscovite. Possibly the roof above this part of the pluton was permeable, allowing escape of gases to the surface, and thus concentrating deuteric and hydrothermal effects chiefly to this one part of the pluton.

	Normal Quartz Diorite	Muscovite granodiorite
SiO_2	58.34 (1)	73.92 (3)
Al_2O_3	16.69	15.13
Fe_2O_3	2.09	.41
FeO	4.69	.40
MgO	3.38	.26
CaO	7.29	1.85
Na_2O	2.94	5.60
K_2O	1.49	1.69
H_2O	.10	.07
H_2O^+	~~1.78~~ 1.98- see analysis typed 55-110 CD Rosted 3-31-53 Granite	.75
TiO_2	.55	.05
P_2O_5	.11	.08
MnO	.14	.05
	99.79	99.66 = 100.26

Note - Arrows indicate direction of increasing proportion of oxide present.

Enrichment in Na_2O, K_2O, SiO_2 readily transported by fluids, is indicated by the relative proportions of their oxides in the normal quartz diorite and in the muscovite rich granodiorite. Removal of iron, magnesia, calcium, titanium and manganese from the original hot quartz diorite magma is also suggested by the present relative proportions of their oxides in the normal and in the altered rock.

The Lower Jurassic breccias, tuff breccias, and flows are preserved on both sides of the Aleutian Range. These volcanic beds grade conformably into the overlying Middle Jurassic sedimentary rocks. Yet these sedimentary beds contain cobble conglomerates of volcanic flows and breccias identical to that of the Lower Jurassic volcanic series. These stratigraphic relationships suggest that the volcanic beds once extended west perhaps across the present site of the batholith and were subjected to erosion by Middle Jurassic time. Perhaps the muscovite granodiorite zone is the deeply dissected root of one of these older volcanoes through which the fluids were escaping.

Granophyric Quartz Monzonite Stocks

From Iniskin Bay to north of Tuxedni Bay pink colored stocks of granophyric quartz monzonite invaded the border region of the quartz diorite batholith and the adjacent Triassic limestone and argillites. Andesine, quartz and orthoclase with a minor proportion of hornblende compose these stocks. The granophyric intergrowths of quartz and orthoclase give this rock a very distinctive appearance under the microscope. The orthoclase components are in crystallographic continuity with the intergrown quartz. The quartz intergrowths likewise are in optical continuity with themselves but extinguish at different positions from the extinction positions of the orthoclase crystals under crossed nicols.

The intergrowth structure of orthoclase and quartz has in places grown around the borders of orthoclase nucleii (Plate 29) which contains no free quartz. The intergrowth of quartz and orthoclase was the last material to solidify, filling in the remaining available spaces, fitting itself against the euhedral boundaries of earlier crystals, and into the unfilled spaces between them.

The fact that the intergrowths begin at definite concentric crystallographic planes around the borders of the orthoclase indicates that replacement of orthoclase by later quartz played no role in their origin. The presence of normal orthoclase nucleii within the granophyre borders is cogent evidence against any exsolution of quartz from the orthoclase.

Carlsbad twinning is present in the normal orthoclase at the nucleus of some of the granophyric intergrowths (Plate 30, fig. 1 and 2). The twinning continues into the quartz intergrowth borders of these orthoclase crystals indicating that growth of the orthoclase was continuous and that during the late stages of crystallization quartz precipitated simultaneously with the orthoclase. Abundant plagioclase is present in the quartz monzonite. The graphic structure between quartz and plagioclase is present, however, on a very

Plate 29

Granophyric Intergrowth

Granophyric intergrowth of quartz around orthoclase. Note that the nucleii of orthoclase contain no quartz. Twin bands in the orthoclase continue into the intergrowth borders. The granophyric quartz intergrowth begins at definite concentric crystallographic planes. These features rule out replacement or exsolution as an origin for the granophyre. It seems to be a late feature of simultaneous crystallization of the quartz and orthoclase fractions.

Abundant plagioclase is present in these quartz monzonite stocks. Note crystal of andesine at the left of the granophyric intergrowth. (X40 crossed nicols)

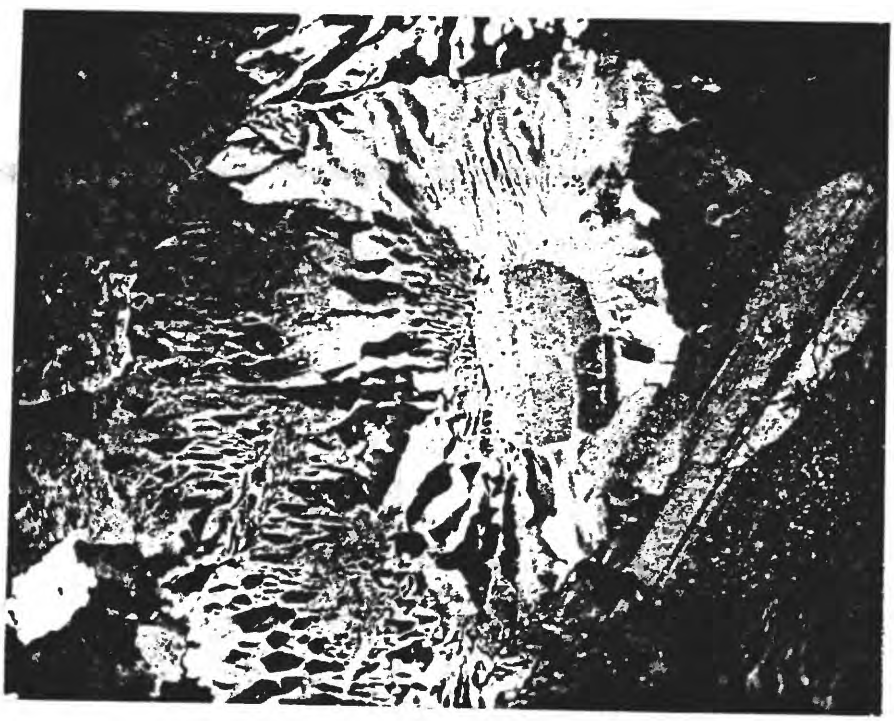

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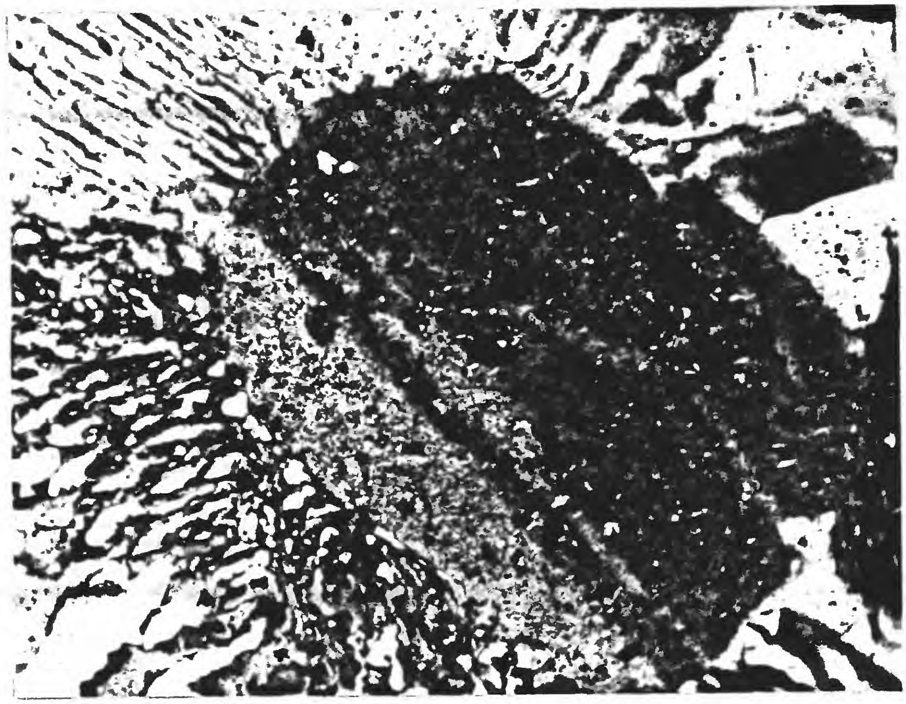
Plate 29

Plate 30

Detailed View of Granophyric Intergrowths

Figure 1. Carlsbad twinning in the orthoclase nucleii. The twinning extends into the granophyric outer zones of the crystal. (X130 crossed nicols)

Figure 2. High power showing quartz intergrown with the orthoclase. Note sharp boundary beyond which intergrowth structure is not present. (X600 crossed nicols)



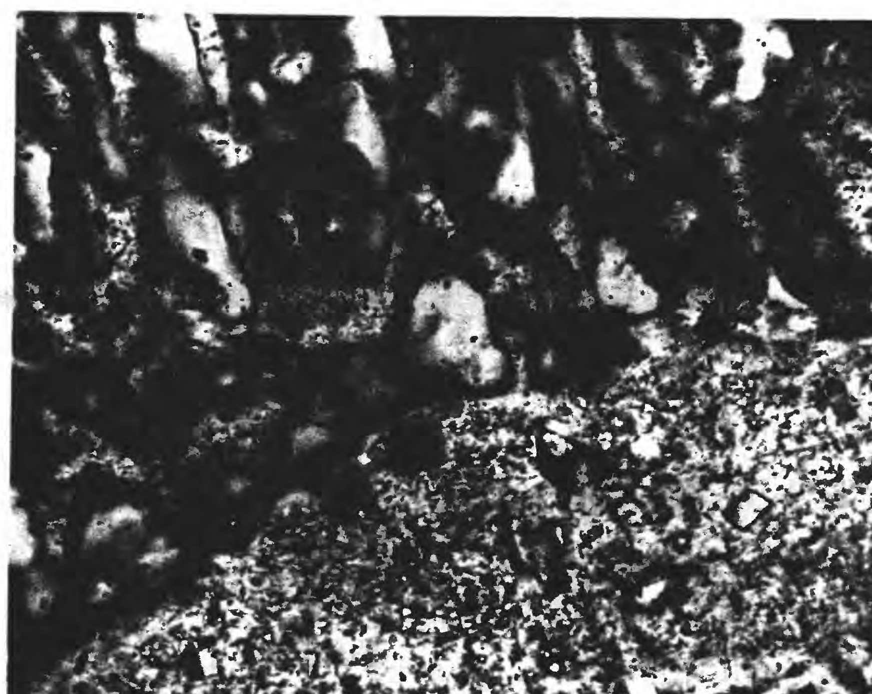


Plate 30

Plate 31

Pink Granophyric Quartz Monzonite Stocks

Figure 1. Pink granophyric quartz monzonite stocks intrude baked Triassic argillite. Note dikelet of quartz monzonite cutting into the argillite near Umbrella Glacier.

Figure 2. Pink quartz monzonite dike in baked argillite near the divide between Tuxedni Bay and Johnson Glacier.

Plate 31

limited scale, indicating that the plagioclase had not all crystallized early.

Two types of contacts are present between these granophyric stocks and the intruded quartz diorite. Sharp discordant intrusive contacts occur from Iniskin Bay to Tooie Creek. Dikes of the pink granophyre invade the quartz diorite, and locally contact breccias appear. West of West Glacier Creek, however, the contact becomes gradational. No dikelets from the stocks intrude the quartz diorite there. Instead the granophyric quartz monzonite merges gradationally into normal quartz diorite. This zone may be as much as several hundred feet wide. The hybrid rock is finer grained than the normal quartz diorite. This gradational zone in which the pink colored quartz monzonite merges into the gray quartz diorite batholith is a pinkish gray color. Such a gradational contact is also present between the granophyric stocks and the quartz diorite along the south coast of Tuxedni Bay. On the north coast of Tuxedni Bay, however, the contact is somewhat sharper but still coarse grained. No dikelets of the granophyric quartz monzonite invade the quartz diorite, however.

North of Johnson River the granophyre outcrops in long narrow belts. They become so lenticular that they almost approach the dimensions of enormous dikes. Smaller dikelets from this quartz monzonite extend into the wall rock for short distances (Plate 31, fig. 2).

Where the granophyric quartz monzonite invades laminated Triassic argillites and massive light brown mudstone it has baked them to dark dense hornfelses along the contact (Plate 31, fig. 1). Limestone is recrystallized (Plate 32) and contains abundant clear garnet grains -- probably grossularite where the stocks have invaded it. In contrast to the quartz diorite contacts with limestone where magnetite is a common skarn mineral, the tactite zones at the quartz monzonite contacts never contain any pyrometasomatic magnetite. The very low iron content of this granophyric quartz monzonite (only about 1 o/o) may account for the absence of magnetite in the tactite borders of the stocks.

Lamprophyre dikes cut these pink quartz monzonite stocks. These dikes are mostly 6" to one foot thick and like the lamprophyres in the quartz diorite, are offset along fractures now hardly discernible. These dikes contain hornblende orthoclase, and oligoclase with abundant small grains of magnetite.

The abundant orthoclase and quartz, the granophyre intergrowth of quartz and potash feldspar, as well as the location of these stocks along the border of the quartz diorite batholith, are features which suggest that these granophyric quartz monzonites may be a late differentiate from the original quartz diorite magma.

Plate 32

Tactite

Recrystallized limestone at contact between pink quartz monzonite stock and Triassic limestone on the ridge between Middle Glacier and Umbrella Glacier. (X43 crossed nicols)

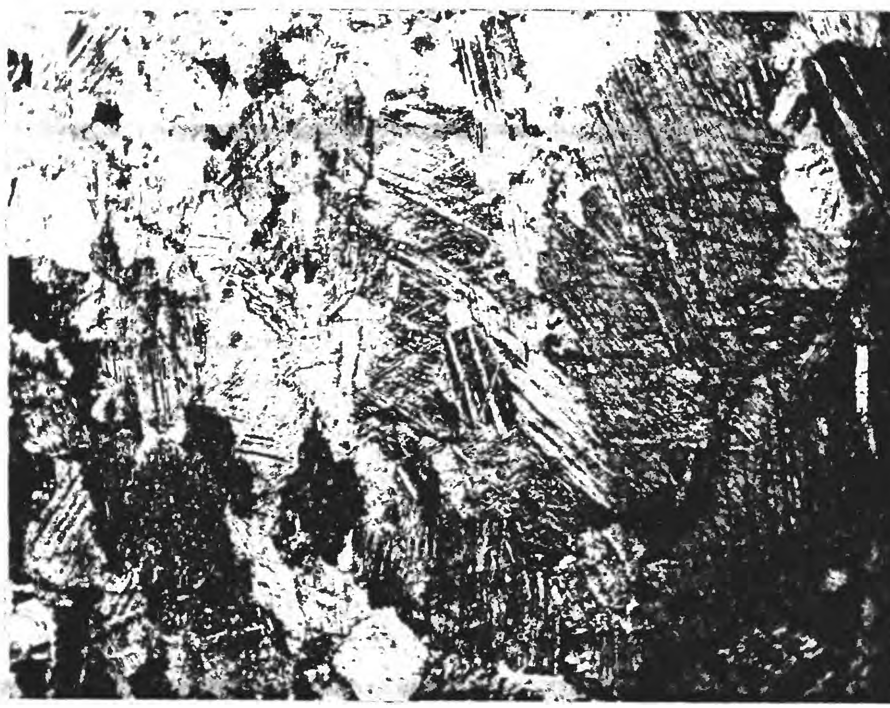


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Plate 32

The generally discordant intrusive contact relationships with the quartz diorite, except west of West Glacier Creek and south of Tuxedni Bay where the contact is somewhat gradational, seem to indicate that the stocks were injected after most of the quartz diorite had solidified. Where the contacts are gradational and no contact breccias or dikelets are visible, local portions of the magma may still have been semi liquid at the time of injection of the granophyre, giving rise to a mixed zone of quartz diorite and its injected late differentiate.

Comparison of the composition of the stocks and the normal quartz diorite reveals that SiO_2 Na_2O and K_2O have increased considerably in the stocks above the proportions present in the batholith.

	Normal Quartz Diorite (1)	Granophyre Quartz Monzonite (2)
SiO_2	58.34	77.61
Al_2O_3	16.69	12.28
Fe_2O_3	2.09	.56
FeO	4.69	.44
MgO	3.38	.09
CaO	7.29	.49
Na_2O	2.94	4.05
K_2O	1.49	3.57
H_2O^-	.10	.12
H_2O^+	~~1.95~~ 1.98	.24
TiO_2	.55	.10
P_2O_5	.11	.02
MnO	.14	.02
	99.79	99.59

See analyst's report 53-190CD dated 3-31-53 G.Loutz.

On the other hand Al_2O_3, Fe_2O_3, FeO, MgO, TiO, P_2O_5, and MnO are present in much lesser amounts in the stocks.

This increase in the ratio of the large light weight alkali and silicon ions is a feature to be expected in the residual siliceous fraction of the crystallized magma. These stocks may be the late residual differentiates which were injected at the borders of the cooling pluton. These silicious fractions from the cooling quartz diorite may have been accumulating from the slowly cooling magma and were subsequently injected along the frozen or nearly frozen border of the quartz diorite forming the present stocks.

Differences in composition of the quartz diorite versus that of the granophyric quartz monzonite stocks is also reflected in the composition of the lamprophyre dikes within these two bodies. The dark green lamprophyre dikes cutting the stocks contain abundant euhedral orthoclase crystals in contrast to the predominance of oligoclase present within the lamprophyres cutting the quartz diorite.

This increase in the light weight potassium fraction present in the lamprophyres transgressing the potash rich stocks may be a consequence of the high content of potassium in these stocks. Whether the lamprophyres are products of assimilation of basic xenoliths by these stocks, or whether they are early differentiates from the magma which were remelted and then injected cannot be conclusively determined. It seems likely however that these lamprophyres are related to the original magma which formed the stocks that they intrude. They are hardly of a completely independent origin because variations in the mineralogy of the lamprophyres seems to be a reflection of the composition of the host magma with which they were associated. Those associated with the potash rich stocks contain orthoclase whereas those cutting the quartz diorite contain chiefly plagioclase.

Structural Features of the Intrusive Rocks

The hornblende quartz diorite exhibits a slight preferred mineral orientation - particularly along the borders (Plate 33). This orientation becomes very faint toward the interior of the batholith and commonly the rocks are quite devoid of any megascopically detectable orientation even in the best exposures.

The linear orientation is manifested in both the hornblende needles and in slightly elongated clots of basic material. Individual hornblende needles within these clots however are commonly oriented at random. In a few places near the border of the batholith such as north of Johnson Glacier a distinct banding of minerals into light and dark layers is present. In addition to segregation into layers these bands also exhibit a faint planar orientation of the hornblende grains. The lineation is not parallel to the planar orientation in every case. It commonly dips slightly out of the plane of the foliation and where it is in the plane of the foliation it may not be directed down the dip of the foliation but instead makes a slight angle of rake with the foliation. Making general statements about the orientation to these hornblended needles and basic inclusions is difficult. In general the clots and hornblende needles seem to dip toward the border of the batholith where they occur near the border. In the western part of the batholith, however, they may parallel the regional trend of the pluton or even dip slightly west.

Longitudinal joints are prominently developed in the quartz diorite. They commonly have roughened surfaces and are spaced closely. Veneers of epidote are conspicuous features of these joint surfaces.

In the mountains north of Tuxedni Bay immense joint faces in the pink quartz monzonite stocks parallel the joints in the surrounding quartz diorite. The contacts between the stocks and the batholith are sharp but not very fine grained. Slight mingling of magmas, shown by effects similar to those in a marble cake, is present along the contacts. No dikes of pink quartz monzonite extend into the quartz diorite and contact breccias are absent. These features suggest that the stock invaded still partially fluid quartz diorite and that the fractures developed in both bodies simultaneously due to cooling stresses or perhaps slight regional stresses which may have been active during the stages of consolidation.

As mentioned, where the quartz diorite grades into the muscovite granodiorite all traces of mineral orientation are lost. The muscovite granodiorite is completely structureless megascopically. In contrast to the steeply dipping joints in the quartz diorite which range generally from 45° to 85° the joints in the muscovite granodiorite are nearly

Plate 33

Preferred orientation of hornblende in quartz diorite.

P 60-1

Plate 33

horizontal having low dips from 5° to 25°. These flat joints are commonly spaced only 4 to 10 feet apart.

The jagged quartz diorite mountains north and south of this muscovite granodiorite area contrast sharply with the gentle high plateau surfaced with numerous small lakes and saturated soil present in the muscovite granodiorite area. Many mesa like knobs of the light granodiorite stand out in this plateau. They seem to be the topographic expression of this flat lying joint system. The joints often bend outward and downward from the center of these mesa like knobs, until terminated by the cliff faces.

In depressions between these mesa-like knobs are the small lakes and swampy areas. This high plateau country with its mesa-like knobs are a striking contrast to the jagged quartz diorite mountains to the north and south of this muscovite granodiorite area. The low flat lying joints thus seem to have drastically affected the topographic development of this region.

BASEMENT SEDIMENTARY AND VOLCANIC ROCKS

Triassic Rocks

Triassic beds outcrop in an irregular belt extending from Iniskin Bay to Tuxedni Bay. They are in contact with the plutonic rocks and have been recrystallized and contact metamorphosed. These beds consist of about 2000 feet of limestone argillite and shale with a few interbedded andesitic lava flows. No rocks older than Triassic are present in the ~~district~~ area.

The limestone occurs in two principal horizons each about 200 feet thick and separated by over 1000 feet of bedded argillites. This limestone is a light blue gray color and in places shows small scale cross bedding. Argillaceous layers only a few inches thick, weather out as crinkly brown ribs on the surface of the finer dense limestone.

The age of these beds is based upon a few scarce fossils of Spongiomorpha (Heptastyloppis) ramosa Frech found near the upper end of the ridge between Middle Glacier Creek and West Glacier Creek. These specimens are similar to those found in Upper Triassic beds along Lake Iliamna on the western side of the Aleutian Range. This scanty fossil evidence coupled with the stratigraphic position of these beds below the Lower Jurassic volcanic rocks into which they grade conformably suggests that these lower beds of limestone and shale are of Upper Triassic age.

North of Tooie Creek a 500 yards wide sliver of these Triassic argillites separates the quartz diorite from one of the granophyric quartz monzonite stocks. This narrow zone pinches out to the north, beyond which the stock merges gradationally into the quartz diorite.

On the south coast of Tuxedni Bay, limestone, argillite, and flows are exposed in a cliff 2000 feet above the tidal marshes. This exposure of Triassic rocks is surrounded by quartz diorite and quartz monzonitee. The quartz diorite border phases become very fine grained near these inlying Triassic beds, indicating that these strata are probably engulfed roof pendents.

On the divide between Tooie Creek and Squaw Girl Creek a small wedge shaped roof pendent of Triassic shale is surrounded by the pink quartz monzonite which also sends dikelets into the roof pendent.

Lower Jurassic Volcanic Rocks

The Triassic beds contain abundant lithic tuffs in the upper section. These lithic tuff beds become more abundant higher in the section and finally grade into coarse breccias, tuff breccias, and flows. The age of these volcanic rocks is only indirectly known. They conformably underly the lowest Middle Jurassic fossil bearing sedimentary rocks containing the Bajocian ammonites Erycites and Tmetoceras. Similar volcanic tuff beds on the Kenai Peninsula near

Plate 34

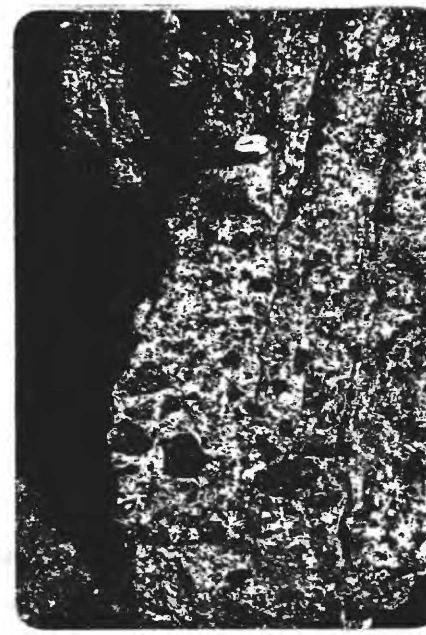
Lower Jurassic Volcanoes

Figure 1. Seaward dipping well stratified Lower Jurassic tuffs and tuff breccias with interbeds of argillite on Middle Glacier ridge north of Horn Mountain.

Figure 2. Close view of the tuff breccias showing angular breccia fragments in a finer tuff matrix.

Figure 3. Coarse fragments of lava imbedded in lapilli tuff matrix.

Figure 4. Silicified log in the well stratified Jurassic lapilli tuff beds which have probably been slightly reworked and deposited near shore. Belemnites are found in the upper part of the section on Tuxedni Bay.



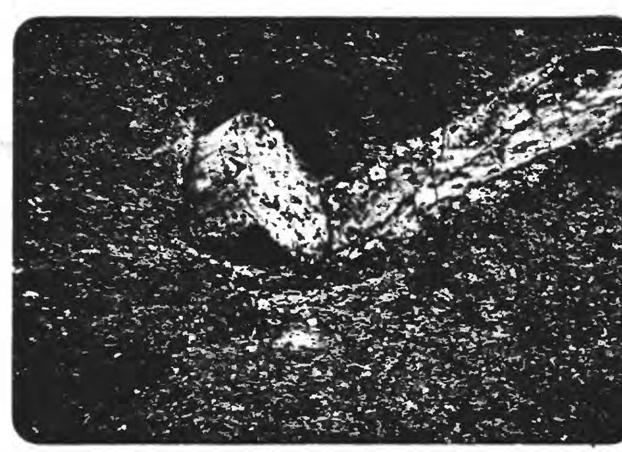


Plate 34

Reference is not shown as direct quote. Factually correct with added point not stated by Imlay that locality is near Seldovia

Seldovia contain an ammonite comparable with Coronicekas of Lower Jurassic Sinemurian age (R. W. Imlay 1952, p. 981).

The lack of fossils in the lower Jurassic beds prevents the specific separation of the Triassic from the Jurassic beds in the ~~Mt.~~ Iliamna ~~region.~~ Volcano area Arbitrarily, the first thick tuff breccia above the argillite was selected as the base of the Lower Jurassic volcanic series.

These Lower Jurassic volcanic rocks are about 8000 feet thick and may be even of greater thickness west of the Iniskin P eninsula.

The lower part of this volcanic sequence contains coarse tuff breccias with angular fragments 2-3 inches across in a finer matrix (Plate 34, fit. 2 and 3). Andesite flows are interbedded with these breccias. These coarse pyroclastics and flows grade into lapilli tuffs, waterlaid volcanic conglomerates, and reworked volcanic sediments. These coarse lithic and Crystal tuff beds are well stratified (Plate 34, fig. 1), units ranging from 10 to over 400 feet in thickness. These rocks change rapidly both in thickness and lithology along their strike making intraformational correlation very difficult. These tuffs are interbedded with argillite beds and limestone lenses indicating their deposition in a marine environment.

Many of these deposits ~~were~~ probably derived from airborne showers of lithic and crystal tuffs and breccias deposited directly into the sea. Rounded pebbles of volcanic material in a tuffaceous

Plate 35

Lower Jurassic Volcanoes in This Section

Figure 1. Calcite filled vesicles in mud flow stocks which have been propylitized (X40 crossed nicols)

Figure 2. Lithic crystal tuff in the Lower Jurassic beds. Note fragment of pyroclastic material in upper right hand corner. (X43 crossed nicls)

Plate 35

matrix indicate that some of these beds were originally deposited subaerially and were subsequently transported to their marine environment. Several of the tuff beds on Middle Glacier Ridge contain silicified wood fragments and in places whole logs may be seen (Plate 34, fig. 4). These well bedded volcanics ranging in thickness from a few feet to several hundred feet contain marine belemnites in the upper part of the section. Several andesite flows and occasional dacite flows are interbedded with these pyroclastic beds. Mud flows or lahars consisting of blocks and boulders set in a coarse matrix of finer rubble are exposed at the headwaters of Hungryman Creek.

The generally porous condition of these tuff beds makes them readily subject to alteration and they respond to the mildest conditions of metamorphism. Calcite fills vesicles in the blocks and matrix of the mud flow deposits (Plate 35, fig. 1). Glass is completely devitrified. These andesites are thoroughly propylitized. Chlorite and other hydrous magnesian minerals such as talc and antigorite replace the original hypersthene and augite. The albitized feldspars are partially altered to zoisite, epidote, calcite, and sericite.

Middle and Upper Jurassic Sedimentary Rocks

No attempt is made to describe in detail the Middle and Upper Jurassic sedimentary beds along the coast of Cook Inlet from

Iniskin Bay to Tuxedni Bay. They will only be described collectively in as much as they record the later geologic history of the basement of the volcano.

Approximately 15000 feet of graywackes, siltstones and conglomerates conformably overly the Lower Jurassic volcanic tuffs and breccias.

The graywackes contain up to 50 o/o or more feldspar. Abundant rock fragments are present consisting predominantly of reworked volcanic rock fragments. Quartz makes up only a small fraction of the rocks. It is usually quite angular and fragmental. These grains of quartz feldspar and rock fragments are embedded in a fine green matrix of clay, chlorite, sericite and carbonate. Hypersthene and augite are commonly present in very small amounts. They become more abundant when the rocks consist of a larger fraction of rock fragments. The feldspar shows considerable alteration to clay minerals and sericite. It is also quite albitized. The high content of volcanic rock fragments rather than fragments of phyllite of slate indicates that these graywackes are not of the normal type but are gradational into tuffaceous sandstones. Perhaps they should be called tuffaceous graywackes.

They exhibit graded bedding and they merge into and are interbedded with fine dark siltstone containing quartz grains in a dark fine grained matrix. Not uncommonly thin layers of ash are present between the siltstone beds indicating the sporadic action of waning volcanism of later Jurassic time.

Siltstone becomes increasingly more abundant in the upper part of the Middle Jurassic beds and in the lower Upper Jurassic beds. The Chinitna formation, approximately ~~200~~ 2000 feet thick consists predominantly of fine dark thick bedded siltstone. The monotony of these thick massive siltstone horizons is commonly broken by thin calcareous sandstone layers and zones of concretions. Well preserved ammonites are commonly found at the cores of these calcareous concretions.

In the area north of Chinitna Bay a local erosional unconformity separates the Chinitna siltstone from the underlying Iniskin* formation. A well exposed channel conglomerate filling is present at the north end of Chisik Island. This local erosional unconformity

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*Note: The Tuxedni formation has been subdivided into two individual formations -- the lower Red Glacier formation and the upper Iniskin formation. These names are not yet officially recognized and are subject to approval and revision by the U.S. Geological Survey.

Plate 36

Chisik Conglomerate

Comglomerate boulder of quartz diorite well rounded and nearly 2 feet across. Note presence of dark volcanic cobbles in this conglomerate.

Plate 36

has not been detected on the Iniskin Peninsula. At the top of the Chinitna siltstone occurs a prominent erosional unconformity. The coarse Chisik conglomerate over 200 feet thick overlies the Chinitna siltstone. Boulders in the conglomerate are quite coarse some being more than two feet in diameter (Plate 36). The majority of the cobbles, however, are under six inches across and are rounded to sub-rounded. This Chisik conglomerate may be an indication of strong uplift in the Aleutian Range.

Conglomerate beds below the erosional unconformity of the Chisik conglomerate contain chiefly volcanic pebbles and cobbles apparently from the lower Jurassic section as well as some quartz diorite cobbles whose source cannot be definitely detemined. These quartz diorite cobbles appear to be similar to the quartz diorite presently exposed in the batholith.

In the Chisik conglomerate, however, cobbles of pink granophyric quartz monzonite identical in texture and color with that of the stocks are present. Furthermore, limestone pebbles probably from the Triassic beds are incorporated. This Chisik conglomerate is only locally present. It may represent a near shore deposit formed in an area not unlike the present indented coast of Cook Inlet with some streams discharging cobbles in one place and other streams discharging sand on silt in other places. The upper Naknek beds contain thick arkose beds as well as ~~s~~siltstone and tuffaceous sandstone beds (Plate 37). These beds were also probably deposited in

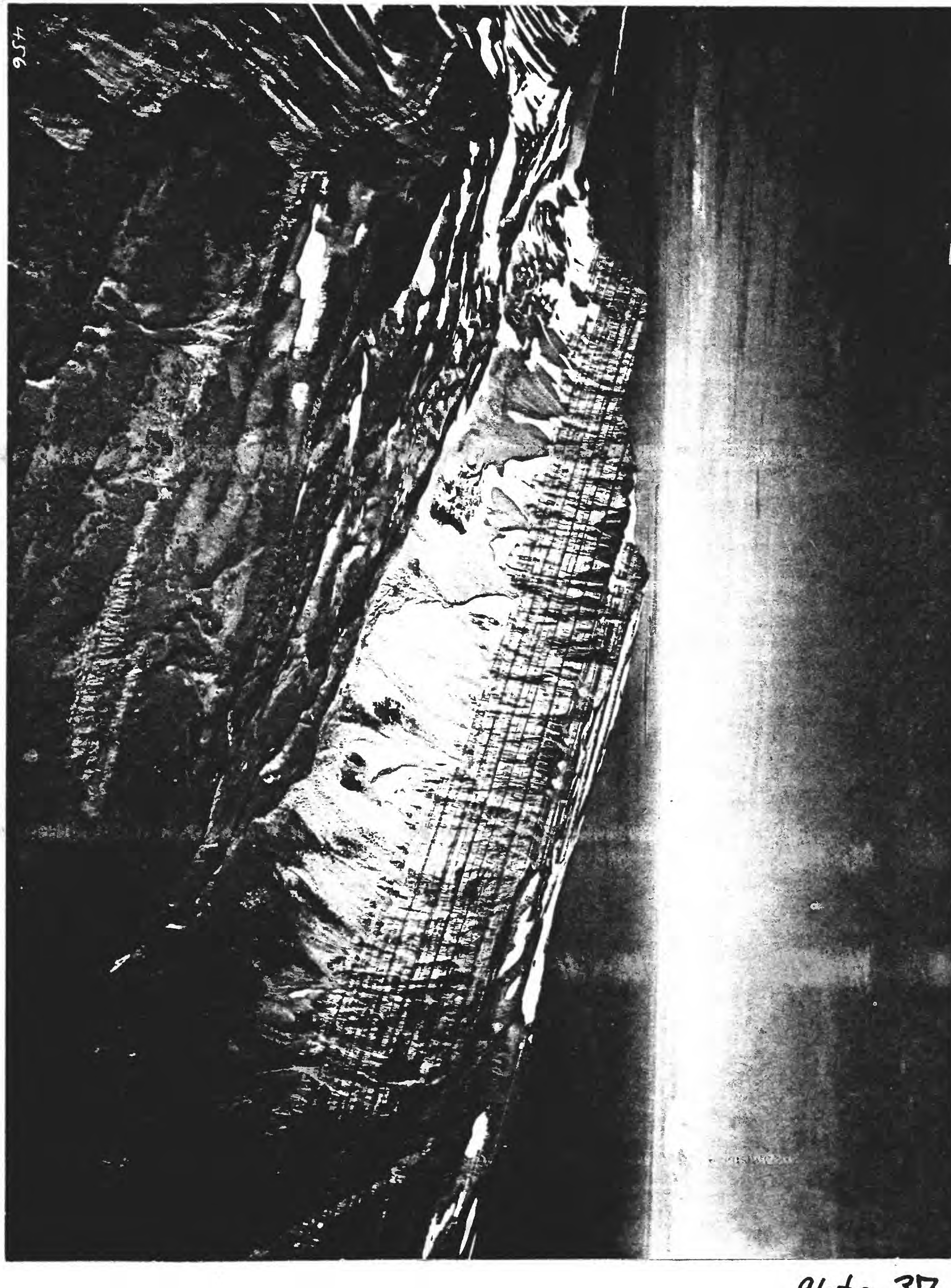


Plate 37

Plate 37

Naknek Formation

Upper Naknek member tilted gently seaward. North side of Johnson River.

by permission of Bradford Washburn

a near shore marine environment as evinced by the presence of Aucella pelecypods.

Tertiary Flows

Remnants of flows disconformably overlie the Lower Jurassic bedded pyroclastics and Middle Jurassic graywackes and siltstones. These flows occur in several small isolated patches from Iniskin Bay to Tuxedni Bay. These lavas are slightly propylitized. Andesine phenocrysts are set in a groundmass of oligoclase. Augite grains are scattered through the groundmass and are commonly replaced by antigorite.

The discordant relations of these flows to the basement across which they advanced are best displayed on the south shore of Tuxedni Bay. Here the flows moved across the eroded edges of graywacke and siltstone beds.

North of Tuxedni Bay the discordant relations of the flows to the basement cannot be seen. There the flow is at sea level and separated from its basement by a 20 - 50 foot thick basal breccia of coarse angular blocks, and smaller dark fragments incorporated into a vesicular matrix. Columnar joints are well developed in this flow. They rise vertically and in places tent joints radiate irregularly in seveal directions.

At the mouth of Marsh Creek the Tertiary flows cover a small area of Lower Jurassic red lithic tuffs. Remnants of these late flows are also exposed on the ridge west of Portage Creek. They can be traced southward to Iniskin Bay over the beveled edges of the underlying beds.

The age of these discordant flows cannot be directly determined. They were extruded after the Jurassic strata had been already uplifted and somewhat eroded. Their severely dissected condition suggests that they are perhaps early Tertiary. Their wide distribution indicates that they were probably not flows from the present ~~volcano of Mt.~~ volcano Iliamna, but rather that they may have erupted from several sources.

Mt. Eleanor, although not investigated in detail, may have been the source of the flows at Marsh Creek and west of Portage Creek. The dense massive lava of Mt. Eleanor contrasts sharply with the tuff breccia of Lower Jurassic age which surrounds it on all sides. The tuff breccias have been sharply upturned to a nearly vertical position west of Mt. Eleanor. Several dikes cut this peak. Today the flows have been eroded from the immediate vicinity of Mt. Eleanor if they were ever extruded from an old volcano there. Further field observations are needed in this area, to determine whether any relationship exists between the flows and Mt. Eleanor.

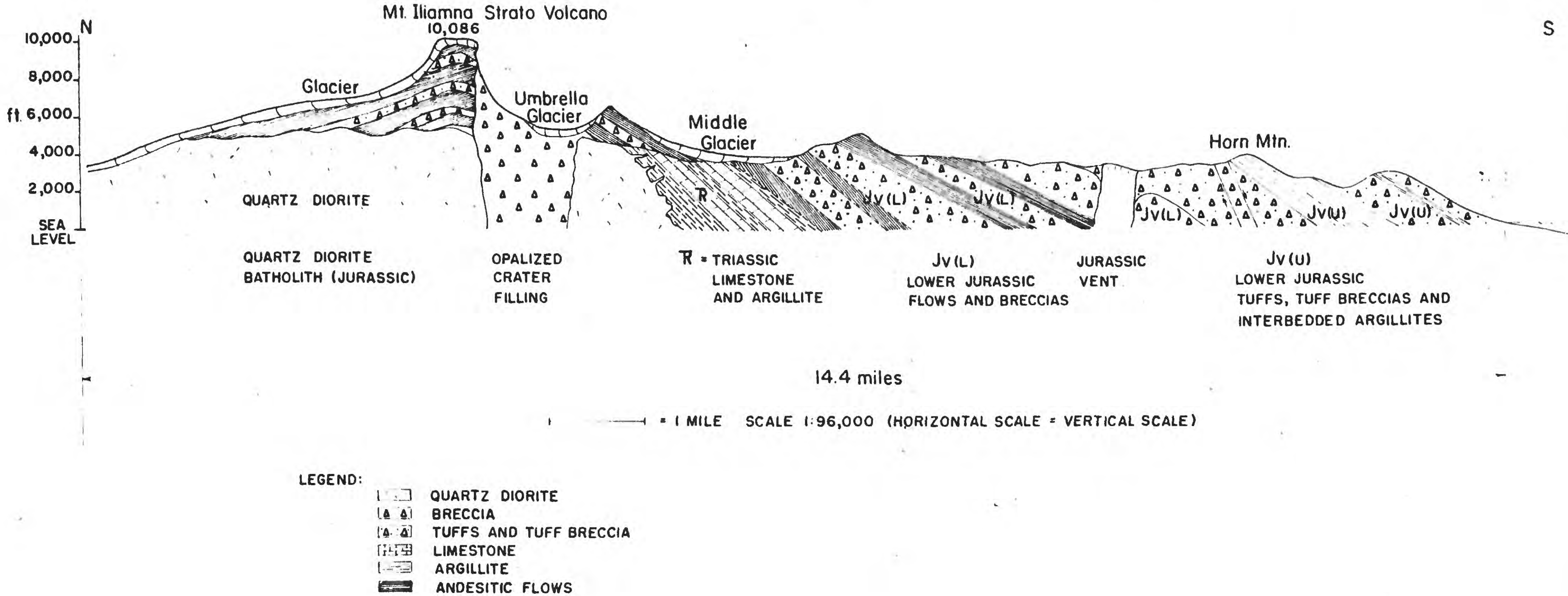
Eocene Conglomerates and Mudstones

Tertiary sandstone and conglomerates are deposited with a low 5° - 10° angular discordance upon the Upper Naknek beds. They are nearly 1000 feet thick at the mouth of Red Glacier Creek. These beds are presumably the equivalent of the Eocene Kenai formation on the east coast of Cook Inlet. At the mouth of East Glacier Creek they contain Eocene plant flora, fossil coniferous wood, and leaves from Eocene redwoods preserved in silicified seams of coal only 2 - 6 inches thick. One large tree trunk is still preserved in an upright position.

Plate 38

Cross Section - Horn Mtn. on Chinitna Bay through

Iliamna Volcano. Total length of section 14.4 miles



Cross Section - Horn Mtn. on Chinitna Bay through ~~M~~ Mt. Iliamna Volcano
Total length of section 14.4 miles

Plate 38

SUMMARY

The oldest rocks in the Mt. Iliamna ~~region~~ Volcano area are Upper Triassic limestones and argillites with a few interbedded flows. These rocks grade conformably into the overlying 8000 feet of lower Jurassic breccias, tuff breccias, andesite and dacite flows, blocky mud flows, and finer tuffs. These volcanic rocks were apparently deposited near shore. Some of the deposits contain direct airborne debris, glass shards, and lithic fragments. Much of the material seems to have been subaerially deposited and subsequently transported to the coastal marine environment of deposition. The rounded cobbles with the tuff beds, interbedded, layers of argillite, limestone, silicified wood fragments and thick stratification tend to substantiate this interpretation. The former site of the volcanoes erupting this material may have been along the site of the present Aleutian Range. Perhaps the light muscovite granodiorite area is the subterranean manifestation of the locus of a former volcano where gases and volatiles were streaming from the batholith. Only two necks in the lower Jurassic volcanic rocks are known. One is on the ridge east of Middle Glacier Creek. It consists of vertically banded lava amidst the gently dipping pyroclastic beds. The pyroclastic strata change their dip near these necks and dip toward it rather than away from it on both sides (Plate 3a). A second neck is located at the ridge across the valley of the Middle Glacier Creek.

The Middle Jurassic tuffaceous graywackes, siltstones and conglomerates, conformably overlie ~~by~~ this lower Jurassic volcanic section. Volcanic cobbles and fine grained detritus in the graywackes makes up much of the lower Red Glacier formation. Apparently this material was being eroded from an already elevated western volcanic belt perhaps along the present core of the Aleutian Range. The batholith and its associated stock were probably emplaced by Middle Jurassic time. Dikes from this batholith cut the Lower Jurassic volcanic rocks and the earliest beds of the Red Glacier formation just east of ~~Mt.~~ Iliamna Volcano. The increasing abundance of quartz diorite in the upper sedimentary beds and the presence of the distinctive pink granophyric quartz monzonite in the Chisik conglomerate member of the Naknek formation indicates that these rocks were exposed only about 12 miles to the west of where they were deposited under near shore conditions in Kimmeridgian time.

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The stratigraphic record as well as the gentle eastward tilt of the sedimentary beds indicates that the central core of the Aleutian Range has gradually been undergoing uplift. Today the cover has been stripped from the batholith exposing the plutonic quartz diorite and its associated stocks of granophyric quartz monzonite.

Tertiary fresh water deposits occur along the coastal areas of Cook Inlet. The presence of coal seams, mudstone, and gravel conglomerates like those found in present stream channels sugge st that the coastal region of Cook Inlet was a swampy lowland during Eocene time.

~~Mt.~~ Iliamna volcano erupted near the contact of the quartz diorite batholith perhaps as much as 1 1/2 miles within the batholith. Its lavas spread over an old mountainous topography. These flows buried the quartz diorite on the west and the Jurassic volcanic and sedimentary rocks on the east. These ~~H~~ypersthene augite andesite and basaltic andesite lavas have a coarse basal breccia at their lower ends. The lava is often oxidized red at the surface and base of the flows. Glass inclusions sealed with the plagioclase crystals suggest that oxygen from the glass may have been utilized in the conversion of the ferrous oxide to crystalline specks of red hematite. The porous vent fillings of the volcano are opalized. Acid solfataric solutions have leached out the cations from the silicates leaving only the hydrous opaline pseudomorphs.

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