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OBSERVATIONS ON THE GEOLOGY AND PETROLEUM POTENTIAL OF THE COLD BAY-FALSE PASS AREA, ALASKA PENINSULA

by

Hugh McLean

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Abstract

Upper Jurassic strata in the Black Hills area consist mainly of fossiliferous, tightly cemented, gently folded sandstone deposited in a shallow marine environment. Upper Cretaceous strata on Sanak Island are strongly deformed and show structural features of broken formations similar to those observed in the Franciscan assemblage of California. Rocks exposed on Sanak Island do not crop out on the peninsular mainland or on Unimak Island, and probably make up the acoustic and economic basement of nearby Sanak basin.

Tertiary sedimentary rocks on the outermost part of the Alaska Peninsula consist of Oligocene, Miocene, and lower Pliocene volcaniclastic sandstone, siltstone, and conglomerate deposited in nonmarine and very shallow marine environments. Interbedded airfall and ash-flow tuff deposits indicate active volcanism during Oligocene time. Locally, Oligocene strata are intruded by quartz diorite plutons of probable Miocene age.

Reservoir properties of Mesozoic and Tertiary rocks are generally poor due to alteration of chemically unstable volcanic rock fragments. Igneous intrusions have further reduced porosity and permeability by silicification of sandstone. Organic-rich source rocks for petroleum generation are not abundant in Neogene strata. Upper Jurassic rocks in the Black Hills area have total organic carbon contents of less than 0.5 percent.

Deep sediment-filled basins on the Shumagin Shelf probably contain more source rocks than onshore correlatives, but reservoir quality is not likely to

be better than in onshore outcrops. The absence of well-developed folds in most Tertiary rocks, both onshore and in nearby offshore basins, reduces the possibility of hydrocarbon entrapment in anticlines.

INTRODUCTION

The Cold Bay-False Pass area of the outer Alaska Peninsula extends west from near Pavlof Volcano to the east end of Unimak Island and from the Black Hills southward to Sanak Island (Fig. 1). This study examines the geology of previously unmapped areas of the Alaska Peninsula, Unimak Island, and several small islands on the Shumagin shelf. The report also examines the petrology and sedimentology of rocks exposed onshore and speculates on the sedimentary facies relations in Sanak basin, an offshore sediment-filled basin located southeast of Sanak Island.

A team of U.S. Geological Survey geologists spent 30 days in June-July 1977 working in the Cold Bay area. Most of the work involved mapping Tertiary strata between False Pass and Belkofski Bay with reconnaissance trips to Unimak and Sanak Islands, the Pavlof Islands, and Beaver Bay (Fig. 2).

Previous work includes reports on the Pavlof Volcano area by Kennedy and Waldron (1955), the Frosty Peak area by Waldron (1961) and regional reconnaissance mapping by Burk (1965). Moore (1973a, 1973b) reported on the structure and petrology of Sanak Island. Sanak basin, a recently discovered sedimentary basin that lies southeast of Sanak Island (Fig. 2), was first described by Bruns and von Huene (1977a, 1977b). A reconnaissance geologic map of the Cold Bay and False Pass 1:250,000 quadrangles has been recently published by McLean, Engelhardt, and Howell (1978).

Newly found megainvertebrate fossil assemblages in Tertiary strata extend stratigraphic age control of these rocks to the end of the Alaska Peninsula.

Sedimentary structures and the distribution of lithofacies provide some insight into late Mesozoic and Tertiary environments of deposition.

MESOZOIC SEDIMENTARY ROCKS

Naknek Formation (Late Jurassic)

The oldest rocks that crop out in the Cold Bay area are exposed in bluffs and low beach cliffs in the Black Hills area on the north side of the Alaska Peninsula (Fig. 2) and consist of gently dipping fine-grained arkosic sandstone of the Naknek Formation (Burk, 1965). Strata are massive to thin-bedded and nearly devoid of sedimentary structures. The section locally contains fossil mollusks, including abundant Buchia and belemnites, and rare ammonites and gastropods. The fossil assemblage indicates a Late Jurassic (Oxfordian-Kimmeridgian) age for the Naknek Formation (Burk, 1965).

The Naknek sandstone is highly indurated mainly due to cementation by clayey matrix, calcite, and laumontite. The composition of four fine- to medium-grained sandstone samples is $Q_{18}F_{80}L_2$ where Q is the sum of quartz, chert, and quartzite, F is total feldspar, and L is rock fragments. Sandstone mineralogy indicates that the Naknek Formation is derived from a source terrane composed of volcanic and granitic rocks. The molluscan fossil assemblage suggests a shallow-marine environment. Sedimentary structures indicating directions of current flow were not found. Belemnites exposed on bedding planes show no systematic alignment, which indicates very low bottom current velocities.

An exploratory well (AMOCO Cathedral River No. 1) shown in Figure 2 in the Black Hills area was spudded in the Naknek Formation and drilled to a total depth of 14,301 feet (4,360 km) before being abandoned in 1974. Well logs indicate the Naknek Formation to be about 3,7600 feet (1,097 m) thick, overlying Lower and Middle Jurassic and Triassic strata. Total organic carbon measurements from the well are discussed in a later section.

Shumagin Formation (Late Cretaceous)

The Shumagin Formation crops out on Sanak Island and nearby islands (Fig. 2). The Shumagin Formation, first mapped by Burk (1965) and later studied in detail by Moore (1973a, 1973b), consists primarily of Upper Cretaceous(?) deep-water flysch. Similar rocks crop out locally along the Kodiak-Shumagin shelf from Sanak Island northeastward to the Kenai Peninsula. No fossils have been found in the Shumagin Formation on Sanak Island, but the formation is intruded by a granodiorite pluton with a K-Ar age of 59.9 m.y. (Moore, 1973b). A Late Cretaceous age has been tentatively assigned to strata on Sanak Island on the basis of lithologic and structural correlation with similar rocks in the outer Shumagin Islands (Moore, 1973a). Details on the structure and petrology of the Shumagin Formation are reported in Moore (1973a, 1973b) and only a few pertinent features of structure and lithofacies observed on Sanak and nearby Long Island are reviewed here.

Structure in the Shumagin Formation is complex and varied, and displays many features commonly observed in melange and broken-formation terranes in the Franciscan assemblage of California. On Sanak Island, structurally coherent blocks of massive sandstone commonly occur in a matrix of black sheared mudstone. Many folds are isoclinal with overturned limbs. Sequences of thin-bedded flysch that locally contain ptygmatic and chevron folds are found in thrust contact with more coherent blocks and slabs of massive sandstone. Cohesive sandstone units and most large fold axes trend northwest, but small folds in thin-bedded mudstone sequences seem to have more random orientations.

Locally sheared thin-bedded chert along the northeast shore of Long Island is interbedded with highly sheared black mudstone and grayish-green weathering metagraywacke. A few meters of fractured and altered pillow basalt is interbedded with the chert-mudstone-graywacke sequence and crops out near the top of the chert and graywacke section. The structural relation of this sequence to the rest of the Shumagin Formation is unclear. The chert-mudstone-graywacke-basalt sequence may be a basement upon which the flysch sequence was deposited, or may represent an exotic block or slab tectonically incorporated into the Shumagin Formation. Several samples of chert (gray, green, and red varieties) were found to be barren of radiolarians. Petrographic and x-ray analyses of the metagraywacke interbedded with the chert sequence indicate that prehnite and pumpellyite form secondary minerals in addition to chlorite, albite, and epidote. This mineral assemblage indicates that the rocks have been metamorphosed to the prehnite-pumpellyite facies, and perhaps locally to the greenschist facies.

Samples of flysch sandstone from Sanak Island were also compared petrographically with Upper Cretaceous sandstone dredged from Pribilof Canyon in the Bering Sea (Hopkins and others, 1969). Although the rocks from both areas were derived primarily from volcanic source terranes, their textures suggest highly dissimilar diagenetic histories. Sandstone from Sanak Island contains adundant pseudomatrix derived from altered volcanic rock fragments, plagioclase is albitized and fractures are filled with secondary quartz and patches of prehnite. Pribilof Canyon samples, on the other hand, are weakly compacted (though tightly cemented with calcite), contain Inoceramus fragments, and show no evidence of fracturing (McLean, 1979). Thus, petrographic and field evidence suggest that the flysch sequence in the Sanak Islands has been strongly folded and metamorphosed, probably along a convergent plate boundary, whereas the Pribilof Canyon rocks are texturally similar to the Naknek Formation and were probably deposited in a shelf environment and have only been subjected to mild deformation.

Hoodoo Formation (Late Cretaceous)

A brief reconnaissance of the Hoodoo Formation in the Canoe Bay area (Fig. 2) was made to determine the general depositional environment. The Hoodoo Formation in this area consists of a monotonous succession of thin bedded black mudstone and shale with a few gray fine-grained turbidite sandstone interbeds. Along the northeast shore of Canoe Bay, the fine-grained beds are cut by channels of massive diorite-bearing cobble conglomerate with clast imbrication indicating flow to the east and south (Fig. 3 and Table 1). The assemblage of mudstone and shale with thin (Ta-c) turbidites (Bouma, 1962) and locally developed conglomerate channels is suggestive of a middle fan setting of a submarine fan system (Mutti and Ricci-Lucchi, 1978; Walker and Mutti, 1973). Aspects of the sedimentology of the Hoodoo Formation are also reported by Mancini and others (1978).

CENOZOIC SEDIMENTARY ROCKS

Tolstoi Formation of Burk (1965) (Paleocene or Eocene)

The Tolstoi Formation of Burk (1965) was briefly studied along the east shore of Pavlof Bay. These rocks consist of three principal lithofacies: (1) a massive volcanolithic sandstone with festoon crossbeds and wispy shale interbeds; (2) thin-bedded turbidite sandstone with flute casts indicating southward flow (Fig. 3, locality 16, Table 1); and (3) massive light-brown weathering crossbedded sandstone with carbonized wood fragments and thin coal beds. Petrographic examination of medium-grained sandstone indicates that the rocks consist mainly of volcanic rock fragments and less than 10 percent quartz and feldspar (Fig. 4). Laumontite forms intergranular cement and replaces detrital grains of plagioclase. The age of the Tolstoi Formation of Burk (1965) is reported to be Paleocene or Eocene.

Stepovak Formation of Burk (1965) (late Eocene(?) and Oligocene)

The Stepovak Formation was examined at Coal Bay and at McGinty Point, areas located about 75 and 100 km respectively northeast of Cold Bay (Fig. 2). The Stepovak at Coal Bay consists of thin-bedded tuffaceous fine-grained sandstone and mudstone. The section also contains beds up to 2 m thick of light-colored angular pyroclastic pebbles interbedded with the sandstone and mudstone. These beds probably are airfall deposits derived from a nearby active volcano. Spectacular north-directed slump folds are exposed in the seacliffs of Coal Bay.

The Stepovak Formation at McGinty Point consists of steeply dipping tuffaceous turbidite sandstone and mudstone with a massive conglomerate composed of andesitic pebbles and cobbles near the middle part of the section. A 600 km thick sequence above the conglomerate contains sequences of turbidite sandstone beds that become finer grained and thinner bedded upward through the section. Asymmetrical ripple marks in the sandstone sequence indicate southeast current flows (Fig. 3, locality no. 14; Table 1). The section below the massive conglomerate consists of massive fine-grained tuffaceous sandstone that contains numerous calcareous concretions and locally abundant fossil bivalves. Much of the tuffaceous material in the McGinty Point section is altered to zeolites. Clinoptilolite, a zeolite, was detected by X-ray diffraction.

Marine fossils collected by Burk (1965) from the Coal Bay and McGinty Point section indicate neritic to upper bathyal water depths and a late Eocene(?) and Oligocene age, although Burk's microfossil collections from McGinty Point did not contain diagnostic forms. An Oligocene age of the Coal Bay and McGinty Point sections indicates that they are in part correlative in age with the Belkofski Formation. Airfall and ash-flow deposits in these two formations indicates that explosive volcanism was active during Oligocene time.

Belkofski Formation (Oligocene)

The Belkofski tuff, named by Kennedy and Waldron (1955) was referred to as the Belkofski Formation by Burk (1965). The name Belkofski Formation is preferrable because the section contains a significant thickness of volcano-lithic sandstone and carbonaceous mudstone in addition to typical tuffaceous sandstone and siltstone. The Belkofski is the oldest known formation in the Cold Bay area. The Belkofski, estimated to be 6,560 feet (2,000 m) thick, by Burk (1965), crops out extensively in the hills surrounding Belkofski Bay (Fig. 2). The lower part of the formation consists of grayish-green massive volcaniclastic sandstone originally called the "green arkose" by Kennedy and Waldron (1955). In spectacular cliff outcrops along the northwest shore of Belkofski Bay, greenish volcaniclastic sandstone beds grade upward into light grayish-brown beds of tuffaceous sandstone, siltstone, and pebble conglomerate. Laumontite cement was observed in several sandstone samples. Dark-brown beds of coal-like carbonaceous mudstone are interbedded with the tuffaceous sequence, becoming more abundant near the top of the bluffs. An indurated but unwelded andesitic ash-flow tuff also occurs in the upper part of the section indicating that volcanism was active during deposition of the Belkofski Formation.

A previously unreported fossil locality containing three pelecypod genera was found in a thin bed of grayish-green silty sandstone near the bottom of the bluffs along the northwest shore of Belkofski Bay. The identified genera include Anadara sp., Macoma sp., and Mya sp. (Table 2, locality no. M-7151) (L. N. Marincovich written comm., 1978). These fossils indicate a probable Oligocene age and are the only marine fossils that have been found in the Belkofski Formation. Kennedy and Waldron (1953) believed the Belkofski was of Tertiary age, whereas Burk (1965) thought it was probably correlative with the Tolstoi Formation (Paleocene and Eocene in age). A shallow marine environment is suggested by local bimodal trough crossbeds (Fig. 3, locality no. 7; Table 1). A mixed assemblage of evergreen needles and broad deciduous leaves occur in several beds of tuffaceous silty sandstone near the top of the northwest Belkofski Bay bluffs. Leaves were collected from newly mapped outcrops of the Belkofski Formation (McLean, Engelhardt, and Howell, 1978) east of Cold Bay, in an area mapped as Bear Lake(?) Formation by Burk (1965). Collections of leaves indicate an Oligocene age (J. A. Wolfe, oral commun., 1979).

The Belkofski Formation is unconformably overlain by Pliocene-Pleistocene volcanic flows and fluvial sedimentary rocks. The base of the Belkofski Formation is nowhere exposed. Andesitic dikes and sills intrude the formation in addition to several stocks of quartz diorite. In outcrops near contacts with the quartz diorite, the tuffaceous siltstone is silicified and highly indurated and acquires a characteristic purplish-brown color. Altered sandstone is usually zeolitized. Analcite forms cement and replaces vitreous rock fragments. Similarly altered strata were also noted on Deer Island, the Pavlof Islands, and along the west side of the Ikatan Peninsula on Unimak Island (McLean, Engelhardt, and Howell, 1978), where plutonic rocks have intruded volcanogenic sedimentary rocks.

If the Oligocene part of the Stepovak Formation at Coal Bay and McGinty Point and the Oligocene Belkofski Formation on Belkofski Bay are age correlative, an interesting paleogeographic model can be constructed (Fig. 5). The Belkofski Bay section in this model represents primarily a nonmarine sequence deposited in a swampy alluvial environment that periodically became inundated with tuffaceous ejecta from nearby volcanic events. Fossil bivalves at Belkofski Bay suggest limited interfingering of shallow marine waters with the nonmarine sequence. At Coal Bay and Beaver Bay the Stepovak Formation may represent more open marine environments located at progressively greater distances from the volcanic centers, but not necessarily in progressively deeper water (Fig. 5).

Bear Lake Formation (Miocene)

Kennedy and Waldron (1955) mapped a thick sequence of agglomerate, tuff, and lava flows in upper Cathedral Valley 10 km west of Pavlof Volcano as "Agglomerates of Cathedral Valley" and considered them to be age equivalent of the unit they mapped as Belkofski Tuff. Burk (1965) however, mapped these rocks and a large area between Cold Bay and Belkofski Bay as rocks that he described as "at least 3,000 feet (915 m) of unfossiliferous tan, brown, and yellow sandstones, conglomerates, and a few volcanic breccias." He referred these strata with reservation to the Miocene Bear Lake Formation, but recognized that the sequence is similar to the late Miocene and upper Pliocene Tachilni Formation.

Careful examination of the area 25 to 30 km southwest of Pavlof Volcano indicates that the rocks are actually the Belkofski Formation unconformably overlain by volcaniclastic fluvial sandstone and conglomerate interbedded with and capped by lava flows. The age of the nonmarine sequence overlying the

Belkofski Formation is unknown but is estimated to be late Pliocene or Pleistocene. This nonmarine sequence should definitely not be correlated with the predominantly marine Bear Lake Formation 120 km to the northeast in the Port Moller area.

Strata of the same age as the Bear Lake Formation crop out along the southeast shore of Ukolnoi Island at the entrance of Pavlof Bay (Fig. 2). Approximately 85 m of locally fossiliferous massive subarkosic sandstone and minor siltstone is unconformably overlain by about 100 km of unfossiliferous reddish-brown to tan volcanic sandstone and cobble breccia (Figs. 6 and 7). Sandstone below the unconformity contains up to 40 volume percent of heulandite or clinoptilolite cement. The fossiliferous sandstone sequence overlies and interfingers with massive volcanic flows and pillow basalt. The upper part of the arkose contains fossil pelecypods and gastropods including Turritella hataiella cf. T. shataii Nomura known only in Miocene rocks of Japan, (L. N. Marincovich, written comm., 1978). The fossil assemblage also contains the bivavle Lucinoma acutilineata (Conrad) whose latest occurrence is in rocks of Newportian age (late early to early middle Miocene). On the basis of this fauna (Table 2), the arkosic sequence below the unconformity is provisionally assigned to the Bear Lake Formation. Strata above the unconformity may be a nonmarine facies of the Bear Lake, or possibly may be correlative with the nonmarine parts of the Tachilni Formation (late Miocene to early Pliocene). The Miocene fauna on Ukolnoi Island suggests very shallow, cool to cold water (L. N. Marincovich, written comm., 1978).

Tachilni Formation (Miocene and Pliocene)

Gently dipping beds of fossiliferous sandstone, mudstone, and conglomerate with black shale that crop out about 30 km southwest of Cold Bay were named the Tachilni Formation by Waldron (1961). Marine mollusks from these beds were dated as early Pliocene by MacNeil and others (1961). Recent mapping by McLean, Engelhardt, and Howell (1978) has extended the distribution of the Tachilni Formation to include strata exposed in sea cliffs between False Pass and Morzhovoi Bay and on the west side of Deer Island.

The Tachilni Formation in the False Pass area consists of interfingering marine and nonmarine sandstone, mudstone, conglomerate, and minor breccia. Sandstone is composed mainly of volcanic rock fragments cemented by montmorillonite and heulandite (Fig. 4). Rapid facies changes are common, both laterally and vertically. Beds tend to be lenticular, and channels are common. Trough crossbeds suggest bimodal current flow reflecting tidally influenced environments (Fig. 3). Columnar sections depicting lithology and fossil distribution in the Tachilni Formation are shown in Figures 8, 9, and 10. These sections were measured in two locations in the seacliffs between False Pass and Belkofski Bay, and a third locality between Cape Tachilni and Frosty Peak (Fig. 3, locality no. 5).

Paleocurrent indicators for the Tachilni Formation are shown in Figure 3, localities 1 through 5 (Table 1). Fossil assemblages in the Tachilni Formation (Table 2) indicate inner sublittoral water depth (0-100 m). Fossil assemblages collected from the Tachilni and Belkofski Formations are listed in McLean, Engelhardt, and Howell (1978) and indicate an age of late Miocene to early Pliocene.

Pliocene and Pleistocene Sedimentary and Volcanic Rocks

Strata east of Cold Bay mapped as Bear Lake(?) Formation by Burk (1965) have been divided by McLean, Engelhardt, and Howell (1978) into Belkofski Formation, and Pliocene and Pleistocene sedimentary and volcanic rocks. The

Pliocene and Pleistocene sequence, which unconformably overlies the Belkofski Formation, chiefly consists of weakly to moderately indurated nonmarine sandstone, conglomerate, and breccia. These rocks represent fluvial deposits interbedded with and overlain by andesitic and basaltic lava flows. The sequence crops out widely in the Cold Bay area, generally overlying older strata with little angular unconformity. The geology and petrology of Quaternary volcanic rocks are reported in Kennedy and Waldron (1955) and in Waldron (1961).

PLUTONIC ROCKS

The oldest plutonic rock in the Cold Bay area is the granodiorite on Sanak Island which intrudes the Shumagin Formation and has a K-Ar date of 59.9 m.y. (Moore, 1973b).

Stocks of quartz diorite intrude the Belkofski Formation to the east and west of Belkofski Bay and on the north shore of Deer Island (Kennedy and Waldron, 1955). A well-exposed contact is located on the north shore of Deer Island where intruded strata of the Belkofski Formation are highly indurated by silicification.

In the absence of radiometric dates, the age of the quartz diorite can only be estimated from stratigraphic and regional relations. A Miocene age of 15-20 m.y. seems reasonable for these rocks because they intrude the Oligocene Belkófski Formation, and several Miocene K-Ar dates have been obtained from plutonic rocks in the central and eastern part of the Aleutian Islands (Marlow, 1973).

PETROLEUM POTENTIAL

Mesozoic Rocks

Little can be deduced about the petroleum potential of the Upper Jurassic Naknek Formation as only a few tens of meters of tightly cemented sandstone are exposed in surface outcrops. Data are available, however, from total organic carbon analyses (TOC) obtained from cuttings from the AMOCO Cathedral River No. 1 well, (McLean, 1977). Percentage TOC for the Naknek Formation ranges from 0.1 percent to a maximum of 0.5 percent, and averages 0.2 percent (Fig. 11). Such low values suggest a general absence of organic source rock in the Upper Jurassic sequence of the Black Hills.

The Shumagin Formation on the Sanak Islands can be considered to be effective economic basement (Bruns and von Huene, 1977a), mainly due to complex structure and burial metamorphism.

Tertiary Rocks

The reservoir potential of sandstone in the Belkofski and Tachilni formations is similar in that both are composed mainly of volcanic grains with adundant tuffaceous matrix (Fig. 4). Grains of plagioclase and volcanic rock fragments are chemically unstable and have been altered to clay matrix, chlorite, and zeolites, which reduce intergranular porosity and permeability. Reservoir properties in the Belkofski Formation are further reduced by silica and zeolite cements generated by burial, and intrusions of granitic rocks, volcanic dikes, and sills. The Tachilni Formation postdates Miocene plutonism but is intruded by numerous dikes and sills that are feeders for overlying Pleistocene lava flows.

Organic-rich source rocks such as carbonaceous marine mudstone and shale are absent in the Belkofski Formation and rare in the Tachilni Formation.

Most carbonaceous beds are nonmarine and contain woody plant material such as leaves, carbonized logs, and branches of trees.

The Tertiary sedimentary rocks are weakly deformed with only local development of broad open folds. Even in the offshore islands between Cold Bay and Cherni Island, columnar jointed flows and interbedded breccia of probable late Tertiary age generally dip less than 10 degrees.

Sanak Basin

Extrapolation of Tertiary onshore sedimentary lithofacies into Sanak basin indicates that the sedimentary section could contain marine facies of Oligocene through late Pliocene or early Pleistocene rocks. If rocks as old as Oligocene exist in Sanak basins they are probably similar to the thin-bedded tuffaceous turbidite sandstone and mudstone section exposed at McGinty Point along the west shore of Beaver Bay. This sequence could in turn be overlain by arkosic sandstone and mudstone of the Bear Lake Formation of middle(?) and upper Miocene age exposed on Ukolnoi Island. The Miocene section may grade upward into more tuffaceous correlatives of the late Miocene and early Pliocene Tachilni Formation. A relatively thin and laterally discontinuous sequence of volcanic flows and breccia similar to rocks that crop out on nearby Cherni Island may constitute the youngest strata in the basin.

An important consideration in evaluating the overall prospective potential of Sanak basin is whether the basin has escaped the numerous episodes of igneous intrusions that occurred on the peninsular mainland. It should be noted that there is no evidence of Tertiary volcanic dikes or sills intruding the Shumagin Formation on Sanak or Long Islands. A comprehensive magnetic survey would provide valuable data regarding the offshore distribution of igneous rocks.

The petroleum potential of the outer Alaska Peninsula as deduced from onshore geologic relations, is limited chiefly by the scarcity of suitable organic-rich source rocks and by reservoir rocks with inadequate porosity and permeability. Most Tertiary sedimentary rocks were derived from an active volcanic source terrane and were deposited in nonmarine or in very shallow nearshore marine environments. Sandstone consists mainly of volcanic grains that have altered to secondary pore-filling minerals such as chlorite, montmorillonite, analcite, heulandite, clinoptilolite, and laumontite. Offshore basins, like Sanak basin, may contain a thicker section of marine source rocks than the onshore area, but reservoir quality is not likely to be improved.

CONCLUSIONS

The geology of the Cold Bay area suggests that the outer part of the Alaska Peninsula, at least since Oligocene time, has been strongly influenced by persistent volcanism and episodes of plutonism. The distribution of volcanogenic nonmarine sedimentary rocks interfingering with very shallow marine strata seems to reflect a paleogeographic setting generally similar to the present Aleutian volcanic arc. Active volcanic centers supplied primary and reworked sediment to adjacent marshy flatlands with locally abundant vegetation. Fluvial systems carried sediment into shallow marine embayments dominated by the ebb and flood of tidal events.

Gently folded Mesozoic and Tertiary strata on the peninsula appear to be structurally decoupled from strongly folded and sheared rocks on Sanak Island. The exact location of this structural discontinuity is unknown, but probably lies offshore between Sanak and Cherni Islands. The folded flysch sequence on Sanak Island is not exposed on either Unimak Island or the Alaska Peninsula.

Sanak basin on the Shumagin Shelf probably has the best petroleum potential of any area of the outer Alaska Peninsula. This is especially true if future magnetic surveys indicate an absence of igneous rock within the basin. The potential of the onshore area is minimized by plutonism, volcanism, and a lack of organic-rich source rock. Although the Cold Bay area lies close to the leading edge of the convergent North American-Pacific plate boundary, there has been very little compressional folding during most of Tertiary time, a fact that limits the size and number of anticlinal structures both onshore and offshore.

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REFERENCES CITED

Bouma, A. H., 1962, Sedimentology of some Flysch deposits: Amsterdam, Elsevier Publ. Co., 168 p.

Bruns, T. R., and von Huene, Roland, 1977a, Sedimentary basins on the Shumagin Shelf, western Gulf of Alaska: 1977 Offshore Technology Conference Proc., v. 1, p. 41-50.

Bruns, T. R., and von Huene, Roland, 1977b, Sedimentary basins on the Shumagin Shelf, western Gulf of Alaska: U.S. Geol. Survey Circ. 751-B, p. 97.

Burk, C. A., 1965, Geology of the Alaska Peninsula--Island arc and continental margin: Geol. Soc. America Mem. 99, 250 p.

Hopkins, D. M., Scholl, D. W., Addicott, W. D., Pierce, R. L., Smith, P. B., Wolfe, J., Gershanovich, D., Kotenev, B., Lohman, K. E., Lipps, J. H., and Obradovich, J., 1969, Cretaceous, Tertiary, and Pleistocene rocks from the continental margin of the Bering Sea: Geol. Soc. America Bull., v. 80, p. 1471-1480.

Kennedy, G. C., and Waldron, H. H., 1955, Geology of Pavlof Volcano and vicinity, Alaska: U.S. Geol. Survey Bull. 1028-A, 19 p.

MacNeil, F. S., and others, 1961, Correlation of Tertiary formations of Alaska: Am. Assoc. Petroleum Geol. Bull., v. 45, p. 1801-1809.

Mancini, E. R., Deeter, T. M., and Wingate, F. H., 1978, Upper Cretaceous arc-trench gap sedimentation on the Alaska Peninsula: Geology, v. 6, p. 437-439.

McLean, Hugh, 1977, Organic geochemistry, lithology and paleontology of Tertiary and Mesozoic rock from wells on the Alaska Peninsula: U.S. Geol. Survey Open-File Rept. 77-813.

McLean, Hugh, Engelhardt, C. L., and Howell, D. G., 1978, Reconnaissance geologic map of the Cold Bay and False Pass quadrangle, Alaska: Open-File Map 78-323, 1 sheet.

McLean, Hugh, 1979, Pribilof segment of the Bering Sea continental margin: A reinterpretation of Upper Cretaceous dredge samples: Geology, v. 7, p. 307-310.

Marlow, M. S., Scholl, D. W., Buffington, E. C., and Alpha, T. R., 1973, Tectonic history of the central Aleutian arc: Geol. Soc. America Bull., v. 84, p. 1555-1574.

Moore, J. C., 1973a, Cretaceous continental margin sedimentation, southwestern Alaska: Geol. Soc. America Bull., v. 84, p. 595-614.

Moore, J. C., 1973b, Complex deformation of Cretaceous trench deposits, southwestern Alaska: Geol. Soc. America Bull., v. 84, p. 2005-2020.

Mutti, E., and Ricci-Lucchi, F., 1978, Turbidites of the northern Appenines: Introduction to facies analysis: Internat. Geol. Review, v. 20, no. 2, p. 125-166.

Waldron, H. H., 1961, Geologic reconnaissance of Frosty Peak Volcano and vicinity, Alaska: U.S. Geol. Survey Bull. 1028-T, p. 677-708.

Walker, R. G., and Mutti, E., 1973, Turbidite facies and facies association, in Middleton, G. V., and Bouma, A. H., co-chairman, Turbidites and deep water sedimentation: Soc. Econ. Paleontologists and Mineralogists Pacific Sec., p. 119-157.

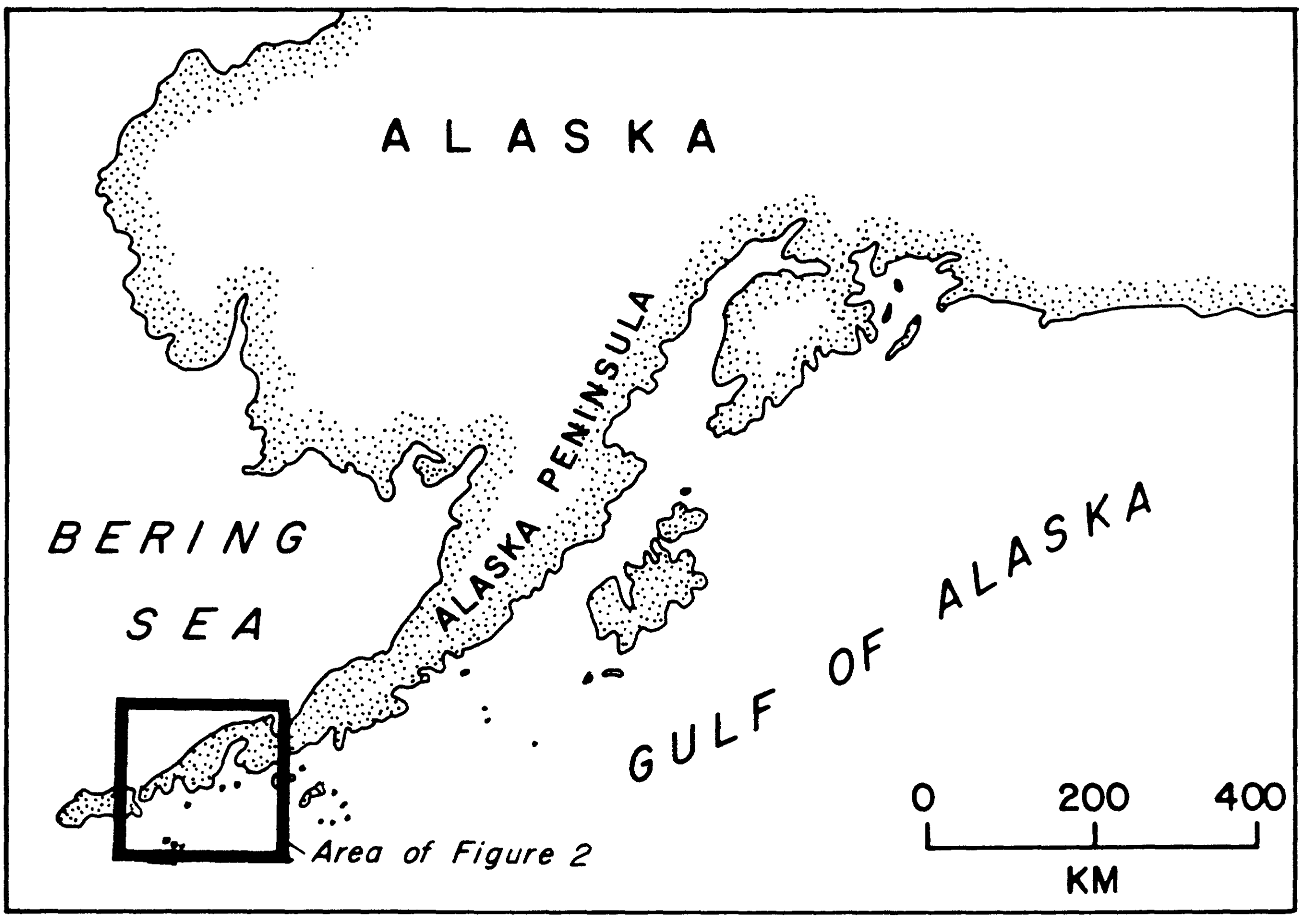

Figure 1.--Index map of the Cold Bay-False Pass area, Alaska.

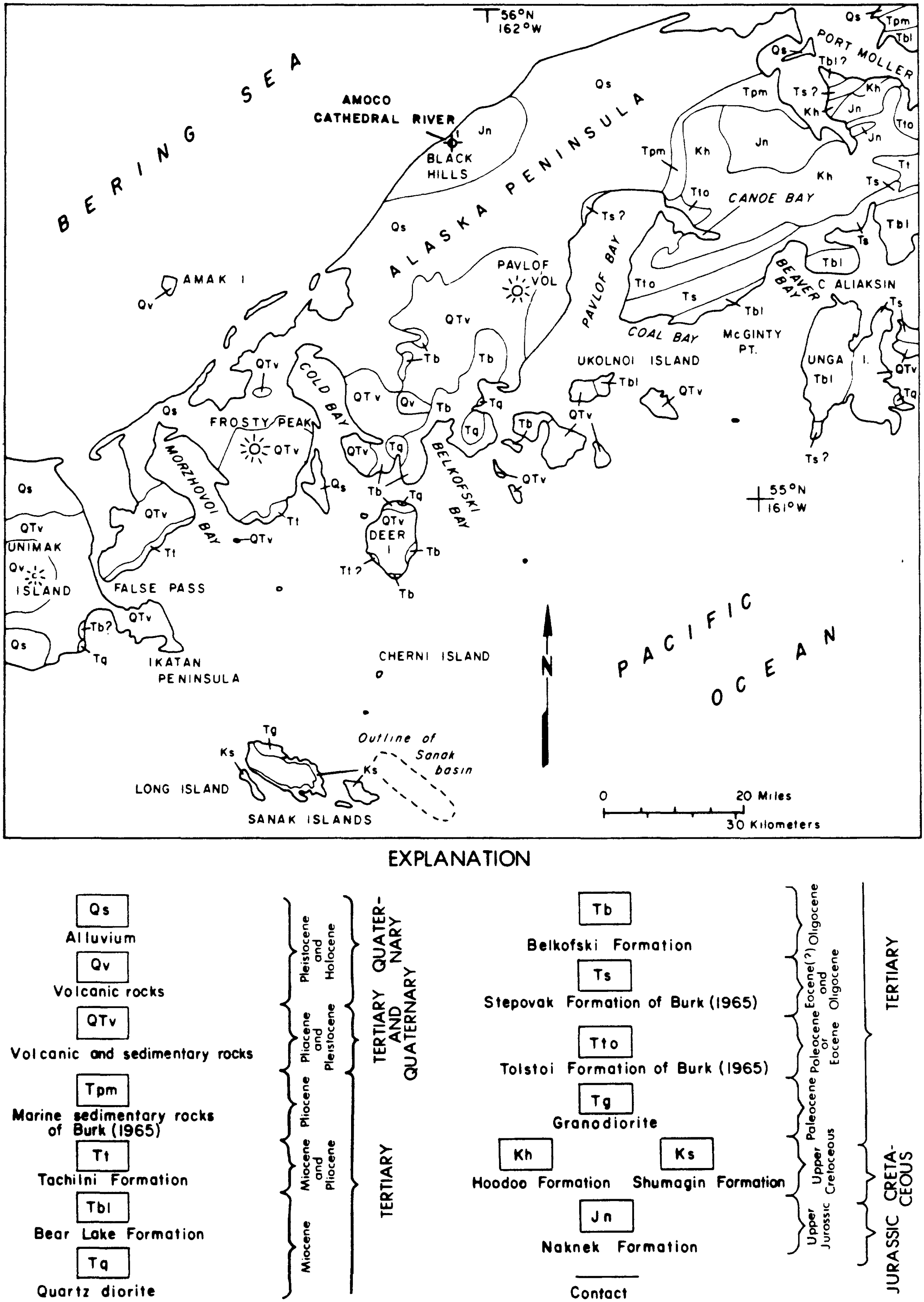

Figure 2.--Generalized geology of the outer Alaska Peninsula. From McLean (1979).

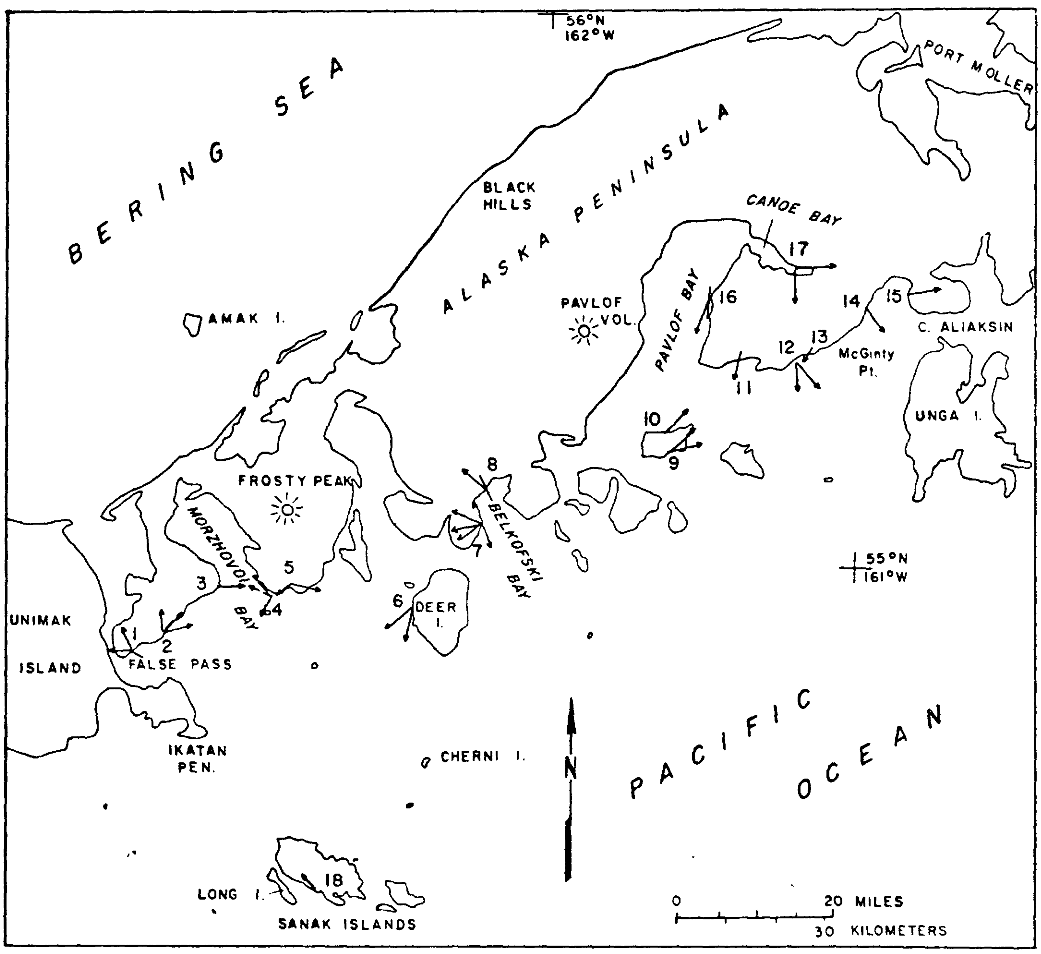

FIG. 3 - Directions of measured paleocurrent flow. Arrows indicate direction of flow. Lines without barbs indicate orientation of lineations. Localities in Table 1.

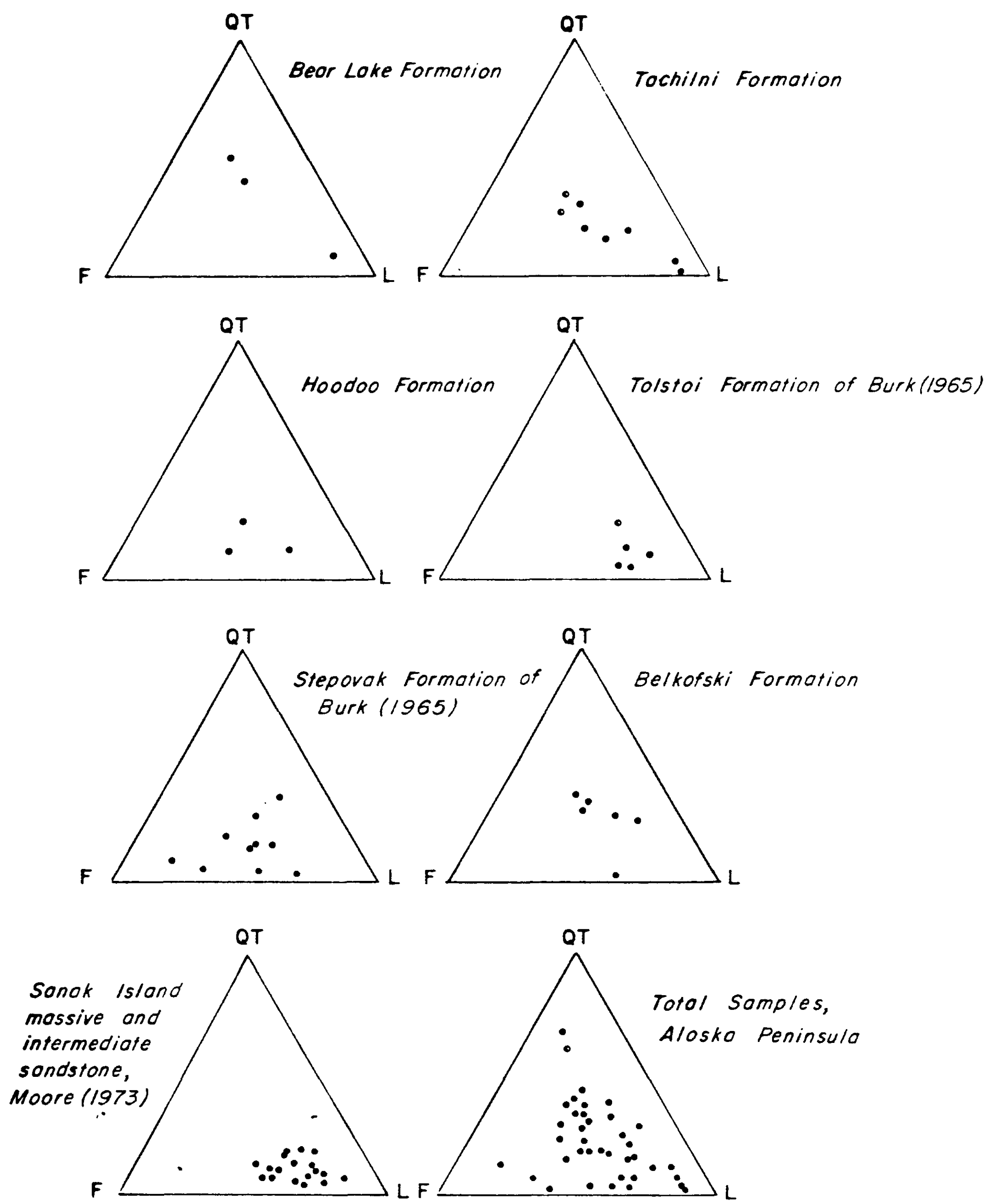

FIG. 4 - Modal grain compositions of sandstone samples. QT is sum of quartz, chert, and quartzite, F is total feldspar, L is sum of volcanic sedimentary, and metamorphic rock fragments.

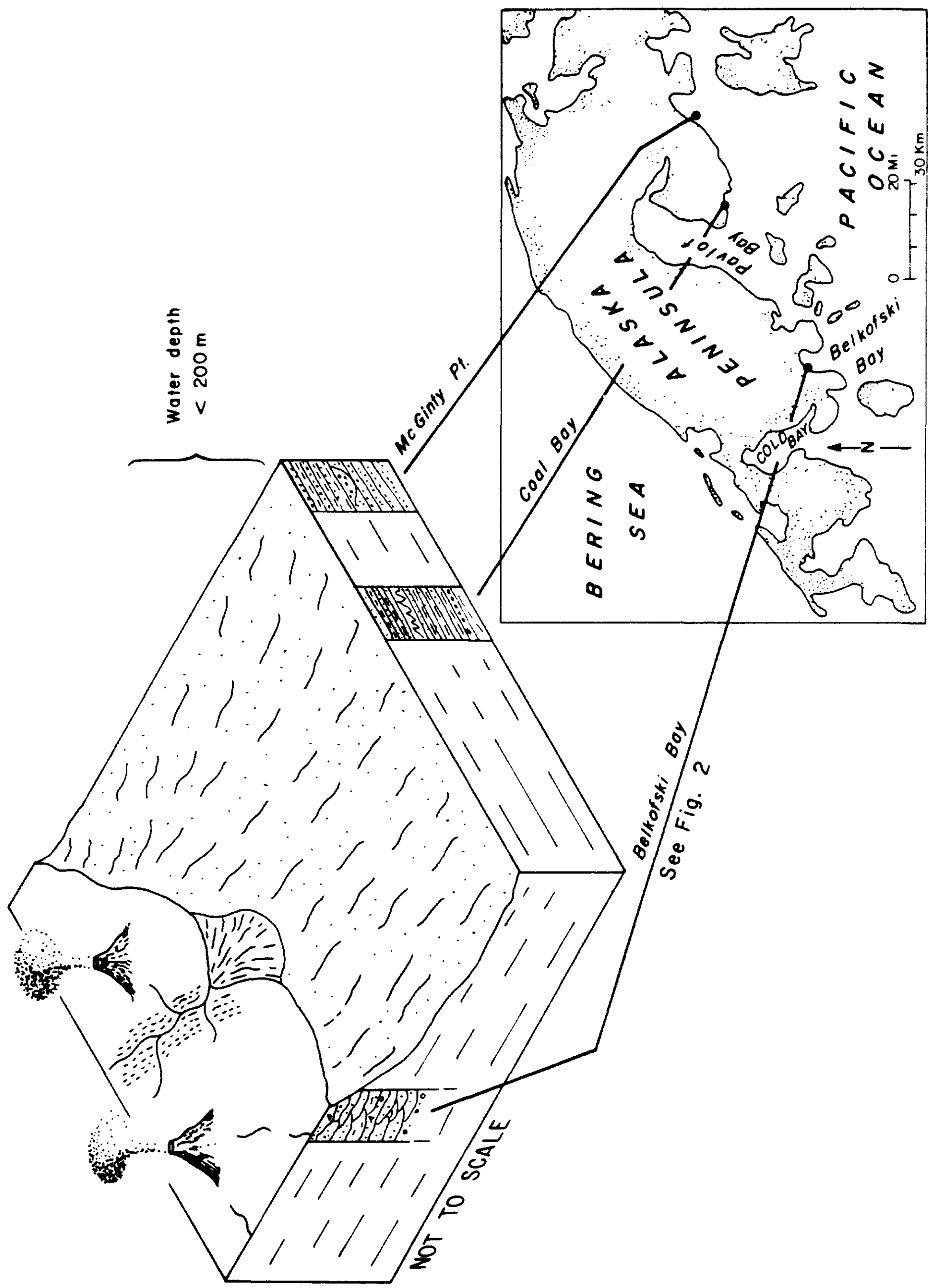

Figure 5.--Inferred stratigraphic relations of the Belkofski Formation and the Stepovak Formation of Burk (1965). Nonmarine rocks at Belkofski Bay are interpreted to interfinger with thin-bedded marine rocks at Coal Bay and McGinty Point. From McLean (1979).

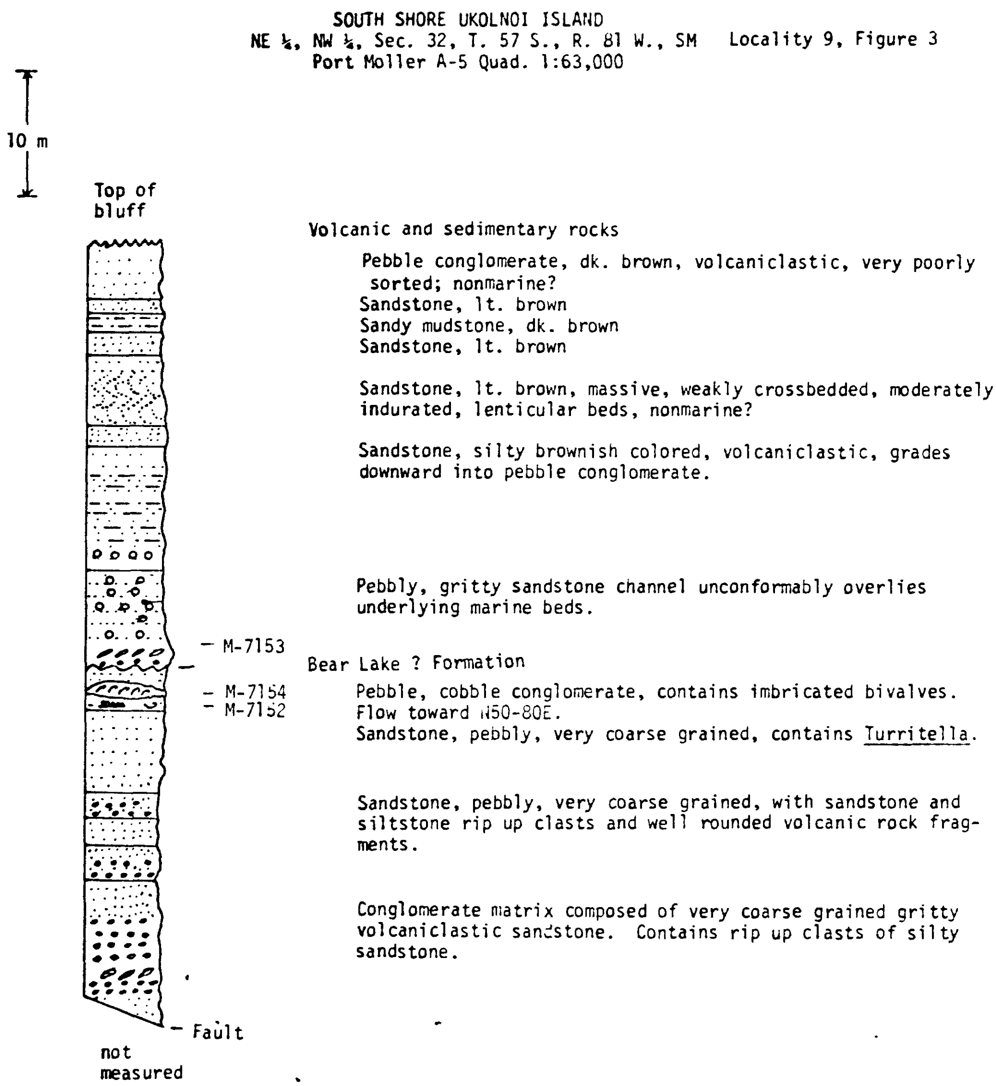

FIG. 6 - Columnar section measured along southeast shore of Ukolnoi Island, approximately 200 m east of columnar section in Figure 7.

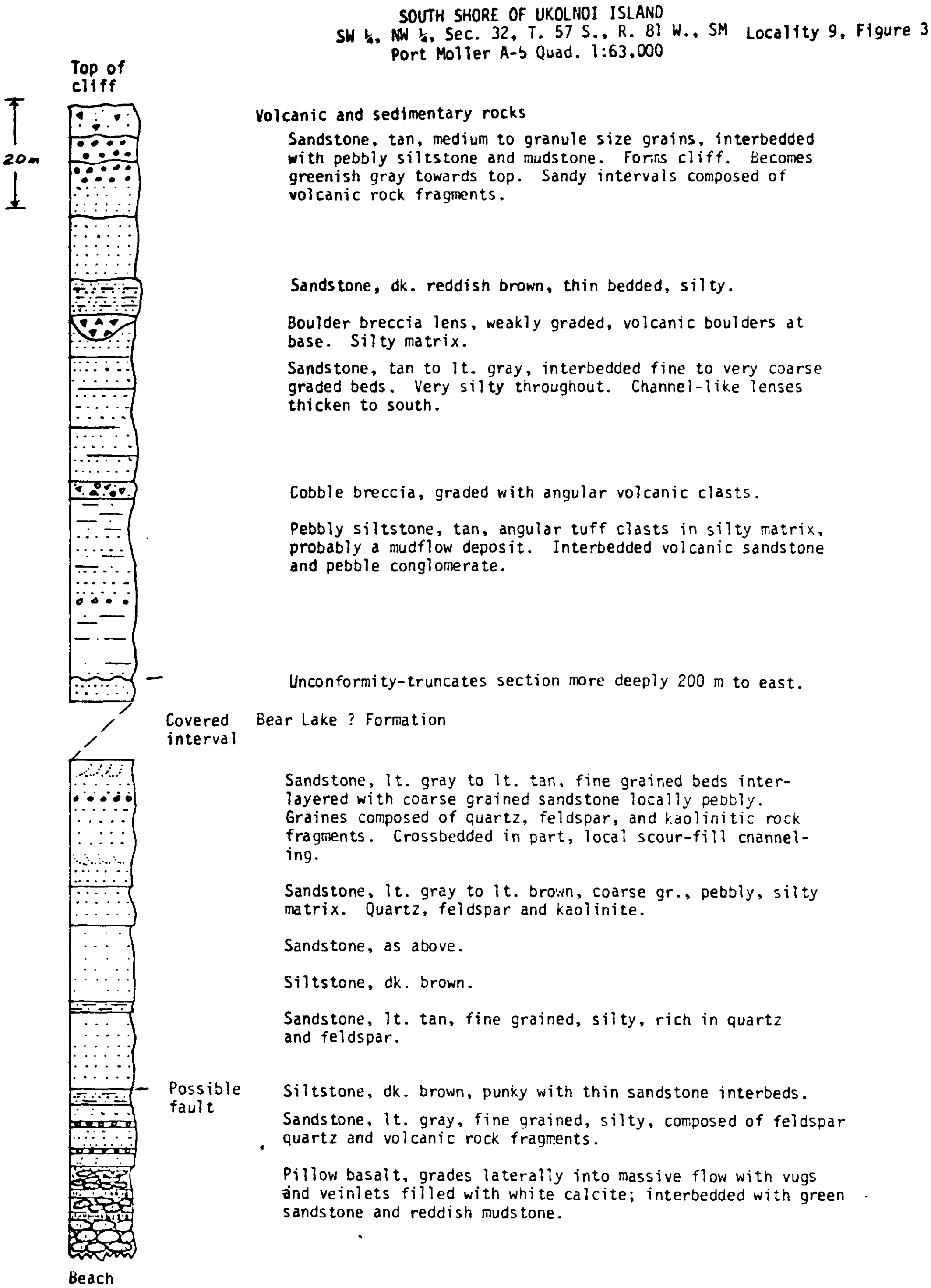

FIG. 7 - Columnar section measured along southeast shore of Ukolnoi Island. Location is about 200 m west of columnar section in Figure 6.

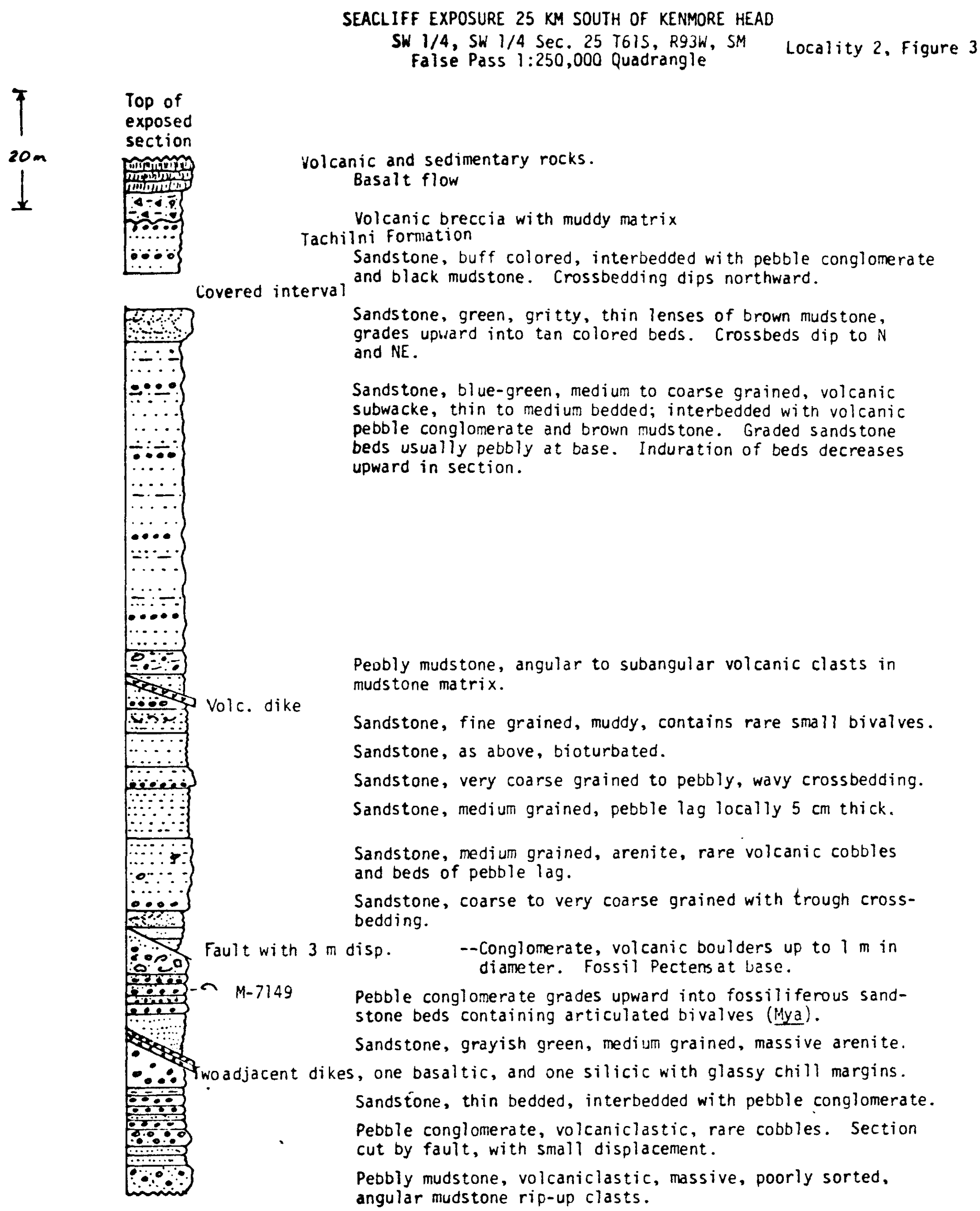

FIG. 8 – Columnar section of Tachilni Formation measured in cliffs between False Pass and Morzhovoi Bay.

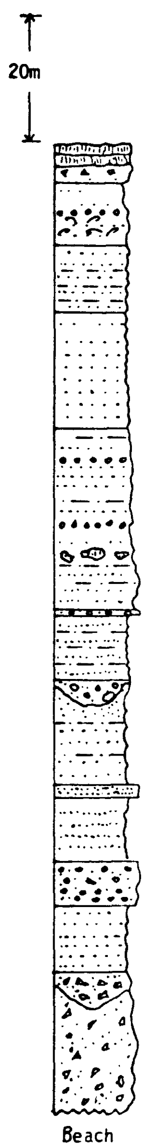

FIG. 9 - Columnar section of Tachilni Formation measured between False Pass and Morzhovoi Bay.

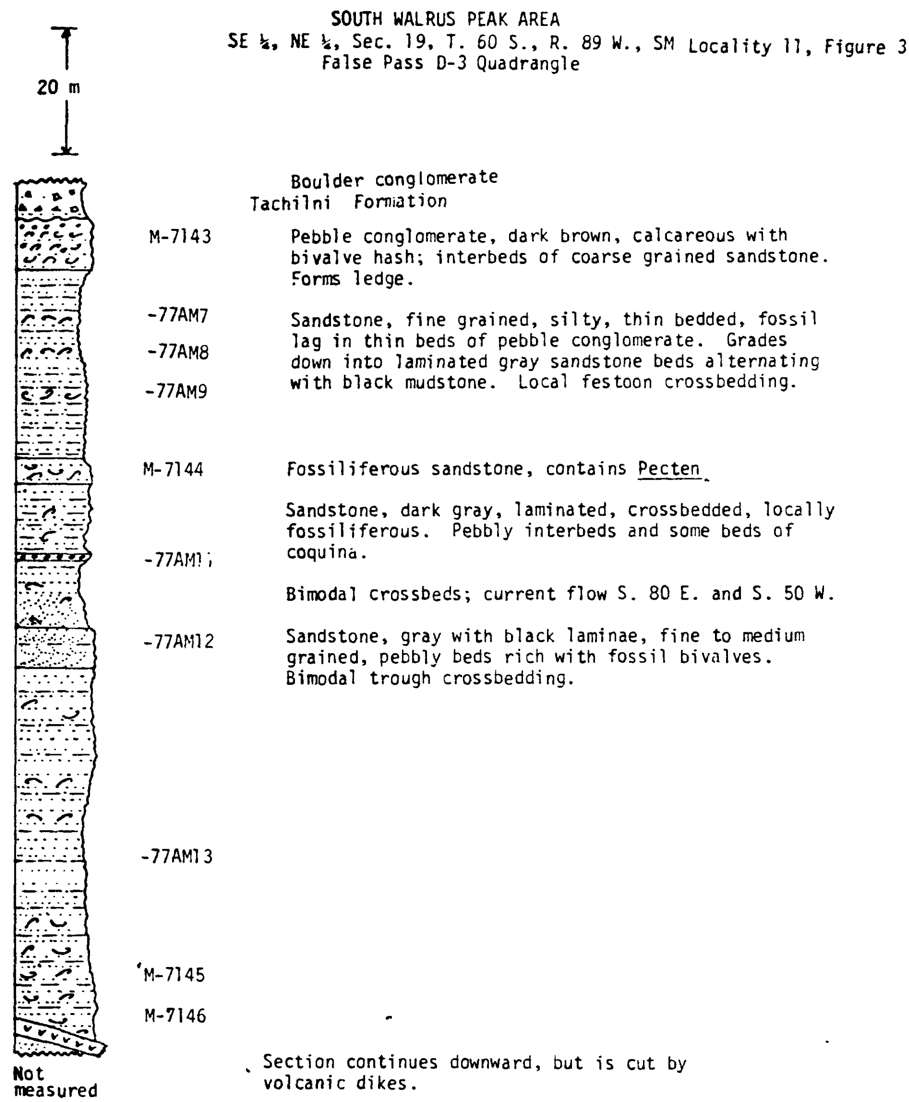

FIG. 10 - Columnar section of Tachilni Formation measured between Morzhovoi Bay and Cold Bay and south of Frosty Peak volcano.

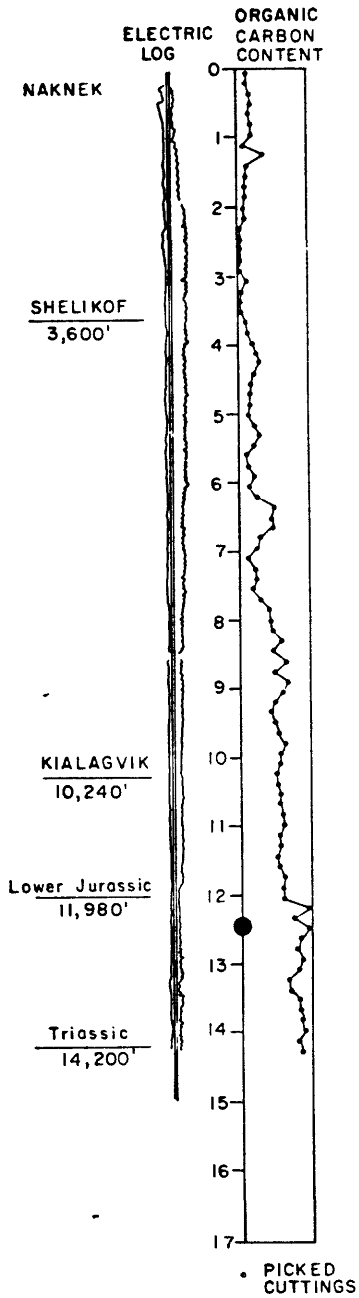

FIG. 11 - Percentage of total organic carbon (TOC) in hand picked cuttings from the AMOCO Cathedral River well. Analyses by GeoChem Laboratories, Houston, Texas. Depth measured in feet x 10^3.

Table 1: Summary of Paleocurrent Data

Map. No. (Fig. 2)	Location (Fig. 3)	Formation Name	Direction	Indicator
1	Morzhovoi Peninsula	Tachilni	west	Crossbeds
	"	"	S 65 E	Crossbeds
2	Morzhovoi Peninsula	"	N-NE	Imbrication
	"	"	NE to N 5 W	Crossbeds
	"	"	N	"
	"	"	N 60 E	"
3	Kenmore Head	"	N 80 E to E	Imbrication
4	Cape Tachilni	"	N 45 W	
	"	"	N 60 W bimodal	Crossbeds
	"	"	N 20 W set	
5	Walrus Pk.	"	S 50 W bimodal	Crossbeds
	"	"	S 80 E set	
6	Deer Island	Tachilni ?	S 40 W	Imbrication
	"	"	S 75 W	"
7	Belkofski Bay (W side)	Belkofski	S 60 W	Crossbeds
	"	"	S 80 W	"
	"	"	N 20 W bimodal	"
	"	"	S 20 E set	"
	"	"	N 70 W	"
8	Belkofski Bay (NW side)	"	N 30-40 W/S 30-40 E	Lineation
	"	"	NW	Crossbeds
9	Ukolnoi I. (S side)	Bear Lake ?	N 50 to 80 E	Imbrication and
	"			Channel axis
10	Ukolnoi I. (N side)	"	NE	Crossbeds
11	Coal Bay	Stepovak	N 10 E/S 10 W	Symmetrical Ripple marks
12	Beaver Bay (SW shore)	Bear Lake	S to SE	Festoon crossbeds
13	Beaver Bay (SW shore)	"	SW	Climbing ripples
14	Beaver Bay (SW shore)	Stepovak	S 35 E	Ripple marks
15	Cape Aliaksin	Bear Lake	NE to E	Festoon crossbeds
16	Settlement Pt. (Pavlof Bay)	Tolstoi	N 10 E/S 10 W	Current lineation
	"	"	S 20 W	Flute cast
17	Canoe Bay (NE end)	Hoodoo	East and south	Conglomerate clast Imbrication
18	Sanak Island	Shumagin	NW	Imbricated rip-up Clasts

Table 2

TERTIARY MEGAINVERTEBRATE COLLECTIONS

U.S.G.S. Cenozoic Locality Number	Formation and Age	Identifiable Taxa	Remarks
M-7139	Tachilni Formation (Late Miocene or Pliocene)	Bivalvia: Chlamys (Swiftopecten) leohertleini MacNeil Cyclocardia sp.- Glycymeris sp.- Tellina sp.- Spisula Polynyma voyi (Gabb) Papyridea sp Macoma sp. Pandora sp. Gastropoda: Polinices (Euspira) pallidus (Broderip and Sowerby), Neptunea (Neptunea) lyrata altispira Gabb. ? Cancellaria sp. Natica (Cryptonatica) clausa Broderip and Sowerby.	Type section of Tachilni Formation at Cape Tachilni. Environment: Distinctly cool to cold marine water is indicated by the Natica, Polinices, and Spisula species. Water depth no greater than 100 m.
M-7140	Tachilni Formation (Pliocene)	Bivalvia: ? Glycymeris sp.- fragments. Clinocardium sp. Macoma cf. M. nasuta Conrad. Gastropoda: Natica (cryptonatica) clausa Broderip & Sowerby, Neptunea (Neptunea) lyrata (Gmelin) subspecies	Located 2.4 m stratigraphically above M-7139. This is the stratigraphically highest megafossil locality at this type section. Numerous articulated bivalve shells indicate little or no post mortem transport.
M-7141	Tachilni Formation (Miocene or younger)	Bivalvia: Mya (? Arenomya) cf. M. (?A.) elegans (Eichwald)- 1 specimen Chlamys (Swiftopecten) sp.- 2 fragments	Located 9 m stratigraphically below M-7139. Cold water, 0-50 meters depth.

Table 2 continued on following page

Table 2 continued

U.S.G.S. Cenozoic Locality Number	Formation and Age	Identifiable Taxa	Remarks
M-7142	Tachilni Formation (Late Miocene or Pliocene)	Bivalvia: *Crenomytilus coalingensis* (Arnold) *Mya* (*Mya*) *truncata* Linnaeus, *Macoma* cf. *M. nasuta* (Conrad), *Papyridia sp.* *Glycymeris sp.*	Located 58 m stratigraphically below M-7139.
M-7143	Tachilni Formation (Late Miocene or Pliocene)	Bivalvia: *Mya* (*Mya*) *truncata* Linnaeus Gastropoda: *Neptunea* (*Neptunea*) *lyrata altispira* Gabb *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby, *?Cancellaria sp.*	Stratigraphically highest megafossil locality in this section. See Figure 10. Environment: Cold water, depth 0-50 m.
M-7144	Tachilni Formation (Age unknown)	Bivalvia: *Pecten sp.* *Clinocardium sp.*	Located about 40 m stratigraphically below M-7143. See Figure 10.
M-7145	Tachilni Formation (Age unknown)	Bivalvia: *Macoma sp.*	Environment: Probably shallow water, depth 0-100 m. See Figure 10.
M-7146	Tachilni Formation (Late Miocene or Pliocene)	Bivalvia: *Spisula polynyma voyi* (Gabb), *Yoldia* (*Cnesterium*) *sp.* *Mya* (*Mya*) *truncata* Linnaeus, *Clinocardium sp.* *Glycymeris sp.* *Siliqua sp.* *Chlamys* (*Swiftopecten*) *leohertleini* MacNeil *Papyridea sp.* *Thracia sp.* *Mya* (*?Arenomya*) *elegans* (Eichwald), *Musculus sp.* *Macoma* cf. *M. nasuta* (Conrad)	Located about 9 m stratigraphically below locality M-7145. This locality is at base of exposed sedimentary section See Figure 10. Environment: Cold water is indicated by these taxa; no warm water taxa are present; water depth 0-50 m suggested by *Siliqua* and *My* species.

Table 2 continued on following page

Table 2 continued

U.S.G.S. Cenozoic Locality Number	Formation and Age	Identifiable Taxa	Remarks
M-7146		Gastropoda: *Neptunea* (*Neptunea*) *lyrata altispira* Gabb. *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby. *?Plicifusus sp. Margarites sp. Oenopota sp. Buccinum sp.*	
M-7149	Tachilni Formation (Late Miocene or early Pliocene)	Bivalvia: *Mya* (*?Arenomya*) *elegans* (Eichwald). *Clinocardium sp. Fortipecten mollerensis* MacNeil.	Seacliff exposure between False Pass and Morzhovoi Bay. See Figure 8. Environment: *Mya elegans* is still living in waters around the Alaska Peninsula Its presence suggests cold water, probably less than 50 m deep.
M-7150	Tachilni Formation (Late Miocene or Pliocene)	Bivalvia: *Siliqua sp. Clinocardium sp. Macoma* cf. *M. brota* Dall. *?Thracia sp. Mya* (*Mya*) *truncata* Linnaeus. Gastropoda: *Natica* (*Cryptonatica*) *clausa* Broderip and Sowerby. *Buccinum sp. Colus sp. Neptunea* (*Neptunea*) *lyrata altispira* Gabb. *?Cancellaria sp.*	Seacliff exposure between False Pass and Morzhovoi Bay. Age: The *Neptunea* sub-species is reported in late Miocene faunas of the Yakataga Formation in the Yakatage District and in numerous Pliocene deposits from the Alaska Peninsula (Tachilni Formation). Environment: The molluscan taxa are typical of a northern, cool-water fauna; the *Natica* species in particular occurs in Miocen to Holocene faunas and indicates cool-to cold wate Water depth probably 0-50 m Many of the bivalves are articulated and closed, indicating little or no post mortem transport.

Table 2 continued on following page

Table 2 continued

U.S.G.S. Cenozoic Locality Number	Formation and Age	Identifiable Taxa	Remarks
M-7151	Belkofski Formation (Oligocene)	Bivalvia: ?Anadara sp. ?Macoma sp. Mya sp. Crustacea fragment of crab claw.	The Mya species is not well preserved, but is similar in form to poorly known Oligocene species in Japan and Alaska.
M-7152	Bear Lake (?) Formation (Age unknown)	Bivalvia: Lucinoma acutilineata (Conrad). Gastropoda: Turritella (Hataiella) cf. T. (H.) shataii Nomura. Scaphopoda: Dentalium sp.	Located on southeast shore of Ukolnoi Island. See Figure 6.
M-7153	Bear Lake (?) Formation	Bivalvia: Lucinoma acutilineata (Conrad) Thracia sp. ?Venericardium sp. Penitella sp. Gastropoda: Turritella (Hataiella) cf. I. (H.) shataii Nomura. Neptunea (Neptunea) Lyrata (Gmelin) subspecies	Same locality as M-7152 but about 50 m farther to the southeast along the seacliff. See Figure 6.
M-7154	Bear Lake (?) Formation (Miocene)	Bivalvia: Lucinoma acutilineata (Conrad). Macoma sp. ?Thracia sp.	Same locality as M-7153 but about 50 m again to the southeast along the cliffs. See Figure 6. Age: The Turritella species, tentatively identified here, is known only in Miocene rocks of Japan. Lucinoma acutilineata has its latest occurrence in rocks of Newportian age (late early to early middle Miocene). The ?Neptunea species is a giant snail that also occurs in the Unga conglomerate at Cape Aliaksin, about 35 km to the northeast.

Identifications and interpretations in this table are by Louie Marincovich, Jr., U.S. Geological Survey, Menlo Park, California.