Recognition Criteria of Igneous and Metamorphic Rocks on Aerial Photographs of Chichagof and Kruzof Islands Southeastern Alaska

By J. S. POMEROY

PROCEDURES AND STUDIES IN PHOTOGEOLOGY

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An aid in the identification of major rock types in a complex geologic terrane

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CONTENTS

ILLUSTRATIONS

TABLE

PROCEDURES AND STUDIES IN PHOTOGEOLOGY

RECOGNITION CRITERIA OF IGNEOUS AND METAMORPHIC ROCKS ON AERIAL PHOTOGRAPHS OF CHICHAGOF AND KRUZOF ISLANDS, SOUTHEASTERN ALASKA

By J. S. POMEROY

ABSTRACT

Various aerial photographic recognition elements such as photographic tone, vegetation, drainage characteristics, structural features, and topographic expression can be used to assist in the semidetailed reconnaissance field mapping of a complex area of regionally and thermally metamorphosed rocks intruded by several types of igneous rocks. Combinations of these recognition elements are effective in distinguishing the igneous and metamorphic rocks of Chichagof and Kruzof Islands. Drainage character is one of the most reliable criteria.

INTRODUCTION

PURPOSE

Field investigations involving regional reconnaissance mapping were conducted on Chichagof, Baranof, and Kruzof Islands during the summer of 1961 (Loney and others, 1963). During the field season the author observed the usefulness of vertical aerial photographs in studying a geologically complex terrane. Because little has previously been written about photointerpretive aspects of specific igneous-metamorphic terranes, it is the purpose of this paper to summarize the photointerpretive features of the igneous and metamorphic terrane of Chichagof and Kruzof Islands (fig. 28). Areas on Chichagof Island which were mapped by other workers (Rossman, 1959; Lathram and others, 1959; Loney and others, 1963; Reed and Coats, 1941) are not discussed here.

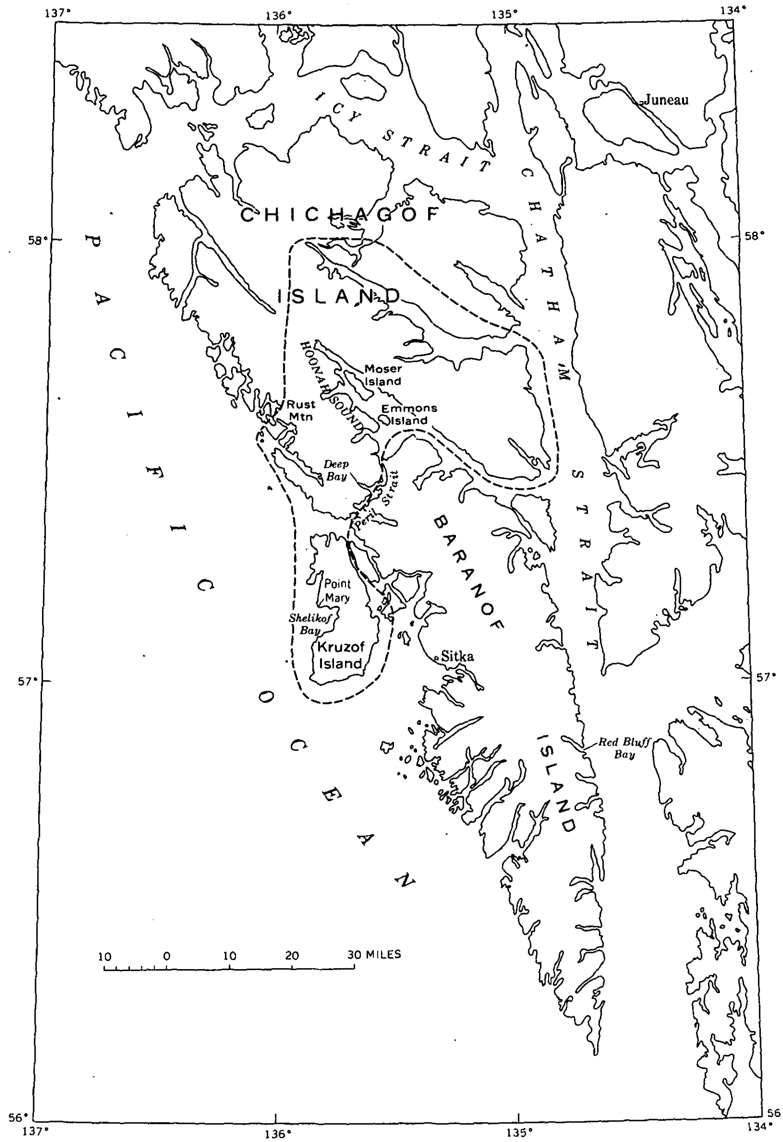

FIGURE 28.—Index map showing area discussed.

GEOLOGIC SKETCH

Rocks ranging in age from Silurian(?) and Devonian(?) to Quaternary crop out on Chichagof and Kruzof Islands. Plutonic rocks are abundant and constitute about 30 percent of the area discussed. Most of the layered rocks are older than the intrusive bodies, and although some of them are metamorphosed only slightly, most of them show the effects of either contact, regional, or dynamic metamorphism. In many places the rock type is a result of more than one form of metamorphism.

The area is complicated structurally by faulting and folding, and some of the layered rock units have been isoclinally folded.

During the Pleistocene Epoch, an ice sheet from the north and northeast covered all but the highest elevations of Chichagof and Kruzof Islands. Aerial photographs indicate that the ice cover reached a minimum elevation between 2,400 and 2,700 feet over a large part of Chichagof Island and much less, below 1,900 feet, on Kruzof Island. Glaciers no longer exist in the area, but the ubiquitous cirques and U-shaped valleys are evidence that glaciation has occurred.

GEOGRAPHY

The area is topographically representative of southeastern Alaska. Mountains rise directly from the major inland waterways, and the only low regions are the alluvial valleys which are best developed at the heads of bays. Some peaks rise to elevations of slightly less than 4,000 feet.

An annual rainfall of more than 85 inches is a major climatic feature. During the winter the climate is usually moderate along the shoreline, although a large amount of snow falls in the higher country. Summers are usually moist and cool; the daily temperature during the summer seldom exceeds 60°–65°.

Hemlock and spruce are the dominant tree growth. Brush, usually alder, devilsclub, and berry bushes, is thick and impenetrable in some places in the low areas. The elevation of the timberline varies but is usually between 2,000 and 2,600 feet.

RECOGNITION ELEMENTS

In studying the aerial photographs of an igneous and metamorphic terrane, different recognition elements—photograph tone, vegetation, topographic expression, drainage and erosional characteristics, as well as the structural features of the rocks such as foliation and jointing—can be used. Some recognition elements are more valuable than others, although any particular recognition element is more effective when other criteria are used with it. Complete interpretation is prevented in many areas by an insufficient number of criteria.

CHICHAGOF ISLAND

SUMMARY OF GEOLOGY

The central and eastern parts of Chichagof Island are dominated by several plutonic bodies composed principally of granodiorite, tonalite, diorite, and gabbro but also containing small amounts of syenite, monzonite, adamellite, trondhjemite, and norite (Loney and others, 1963). These plutonic bodies have intruded and metamorphosed many of the Paleozoic and Mesozoic rocks. Large areas of mixed migmatitic rocks lie adjacent to several plutonic bodies. Most of the intrusive rocks are probably the same age as those of the Coast Range batholith (Cretaceous), but a few may be older. Roof pendants consist principally of intensely folded hornfels, marble, amphibolite, and schist. A belt of graywacke, argillite, conglomerate, limestone, and marble crops out along the northeast edge of the area. To the west is a thick section of nonplutonic rocks—mapped as several distinct units—which range in age from Permian(?) and Triassic(?) to Early Cretaceous. These units, some of which are nearly monolithologic, consist of greenstone, marble, greenschist, phyllite, and graywacke.

RECOGNITION CRITERIA OF METAMORPHIC ROCKS ON AERIAL PHOTOGRAPHS

Marble is one of the major metamorphic rock types in the region. Because marble is lighter in tone on the photographs than any other metamorphic rock, it can be distinguished from other rock types wherever it is fairly homogeneous (fig. 29); marble is also generally lighter in tone than intrusive rock. Depending on the scale of the photographs or the magnification of the lens of the stereoscope, karst features may be observed. In a few places where massive nonfoliated marble occurs, it can be distinguished from other metamorphic rocks which usually have conspicuous foliation traces. Also, joints appear to be less developed in marble than in greenschist, phyllite, and hornfels.

Marble usually supports a stand of forest that is denser than that most characteristic of intrusive terranes. On eastern Chichagof Island a wide belt of nearly homogeneous marble crops out along Chatham Strait; a thick stand of forest obscures the area between the shoreline and the few ridge crests above timberline where the marble is exposed. Elsewhere in southeastern Alaska, marble supports a denser stand of evergreen forest than do other metamorphic

FIGURE 29.—Tonal differences and drainage characteristics of metamorphic-igneous terrane, Rust Mountain area, Chichagof Island. Light-toned marble (A) can easily be differentiated from adjacent metamorphic rocks. Extensive gullying as at B is diagnostic of terrane underlain by plutonic rock. Greenstone (C) has been intruded by granodiorite which crops out along mountain flank and along ridge at D. A thin veneer of greenstone masks the granodiorite in places. Note drainage in greenstone at E and probable fault scarp at F.

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and intrusive rocks (Condon, 1961, p. 9, 14, 19; Ray, 1960, p. 135). In the eastern part of the island, the small number of rills along the ridge slopes indicates a low surface-drainage density in the marble, where there is much greater subterranean drainage through solution channels.

Fine-grained mafic igneous rocks and metamorphic derivatives of pelitic sedimentary rocks such as phyllite usually have a fine-textured, or high, drainage density (fig. 30), but the drainage density of coarser grained derivatives such as gneisses or quartzofeldspathic schists and amphibolites is often much less (fig. 31). When discussing gully characteristics associated with the erosion of different materials, Lueder (1959, p. 69) writes about one type of gully which develops in very small grained cohesive materials that are low in porosity. These gullies have long and wide channels, a moderate to large number of branches, and a fairly uniform gradient. This type of gully is typical of many of the fine-grained metamorphic rocks.

Practically all the observed drainage of both metamorphic and igneous terranes is imposed upon a thin regolith. Research workers at Purdue University (1953, p. 16) found that gully characteristics of the major soil textural groups become nondistinctive and also that combinations are found when the soil has a "strong" or well-developed profile. Conversely, a thin soil mantle would have definite gully characteristics.

On the photographs, most metamorphic rocks show not only a conspicuous foliation but also an equally well developed joint system (figs. 32, 33). These "checkerboard" or grid patterns usually indicate an area of metamorphic rocks. Gneisses or quartzofeldspathic schists, however, do not have these characteristics in this region.

The metamorphic rocks of the average roof-pendant area cannot be divided on the photographs. Owing to the complexity of these rocks, field mapping of any particular lithology, even at a semidetailed scale, is often practically impossible. In these areas, particularly, any metamorphic unit tends to be thin and of short lateral extent.

On southwestern Chichagof Island where the units are nearly monolithologic, few criteria are available to distinguish the metamorphic rocks (other than marble), with but one exception. In massive greenstone foliation is commonly obscure or nonexistent both on the photographs (figs. 29, 34) and in the field; conversely, adjacent bodies of greenschist and phyllite have a pronounced foliation. In places the phyllite reproduces a lighter photographic tone than the greenschist, but this distinction is probably due to the abundant siliceous laminae which are associated with a particular phyllite unit.

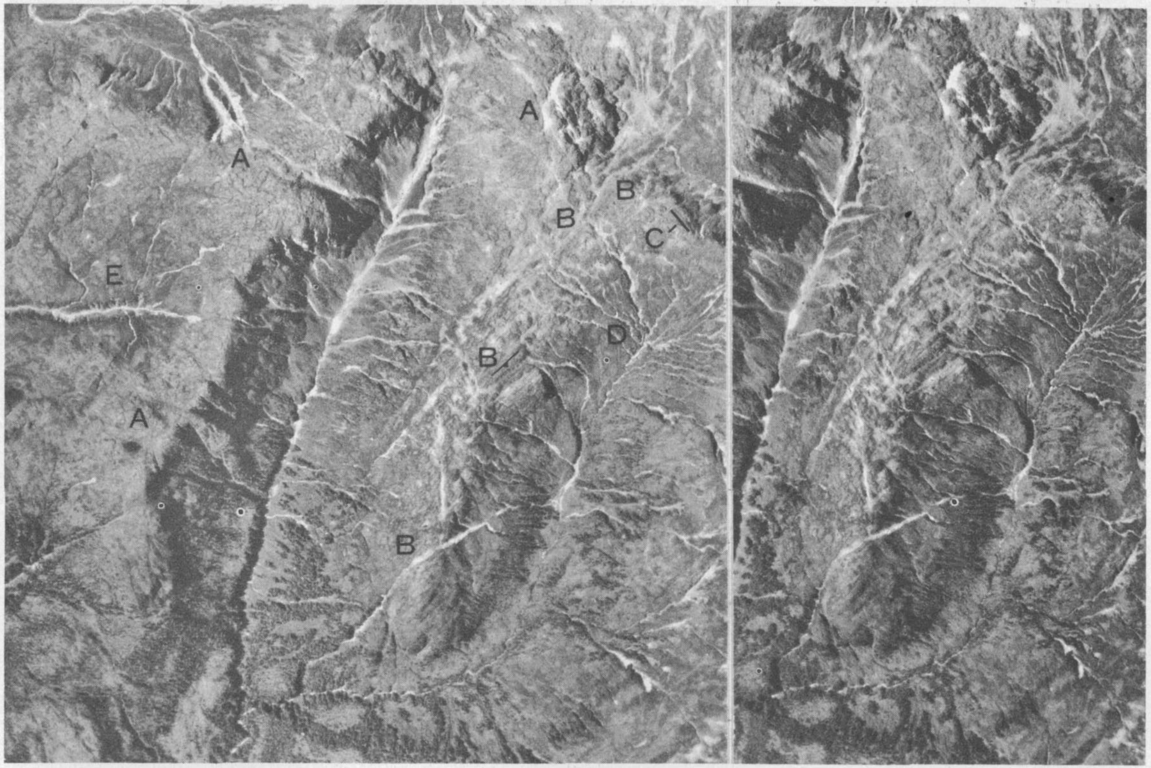

FIGURE 30.—Structural features and drainage characteristics of igneous-metamorphic terrane north of the head of Hoonah Sound, Chichagof Island. Plutonic rock (A) is gabbro and diorite. B is mainly fine-grained metamorphic rock. Strike and dip of foliation in the metamorphic rocks is apparent; also fractures as at C. Note difference in drainage density at D and E. The finer textured drainage at D than at E indicates less permeable rock at D. In vicinity of D, a thin cover of slope wash masks the outcrops.

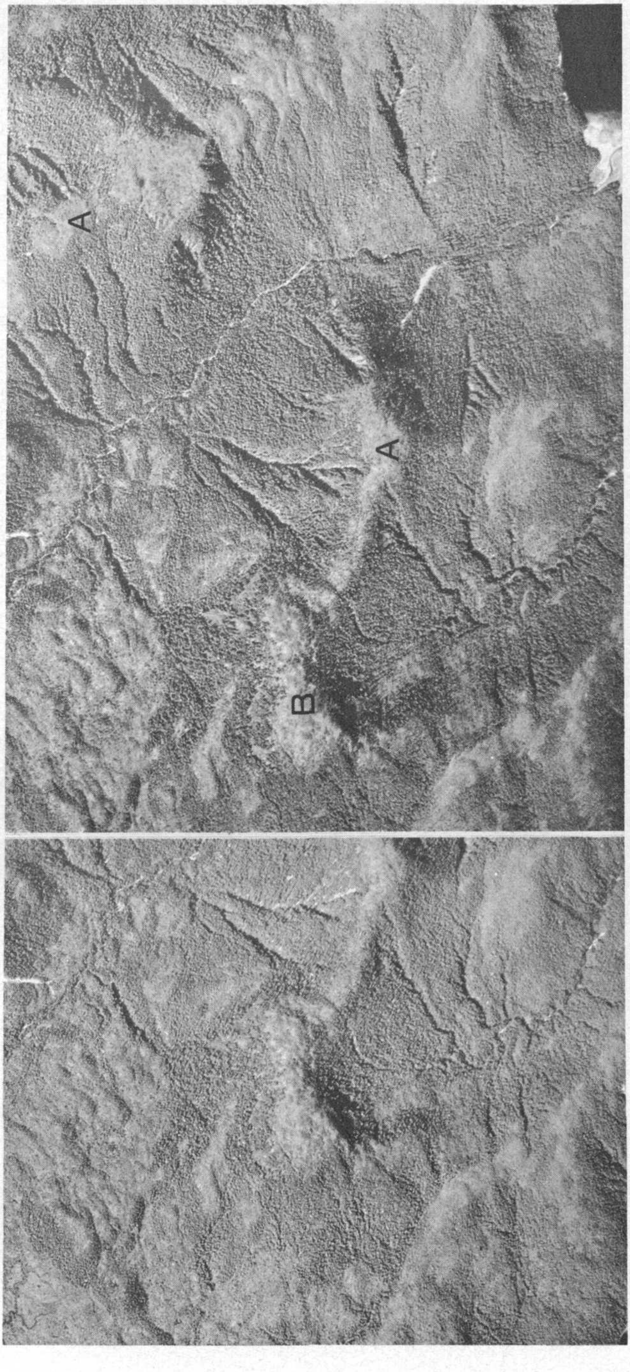

FIGURE 31.—Drainage characteristics of igneous-metamorphic terrane in Deep Bay-Peril Strait area, Chichagof Island. The deeply incised drainage system developed on slopes of the granodiorite hill at A contrasts with the drainage system of hill slopes underlain by medium- to coarse-grained quartzofeldspathic schist (gneiss) at B. Both rock types, especially the latter, feature a low drainage density, but the terrane underlain by quartzofeldspathic schist appears to lack deeply incised gullies.

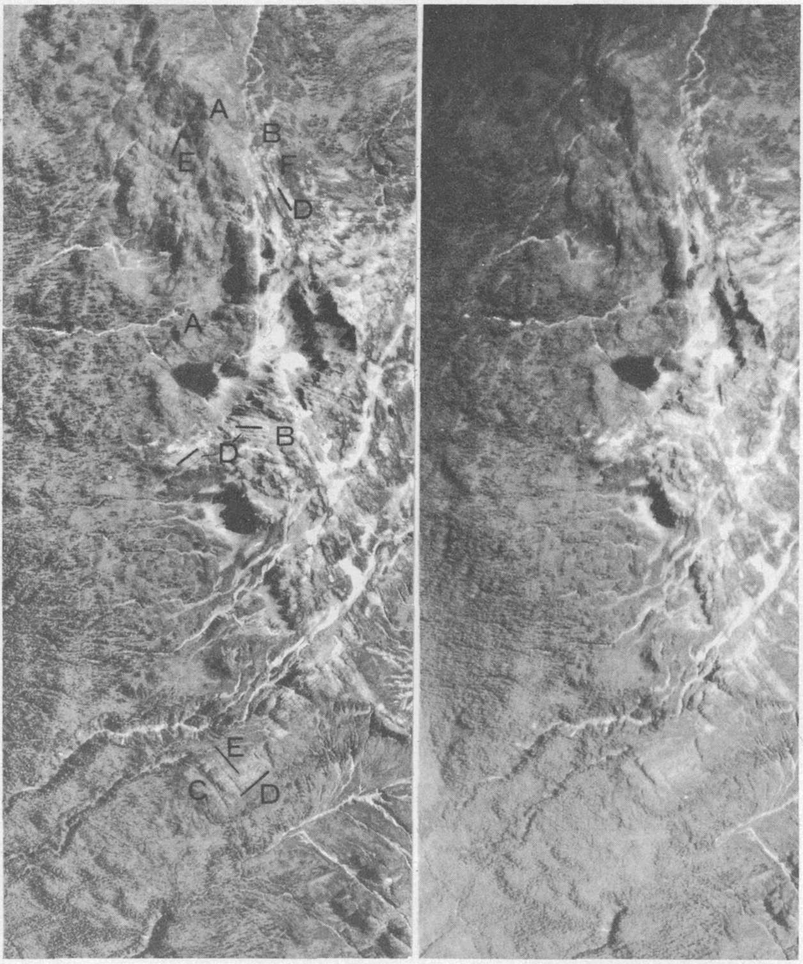

FIGURE 32.—Tonal differences and structural characteristics of igneous-metamorphic terrane north of the head of Hoonah Sound, Chichagof Island. A, gabbro; B, marble; C, interbedded hornfels, schist, amphibolite, and minor marble; D, foliation; and E, joints. Although the tone of the marble exposures (B) is lighter than that of the gabbro (A), the tone of the vegetation is darker (F). Marble usually shows less well-developed joints than do most other metamorphic rocks. Note checkerboard (grid) pattern at C.

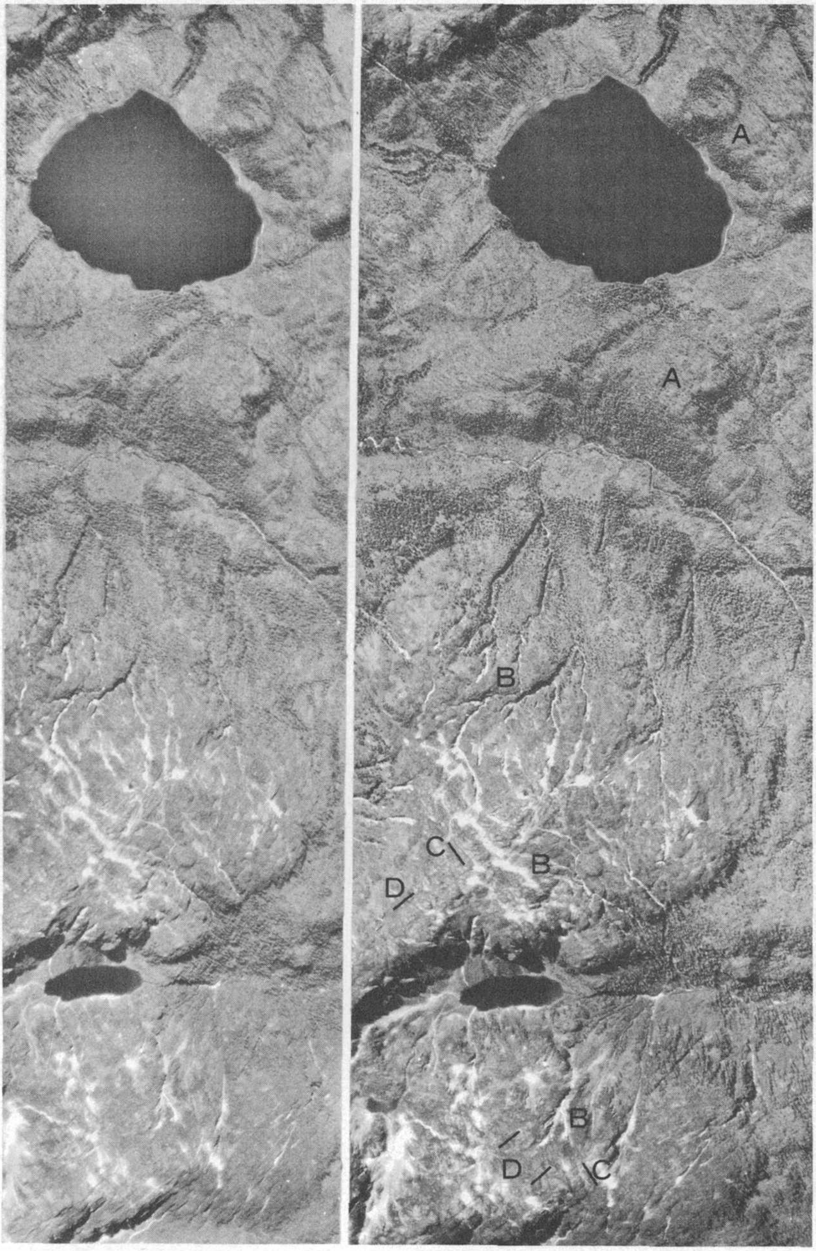

FIGURE 33.—Vegetation and structural features of igneous-metamorphic terrane northeast of the head of Hoonah Sound, Chichagof Island. Gabbroic terrane (A) is comparatively sparsely wooded even at elevations as low as 900 feet. Higher country (B) is underlain mostly by hornfels. C represents joints, and D is the strike of the foliation in the metamorphic rocks.

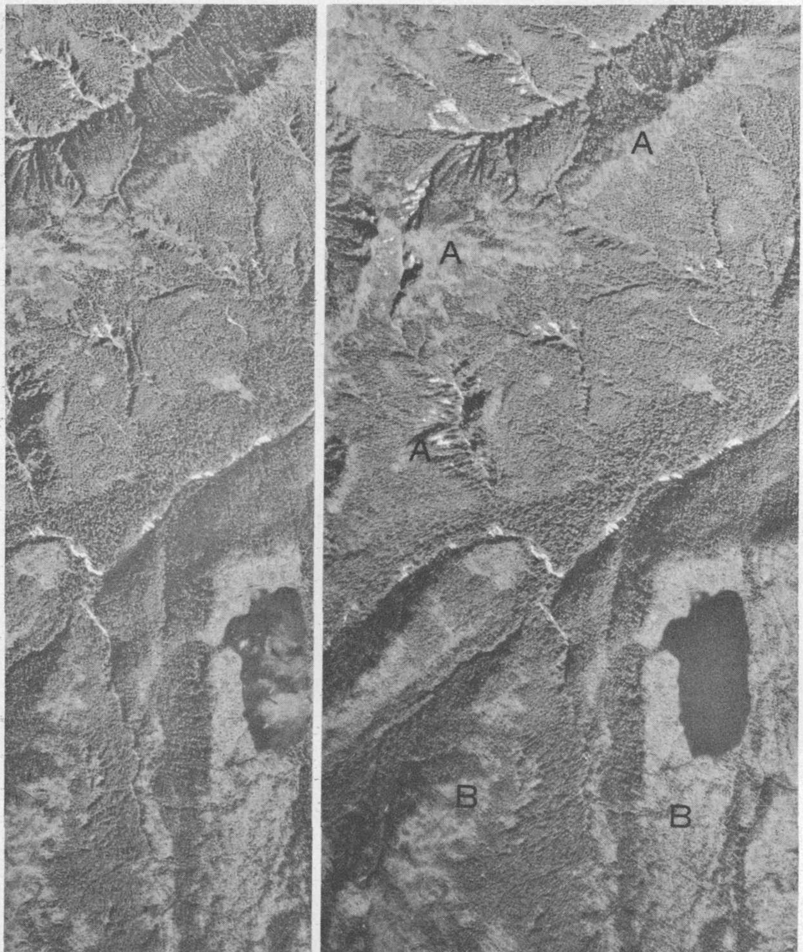

FIGURE 34.—Drainage characteristics and structural features of igneous-metamorphic terrane near Rust Mountain, Chichagof Island. A deeply incised drainage system is developed on granodiorite at A. Metamorphic area (B) is underlain by massive greenstone. Note absence of foliation traces in the greenstone.

A thick unmetamorphosed graywacke unit borders the metamorphic rocks to the west, but on the photographs the graywacke cannot be distinguished from the metamorphic rocks.

RECOGNITION CRITERIA OF INTRUSIVE ROCKS ON AERIAL PHOTOGRAPHS

Aerial photographs are of little value in differentiating intrusive rock types. As shown by field mapping, individual plutons on Chichagof Island are usually very complex and may include diverse rock types. Also, migmatitic areas cannot be recognized on the aerial photographs.

Tonal variations, for example, between a granodiorite or tonalite and a gabbro outcrop are either nonexistent or very weakly reproduced on the same photograph. Although tonal distinctions would logically result from the predominance of light- or dark-colored minerals in the rock type and from the tone of the weathered surface, only occasionally is this criterion reliable. Likewise, tonal variations between intrusive rock types mapped by the author in other areas of southeastern Alaska are not well reproduced on the aerial photographs.

Vegetational differences are sometimes more useful than tonal contrast in distinguishing plutonic rock types. Residual soils developed on silicic rocks are usually fertile and support a great variety of vegetation. Mafic rocks and their residual soils, however, contain a less well balanced supply of nutrients and support a more restricted type of vegetation. Soils derived from ultramafic rocks are infertile and frequently lack vegetation (Eardley, 1942, p. 159–160).

The silicic plutonic rocks of the eastern half of Chichagof Island as well as the granodiorite of Kruzof Island (fig. 35) tend to support a dense forest. In contrast, the gabbroic area northeast and northwest of the head of Hoonah Sound has a low timberline and a scanty brush growth. (See figure 33.) Admittedly, some terranes underlain by silicic plutonic rock do not support a dense stand of vegetation; for example, in some areas of central and western Chichagof Island, a scant tree growth is typical. Local climatic factors and the effect of glaciation on soil cover and drainage possibly cause these differences.

An area, however, of ultramafic rocks along the eastern shoreline of nearby Baranof Island has a vegetation-rock-type relation unaffected by other influences. The boundary of the Red Bluff Bay chromite-bearing body as mapped in detail by Guild and Balsley (1942) coincides with the vegetational boundary. Although it is near sea level, the ultramafic area has almost no vegetation. Robinson and others (1935) state that large quantities of chromium and nickel in soils cause infertility.

Surface drainage patterns in the intrusive rock of Chichagof Island are less dense than those in most metamorphic rocks. (See figures 30, 33, 34, 36.) Such wide spacing of streams results in a coarse-textured drainage system. The channels tend to be curvilinear although a few are nearly straight where slopes are steep. As previously mentioned (p. 92), the fine-grained metamorphic rocks have fine-textured or high drainage densities. Ray and Fischer (1960) discuss the drainage density of different rock types.

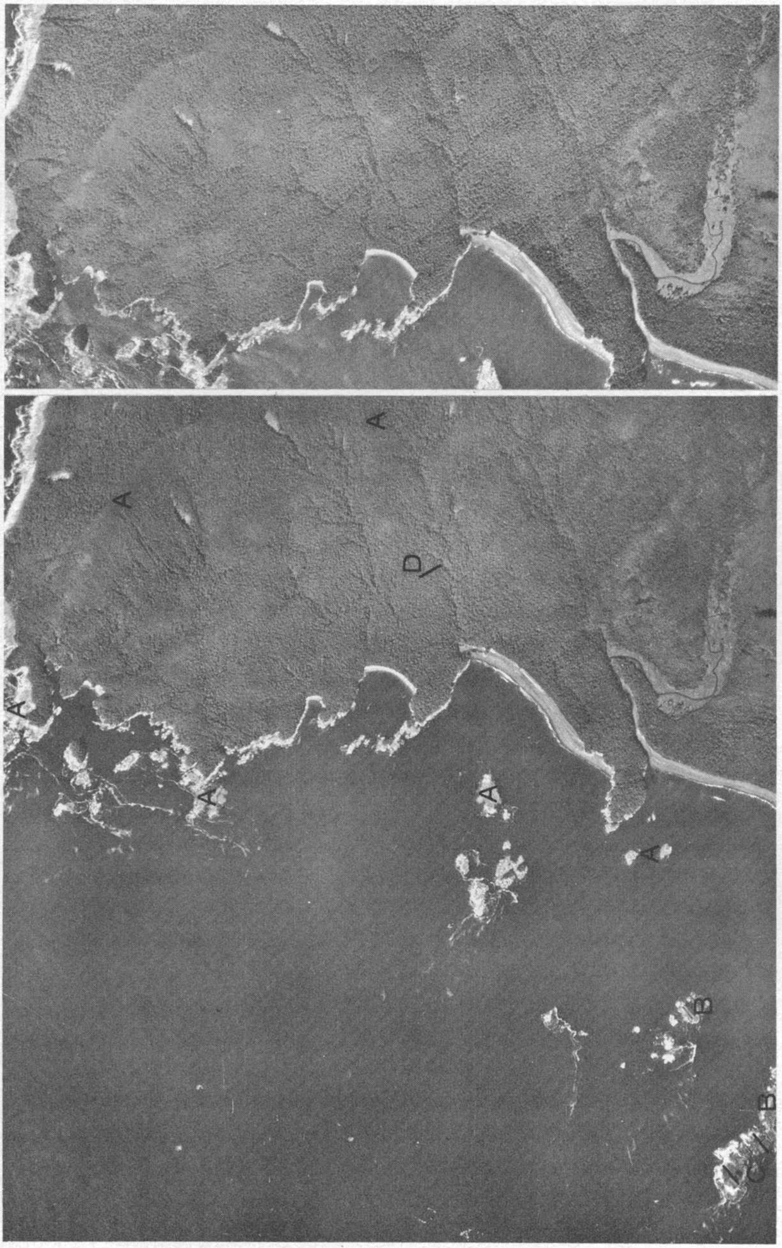

FIGURE 35.—Vegetation and structural features of igneous-metamorphic terrane in Point Mary–Shelikof Bay area, Kruzof Island. Densely wooded area along Pacific Ocean at A is underlain by granodiorite. Along the west coast of Chichagof Island where graywacke and schist crop out less dense vegetation and a lower timberline is typical. The light tone of granodiorite (A) along shoreline contrasts with darker tone of metagraywacke (B). Linear feature C represents the foliation of the metagraywacke. Linear feature D is indicative of a conspicuous regional joint set in the plutonic rock.

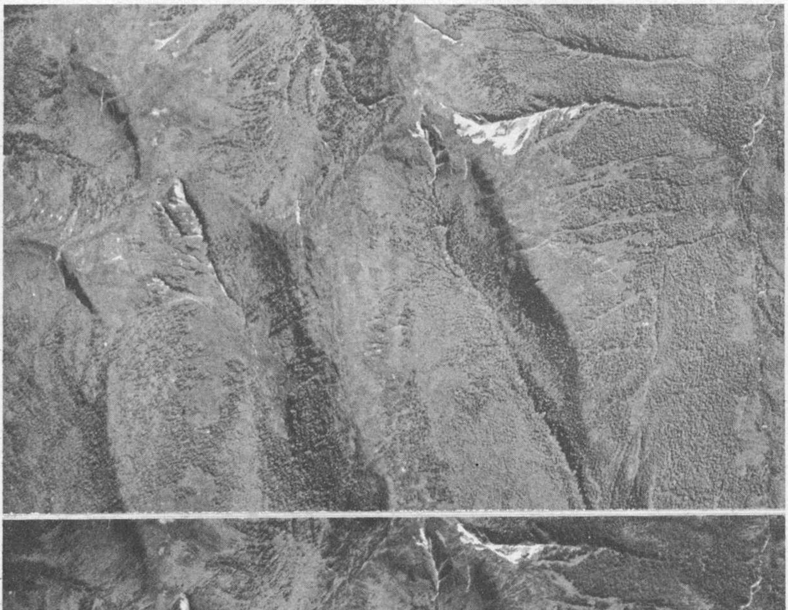

FIGURE 36.—Drainage characteristics of igenous terrane northeast of Emmons Island, Chichhagof Island. Deeply incised drainage system has developed on tonalite. Rapid disintegration of rock accounts for light-colored tone of hillside ravines. This characteristic is usually reliable in differentiating plutonic from metamorphic rock in areas largely covered by vegetation.

One of the best criteria for distinguishing plutonic from metamorphic rocks is the recognition of the steeply incised heads of hillside ravines characteristic of many areas of intrusive rock. (See figs. 29, 31, 34, 35, 36.) This criterion is helpful and reliable in areas where outcrops are sparse and where ridges are covered by trees or brush. Lueder (1959, p. 69) discusses one type of gully which develops in noncohesive material that has appreciable grain size and porosity; it is characterized by "* * * comparatively short length; simple and direct plan with few or no short simple branches, steep, uniform gradient with sharp knickpoint at head end, and a descriptive short steep gash or nick." Such a description fits most areas underlain by silica-rich to intermediate plutonic rocks on Chichagof Island.

Residual soils developed from rocks of gabbroic composition sometimes will have gullies of the type mentioned by Lueder. Gabbroic rock, however, even though it is usually coarse-grained, more often produces a somewhat clayey and impermeable soil, the soil composition depending on the amount of hornblende or other mafic minerals in the parent rock. Characteristics of the drainage system will likely include features of gullies developed both in silicic intrusive rocks and in pelitic and other fine-grained metamorphic rocks.

A large part of the plutonic rock on Chichagof Island is directionless or nonfoliated. Occasionally, however, an intrusive mass is foliated, and traces of the foliation are sometimes distinct in the photograph if the area is large enough. This feature can be confused with the conspicuous steep joint set that prevails in some plutons (fig. 37). Joint systems are more common and as easily distinguished in areas partly covered by sparse vegetation as they are in areas of good outcrop.

In the higher areas of Chichagof Island, igneous and metamorphic rocks can often be distinguished by the topographic expression of the ridges. Plutonic ridge crests are somewhat rounded or much less rugged than the characteristic sharp-crested serrate ridges of metamorphic rocks such as marble, phyllite, greenschist, and hornfels. Gneissic ridges are much less rugged than those ridges underlain by most metamorphic rocks.

Dikes intruding metamorphic rock are usually discernible on the photographs (fig. 38). As they are more resistant than the country rock in this area, the dikes occasionally have some relief.

KRUZOF ISLAND

SUMMARY OF GEOLOGY

Rocks ranging in age from Triassic and (or) Jurassic to Recent crop out on Kruzof Island. The oldest rocks, which constitute only a very small part of the island, consist of greenstone, greenschist, graywacke semischist, metachert, and phyllite. Graywacke, metamorphosed in places, overlies and is transitional with these rocks. A granodioritic pluton was emplaced after the deposition of the graywacke and has caused contact metamorphism in the adjacent rocks. Post-Pleistocene basaltic flows erupted over what is now southern Kruzof Island.

RECOGNITION CRITERIA OF ROCK TYPES ON AERIAL PHOTOGRAPHS

Aerial photographs are useful in distinguishing intrusive rock from the graywacke and its metamorphic equivalents. Pronounced contrast in tone is found along the shoreline on both the east and the west sides of the island (figs. 35, 39, 40) where plutonic rock is light in tone when compared to the medium-toned graywacke and graywacke hornfels. As only a few parts of the ridges are above the timberline, tonal

FIGURE 37.—Structural features northeast of Emmons Island, Chichagof Island. A, dominant joint set in tonalite. Persistent linear features represent dominant vertical joint set in nonfoliated tonalite. These trends could be mistaken for foliation in a metamorphic (or igneous) rock.

FIGURE 38.—Structural features of metamorphic terrane on southern Chichagof Island. Altered gabbroic bodies (A) cut a sequence of greenstone, greenschist, and metachert. Note light tone of A. Linear trend at B represents foliation of the metamorphic rocks. At C thin beds of light-toned metachert could be mistaken for felsic sills. Light-toned linear bodies at D are dikes that have filled joints in the metamorphic rocks.

variations cannot be used here. The metagraywacke ridges, however, tend to be sharper crested than the less rugged ridges of intrusive rock that lie at similar elevations.

The photographs show that the structural patterns in the two rock types are dissimilar. Fairly to moderately well defined northeastward-trending joints are common in the granodiorite. Conspicuous northwestward-trending bedding and foliation traces are found in the graywacke and graywacke hornfels.

The contact between the graywacke and its metamorphic equivalent is gradational; so neither unit can be distinguished on the photographs, nor can a contact be delineated between the graywacke and the older rocks which are transitional with it.

The basaltic flows and their associated cones of southern Kruzof Island are obvious features on the aerial photographs (fig. 41). The landscape is characterized both by a radial and by a dendritic drainage pattern having more dense vegetation growing along the creeks and shoreline and by an absence of structural trends (fig. 40). Although the photographic tone of the basalt and metagraywacke along the shoreline is similar, closely spaced persistent northwest foliation traces in the metagraywacke contrast with the featureless and flat-lying basalt.

SUMMARY AND CONCLUSIONS

Recognition criteria of the major igneous and metamorphic rock types on the aerial photographs of Chichagof and Kruzof Islands are summarized in table 1. The author believes that most of these recognition elements are applicable elsewhere in southeastern Alaska, and that a few can be used in almost any region. While photointerpretation techniques can seldom be used as a substitution for field mapping, they can greatly assist an experienced field mapper even in a complex geologic terrane. The author certainly cannot subscribe to any suggestion that rocks, particularly those of igneous and metamorphic origin, might be best differentiated by using aerial survey instead of field and laboratory methods (Lueder, 1959, p. 269, 272, 274).

Aerial photographs for the discussed area are chiefly valuable for the help they give in the differentiation of igneous from metamorphic rocks. Aerial photographs are of limited value when distinguishing the complexly folded and varied metamorphic lithologies from one another or when identifying intrusive rock types. Various recognition elements such as outcrop tone, vegetation, topographic expression, drainage and erosional characteristics, and structural features of the rocks themselves are used in the demarcation of the major rock types. Of these criteria, drainage character is one of the more reliable recognition elements.

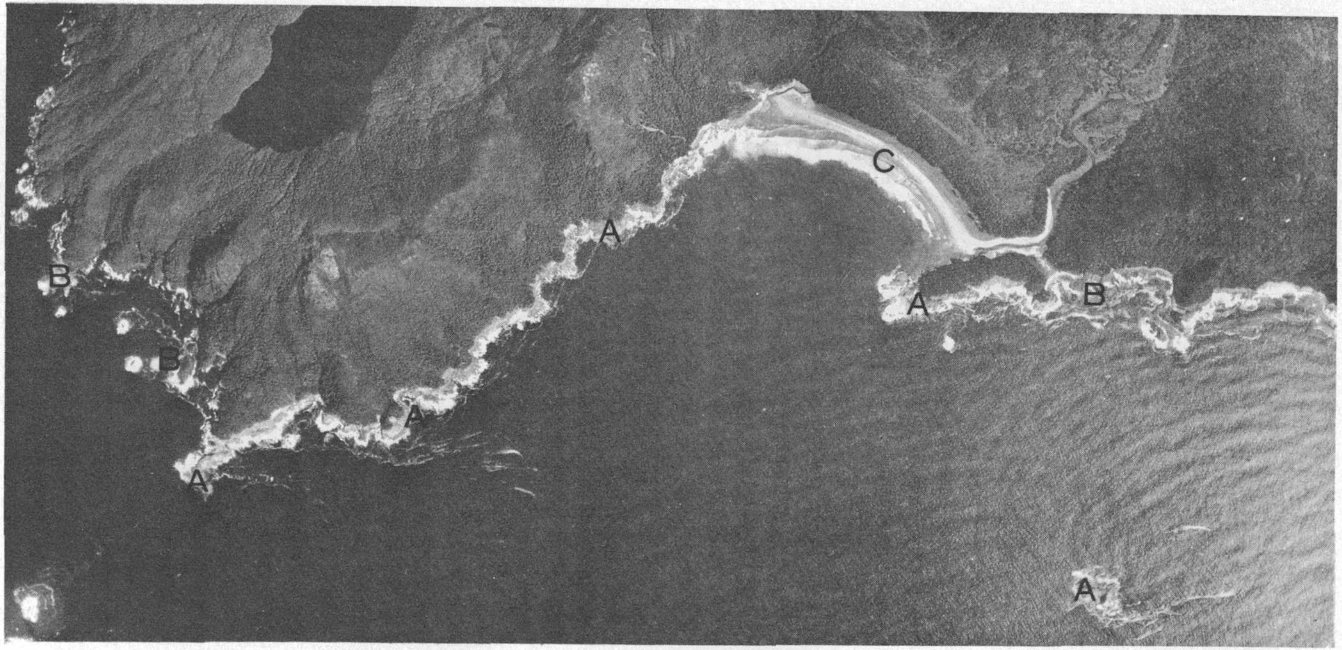

FIGURE 39.—Tonal differences in igneous-metamorphic terrane along coast of northwestern Kruzof Island. Light-toned rock (A) is granodiorite. Darker-toned rock (B) is hornfels. Along well-exposed shorelines tonal distinctions between plutonic and metamorphic rock are usually apparent. Sea foam obscures rock tone somewhat on left side of photo. Wide sandy beaches where outcrops are lacking as at C are indicative of nearby granitic rock.

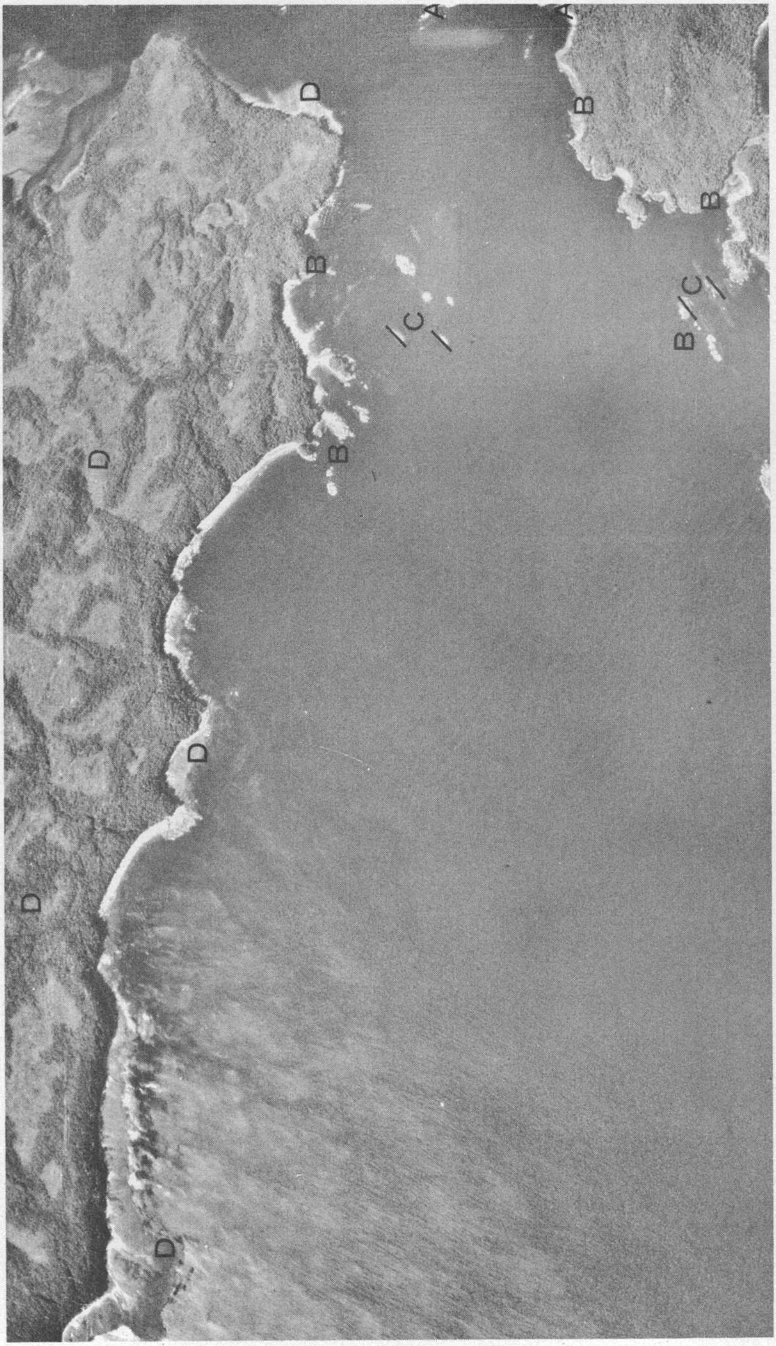

FIGURE 40.—Tonal differences and structural features of igneous-metamorphic terrane along eastern Kruzof Island. Sharp tonal contrast is evident between tonalite (A) and metagraywacke (B). At C, the strike of foliation in nearly vertical contact metamorphic rocks can be seen. Wide beach exposures of flat-lying rocks are Recent basaltic flows (D). Note dendritic drainage system and concentration of tree growth along stream courses.

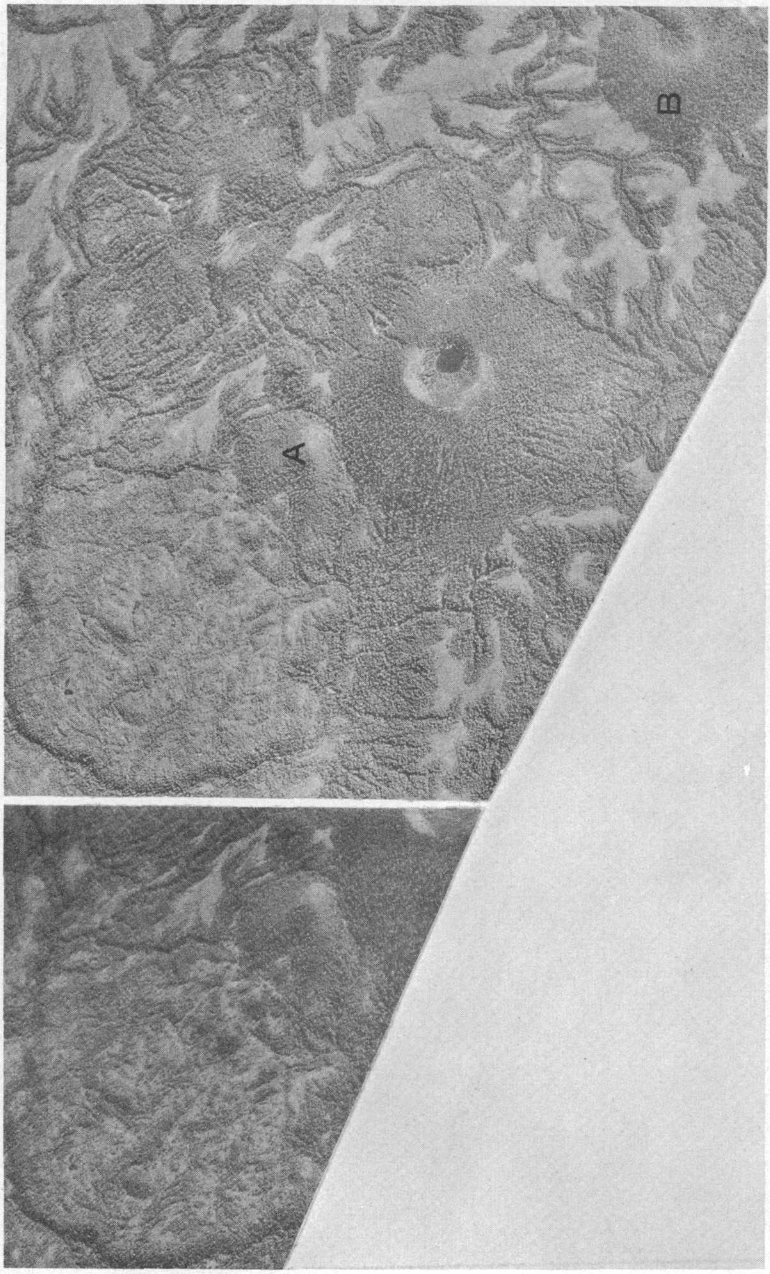

FIGURE 41.—Topographic expression of volcanic landscape, southern Kruzof Island. Quaternary basalt, ash, and lapilli characterize the landscape. A, parasitic cone and its flow; and B, breached cone. Note radial and dendritic drainage system and concentration of vegetation along creeks and slopes of cones.

TABLE 1.—*Summary of recognition criteria of igneous and metamorphic rocks on aerial photographs of Chichagof and Kruzof Islands*

Rock types			Photographic tone of outcrop	Vegetation	Drainage characteristics	Structural features	Topographic expression
Igneous	Intrusive	Granitic to tonalitic.	Light to medium	Variable but commonly dense.	Coarse textured drainage (low drainage density); deeply incised gullies.	Joints, unidirectional to multidirectional sets. Foliation, prominent in places.	Ridge crests are rounded; less rugged but with steeper slopes than those of metamorphic rocks. (Applicable only on Kruzof Island and at high elevations on Chichagof Island.)
		Gabbroic	Variable but usually medium.	Commonly less dense than on granitic to tonalitic rock.	Same as above in places, but more commonly intermediate between silicic intrusive rocks and fine-grained metamorphic rocks.		
	Extrusive	Quaternary basalt.	Medium to dark	Dense along creeks, shorelines, and slopes of cones.	Radial and dendritic patterns.	Absent	Cones, craters, individual flows.
Metamorphic	Marble		Very light	Commonly dense	Low surface drainage density; Karst features in places.	Foliation, usually moderate to strong expression where rock nonmassive. Joints, fair expression.	Generally sharp-crested serrate ridges for marble, phyllite, greenschist, and hornfels; less rugged expression for other metamorphic rock types. (Applicable only on Kruzof Island and at high elevations on Chichagof Island.)
	Greenstone		Medium	Commonly less dense than on marble.	Fine-textured drainage (high drainage density) for phyllite and other fine-grained rocks. Coarser textured drainage and lower drainage density for gneisses or quartzofeldspathic rocks.	Foliation, poor expression. Joints, poor expression.	
	Phyllite Greenschist Hornfels Amphibolite Gneiss		Variable but commonly medium.	Variable but less dense than on marble.		Foliation, usually moderate to strong expression except in gneiss. Joints, usually moderate to strong expression except in gneiss.	

SOURCE AND IDENTIFYING DATA OF PHOTOGRAPHS

[Project code SEA (Southeastern Alaska)]

Figure	Roll	Exposures	Topographic quadrangle (1:63,360)
29	135	22–23	Sitka C–6
30	139	38–39	D–6
31	128	90–91	B–5
32	139	39–40	D–6
33	128	80–81	D–5, D–6
34	135	75–76	C–6
35	135	39–40	A–6
36	128	39–40	C–5
37	128	39	C–5
38	135	70	C–6
39	135	35	B–6
40	128	103	A–5
41	135	57–58	A–5, A–6

Other data:

Approximate scale of photographs is 1:40,000.
Photographs were taken by U.S. Navy during July 1948.
Focal length of lens of camera was 6 inches.
Photographs may be purchased from:
U.S. Geological Survey
Map Information Office
Washington, D.C. 20235

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