# RECONNAISSANCE GEOLOGIC MAP OF THE WESTERN ALEUTIAN ISLANDS, ALASKA

*Compiled by* Frederic H. Wilson, Solmaz Mohadjer[1], and Delenora M. Grey[1]

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[1] Kelly Services, Anchorage, Alaska

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## ABSTRACT

The western Aleutian Islands, which extend from Great Sitkin Island westward to Attu Island in the eastern hemisphere, form a transition zone between oblique subduction and strike-slip motion between the Pacific plate and the North America plate along the Aleutian margin. Volcanoes of Holocene age are present in the eastern part of the map area, whereas no evidence of Quaternary volcanism exists on Attu Island, the westernmost of the Aleutian Islands. Bedrock map units of early Tertiary and possibly Mesozoic age underlie the westernmost of the islands, whereas the more eastern islands are underlain by rocks thought to be of Eocene age, or possibly Paleocene age at the oldest. The vast majority of rocks are either igneous or else sedimentary rocks derived from erosion of the igneous rocks. The geologic mapping shown here is largely of a reconnaissance nature; recently published geologic maps have been generalized in this presentation.


## INTRODUCTION AND PREVIOUS WORK

This map and accompanying digital files (Wilson and others, in press) represent part of a systematic effort to release geologic map data for the United States in a uniform manner. The geologic data in this series have been compiled from a wide variety of sources, ranging from state and regional geologic maps to large-scale field mapping. Nationally, the data is intended for use at a nominal scale of 1:500,000. However, individual datasets are suitable for use at larger scales, such as that for the western Aleutian Islands presented here at varying scales. The metadata associated with each release will provide more detailed information on sources and appropriate scales for use. Associated attribute databases accompany the spatial database of the geology and are uniformly structured for ease in developing regional- and national-scale maps.

The western Aleutian Islands are defined herein to be those islands that are located west of the eastern edge of the Adak 1:250,000-scale quadrangle boundary. The map area, which includes Great Sitkin Island on the east and Attu Island on the west, is largely uninhabited. Exceptions are the village of Adak, which contains an abandoned military base and is now a developing fishing community on Adak Island on the eastern margin of the map area, the small Air Force base on Shemya Island, and the U.S. Coast Guard LORAN Station on Attu Island at the western margin of the map area. At various times in the past, inhabitation has been much higher, including at many Aleut villages in existence at the time of Russian contact in the 1740's (Black, 2004); before World War II, a village existed on Attu Island. During the war, owing to the Japanese capture of Attu and Kiska Islands, the U.S. and Canadian military established a number of bases in the islands, including major bases on Adak, Amchitka, and after the recapture, on Attu Islands; smaller bases and outposts were established on other islands. Other than at Adak and Shemya Islands, most of these bases were largely abandoned soon after the war. An active minefield, placed by the Japanese, still remains on Attu Island. In the 1970's, nuclear tests were conducted on Amchitka Island and since then, clean-up efforts have been undertaken periodically there and elsewhere in the Aleutian Islands.

For the most part, mapping of the western Aleutian Islands was conducted more than 50 years ago, in the late 1940's and early 1950's as part of the USGS Investigations of Alaska Volcanoes project that was undertaken immediately following World War II. The results of these studies were published in the multichaptered USGS Bulletin 1028, many of which have been cited here (Coats, 1956a, b, c, 1959a, b; Coats and others, 1961; Fraser and Barnett, 1959; Fraser and Snyder, 1959; Gates and others, 1971; Lewis and others, 1960; Nelson, 1959; Powers and thers, 1960; Simons and Mathewson, 1955; Snyder, 1959). In addition, a summary of the geology of the Aleutian Islands was written for the Geological Society of America Decade of North American Geology (DNAG) volume on Alaska (Vallier and others, 1994). This DNAG publication summarizes the past work and the many topical studies undertaken since the USGS Volcanoes project. In the 1990's, the staff of the Alaska Volcano Observatory has begun studies of the active and potentially active volcanic centers in the region, some of the results of which are represented by Waythomas and others (2003) and Miller and others (2003). During the 1980's, a number of topical studies were undertaken in the western Aleutian Islands, and these provide most of the data for age control of the rocks in the islands (table 1). On Tanaga Volcano and on the volcano at Mount Gareloi on Tanaga and Gareloi Islands, respectively, the contacts between map units are slightly modified from Coats (1959a) using data from recent unpublished mapping (Michele Coombs, USGS, written commun., 2005). In the 1:250,000-scale Attu quadrangle, Alaid and Nizki Islands, just west of Shemya Island in the Semichi Island group, remain unmapped.

This map and the accompanying digital files present a compilation of the best available mapping in an integrated fashion. Locally, however, maps from differing sources were incompatible at their boundaries (for example at the southwest end of Kanaga Island); as a result, some unit boundaries are shown as straight lines, thereby reflecting the boundaries of the sources.

## GEOLOGIC AND PHYSIOGRAPHIC FRAMEWORK

The western Aleutian Islands are located near the western end of the Aleutian magmatic arc, where, owing to the curvature of the arc, plate convergence is oblique. At the eastern end of the segment covered by this map, convergence is west directed at an approximately 40° angle to the trend of the arc, whereas at the western end of this segment, the Pacific plate is moving nearly parallel to the trend of the trench (Engebretson and others, 1985). As a consequence, subduction-related volcanism declines westward along the island arc.

Conceptually, the rocks of the Aleutian Islands have been placed in three informally defined chronostratigraphic series (Vallier and others, 1994). Each series, although lithologically variable, corresponds to an evolutionary stage in the history of the Aleutian Ridge or magmatic arc. Rocks of the Lower Series are older than 37 Ma and consist of predominantly mafic volcanic, hypabyssal, and volcaniclastic rocks (Vallier and others, 1994). The Lower Series is thought to represent the major constructional stage of the Aleutian Ridge; the upper age limit of this series indicates the end of voluminous and widespread igneous activity along the ridge. Lower Series rocks generally are hydrothermally altered, contact metamorphosed by later plutons, or locally metamorphosed to greenschist facies (for example, on Attu Island). As such, the minimum age of 37 Ma largely is interpretive, and determining a maximum age is difficult. Middle Series rocks are Oligocene and Miocene in age and largely consist of volcanic and plutonic rocks but also include extensive sedimentary rocks of turbiditic and of shallow-marine, nearshore character. Upper Series rocks are Pliocene and younger and, on the islands, are the products of the modern Aleutian magmatic arc. Offshore, Upper Series rocks and sediments "fill fore arc and summit basins, thinly mantle parts of the summit platform and sloping flanks of the ridge, and constitute most of the accretionary complex that underlies the landward slope of the trench. [Upper Series] sediments fill the Aleutian Trench" (Vallier and others, 1994, p. 371).

The oldest rocks in the eastern part of the map area are the Finger Bay Volcanics (Tvo) on Adak, Kagalaska, and Great Sitkin Islands as well as similar rocks elsewhere that are thought to be largely of Eocene age (Vallier and others, 1994) and are typical for an intraoceanic magmatic arc. In contrast, the oldest rocks in the western part of the area, the undifferentiated basement rocks unit (TMzv), mapped on Attu Island, have many characteristics that are more appropriate for an oceanic spreading center and inconsistent with those of a magmatic arc. Yogodzinski and others (1993) defined the Attu Basement Series to include the oldest Attu Island rocks, which consist of the pillow-basalt and volcaniclastic-rocks, diabase-gabbro intrusions, and albite-granite (informal) units of Gates and others (1971; units TMzv, Td, and Tagr, herein). Yogodzinski and others (1993) proposed a model wherein these rocks were erupted or emplaced in a back-arc transtensional rift environment "wherein the lithosphere of the overriding plate is stretched in response to tectonic adjustments resulting from a switch from convergence to strike-slip dominated tectonics" (Yogodzinski and others, 1993, p. 11,827), suggesting that this produced oceanic-type crust that has the signature of a subduction-related ophiolite; however, they stated that the Attu Basement Series rocks are not allochthonous, but rather formed *in situ*.

Yogodzinski and other's (1993) Attu Basement Series differs from the Lower Series, as defined in Vallier and others (1994), in that the Chirikof and the Nevidiskov Formations (Tc and Tn, respectively) are not included in the Attu Basement Series, whereas they are included in the Lower Series; however, although assigned to the Lower Series, these two formations more closely correspond in character and age to the Middle Series of Vallier and others (1994). The younger rocks, less than 15 Ma age, have strong calc-alkaline characteristics, and so Yogodzinski and others (1993) suggested that they represent a change in the tectonics of the western Aleutian Islands from a back-arc transtensional rift environment to a transpressional (oblique subduction) setting.

A maximum age for early Aleutian-Arc volcanism is suggested by the ages of rocks included in the Meshik Arc on the Alaska Peninsula (Wilson, 1985), the rocks of which appear to directly correlate with those of the Lower Series in the Aleutian Islands. The earliest reliable ages for the Meshik Arc are about 42 Ma; a few less reliable dates of as old as 54 Ma were determined on rocks in the Port Moller 1:250,000-scale quadrangle, located at the west end of the Alaska Peninsula (Wilson and others, 1994, 1995). On the Alaska Peninsula, Meshik-Arc volcanism largely ended by 30 Ma (Wilson, 1985; Wilson and others, 1994, 1995), which, although younger than the upper age limit suggested (Vallier and others, 1994) for the Lower Series rocks of the Aleutian Islands, is still largely compatible with the Lower Series.

Middle Series rocks in the western Aleutian Islands indicate a transition from largely basaltic volcanism to less mafic andesitic and basaltic volcanism, as well as deposition of sedimentary rocks that indicate erosion of the earlier Lower Series rocks. Rocks of the Chitka Point, Chuniksak, Chirikof, and Nevidiskov Formations (Tcp, Tch, Tc, and Tn, respectively) suggest a significant decline in the importance of volcanism relative to the erosion of preexisting rocks. Fossils are uncommon in these sedimentary rocks; plant material seems to be the most commonly reported fossil. Depositional environments vary from nearshore, yielding beach deposits, to submarine fans, yielding turbidites. Dated calc-alkaline plutonic rocks of the Aleutian Islands commonly yield ages that place them in the Middle Series (Scholl and others, 1987). Some disagreement exists as to the inclusion of the Nevidiskov Formation (Tn) in the

Middle Series: Scholl and others (1987) and Vallier and others (1994) placed it unit in the Lower Series, whereas Yogodzinski and others (1993) placed it in the Middle Series. The Nevidiskov Formation, mapped on Attu Island, was, in part, placed in the Lower Series by its correlation with the Krugoli Formation (TMzk), mapped on Agattu Island (Vallier and others, 1994); however, as described herein, the relation between the two units and their surrounding units differs. On Agattu Island, rocks of the Krugoli Formation have a gradational contact with those of the undifferentiated basement rocks unit (TMzu), whereas, on Attu Island, rocks of the Nevidiskov Formation rocks are less deformed than those of the basement rocks unit, and they are gradational with the overlying Chuniksak Formation (Tch) of Miocene age. On the basis of the published unit description (Gates and others, 1971), we suggest that the Nevidiskov Formation is more appropriately placed in the Middle Series. At the stratigraphically higher end of the Middle Series, similar disagreement exists on the inclusion of the Massacre Bay Formation of Gates and others (1971), included in the undivided older volcanic rocks unit (QTv) herein, as well as the Faneto Formation (QTf). Scholl and others (1987) placed them in the Middle Series, whereas Vallier and others (1994) either placed them both in the Upper Series, as shown in their figure 3, or placed only the Faneto Formation in the Upper Series, as stated in their text.. If the Upper Series represents the initiation of the modern Aleutian Arc, then the rocks of the Massacre Bay Formation (included in unit QTv herein) may represent the first stage of that initiation and, therefore, are transitional in a sense between the Middle Series and the Upper Series. If this is true, then the overlying Faneto Formation should be assigned to the Upper Series.

Upper Series rocks largely consist of the constructional volcanic centers that constitute the modern Aleutian magmatic arc, as well as the sedimentary rocks derived from erosion of these and older rocks and deposits along the Aleutian Ridge. Owing to the hazards studies by the Alaska Volcano Observatory, these Upper Series rocks are becoming the best known rocks of the Aleutian Islands (Waythomas, 1995; Waythomas and others, 2003; Miller and others, 2003); however, the most recently erupted volcanic rocks, of greatest interest for modern volcano studies, are not found west of Buldir Island above sea level.

# QUATERNARY GLACIATION

Most of the Aleutian Islands were covered by extensive ice caps during the late Wisconsin, according to Thorson and Hamilton (1986). As a consequence, glacial deposits older than late Wisconsin age largely have been removed, and even late Wisconsin age deposits are uncommon. Nevertheless, glacial landforms are common and glaciation has been an important shaper of the topography in the western Aleutian Islands. Glacial deposits apparently were carried offshore or are now covered by thick peat and tephra deposits. Estimates of the elevation of the Pleistocene-age snowline suggest that it was from 750 to 1,500 m lower than the present-day snowline; however, the present-day snowline is rapidly changing. At the time of the mapping (1945-1955) that resulted in USGS Bulletin 1028, Investigations of Alaska Volcanoes (see, for example, Gates and others, 1971 or Simons and Mathewson, 1955), many Aleutian Islands still had small alpine glaciers, but by the time of the preparation of this map and its sources (see, for example, Waythomas and others, 2003) most of those had melted.

Glacial deposits probably are far more extensive in the Aleutian Islands than presently mapped owing to confusion with volcanic deposits such as debris-flow and lahar deposits. Conversely, some moraines mapped on Mount Moffett, on Adak Island, by Coats (1956a) have been reinterpreted as lahar deposits by Waythomas (1995), some of which are related genetically to early Holocene eruptions of Mount Moffett and possibly Mount Adagdak, also on Adak Island (Waythomas, 1995). Evidence exists on many of the eastern Aleutian Islands for advances of glaciers during Holocene time; however, age control for the timing of these advances is lacking (Thorson and Hamilton, 1986). No evidence has been reported for Holocene glacial advances west of Adak Island; however, the presence of numerous small alpine glaciers on Attu Island (Gates and others, 1971) suggests that the lack of evidence most likely is due to the lack of investigation. Gates and others (1971) reported a number of young till ridges on Attu Island; their discussion focused on Wisconsin-age glaciation; however, many till ridges are not vegetated and so most likely are of Holocene age. With further work that adds to the three localities discussed by Thorson and Hamilton (1986), it is likely that more evidence of late-Holocene glaciation will be demonstrated.

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# DESCRIPTION OF MAP UNITS

[Sizes, thicknesses, and elevations shown in brackets are quoted from original sources]

## SEDIMENTARY ROCKS AND SURFICIAL DEPOSITS

Qs Surficial deposits, undivided (Quaternary)—Unconsolidated beach, eolian, delta, lagoon, landslide, glacial, and alluvial deposits; composed of silt, sand, gravel, and boulder-sized material; primary and reworked pyroclastic material is common component. In many locations, deposit includes soils rich in volcanic ash and peat deposits, particularly on northern Kanaga Island (Miller and others, 2003), on Great Sitkin Island (Waythomas and others, 2003; Simons and Mathewson, 1955), on Kavalga, Ogliuga, and Skagul Islands (Fraser and Barnett, 1959), and on Adak and Kagalaska Islands (Fraser and Snyder, 1959). Delta deposits largely consist of reworked pyroclastic and glacial deposits (Coats, 1956a). Unit also is shown on Attu Island (Gates and others, 1971), Kiska Island (Coats and others, 1961), Semisopochnoi Island (Coats, 1959b), Little Sitkin Island (Snyder, 1959), Amchitka Island (Powers and others, 1960), and Segula Island (Nelson, 1959). On Adak Island, includes marine-terrace boulder gravel mapped by Coats (1956a) and the lagoonal deposits of Waythomas (1995). Locally subdivided into the following:

Qa Alluvium—Sand, gravel, and silt; includes reworked cinders and ash. On Attu and northern Adak Islands, includes old beach deposits in lower parts of some valleys (Gates and others, 1971; Waythomas, 1995); also includes on northern Adak Island, alluvial terrace deposits in low benches, as well as unpaired terraces along streams and creeks (Waythomas, 1995), both of which are usually mantled by tephra. Unit also is shown on southern Adak and Kagalaska Islands (Fraser and Snyder, 1959), on Kanaga Island (Coats, 1956b), and on Buldir Island (Coats, 1953). On Adak Island, also includes the delta deposits of Waythomas (1995)

Qf Alluvial fan deposits—Sand, gravel, and cobbles, as mapped on Attu Island (Gates and others, 1971). On northern Adak Island, also may contain variable amounts of debris-flow deposits and talus, usually mantled by tephra (Waythomas, 1995)

Qc Colluvial deposits—On Little Sitkin Island, consists of boulders and boulder-sized debris in slope wash, talus, landslide, and mudflow deposits (Snyder, 1959); locally, contains clasts consisting of kaolinized, silicified, and pyritized rock. On Great Sitkin Island and on Kanaga Island in vicinity of Kanaga Volcano, includes accumulations of poorly sorted, angular rock debris on slopes below bedrock outcrops (Waythomas and others, 2003; Miller and others, 2003). On northern Adak Island, includes talus, rock-fall avalanche debris, debris-flow deposits, and reworked volcanic-ash and eolian deposits on hillslopes (Waythomas, 1995)

Qls Landslide and mudflow deposits—Poorly sorted accumulations of gravel, sand, and silt, as mapped on Great Sitkin Island (Simons and Mathewson, 1955; Waythomas and others, 2003) and on Kanaga Island near Kanaga Volcano (Miller and others, 2003). On northern Adak Island, also commonly found on lower slopes of Mount Moffett and Mount Adagdak and along most stream channels (Waythomas, 1995)

Qb Beach deposits—Sand, pebbles, gravel, and boulders; includes some narrow stretches of bare-rock shore platform. Deposits are mapped on Adak Island (Waythomas, 1995), Great Sitkin Island (Waythomas and others, 2003), Kanaga Island (Miller and others, 2003), Ogliuga and Skagul Islands (Fraser and Barnett, 1959), Little Sitkin Island (Snyder, 1959), Amchitka Island (Powers and others, 1960), Segula Island (Nelson, 1959), and Buldir Island (Coats, 1953). On Great Sitkin Island and on Kanaga Island along shore at base of Kanaga Volcano, deposits are found on pocket beaches and in steep berms; the consist of rounded-cobble and boulder gravel and locally include eolian deposits mostly of well-sorted, medium to coarse sand (Waythomas and others, 2003; Miller and others, 2003). On northern Adak Island, Waythomas (1995) subdivided beach deposits into variety of subunits (not subdivided here) that include deposits on uplifted wave-cut terraces, in beach ridges and beach-ridge complexes, and on younger and older boulder beaches. On Amchitka Island, some beach deposits contain shells of marine fauna that are characteristic of waters warmer than present-day temperatures and so are inferred to be of late-interglacial age (Powers and others, 1960)

Qd Eolian deposits—Sand dunes, typically consisting of sand derived from beaches; mapped on Kiska, Semisopochnoi, Little Sitkin, Ogliuga, Skagul, Amchitka, and northern Adak Islands (Coats, 1956a; 1959b; Coats and others, 1961; Snyder, 1959; Fraser and Barnett, 1959; Powers and others, 1960). On northern Adak Island, also includes reworked ash carried by winds from eruptions on other islands (Coats, 1956a; Waythomas, 1995)

Qg Glacial deposits, undivided—Ground, terminal, or lateral moraine deposits, as well as local outwash deposits. On northern Adak Island, consists of subangular and rounded boulders, many of which are faceted, all in semi-indurated, tough, and clayey matrix (Coats, 1956a). On Kagalaska and southern Adak Islands, consists of rare, scattered till and sparse erratic boulders, as described by Bradley (1948, see also Fraser and Snyder, 1959); however, these deposits were too small to show at map scale on their map and so are not shown here. According to Schafer (*in* Gates and others, 1971), glacial-erratic boulders are common in western Aleutian Islands, and till, most likely ground-moraine deposits, can be found locally in cuts and quarries. On Attu Island, according to Schafer (*in* Gates and others, 1971), many cirques contain Holocene(?) moraines. Simons and Mathewson (1955) mapped glacial-moraine deposits on Great Sitkin Island. On Amchitka Island, Powers and others (1960) noted that till, outwash-gravel deposits, and silt, which has varve-like bedding contain constituents that are not of local origin, suggesting an off-island source

Qhdd Anthropogenic deposits (Holocene)—Unconsolidated deposits concentrated around former Adak Naval Air Station on Adak Island; derived from filling low-lying marsh areas and reworking other deposits to construct runways and other facilities. Unit is equivalent to Waythomas' (1995) "disturbed land" map unit and probably is present in many other areas (not mapped) on northern Adak Island, as well as on Amchitka, Shemya, Kiska, and Attu Islands and perhaps others

QTs Older silt, sand, and gravel (Quaternary or Tertiary)—Boulder-rich conglomeratic deposit on east flank of Mount Adagdak on Adak Island, mapped as Tertiary by Coats (1956a) but is probably Quaternary in age or certainly Pliocene or younger. Cobbles and boulders, which range in size from about 5 cm [few inches] to 3 m [10 ft] and are found in steeply east-dipping beds. Coats (1956a) interpreted these deposits as probably marine talus that accumulated along steep coastal sea cliffs. Also included in unit is fossiliferous marine sandstone, found on northern Adak Island (Coats, 1956a), that consists of soft, yellow-to-gray sandstone and contains lenses of pebble conglomerate. Sandstone, which overlies boulder-rich conglomerate on Mount Adagdak, is richly fossiliferous; however, Coats (1956a) reported that fossils are not of diagnostic species and most appear to represent genera present on modern beaches in Aleutian Islands. Coats (1956a) suggested a late Tertiary age for sandstone; however, its position overlying boulder-rich conglomerate suggests a likely Quaternary age. On Amchitka Island, bedded, nonindurated sand and gravel, composed of hornblende-andesite fragments, is present at elevation of 180 m [600 ft]; some beds contain subangular cobbles and boulders, whereas others contain well-rounded cobbles and boulders as much as 0.6 m [2 ft] in diameter, which Powers and others (1960) interpreted as a beach and nearshore-marine deposit. Also on Amchitka Island, small area of tilted sedimentary rocks (dipping about 12º to southwest), found at South Bight (Powers and others, 1960), consist of, from base, 60 m [200 ft] of layers of carbonaceous sandy silt, fine- to medium-grained sand, and pebbly sand to sandy fine gravel, in random order; layers are about 5 to 60 cm [few inches to 2 ft] thick and grade upward to about 45 m [150 ft] of less well bedded gravel. Color is generally pale reddish yellow to greenish yellow. Fragments of carbonized wood are common in silt layers. Beds are both truncated and overlain by beach deposits (Qb) of Quaternary age

QTf Faneto Formation (early Pleistocene or late Tertiary)—Pebble, cobble, and boulder conglomerate, coarse sandstone, coarse graywacke, and thin argillite lenses 450 m [1,500 ft] thick; mapped on Attu Island (Gates and others, 1971). Beds are predominantly red (from abundance of pebbles of red argillite or lava fragments) and greenish red; a few are gray. Clasts are round to subangular and are composed of lava fragments, argillite, gabbro, and diabase. Unit contains high percentage of pebbles of argillite that resembles argillite of the Chuniksak Formation (Tch), which the gently dipping Faneto Formation overlies unconformably. Unit is poorly sorted, although grain size generally fines upward overall. Lenses and crossbedding are common, as are cut-and-fill structures. The Faneto Formation apparently has provenance in many of older units on Attu Island: Gates and others (1971) reported that sandstone from the Faneto Formation contains angular to subangular grains of argillite, basalt keratophyre, albite granite, quartz, weathered plagioclase, pyroxene, hornblende, chlorite, epidote, and opaque oxides, most of which is magnetite. No fossils have been reported from the Faneto Formation, but Gates and others (1971), on the basis of its stratigraphy and its deep erosion by glaciers suggested that it is no older than late Tertiary and considered it to be preglacial or early Pleistocene. Gates and others (1971) thought the Faneto Formation represents a braided-stream environment, red color possibly indicating subaerial weathering

QTkh Kiska Harbor Formation (Quaternary? and late Tertiary)—Subaerial lava flows, autoclastic breccias, pyroclastic rocks, and water-laid pumiceous sand and conglomerate (Coats and others, 1961); mapped on Kiska and Little Kiska Islands. Flows are predominant to north; sedimentary (water-laid) beds, south. Flows and sedimentary rocks interfinger; flows thin southward and grade into autoclastic breccias; as sedimentary layers thin northward (Coats and others, 1961). Sedimentary rocks are composed entirely of volcanic debris and are generally crossbedded. Depending on location, crossbeds are inclined either to east and southeast or to south and southwest (Coats and others, 1961). On Little Kiska Island, the Kiska Harbor Formation unconformably overlies steeply dipping beds of the Vega Bay Formation (Tvb); on Kiska Island, units are in fault contact. On Kiska Island, breccia layer and lava flow were mapped as members of the Kiska Harbor Formation by Coats and others (1961); they are shown as subunits QTkb and QTkf, respectively, herein. Volcanic rocks of Kiska Volcano (units Qvu, Qv) overlie the Kiska Harbor Formation. "The rocks of the Kiska Harbor Formation resemble the rocks of dissected composite volcanoes on the north end of Tanaga and Kanaga Islands that contain fossils of Pliocene age" (Coats and others, 1961, p. 573); on the basis of this fossil age, Coats and others (1961) assigned a late Tertiary or early Pleistocene age to unit. Potassium-argon ages from are between 3.3 and 5.5 Ma (table 1, nos. 14, 17, 18, 19, 20; see also, Panuska, 1981)

QTkb Kiska Harbor Formation, breccia member—Volcanic breccia consisting of coarse, angular to subrounded basalt fragments in a dark-brownish-gray, fine-grained volcanic-debris matrix (Coats and others, 1961). Proportion of basalt fragments varies: locally, fragments are uncommon, and breccia is composed nearly entirely of matrix; elsewhere, breccia grades laterally into massive basalt. Coats and others (1961) suggested that this breccia was of autoclastic origin, possibly resulting from lava flow entering water

QTkf Kiska Harbor Formation, flow member—Vitrophyric basalt lava flow lacking pillow structure and therefore presumably of subaerial origin. Flows in the Kiska Harbor Formation range in thickness from 1 to 100? m ["a few to several hundred feet"] (Coats and others, 1961)

Tcp Chitka Point Formation (Miocene)—Subaerial hornblende- and pyroxene-andesite lava flows, breccia, tuff, and marine conglomerate; mapped on Amchitka Island (Powers and others, 1960). Thickness exceeds 300 m [1000 ft] (Powers and others, 1960). Carr and others (1970) redefined the Chitka Point Formation by extending outcrop area, to include andesitic rocks that originally were defined (Powers and others, 1960) as part of the Amchitka Formation of Powers and others (1960), included in the Finger Bay Volcanics and similar rocks unit (Tvo) herein, and Banjo Point Formation (Tbp), excluding basaltic rocks that we now consider to be part of the Banjo Point Formation (Tbp). Carr and others (1970) reported thickness for their redefined formation of at least 1,200 m [4,000 ft] from drill hole. Conglomerate primarily consists of well-rounded to subrounded cobbles of porphyritic andesite; also common but less abundant are clasts derived from the Amchitka Formation of Powers and others (1960), included in unit Tvo herein. At type locality, conglomerate contains abundant carbonized fragments of woody material, which suggests nearness to land. Coal sample from conglomerate yielded numerous pollen and spores, probably of middle to late Miocene age (Estella Leopold *cited in* Carr and others, 1970). In addition, Carr and others (1970) reported late Miocene K-Ar ages (minimum age, 12.7 to 14.5 Ma; nos. 24, 25, 26, table 1) from flows within the Chitka Point Formation and, therefore, assigned unit a Miocene age, thereby revising age assignment by Powers and others (1960) of Tertiary or Quaternary

Tch Chuniksak Formation and similar rocks (Miocene)—Fine-grained, well-bedded and laminated, siliceous, argillic, and limy marine sedimentary rocks; mapped on Attu Island

(Gates and others, 1971). According to Gates and others (1971), unit consists principally of siliceous shale, argillite, calcareous argillite, chert, siliceous siltstone, sandstone, sandy shale, graywacke, and minor amounts of pebble conglomerate. Rocks, which range widely from dark-gray, yellow, and brown to green, purple, and red, weather rapidly to red angular chips and blocks that form rounded hills (Gates and others, 1971). Beds, which range from about 2 cm to 30 cm [less than 1 in to 1 ft] in thickness, have sharp contacts that serve as parting planes in weathered fragments. Calcareous and siliceous nodules as much as 3 m [10 ft] long are present parallel to bedding, generally in preferred stratigraphic horizons. Where nodules are found, bedding thins around nodules, which indicates that "they were probably formed as primary sedimentary features on the sea floor rather than as replacements of previously existing sediments" (Gates and others, 1971, p. 734). Diatoms and foraminifers are sparsely scattered throughout unit; fossil mollusks and plants are found at Chuniksak Point, on Attu Island, in narrow concretion-bearing zones, which are near middle of measured section (Gates and others, 1971). Best inferred age for unit probably is Miocene (Gates and others, 1971), although plant fossils identified by Roland W. Brown (*cited in* Gates and others, 1971, p. 736) suggest a probably early Tertiary, and possibly Eocene, age. The Chuniksak Formation conformably overlies the Nevidiskov Formation (Tn) and is unconformably overlain by the Faneto Formation (QTf). Unit is at least 600 m [2,000 ft] thick; top of unit has been removed by erosion, and locally it is highly deformed and faulted. Also included in unit are the "basement rocks of Shemya Island" [Tb] unit of Gates and others (1971, p. 776), which, although not formally assigned to the Chuniksak Formation, do bear some lithologic similarity and are of common age

Tc Chirikof Formation (Miocene?)—Boulder and pebble conglomerate, coarse sandstone, carbonaceous shale and sandstone, and possibly one single lava flow; mapped on Attu Island, southwest of Chirikof Point (Gates and others, 1971). Boulder conglomerate contains rounded boulders; in pebble conglomerate, fragments and coarse sandstone are angular to round. Pebble conglomerate contains fragments "of argillite, basalt, chert, and albite granite in a crudely bedded and poorly sorted sand matrix" (Gates and others, 1971, p. 738). Sandstone contains "grains of quartz, plagioclase, argillite, chert, basalt and carbonaceous fragments cemented by limy, carbonaceous, and siliceous material. Interbedded with the coarse sand are beds of coaly shale with many leaf and stem imprints and a few silicified tree limbs" (Gates and others, 1971, p. 738). Gates and others (1971) noted a single amygdaloidal, keratophyric pillow-basalt lava flow that may be part of formation: Contact between this flow and other rocks of the Chirikof Formation is faulted where best observed; however, lower parts of flow contain fragments of pebble conglomerate and coarse sandstone that may be derived from the Chirikof Formation, indicating that flow is interbedded in formation. Gates and others (1971), however, suggested another alternative in which flow and fragments of sedimentary rocks included therein may be basement rocks faulted against the Chirikof Formation. Plant fossils from coal shale beds in the Chirikof Formation, identified by Roland W. Brown (*cited in* Gates and others, 1971, p. 739), include some of same species found in the Chuniksak Formation and so suggest similar age, possibly Miocene. Although the Chirikof Formation crops out only in a small area of eastern Attu Island, it is retained herein because of its distinct difference in character from the coeval Chuniksak Formation

**Tn** Nevidiskov Formation (early Miocene? or late Oligocene?)—Coarse graywacke and conglomerate, in general in fining-upward sequence; mapped on Attu Island (Gates and others, 1971). Conglomerate clasts, which are as much as 0.7 m [2 ft] in diameter, consist of fragments of the undifferentiated basement rocks (unit TMzu), which include porphyritic basalt, graywacke, and cherty argillite. In upper part of unit, lenses of argillite are more common, and contact with argillite of the Chuniksak Formation (Tch) is gradational. Both the Nevidiskov and the Chuniksak Formations are less deformed than the undifferentiated basement rocks unit, erosion of which was probably provided source material for these two units. Single *Pecten* fossil from near base of the Nevidiskov Formation was of indeterminate age and so could not be used to establish its age; however, Gates and others (1971) considered unit to be perhaps of late Oligocene or early Miocene age because of its conformable contact with the overlying Chuniksak Formation of Miocene age

**Tgc** Gunners Cove Formation (Tertiary)—Tuffaceous conglomerate and sandstone, crystal-vitric basaltic tuff, thin basalt flows, and basaltic dikes (Lewis and others, 1960); forms about two thirds of Rat Island. Sandstone and conglomerate contain moderately well to well-rounded mafic-volcanic clasts, primarily of basalt, in matrix of basaltic-glass and marine shell fragments. One conglomerate outcrop along north shore of Gunners Cove is especially rich in fragmentary barnacles, crinoids, echinoids, and pectinid bivalve fossils. Basalt is present in thin flows, some of which have pillow structures and, locally, columnar jointing, as well as in crudely bedded masses of glassy scoria and in thin dike swarms (Lewis and others, 1960). Identified fossils include *Isocrinus* aff. *I. oregonensis* (Moore and Vokes) and *Chlamys* aff. *C. washburnei* Arnold, both of probable Oligocene or early Miocene age; however, Carr and others (1970) assigned an age of late Eocene or Oligocene on the basis of mollusks and foraminifers and they correlate unit with the Banjo Point Formation (Tbp), mapped on Amchitka Island

**Tbp** Banjo Point Formation (Oligocene or late Eocene)—Bedded marine sandstone, conglomerate, tuffaceous shale, and lapilli tuff of basaltic composition; mapped on Amchitka Island (Powers and others, 1960). Carr and others (1970) slightly revised unit definition and its defined outcrop area, and they also indicated presence of minor amount of pillow lava; they distinguished unit from the overlying Chitka Point Formation (Tcp) because of its submarine and basaltic character, in contrast to the subaerial and andesitic Chitka Point Formation. Originally assigned an age of late Oligocene or early Miocene on the basis of 36 species of forams and poorly preserved mollusks (Powers and others, 1960). Additional fossil collections, as well as re-examination of existing collections by Carr and others (1970), suggest a revised late Eocene or Oligocene age. Potassium-argon ages on dikes intruding unit are between 9.1 and 10.5 Ma (nos. 22, 23, table 1; see also Carr and others, 1970)

**Tal** Andrew Lake Formation and similar rocks (late Eocene)—Tuffaceous sandstone and siltstone and siliceous and cherty shale interbedded with mafic flows or penecontemporaneous sills; mapped on Adak and Amatignak Islands. "Graded sandstone beds as much as 0.3-m-thick are common, and alternating beds of sandstone and shale *** form graded sequences 3 to 4 m in thickness" (Scholl and others, 1970, p. 3,586). Fossils identified by R.W. Brown (*cited in* Coats, 1956a) reported to be *Annularia stellata* of Pennsylvanian or Permian age are present, along with mollusks, fish skeletal remains and scales, foraminifers, dinoflagellates, and *Pectens*, all of Eocene age. Later sample collections, as well as reanalysis of original fossil collection, by Scholl and others (1970) resulted in assignment of age of these rocks to late Eocene and, thus, subsequent definition of the Andrew Lake Formation (Scholl and others, 1970). On Amatignak Island, unit also includes altered tuffaceous sedimentary beds that contain coarse pyroclastic rocks. Beds consist of dark-gray, greenish-gray, olive-green, bluish-gray, and light-brown tuffaceous argillite and siltstone, tuffaceous sandstone, and tuffaceous breccia; finely laminated and banded green and gray argillite also is common. Beds are well indurated, chloritized, pyritized, and silicified, and they are intruded by andesitic or basaltic dikes and sills, as well as by small dioritic or diabasic sills and one large quartz-diorite sill (Fraser and Barnett, 1959). On Amatignak Island, altered pillow-basalt flow yielded 24.3 Ma potassium-argon age, and diabase sill yielded 29.8-Ma-age (nos. 36, 37, table 1; see also, DeLong and others, 1978). On Adak Island, andesite sills yielded K-Ar ages of 14.4 and 5.23 Ma (nos. 40, 41, table 1; see also, Hein and McLean, 1980; Cameron and Stone, 1970 herein)

TMzk Krugoli Formation (early Tertiary or late Mesozoic?)—Bedded argillite, siltstone, chert, basaltic and spilitic lava flows, tuff, tuff agglomerate, and conglomerate; mapped on Agattu Island (Gates and others, 1971). About 2,250 m [7,400 ft] thick. Unit is lithologically similar to the undifferentiated basement rocks unit (TMzu) and subunits (TMzt, TMzc, TMzbv), mapped on Agattu and Attu Islands; however, unit has lower proportion of volcanic components than the undifferentiated basement rocks unit (Gates and others, 1971). Contact with the undifferentiated basement rocks unit is gradational; the Krugoli Formation is recognized by its greater proportion of coarse-clastic to fine-grained sedimentary rocks. According to Gates and others (1971), coarse sandstone and pebble conglomerate make up about two-thirds of sedimentary part of unit. Subdivided into the following:

TMzkc Coarse-grained and conglomeratic sedimentary rocks—Coarse graywacke and conglomerate interbedded with pillow-lava flows, pyroclastic rocks, and fine-grained siliceous rocks. Clasts consist of sandstone, fine-grained siliceous sedimentary rocks, basalt, and tuff; no schistose or granitic clasts were observed (Gates and others, 1971)

TMzkv Tuff and lava—Chiefly basaltic and spilitic. Single sequence of volcanic rocks, located about 730 m [2,400 ft] above base of the (undivided) Krugoli Formation, consists of 60 m [200 ft] of massive green tuff and tuffaceous sandstone, overlain by 15 m [50 ft] thick porphyritic-basalt flow or by porphyritic-basalt pillow lava, in turn overlain by 20 m [70 ft] of coarse-grained tuff and thin-bedded, well-bedded, fine-grained sedimentary rocks and an amygdaloidal pillow-lava flow (Gates and others, 1971). Originally mapped as separate units by Gates and others (1971)

TMzu Basement rocks, undifferentiated (early Tertiary or late Mesozoic?)—Undifferentiated basement rocks. On Agattu Island, consists of marine argillite, sandstone, graywacke, and conglomerate, as well as submarine pyroclastic rocks; also includes columnar-jointed and pillowed (mostly basaltic) lava flows. On Attu Island, sedimentary rocks are divided into fine- and coarse-grained subunits (TMzf and TMzc, respectively); on Agattu Island, all sedimentary rocks are included in unit TMzc. Overall thickness is unknown; Gates and others (1971) suggested that unit may be about 3,000 to 4,500 m [10,000 to 15,000 ft] or more thick. Gates and others (1971), lacking fossils and age control, assigned an early Tertiary, or possibly late Mesozoic, age to this unit; later K-Ar ages (DeLong and McDowell, 1975; DeLong and others, 1978) of about 30 Ma were interpreted by DeLong and McDowell (1975) to reflect the timing of metamorphism and, therefore, suggest only minimum age for unit. Gates and others (1971) pointed out that outstanding characteristic of the undivided basement rocks unit is its heterogeneity, as all lithologies of unit are interbedded and grade laterally into each other. Gates and others (1971, p. 728-729) interpret that this

> ”reflects heterogeneity in the environment of deposition, in the source area, and in the processes of deposition. Rounded pebbles imply subaerial sources; the characters of the volcanic rocks clearly indicate widespread submarine volcanism; and the slumping, chaotic bedding, and structures formed by turbidity currents imply steep gradients which in turn suggest tectonic movements and perhaps also volcanic islands or submarine peaks. However, the finely laminated, primarily siliceous sedimentary rocks suggest quiet deposition at some depth in basins free from currents, wave action and the dumping of detrital sediments.”

Unit is part of the Attu Basement Series of Yogodzinski and others (1993). Locally subdivided into the following:

TMzf Fine-grained sedimentary rocks—Fine-grained, thin-bedded sedimentary rocks, consisting of chert, siliceous siltstone, argillite, limestone, and fine tuffaceous graywacke, in “thin varicolored black, green, red, yellow, and gray beds” (Gates and others, 1971, p. 715); mapped only on Attu Island. Beds vary from thin laminae to graded beds possibly 5(?) to 100(?) cm [several inches to several feet] thick. Individual chert, argillite, silty, and tuffaceous beds, as little as 2.5 cm [1 in] thick, can be traced for 100(?) m or more [hundreds of feet] along strike. Other beds form short lenses within coarser grained sedimentary rocks of unit TMzc (Gates and others, 1971). Deformed beds present between undeformed beds are indicative of soft-sediment deformation; turbidity-current deposition is indicated by graded bedding, small-scale crossbedding, slight erosional unconformities between beds, and presence of mud chips or mud balls at base of individual beds (Gates and others, 1971, p. 717)

TMzc Coarse-grained and conglomeratic sedimentary rocks—Coarse-grained graywacke and conglomerate interbedded with pillow lavas, pyroclastic rocks, and fine siliceous rocks; mapped on Attu and Agattu Islands. Generally drab dark-gray, grayish-purple, or grayish-green color, in thin beds of graywacke and much thicker conglomerate horizons. Graywacke displays good sorting, minor crossbedding, and slight scouring and erosional irregularities between beds. Pebble-cobble conglomerate horizons have crude irregular bedding and poor sorting, and they contain lenses of coarse graywacke or small-pebble conglomerate. Conglomerate beds can be more than 300 m [1,000 ft] thick as indicated by measured sections in Gates and others (1971). Clasts in conglomerate are primarily basaltic and keratophyric volcanic rocks but also include tuff and tuff-breccia, argillite, limestone, graywacke, and pebble conglomerate; matrix varies from tuffaceous(?) to detrital sand and clay. Rocks that are similar, except that they contain thinner conglomerate beds as much as 15 m [50 ft] thick are found on Agattu Island; Gates and others (1971) did not subdivide these sedimentary rocks, and so all are included within this unit herein

TMzbv Volcanic rocks—Largely tuff and tuff-agglomerate of generally basaltic composition interbedded with pillow-lava flows; mapped on Attu and Agattu Islands. Pyroclastic rocks vary from coarse-grained, bomb-filled lapilli tuff to fine-grained, silt-sized tuff, agglomerate, and breccia. Beds, as much as 30 m [100 ft] thick vary from massive and poorly sorted to well bedded and graded (Gates and others, 1971). Agglomerate consists of angular to subrounded blocks, as much as 30 cm [1 ft] in diameter, of basalt, keratophyre, and rare albite granite, all in mottled, pale-green and white, tuffaceous matrix (Gates and others, 1971, p. 718-719). Pillow-lava flows are important component of basement rocks: individual flows range in thickness from 30 cm to tens of meters [1 foot to several tens of feet] and contain pillow structures that typically are 1 to 2 m [3 to 6 ft] in horizontal dimension. Columnar jointing is present locally. Pillow structures have glassy-appearing selvages on outer surfaces; in cross section, some display concentric layering of amygdules. Interstices between pillow structures are filled with varicolored chert, chalcedony, red jasper, or calcareous mud, as well as red limestone locally (Gates and others, 1971). Basaltic rocks commonly are altered to spilite; more siliceous volcanic rocks are altered to keratophyre and quartz keratophyre (Gates and others, 1971). Two K-Ar ages, interpreted as minimum ages, are 29.0 Ma on pillow-basalt flow and 30.7 Ma on amphibolite (nos. 3, 6, table 1; see also DeLong and McDowell, 1975)

## VOLCANIC ROCKS AND DEPOSITS

Qvu Volcanic rocks and deposits, undivided (Quaternary)—Consists of basalt and andesite lava flows, minor amounts of intrusive rocks, and pyroclastic rocks and deposits that include scoria, tuff breccia, and vent agglomerate; mapped throughout western Aleutian Islands. Unit includes, on Kanaga Island, rocks and deposits of older eruptive stage of Kanaga Volcano (Coats, 1956b) and two-pyroxene silicic-andesite lava domes at Kanaga Volcano (Miller and others, 2003) and basalt flows and tuff beds from vent older than ancestral "Mount Kanaton" volcano at Kanaton Ridge near north coast of island (Coats, 1956b; Miller and others, 2003); on Kiska Island, lava flows and interbedded pyroclastic rocks that form Kiska Volcano (Coats and others, 1961); on Great Sitkin Island, basalt flows (on Sitkin Creek) and composite cone of the Great Sitkin Volcanics of Simons and Mathewson (1955) and cone-building flows and volcaniclastic rocks (Waythomas and others, 2003); on Tanaga Island, the early eruptive phase of Tanaga Volcano (Michele Coombs, USGS, written commun., 2005); on Adak Island, rocks and deposits of Mount Moffett (Coats, 1956a), including basalt domes at Mount Moffett and Mount Adagdak originally mapped as Tertiary (Coats, 1956a); on Semisopochnoi Island, basaltic tuff breccia and tuffaceous sand (Coats, 1959b); on Buldir Island, the Buldir Volcanics of Coats (1953); on Gareloi Island, olivine basalt flows and scoria (Coats, 1959a). Unit also includes interbedded lava flows and pyroclastic material on Segula, Davidof, and Khvostof Islands, at Mount Adagdak on Adak Island, and elsewhere in western Aleutian Islands (Fraser and Barnett, 1959; Coats, 1956a, c; Nelson, 1959). Three attempts to date rocks from this unit yielded equivocal results; dacite from Davidof Island yielded age of 1.5±0.7 Ma (no. 28, table 1, from T.L. Vallier, written commun., 2004); andesite for ancestral "Mount Kanaton" at Kanaton Ridge on Kanaga Island, yielded 0.26±0.08 and 0.13±0.09 (no. 39, table 1; see also Bingham and Stone, 1972); and basalt from Mount Adagdak, on Adak Island, yielded ages of 0.0±0.16 and 0.0±0.23 Ma (no. 48, table 1; see also Cameron and Stone, 1970). Internal contacts, shown in areas such as on Tanaga Volcano, on Tanaga Island, reflect original source unit distinctions that were lumped for this map. Locally subdivided into the following:

Qv Younger volcanic rocks—Largely basalt flows and interbedded pyroclastic rocks associated with Mount Moffett and Mount Adagdak, on Adak Island (Coats, 1956a); on Kiska Volcano, on Kiska Island,(Coats and others, 1961); and on Mount Cerberus, Sugarloaf Peak, and Lakeshore Cone, on Semisopochnoi Island (Coats, 1959b). Includes on Gareloi Island, "lava of the 1929 eruption" of Fraser and Barnett (1959) and Coats (1959a) and black to dark-reddish-brown basaltic lava and scoria and viscous andesitic flows (Coats, 1959a), as well as young basalt flows on Segula Island (Nelson, 1959), where flows generally are dark-gray, glassy or fine-grained, porphyritic two-pyroxene andesite and olivine basalt and have noneroded flow forms. Also includes, on Buldir Island, hornblende basalt dome on East Cape Volcano (Coats, 1953), as well as hypersthene-bearing hornblende basalt and basaltic andesite of the East Cape Volcanics of Coats (1953), which are herein considered to be Holocene in age; although Coats (1953) reported no age other than Quaternary for East Cape Volcano, on Buldir Island, fresh condition of flows suggests a Holocene age. Unit includes many volcanic rocks that are of historic or late prehistoric age. For example, unit includes dark-gray to black basaltic andesite, erupted during 1974 eruption, which occupies most of summit crater of Great Sitkin Volcano, Great Sitkin Island (Waythomas and others, 2003); unit also includes remnants of lava dome of 1945 eruption, as well as earlier Holocene eruptive products from summit and flank vents. In addition, on Kanaga Volcano, on Kanaga Island, Miller and others (2003) have distinguished number of Holocene eruptive rocks, including andesite flows from 1994, 1906, and earlier eruptions. Age of unit is Holocene

Qp Pyroclastic rocks—Includes pyroclastic rocks and deposits of dacitic and andesitic composition and minor lava flows associated with Great Sitkin Volcano, on Great Sitkin Island (Simons and Mathewson, 1955; Waythomas and others, 2003); older composite cone of Mount Adagdak, on Adak Island (Coats, 1956a); and andesite tuff at Kanaga Volcano, on Kanaga Island, (Coats, 1956b; Miller and others, 2003). On Great Sitkin Island, includes moderately well to poorly sorted, nonwelded, pumiceous pyroclastic flow deposits that have ash-rich matrix and contain rounded to subrounded pumice clasts as much as 75 cm [30 in] in diameter and abundant angular to subangular lithic clasts as much as 25 cm [10 in] in diameter (Waythomas and others, 2003); thickness varies but is generally between 1 and 10 m. At Great Sitkin and Kanaga Volcanoes, unit also includes poorly sorted, loose rock rubble, which is derived from fragmentation of lava flows and ejecta, and variable amounts of reworked lapilli tephra (Waythomas and others, 2003; Miller and others, 2003). On Semisopochnoi Island, lava flows and pyroclastic rocks, largely on Anvil Peak, but also on 278-m-high [914-ft] pyroclastic cone near Tuman Head and on Threequarter Cone, overlie or are interbedded with dacite pumice of caldera eruption (Coats, 1959b); also includes Patterson Point Formation of Little Sitkin Island (Snyder, 1959). Age of unit is late Pleistocene? or Holocene

Qat Ash and tephra deposits—Consists of pyroclastic mantle covering constructional surfaces on Segula Island and possibly Davidof and Khvostof Islands (Nelson, 1959), and on northern Adak Island (Waythomas, 1995). On Segula Island, consists of clasts that range in size from fine-grained sand to large blocks of lava about 1? m [several feet] across; fragments between 3 mm and 8 cm [one-eighth and 2 or 3 in] predominate. Clasts of andesite and glass vary from pumiceous to scoriaceous to massive and may be red, brown, gray, tan, or black (Nelson, 1959). At Gray Point, on Davidof Island, light-gray debris at least 45 m [150ft] thick is well exposed (Nelson, 1959). On northern Adak Island, ash and tephra deposits, which mantle wide variety of other deposits and bedrock map units, are typically fine grained but also contain beds of lapilli-sized tephra and peat interbeds (Waythomas, 1995). Age of unit is Holocene

Qdd Little Sitkin Dacite and Double Point Dacite, undivided—White to black, low-silica dacite and rhyodacite flows of the Little Sitkin Dacite. Internal contacts shown reflect two members, the West Cove and Pratt Point members of Snyder (1959), that were lump on this map. Also includes Double Point Dacite of Snyder (1959), a sequence of light- to dark-gray high-silica dacite flows containing many miarolitic inclusions of labradorite andesite containing minor amounts of associated pyroclastic material. Unit is associated with youngest eruption of Little Sitkin Volcano. Contains areas of kaolinized, silicified, and pyritized rock. Age of unit is late Pleistocene? and Holocene

Qba Basalt and andesite domes—Consists of dark-gray to black, glassy, porphyritic-basalt dome, which was extruded in crater of Great Sitkin Volcano, on Great Sitkin Island, in 1945, but was largely removed by 1974 eruption (Waythomas and others, 2003). Also includes dark-gray to black, basaltic-andesite dome that has highly fractured and blocky carapace, which was emplaced during 1974 eruption and which now occupies most of summit crater of volcano. In addition, medium- to dark-gray andesite and basaltic andesite, which form resistant knobs and hills on northwest and east flanks of Great Sitkin Volcano, are included and retain little the original eruptive surface morphology (Qld, Waythomas and others, 2003). Age of unit is Holocene

Ql Lahar and debris avalanche deposits—Fan-shaped deposits of poorly sorted gravel, sand, silt, and boulders in on Great Sitkin and Kanaga Volcanoes, on Great Sitkin and Kanaga Islands, respectively (Waythomas and others, 2003; Miller and others, 2003). Deposits, which are present in most major valleys, range from 1 to 5 m in thickness. Likely formed when pyroclastic flows and lava flows encountered snow or ice on upper flanks of volcanoes (Waythomas and others, 2003; Miller and others, 2003). Locally interbedded with pumice-flow deposits; may be overlain by thin amounts of volcanic ash. Unit also includes, on Kanaga Island, poorly sorted, heterogeneous accumulations of volcanic rock rubble, sand, and gravel, which were interpreted as debris-avalanche deposits by Waythomas and others (2003). On northern Adak Island; unit is found on the slopes of Mount Moffett and Mount Adagdak locally mantled by tephra (Waythomas, 1995). Age of unit is Quaternary

Qvd Vent volcanic rocks and deposits—On Segula Island, consists of dark-gray, glassy or fine-grained, compact or diktytaxitic, porphyritic feldspathic basalt associated with central and rift vents of volcano at Segula Peak (Nelson, 1959). On Adak Island, principally consists of basalt lava flows but also includes subordinate tuff breccia forming composite and parasitic cones of Mount Moffett volcano (Coats, 1956a). On

Great Sitkin Island, includes poorly sorted, oxidized, and scoriaceous ejecta, bombs, and bomb aggregates at summit crater of Great Sitkin Volcano, as well as short, stubby flow of dark-gray basalt erupted from flank vent at head of Sitkin Creek (Waythomas and others, 2003). On Kanaga Island, coarse-grained near-vent ejecta, including volcanic bombs, blocks, and scoriaceous debris, is present on and around rim of modern crater of Kanaga Volcano (Miller and others, 2003). Age of unit is late Pleistocene and Holocene

Qep East Point Formation—Andesite and basalt flows more than 150 m [500 ft] thick exposed at East Point on Little Sitkin Island (Snyder, 1959). Flows tend to be massive but have clinkery, vesicular flow tops. Flows were erupted onto deeply dissected topography, which led Snyder (1959, p. 177) to suggest that the East Point Formation is younger than the Sitkin Point Formation (Qsp). Age of unit is Quaternary

Qsp Sitkin Point Formation and similar rocks—On Little Sitkin Island, consists of water-laid pyroclastic material that includes tuffaceous graywacke, dacite-boulder tuff-breccia, andesitic tuff, and pumiceous tuff (Snyder, 1959); locally, includes areas of kaolinized, silicified, and pyritized rock. On Segula Island, includes unconsolidated, crudely sorted, moderately well bedded volcanic detritus at least 150 m [500 ft] thick (Nelson, 1959); fragments vary from fine-grained sand to blocks as much as a meter [several feet] across, though sizes of 3 mm to 8 cm [one-eighth to 2 or 3 in] are most common. Although unconsolidated, unit forms steep cliffs where eroded at sea coast. Age of unit is Quaternary

QTv Older volcanic rocks, undivided (Quaternary and Tertiary)—On Semisopochnoi Island, includes the Pochnoi Volcanics of Coats (1959b), which consists of tuff-breccia, lava flows, and agglomerate; on Kanaga Island, olivine and hypersthene basalt and andesite flows of ancestral Mount Kanaton volcano on Kanaton Ridge, as well as older agglomerate (Coats, 1956b; Miller and others, 2003); on Attu Island, the Massacre Bay Formation of Gates and others (1971); on Little Sitkin Island, the Williwaw Cove Formation of Snyder (1959); on Adak Island, flows and tuff-breccia of olivine-, hypersthene-, and hornblende-bearing andesite associated with volcano at Andrew Bay (Coats, 1956a); on Great Sitkin Island, flows and agglomerate of the Sand Bay Volcanics of Simons and Mathewson (1955); on Semisopochnoi Island, sandstone from reworked pyroclastic deposits, as well as pyroclastic rocks, lava flows, and crystalline vent plugs (Coats, 1959b); on Tanaga, Kanaga, and Unalga Islands, interbedded flows, pyroclastic deposits, sedimentary rocks, and fine-grained dikes and sills (Fraser and Barnett, 1959); on Shemya Island, andesitic and basaltic tuff and tuff-breccia (Gates and others, 1971); on Bobrof Island, Quaternary or Tertiary basaltic rocks (Coats, 1956c). On Little Sitkin Island, unit locally contains areas of kaolinized, silicified, and pyritized rock (Snyder, 1959). Sample from the Massacre Bay Formation of Gates and others (1971) on Attu Island yielded questionable K-Ar ages of 7.6±0.6 and 8.57±2.0 Ma (no. 1, table 1); age on hornblende-bearing gabbro xenolith associated with volcano at Andrew Bay on Adak Island was 2.46±1.3 Ma (no. 49,table 1; see also Marlow and others, 1973); ages on andesite and dacite on Tanaga Island were 3.0±1.1 and 15.7±3.0 Ma (nos. 30 and 31, table 1; see also, Marvin and Cole, 1978 and T.L. Vallier, written commun., 2004); on Shemya Island, porphyritic, fine-grained, columnar-jointed basalt plugs (Gates and others, 1971), which yielded K-Ar age of 12.62±1.5 Ma (no. 8, table 1; see also, Cameron and Stone, 1970). Locally subdivided into the following:

QTob Olivine basalt flows—Olivine-basalt flows from vent older than caldera of ancestral Mount Kanaton at Kanaton Ridge, near Round Head on northern Kanaga Island (Coats, 1956b; Miller and others, 2003). K-Ar whole-rock age determination yielded 0.0±0.6 age for basaltic andesite (no. 38, table 1; see also, Bingham and Stone, 1972), suggesting that Tertiary age may be unlikely for this unit

QTqk Quartz-keratophyre dikes—Quartz-keratophyre dikes (Gates and others, 1971), found on widely separated parts of Attu Island. Dikes consist of chalky-white euhedral feldspar (albite) crystals and glassy quartz, in a bluish-gray to light-gray groundmass of fine-grained albite, quartz, and minor amounts of sericite, calcite, epidote, chlorite, magnetite, and apatite (Gates and others, 1971, p. 748). Age of unit is late Tertiary or early Quaternary

QTha Hornblende andesite and dacite—On Attu Island, porphyritic dikes and stocks of hornblende andesite and dacite (Gates and others, 1971); hornblende-dacite porphyry that cuts the Chirikof Formation (Tc) yielded 6.1±0.4 Ma whole-rock K-Ar age (no. 5, table 1; see also, DeLong and McDowell, 1975). On Shemya Island, includes hornblende dacite porphyry that yielded K-Ar age of 15.39±3 Ma (no. 9, table 1; see also, Cameron and Stone, 1970). Age of unit is late Tertiary or early Quaternary

Tvu Oldest volcanic rocks, undivided (Tertiary)—Principally basalt and andesite flows but also includes agglomerate, tuff, and tuff breccia. Locally subdivided into the following:

Tlp Lavas and pyroclastic deposits, undifferentiated—On Kavalga, Ogliuga, Ulak, and Skagul Islands, includes basaltic or andesitic lava and pyroclastic deposits, in some places fractured and silicified (Fraser and Barnett, 1959); also includes pillow lava flows on Kavalga, Ogliuga and Skagul Islands (Fraser and Barnett, 1959). Could be subdivided locally into either predominantly lava and flow breccia or tuff and breccia units (Fraser and Barnett, 1959), although undivided herein. K-Ar age determinations on these rocks suggest bimodal age distribution: ages on altered-rock samples from Ulak Island are 33.9±1.1 Ma and 43.4±4.6 Ma (nos. 32, 33 table 1; see also, DeLong and others, 1978, and Marvin and Cole, 1978), whereas andesite samples from Skagul and Kavalga Islands yield ages of 5.2±0.9 Ma and 6.2±0.4 Ma on (nos. 34, 35 table 1; see also, Marvin and Cole, 1978 herein). Age of unit is Miocene or older

Tvb Vega Bay Formation—Marine deposits of volcanic breccia, tuff, and a few pillow-lava flows, all of basaltic composition, as well as a few interbeds of conglomerate and sandstone of similar material; mapped on Kiska Island (Coats and others, 1961). Samples from flows, dike, and basalt boulder with the Vega Bay Formation yield ages that range from 14.7 to 55.3 Ma (nos. 10 to 13, table 1; see also, DeLong and others, 1978, and Marvin and Cole, 1978): oldest age is inconsistent with presumed stratigraphic position of the Vega Bay Formation and therefore is viewed as incorrect; next oldest age of 29.2±4.4 Ma is on olivine-basalt boulder within sedimentary rocks of unit clearly indicates protolith age; age of 17.8±1.1 Ma determined on dike cutting unit, presumably suggests minimum age for unit; and flow in unit yielded 14.7±1.2 Ma age. These equivocal results raise some doubt as to age of unit

Tvo Finger Bay Volcanics and similar rocks—Includes, on Adak and Kagalaska Islands and most of Andreanof Islands east of Adak Island, the Finger Bay Volcanics (Coats, 1956a, c; Fraser and Snyder, 1959); on Amchitka Island, the Amchitka Formation of Powers and others (1960; see also, Carr and others, 1970); on Rat Island, the Rat Formation of Lewis and others (1960). Also includes similar rocks on southeastern Great Sitkin Island (Simons and Mathewson, 1955; Waythomas and others, 2003). Consists of basalt flows, hornblende-basalt tuff, flow breccia, agglomerate, basalt dikes, and subordinate rhyolite tuff and quartz porphyry dikes; intruded by large masses of gabbro (unit Td), small dikes and sills (Tid), and small masses of rhyolite, not mapped separately herein (Coats, 1956a). The Finger Bay Volcanics were mapped as Paleozoic by Coats (1956a) but have been revised to Eocene (Scholl and others, 1970): original age designation was based on recovery of plant fossils identified as *Annularia stellata* of Pennsylvanian or Permian age (Coats, 1956a); later sample collections and reanalysis of the original collection resulted in reassignment of unit age to late Eocene and separation of the fossil-bearing rocks from the Finger Bay Volcanics and their assignment to the newly defined the Andrew Lake Formation (unit Tal) of Scholl and others (1970). The Finger Bay Volcanics were restricted to underlying eruptive rocks and similar lithologies on Adak and Kagalaska Islands (Scholl and others, 1970). The Rat Formation of Lewis and others (1960) consists of flows and flow breccias of porphyritic andesite, and minor amounts of conglomerate composed of andesitic debris. The Amchitka Formation of Powers and others (1960; see also, Carr and others, 1970), which consists of volcanic agglomerate, tuff-breccia, tuff, and pillow-lava flows of andesitic to latitic composition, was areally restricted and divided into two informal members by Carr and others (1970): lower member consists of fine- to coarse-grained sedimentary breccia and minor amounts of interbedded sandstone, siltstone, and claystone, all composed of volcanic debris; upper member, or Kirilof Point unit of Carr and others (1970), is “generally monolithologic breccia and tuff breccia, subordinate pillow lava flows, and very minor bedded volcanic sedimentary rocks” (Carr and others, 1970, p. A17). Upper member ranges in thickness from 425 to 1,110 m [1,400 to 3,650 ft] thick in drill holes and has maximum thickness of 1,220 m [4,000 ft]. Age control on the Amchitka Formation of Powers and others (1960) is limited to a single fossil collection that is very similar to that of the Banjo Point Formation (Tbp) (Carr and others, 1970), which is designated as late Eocene or Oligocene; however, Carr and others (1970) designated the Amchitka Formation as early Tertiary because base of unit is not exposed. Therefore, best age assignment for this composite unit is Oligocene or older, on the basis of its on fossil similarities with the Banjo Point Formation and its lithologic, and so its apparent stratigraphic, correlation from island to island

## INTRUSIVE ROCKS

Tid Dikes and hypabyssal intrusive rocks (Tertiary)—Dikes and small intrusive bodies, largely of basalt and andesite. On Adak and Kagalaska Islands, includes altered basalt in small dikes and sills (Coats, 1956a; Fraser and Snyder, 1959) that intrude the Finger Bay Volcanics (Tvo); according to Fraser and Snyder (1959), these dikes in probably vary from basalt to rhyodacite, although thin-section studies showed no basalt in these dikes, which, instead, ranged in composition from pyroxene andesite to rhyodacite. On Kanaga Island, includes basalt dome older than caldera of ancestral Mount Kanaton volcano at Kanaton Ridge (Coats, 1956b). On Kavalga, Ogliuga, and Skagul Islands, consists of columnar-jointed, porphyritic-andesite sills, as well as andesite and basalt dikes (Fraser and Barnett, 1959). On Kiska Island, includes rocks associated with the Kiska Harbor and the Vega Bay Formations (QTkh and Tvo, respectively) (Coats and others, 1961). On eastern one-third of Agattu Island, includes dacite porphyry that cuts both the undifferentiated basement rocks unit (TMzv) and the Krugloi Formation (Tk); also includes several diabase and gabbro bodies that contain striking phenocrysts, some as much as 2.5 cm [an inch] long, of quartz, plagioclase, biotite, and hornblende, all in light-gray fine-grained matrix (Gates and others, 1971). Available K-Ar ages on this unit suggest a late Tertiary age: oldest age, on dacite dike on eastern Agattu Island, was 15.6±0.8 Ma on hornblende (no. 7, table 1; see also, Scholl and others, 1976); on Kiska Island, two dates on dikes of 4.4±0.1 and 3.7±0.1 Ma both of which are suspect owing to alteration (nos. 15, 16, table 1; see also, Panuska, 1981), are considered minimum ages and also are not consistent with cross-cutting relations with other units; finally, andesite dome intruding the Andrew Lake Formation (Tal) yielded an age of 5.03±1.8 Ma (no. 50, table 1; see also, Marlow and others, 1973). Unit contains many exposures of that are too small to show at map scale

Td Diabase and gabbro (Tertiary)—Diabase and gabbro dikes, sills and small plutons. Widespread unit forms two-thirds of intrusive rocks on Attu Island and is very common on Agattu Island (Gates and others, 1971). On Kiska Island, two large gabbroic intrusions are found (Coats and others, 1961), and on Adak Island, large mass of gabbro, which locally includes hornblende gabbro and augite-quartz syenite, intrudes the Finger Bay Volcanics (Tvo) (Coats, 1956a). Dikes and sills intrude all units on Attu Island as old as the Chuniksak and the Chirikof Formations (Tch and Tc, respectively) but not the Massacre Bay Formation of Gates and others (1971), included in the undivided older volcanic rocks unit (QTv) herein, nor the Faneto Formation (QTf): hence, they are considered to be Miocene in age, although some rocks may be older (Gates and others, 1971, p. 746). On Attu Island, K-Ar whole-rock ages on diabase and gabbro that intrudthe volcanic rocks suunit (TMzbv) of the undifferentiated basement rocks unit were 27.2±1.4 and 32.7±1.4 Ma (nos. 2, 4, table 1; see also, DeLong and McDowell, 1978). Placed in the Attu Basement Series by Yogodzinski and others (1993)

Tqgd Younger quartz diorite and granodiorite (Miocene)—On Adak and Kagalaska Islands, Younger granodiorite, quartz diorite, and gabbro in stocks, sills, and dikes (Fraser and Snyder, 1959); on Amchitka Island, quartz diorite (Powers and others, 1960); on Ilak Island, andesite dikes (Fraser and Barnett, 1959) as well as granite(?) or granodiorite on Ilak and Amatignak Islands (Coats, 1956c; Fraser and Barnett, 1959). On Amchitka Island, medium-grained quartz diorite intrudes the Amchitka Formation of Powers and others (1960), included in the Finger Bay Volcanics and similar rocks unit (Tvo) herein, as well as the Banjo Point Formation (Tbp). On Adak and Kagalaska Islands, K-Ar age determinations range between 12.71±0.53 and 14.26±0.16 Ma (nos. 53, 54, 55 table 1; see also, Marlow and others, 1973; Citron and others, 1980); on Amchitka Island, Carr and others (1970) reported K-Ar age on biotite of 16.2±0.7 Ma (no. 27, table 1). On Ilak Island, granite(?) or granodiorite, yielded a late Miocene age (no. 29, table 1; from T.L. Vallier, written commun., 2004)

Tagr  Albite granite (Tertiary)—Albite granite; mapped on Attu Island, in irregular masses at Steller Cove and as a small stock east of Mikhail Point (Gates and others, 1971). Granite is gray, pale pink, or purplish, has widely varying grain size, and locally contains euhedral gray-green feldspar (albite) phenocrysts as much as 5 mm long; described sample (Gates and others, 1971, p. 747) contains about 20 percent quartz and euhedral to ragged amphibole crystals. Locally, granite may have as much as 5 percent green amphibole. Albite granite is surrounded by halo as much as 3 km [2 miles] wide of albitized and silicified rocks of the undifferentiated basement rocks unit and its coarse-grained sedimentary rocks subunit (TMzu and TMzc, respectively). Age control is limited; albite-granite blocks are present in keratophyric tuff in basement rocks, although main intrusions cut basement rocks. On Attu Island, diabase dikes cut granite, and boulders of granite are present in the Chirikof Formation (Tc) suggesting that the granite may be largely pre-Miocene. Placed in the Attu Basement Series by Yogodzinski and others (1993)

Tgd  Older granodiorite, quartz diorite, and gabbro (Tertiary)—Older granodiorite, quartz diorite, and gabbro; mapped on Adak Island, in plutons, stocks, sills, and dikes. Originally mapped in a single unit by Fraser and Snyder (1959) that included rocks assigned to the younger quartz diorite and granodiorite unit (Tqgd) herein. However, K-Ar dating has shown that Fraser and Snyder's (1959) unit included plutons are of 2 separate ages (Marlow and others, 1973; Citron and others, 1980). Therefore, only older of intrusive rocks are included in unit; younger rocks are in the younger quartz diorite and granodiorite unit (Tqgd). K-Ar dates range from 31.8 to 35.85 Ma (nos. 44, to 47 table 1; see also, Citron and others, 1980)