isolated, and breached cinder cone northwest of Table Top Mountain. The lava and cone are composed of a brown to black, slightly porphyritic basaltic-andesite containing 13 vol.% plagioclase, 2 vol.% clinopyroxene, and minor olivine and magnetite in a groundmass of WIDE BAY CONE DEPOSITS (Holocene)—Basaltic tephra and lava flows form the monogenetic Wide Bay Cone near Eider Point, the easternmost volcano of the Makushin icanic field. Both tephra and lava flows are dominated by up to 20 vol.% of large, single phenocrysts and glomerocrysts of clinopyroxene. The clinopyroxene is zoned and may reach 4 mm in diameter. Additional important phenocryst phases include plagioclase (15 to 19 vol.%),

olivine (1 to 5 vol.%), and minor magnetite in a microlite-rich, sideromelane groundmass Lowermost flows at the base of the cone are glacially striated although the cone remains well SUGARLOAF CONE (Holocene)—A monogenetic cinder cone, subsequently partially buried Lava Ramp flows, located at the head of Driftwood Valley. The Sugarloaf tephra consists of sicular, porphyritic basaltic-andesites, some highly oxidized. Phenocryst contents vary slightly; tephra may consist of 24 to 30 vol.% plagioclase, 5 to 10 vol.% clinopyroxene and minor orthopyroxene and olivine in a black, microlite-rich glassy groundmass. Inclusions of hypohyaline brown glass with plagioclase and orthopyroxene phenocrysts and crystal clots of intergrown plagioclase and clinopyroxene occur in the tephra (Roach, 1997). Although differences in major- and trace-element geochemistry indicate that Sugarloaf and Lava Ramp are not co-magmatic as suggested by Drewes and others (1961), it is possible that the Sugarloan

and sides of the cone are covered by a series of later surge and tephra deposits. "Ar/" Ar age PAKUSHIN CONE DEPOSITS—The largest of the satellite vents and is composed of distinctive porphyritic basalt to basaltic-andesite volcanic rocks. The deposit consists of an apron of basaltic pyroclastic flows overlain by a plateau of lava flows. The edifice of Pakushin Volcano is constructed of agglutinates and cinders and contains a single, nested cinder cone. Pakushin Cone displays cirque-like erosion on the south side and flows have been glacially scoured. Ar/ Ar age determinations place eruption time at approximately 22±5 ka (table 2)

vol.% plagioclase in 1-mm-diameter radiating clusters, 3 to 5 vol.% pyroxene and 1 to 2 vol.% each olivine, magnetite, and orthopyroxene phenocrysts in a microlite-rich glassy matrix.

Vesicles are sparse and often display a dictytaxitic texture (Roach, 1997) LAVA FLOWS OF PAKUSHIN CONE — The lava flows consist of 30 to 40 vol.% plagioclase in 1-mm-diameter radiating clusters, 3 to 5 vol.% pyroxene and 1 to 2 vol.% each olivine,

MgO composition enough to shift their composition from tholeiltic to calc-alkaline, unusual for

nagnetite, and orthopyroxene phenocrysts in a microlite-rich glassy matrix. Vesicles are sparse and often display a dictytaxitic texture (Roach, 1997) PYROCLASTIC FLOWS OF PAKUSHIN CONE—The basal basalt pyroclastic flows and Opf tephras contain 7 to 20 vol.% Ca- and Mg-rich augite and chromite-bearing olivine crystal

TABLE TOP MOUNTAIN CONE AND FLOWS (Pleistocene)—An Ar/Ar age of 68±14 ka places this unit as the oldest satellite vent. Basaltic lavas and tephra form Table Top Mountain ortheast of Makushin Volcano and a small, glaciated ramp of lava north and west of the cone. beginning with crystals less than 1 mm long in the lowest flow to greater than 2 mm in the upper flows. The lowermost flow contains up to 5 vol.% highly-altered olivine phenocrysts in a lava

Makushin Lavas

ORB-BEARING BOMBS (Holocene)—Proximal deposit of vesicular andesite bombs, many of which contain distinctive orbicular enclaves of radiating plagioclase (Anes) and bands of ntergrown olivine (Fon) crystals. Although orbs were found on the north and east flanks of Makushin Volcano, the unit is mapped only where orbs were found still contained within the andesite bombs. The roughly spherical orbs range from 1 to 10 cm in diameter and are

This map covers most of the north end of Unalaska Island, which is the extent of

the Quaternary Makushin volcanic field (MVF). The map expands upon previous

DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

KORIGA POINT FLOW (Holocene)—Vesicular, slightly phyric trachyandesite that emanates from beneath modern Koriga Point glacier and flows north. Interfingered with debris avalanches and lahars near terminus of flow. Matrix is comprised of black glass containing trachytic to felty microlites of plagioclase and magnetite. Phenocrysts include 3 to 4 vol.% plagioclase, and trace amounts of clinopyroxene, orthopyroxene, and magnetite with ilmenite lamellae, all of which generally display subparallel orientation with elongate vesicles. Crystal clots of plagioclase, clinopyroxene, and magnetite are found throughout the flow. Although obscured by the present-day glacier, the source of the lava appears to be either on the north flan of Makushin Volcano along the trend of the Point Kadin fissure, or from the modern summ

LAVA VALLEY FLOW (Holocene)—Well-exposed, unglaciated lava flow that partially fills the floor of Lava Valley, north of Pakushin Cone. It appears from beneath a glacier at the head of the valley at an elevation of 610 m and terminates mid-valley. The source vent location is unknown. This porphyritic trachytic lava is the most siliceous of all Makushin flows measured (figure 1). Plagioclase phenocrysts and crystal shards are the dominant crystal phase (20 to 25 vol.%), with <10 vol.% pyroxene, and magnetite in a glassy, microlitic matrix. Crystal clot cumulates of sieve texture plagioclase, clinopyroxenes, and magnetite crystals are common

Gmbp BISHOP POINT FLOW (Holocene)—Porphyritic, slightly vesicular basaltic-andesite lava and agglutinate flows draping over upper Bishop Point Valley. Phenocrysts of plagioclase (19 to 21 vol.%) and augite (5 vol.%) (Roach, 1997) dominate. Other crystal phases include orthopyroxene with clinopyroxene overgrowths, minor small, rounded olivine crystals, and < clinopyroxene, and magnetite cumulates. The matrix is microcrystalline plagioclase and magnetite crystals. Elongated, flattened pumices occur parallel to orientation of phenocrysts. Source vent is most likely within modern Makushin Volcano summit caldera

AGGLUTINATE DEPOSIT (Holocene)—Basaltic to andesitic bomb deposits that form the carapace and caldera rim of Makushin Volcano (Roach, 1997) to the north above Qmaa and to the south above Qmsg. The deposit can be traced from the summit down the east flank to the terminus of the Makushin Valley glacier where it is intercalated with pyroclastic deposits.

Qiri LAVA RAMP FLOWS (Holocene)—Approximately 5 km³ (Nye and others, 1986) of massive andesite lava flows which fill the glacially carved Driftwood Valley. The upper reaches of the Lava Ramp flows are obscured by a glacier, but it is believed that the flows were erupted from a flank vent on the eastern side of Makushin volcano (Nye and others, 1984). The andesites are porphyritic containing 30 vol.% plagioclase, 5 vol.% clinopyroxene, 2 vol.% reversely zoned orthopyroxene and minor amounts of normally zoned olivine and opaques in a brown, microlitic groundmass. Flows exposed in upper Makushin Valley exhibit contorted columnar jointin suggestive of contact with glacial ice. At least some fraction of Makushin Valley was sti choked with ice at the time of eruption, blocking the flow from inundating that valley. The surface of the Lava Ramp flow has been modified by glacial scouring. *Ar/*Ar age

Comiv1

LAVA VALLEY FLOW (Holocene)—Remnants of a vesicular, porphyritic gray basalt lava flow overlain by Qmlv2 at head of Lava Valley. This lava contains approximately 5 vol.% plagioclase and olivine and up to 10 vol.% clinoenstatite and pigeonite (Roach, 1997)

OLDER LAVAS (Pleistocene)—Volcanic deposits from older volcanic centers and present-da Makushin Volcano that form the underlying Quaternary volcanic base of the northern part of Unalaska Island. Deposits consist of inhomogeneous basaltic to andesitic lavas and interdigitated pyroclastic deposits common to stratovolcanoes. The oldest Makushin Volcano deposits are those east of Driftwood Valley with K-Ar ages of less than 1 Ma. A single age from a volcanic deposit west of Driftwood Valley yielded a "Ar/" Ar isochron age of 2.49±0.08 Ma (table 2, M42). Deposits to the south and west of the present-day Makushin Volcano range from ~780 ka east of Glacier Valley to ~330 ka around Cape Kovrizhka according to K-Ar dates of Nye and others (1986). The deposits on the northern flanks of Makushin Volcano are the youngest. Flows that form Koriga Point are 45±11 ka as determined by ⁴⁰Ar/⁶⁷Ar geochronology (table 2, 96Mv60)

A'A FLOW (Pleistocene)—Plagioclase-dominant (up to 27 vol.%), two-pyroxene andesitic a'a flow. The end of the flow extends from above Bishop Point Valley to above Koriga Point. Rubbly surface characteristic of a'a flows is still evident at lower elevations. This flow is overlain by the younger Qmbp flows above Bishop Point Valley and Qag above Koriga Point The matrix is microcrystalline plagioclase and magnetite and the mineralogy also includes minor (<1 vol.%) olivine. Clinopyroxene overgrowths of orthopyroxene are common as are crystal clots of plagioclase and clinopyroxene. *Ar/*Ar age determinations place its deposition

and volcanic breccias. The deposits commonly contain pillow basalt, chaotic columnar jointing, and palagonitized matrix glass. These flows comprise most of the older volcanic deposits on the south flank of Makushin Volcano above Glacier Valley

Pyroclastics and Tephras

YOUNGER PYROCLASTIC DEBRIS—Pyroclastic deposits that form flat-topped terraces in valley bottoms and locally bury older lava flows, debris avalanches and older deposits. These

LAHARS-Volcanic-rich debris flows, alluvium, and non-cohesive lahars that form flattopped terraces in valleys. Some lahars contain prismatic blocks and were produced during

DEBRIS AVALANCHE—Hummocky, irregular assemblages of poorly sorted, cohesive volcanic rock and sediment, deposited by collapse of the Makushin Volcano summit edifice. nese deposits are locally more than 50 m thick. Two debris avalanche deposits on the north flank of Makushin Volcano are intercalated with pyroclastic surge deposits recording explosive eruptive blasts at the time of the debris avalanche OLDER PYROCLASTIC DEBRIS-Valley-filling pyroclastic deposits that form thick, flat-

INTRUSIVE ROCKS AND UNALASKA FORMATION DIKES AND SILLS (Quaternary to Tertiary)—Basaltic, andesitic, and dacitic dikes and sills that intrude the Unalaska Formation, gabbronorite, and rocks of the Makushin volcanic field.

topped fills in valley bottoms. A 10- to 20-m-thick sintered ignimbrite sometimes forms a

prominent cliff within the valley fill. These deposits are locally interbedded with lahars, debris

nese hypabyssal equivalents of lavas are shown only where strikes could be accurately GABBRONORITE STOCK (Pleistocene)—Gabbronorite comprises a medium-grained porphyritic, unzoned stock exposed in several outcrops south and east of Makushin Volcano. rimary mineralogy is plagioclase (50 to 70 modal percent, An, to An,), subequal amounts of

clinopyroxene and orthopyroxene, and accessory magnetite and apatite. Intergranular quartz may comprise up to a few percent of the mode, and alkali feldspar is absent. Orthopyroxene is commonly, and clinopyroxene less commonly, altered to a light-green fibrous chlorite and/or actinolite mat or to anthophyllite and/or cummingtonite. Euhedral, reddish brown biotite of either deuteric or post-magmatic hydrothermal origin occurs in a few restricted localities. Present-day hydrothermal activity has argillized much of the stock in the Glacier Valley area. K-Ar age determinations from deuteric homblende and homfels (Tuh) yield ages of 1.05±.06 Ma and 0.43±.04 Ma, respectively (Queen, 1989). Based on the alteration mineralogy, these dates can be considered minimum ages associated with primary alteration due to cooling of the

UNDIFFERENTIATED UNALASKA FORMATION (Tertiary)—The member of the Unalaska Formation comprised of at least 75 percent pyroclastic material in the area mapp Nye and others (1984) and this map. It contains lithic to vitric ash and lapilli, air-fall and ashflow tuffs, debris flows, and volcanic breccias, with very minor amounts of well-sorted, crystaland volumetrically minor flows are also present. The member is primarily fine-grained volcaniclastic sedimentary rocks east of Captain's Bay in the area mapped by Drewes and others

UNALASKA FORMATION HORNFELS (Tertiary)—Unalaska Formation metamorphos the albite-epidote, hornblende, and pyroxene hornfels facies adjacent to the gabbronorite intrusion. The hornfels is very dark green to black and aphanitic to fine grained. In hand specimen, only small plagioclase laths can be distinguished, but relict textures, even of some

UNALASKA FORMATION LAVA FLOWS (Tertiary)—Unalaska Formation dominated by Tuf lava flows containing less than 10 percent interbedded volcaniclastic rocks. The flow-rich portion lies stratigraphically below the volcaniclastic portion. The lavas have characteristic flow features such as ramp structures, minor columnar jointing, interflow breccias, and oxidation horizons. These structures are overprinted by tectonic jointing. The lavas are altered, with green, chloritic groundmasses and hematitically-stained plagioclase. These flows, before alteration, were mineralogically and texturally similar to unit Qom

volcano (Nye and others, 1984). Deposits of high-elevation older Makushin lavas in the eastern part of the map may have been erupted from ancestral cones in that area.

One fossil vent was recognized between Table Top Mountain and Wide Bay Cone.

diameter found in bombs of vesicular andesite near the head of Makushin Valley

These enclaves most likely result from entrainment of crystal cumulates during

magma mixing. We suggest that there is an evolving, shallow chamber beneat

Makushin Volcano that is periodically reinjected from one or more deeper, more mafic

chambers resulting in magma mixing, entrainment of xenocrysts and cumulates

active hydrothermal system containing several fumaroles, hot springs, and seeps lying

in a northeast-to-southwest trend from Sugarloaf Mountain to mid Glacier Valley

Numerous fumaroles and depressions, and a green, sulfurous lake filling a small

fumarole-lined crater are present at the summit. Very recent phreatic and

phreatomagmatic deposits of bombs, lapilli, and ash were identified at the summit and

along the south flank of the volcano and mapped as vent tephra (Qvt).

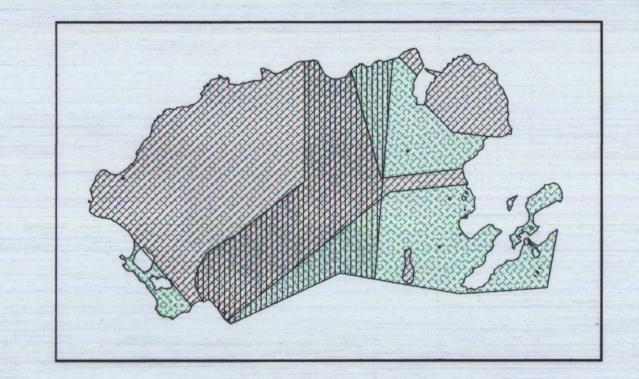
GRANODIORITE INTRUSIVE ROCKS (Tertiary)—Granodiorite of the Captain's Bay pluton (Drewes and others, 1961) appears in the southeastern corner of map. K-Ar age determinations indicate the pluton was emplaced in the middle Miocene (~13m.y.) **Tertiary rock unit descriptions taken from Nye and others (1984)

REPORT OF INVESTIGATIONS 97-20 McConnell and others, sheet 1 of 2

EXPLANATION OF MAP SYMBOLS Contact-Solid where known; dashed where inferred; dotted Normal fault—Solid where known; dashed where inferred; dotted where concealed; queried where uncertain; U on the upthrown block, and D on the relatively downthrown block Dikes or sills (QTi) Quaternary volcanic vent Fossil volcanic center Hot spring, or seep location Fumarole location, number indicates that the site was field checked for this map. Unnumbered locations from Nye, et al., Location of seismic stations installed by the Alaska Volcand Observatory during the 1996 Aleutian Expansion Project Aerial photo centers and reference numbers; inherent to USGS Strike and dip of beds

CORRELATION OF MAP UNITS

COMPILATION INDEX



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SOURCES FOR GEOLOGIC MAP

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DISCUSSION

7 km south-southwest of Makushin Volcano. The basal pyroclastic unit (Qpp) is high in MgO, Ni, Cr, and modal clinopyroxene, and anomalously low in Al₂O₃ (table 1). Crystal chemistry and evidence of mineral-melt disequilibrium suggest the olivine and clinopyroxene population are xenocrystic (Nye and others, 1986; Roach, 1997). Pakushin lavas (Qpf) contain distinct radiating bundles of plagioclase glomerocrysts (An_{36.78}), co-crystallizing with clinopyroxene, orthopyroxene, olivine, and magnetite in a groundmass of black glass, magnetite, and plagioclase (An_{50.54}) microlites (Roach,

The eastern section of the Makushin volcanic field (MVF) is dominated by two cones, Table Top Mountain (Qtt) and Wide Bay Cone (Qwbc), of similar basaltic composition (\sim 50 wt.% SiO₂). They are distinct in hand specimen from other MVF lavas, containing large phenocrysts and glomerocrysts of clinopyroxene with subordinate plagioclase and olivine. The volume of olivine crystals decrease upsection as the volume and size of plagioclase crystals increase (Roach, 1997). Mineral-mineral equilibrium between the olivine and the clinopyroxene and disequilibrium between minerals and liquid suggest the glomerocrysts are xenocrysts (Nye and others, 1986). A small, breached cinder cone sits at the eastern head of Wislow Cape. Its lava (Qwc) is more evolved than lavas at Table Top Mountain (Qtt) and Wide Bay Cone (Owbc) with ~53 wt.% SiO, and less than 15 vol.% total crystal

Northwest of the summit of Makushin Volcano are a series of cinder and spatter cones and lava flows, ejecta blankets, and maars. Lava compositions range from basaltic Half Moon lavas (Ohm) to andesitic Point kadin vent deposits (Opky) and trachvandesitic Baby Moon lavas (Qbm). The Half Moon lavas are stratigraphically older than the other deposits. The Point kadin vent deposits and Half Moon lavas are slightly phyric andesites with a whole-rock SiO, content of 61 to 64 wt.% and a groundmass glass of 65 wt.% SiO2, making them some of the most evolved lavas measured from the Makushin volcanic field. Complex overlapping relationships between these units and nested vents of contrasting composition indicate reactivation of the fissure over time. There is no evidence of any glacial erosion of vents or deposits ndicating that all eruptions are Holocene. Peat collected from between two tephra layers deposited in a small water-filled maar yields an upper limiting age of ~220 calendar years B.P. (table 3) for activity from the fissure. These are thought to be some of the youngest volcanic deposits from this volcanic center.

Xenocrystic material and crystal cumulates occur in volcanic deposits from all the vents comprising from 11 to 41 vol.% for the flank vents and 0 to 28 vol.% for the Makushin lavas (Roach, 1997). Glomerocrysts of clinopyroxene with or without olivine or plagioclase occur in all satellite vents while in Makushin volcanic deposits the cumulate assemblages are more varied in composition and abundance (Roach, 1997). Although the glomerocrysts are found in northwest fissure flank vent deposits. they are smaller and rarer. These admixed crystal phases have strong control on the whole rock composition (Roach, 1997). The presence of lavas such as the plagioclasespherulitic lava of Pakushin cone (Qpf) or the plagioclase-olivine orbicular cumulates n andesite bombs (Omob) are indicators that entrainment of cumulates into erupting lavas has occurred across the Makushin volcanic field since the close of the

A summary of the chronology of volcanic activity of the Makushin volcanic Eruptions of chemically diverse basaltic to andesitic lavas and pyroclastics from

an ancestral Makushin Volcano near the modern vent began approximately 1 Ma. At least two other volcanic centers were active at the northern bulge of Unalaska Island during part of the Pleistocene, one near Round Top and one between Table Top Mountain and Wide Bay Cone.

Chemically diverse basaltic to andesitic explosive eruptions from Makushin Volcano occurred numerous times during the Holocene and continue to the present. A major pyroclastic eruption between 8800 and 7900 radiogenic years 3.P. may have formed the present-day summit caldera. The most recent Makushin Volcano lavas are the most evolved and are very

chemically similar to lavas produced by the Point kadin fissure eruptions. Most avas have been deposited on the north and west sides of the volcano. In the last 4000 years at least 26 explosive eruptions produced airfall tephras and other deposits that have covered much of the northern bulge of Unalaska Island airfall tephras, all of Holocene age, record multiple episodes of subplinian and

The most recent deposits are bombs, lapilli, and ash deposits at the summit and along the southern flanks of Makushin Volcano. These may have been produced during a small eruption reported in 1993-94 (Neal and others, 1995). The magmatic component of this and other very recent deposits from Makushin Volcano are again in the andesite range (~58 wt.% SiO₂) and may be the result of more mafic magma mixing with evolved resident magma beneath Makushin

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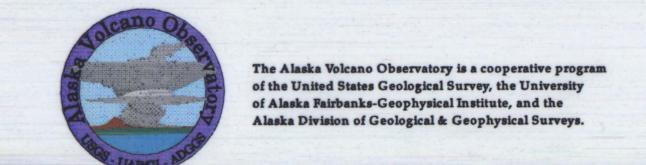
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GEOLOGIC MAP OF THE MAKUSHIN VOLCANIC FIELD, UNALASKA ISLAND, ALASKA

Location of Map Area

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Base modified from U.S. Geological Survey Unalaska C-2 (1990)

C-3 (1989), C-4 (1989), and portions of D-2 (1989) and D-3 (1989)

1:63,360 Quadrangles, Alaska. Universal Transverse Mercator

Projection, 1927, North American Datum. Scanned and rectified

UPPROXIMATE MEAN DECLINATION, 1989

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Geology by: V.S. McConnell, J.E. Begét, K.W. Bean, C.J. Nye,

and A.L. Roach. Digital cartography and layout by L.K. Queen

with cartographic input from A.G. Sturmann and A.L. Schell.

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the Ounalaska Corporation of Unalaska Island for permission

6,000

to traverse their territory during our field work. We also

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and D.H. Richter.

geologic mapping, in particular the early regional mapping of Unalaska Island by the U.S. Geological Survey (Drewes and others, 1961) and the detailed mapping of Several subglacial Pleistocene volcanic deposits (Qmsg) form the top of the scarp along the southern flank of modern Makushin Volcano. Flows of older Makushin lavas geothermal areas conducted by the Alaska Division of Geological & Geophysical curveys (Nye and others, 1984) (see Compilation Index). This study emphasizes the on the north side of the island form a ragged coastline along Koriga Point and prominent outcrops at Bishop Point. The age of the Koriga Point lavas are 45 ± 11 ka Holocene-Pleistocene eruptive history of Makushin Volcano and its satellite vents. tratigraphic nomenclature of Drewes and others (1961) for the Tertiary Unalaska (table 2). A similar age (40 ± 6 ka) was determined for a poorly exposed a'a lava flow (Qmaa) stretching from upper Bishop Point Valley to near Koriga Point. Formation is retained but unit and member descriptions are largely by Nye and others Holocene lava flows from Makushin Volcano partially fill Pleistocene glacial (1984). We have used many informal names to help describe and locate the volcanic ed on the map as Lava valley flows (Omivi and Omivi), an Bishop Point flow (Ombp). These units have a wide range in composition from basals Unalaska Island forms an elongated land mass roughly parallel to the Aleutian to trachyte (figure 1). Note the wide variation in composition from adjacent flows suc Arc trend. Bedrock consists of altered andesitic intrusive and extrusive rocks, and as the older Lava Valley flow (Qmlv1) and the younger Lava Valley flow (Qmlv2) (figures 1 and 2). The Makushin orb-bearing bombs (Omob) consist of orbicular enclaves of interlocking plagioclase (Anos) and olivine (Fon) crystals up to 10 cm in

volcaniclastic sedimentary rocks (Drewes and others, 1961) of the Unalaska Formation (map units Tuf, Tuh, and Tu). Vertebrate fossils found near the town of Unalaska have been identified as desmostylid, a distant relative of the modern sea cow. which places the formation as old as late Oligocene to early Miocene (Drewes and others, 1961; R. Gangloff, pers, comm., 1997). Plant fossils in the upper Nateekin Valley of a species of mat-forming willows (Salix) unique to subarctic regions suggest that the Unalaska Formation may be as young as latest Miocene or Pliocene (Nye and others, 1984). No lithologic difference is evident between the older and younger parts of the Unalaska Formation, however unconformities are noted in the formation (Nye convective overturn, vesiculation, and eruption. Makushin Volcano also hosts an and others, 1984). Often the only evidence of an uncomformity is the occurrence of boulder lag deposits that contain lithic fragments of a Pliocene-aged gabbronorite stock (Qgn) (Nye and others, 1986). Of the several granodioritic batholiths (Tg) napped by Drewes and others (1961) on the island, only Captain's Bay pluton appears within the area covered by this map. The age of the pluton is thought to be middle Miocene according to K-Ar age determinations (Langford and Hill, 1979). Other intrusive outcrops designated as Qgn nearer the Makushin volcanic field are part of a gabbronorite stock (Nye and others, 1984) which, in several areas, is highly altered by present-day hydrothermal activity. K-Ar ages determined from deuteric amphibole and biotite in veins in the gabbronorite, as well as from amphibole from contact hornfels suggest that the gabbronorite maybe much younger than the Captain's Bay pluton—perhaps as young as a few Ma (Queen, 1989). A hypabyssal texture to the gabbronorite indicates a more shallow emplacement depth than the older plutons (Nye and others, 1986) and may suggest it is related to the Quaternary volcanic activity. Numerous dikes and sills of basaltic, andesitic, and dacitic composition (Qti) intrude

oth the Unalaska Formation and the Quaternary volcanic rocks. Nye and others (1986) noted an unconformity exists between Tertiary volcanic activity recorded in the Unalaska Formation and the Quaternary volcanic activity restricted to the north end of the island. In the field, Makushin lavas can be differentiated from older volcanic deposits by their lack of tectonically-induced jointing. Although most radiogenic age determinations are less than 1 Ma for lavas associated with the Makushin volcanic field (Nye and others, 1984; this study), a single sample of basaltic lava from western Driftwood Valley yielded a 40 Ar/ 89 Ar age of 2.49 \pm 0.08 Ma (table 2). It is possible initiation of volcanic activity associated with the Makushin volcanic field began as early as the Pliocene. The volcanic field is dominated by the 2,036-m-high glaciated Makushin Volcano stratovolcano, but also contains a series of satellite vents trending northeast to southwest, south and east of Makushin Volcano; a northwest-trending flank fissure on the north side of Makushin delineated by a series of cinder cones, ejecta blankets, and maars; and several fossil vents scattered across the northern part of Unalaska Island. Thick deposits of basalt and andesite flows, debris avalanches, lahars, and pyroclastic flows at Makushin Volcano were produced by sporadic, relatively small volume eruptions characteristic of polygenetic stratovolcanoes (Nye and others, 1984). The bulk of the older Makushin lavas (Qom) were most likely erupted from the summit area of stratovolcanoes where necks of fossil vents form resistant spires along the northwest and west edges of the summit caldera. West and southwest of Makushin Volcano, large erosional remnants of older Makushin deposits form a broad shield of ribbon lavas of

approximately 540 ka indicating a major ancestral cone was located near the modern

Postglacial volcaniclastic rocks and deposits partially fill all of the deeply eroded Pleistocene glacial valleys which originate on Makushin Volcano. These deposits consist of pyroclastic flows and surges, debris avalanches, cohesive and noncohesive lahars, and airfall tephra. The oldest postglacial deposits are debris avalanches, recording edifice collapse affecting both the north and east flanks of the volcano. Subsequent pyroclastic flows, surges, and airfall tephra are associated with the formation of the 2.5 km diameter summit caldera (figure 3). Radiocarbon dating of interbedded peat layers indicate the summit caldera formed between 8800 and 7900 radiocarbon years B.P. (table 3). At least 26 subsequent smaller, explosive eruptions have occurred since, most within the last 4000 years (table 3). A lateral blast deposit is intercalated with debris avalanche deposits at Koriga Point, 10 km north of the

The satellite vents produced high-volume, individually homogeneous deposits characteristic of monogenitic eruptions. Individual vents and flows are differentiated by location, petrology, and stratigraphy and occur along a zone parallel to the Aleutian Are trend. None show evidence of activity into historic times and similar erosional features suggest they were all active after the Pleistocene glaciation receded. Samples from all the satellite eruptive centers were analyzed for 40 Ar/89 Ar ages. Only the dates from Table Top Mountain and Pakushin Cone are statistically different from zero with

ages of 68 ± 14 ka and 22 ± 5 ka, respectively (table 2).

The vent for the Lava Ramp flows (Qlrf) is almost certainly located somewhere on the upper Makushin Volcano flank, possibly from the summit area. Approximately 8 to 10 km³ (Nye and others, 1984) of these plagioclase-rich andesite flows traveled eastward down valley before turning north to fill Driftwood Valley. The lack of soils, weathering, or erosion between flow units suggests that the andesite was deposited over a relatively short timespan (Nye and others, 1984). Chaotic columnar joints found in the Lava Ramp flows in upper Makushin Valley suggest contact with ice. This could mean that Makushin Valley was still choked with glacial ice and would explain the odd flow pattern of Lava Ramp into Driftwood Valley. Sugarloaf Cone (Qs. erupted before the Lava Ramp to form a small monogenitic cinder cone near the head of Driftwood Valley. The vent tephras, lavas, and pyroclastic flows that form the ,050-m-high Pakushin cone and ejecta apron (Qpv, Qpf, and Qpp) are approximately

Toward the close of the Pleistocene, a dramatic change in the eruptive scenario occurred when a series of high-volume, basalt to andesite eruptions formed the satellite vents from Pakushin Cone to Wide Bay Cone. Individual eruptive