Geology of the Craig Quadrangle Alaska

By W. H. CONDON

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ABSTRACT

The Craig quadrangle, in southeastern Alaska, lies entirely within the Tongass National Forest and includes a large part of Prince of Wales Island, the largest island of the Alexander Archipelago. Sedimentary, volcanic, and metamorphic rocks of Paleozoic and Mesozoic age are exposed as complexly folded and faulted sequences. Paleozoic rocks occupy a broad geanticlinal area comprising Prince of Wales Island and the islands to the west. Metamorphosed Mesozoic rocks form a geosynclinal area along and east of Clarence Strait. Granitic and dioritic stocks and masses, mainly of Mesozoic age, intrude the Paleozoic and Mesozoic rocks. Remnants of volcanic rocks of Tertiary age exist on Suemez Island, and scattered areas of Tertiary clastic rocks and volcanic rocks are exposed near Clarence Strait. Deposits of Quaternary age are mainly thin glacial deposits and narrow bands of stream alluvium.

The fault pattern within the quadrangle is reflected by well-defined major lineaments striking northward to northwestward, and by generally less conspicuous linear features trending northeastward and eastward. A complex history of faulting seems indicated beginning in the Paleozoic, extending through the Mesozoic, and into Recent times.

In the past, there has been production of or extensive prospecting for, metallic mineral deposits, including the copper and copper-iron deposits of the Kasaan Peninsula, Hetta Inlet, and Niblack areas, the gold deposits of Helm Bay, and the complex sulfide deposits of the Dolomi-Cholmondeley Sound area. Other noteworthy mineral occurrences include the molybdenite of Baker Island, the iron-chromium deposits of Mount Burnett, and the galena of Coronation Island; zinc is not uncommon in complex sulfide deposits. Some gold, silver, and palladium have been recovered as byproducts of base-metal mining. The only significant development of nometallic deposits has been the prospecting for, and quarrying of, limestone and ornamental marble.

INTRODUCTION

LOCATION

The Craig quadrangle comprises an area of about 7,000 square miles between lat. 55° and 56° N., and long. 132° and 134°30′ W. It is one of the southernmost quadrangles of southeastern Alaska and lies about 15 miles west of Ketchikan and 170 miles south of Juneau (fig. 1). The quadrangle is entirely within the Tongass National Forest.

HISTORY OF GEOLOGIC INVESTIGATIONS

Systematic surveys and investigations in southeastern Alaska began with a very general reconnaissance of the Ketchikan district by A. H. Brooks in 1901. This reconnaissance included parts of the Craig quadrangle. A reconnaissance of Kasaan Peninsula was made in 1904–05 by F. E. Wright and C. W. Wright. In 1907, C. W. Wright and Sidney Paige did reconnaissance mapping and made short investigations on the Kasaan Peninsula and Jumbo Basin areas; the fieldwork was completed in 1908 by Wright. No investigations took place other than brief mine visits until 1912 when E. F. Burchard studied the marble and gypsum resources in the Ketchikan and Wrangell districts.

In 1913, P. S. Smith began stratigraphic studies in the Ketchikan district. The work was continued and expanded by Theodore Chapin through 1915 to 1917 resulting in the mapping of the district south

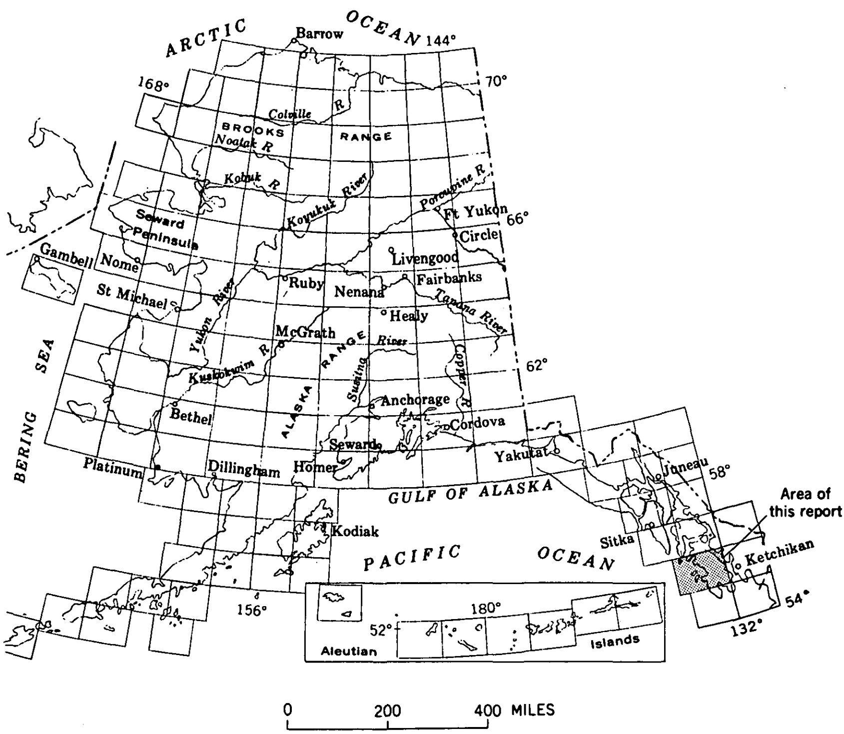

FIGURE 1.—Index map of Alaska showing location of the Craig quadrangle.

of lat. 55°40′ N., and a report on the mineral deposits of the area. Some paleontologic investigations by Edwin Kirk and others, dealing mainly with Silurian Strata, were conducted in 1917. J. B. Mertie, Jr., investigated some iron ores of the Ketchikan district in 1917 and 1919. The work of Chapin was continued by A. H. Buddington in 1921-25, their joint efforts resulting in publication of U.S. Geological Survey Bulletin 800 (1929). This geologic reconnaissance mapping consisted largely of shoreline observations. Some large areas remained unmapped, notably the interiors of central Prince of Wales Island and Cleveland Peninsula, Coronation Island, and small parts of other islands.

After the work of Buddington and before 1941 very little or no geologic investigation was done by the Geological Survey within the Craig quadrangle. In 1941–48, investigations of many mines and small areas were made to evaluate or search for deposits of various strategic metals including iron, copper, zinc, the platinum metals, nickel, and chromium. The largest volume of these investigations was done in 1942–44 on Kasaan Peninsula and vicinity by Warner, Goddard, Walton, Gault, Wahrhaftig, and others who studied copper and iron deposits; much of their work is unpublished except as open-file material. Molybdenum deposits on Baker Island were investigated in 1943 by G. D. Robinson. The ultramafic rocks of Mount Burnett were investigated also in 1943 for nickel, chromium, and the platinum metals by G. C. Kennedy and M. S. Walton, Jr. Copper and iron deposits of Jumbo Basin on Hetta Inlet were studied in 1904 by Kennedy. Zinc and lead deposits of the Dora Lake area were reported upon by W. S. Twenhofel. In some of these mining areas drilling and trenching work was done by the U.S. Bureau of Mines.

The most recent investigations and mapping by the Geological Survey in Craig quadrangle have been by G. D. Eberlein and by C. L. Sainsbury. In the field seasons of 1947–49, Eberlein completed detailed mapping of Heceta and Tuxekan Islands, and some reconnaissance of other smaller areas (Eberlein, oral communication, 1949). Spot field checks were made by Eberlein, Sainsbury, and the writer as a brief reconnaissance in 1954. In 1954 and 1955, Sainsbury made reconnaissance studies of parts of eastern Prince of Wales Island. Reconnaissance has been made for radioactive deposits by J. R. Houston and others.

The object of the present compilation is to summarize, consistent with the scale of plate 1, the known geologic data from maps and reports, and to supplement and modify locally this summation with geologic interpretations from aerial photographs. The reliability of geologic data within this quadrangle varies; in areas previously mapped, reliability depends upon the amount of basic data available and whether it is reconnaissance or detailed. (See compilation on pl. 1.) In areas previously not mapped, reliability depends upon how well the criteria for identifying formations are expressed on aerial photographs. The identification and extension of certain rock units are tenuous owing to the complexity of folding and faulting, the lack of basic field data for some large areas, and to the masking effects of vegetal cover, glaciation, and metamorphism. Spot field checks were made of some selected key points in 1954.

Geologic data for this compilation have been extracted from all available published and unpublished information and have been supplemented and modified by interpretation of vertical aerial photographs of about 1:40,000 scale (pl. 1). Several of the published references are now out of print. This text is based mainly upon U.S. Geological Survey Bulletin 800 (Buddington and Chapin, 1929), a large part of which is reconnaissance confined chiefly to shoreline. Compilation of the geologic map along the shoreline is based mainly upon Bulletin 800, but inland mapping is mostly based upon interpretation of aerial photographs. Detailed or semidetailed geologic mapping and description cover small and scattered but important areas. These include the Heceta-Tuxekan Islands area (Eberlein, written communication, 1949), part of Baker Island (Robinson, 1946), the Hetta Inlet area (Kennedy, 1953; Wright, 1915), Kasaan Peninsula (Wright, 1908, p. 78–97, 116–126; 1915; Warner and others, 1960), and Mount Burnett (Kennedy and Walton, 1946). The work of Twenhofel and Sainsbury (1958) on the pattern of faults and lineaments in southeastern Alaska strengthens the photogeologic interpretation of a similar pattern in Craig quadrangle. These reports and many others contain useful data as brief references, summations of previous information, or annual progress reports on mines, quarries, and prospects.

The selected bibliography represents those publications considered by the writer to be most useful in the compilation of this text and map at the 1:250,000 scale. Many publications not listed were useful as spot checks of small areas. These include mine reports of the Territorial (Alaska) Department of Mines (now Alaska Division of Mines and Minerals), reports of investigations by the U.S. Bureau of Mines, and the annual mineral resources bulletins, open-file material, and unpublished information of the Geological Survey.

ACKNOWLEDGMENTS

The writer is indebted to the publications previously mentioned for most of the information in this compilation. Further acknowledgment is extended to G. D. Eberlein and C. L. Sainsbury for generous counsel in the field and in the office, especially regarding their field observations and unpublished mapping, and to C. W. Merriam and J. T. Dutro, Jr., for preliminary examination of fossils. Some information on current mining activity has been supplied by the Territorial (Alaska) Department of Mines.

GEOGRAPHY AND GEOMORPHOLOGY

The largest part of the land area of Craig quadrangle is in Prince of Wales Island, the southernmost major island of the Alexander Archipelago. This island is separated from Cleveland Peninsula and Etolin Island by the broad expanse of Clarence Strait, and from the many large and small islands seaward by generally narrow irregular channels and straits.

Prince of Wales Island is characterized by rugged mountain groups of low to moderate relief, generally with altitudes of 3,000 feet or less but locally nearly 4,000 feet, as in the Copper Mountain area. The mountains are separated by steep-sided glacial valleys and fiords. Deep sounds and long arms of the sea extend inland, and with the many small inlets and bays form an extremely irregular coastline. Lakes are abundant at the lower altitudes as well as in the many glacier-carved rock basins. Streams are mostly small and short. They have the steep and irregular profile of the early stage of stream development. A few of the larger streams are tidal for short distances from their mouths where gradients are low, and some flow through small tidal flats. The terrain of Cleveland Peninsula and the other islands of the quadrangle is similar to that of Prince of Wales Island.

The geomorphic development of the region has been strongly influenced by underlying rocks and the geologic processes. Many topographically low areas or arms of the sea occupy crest or trough lines of anticlinorial or synclinorial structures. Faults or shear zones probably have determined parts of the courses of many present-day or preglacial streams. Differential erosion of underlying rock has influenced the distribution of highland and lowland areas. Shoreline characteristics are affected largely by the composition and structure of the rocks. Intrusive rocks tend to form resistant headlands; limestone tends to form blocky shorelines where exposed to wave action of the open sea, or regular shorelines where protected; deep water close to shore is characteristic in either situation. The widespread volcanic rocks and thinly interbedded rocks of different types commonly form dangerous offshore reefs and ragged coastlines.

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Glaciation has been the most significant factor in modifying the land. No present-day glaciers exist but past glaciation by ice sheets and alpine glaciers have had marked effects. Preglacial drainage lines were widened and deepened to form U-shaped valleys and fiords; mountain peaks and ridges were rounded and probably only a few of the highest peaks stood above the limits of glaciation. Alpine glaciation has produced steep-walled cirques whose horseshoe-shaped rock basins are generally occupied by tarns, and surrounded by sharp ridges.

The climate of the region is mild with a mean annual rainfall of 100 to 150 inches. The density of forest cover and undergrowth is typical of the rain forest of cold temperate regions. The dominantly coniferous growth consists mainly of hemlock, spruce, and less abundant cedar, with sparse intergrowths of deciduous trees such as ash, cottonwood, and alder. Undergrowth consists of berry bushes and devilsclub. Muskeg is widely distributed especially in the lowlands and flatter parts of the upland areas, where it occurs as patches within timbered areas or locally as broad, swampy, nearly treeless expanses. The timberline is commonly between altitudes of 1,700 and 2,200 feet.

Transportation into and within the quadrangle is limited to the use of boats and float planes. Most shoreline points are easily accessible to small boats and many deepwater channels and anchorages exist for larger vessels. Charter and schedule service of small float and amphibian planes is maintained from Ketchikan, the nearest distributing point to the quadrangle. On Prince of Wales Island and Cleveland Peninsula, many lakes in the lowlands and a few in the uplands, as well as protected bays and inlets, are suitable for float-plane landings. Only a few such lakes are suitable on the smaller islands. No landing fields are maintained in the quadrangle. Public roads are not developed except for one between Craig and Klawak. Private roads exist as short mine or logging roads in various states of repair. Some of these, especially logging roads, have been recently constructed or improved and extended.

The larger settlements are Hollis, Craig, Klawak, and Hydaburg. Small groups of permanent residents live near sites of canning, lumbering, and mining activity.

DESCRIPTIVE GEOLOGY

Most of the exposed sedimentary and volcanic rocks are of Paleozoic age. A smaller part of the bedrock comprises a belt of Mesozoic rocks as well as scattered remnants of the Cenozoic system. Igneous dikes, sills, stocks, and small batholithic masses cut the rocks of Paleozoic and

Mesozoic age. Much of the quadrangle area is covered by Pleistocene glacial drift of varying thickness.

The lithology is widely varied both stratigraphically and areally. Sequences of thinly interbedded graywacke, tuff, conglomerate, lava flows, slate, tuffaceous or arkosic sandstone, limestone, and chert in varying combinations are characteristic of much of the Paleozoic rocks. Volcanic rocks are abundant as are thick sections of massive limestone within the Paleozoic rocks.

The composite stratigraphic column of the rocks exposed within the Craig quadrangle indicates several unconformities. The column contains several units whose stratigraphic position is not thoroughly understood, thus their relations are generalized. The lack of close and reliable correlation of the strata of the region as a whole, the facies, changes, the complexity resulting from several periods of folding and faulting, and the effects of regional and contact metamorphism, prevent clear interpretation.

Intrusive igneous rocks are widely distributed and are generally believed to be genetically related to the Coast Range batholith as outlying satellitic masses emplaced during Jurassic and Cretaceous times. Emplacement of these bodies and the metamorphism associated with it altered large areas of bedrock, superimposed new trends of structure, and possibly masked the evidence of previous igneous intrusion.

METAMORPHOSED ROCKS OF UNDETERMINED AGE

Metamorphosed rocks of undetermined age have previously been mapped as the Wales group in the southeastern part of the quadrangle and the Wrangell-Revillagigedo belt in the northeastern part. The original clastic and limy sedimentary rocks, limestone, and volcanic rocks have been transformed by regional and contact metamorphism to schist and phyllite, crystalline limestone and marble, and the schistose greenstone and other metavolcanic rocks now exposed. The age of these metamorphosed rocks is commonly given as possible pre-Ordovician to Early Cretaceous and the grade of metamorphism is generally low.

WALES GROUP

The Wales group as mapped and described by Buddington and Chapin (1929, p. 45–49) for southeastern Alaska comprises four units. From oldest to youngest, they are: (a) schist, (b) schist with interbedded limestone and slate, (c) a unit dominantly of limestone, and (d) a unit dominantly of greenstone. Only the last three units were mapped in the Craig quadrangle. Contacts are gradational, with interbedding of the dominant rock types. In the Jumbo Basin area, upper Hetta Inlet, Kennedy (1953, p. 1, 5) distinguished two major divisions of the Wales group: folded metamorphosed limestone conformably overlain by calcareous schist and quartz-mica schist; and a greenstone unit with a small proportion of clastic rocks unconformably overlying the limestone and schist. Contact metamorphism by intrusive igneous masses as well as regional metamorphism by tectonic forces have obscured or complicated the original structure.

The Wales group has been mapped in a broad belt in the southeastern part of the quadrangle between Cholmondeley Sound and Dolomi and forms most of the rock between the sound and Hetta Inlet to the west and southwest. The belt is anticlinorial with a northwestward-trending axis. The northwestward extension of this belt, as interpreted from aerial photographs, has a similarity of topographic expression to rocks of the Wales group. Data concerning rock type are scant, but those given for the Marble Heart claim (Brooks, 1902, p. 93) favor this northwestward extension of the Wales group. The northern limit of the group is probably at or near a fault zone that trends eastward from the head of Trocadero Bay. The western limit of these rocks is indefinite on aerial photographs.

The Wales group is presumed by Buddington and Chapin (1929) to include the oldest strata within the Craig quadrangle, and its base is nowhere exposed. The group is probably largely of Ordovician and Silurian age, and probably includes Devonian and possibly some pre-Ordovician rocks. The few fossil fragments reported from this group are not diagostic (Buddington and Chapin, 1929, p. 49) and ages based upon comparison of rock types are tenuous at best. The Wales group is unconformably overlain in places by Devonian beds, in others by Silurian beds with undetermined relations. The Wales is deformed and metamorphosed to a much greater degree than known Silurian or younger rocks.

Mineral deposits within the Wales group have been developed locally, and many mines in the Hetta Inlet and Dolomi areas in the southeastern part of the quadrangle have been limited producers. Gold-bearing veins are abundant in the schist of the Dolomi area. Copper and iron deposits are associated with skarn at the contacts of limestone with intrusive igneous masses near Hetta Inlet. Scattered sulfide deposits of lead, zinc, and other metals, and shear-zone deposits of copper have been prospected. Limestone is widely distributed and commercial deposits of marble have been prospected and quarried locally. Barite occurs in limestone on Lime Point, Hetta Inlet.

SCHIST AND LIMESTONE

This unit comprises mainly schist with some limestone and minor quartzitic and slaty beds. It is transitional to the overlying limestone. Kennedy (1953, p. 6) locally distinguishes calcareous schist and quartz-mica schist between the next younger limestone unit and the greenstones, which are the youngest rocks of the Wales group. The schists are not everywhere present between the greenstone and the limestone units.

LIMESTONE

This unit is predominantly metamorphosed limestone with some interstratified schist and quartzite. The limestone is white to blue or black, intensely folded and sheared, and commonly metamorphosed to marble. The limestone in its upper part is intercalated with volcanic rocks and passes into the greenstone schist unit. Individual limestone sequences of this unit and those within the schist range in thickness from less than 100 feet to more than 1,000 feet (Wright, 1915, p. 30). Kennedy (1953) has suggested an unconformity between the limestone unit and the overlying greenstone schist unit. According to Buddington and Chapin (1929) fossil fragments are not diagnostic, and comparison of rock types with those of known age is tenuous but may indicate that some of the limestone intercalated with the greenstone schist is of Silurian age; some lower beds are possibly pre-Ordovician.

Mapping of the limestone has been extended photogeologically northwestward from the Hetta Inlet area on the basis of similarity of topographic expression to known limestone of the Wales. An area north of Dolomi has likewise been interpreted to be mainly limestone on the basis of vegetation pattern. Both interpretations are to some extent supported by mine and prospect reports.

GREENSTONE

This unit is predominantly schistose greenstone derived from tuff, agglomerate, and basaltic and rhyolitic lava flows. Interbedded slate and argillaceous rocks occur, and in the lower part of the unit, beds and lenses of limestone are common. The greenstone unit has been extended with the limestone unit but its western extent is indeterminable on aerial photographs.

WRANGELL-REVILLAGIGEDO BELT OF METAMORPHIC ROCKS

The Wrangell-Revillagigedo belt of metamorphic rocks roughly parallels the Coast Range batholith east of this quadrangle. A small part of this belt crosses the northeastern corner of the Craig quadrangle and occupies the south end of Etolin Island, as well as much of Cleveland Peninsula, Brownson Island, and Deer Island. The rocks have been mapped and described (Buddington and Chapin, 1929, p. 49–55) in two units: phyllitic, quartzitic, and slaty rocks; and crystalline schist and phyllite. This division was based on the degree of metamorphism and amount of intrusion by igneous material as described by Wright and Wright (1908, pl. 2); no contradistinction was made by use of aerial photographs. The belt has been intruded by many batholiths, stocks, sheets, and dikes probably genetically related to the Mesozoic intrusive rocks of the Coast Range. The metamorphic rocks are cut in many places by basalt sheets and dikes of Tertiary age, which are especially abundant near the area of Tertiary lava on Eagle Island.

The age of the rocks has not been determined adequately, and a diversity of opinion exists for the age of the belt as a whole. Buddington and Chapin (1929) state that Carboniferous and Triassic formations probably make up a large part, but that the belt possibly ranges in age from Ordovician to Cretaceous. Wright and Wright (1908, p. 56) favored a Carboniferous age for most of the crystalline schists and argillites.

Mineral deposits are scattered within the metamorphosed rocks of the Wrangell-Revillagigedo belt. Base-metal sulfides are found locally in the more intensely metamorphosed rocks, and gold-quartz fissure veins occur in phyllite and low-grade schist. Garnet and graphite may occur in some places within this part of the belt. Kyanite and sillimanite are economically unevaluated.

PHYLLITE, QUARTZITE, AND SLATE

The rocks of this unit are described by Buddington and Chapin (1929) as phyllite, argillaceous and micaceous phyllite, quartz phyllite, foliated quartzite, and locally slate and limestone. Metamorphism is marked near the intrusive igneous masses at Union Bay and Eaton Point on Ernest Sound, and the contorted, sheared, and baked rocks are cut by aplite dikes or quartz veinlets.

CRYSTALLINE SCHIST AND PHYLLITE

The crystalline schist, phyllite, and gradations between are more highly metamorphosed in general than the rocks of the preceding unit. The stratigraphic relation to the preceding unit is not known. Large masses of quartz diorite and granitic rocks intrude these rocks. Quartz schist with intercalated kyanite schist predominates north of Eaton Point. Phyllitic schist on Deer Island, in the northeast corner of the mapped area, contains some *sillimanite*.

PALEOZOIC ROCKS

Virtually all the stratified sedimentary and volcanic rocks of Prince of Wales Island and the islands to the west are of Paleozoic age. The Wales group of metamorphic rocks probably is largely or entirely Paleozoic, but correlation with Paleozoic units of existing geologic maps has not been established. Interbedded clastic rocks of various lithologies with or without volcanic rocks, characterize much of the Ordovician, Silurian, and Devonian systems. Conspicuous stratigraphically are the thick massive limestones of the Silurian and Devonian systems, and the scattered remnants of the limestone and chert of the Mississippian, Pennsylvanian(?), and Permian systems. Volcanic rocks and associated tuffaceous sedimentary rocks represent thick sequences of the Devonian system, and are sparsely distributed within the Ordovician and Silurian systems. Unusually thick but discontinuous conglomerate lenses and beds exist within the Silurian limestone.

ORDOVICIAN AND SILURIAN SYSTEMS, UNDIFFERENTIATED

The Ordovician system and lower part of the Silurian system comprise mainly indurated graywacke and slate within which locally and at different horizons volcanic rocks are mappable. These rocks are widespread in the northern half of Craig quadrangle and form a belt across Dall Island. The mapping of the rocks is extended to the east by comparing terrane expression with that of known formations on aerial photographs. These rocks have been mapped and described as time-stratigraphic units by Buddington and Chapin (1929) who divided the graywacke-slate sequence into Ordovician and Silurian with the reservation that each possibly contained parts of the other. The sequences are thinly bedded, closely to isoclinally folded, and complexly faulted. The similarity between faunally identified Ordovician and Lower Silurian rocks, both structurally and lithologically, makes their separation as map units very tenuous with the sparse faunal data available.

Mineral deposits reported within the graywacke-slate sequence are few and widely scattered. Small sulfide deposits containing copper, lead, gold, and silver have been reported on Dall Island. A copper prospect in a shear-zone deposit is located near Sweetwater Lake on Prince of Wales Island. Buddington and Chapin (1929) suggest that the apparent sparsity of deposits may be in keeping with a like sparsity of intrusive rocks.

GRAYWACKE-SLATE SEQUENCES

These sequences are mapped and described by Buddington and Chapin (1929, p. 74–77, and 81–82) as indurated thin-bedded graywacke and dark to black slate with varying amounts of thinly interbedded black chert, conglomerate, and limey beds. Andesitic volcanic rocks occur at various zones but are mappable only locally. The total thickness of these sequences is undetermined but they contain several thousand feet of Ordovician strata alone.

Age of parts of the sequences has been assigned at widely separated points. Ruedemann (*in* Buddington and Chapin, 1929, p. 74) identified fauna of several Lower and Middle Ordovician localities. Lower Ordovician graptolites are described from slate partings in the thin-layered black chert and graywacke of Lulu and San Fernando Islands and the island barrier of Big Salt Lake. On these islands, Middle Ordovician graptolites are reported from graywacke and black slate. A Lower Silurian age is assigned by Ruedemann (*in* Buddington and Chapin, 1929, p. 82) to the dark to black graptolitic slate and graywacke mapped previously on San Fernando, Lulu, Dall, Heceta, and Noyes Islands. On Heceta Island strata previously mapped as Silurian contain Silurian and Middle Ordovician graptolites at different horizons. These rocks are mapped by Eberlein (written communication, 1949) as coarse-grained graywacke facies (sandstone, conglomerate, and breccia) and fine-grained graywacke facies (siltstone, mudstone, and fine-grained sandstone).

The position and conformity of the contact between Ordovician and Silurian strata within the graywacke-slate sequence has not been established. Smith (1939, p. 12) suggests that the absence of recognizable Upper Ordovician strata probably indicates a marked unconformity representing Late Ordovician and perhaps some of Early Silurian time. On Heceta Island, no break in the graywacke-slate sequence has been observed between Middle Ordovician and similar Early Silurian strata, both faunally identified, but disconformity is a distinct possibility.

The base of this Ordovician-Silurian sequence has not been observed. The upper contact is varied and where observed is marked by generally unconformable or faulted relationships. Angular unconformities are reported with Devonian rocks on San Fernando Island and with conglomerate at Sarkar Cove on El Capitan Passage. The conglomerate is probably a basal unit within the Silurian limestone. Mississippian strata and Devonian volcanic rocks overlie Ordovician strata west of Big Salt Lake either unconformably or through faulting. The sequence is overlain by Silurian limestone on Heceta Island with no apparent angular unconformity.

VOLCANIC ROCKS AND CONGLOMERATE

This unit as mapped and described by Buddington and Chapin (1929) comprises andesitic laval flows locally with pillow structure, conglomerate containing lava and limestone, and minor amounts of graywacke, black slate, limestone, and tuff. The maximum total thickness is about 3,000 feet. It is only locally conspicuous and the proportion of conglomerate to volcanic rocks varies greatly. Eberlein (written communication, 1949) mapped similar volcanic rocks within his Ordovician-Silurian graywacke-slate sequence. Typical rocks of this unit occur on El Capitan and Kosciusko Islands. Similar rocks occur elsewhere in several zones within the graywacke-slate sequence of Ordovician and Early Silurian age on Prince of Wales Island but are generally not mappable at this scale. This unit has previously been mapped on the east side of Prince of Wales Island and is so mapped in this report although it may be better described as a graywacke-slate sequence with varying proportions of volcanic rock.

Age assignment of the separate areas of volcanic rocks varies. Smith (1939) grouped them as Lower Silurian conformable with overlying rocks. The andesitic volcanic rocks are described by Buddington and Chapin (1929) as locally partly contemporaneous with the massive Silurian limestone. Elsewhere they are intercalated with Lower Ordovician slate (Kosciusko Island), with Middle Ordovician graywacke and graptolitic slate in the base of the volcanic section (El Capitan Island). They also occur between the Silurian limestone and the Ordovician graywacke-slate sequence. Strata previously mapped near Thorne Bay as Ordovician slates and graywackes have been included with this unit. Fauna collected near Thorne Bay by Sainsbury (1960) in the summer of 1955 indicate a Silurian age. Some strata mapped as Devonian slates, volcanic rocks, and andesitic volcanic rocks, both south and west of Kasaan Bay may be Silurian or older (Sainsbury, oral communication February 25, 1956).

MIDDLE AND UPPER SILURIAN SERIES, SILURIAN SYSTEM

Middle and Upper Silurian strata comprise a thick section of massive limestone containing intraformational conglomerate beds and lenses and overlain by a thick graywacke-sandstone sequence. These strata have been mapped and described by Buddington and Chapin (1929, p. 83–94) and discussed by Smith (1939, p. 15–16). They were mapped in detail by Eberlein (written communication, 1949) in the Heceta and Tuxekan Islands area.

Strata of known Silurian age are mapped in a broad northwestward-trending synclinorium occupying Kosciusko, Heceta, and Tuxe-

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kan Islands and extending onto Prince of Wales Island; smaller exposures occur on Dall Island. The general distribution of the Silurian formations reflects the northwestward trend of dominant folding in southeastern Alaska. The Tuxekan syncline trends more easterly as it extends onto Prince of Wales Island. The mapping of Silurian formations has been extended eastward by photointerpretation and basic assumptions and interpretations are: the Silurian sequence eastward is similar to that on Heceta and Tuxekan Islands; extensive faulting, probably with downthrow to the west, has probably helped to restrict the upper graywacke-sandstone sequence to the Tuxekan Passage and Naukati Bay area.

No mention of metallic mineral deposits within the Middle and Upper Silurian series is found in the literature. High-calcium limestone and commerical marble deposits have been developed and prospected locally, notably on Dall and Marble Islands. Quarries and prospects of limestone and ornamental marble on Dall, Heceta, Kosciusko, Marble, and Orr Islands have been described in detail by Burchard (1920) and Roehm (1946, p. 1–85).

LIMESTONE AND INTRAFORMATIONAL CONGLOMERATE

These rocks have been mapped and described by Buddington and Chapin (1929) as limestone and locally intercalated coarse conglomerate, and sandy or argillaceous beds. The intercalated beds and lenses include coarse conglomerate, thin-layered limestone, nodular or shaly limestone, and some shale and sandstone. The coarse clastic rocks are most common in the middle part of the limestone section but occur at all levels including the base and top. Eberlein (written communication, 1947) estimates a thickness of 17,000 feet or more, including 2,700 feet of clastic rocks, in his work on Heceta and Tuxekan Islands. The massive limestone is widely distributed on the west side of Prince of Wales Island, on Heceta, Tuxekan, Kosciusko, and nearby islands. It occurs as two broad belts on Dall Island, and locally on Noyes Island. Limestone-marble, not previously mapped south of Coco Harbor on Dall Island, is here mapped tentatively as Silurian and overlies Wales greenschist. The intraformational conglomerate beds are most prominent on Heceta, Tuxekan, and Kosciusko Islands. Basal conglomerate occurs at Sarkar Cove, and conglomerate seems to underlie limestone on Orr Island, possibly unconformably. Mapping of limestone areas has been extended into Prince of Wales Island by interpretation of aerial photographs, the main criterion being the prevalence of dense timber stands on limestone terrane. The belt across Dall Island between Reef Point and Diver Islands seems to have the typical topographic expression of limestone but previously has been mapped in two parts separated by overlying Devonian volcanic rocks. The massive limestone on Coronation Island is arbitrarily mapped as Silurian on the assumption that it corresponds to the limestone of Kosciusko and Heceta Islands across the axis of the Kuiu anticlinorium of Buddington and Chapin (1929, p. 307), which exposes supposed Ordovician strata on Warren Island.

The limestone has been grouped with Middle Silurian rocks by Smith (1939), and Silurian fossils have been reported from several localities in the limestone (Buddington and Chapin, 1929, p. 93-94). The lower contact of the limestone may mark a general unconformity, which in places is markedly angular with the Ordovician rocks. The limestone and conglomerate conformably overlie volcanic rocks locally according to Smith (1939) and Buddington and Chapin (1929). The upper contact of the limestone with the overlying graywacke-sandstone sequence may be mostly conformable. The limestone on Dall Island is locally overlain by Devonian volcanic rocks.

UPPER GRAYWACKE-SANDSTONE SEQUENCE

This sequence is mapped and described by Buddington and Chapin (1929) as predominantly green-gray graywacke, locally red, greenish-gray and gray sandstone, or interbedded conglomerate and sandstone, or shale. The thickness is 5,000 feet or more. Along Karheen Passage, Eberlein (written communication, 1949) distinguished a platy limestone and a thin-bedded to massive limestone within the sequence. The sequence is most conspicuous in the troughs of synclinal structures along Naukati Bay, Karheen Passage, and on Kosciusko Island; it extends for an unknown distance into Prince of Wales Island. The outcrops mapped in this report are probably bounded not far inland by northward-trending faults downthrown to the west. This sequence is mentioned but not mapped by Buddington and Chapin (1929) as occurring on the south end of Marble Island. Its ragged shoreline expression contrasts with the more regular expression where limestone forms the shoreline.

The age of these beds on Heceta and Kosciusko Islands is indicated by Kirk and Amsden (1952, p. 53-54) in their descriptions of an Upper Silurian Brachiopod fauna. The lower contact of the sequence is questionably conformable to the massive Silurian limestone. The sequence has not been previously mapped in contact with younger rocks. Limestone was interpreted from aerial photographs as overlying the sequence at one locality east of Tuxekan Passage and was later verified by field checking; this limestone is probably Middle Devonian. A marked stratigraphic gap in Middle Devonian rocks is implied by both Smith (1939) and Buddington and Chapin (1929).

DEVONIAN SYSTEM

Units of the Devonian system are widespread and have been mapped and described by Buddington and Chapin (1929, p. 94–109) and later discussed by Smith (1939, p. 19). Data have been compiled in somewhat more detail by Eberlein (written communciation, 1949) along South Arm of Cholmondeley Sound, by Warner and others (1960) on Kasaan Peninsula, and by Robinson (1946, p. 31) on Baker Island. Stratigraphic relations within the Devonian rocks are not closely or reliably established because of structural complexity, lack of detailed study, scarcity of fossils, and facies changes. The general stratigraphic succession has been summarized in three assemblages, but the composite sequence is nowhere exposed. The lower assemblage mainly comprises mafic volcanic flows and breccias and locally clastic sedimentary rocks. The middle assemblage is mainly interbedded pyroclastic and sedimentary rocks including some black slate and fossiliferous limestone, which contain more volcanic material than the younger rocks. The lower part of the upper assemblage consists of conglomerate, slate, graywacke, and volcanic rocks, and the upper part of massive limestone.

Strata of Devonian age occupy most of the southern synclinorial province of Buddington and Chapin (1929), which includes much of Prince of Wales Island, a large part of Dall, Baker, Noyes, Suemez, and Sukkwan Islands, and the islands of San Alberto Bay. The structure of the Devonian rocks is complex—isoclinal folding is common, as in the Devonian(?) of Kasaan Peninsula; general overturning of strata is characteristic over wide areas, for example, south of Dolomi. Locally the Devonian rocks may be partly coextensive with parts of the Wales group.

Field investigations in the summer of 1955 near Kasaan Bay indicate that part of the strata previously mapped as Devonian is actually of Early Silurian age, and geologic relations south of Kasaan Bay strongly suggest that some strata are of Silurian age or older (Sainsbury, oral communication, February 25, 1956).

In extending the mapping of Devonian rocks by aerial photograph interpretation into previously unmapped central Prince of Wales Island only a very tentative separation of map units is intended, and this is based solely on topographic similarity to known Devonian units.

A Middle or Upper Devonian age is indicated by fossils collected from the sequences stratigraphically above the lower assemblage of predominantly volcanic rocks. Precise relations between the sequences of the Devonian as a whole are not well established. The lower contact of the system is known in places to be markedly unconformable with Silurian or older rocks.

Mineral deposits are widely distributed in the altered volcanic flows and breccias, and in the black slate, graywacke, and conglomerate of Middle Devonian age. They occur as contact-metamorphic deposits of copper and iron, shear-zone deposits of copper and other metals, and fissure-vein deposits of gold and other metals. The Upper Devonian strata are not known to be mineralized. The development of mines and prospects in some areas has been extensive. Kasaan Peninsula has long been noted for its copper-iron and copper ores, and a unique copper-palladium deposit. The Hollis and Granite Mountain areas have many gold mines and prospects. Occurrences of molybdenite on Baker Island are notable. Ornamental marble and limestone are quarried locally in the Dolomi and Dickman Bay areas. Barite has been noted on the southeast end of St. Ignace Island.

CONGLOMERATE-GRAYWACKE SEQUENCE

This sequence is mapped by Buddington and Chapin (1929) as mainly conglomerate and graywacke or sandstone with a total thickness of 2,000 feet or more. These rocks are exposed along San Christoval Channel, on San Fernando, Lulu, and Blanquizal Islands, and on the islands and north side of San Alberto Bay.

The sequence has been grouped with the Middle Devonian although fossils are not abundant. The lower contact is unconformable with Silurian or older rocks and the sequence seems to pinch out at the head of San Alberto Bay. The upper contact where observed is with the overlying massive limestone. On the north end of Lulu Island the conglomerate is overlain by fossiliferous limestone of unassigned age; relation of the sequence to other Devonian units has not been demonstrated.

LOWER SLATE AND VOLCANIC ROCKS

This unit is mapped on the northeast end of Noyes Island by Buddington and Chapin (1929) as interbedded slate, limestone, chert, and volcanic rocks including tuff and breccia. A Middle Devonian age for fossils from the limestone within this unit was given by Kirk (*in* Buddington and Chapin, 1929, p. 105). Contact relations have not been described.

ANDESITIC VOLCANIC ROCKS

The lower dominantly volcanic rocks are described by Buddington and Chapin (1929) as andesitic lava flows, breccia, and tuff, locally including conglomerate and rhyolitic lava flows. The conglomerate is made up mainly of limestone and andesite fragments. The lava is fine grained, dense, green to gray, and interbedded with coarse breccia locally of a flow type. Submarine deposition of part of the volcanic rocks is indicated by pillow structure in the lava. Total thickness is about 2,000 feet. These rocks occupy large parts of Noyes, Baker, Suemez, Sukkwan, Dall, and Prince of Wales Islands. In southern Prince of Wales Island the volcanic rocks occupy the cores of anticlinal structures that are generally overturned to the northeast and flanked by younger slates and volcanic rocks. Mapping the extension of these volcanic rocks on Prince of Wales Island by photointerpretation is tenuous.

The volcanic rocks have been grouped with the Middle Devonian rocks but they may be partly Silurian particularly as mapped east of Big Salt Lake. According to earlier work the lower contact is unconformable with Silurian or older rocks, and the upper contact is conformable with overlying slate and volcanic rocks but the relation to younger rocks is not well known.

GRAYWACKE-TUFF SEQUENCE

A unit predominantly of graywacke and tuffaceous beds is mapped locally by Buddington and Chapin (1929) on Suemez Island and small islands in the Maurelle group. Dark slate, and conglomerate of limestone and andesite fragments are included. The unit may be equivalent to part of the slate and volcanic rocks next described. Aerial photographs indicate a similar belt of rocks northwest of Port Refugio between the underlying andesitic volcanic rock and the overlying Upper Devonian rocks. The topographic expression and vegetation pattern appears to be similar to that of the belt along the northern slope of Suemez Island.

The unit is grouped with rocks of Middle Devonian age and overlies the andesitic volcanic rocks, probably conformably. It underlies the Upper Devonian rocks, probably unconformably.

UPPER SLATE AND VOLCANIC ROCKS

The rocks of this sequence are mapped and described by Buddington and Chapin (1929) as andesitic green to gray tuff, locally conglomerate, slate, limestone, and some chert. Associated volcanic rocks include minor amounts of andesitic lava, breccia, and tuff. They give the total thickness as more than 2,400 feet. The volcanic material decreases upward in the sequence. Limestone in places is particularly abundant and interbedded with greenstone, siltstone, quartzite, graywacke and conglomerate as on Kasaan Peninsula. Robinson (1946, p. 31) indicates that the rocks of Baker Island are arenaceous and calcareous argillites and argillaceous rocks with some marble and tuffaceous beds. Along Klakas Inlet, Eberlein (written communication,

1949) has mapped a sequence of banded siliceous sandstone and siltstone with locally wide bands of volcanic and pyroclastic rocks and agglomerate; at the northern end of the inlet these rocks grade into tuffaceous locally conglomeratic graywacke-sandstone. On Kasaan Peninsula, Warner and Goddard (1960) suggest that sill-like intrusive bodies of Triassic age have metamorphosed the strata and locally form most of the bedrock. This suggestion contrasts with earlier ideas that the sequence considered of interlayered metamorphosed volcanic rocks (greenstone) and conglomerate, graywacke, tuff, and limestone. The sequence is widely distributed and forms a large part of the bedrock of Sukkwan Island and Prince of Wales Island south and west of Kasaan Peninsula. In the southeastern part of the quadrangle the sequence occupies the troughs of synclines overturned to the northeast and is underlain by older andesitic volcanic rocks.

The Middle Devonian age of this sequence has previously been assigned from faunal analysis, but only locally. The lower contact is described as gradationally conformable with underlying volcanic rocks and unconformable with underlying rocks of the Wales group.

LIMESTONE

The Devonian limestone is described by Buddington and Chapin (1929) as uniform, gray or white limestone, locally with sandy or argillaceous beds, more than 600 feet thick. Eberlein (written communication, 1949) mapped it near Karheen Passage as argillaceous limestone with interbedded shale. The limestone is exposed on some islands in San Alberto Bay (notably Wadleigh and Fish Egg Islands), on islands in Trocadero and Kasaan Bays, on Prince of Wales Island near Craig and Klawak Lake, and on San Fernando Island. From the study of aerial photographs, a small area east of Tuxekan Passage was interpreted as limestone and later verified by a field check. Its stratigraphic position overlying the Upper Silurian graywacke-sandstone sequence and a tentative identification of fauna (C. W. Merriam, oral communication, April 1955) indicate a probable Devonian age. Another small area of limestone was mapped by photointerpretation east of Craig.

The age of this richly fossiliferous limestone has been established faunally as Middle Devonian in many places in San Alberto Bay and the Klawak Inlet area, the Coronados Islands, and Kasaan Bay. On Ham Island in Karheen Passage silicified fossils are abundant. The limestone is locally unconformable with underlying units of Silurian or older rocks. Contact relations with underlying Devonian or Upper Silurian rocks is nowhere clearly demonstrated but a general unconformity seems indicated. The actual contact with the overlying Upper Devonian rocks has nowhere been observed.

UPPER DEVONIAN ROCKS

Upper Devonian rocks are not extensive but are mapped by Buddington and Chapin as limestone with calcareous sandstone and some conglomerate and argillite interbedded, or as volcanic rocks including basalt, andesite, and tuff. Thickness is given as about 1,000 feet. The rocks occupy most of San Juan Bautista Island, part of Suemez Island, and some islands in Trocadero Bay.

The Late Devonian age of the rocks on San Juan Bautista and Suemez Islands was assigned on the basis of marine fossils and locally fossil plants (Buddington and Chapin, 1929, p. 107–109). The nature of the contacts is not clearly defined. Both upper and lower contacts are probably unconformable.

MISSISSIPPIAN SYSTEM

The Mississippian rocks of Craig quadrangle occur in a few scattered small areas. The outcrops probably represent only a part of the Mississippian sequence as known for southeastern Alaska as a whole. The system is mapped and described by Buddington and Chapin (1929, p. 110) and described by Smith (1939, p. 26). A thin sequence of basal conglomerate and calcareous arkose is overlain by coarsely crystalline highly fossiliferous limestone interbedded with thin-bedded black chert. The limestone is in turn overlain by a sequence of interbedded chert, dense gray quartzite, cherty limestone, and thin-layered chert. A thickness of about 1,000 feet is represented by these beds, but the whole sequence is not present in all outcrops.

Mississippian rocks crop out in the Klawak area, occupying all or parts of many islands in Trocadero Bay, and occurring along Klawak Inlet, and in parts of Suemez and Shelikof Islands. Structually, the rocks crop out in the troughs of synclines. In the Klawak area they are folded along a north-south axis and cross folded along east-west axes; they may be overturned to the west. Photointerpretation indicates that Mississippian outcrops are probably bounded by a fault south of Point Bocas on Suemez Island.

The Mississippian age of the rocks is based upon fossils from Shelikof, Suemez, Madre de Dios, and the Coronados Islands as well as many localities in the Klawak area (Buddington and Chapin, 1929, p. 110–117); the rocks have been assigned to the upper part of the Mississippian by Girty (*in* Smith, 1939, p. 26). The Mississippian rocks overlie the Upper Devonian system on Suemez Island but the contact is not described in detail and no angular unconformity has been observed. Pennsylvanian (?) limestone overlies the Mississippian limestone on Shelikof Island.

PENNSYLVANIAN(?) SYSTEM

Rocks of the Pennsylvanian system may occur in one locality in the quadrangle. The strata, briefly described by Buddington and Chapin (1929, p. 117) and Smith (1939, p. 26), were mapped with rocks of the Permian system by Buddington and Chapin. Massive white limestone 100 feet or more thick occurs on the southwest end of Shelikof Island in Soda Bay. Fauna of the limestone seemed indicative of the Pennsylvanian and was so assigned tentatively by Girty (*in* Buddington and Chapin, 1929, p. 117). This limestone overlies the Mississippian limestone with no apparent stratigraphic break.

PERMIAN SYSTEM

The Permian system is represented in only one locality in the quadrangle and has been mapped and described by Buddington and Chapin (1929, p. 118) and discussed by Smith (1939, p. 26). On the eastern tip of Suemez Island about 300 feet of closely folded blue and gray limestone is described by Chapin as part of the upper division of the two Permian units mapped in southeastern Alaska. Fossils were identified by Girty (*in* Buddington and Chapin, 1929, p. 129). The Permian rocks overlie Upper Devonian and older strata probably unconformably.

MESOZOIC ROCKS

The Mesozoic era is represented only in the northeastern corner of the quadrangle where the systems comprise metavolcanic and metasedimentary rocks. A general hiatus involving all or most of the Triassic system probably exists, although in adjacent quadrangles to the north and east, thick sections of Triassic metavolcanic and metasedimentary rocks crop out. The metamorphosed volcanic and sedimentary rocks of Jurassic or Cretaceous age originated mainly as flows and pyroclastic rocks.

TRIASSIC SYSTEM

Triassic strata are not mapped as such in Craig quadrangle but occur in adjoining quadrangles to the north and to the east. An area too small to map at the head of Clover Bay, eastern Prince of Wales Island, comprises graywacke of probable Triassic or younger age and was reported to be infolded with Devonian limestone and conglomerate by Martin (1926, p. 73–74).

JURASSIC OR CRETACEOUS SYSTEMS

Jurassic and Cretaceous rocks, if both occur, have not been separated in Craig quadrangle. The rocks have been described and mapped as Jurassic or Cretaceous by Buddington and Chapin (1929, p. 163, 166) and discussed by Smith (1939, p. 40–41, 48). The rocks are described as dominantly volcanic; that is: schistose greenstone, breccia with intercalated tuff, agglomerate, lava flows, associated with black slate and graywacke. Generally the black slate is intercalated in the greenstone in variable proportions. In some other parts of southeastern Alaska, units of predominantly sedimentary rocks are mapped both above and below the greenstone.

These metavolcanic and metasedimentary rocks occupy Onslow Island and the southwestern part of Cleveland Peninsula with synclinal structure overturned to the southwest. The rocks are highly metamorphosed and schistose and have been intruded by large masses of igneous rock that are associated with the Mesozoic period of intrusion.

No specific basis exists for distinguishing the Jurassic from the Cretaceous system over wide areas of southeastern Alaska, according to Smith (1939). Martin (1926) specified that the rocks of the two systems differ in degree of metamorphism and are slightly different in fossil content across a pronounced unconformity. Buddington and Chapin (1929) did not concur with so definite a separation on the basis of what was known of the rocks. As mapped, the Jurassic and Cretaceous rocks may include parts of older systems. The lower contact is generally believed to be unconformable with Triassic or older rocks, but relations are not clearly demonstrated on Cleveland Peninsula.

Mineral deposits in the greenstones are prominent in a belt along Helm Bay, mainly as gold-bearing fissure veins.

CENOZOIC ROCKS

The Cenozoic era is represented by scattered remnants of Tertiary clastic and volcanic rocks, and by Quaternary glacial deposits in addition to those unconsolidated deposits now being formed as a result of subaerial weathering or submarine deposition.

TERTIARY SYSTEM

The Tertiary system comprises scattered remnants of clastic and volcanic rocks mostly confined to a narrow trough and the valleys leading into it. This outcrop belt roughly corresponds to the Seymour geosyncline of Payne (1955) in Craig quadrangle. The Tertiary rocks of southeastern Alaska have been mapped and described by Buddington and Chapin (1929, p. 260-273) and discussed by Smith (1939, p. 58, 59, 79). The clastic rocks near Union Bay are described briefly by Kennedy and Walton (1946, p. 81). Other small areas northwest of Kasaan Bay (Sainsbury, oral communication, 1956) have been reported but not mapped.

Tertiary clastic rocks contain coal seams or lignitic material in places, but these are not commercially significant. Metalliferous deposits are not known in association with Tertiary rocks; their deposition postdates the general period of mineralization.

SANDSTONE AND CONGLOMERATE

Clastic nonmarine sedimentary rocks—sandstone to boulder conglomerate—crop out at Coal Bay and at Union Bay. Sandstone with thin coal seams occupies a small basin at Coal Bay. The rocks are largely covered by glacial material; they have a maximum total thickness of about 100 feet, and are commonly flat lying or dip 15° or less. As mapped, the area shown indicates probable distribution, not actual known outcrop. At Union Bay, coarse boulder conglomerate locally grades into poorly sorted sandstone.

Time relations among the scattered remnants of Tertiary clastic rocks in southeastern Alaska have not been satisfactorily worked out. They are generally regarded as nonmarine and of Eocene age on the basis of plant fossils; they rest with angular unconformity upon older rocks.

VOLCANIC ROCKS

The Tertiary basaltic, andesitic, and rhyolitic flows and pyroclastic rocks, tuffs, and breccias are associated with minor amounts of interbedded sedimentary material. A large part of the volcanic rock is probably the result of fissure eruptions that filled existing valleys, for example, the basaltic and andesitic flows and pyroclastic rocks of Eagle Island. On Suemez Island, basalt, andesite, rhyolite, and obsidian flows occupy a large area; thin coal seams have been reported from the northern part.

The Tertiary volcanic rocks of southeastern Alaska are generally regarded as Eocene and rest with angular unconformity on older rocks. A possible Pliocene age is postulated (Buddington and Chapin, 1929, p. 271) for the volcanic rocks of Suemez Island on the basis of their position and lithologic similarity to those of Graham Island, British Columbia. Their topographic expression indicates an age definitely predating the last glaciation at the head of Arena Cove.

QUATERNARY SYSTEM

The Quaternary deposits of southeastern Alaska have been described in general terms (Buddington and Chapin, 1929, p. 275–281; Smith, 1939, p. 66–67; and others) but they have not been mapped or described in detail. Quaternary deposits have been mapped in this report by photogeologic methods and are not subdivided. Mineral deposits are not commonly associated with the Quaternary deposits. Buddington and Chapin (1929, p. 355) reported small placer deposits in eluvium resulting from weathering of gold-bearing rocks along the west side of Helm Bay. Economic value of sand and gravel is undetermined.

PLEISTOCENE DEPOSITS

Very little data are available concerning these deposits, and the topographic forms of the glacial features are not sufficiently definite for identification and classification by means of aerial photographs. Brooks (1902, p. 33) indicated that morainic material was observed at few localities and in very limited quantities, but that evidence of glaciation at low altitudes is present in nearly every part of the Ketchikan mining district. Well-developed cirques indicate that past glaciation reached 2,000 feet or more on certain peaks of Prince of Wales Island. However, the scouring action of alpine glaciers during the waning stages of the glacial period is also reflected in the cirques at altitudes of 400 feet or less as on certain islands west of Prince of Wales Island Most valley bottoms are covered by varying thicknesses of glacial debris or valley drift. Thin veneers of glacial debris may be expected nearly everywhere except on the highest peaks. Small, scattered deposits of stratified gravel and sand are undoubtedly present but probably not in abundance.

Certain postulations about Quaternary deposits may be made on the basis of aerial photographic study of topography:

1. The flat to gently sloping bottoms of broad U-shaped valleys, such as those of the Harris River and Andersen Creek, are undoubtedly occupied by relatively deep deposits from melted valley glaciers. The deposits in upper parts of valleys probably taper to a thin veneer over scoured bedrock, and many of the valleys terminate in criques.
2. Most of the broad valley of the Thorne River is occupied by drumlinlike features, almost certainly of glacial origin because mostly till and but very little bedrock occurs below an altitude of 200 feet (Sainsbury, written communication, July 1955) Parts of the broad saddle area southward from the head of Trocadero Bay to the heads

of Soda Bay and South Pass seem to contain similar glacial features.

3. A broad flat area drained by Staney Creek may once have been covered by a temporary glacial lake if an ice dam were formed in Tuxekan Passage. Such a lake may have overflowed to the northwest toward Naukati Bay, or it may have been connected to another flooded area near the head of Naukati Bay. Deposits in such an area would be silts and clays beneath a swampy surface with a peripheral belt of deltaic sand and gravel which would have been deposited by streams entering a relatively quiet lake from surrounding mountains.

RECENT DEPOSITS

Surficial deposits formed during late stages of glaciation or after the glacial epoch are unevaluated. Subaerial weathering in place, landslides, and creep have created eluvial and residual deposits of soil and talus. Large stream systems are not developed in the quadrangle, but fine sand and silt have built up tidal deltas and flats locally, for example, at the mouth of Staney Creek. Some sorting and concentration of glacial material to sand and gravel bars by streams is probable but large deposits are not to be expected. Well-developed beach deposits are also uncommon. Elevated marine terraces and benches of clay, sand, and gravel have been noted at different levels up to altitudes of 600 feet throughout southeastern Alaska (Buddington and Chapin, 1929, p. 216). Quaternary volcanic rocks, although known not far to the north and east, are not known in Craig quadrangle.

INTRUSIVE IGNEOUS ROCKS

Intrusive igeneous rocks are common and widespread in the Craig quadrangle as batholiths, stocks, and smaller masses such as dikes and sills. Most of these intrusions were probably emplaced during Jurassic and Cretaceous time and are genetically related to Coast Range intrusions. Despite some evidence of pre-Mesozoic intrusions their location and period of intrusion is conjectural. Some small tabular masses have been assigned to the Tertiary by several field workers.

PRE-MESOZOIC INTRUSIVE ROCKS

No outcrops of pre-Mesozoic intrusive rocks are known, but granitic pebbles and cobbles in the conglomerates of Silurian and Devonian age must be explained by one or more of the following: the existence of Early or pre-Silurian intrusive rocks as yet unproved; the former existence of such intrusive rocks, which could have been subsequently eroded or assimilated by Mesozoic intrusive rocks; or glacial transportation. The role of glaciation is controversial.

MESOZOIC INTRUSIVE ROCKS

Intrusive igneous rocks of the Mesozoic era, generally associated with the Coast Range intrusions, are widely distributed in the Craig quadrangle. The scope of this report and lack of detailed information within the area allows only a general description and classification of the intrusive igneous rocks. Those of southeastern Alaska have been described and mapped by Buddington and Chapin (1929, p. 173–253), and their work and that of others discussed by Smith (1939, p. 8). More detailed studies have been carried on locally (Wright, 1915; Robinson, 1946; Kennedy and Walton, 1946; and Kennedy, 1953). Most intrusive masses have been considered as outlying satellitic bodies related to the Late Jurassic and Early Cretaceous Coast Range intrusions to the east. They are mostly dioritic, but granitic and ultramafic rocks are not common. Younger dikes, commonly diabase or aplite and locally pegmatite, may be of Mesozoic age but some are of Tertiary age.

UNITS MAPPED

The following division of igneous intrusive rocks has been used in this compilation:

1. Granite and granitic rocks as mapped by Buddington and Chapin (1929) occur as stocks throughout the Alexander Archipelago but form a minor part of the igneous complex. The mapped rocks lie within the Wrangell-Revillagigedo belt of metamorphic rocks where granite porphyry underlies a large part of Etolin Island, and forms the small islands near Deer Island. The Etolin Island mass probably includes a large amount of rocks more mafic in composition than true granite. Elsewhere small bodies of granite and syenite are known but are not of mappable size. Pegmatitic and aplitic facies occur mainly as tubular intrusive bodies within both igneous rock and adjacent country rock.
2. Dioritic rocks include granodiorite, quartz diorite, and diorite and their variants. Gabbro, diorite, and rocks of intermediate composition occur as small masses and marginal variants. Diorite forms the largest part of the igneous masses of Prince of Wales Island and adjoining islands. Quartz diorite is one of the predominant igneous rocks on Dall Island and northeast of Clarence Strait. Granodiorite is less common but forms the bulk of some important igneous bodies such as that of the Copper Mountain

area. In the Kasaan Peninsula area, Warner and others (1960) locally distinguished an early diorite and a late granodiorite.

3. Mafic and ultramafic rocks include dunite, pyroxenite, hornblendite, and marginal variants of gabbro and other rocks of intermediate composition. The ultramafic rocks occur as stocks and sills but masses of mappable size are few. In Craig quadrangle the pyroxenite and associated rocks of the Mount Burnett and Kasaan Bay areas, and the ultramafic rocks of Helm Bay and southern Sukkwan Island are noteworthy. Elsewhere small masses or marginal variants of more silicic igneous rocks are too small to map.
4. An interpreted unit has been mapped, possibly of igneous intrusive rocks or a complex of igneous and metamorphic rocks. This unit, as interpreted from aerial photographs, is extended from previously mapped igneous bodies, or comprises separate and strictly interpretive areas on plate 1. Possible extensions of igneous bodies have been indicated on Prince of Wales Island northeast of Thorne River, and on Cleveland Peninsula northwest of Helm Bay on the basis of similarity of surficial characteristics and fracture pattern. By the same criteria, igneous intrusive rocks are indicated in large areas east of Kogish Mountain and in the Black Bear Lake area on Prince of Wales Island. Smaller areas interpreted as either wholly or partly intrusive igneous rock include those near Emerald Bay on Ernest Sound, near Salmon Lake, near the head of Polk Inlet, and on Suemez Island. The presence of any large area of intrusive rock on Noyes Island is questionable, but scant information indicates that possibility.

Most of the intrusive masses are complexes of rocks of several compositions, generally with indefinite and gradational contacts. Marginal variants such as gabbro-diorite, gabbro, and hornblendite are not uncommon within both the ultramafic and dioritic groups. Various composition symbols are used in mapping the complex masses (pl. 1) where information shows approximate distribution, but the gradational contacts and lack of information generally precludes a breakdown. Previously mapped contacts have been slightly changed in places where later information or aerial-photographic study seemed to justify the change. Detailed descriptions of local areas of intrusive rocks include Mount Burnett (Kennedy and Walton, 1946), the Hetta Inlet area (Wright, 1915; Kennedy, 1953), Kasaan Peninsula (Wright, 1915; Warner and others, 1960), and Baker Island (Robinson, 1946). On Coronation Island the mapped extent of intrusive rock is based on photointerpretation and rather inconsistent early sketch mapping.

AGE AND CONTACT RELATIONSHIPS

Several episodes of igneous intrusion were more or less continuous within one general period embracing the late part of the Jurassic and the early part of the Cretaceous periods. Contact relations between igneous bodies and the order of their intrusion are broad and complex. Published data indicate that intrusion by the larger stocklike bodies progressed from the more mafic to the more silicic rocks; the ultramafic rocks were cut by gabbro and dioritic rocks, and the more silicic members of the dioritic group cut the more mafic ones. The granitic group in general is probably the youngest of the massive igneous rocks. Aplite and pegmatitic dikes are associated with the dioritic and granitic rocks. Lamprophyre dikes cut all other rocks of the igneous complex, but their age assignment to the Mesozoic or the Cenozoic era is problematical. Marginal variants, either of more mafic or more silicic rocks are fairly common. For example, gabbro may occur marginal to either diorite or the ultramafic rocks, and diorite may have marginal variants of either quartz diorite or gabbro.

RELATION TO STRUCTURE AND MINERAL DEPOSITS

The emplacement of the Mesozoic intrusive bodies and the orogenic movements associated with it had a marked effect upon the country rock and structures existing at the time. Metamorphism, contact and regional, converted rocks to gneiss and schist, and limestone to crystalline limestone and marble. Folding associated with intrusion superimposed the now-dominant northwestward trend of structures upon the previous northward and northeastward trends. Faulting and brecciation accompanying intrusion resulted in faults and shear zones, many of which have formed channels for ore-bearing solutions and contain valuable mineral deposits. The genetic relation of the intrusive rocks to ore deposition in southeastern Alaska has been generally recognized.

POST-MESOZOIC INTRUSIVE ROCKS

Post-Mesozoic igneous intrusive rocks the quadrangle are present only as dikes and sills associated with the extrusion of lava. Some diabase dikes not related to volcanic rocks are believed by Sainsbury (written communication, 1956) to be Tertiary.

Dikes and sills granitic to basaltic in composition but most commonly basaltic or andesitic, cut country rock adjacent to certain Tertiary flows and locally are of Tertiary age, cutting basal parts of

Tertiary sequences. Notably abundant are the tabular igneous bodies—dikes and sills—of southern Etolin Island and the southern end of Onslow Island. Elsewhere, some lamprophyre dikes that cut country rock and Mesozoic intrusive masses are probably of Tertiary age. A few small Tertiary igneous instrusive masses have been noted but not mapped in southeastern Alaska. The mass nearest to Craig quadrangle is the granite porphyry of Zarembo Island.

STRUCTURE

FOLDING

Folding was significant during at least three periods as indicated by trends of major and minor fold axes. The oldest folding, that of the Ordovician and Lower Silurian strata, is most commonly isoclinal with northward strike and vertical or steep eastward dips and suggests a pre-Middle Silurian period of folding. At the close of the Paleozoic era, pre-Mesozoic rocks were folded with northeastward-trending axes according to Wright and Wright, (1906, p. 39). The dominant folding of the rocks of southeastern Alaska occurred during the Mesozoic era when rocks including Jurassic and possibly some Cretaceous strata were folded with northwestward-trending axes. This later and dominant folding partly or totally obliterated previous trends of folding or was superimposed on them, resulting in very complicated structure. Evidence of a Tertiary period of warping along nearly east-west axes is known in some parts of southeastern Alaska but is not obvious in this quadrangle. In the Jumbo Basin area on Hetta Inlet east-west cross folds may be either a result of Tertiary folding or contemporaneous with earlier north-south trends (Kennedy, 1953, p. 13).

Two major tectonic elements are shown by Payne (1955). (See also this report, fig. 2.) The most prominent, the Prince of Wales geanticline, is described as a linear positive element where little or no sedimentation took place or where uplift and subsequent erosion occurred during the Mesozoic era and later periods. Its axis corresponds roughly to that of the Prince of Wales-Kuiu anticlinorium as described by Buddington and Chapin (1929, p. 304–314). The Seymour geosyncline is described as a linear negative element in which sediments accumulated during and after the Mesozoic period. Its axis corresponds closely to that of the Keku-Gravina synclinorium of Buddington and Chapin (1929, p. 300).

PRINCE OF WALES GEANTICLINE

The Prince of Wales geanticline has a northwestward axial trend through Prince of Wales Island. The geanticline occupies the whole island and those to the west, and exposes Paleozoic rocks throughout most of the area. Five large structural provinces roughly defined by Buddington and Chapin (1929) include: (1) Kuiu anticlinorium; (2) Kosciusko-Texekan-Heceta synclines; (3) a central anticlorial province; (4) a southern synclinorial province divided into two parts by the Dolomi-Sulzer anticlinorium; and (5) a southern anticlinorium of which only the northern part falls within the quadrangle (fig. 2). The Kashevarof anticlinorium, sketchily described, lies east of the main anticlinorial axis on the north border of the quadrangle. It extends southward an unknown distance, is complexly folded with a general northward plunge, and exposes mostly Ordovician strata with some infolded Silurian rocks.

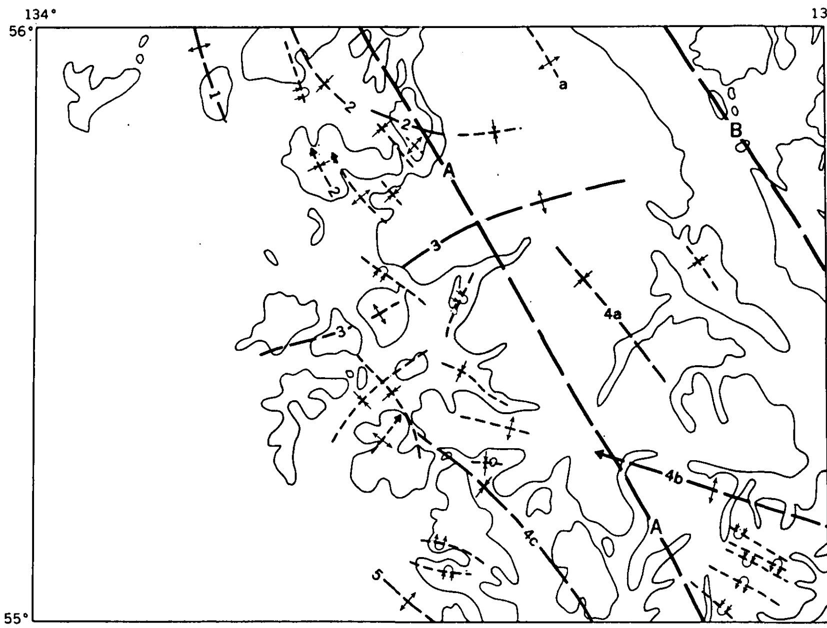

FIGURE 2.—Sketch map of major structural features and most prominent auxiliary folds as previously mapped or described in the Craig quadrangle. Location of axes and folding mostly diagrammatic. Features are numbered according to the following outline:

A. Prince of Wales geanticline (Payne, 1955). Prince of Wales-Kuiu anticlinorium of Buddington and Chapin (1929) ; includes Kashevarof anticlinorium (a) :

1. Kuiu anticlinorium.
2. Kosciusko-Tuxekan-Heceta synclines.
3. Central anticlinorial province (includes San Fernando anticlinorium).
4. Southern synclinorium : a, central synclinorial province ; b, Dolomi-Sulzer anticlinorium ; c, southern synclinorial province.
5. Southern anticlinorium (northern part only).

B. Seymour goesyncline (Payne, 1955). Keku-Gravina synclinorium of Buddington and Chapin (1929).

SEYMOUR GEOSYNCLINE

The Keku-Gravina synclinorium of Buddington and Chapin (1929) coincides roughly with the Seymour geosyncline of Payne (1955) and trends northwestward with its axis crossing the south end of Cleveland Peninsula. The structure is closely folded and overturned toward the southwest. Mesozoic greenstones and small isolated remnants of Tertiary rocks occupy its trough.

FAULT SYSTEMS

Many linear features are interpreted from aerial photographs as the traces of possible faults, major joints, or shear zones. Recognition criteria for such traces include topographic vegetation and stream alinements. Fault control has been suggested for certain river valleys, straits, and fiords of southeastern Alaska; these major alinements are termed "lineaments." It is assumed in this report that on aerial photographs the still smaller and less conspicuous traces representing sheared or brecciated zones can be delineated where erosion by streams and other agents has progressed along the relatively weak zones. Field evidence has confirmed locally that many of these traces do represent faults or shear zones, but most have not been field checked. Little or no information on direction or magnitude of fault movement has been recorded by field workers, and recognizable criteria for such interpretation is lacking on the aerial photographs of the well-forested terrane. The same is true of the type of faulting, for although most minor alinements linears probably represent high-angle faults, some thrust faulting is very probable. Movement along the faults according to past interpretations has occurred throughout a large span of geologic time. Much faulting and brecciation is attributed to disturbances during the Mesozoic era, and to gentle folding and warping during Tertiary time.

REGIONAL FAULT PATTERN

The pattern of major lineaments related to faulting southeastern Alaska has been discussed by Twenhofel and Sainsbury (1958) and analyzed with respect to known field relations. They describe the well-defined major lineaments as striking northward and northwestward. In southeastern Alaska they say northward-trending faults marked by northward-trending lineaments have a complex history of movement before Late Cretaceous time, during the Tertiary period, and possibly in Recent time. The northwestward-trending faults cut and are later than intrusive rocks related to Coast Range intrusions but are also mostly pre-Tertiary. They further state that less conspicuous alinements, not forming an integral part of the major lineaments, form two systems: one of northeastward- and northwestward-trending linear features, and one of northward- and eastward-trending linear features. The first is the more prominent and older of the two minor systems; the northward- and eastward-trending system is Cenozoic in age and not well developed in southeastern Alaska. Within these two systems, the northwestward- and northward-trending linears features are the most prominently expressed, whereas those trending eastward and northeastward are relatively ill defined. Localization of certain mineral deposits near major faults has been noted by many workers in the region. A strong relation seems indicated between the combination of igneous activity, northwestward-treding regional faults, and the localization of mineral deposits.

INTERPRETED FAULT PATTERN

Most of Craig quadrangle lies between two major lineaments, one striking northwestward along Clarence Strait and the other striking northward along the southward extension of Chatham Strait. The following paragraphs are based on the interpretations made in this report.

A northerly trend of linear features diverging slightly southward is conspicuously expressed on Prince of Wales Island west of Thorne River and north of Andersen Creek and the Klawak area, and may be related to the major lineament along Chatham Strait extended. Less conspicuous linear features are on Coronation, Sukkwan, Etolin, and San Fernando islands, and some small parts of southern Prince of Wales Island. Northward-trending linear features are well defined in the granitic and dioritic rocks of Etolin and Sukkwan Islands; associated faults are probably of Late Cretaceous or Cenozoic age.

A northwestward trend of linear features is most conspicuously expressed on Cleveland Peninsula and along the east side of Prince of Wales Island particularly east of the well-expressed lineament extending northwestward from Karta Bay (here named the Thorne River lineament). Smaller areas with this trend less conspicuously expressed include Heceta, Orr, Kosciusko, and Sukkwan Islands. On the aerial photographs of southern Cleveland Peninsula linear features that are conspicuous elsewhere cannot be traced across an ill-defined area of ultramafic rocks commonly considered closely related to batholithic intrusive rocks of Mesozoic age. Therefore, latest movements along these faults most probably occurred during Late Jurassic or Early Cretaceous time. A structural relation to the regional trend along Clarence Strait seems obvious.

Westward- or west-northwestward-trending linear features are dominant on Prince of Wales Island southward from the Andersen Creek-Salmon Lake area, and also on a large part of Dall Island. Reasonably well defined linear features of this system appear between Staney Creek and Thorne River. The linear features trending west-northwest are probably correlative with the fault zone reported (Buddington and Chapin, 1929, p. 39) along Bocas de Finas and San Christoval Channel. The most continuous linear feature of this system extends from the North Arm of Moira Sound west-northwestward to Hetta Inlet where a fault seems to cut the Mesozoic intrusive rocks, thence westward, but less distinctly expressed, to Soda Bay. This feature seems to connect with one that crosses Suemez Island and that seems to have no expression across an area of Tertiary lava flows. If assumptions are correct concerning continuity of the feature and its relations to flows and Mesozoic intrusive rocks as they appear on aerial photographs, then the age of associated faults is most probably Late Cretaceous to Early Tertiary. Kennedy (1953, p. 13) maps no major faults in the Hetta Inlet area, but states that faults of a few hundred feet in displacement may be associated with east-west cross warping. A well-defined zone of linear features extends between the heads of Hetta Inlet and Trocadero Bay, and closely corresponds in trend to faults and shear zones reported at some mines and prospects along this zone. Another less conspicuous zone passes westward from the Salmon Lake area.

Northeastward-trending linear features are nowhere dominant but appear on Heceta Island, northern Dall Island, and along eastern Prince of Wales Island.

MINERAL DEPOSITS

METALLIC DEPOSITS

Metallic deposits are widespread in the Craig quadrangle. The major factors in localization of deposits seem to be the proximity of igneous intrusive bodies and the presence of fissures and shear zones. A genetic relationship of metallization to the Mesozoic intrusive rocks has been postulated for a large part of the metallic deposits of southeastern Alaska by many workers. A close spatial relation with faults and shear zones exists for many deposits. Rock type and structure locally have influenced the type or form of deposit, such as: skarn and replacement deposits within limestone; the relation between ultramafic rocks and certain uncommon elements (Pd, Ti, Cr, Ni); and the relation between gold occurrences and greenstone. Metallization has taken place within a variety of rocks in the quadrangle; however, deposits are notably scarce on a large part of western Prince of Wales Island and adjacent islands where igneous intrusions are not as common in strata of Ordovician to Devonian age.

The most important types of ore deposits within the quadrangle are the contact-metasomatic copper and iron deposits of Hetta Inlet and Kasaan Peninsula, and deposits formed by hydrothermal processes such as cavity filling and replacement as fissure veins, shear-zone deposits, breccia fillings, and replacement deposits. Copper deposits in shear zones, and sulfide deposits of one or several metals in fissure veins are widespread. Notable locally are breccia fillings (Dolomi area), complex lode deposits (Salt Chuck and Khayyam mines), and impregnation zones of molybdenite. Known placer deposits are local and insignificant.

DISTRIBUTION OF MINES AND PROSPECTS

The mines and prospects may conveniently be grouped within distinct areas of development for similar metals as follows: Kasaan Peninsula-Karta Bay (copper and copper-iron deposits); Hetta Inlet deposits (mainly copper); Niblack-North Arm (Moira Sound) area deposits (mainly copper); the gold deposits of Helm Bay on Cleveland Peninsula; Dolomi-Cholmondeley Sound area deposits (gold, silver, lead, zinc); and the Hollis-Granite Mountain-Pin Peak area gold deposits. A final group includes mines and prospects not within these areas. Many writers have described the mining areas and individual mines and prospects (see "Selected bibliography").

Kasaan Peninsula-Karta Bay area.—The mines and prospects of Kassan Peninsula are contact-metasomatic deposits of copper and iron at or near the contact of instrusive rocks with country rock. The deposits, chiefly magnetite and chalcopyrite, commonly replace calcareous rocks, limestone, and greenstone. Fissure-vein, replacement, and disseminated copper sulfide deposits with small gold and silver content also occur. For a few miles on either side of Thorne River, shear-zone deposits are fairly common. The complex lode deposit at Salt Chuck Mine is unique in that appreciable palladium has been produced. Many of the mines of this area have been described in detail (Warner and others, 1960; Wright, 1915).

Hetta Inlet area.—Contact-metasomatic deposits of copper and iron are localized at the contact between country rock—especially the limestone—and igneous intrusive rocks of Jumbo, Copper, Billie, and Green Monster Mountains. Chalcopyrite and magnetite are the chief ore minerals. Shear-zone, fissure-vein, and disseminated deposits occur farther from the intrusive masses. Small amounts of gold, silver, lead, and zinc are recoverable locally. Several mines of the area have been described in detail (Kennedy, 1953; Wright, 1915).

Niblack-North Arm (Moira Sound) area.—The mines and prospects of this area are located chiefly in shear-zone and fissure-vein deposits of copper sulfides with varying amounts of gold, silver, lead, and zinc.

Helm Bay area on Cleveland Peninsula.—The gold mines and prospects along the west side of Helm Bay are located mainly on fissure-vein deposits in greenstone schist. Gold occurs free in quartz or combined with sulfides. Small placer deposits have been reported locally (Buddington and Chapin, 1929, p. 355).

Dolomi-Cholmondeley Sound area.—Sulfide deposits of gold, silver, lead, zinc, and some of copper are localized in veins or as replacement deposits along shear zones and fissures; breccia veins and replacement deposits are the common types. The chief ore minerals are galena, sphalerite, and sulfides of silver and copper, and some free gold.

Other localities.—Other scattered mineral deposits are mostly sulfides of copper, lead, zinc, or molybdenum. Vein deposits locally contain free gold or gold combined with sulfides. At Mount Burnett, an ultramafic intrusive mass contains pods and irregular bodies of the oxides of chromium and iron. The area is mapped and described in detail by Kennedy and Walton, (1946). Molybdenite, occurring as impregnations or in quartz veinlets, is noteworthy on Baker and Noyes Islands. The occurrences on Baker Island have been mapped and described in detail (Robinson, 1946). A close spatial relation is noteworthy between photointerpreted faults and shear zones and many sulfide deposits in shear zones or breccia veins. Among these are the copper deposits at the Big Harbor mine, at the Nancy claim, and the lead deposits on Coronation Island.

OCCURRENCE OF THE METALS

Gold.—Gold occurs either combined with the sulfides of other metals (iron, copper, lead, zinc, and silver) or as free gold. The deposits most commonly are quartz veins and sulfide impregnation zones to a greater or lesser degree controlled by shear zones and fissures. Most areas of prospecting and development are within the greenstones of the Helm Bay area and in the black slaty argillite of the Hollis–Granite Mountain area. Moderate amounts of gold have been recovered from contact-metamorphic deposits locally, and small amounts have been recovered from residual deposits resulting from weathering of gold-bearing veins along the west side of Helm Bay. Potential placer deposits are thought by several writers to have been dissipated or covered as a result of glacial action.

Copper.—The copper mines of Prince of Wales Island have produced more than 27 million pounds of metallic copper, mainly between 1906 and 1918. A large part of the copper was produced from the contact-metamorphic deposits of Kasaan Peninsula and Hetta Inlet where magnetite, chalcopyrite, and pyrite comprise the chief ore minerals. Bornite is an ore mineral in the Salt Chuck deposit. Copper deposits in fissure veins and shear zones are widely distributed throughout the quadrangle; chalcopyrite is the chief ore mineral but other sulfides and oxides are present locally. Secondary copper minerals are nowhere in sufficient quantity to be mined without the primary sulfides.

Iron.—The iron deposits of Kasaan Peninsula and Hetta Inlet are contact-metamorphic deposits in which magnetite is the chief source of the metal. They are commonly small deposits of high-grade ore containing negligible amounts of titanium and phosphorus but much sulfur. Large pyrite deposits occur locally as in the complex deposits of the Khayyam mine. Titaniferous magnetite forms a large potential source within the Mount Burnett mafic intrusive body.

Silver, lead, and zinc.—Potentially workable deposits of silver, lead, and zinc are not plentiful. Deposits of the sulfides of these elements are most abundant in the Dolomi-Cholmondely Sound area in fissure veins, breccia veins, and replacement deposits. Small amounts of silver, lead, and zinc have been recovered as byproducts of copper and gold mining. The isolated lead occurrence on Coronation Island is noteworthy.

Molybdenum.—Scattered deposits of molybdenite have been reported within the quadrangle. Small amounts of the mineral occur in contact-metamorphic deposits, fissure veins in dioritic rocks, and as disseminations in schist. The low-grade deposits of Baker Island are described in detail by Robinson (1946). Minor occurrences are reported in the Hetta Inlet area, on Kasaan Peninsula, and on Noyes Island.

Other metals.—Palladium has been recovered from the Salt Chuck mine in association with complex sulfide deposits disseminated in gabbro and pyroxenite. Kennedy and Walton (1946) state that further investigation of ultramafic rocks may reveal minable quantities of the platinum metals.

The composite stock of ultramafic rocks comprising Mount Burnett contains small bodies of chromite. The deposits are of inferior grade (Kennedy and Walton, 1946).

Nickel has been reported only as traces in some sulfide deposits. It occurs in some ultramafic rocks of southeastern Alaska but is not reported within those of Craig quadrangle. Bismuth in small quantities occurs at some mines on Cleveland Peninsula (Wright and Wright, 1908).

Not far to the south in the Dixon Entrance quadrangle, recent discoveries of primary uranium and thorium minerals associated with hematite and minor secondary uranium minerals indicate the possibility of similar deposits in the Craig quadrangle. A reconnaissance of many mines in the Craig quadrangle indicated no potentialities for high-grade uranium ores (Houston, 1952 p. 13–17).

NONMETALLIC DEPOSITS

The most commercially important nonmetallic deposits are those of marble and limestone. Marble deposits have been prospected and quarried in several areas where limestone has been metamorphosed to marble suitable for decorative building stone. These deposits are described in detail in the Dolomi-Dickman Bay area, and on Dall, Marble, Heceta, and Kosciusko Islands by Burchard (1913, 1920). The only recently operated limestone quarry is at View Cove, Dall Island. A vast reserve of high-calcium limestone is the massive Silurian limestone exposed over much of Heceta, Tuxekan, and Kosciusko Islands, the western part of Prince of Wales Island, and many adjacent smaller islands. The most recent work of the Geological Survey involving this limestone has been the mapping of Heceta and Tuxekan islands by G. D. Eberlein in 1947–49. Within the quadrangle, large masses of granitic and dioritic intrusive rock exist. Their potentialities for building stone have not been evaluated although the central parts of these masses should provide good possibilities where crosscutting dikes are not too numerous.

Bituminous material occurs as a cementing agent in a fetid bioclastic limestone breccia on some small islands in Tuxekan Passage, 1 mile or less south of the tip of Tuxekan Island. Laboratory tests by the Geological Survey have indicated that this material is probably not a petroleum derivative.

Other nonmetallic deposits are few and scattered. Barite occurs as replacement deposits on Lime Point (Hetta Inlet), and a minor amount has been reported in a fissure vein on Ste. Ignace Island. Graphite occurs locally in small quantities in carbonaceous slate, phyllite, or schist, but no large concentrations have been reported. Refractory materials have been reported but are unevaluated as to grade or reserve; dunite is described at Mount Burnett (Kennedy and Walton, 1946, p. 84) and sillimanite is reported on the southern end of Deer Island (Buddington and Chapin, 1929, p. 335).

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