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Title: STRATIGRAPHY AND SEDIMENTATION OF THE ONION PEAK AREA, CLATSOP COUNTY, OREGON

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Six Tertiary units are exposed in the Onion Peak area near the town of Cannon Beach, Oregon. The units consist of: late Eocene to early Miocene Oswald West mudstones (informal), middle Miocene Astoria Formation (Angora Peak sandstone and Silver Point mudstone members-informal), middle Miocene basalts of intrusive and extrusive Depoe Bay Basalt, and intrusive Cape Foulweather Basalt. Beach sands, Pleistocene marine terraces, and stream alluvium unconformably overlie these Tertiary units.

The Oswald West mudstones consist of more than 1600 feet of well-bedded, burrowed, tuffaceous siltstones and mudstones with subordinate tuff and glauconitic sandstone beds. Foraminiferal and trace fossil evidence suggest that these mudstones were deposited in marine waters of upper bathyal depths.

The overlying 1700-foot thick Astoria Formation is divided into two informal mappable members: the 1100-foot thick Angora Peak sandstone and the 600-foot thick Silver Point mudstone (proposed informally in this study). The Angora Peak sandstone member is composed of several hundred feet of thickly laminated feldspathic sandstones with local cross-bedded lithic conglomerates and carbonaceous siltstones. The overlying Silver Point mudstone member consists of rhythmically interbedded mudstones and graded turbidite sandstones, overlain by bedded mudstones, thin siltstones, and local conglomerate lenses. Conglomerate clast lithologies and heavy mineral suites of the Silver Point and Angora Peak members are similar to the sediment carried by the Columbia River today and may be an ancient deposit of that river system. The provenances for these strata were pre-Miocene andesitic and dacitic rocks of the western Cascades, the Coast Range Eocene Tillamook basalts, and plutonic, metamorphic, and sedimentary contributions from eastern Oregon and Washington, Idaho, Montana, and Canada. Channel fluvial sandstones, conglomerates, and well-bedded shallow marine sandstones of the Angora Peak member, probably interfingering with interbedded, deeper marine (600 feet-outer shelf) mudstones and turbidite sandstones of the Silver Point member, are interpreted to have been deposited near the mouth of a river, adjacent to the ocean as a delta.

Dikes, sills, peperites, and irregular intrusive bodies of middle Miocene Depoe Bay Basalt intruded Oswald West mudstones and the Astoria Formation. These aphanitic to finely crystalline equigranular basaltic intrusives locally fed over 2000 feet of palagonitized pillow lavas and basaltic breccias which now form the highest peaks in the area. The intrusives locally penecontemporaneously deformed the Astoria strata into a series of large-scale soft sediment deformation folds and sedimentary breccias.

Cape Foulweather Basalt intrudes all sedimentary units and cuts the Depoe Bay Basalts. The basalt is recognized by sparse, large plagioclase phenocrysts.

The area is cut by several east-west and north-south trending high angle faults with up to 500 feet displacement. A large north-south syncline in the central part of the thesis area delineates a structural and depositional basin. A smaller north-plunging anticline is present near the coast.

Recent landslides in the Silver Point member have been particularly destructive along the coast and inland; they have been caused by wave, stream action, and by man over-steepening unstable slopes. Crushed basalt quarry rock and potential petroleum reservoirs in the Angora Peak sandstones in stratigraphic and structural tra traps, particularly in nearby offshore areas, are the main geological economic resources of the area.

Stratigraphy and Sedimentation of the Onion Peak Area, Clatsop County, Oregon

by

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I would also like to thank my parents and close friends for their aid and understanding while writing this thesis.

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STRATIGRAPHY AND SEDIMENTATION OF THE ONION PEAK AREA, CLATSOP COUNTY, OREGON

INTRODUCTION

Location and Accessibility

The area investigated is located in southwestern Clatsop County, approximately 30 miles south of the city of Astoria, Oregon. The rectangular-shaped area extends ten miles inland and five miles along the coast between the towns of Tolovana Park and Arch Cape, a total area of 50 square miles (Figure 1). The tallest peaks in the thesis area, Onion Peak and Sugarloaf Mountain, reach heights of over 3000 feet.

U.S. Highway 101 traverses the west side of the area, and State Highway 53 delineates the eastern border. Hug Point mainline logging road from Highway 101 provides easy access to the southern and central parts of the area while the northern part can be reached by the Tolovana mainline logging road. Kidders Butte and Onion Peak logging roads off Highway 53 provide access to the eastern half of the thesis area. Numerous gravel and dirt spur roads provide vehicular access to the remaining points within the thesis area.

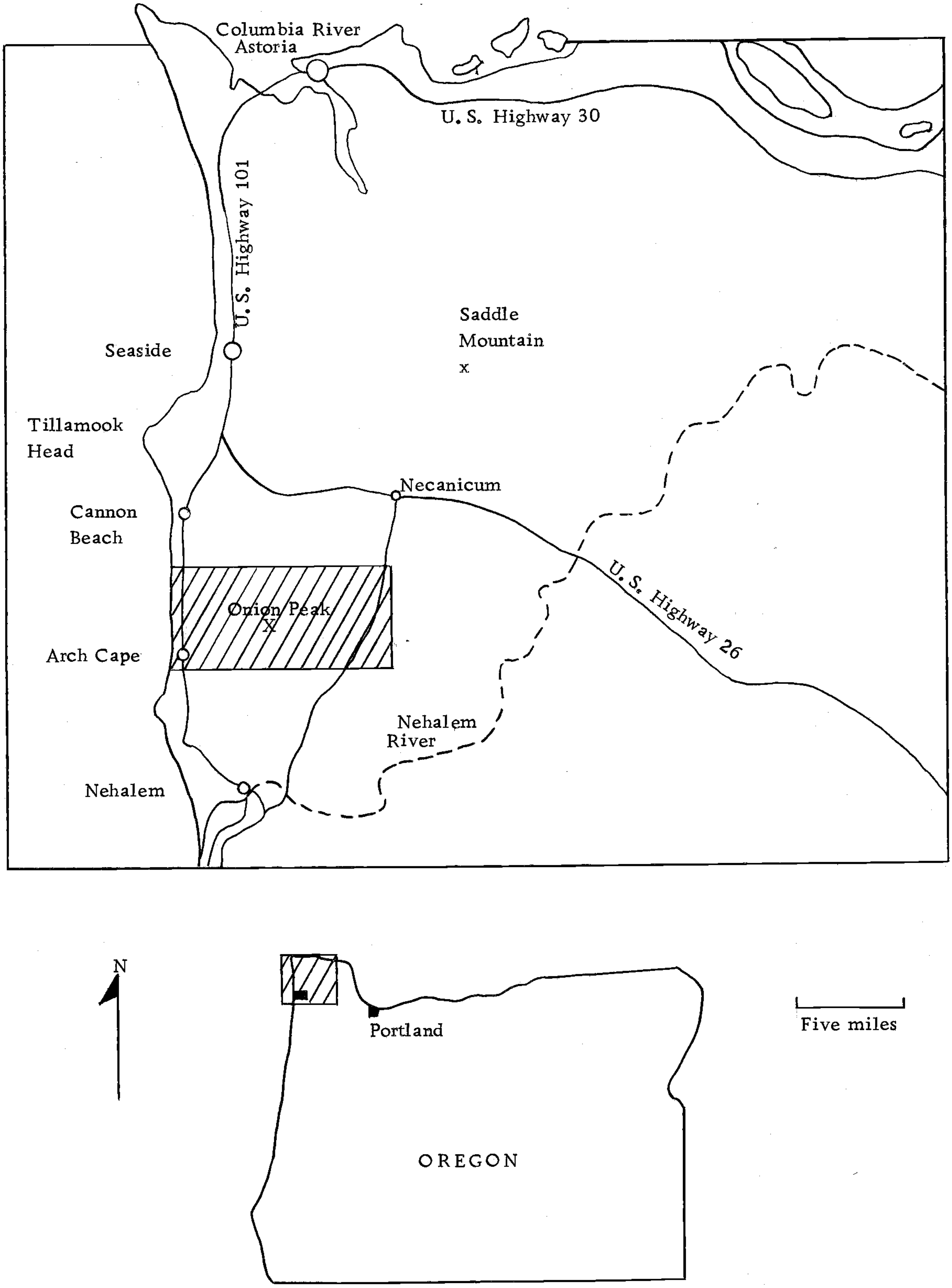


Figure 1. Index map showing the location of Onion Peak thesis area.

Figure 2. View looking south from Ecola State Park across thesis area. Extrusive breccias of Depoe Bay Basalt form the rugged mountain terrain (Onion Peak and Sugarloaf Mountain) in the background with the lower hilly slopes to the coast formed by Silver Point mudstones. Haystack Rock (far right), the town of Cannon Beach, and basaltic sea stacks are in the middle of the photograph.

Climate and Vegetation

The ameliorating effect of the ocean generates a mild and wet climate in the Onion Peak area. Seaside, Oregon, has an average annual temperature of 51°F. Monthly average temperatures range from 43°F in January to 60°F in July. Temperature extremes at Seaside during the year of 1971 ranged from 23°F in January to 89°F in August. Temperature extremes are greater inland. Precipitation is heavy during winter and light in summer. Seaside received 75.39 inches of rain during 1972 (U.S.N.O.A.A., Climatological Data, Oregon, 1972).

The area is subject to severe winter storms. These storms produce as much as five inches of rain in 24 hours. Sheet wash and flooding are primary agents of erosion. Due to the prevalent mild, wet climate, chemical leaching of the soils is extensive. Some zones of leaching penetrate more than 20 feet below the surface. In summer, upwelling causes coastal fog.

The densely vegetated area is covered with extensive stands of Douglas fir, lesser stands of hemlock, spruce, cedar, and alder. The understory is a dense growth of berry bushes, vines, shrubs, ferns, and grasses. Most of the thesis area was recently clear cut (1970) and now contains new stands of small firs.

Purposes of Investigation

The purposes of this investigation were (1) to map the rocks and structure of the area, (2) to describe the geologic units, (3) to reconstruct the geologic history, and (4) to determine the paleoenvironments, source areas, and economic potential of these units.

Previous Work

The earliest geologic work in the area was by Diller (1896) who referred to Onion Peak as an old volcano during his reconnaissance of the northern coast of Oregon. The peak was thought to be an eroded remnant of a larger volcanic ridge, which included Saddle Mountain (to the north of the thesis area).

Washburne (1914) explored the Cannon Beach area in an early search for petroleum and coal resources. He described a coarse-grained, massive, and locally cross-bedded pebbly sandstone in the Hug Point area (now the Astoria Formation). Washburne estimated that 400 feet of sedimentary rocks cropped out in this region. The laminated sandstones and siltstones at Silver Point were assigned to the "Astoria Shales" and the sandstones in the southern half of Cannon Beach (near Hug Point) to the formation above the "Astoria Shales".

Warren, Norbisrath, and Grivetti in 1945 published an oil and gas investigations reconnaissance map (scale 1:143,000) of the northern

Coast Range of Oregon which included the thesis area. They distinguished between basalts and undifferentiated Oligocene to Miocene sedimentary rocks in the thesis area. Wells and Peck (1961) compiled a map of Oregon west of the 121st meridian. On this map middle Miocene intrusive and extrusive basalts were differentiated from the middle Miocene Astoria Formation and marine sedimentary rocks of Oligocene and early Miocene age.

Because of rapid population increases in the area during the 1960-70 decade, the need for an evaluation of geologic hazards of the area became apparent. Schlicker and others (1972) published a series of engineering geologic maps of Clatsop County. They restricted the Astoria Formation to the thick middle Miocene sandstones near and at Hug Point. Middle Miocene basaltic breccias and pillow basalts forming Onion Peak and Sugarloaf Mountain (correlative to the Columbia River Basalts) are differentiated from basaltic intrusives. Oligocene to Miocene sedimentary rocks are undifferentiated in the eastern and northwestern parts of the thesis area. A review of the landsliding hazards is also presented.

Detailed studies of the Miocene volcanic rocks of the Oregon Coast Range have been published by Snavely and others (1973). Two major basalt types in the Coast Range were recognized: the Depoe Bay Basalts and the younger Cape Foulweather Basalts. They made several chemical analyses of the basaltic breccias on a reconnaissance of the thesis area. Based on petrographic and chemical evidence, the basaltic breccia was correlated to the Columbia River Basalts of eastern Oregon and Washington.

A master's thesis on 35 square miles adjacent to the south boundary of this thesis area was recently completed at Oregon State University by Frank Cressy (1974). Cressy differentiated middle Miocene basalt intrusive sills and dikes, extrusive breccias, and an 1800-foot Oligocene turbidite sequence (mudstones of Oswald West State Park) from the Angora Peak sandstone member of the Astoria Formation. He made a detailed stratigraphic, paleocurrent, and petrographic analysis of the sandstones and mudstones of Oswald West mudstones and the Angora Peak sandstone member. Cressy located several layers of bituminous and subbituminous coal in the Angora Peak sandstone member.

Methods of Investigation

Field Methods

Field work was conducted for four months during the summers of 1972 and 1973. Field work consisted of geologic mapping, measurement and description of stratigraphic sections, collection of rock and fossil samples, and measurement of paleocurrent indicators. Rock units and structure were mapped on State of Oregon Department of

Forestry aerial photographs (1971, scale 1:12,000). Data from these photos were transferred to enlarged (four inches equal one mile) copies of the Cannon Beach (1955) quadrangle (Plate I).

Three partial stratigraphic sections were measured with a Brunton compass and an Abney level mounted on a five-foot Jacob staff (descriptions in Appendices I, II, and III). Hand specimen descriptions were aided by a 10X hand lens, a sand gauge chart, and a Geological Society of America Rock-Color Chart (1963). Orientation of paleocurrent structures (cross-bedding, imbrication, and flute marks) was measured with a Brunton compass and rotated for tectonic tilt on a stereonet according to the methods outlined by Pettijohn and Potter (1961).

One-hundred and fifteen rock and fossil samples of representative major lithological units were collected for further laboratory study. In addition, over 70 plant, invertebrate, vertebrate, and trace fossil (burrow) samples were collected for identification. Pebble counts were made of 100 or more randomly collected pebbles at seven conglomerate localities (see Appendix IV).

Wentworth grain size and Fisher's (1961) volcaniclastic size terminology were employed to help classify clastic rocks. Sandstones and igneous rocks were further classified according to petrographic schemes from Williams, Turner, and Gilbert (1954). Stratification and cross-stratification terminology is in accordance with that of McKee and Weir (1953).

Analytical Methods

Laboratory study of field samples consisted of sieve and heavy mineral analysis of selected sandstones, plus thin section study and modal analysis of both sandstones and basalts. Chemical analysis of major metal oxides was performed on four basalt samples and three selected "unusual" igneous conglomerate pebbles. Mudstones were disaggregated to recover foraminifera. Eleven X-ray diffraction analyses of clay minerals from sandstones and of mudstones were made.

Modal analysis (600 points counted per slide) of thin sections of ten sandstone samples and six basalt samples was conducted with the aid of a mechanical stage (1x1 mm spacing and 10X or 50X power objective, depending upon grain size). Rock billets were stained for plagioclase and potash feldspar using the methods of Laniz and others (1964).

Seven basalt samples were prepared for chemical analysis using the Oregon State University Department of Geology's crushing and pulverizing equipment. The powder was then fluxed in an oven at 1100°C. to produce glass buttons. The buttons were submitted to Dr. E. M. Taylor (Associate Professor, Department of Geology at Oregon State University) who used X-ray fluorescence, spectrometer, and atomic absorption equipment to calculate percentage abundance of eight common metal oxides (Appendix IX).

Forty mudstone samples were disaggregated by boiling in Calgon and wet sieved to separate silt from clay-sized material. Foraminifera were separated from the coarser material, mounted on slides, and sent to Weldon Rau (Geologist, State of Washington Department of Natural Resources) for identification. These muds were treated with 30% H_2O_2 to obtain their organic carbon content. Further pretreatment included removal of iron and carbonate. After decanting and centrifuging, slides of nine oriented clay samples were X-rayed on the Norelco diffraction unit of the Oregon State University Department of Geology. Further treatment of X-rayed samples included glycolation and heating to 400°C. and 550°C. Interpretation of clay mineral diffraction patterns was aided by the use of the U. S. Geological Survey flow chart for clay mineral identification (Hathaway) and by a guide to clay mineral identification (Carroll, 1970).

Size analysis of sieved samples of Angora Peak sandstones and one from the Silver Point member was undertaken using sieving and hydrometer methods outlined by Royse (1970). Samples were disaggregated by using a rubber pestle and ten percent HCl. Pretreatment also included removal of carbonaceous organic material with 30% H_2O_2. Disaggregated material was passed through Tyler sieves in 1/2 phi intervals. Samples composed of abundant fines (less than four phi in size) were first wet sieved, then the fine fraction was placed in a 1000 ml beaker for hydrometer analysis. Statistical grain size parameters (mean, mode, standard deviation, kurtosis, and skewness) of Folk and Ward (1957) were calculated from cumulative weight percentage curves, and then plotted on Friedman's (1962) and Passega's (1957) graphs, in order to determine depositional environments.

Heavy minerals of eight sandstone samples from 3.5 and 4.0 phi size fraction were separated from the light fraction by use of tetrabromoethane (specific gravity 2.85). Mineral separates were mounted on slides with Lakeside 70 for petrographic analysis. Milner's (1962) heavy mineral guidebook was used as a reference for identification of heavy minerals (Appendix VI).

Molluscan fossils were sent to Dr. Warren Addicott of the U.S. Geological Survey and fossil burrows (ichnofossils) were sent to Dr. C. Kent Chamberlain, Department of Geology at Ohio University, for identification and paleoecological information.

REGIONAL STRATIGRAPHY

The strata of the northern Coast Range (Baldwin, 1964) comprise a total thickness of over 20,000 feet (Schlicker and others, 1972). The rocks exposed in this area include middle and late Eocene and middle Miocene basaltic flows, intrusives, and breccias, late Eocene, Oligocene, and Miocene shallow and deep marine mudstones, siltstones, and sandstones, deltaic deposits, recent marine terrace deposits, and alluvium. The oldest rocks exposed in the northern Coast Range are early to middle Eocene submarine lava flows, breccias, and tuffs of the Tillamook Volcanic Series (Warren and others, 1945). Six thousand to 10,000 feet of volcanic rocks crop out along the Trask River near the town of Tillamook. The base of the sequence is not exposed. The volcanics form the core of the anticlinorium in the northern Coast Range. Most of the tholeiitic and alkalic basalts are petrographic and age equivalents to the Siletz River Volcanic Series of the central Coast Range (Snavely and Baldwin, 1948). The basalts interfinger with late Eocene tuffs and tuffaceous shales to the east and south.

The Yamhill Formation directly overlies the early Eocene Siletz River Volcanic Series in the southern part of the anticlinorium (Baldwin, 1964). It occupies the same stratigraphic position as the Tyee Formation elsewhere in the Coast Range (Figure 3) and consists of basal basaltic conglomerate beds eroded from the older Tillamook Volcanics and deep marine siltstones.

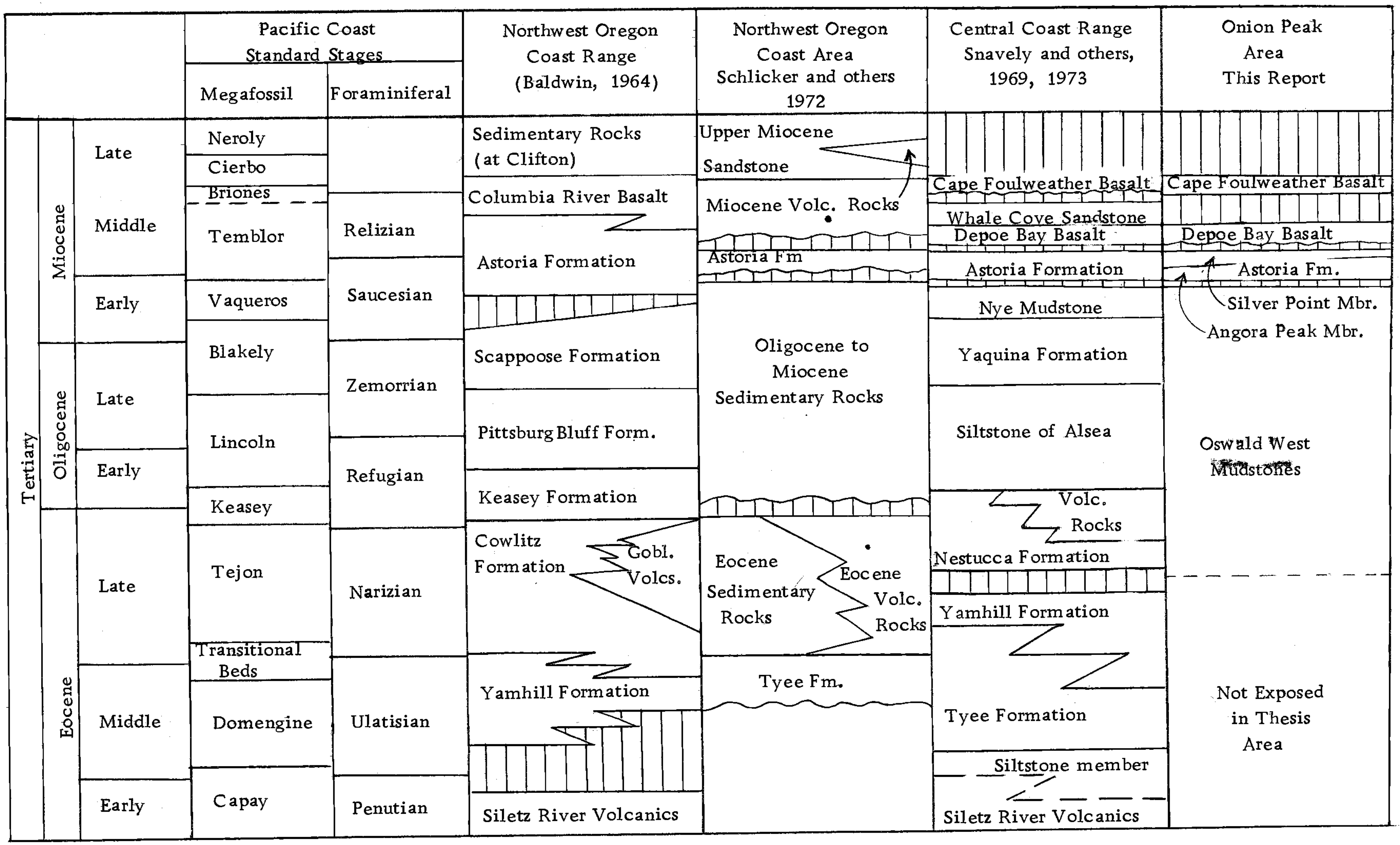


Figure 3. Correlation chart of tertiary formations of the northern and central Oregon Coast Range.

Late Eocene basaltic conglomerates and sandstones, glauconitic sandstones, tuffaceous claystones to siltstones and locally micaceous, quartzose sandstones of the Cowlitz Formation enclose the Tillamook Volcanic Series to the north, east, and west. The intervening Yamhill Formation is not recognized in these areas. An angular unconformity separates the Cowlitz from the Tillamook Volcanics. The Cowlitz is approximately 950 feet thick and is exposed in the northeastern part of the Coast Range (Warren and others, 1945).

Interfingering with the Cowlitz Formation is the latest Eocene and possibly early Oligocene Goble Volcanic Series (Wilkinson, Lowry, and Baldwin, 1946). The series comprises over 5000 feet of widespread basalt flows and pyroclastics with associated sediments.

The Keasey shale overlies the Cowlitz Formation with no structural discordance and has not been found in contact with the Goble Volcanic Series (Warren and others, 1945). The type Keasey is subdivided into three members: a lower dark mudstone member, a middle member consisting of fossiliferous uniform, massive silty tuffaceous mudstones, and an upper member consisting of well-bedded tuffaceous sandy mudstones. The 1800 feet of strata are early Oligocene in age.

The middle Oligocene Pittsburg Bluff Formation conformably overlies the Keasey shale. It consists of two members. The basal member varies from shallow marine, massive quartzose sandstone to fine-grained fluvial sandstones associated with coal beds. This member is 500 feet thick and thins both to the north and to the south. The upper member contains several ash beds in a poorly stratified, sandy tuffaceous mudstone.

Fifteen hundred feet of fine-grained sandstone and sandy tuffaceous mudstones of the Scappoose Formation conformably overlie the Pittsburg Bluff Formation in the northeastern Coast Range. The local occurrence of cross-bedded sandstones, containing carbonized wood and leaf imprints, channelized basalt, and quartzite conglomerates, suggest a deltaic origin for these strata (Van Atta, 1971). These beds are Blakely in age (late Oligocene and early Miocene). The Scappoose Formation has not been recognized in the northwest part of the Coast Range. Along the Oregon coast, Blakely age sedimentary rocks are exposed at Short Sands Beach and have been informally called the Oswald West mudstones by Niem and Van Atta (1973) and Cressy (1974). The strata here consist of 1500 feet of alternating mudstones and tuffaceous siltstones containing graded sandstones, submarine mudflow deposits, and clastic dikes. The beds were deposited in a deep-water open marine environment and are well-bedded and burrowed (Cressy, 1974).

The Cowlitz, Keasey, and Pittsburg Bluff formations are recognized only in the northeastern part of the Coast Range. The Nestucca and the siltstones of Alsea (Snavely and others, 1964) are correlatives of these units in the central Coast Range. Late Eocene-Oligocene strata corresponding to these formations are undifferentiated on the western flank of the northern Coast Range (Wells and Peck, 1961). Only the Scappoose formation, which is correlative to the Yaquina Formation, the Oswald West mudstones (Cressy, 1974), and partly equivalent to the Nye mudstone, to the south, has been correlated to the northwestern Coast Range units.

The Astoria Formation overlies the undifferentiated Eocene to Oligocene strata with an angular unconformity mapped in the western part of the northern Coast Range (Wells and Peck, 1961). Three members of the Astoria Formation were recognized in the type area by Howe (1926). The three members included a lower member composed of 150 feet of thinly bedded mudstones and sandstones, a 1000-foot mudstone member including thin glauconite sandstones, and an upper structureless and cross-bedded arkosic sandstone unit. In the thesis area, the Astoria Formation contains two mappable members: the Angora Peak sandstone member (informal) and the Silver Point mudstone member (informal). The Angora Peak sandstone member, which overlies the Oswald West sandstones with an angular conformity, was proposed informally as a member of the Astoria Formation by Niem and Van Atta (1973) and Cressy (1974). The Angora Peak member consists of over 1000 feet of thick laminated and cross-bedded shallow marine arkosic sandstones and rare volcanic conglomerate, structureless micaceous siltstones, and coal beds. The Silver Point mudstones are informally proposed as the overlying member of the Astoria Formation in this thesis.

Subaerial Columbia River Basalts overlie older formations with an angular unconformity in the eastern part of the northern Coast Range (Baldwin, 1964). Two middle Miocene volcanic units, the Depoe Bay and the Cape Foulweather Basalt, are recognized in the western Coast Range (Snavely and others, 1973). The units are petrologic and age equivalents of the Yakima and late Yakima Basalts of the Columbia River Group. The Depoe Bay Basalts and the younger Cape Foulweather Basalts occur as a series of dikes and thick sills, pillow breccias, pillow lavas, and rare tuff beds. Cape Foulweather Basalt is characterized by scattered large plagioclase phenocrysts.

Thick, cross-bedded, non-marine beds of arkosic sandstone overlie the Columbia River Basalts in northern Clatsop County. The sandstones may be late Miocene or early Pliocene in age. The beds are approximately 600 feet thick (Warren and others, 1945).

DESCRIPTIVE GEOLOGY OF THE THESIS AREA

Late Eocene to Early Miocene Mudstones

Oswald West Mudstones

Warren and others (1945) mapped undifferentiated mudstones and interbedded tuffaceous siltstones of late Eocene to Oligocene age in the eastern part of the thesis area. Cressy (1974) defined, measured, and described over 1000 feet of well-exposed bedded mudstones and tuffaceous siltstones along the sea cliffs in Oswald West State Park (four miles south of the thesis area) and informally referred to this type section as the "Oswald West mudstones". He mapped these late Oligocene to early Miocene mudstones in detail in the eastern and southern parts of his thesis area (adjacent to the south boundary of the Onion Peak area). The informal name, Oswald West mudstones, is applied in this thesis to mudstones that are lithologically similar to the mudstones in Oswald West State Park. The Oswald West mudstones are overlain with angular unconformity by the Angora Peak sandstone member of the Astoria Formation at Oswald West State Park (Cressy, 1974).

The mudstones are the oldest unit exposed in the thesis area and cover approximately 13 square miles in the eastern part along Oregon Highway 53 (Plate I). In general, the mudstones are deeply weathered and form a low, hummocky topography of hills and small valleys.

Only in recent road cuts and deeply incised streams can fresh exposures be found. The freshest exposures occur along the west bank of the Nehalem River and in a quarry in the SW 1/4 of section 29, T. 4 N., R. 9 W.

Lithologies and Structures. The dominant lithologies in the Oswald West mudstones are burrowed, well-bedded, gray, silty mudstones and subordinate light colored tuffaceous siltstones (Figure 4). Clastic dikes of fine-grained sandstone and a glauconitic sandstone occur in the middle of the unit. In fresh exposures, the mudstone is well-indurated and ranges from medium gray (N5) to very light gray (N8) in color. Weathered outcrops are typically iron-stained and quite crumbly, breaking into small chips. The weathered color is moderate brown (5YR 4/4). Based on a map measurement using regional dips and outcrop distribution, it is estimated that several hundred feet of Oswald West mudstones occur in the thesis area. A complete exposure defining total thickness was not located. In the northeastern part of the area, the Oswald West mudstones consist of thick-bedded mudstone layers ranging from 2 to 15 feet in thickness, with light buff colored, thin (0.3 to 1.0 feet) tuffaceous beds and a few calcareous concretions and nodules aligned along bedding planes (Figure 4). These exposures are estimated to be stratigraphically near the middle of the Oswald West mudstones exposed in the area and can be observed along logging road cuts in sections 9 and 10, T. 4 N., R. 9 W.

Figure 4. Typical crumbly outcrop of Oswald West mudstones. Note horizontal white tuffaceous interbeds. Person in upper right of photo for scale. Sample locality 13 (Plate I), Section 9, T. 4 N., R. 9 W.

The tuffaceous siltstones and rare very fine-grained sandstone beds in the Oswald West mudstones are very light gray (N8) in color. These beds range from mere wisps to one foot in thickness, display sharp, planar contacts with the mudstone, and contain no visible sedimentary structures. Calcareous concretions are aligned along bedding planes. The concretions are elongate, averaging five inches long by one inch thick and contain no fossils. Concretionary beds are slightly coarser grained than the surrounding mudstones.

A glauconitic sandstone bed (up to 20 feet thick) occurs in the middle of the Oswald West mudstones and is exposed in section 9, T. 4 N., R. 9 W. (Plate I). The fresh color is dusky yellow green (5 GY 5/2) and weathers to dark yellowish orange (10 YR 6/6) color in an iron-stained, spheroidal form.

The contacts of the glauconitic sandstone with the overlying and underlying mudstones are abrupt, sharp, and planar. This sandstone, being slightly more resistant to erosion than the surrounding mudstones, forms a north-south trending ridge (Plate I). The greenish sandstone is structureless. Bedding is recognized by the occurrence of aligned, elongated calcareous concretions and rare light buff, thin (less than six inches thick) tuffaceous siltstone beds much like those found in the mudstones. The sandstones are generally one to two feet thick, separated by thin, tuffaceous siltstones up to six inches thick. Glauconite sandstones have been hydroplastically squeezed into the overlying mudstones, forming clastic dikes up to one foot in thickness. These dikes are very irregular and less than 15 feet long. Hydroplastic deformation of these sandstones during deposition and early diagenesis obliterated original bedding and resulted in a swirled or marbled appearance. Neel (1975) recognizes and mapped a similar glauconitic sandstone in the Oswald West mudstones at the same approximate stratigraphic horizon near Kidders Butte (adjacent to the northern boundary of this thesis area).

Two fossil localities were found in the Oswald West mudstones. One is in the SE 1/4 of section 16, T. 4 N., R. 9 W. and the other is in the NE 1/4 of the same section. Fossils from these localities include gastropods (Naticid, Cidarina n. sp. ?, and Cavolinid) and pelecypods (Lima sp., undetermined mud pecten, and Nucula hannibali Clark) (Addicott, written communication, 1974). Foraminifera were also noted in these mudstones; however, extensive weathering has destroyed identifiable characteristics.

Near the Nehalem River, in section 29, T. 4 N., R. 9 W., over 100 feet of well-bedded, fresh Oswald West mudstones have been quarried for road material. These mudstones are situated in the upper part of the Oswald West mudstones within a few hundred feet of the contact with the overlying Angora Peak sandstones. The mudstones are typical of the upper part of the Oswald West mudstones mapped in the thesis area above the glauconitic sandstone. The mudstone beds are thinner and have been disrupted by burrowing more than the beds in the middle section of the Oswald West mudstones. Small clastic sandstone dikes up to six inches wide and several feet long cut through the mudstones. The dikes are composed of angular, poorly sorted, very fine-grained sandstone. Source sandstone beds are absent, presumably not exposed in the limited outcrop area.

These mudstones are extensively burrowed. Many of the light colored tuffaceous siltstones and darker mudstones have been reworked into discontinuous beds by burrowing organisms, giving the mudstone an overall mottled appearance. Burrows are found on bedding plane surfaces as dark, ribbon spiraling tubes, composed of darker fecal pellets surrounded by lighter tuffaceous detritus. The burrow forms were identified by Dr. C. Kent Chamberlain of Ohio University (written communication, 1974) as fecal ribbon <u>Scalarituba</u> (<u>Helminthoida</u>) and branching, agglutinated worm tubes called <u>Terebellina</u>. These burrows are indicative of deposition in deep water (upper bathyal depths). No foraminifera or molluscan fossils were found in this area.

<u>Petrology</u>. In thin section, the light buff colored tuff beds in the Oswald West mudstones consist of altered bubble-wall and sickle-shaped glass shards, with scattered euhedral grains of quartz and plagioclase in a clay matrix. Most of the shard shapes are still recognizable despite the transformation of the volcanic glass to clay and zeolite minerals. The clay matrix forms approximately 50% of the tuff and

appears as nearly isotropic volcanic dust altered to clays. The presence of rare small spherical organic fecal and limonite pellets suggests that these water-laid tuffs were reworked in part by burrowing organisms. X-ray diffraction analysis showed only the zeolite clinoptilolite is present. Clinoptilolite is typically a solution and replacement product of intermediate to acidic volcanic glass rather than a product of devitrification or hydration of volcanic glass in the solid state (Hay, 1966). In marine tuffs, the formation of clinoptilolite is typically aided by the presence of montmorillonite; montmorillonite was absent in the sample studied.

Petrographically, the glauconitic sandstone is composed of 54% glauconite, 24% carbonate and limonite cement, 10% detrital grains, and 10% clay matrix. The medium sand-sized detrital grains are comprised of rounded volcanic rock fragments and minor quantities of angular to subangular quartz and plagioclase grains. Well-rounded pellets of glauconite are in grain support. The glauconite grains are coarse sand-sized and well-sorted. Some pellets partially replace volcanic rock fragments. Weathered glauconite grains are commonly oxidized to yellowish-orange limonite. The contorted brownish clay matrix appears wrapped and squeezed around the framework grains, suggesting extensive compaction of the sandstone strata during diagenesis. Scattered glauconite pellets are suspended in the clay matrix of clastic dikes.

X-ray diffraction analysis of fresh samples of Oswald West mudstones revealed a composition of mixed-layer chlorites and illites. Montmorillonite was identified in addition to the other two clays in more weathered samples (Appendix VIII). These clays may be detrital and/or diagenetic in origin. Polymorph chlorite is formed in marine sediments from the diagenetic alteration of ferro-magnesian minerals. Montmorillonite forms authigenically from basic and intermediate volcanic rock fragments and glass in contact with sea water. The mixed-layer clays probably reflect a readjustment of pure clay minerals during weathering and diagenesis. Detrital illite is common in marine sediments (Carroll, 1970).

Contact Relations. The basal contact of the Oswald West mudstones is not exposed in the thesis area. The contact of these mudstones with the overlying Angora Peak sandstone member of the Astoria Formation is an apparent angular unconformity. Deep-water Oswald West mudstones are sharply overlain by fluvial conglomerates and shallow marine sandstones. This lithologic change is abrupt rather than a gradual transition of one facies to another. Cressy (1974) noted that in the Oswald West State Park-Angora Peak area molluscan fossil assemblages yielded Blakely age for the Oswald West mudstones and Temblor age for the Angora Peak sandstones. The abruptness in change of facies and local angular discordance in dips, and the fact that fossils of the intervening Vaqueros age are absent further indicate the existence of an unconformity.

Age and Correlation. On the basis of molluscan faunas, a late Oligocene to early Miocene age is definitely assigned to the Oswald West mudstones in the thesis area. Gastropods (Naticid *Cidarina* n. sp. ?, and Cavolinid) and pelecypods (*Lima* sp., undetermined mud pecten, and *Nucula hannibali* Clark) place the age at Blakely Stage (Addicott, written communication, 1974).

Adjacent to the thesis area, similar mudstones that occupy the same stratigraphic position were also dated as Blakely Stage. Microfauna and megafauna collected from the type Oswald West mudstones by Cressy (1974), Diller (1896), and Warren and others (1945) include the Blakely Stage from megafossils (late Oligocene to Miocene); and Zemorrian (late Oligocene) to Saucesian (early Miocene) from foraminifera. Since the lower contact of Oswald West mudstones is not exposed in the thesis area, these ages are minimal. Neel (1975) found foraminifera of late Eocene age in strata he mapped as the lowest part of the Oswald West mudstones five miles north of the thesis area. A probable late Eocene alkalic basalt dike intrudes the Oswald West mudstones in the southeast part of the thesis area (Plate I), suggesting that the Oswald West mudstones in the thesis area below the glauconitic sandstone also include late Eocene-middle Oligocene strata. Thus, the Oswald West mudstones in this thesis area include more and older strata than the original defined by Cressy (1974). Cressy did not recognize a basal contact of the Oswald West mudstones in his thesis area. However, in general, since the mudstone appears everywhere lithologically similar (with the exception of the glauconitic sandstone), it is believed to be the easiest way to map the late Eocene to early Miocene rocks in the area. The Oswald West mudstones above the glauconitic sandstone closely resemble the type Oswald West described by Cressy at Short Sands Beach in Oswald West State Park. The older mudstone strata below the glauconitic sandstone, mapped as Oswald West mudstones, although similar to the type Oswald West mudstones, appear overall to be darker in color and much more crumbly (weathering to small chips). The glauconitic sandstone then would be roughly the describing horizon between typical Oswald West mudstones and older undifferentiated late Eocene-Oligocene strata. (The glauconitic sandstone would be included in the older unit because Cressy did not recognize a glauconitic sandstone in the type Oswald West mudstones.) However, the glauconitic sandstone does not appear everywhere for mapping purposes and many times the cited mudstone distinctions are difficult to discern. Therefore, for the sake of convenience, all the mudstones below the Angora Peak sandstones in the thesis area are mapped as the Oswald West mudstones. Perhaps, at some further date when the regional geologic picture of the late Eocene-middle Oligocene stratigraphy is more thoroughly understood, the Oswald West mudstone strata will be further differentiated in this thesis area into typical Oswald West mudstones (late Oligocene to early Miocene) and into older units (late Eocene to middle Oligocene) as has been done in the northeastern part of the northern Coast Range (Warren, Norbisrath, and Grivetti, 1945). Oswald West mudstones are included in units mapped by Wells and Peck (1961) as undifferentiated late Eocene to Oligocene sedimentary rocks and by Schlicker and others (1972) as undifferentiated Oligocene to Miocene sedimentary rocks.

The Yaquina Formation, Nye mudstones, and upper part of the Siltstones of Alsea, near Newport, Oregon, and the Scappoose Formation, located 40 miles to the east of the thesis area, are age correlatives to Oswald West mudstones (Figure 3).

Depositional Environments. Benthonic foraminifera and molluscan fossils collected in Oswald West mudstones immediately adjacent to the thesis area by Cressy (1974) and Neel (1975) indicate that sediment deposition occurred in cool marine waters in outer sublittoral to upper bathyal depths (500 to 2000 feet). A moderate to deep water normal marine environment for the Oswald West mudstones in the thesis area is also suggested by the occurrence of the trace fossils (burrows) *Scalarituba* (=*Helminthoida*) and *Terebellina* (Chamberlain, written communication, 1974). The abundance of these intricate feeding burrow patterns located on bedding plane surfaces suggests slow deposition in a nutrient-starved environment.

The predominance of laminated and burrowed mudstone and tuffaceous siltstone lithologies in the Oswald West mudstones further suggests slow deposition of clay- and silt-sized fragments, including volcanic ash settling out of suspension in a low energy environment. Some size separation of detritus into silt and mud beds probably occurred by reworking by gentle tractive currents. Sedimentation rates fluctuated; however, the clastic dikes and loading features in the glauconitic sandstones and tuffaceous siltstones indicates relatively high rates of sedimentation and compaction.

The presence of glauconite and abundant disseminated organic matter in the darker mudstones, the lack of fossils and current-formed sedimentary structures, and local pyrite imply that deposition of the Oswald West mudstones occurred in a partially restricted reducing environment.

The thick glauconitic sandstone bed probably formed under the general depositional conditions postulated for the Oswald West mudstones, but in a shallower water, more current agitated environment. The sandstone was probably created in a two-stage process: (1) deposition of argillaceous material in pellet form, and (2) then glauconitization (Degens, 1965).

It is hypothesized that the glauconitic sandstones in the Oswald West mudstones formed during times of slow sedimentation from abundant fecal pellets or clay agglomerates (step 1) which were then glauconitized (step 2). Many glauconite pellets in thin section contain cores of small angular grains of quartz which can be observed under high power (50X objective) and some appear to be composed of an aggregate of smaller pellets. Most of the pellets are coarse sand-size, but some are as large as 0.25 inch.

It is hypothesized that clay minerals settle from suspension by forming flocs. The clay flocs were gradually worked back and forth by gentle currents and as a result of their cohesive nature (due to Van der Waals forces and electrostatic interaction) they began to adhere to one another to form larger clay pellets or clay agglomerates (snowball effect) until they reached a size that could no longer be moved by currents. Thus, a moderately sorted, glauconitic sandstone was formed with an extremely small amount of clay matrix. Abundant organic clay agglomerates of one size could have also formed through excretionary processes of sediment-ingesting worms and other invertebrate organisms. There are abundant fine sand-sized dark fecal pellets filling burrows in much of the Oswald West mudstones.

In order for glauconitization of the pellets to occur, the following conditions must be present: abundant three-layer lattice clays, a chemical environment enriched in K and Fe at reducing conditions, very slow sedimentation rates, weak current activity, normal ocean salinities, and a high organic content (White, 1967). These conditions were largely met in the Oswald West sedimentary environments as evidenced by: (1) presence of montmorillonite, mixed-layer, and illite clays in many of the mudstones, (2) abundant diagenetically unstable volcanic rock fragments and volcanic glass in the sandstone and mudstone which would yield iron and potassium ions during halmyrolysis (submarine weathering of clastics in contact with sea water), reducing conditions suggested by local presence of pyrite, and an abundance of disseminated organic matter (up to 6%), (3) low content of clay matrix and other detrital grains in the glauconitic sandstone, suggestive of slow sedimentation rates, and (4) occurrence of marine molluscan and foraminifera fossils which indicate normal marine salinities.

The contacts of the glauconite sandstones with the adjacent mudstones are sharp and planar. As a result of higher sedimentation rates or changes in chemical conditions, the formation of glauconite abruptly ceased, producing a sharp lithological change.

Oswald West mudstones were probably deposited in an open, moderate to deep water, outer shelf environment similar to that which exists off the present Oregon coast. Cressy (1974) and Neel (1975) noted, however, that the depth of water indicated by fossils, strata thickness, highly burrowed nature, and sedimentary structures of the Oswald West mudstones are similar to deposits of modern distal prodelta environments described by Gould (1970) for the Mississippi delta and by Allen (1970) for the Niger delta. They postulated that the Oswald West mudstones may represent deep-water prodelta facies associated with the deltaic shallow marine and fluvial sandstones of the coeval Scappoose Formation, which is exposed on the eastern side of the northern Coast Range.

Astoria Formation

The Astoria Formation occurs in a series of marine embayments from Newport, Oregon to Astoria, Oregon (Wells and Peck, 1961). The first published description of the Astoria Formation was by Cope in 1880. Howe (1926) divided the type Astoria Formation in the city of Astoria into three members: a lower 150-foot thick fine-grained sandstone member overlain by a 1000-foot thick mudstone member, and an overlying upper coarse-grained, arkosic sandstone member. The type area is now covered by urbanization of the City of Astoria and is no longer available for study. This cover has added to the confusion in studying the type Astoria Formation and tracing it elsewhere in Oregon and Washington.

The Astoria Formation is now considered to be middle Miocene in age by molluscan and foraminiferal faunas (Moore, 1963). The formation has been correlated by time-stratigraphic procedures as far south as Cape Blanco, Oregon (Durham, 1953) and into western Washington (Pease and Hoover, 1957; Snavely and others, 1958). Correlation of the Astoria Formation to other areas has been accomplished on a faunal basis, not by lithologies. As a result, middle Miocene strata mapped as Astoria Formation in western Oregon and Washington exhibit rapid facies changes from shallow marine sandstones to deep marine siltstones and mudstones that do not always correspond lithologically with the type Astoria Formation. The Astoria Formation has become a unit referring to middle Miocene strata in western Oregon and Washington and is deeply ingrained into the literature. As of 1963, over 75 papers had been published dealing with the Astoria Formation (Moore, 1963). To avoid further confusion, the name Astoria Formation is retained to refer to the middle Miocene strata traditionally mapped as Astoria Formation. However, very different mappable lithologic facies within this unit will be referred to as informal members within the formation. This is in accordance with the Code of Stratigraphic Nomenclature (1961). The subdivision of the Astoria into mappable members aids in mapping and describing distinctive lithologies while retaining the middle Miocene status of the unit. Over 1700 feet of Astoria Formation were measured in the thesis area (Appendix III).

Angora Peak Sandstone Member

Cressy (1974) proposed the informal use of Angora Peak sandstone member of the Astoria Formation to refer to sandstone traditionally mapped as the Astoria Formation by Wells and Peck (1961) and by Schlicker and others (1972) in the Angora Peak-Neahkahnie Mountain area. Cressy described a 1000-foot thick section of shallow marine, laminated, and cross-bedded feldspathic sandstones and subordinate fluvial lithic conglomerates, coal beds, and minor carbonaceous siltstones and mudstones near Angora Peak. This mappable member overlies Oswald West mudstones with an angular unconformity and underlies the Silver Point mudstone member of the Astoria Formation (defined in this thesis). The Angora Peak sandstone member can be physically traced into the thesis area from the type section, two miles to the south.

The Angora Peak sandstone member covers approximately four square miles near the coast and six square miles along the east-central part of the thesis area (Plate I). The best exposures of the laminated and cross-bedded sandstones and conglomerates occur along the coastal sea cliffs in the vicinity of Hug Point State Park and the Hug Point mainline logging road. One hundred and thirty-three feet of Angora Peak sandstone were measured near Austin Point in Hug Point State Park (Appendix I) and over 1100 feet along the Hug Point mainline logging road (Appendix III). The Angora Peak sandstone member in the thesis area is estimated to average 1000 feet thick from geometric calculations using average width of outcrop area and average dip of the strata.

Lithologies and Structures. The Angora Peak member in the thesis area is characterized by fine- to coarse-grained arkosic and lithic cross-bedded and laminated sandstones. In addition, there are cross-bedded conglomeratic sandstones and, in the upper and lower parts of the unit, thin micaceous and carbonaceous to coaly laminated mudstones and siltstones, and unusual channelized pebble and boulder conglomerates. These resistant sandstones form a series of intermediate ridges, in comparison to the low hills and irregular topography formed by the Oswald West and Silver Point mudstones.

In fresh exposures, the Angora Peak sandstones are firmly cemented by calcite and iron oxide and locally contain small egg-shaped pyrite concretions and nodules. They are grayish orange (10 YR 7/4) in color. In weathered outcrops, typical of inland exposures, the sandstones appear friable, noncalcareous, and are commonly iron-stained to a moderate brown (10 YR 5/4) color. Along the coast, the resistant sandstone weathers to large, angular blocks. Inland, the carbonate cement is leached from the sandstones, resulting in less resistant, friable outcrops which break down into small individual sand grains and pebbles when scratched with a geologic hammer.

The basal Angora Peak member is best exposed in the eastern part of the thesis area along Grassy Lake Creek and the logging road which parallels it (sections 29 and 30, T. 4 N., R. 10 W., near sample locality 58, Plate I). Here, directly overlying Oswald West mudstones, the basal 50 to 100 feet of the member are characterized by well bedded alternating highly carbonaceous and micaceous mudstones, siltstones, and thin (up to two inches) fine-grained sandstones. There are nearly equal amounts of sandstone and carbonaceous mudstone and siltstone. Sandstones are moderately sorted, feldspathic and micaceous and contain well preserved carbonized fossil leaves in calcareous concretions. These leaves have been identified by Dr. Dennis of the Botany Department of Oregon State University (written communication, 1973) as maple and alder. The highly carbonaceous mudstones are dark gray (N3). The feldspathic sandstones are light gray (N7) in color. These strata appear to be swamp, estuarine, and overbank deposits. Immediately above these basal beds are similar but thicker (up to seven feet), medium-grained, laminated sandstones. Overlying these laminated carbonaceous and micaceous sandstones are well indurated, coarse-grained pebble conglomerates at least 20 feet thick (see sample locality 57, Plate I, section 30, T. 4 N., R. 10 W.). These carbonate cemented conglomerate beds appear to be lenticular in shape. Individual pebbles are well rounded, in grain support, and are contained within a coarse feldspathic and quartz sandstone matrix. Pebbles range from one-half to three inches in diameter, are moderately sorted, and are predominantly quartzite, chert, and intermediate volcanics (Appendix IV).

The sea cliffs along the beach one-half mile south of Hug Point have excellent exposures of cross-bedded, fluvial, conglomeratic sandstones typical of the lower part of the Angora Peak sandstone member (see measured section, Appendix I). The coarse-grained sandstones grade upward into laminated micaceous and carbonaceous fine-grained sandstones typical of the upper part of the Angora Peak sandstones north of Hug Point. The lower 150 feet of the Angora Peak sandstones consist of large (one to seven feet in thickness), high angle (over 15^{o}), planar and trough cross-bedded sandstones (Figure 5) which appear to be graded. Individual cross-bed sets commonly begin with a thin basal layer of pebble conglomerate (only one or two pebbles thick) that grades upward into coarse sandstone along the inclined cross-bedding laminae. This unusual grading probably formed as a result of an "avalanche effect" of larger and heavier clasts sliding down the inclined cross-bed surface before the finer material, and then being preserved by the advancement of succeeding inclined cross-bed laminae during progradation. Layers of cross-beds are commonly sharply truncated by an overlying set. Fine-grained, micaceous, ripple microtrough cross-laminated sandstone beds, one to three feet in thickness, occur between the large-scale cross-bedded conglomeratic sandstones (Figure 5). Individual microtrough cross-bed sets are one-half inch in amplitude and contain six inch wave-lengths. In some places, cross-beds (one to three feet thick) contain no pebbles

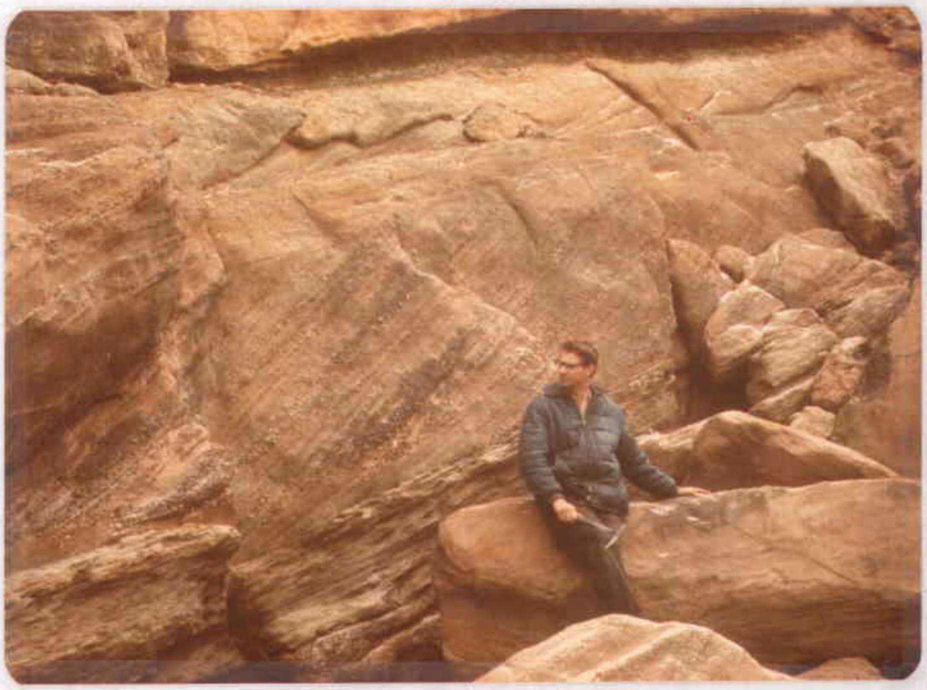


Figure 5. Large-scale planar cross-bedding in Angora Peak pebbly sandstones form the headland just south of Hug Point State Park. Note thin mudstone lens forming hollow near top of photo, and microtrough cross-laminated bed directly below the large foresets.

Figure 6. Calcareous concretions in laminated Angora Peak sandstone; sea cliff at Hug Point State Park.

but also exhibit normal grading from coarse, poorly sorted, angular sandstone into better sorted, medium-grained sandstones. Bedding contacts between adjacent cross-beds are commonly sharp with minor scour-and-fill structures (one to two-foot in relief).

Thin mudstone and siltstone interbeds (average four inches, up to one foot thick) occur between some of the cross-bedded sandstone units (Figure 5). These fine-grained beds are light gray (N7) in color and are structureless to laminated. Laminations are produced by the alternation of non-carbonaceous and darker carbonaceous mudstone beds, and by thin siltstones alternating with thin mudstones. The contacts between lens-shaped mudstone beds and the overlying and underlying sandstones are sharp and irregular. Loading and possibly scour-and-fill by the overlying sandstone beds account for the irregularities.

The conglomeratic sandstones of the lower part of the Angora Peak sandstone member are poorly sorted, arkosic to lithic in composition, and contain coarse sand to fine pebbles (up to two inches). Sand grains are angular to subangular and are dominantly quartz and feldspar. The pebbles are subrounded to rounded and are mainly composed of pumice, silicified tuff, basalt, andesite, dacite, quartzite, and chert (Appendix IV). The sandstones are firmly cemented by carbonate and limonite and form small headlands in the Hug Point State Park area.

Northward along the coast from the Hug Point State Park picnic area to the old wagon road crossing Hug Point, there is a 100-foot thick section of bedded (up to 30 feet) laminated sandstones which appear to overlie and intertongue with cross-bedded conglomeratic sandstones (15 to 20 feet thick) which are typical of the lower Angora Peak sandstone. The stratigraphic relationships between the cross-bedded and the thickly laminated sandstones is uncertain because of large-scale penecontemporaneous faulting and folding in this area. The laminated sandstones are highly deformed as a result of penecontemporaneous slumping which occurred soon after deposition (see section on Soft Sediment Deformation Features). Large laminated dark mudstone and siltstone blocks (up to ten feet long and three feet wide) also occur within these deformed strata. The laminated sandstones are coarse- to medium-grained, feldspathic, and are carbonate cemented. The cement forms an unusual nodular concretionary pattern in the sandstone (Figure 7).

In the sea cliffs immediately north of Hug Point, this soft sediment deformation zone continues (Figure 31). Near the base of these cliffs are conglomeratic sandstone channels (up to eight feet wide and two feet deep). Pebble sizes and lithologies are similar to those previously discussed (Appendix IV). Above these channels there are cross-bedded fine-grained sandstones and overlying laminated fine-grained sandstones. These are vertical and contorted (Figure 7).

Figure 7. Vertical and contorted Angora Peak strata in the 100-foot sea cliff immediately north of Hug Point. Note thin basaltic dike (arrow) cutting across deformed strata.

Figure 8. Thoroughly mixed (soft sediment deformed) "dirty" sandstone containing scattered cohesive mudstone clasts and large rounded pebbles; just north of Hug Point near locality in Figure 7.

In places where penecontemporaneous soft sediment deformation was more severe, bedding was thoroughly disrupted; gravel, sand, and mud beds were mixed to form structureless "dirty" sandstones containing scattered angular mudstone rip-ups and conglomerate pebbles and cobbles (Figure 8).

A sequence of lower Angora Peak sandstone lithologies similar to the coastal section can be observed in roadcuts above Hug Point State Park, along the Hug Point mainline logging road (NW 1/4 of section 20, T. 4 N., R. 10 W.) where nearly 100 feet of small-scale, planar cross-bedded conglomeratic sandstones are interbedded with laminated fine-grained sandstones (see measured section, Appendix III).

An unusual boulder and cobble conglomerate occurs in the lower Angora Peak sandstone along a logging road in the eastern part of the thesis area (sample locality 54, Plate I, section 24, T. 4 N., R. 10 W.). The conglomerate forms a 15-foot deep channel scoured into 20 feet of thin bedded siltstones and fine-grained sandstones. A thin (four feet thick) basaltic dike intrudes the deposit. Mudstone and siltstone rip-ups ranging from two to six inches in length are scattered throughout the channel deposit. Thin lenses of sandstone occur within the channel conglomerate fill (Figure 11). The conglomerate beds are poorly sorted, friable, and are composed of predominantly finely crystalline and porphyritic andesite and basalt cobbles and boulders one to two feet in longest diameter. Smaller quartzite, rhyodacite, chert, and rare cobbles of black, rounded silicified fossil wood also occur (Appendix IV). There is no known source for many of these unusual clasts in the Oregon Coast Range. Conglomerate cobbles and boulders are contained within a sand matrix. The matrix is coarse-grained, poorly sorted, and is composed of subangular quartz, feldspar, and lithic fragments. However, in places, the conglomerate pebbles are suspended in a siltstone matrix.

The contorted fine-grained well-laminated sandstones and the sandstones exposed in the sea cliffs from one-half mile north of Hug Point to Humbug Point, are progressively stratigraphically higher in the Angora Peak sandstones. They typify the upper Angora Peak sandstone in the thesis area. The upper Angora Peak sandstones are characterized by several hundred feet of well developed, planar, dark carbonaceous to coaly and micaceous sandstone laminations (0.1 inch thick) alternating with fine, well to moderately sorted feldspathic sandstones. Low angle cross-laminated beds range up to one foot in thickness. In places, the laminated sandstones have been microfaulted (Figure 9) and broken into angular blocks (Figure 10) as a result of soft sediment deformation. There is an upward increase of carbonaceous siltstone (in beds several inches thick) and very fine-grained sandstone beds northward along the coast, forming as much as 30% of the rock near Humbug Point. Immediately north of

Figure 9. Microfaulted, typical laminated upper Angora Peak fine-grained sandstones; dark laminae are gray, thin, very fine-grained, carbonaceous sandstones one-half mile north of Hug Point.

Figure 10. Broken chaotic mixture of soft sediment deformed angular blocks of laminated upper Angora Peak fine-grained carbonaceous sandstones associated with a Depoe Bay Basalt dike near Humbug Point.

Humbug Point are the overlying mudstones, siltstones, and sandstones of the overlying Silver Point member.

Similar well-laminated, well-sorted, micaceous, and carbonaceous fine-grained sandstones typical of the upper part of the Angora Peak member occur along the powerline in section 13, T. 4 N., R. 10 W., in the eastern part of the thesis area, in the sea cliffs associated with a basalt intrusive at Arch Cape, and above Arch Cape in the southern part of section 30, T. 4 N., R. 10 W. The sandstones in these areas are all located near the contact with the overlying Silver Point mudstones. Pelecypods (Spisula sp.; Addicott, written communication, 1974) were found in a very fossiliferous, fine-grained, laminated sandstone bed along the powerline in section 13, T. 4 N., R. 10 W. The shallow marine fossils, preserved as molds, showed no evidence of current abrasion as both valves are intact. The fossils testify to the shallow marine origin of much of the well laminated, fine-grained sandstones of the upper part of the Angora Peak sandstones. Above these fossiliferous sandstone beds and the laminated, fine-grained sandstones at Arch Cape are thick beds, ranging from 12 to 20 feet in thickness, of light colored tuffaceous siltstones. These siltstones are thinly laminated, micaceous, carbonaceous, and range from grayish yellow (5 Y 8/4) to light gray (N7) in color.

Petrology. Eight thin sections from representative samples of the Angora Peak sandstones were microscopically examined. Eight

Figure 11. Sandstone lens in poorly sorted boulder conglomerate channel; lower Angora Peak sandstone member. Note large rounded andesite boulders on slope at lower center of photo (arrow). Sample locality 54 (Plate I), section 24, T. 4 N., R. 10 W.

billets were stained using the method of Laniz and others (1964) to obtain plagioclase and potassium feldspar contents. Modal analysis of three coarse-grained samples (Appendix VII) was used to aid in classification of these sandstones. Using the classification scheme of Williams, Turner, and Gilbert (1954), the sandstones were determined to be variously lithic arenites and lithic wackes (Figure 12).

Generally, lower Angora Peak sandstones are composed of poorly sorted, fine to coarse, subangular to subrounded sand grains. Porosity is low (less than one percent measured by point counting) due to pervasive cementation of clasts by hematite and calcite, and breakdown of volcanic rock fragments to form a clay mineral matrix (Figure 13). Using Folk's textural maturity classification (1968) these sandstones are texturally submature on the basis of poor sorting and general angularity of grains. This immaturity is probably a function of rapid deposition and burial of detritus with little or no current reworking. The abundance of chemically unstable rock fragments, feldspars, and other unstable grains suggests these sandstones are compositionally very immature. This immaturity indicates that the source areas of the detritus were of rugged relief, contained steep stream gradients, and had cool or temperate climates so that chemical weathering and erosion dominated over chemical weathering processes to produce an abundance of chemically unstable mineral and rock fragments.

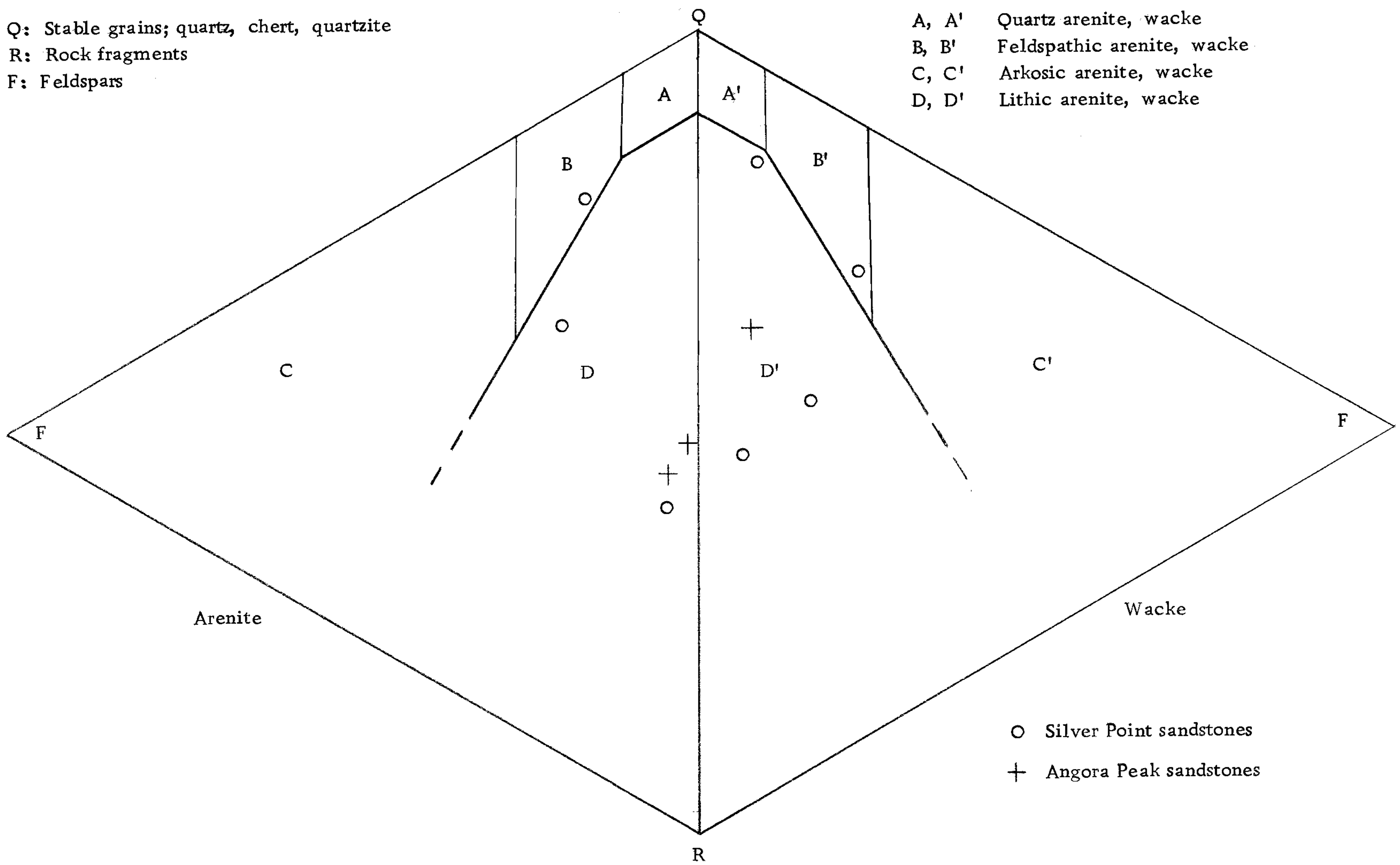
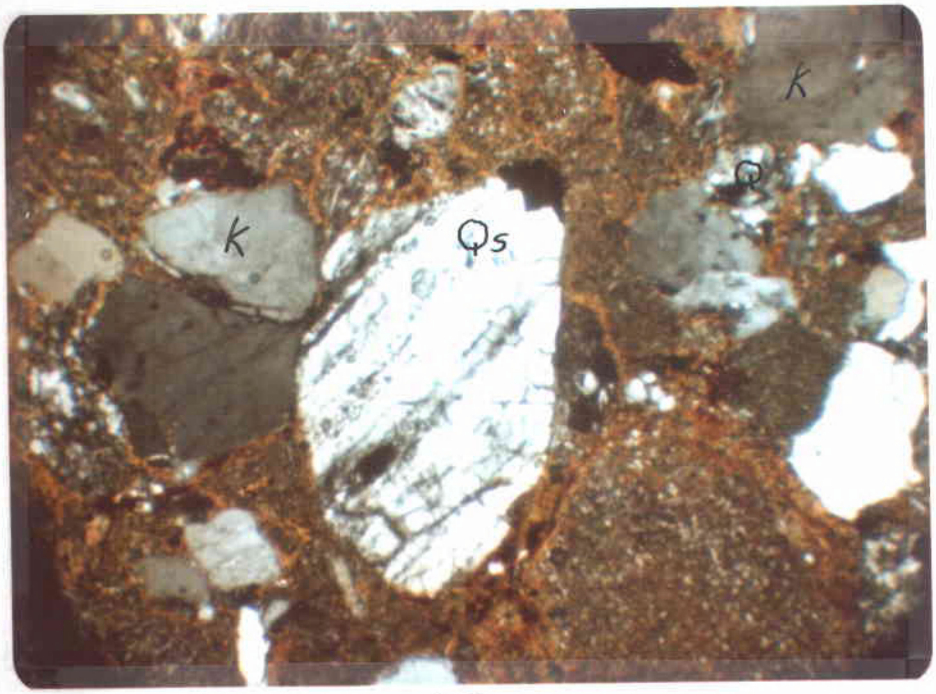


Figure 12. Classification of Angora Peak and Silver Point sandstones. (Gilbert, 1954)



0.5 mm

Figure 13. Quartz schist fragment (Qs) in poorly sorted Angora Peak sandstone. Note volcanic rock fragments whose grain boundaries merge with diagenetically formed yellow-orange clay matrix, large angular potash feldspar (K), and polycrystalline quartz grains (Q); crossed nicols.

The main mineralogical constituents of Angora Peak sandstones are quartz, potassium feldspar, intermediate plagioclase, basaltic andesitic and dacitic volcanic rock fragments, clay minerals, organic detritus, and calcite cement. Lesser amounts of chert, sedimentary and metamorphic quartzite, and heavy minerals (mainly opaques) occur. Rare sandstone and altered granitic clasts are also found.

Quartz ranges from 15% in conglomerates to 44% in fine-grained sandstones. A few grains are rounded, but the majority are angular to subangular. Both strained (undulatory) and normal quartz are present in nearly equal amounts. Polycrystalline quartz grains are much less abundant (2 to 10%). Microfractures, evidence of extensive diagenetic chemical etching, are present on many quartz grains observed under the binocular microscope. Some embayed quartz is present, suggesting a volcanic phenocryst origin. However, in thin section, calcite cement commonly replaces quartz grain boundaries, occurs along fractures, and forms embayments. This indicates a diagenetic origin for much of the embayed quartz. A significant rise in pH to alkaline conditions soon after deposition could have resulted in corrosion and solution of quartz boundaries, precipitating calcite in its place (Siever, 1959).

Microcline, orthoclase, and rare sanidine comprise five to nine percent of the rock. Plagioclase (An_{40} to An_{80}; mostly andesine and labradorite) comprises only two percent. Orthoclase and sanidine is altered to kaolinite and sericite. Microcline generally remains unaltered. Plagioclase feldspars show various degrees of alteration but are generally fresher in appearance than orthoclase. Since calcic plagioclases are generally more chemically unstable than potassium feldspars, possibly the plagioclase grains probably were derived either from a closer source or underwent less intense chemical weathering processes at the source area.

Volcanic clasts are the most abundant rock fragments, ranging from 20% in fine-grained sandstones to 44% in coarse-grained sandstones. The clasts are subrounded to rounded and have undergone various degrees of alteration, ranging from unaltered to completely altered groundmasses of clay minerals and/or cryptocrystalline quartz (chert). The diagenetic alteration of these clasts formed much of the clay matrix in the Angora Peak sandstones. In several instances indistinct boundaries merge with the clay matrix (Figure 13). Recognizable volcanic rock fragments are commonly porphyritic basalt and andesite containing phenocrysts of plagioclase (andesine) in a partially altered glassy groundmass. Common volcanic textures are pilotaxitic, intersertal, and intergranular. Rare silicic clasts appear as small quartz or feldspar phenocrysts in a cherty groundmass indicating an origin from the devitrification of silicic volcanic glass (e.g., dacite flows). Some vesicular chert clasts probably are silicified pumice. Minor pumice and glass fragments were found.

Possible sources for these volcanic rock fragments are western Cascade andesites, dacites, and Eocene Coast Range basalts.

Two much-altered plutonic clasts, possibly granitic, were noted. The remaining rock fragments are cherts (1 to 14%) and quartzites (2 to 10%). Most chert clasts have unknown sedimentary or volcanic provenance affinities because these chert clasts lack phenocrysts. They are composed of cryptocrystalline quartz and contain microveinlets of polycrystalline quartz. Obvious phenocryst-bearing volcanic chert clasts were point counted as volcanic rock fragments.

A variety of sedimentary quartzite and metaquartzite rock fragments were noted. Polycrystalline quartz clasts have the randomly interlocking, sutured pattern characteristic of sedimentary quartzite formed by pressure solution of quartz arenite under deep burial (Thomson, 1959). Some polycrystalline quartz may be hydrothermal vein quartz that was associated with the micropolycrystalline quartz veinlets in the chert clasts. Metamorphic quartzite fragments are composed of aligned micas and aligned, elongate crystalline to polycrystalline strained quartz with interlocking sutured boundaries (Figure 13). Additionally, a few quartz sandstone clasts consist of angular, very fine-grained monocrystalline quartz, surrounded by a dark clay matrix.

Most of the clay matrix in the Angora Peak sandstones is diagenetic in origin, because it is composed of the alteration products of volcanic rock fragments. There is little obvious detrital matrix. Matrix content ranges from 3 to 24% depending upon the degree of weathering and alteration a sample has undergone. Over 60% of the matrix is clay; the remaining matrix is composed of silt-sized angular clasts of quartz, feldspar, and lithics. Thin section evidences of a diagenetic origin for the matrix are ghost outlines of volcanic rock fragments, consisting of plagioclase laths in a clay groundmass that merges with the clay matrix of the sandstones (Figure 13). Many volcanic rock fragments lack distinct grain boundaries but contain a chloritic groundmass that merges with a similar clay matrix. X-ray diffraction indicates that these matrix-forming clays are composed of mixed-layer illite, mica, and vermiculite. Illite and vermiculite commonly occur in soils as a mixed-layer clay, the result of mica and volcanic rock fragment hydration in humid climates (Carroll, 1970).

Pore-filling calcite (2 to 7%) and lesser amounts of hematite, limonite, and pyrite cement most of the sandstone. Calcite occurs as concretions and widely distributed cement. Locally, where pyrite partially cements sandstones, the sandstones weather in a nodular pattern similar to the laminated calcite-cemented sandstones mentioned above (Figure 6). The calcite probably was formed from Ca^{++}, and $CO_3^{=}$ saturated pore waters migrating through Angora Peak sediment. Source of the Ca^{++} was from (1) near saturated ocean waters, (2) breakdown of calcic feldspar, basaltic, and andesitic volcanic rock fragments, and (3) dissolving fossil shells (foraminifera and mollusks). Much of the plagioclase and volcanic rock fragments was observed to be partly altered to calcite and therefore these appear to be the most likely source for the calcite cement.

Organic detritus composes up to 15% of these sandstones. The organic debris occurs as finely disseminated dark organic matter and carbonaceous plant fragments surrounding clasts, and as dark carbonaceous fibers in thin coaly seams.

Heavy minerals (specific gravity greater than 2.95) compose less than 3% of the 3.5 and 4.0 phi size sand fraction of the sandstones. Seven samples taken from Angora Peak sandstones were separated using the heavy liquid tetrabromoethane (specific gravity 2.95). Opaque minerals, the most abundant minerals in all the heavy mineral suites, comprise over half of all the heavy minerals, followed in abundance by green hornblende, augite, garnet, hypersthene, and zircon (Appendix VI). Magnetite, hematite, and leucoxene-ilmenite are the dominant opaque minerals. Traces of pyrite were found in only one sample. These minerals are angular to rounded. Magnetite and ilmenite were probably derived from basic and ultrabasic sources (e.g., basalts) whereas detrital hematite probably was eroded from acidic igneous and metamorphic terrains (Milner, 1962).

Angular green hornblende is abundant or present in all samples. It is usually broken along cleavage planes and unaltered. Green hornblende sources are many, including granitics, syenites, diorites, hornblende schists, and equivalent intermediate and acidic volcanic rocks (e.g., andesites, rhyolites) (Milner, 1962). Brown hornblende (lamprobolite), present in three samples, indicates some sediment contribution from basaltic sources.

Rounded monazite is abundant. Zircon, present in trace amounts in seven of the samples, occurs as euhedral crystals and rounded grains. Rounded zircon is suggestive of recycled sedimentary rock sources for some Angora Peak sandstones because of its high resistance to abrasion (Pettijohn, 1957). Monazite and zircon are characteristic of derivation from acidic igneous and metamorphic parent rocks.

Augite, enstatite, and hypersthene are heavy minerals generally derived from intermediate, basic, and ultrabasic sources. These minerals are angular and broken along cleavage surfaces. Hypersthene is very abundant with lesser amounts of augite and only trace amounts of enstatite.

Rutile and tourmaline also indicate acid igneous sources and are found in only trace amounts. Minerals characteristic of metamorphic terrains contained in the Angora Peak mineral suite are epidote, garnets (almandite and grossularite), clear to brown tourmaline, and rutile. Garnets are common, generally found in the form of euhedral crystals with many faces and as small chips.

General indicators of silicic intrusives and metamorphic terrains are biotite and muscovite (Milner, 1962). Biotite is found in trace amounts in seven samples, while muscovite is found in only one.

Structureless mudstone interbeds in the Angora Peak sandstone member consist entirely of clay minerals while laminated siltstones (overbank deposits) contain a high silt content (60%) of angular quartz, feldspar, and micas in a clay matrix (Appendix VIII). X-ray diffraction analysis of one mudstone sample indicates that montmorillonite, chlorite, and a mixed-layer clay are the main clay minerals. Laminated siltstones contain only vermiculite and mica.

Contact Relations. The angular unconformity between the Angora Peak sandstone member and the underlying Oswald West mudstones has been discussed previously in the Contact Relations of the Oswald West mudstones. The 600-foot thick overlying Silver Point mudstone member of the Astoria Formation conformably overlies and possibly intertongues with the Angora Peak sandstone member. A gradational transition between the Angora Peak and Silver Point members can be observed on the Hug Point logging road along the north section line of section 20, T. 4 N., R. 10 W., northward along the coast from Hug Point, and along the powerline which runs through the centers of sections 12 and 13, T. 4 N., R. 10 W. This transition generally ranges over about 100 feet and consists of a gradual fining and thinning upward of coarse-grained conglomeratic sandstones and thick shallow marine laminated fine-grained sandstones of the Angora Peak sandstone member to interstratified, well-bedded, dark silty mudstones and thin fine-grained sandstones of the Silver Point member. The contact is a gradual change of lithologies and bedding style, not a sharp break from deep-marine strata to shallow marine sandstones as is the contact between the underlying Oswald West mudstones and Angora Peak sandstones. Neel (1975) recognized a possible intertonguing between Angora Peak sandstones and the Silver Point member in the Seaside-Cannon Beach area and Kidder's Butte area. The possibility of intertonguing is discussed further in the section on a Depositional Model.

Age and Correlation. In the Angora Peak-Neahkahnie Mountain area, Angora Peak sandstones overlie late Oligocene to early Miocene Oswald West mudstones with an angular unconformity and are overlain by middle Miocene Depoe Bay basaltic breccia also with an angular unconformity. Cressy (1974) did not differentiate Silver Point mudstones from Angora Peak sandstones (he mapped both as Angora Peak sandstones) although both members are locally present in the Angora Peak-Neahkahnie Mountain area. The lithologies and stratigraphic thickness of the Angora Peak sandstones in this thesis closely correlate with those described by Cressy (1974) for the type Angora Peak sandstone. The fact that the Angora Peak sandstone was physically traced to the type Angora Peak sandstones establishes this correlation. Cressy also collected molluscan fossils in the area to the south of this thesis area which indicate a middle Miocene (Temblor) age for the Angora Peak sandstones. On the basis of these fossils, this sandstone correlates with the type Astoria Formation.

Depositional Environments. The existence of poorly sorted, conglomeratic, cross-bedded sandstones and large conglomerate channels incised in laminated, carbonaceous siltstones and mudstones in the lower Angora Peak sandstone is evidence for fluvial deposition. Carbonaceous, laminated mudstone and siltstone beds between the large-scale cross-bedded sandstones represent possible overbank and/or swamp deposits. The large rounded andesite boulders (two feet in diameter) in the unusual channel deposit at sample locality 54 (Plate I) in the eastern part of the thesis area probably represent flood deposits from a fairly large river of high competence. Most likely, it took several catastrophic floods to move such large boulders from the ancestral Cascades, the presumed source area, 100 to 200 miles to the east.

Laminated, moderately sorted, fine-grained sandstones typical of the upper part of the Angora Peak sandstones contain shallow marine fossils (e.g., along the powerline road) and represent an offshore, littoral environment in which currents were strong enough to accomplish moderate sorting and winnowing of fine clays but not so strong as to abrade or break up the molluscan fossils. The molluscan fossil, Spisula sp., from the powerline locality, generally ranges from intertidal to 150 feet of water in a sandy domain (Addicott, written communication, 1974). Local small-scale cross-bedding in fine-grained sandstones indicates that greater current energy prevailed at times. Vertical burrows in these sandstones could have been formed along large tidal channels or in estuaries.

The general depositional environment of the Angora Peak sandstones is pictured as a large river depositing a sediment load at the mouth. Large river channels perhaps meandered on their flood plains or on subaerial parts of a delta, depositing channelized, cross-bedded pebbly sands and gravels with interbedded muds possibly representing oxbow lakes, swamp deposits, and overbank laminated carbonaceous muds and silts. Longshore, tidal, and other marine currents reworked the front of these fluvial sediments and possibly deposited them as offshore bars and banks of sorted and laminated, fine-grained sands on the continental shelf.

The progradation of this, in part, subaerial fluvial environment represented by the lower Angora Peak sandstones over the deep marine Oswald West mudstones was followed by a general transgression of the sea by basin subsidence and deposition of fine-grained, laminated, shallow marine upper Angora Peak sandstones.

Silver Point Mudstone Member

The name, Silver Point mudstone member of the Astoria Formation, is herein informally proposed for a 650 feet thick sequence of well-bedded, silty mudstones which contains minor thinly bedded, graded, laminated, carbonaceous, fine-grained sandstones and siltstones. This member is proposed to help untangle confusion over lithologies mapped as the Astoria Formation. In the Onion Peak area, strata mapped as Astoria Formation on the geologic map of western Oregon are described as dominantly thick-bedded, laminated to cross-bedded, arkosic sandstones, which are locally conglomeratic (Wells and Peck, 1961). Schlicker and others (1972) restricted the definition of the Astoria Formation to this distinctive unit in the north coastal area, but the thick sandstone unit is not found in the type Astoria Formation in Astoria, Oregon. Cressy (1974) informally proposed Angora Peak sandstone member of the Astoria Formation to represent these lithologies. In mapping the Onion Peak area, the writer discovered a distinct thick sequence of predominantly deeper marine, well-bedded mudstones, previously mapped as the sandstone-rich Astoria Formation. The name, Astoria Formation, should be retained because it is deeply ingrained in the geological literature and refers to middle Miocene sedimentary rocks found along the Oregon Coast (Moore, 1963). However, Silver Point mudstone member of the

Astoria Formation will be used to designate informally the distinct sequence of mudstones which does not appear in the description of the Astoria Formation by Wells and Peak (1961) or by Schlicker and others (1972). This proposal is in accordance with the Code of Stratigraphic Nomenclature (1961) which states that "a member is part of a formation: it is not defined by specific shape or extent... Although members are normally in a vertical sequence, laterally equivalent parts of a formation that differ recognizably may also be considered members." Thus, there are two distinct sequences of strata which have been mapped as the Astoria Formation in the Seaside-Cannon Beach-Angora Peak area. They are the 1000-foot thick Angora Peak sandstone member (Cressy, 1974) and the herein-defined overlying 600-foot thick Silver Point mudstone member.

The Silver Point member is a widespread unit in the northern Coast Range. It covers much of the Seaside-Cannon Beach area north of the thesis area (Neel, 1975) and can be traced 20 miles northward, almost to the type area of the Astoria Formation at Astoria, Oregon. The unit may correlate, in part, with the lower sandstone and middle "shale" members of the Astoria Formation described by Howe (1926) at the type area (Cooper, personal communication, 1974).

The Silver Point mudstone member covers seven square miles in the west and east-central parts of the thesis area (Plate I). These well-laminated mudstones, with subordinate micaceous and carbonaceous siltstones and sandstones are well exposed in the sea cliffs at Silver Point, inland on logging roads, and in steep-sided creek beds along the West Fork of Elk Creek, and on the southern part of Kidders Butte. More than 400 feet of mudstones were measured at the principal reference section at Silver Point (Appendix II). A complete section of 645 feet of Silver Point strata was measured along the Hug Point mainline logging road between the underlying Angora Peak sandstone member and the overlying Depoe Bay Basalt breccias.

The member weathers readily and forms low, subdued slopes and hilly topography between rugged, steep ridges of Depoe Bay Basalt breccias and intermediate slopes formed by Angora Peak sandstones. The mudstone member is subject to undercutting by waves along the coastline and by streams in valleys, resulting in extensive landslides.

Lithologies and Structures. The Silver Point mudstone member of the Astoria Formation is characterized by well-bedded, dark, laminated mudstones, with subordinate amounts of rhythmically interbedded thin siltstones and thicker, laminated and graded, carbonaceous and micaceous sandstones (Figure 15). Local sandstone lenses and pebble conglomerate channels (up to ten feet deep) occur.

The silty mudstones are commonly dark gray (N3) in color and weather to light olive gray (5 Y 6/1) chips. Mudstones range from thin laminae to beds up to ten feet thick (average three inches) and

Figure 14. Well-bedded sandstones and mudstones of the Silver Point member in the 100-foot sea cliff at Silver Point. More resistant sandstone lens near top of photo is a maximum of five feet thick.

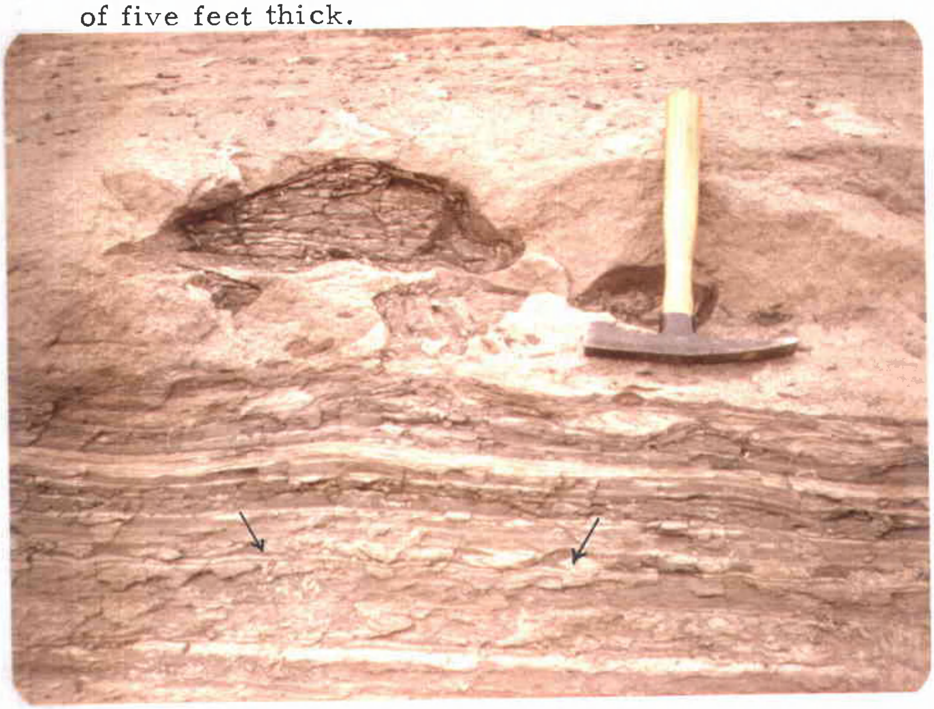


Figure 15. Close-up of bedded sandstones and mudstones of the Silver Point member at bottom of sea cliff at Silver Point. Note contorted bedding in the thinly bedded sandstones (arrows) and large mudstone rip-ups in the thicker sandstone.

contain laminae of micaceous and carbonaceous silt. Local carbonate concretions containing plant debris, fish scales, and other fossils are found in thick mudstone beds. Abundant, finely laminated, and micro-cross-laminated lighter colored siltstones, ranging from 0.1 to 1.0 inch thick, commonly define the bedding.

Fresh exposures of the sandstones are very light gray (N8). The sandstones weather to small iron-stained yellowish orange (10 YR 6/6) blocks which range from three inches to one foot in size. The sandstones are characterized by graded bedding, well developed parallel laminations, abundance of carbonaceous and micaceous debris, mudstone rip-ups, load structures, and a "dirty" feldspathic appearance (wackes). Sandstones are also moderately sorted to well-sorted and are composed of subangular, fine- to medium-grained sand. A few poorly sorted and coarse-grained sandstones also occur but they are relatively rare. Quartz, feldspar, micas, and carbonized plant fragments are the dominant framework grains. Rock fragments are a relatively minor component. Laminations are formed by concentrations of coarse sized mica flakes (mostly muscovite) and carbonaceous fossil plant fragments alternating with thin laminae of fine-grained quartz, feldspars, lithics, and heavy minerals. Sandstones are generally friable, but some are well cemented by calcite.

The principal reference section of the Silver Point mudstone member is exposed in the 100-foot sea cliff at Silver Point (Appendix

II). The base of the sea cliff section is approximately 500 feet below the contact with the overlying Depoe Bay Basalt breccias which form Twin Peaks, and probably lies 50 to 100 feet above the buried contact with the underlying Angora Peak sandstone member which is exposed less than one-half mile to the south at Humbug Point.

The lower part of the Silver Point reference section consists of rhythmically alternating sandstones and laminated mudstones (Figure 14). There are nearly equal percentages of mudstones and sandstones. The sandstones range from one inch to four feet thick, are fine- to very fine-grained, and many are normally graded (medium-grained at base to fine-grained at top). The sandstone beds are finely laminated and contain abundant coarse flakes of muscovite and carbonaceous fossil plant debris. Many contain angular mudstone clasts up to three inches long which formed from current erosion and penecontemporaneous loading and slumping of adjacent sandstone and mudstone beds (Figure 15). Penecontemporaneous movement also produced contorted bedding in some of the sandstones. Sandstone bottom contacts are sharp and irregular, and contain rare flute, groove, and prod marks. Sorting is generally moderate to good; a few are poorly sorted. Ripple microcross-laminations and tubular burrows subparallel to the bedding occur in some sandstone beds. Small (two to five inches long) sandstone dikes penetrate the mudstones; flame and load structures are common. Although many sandstone beds appear even bedded on initial observation, detailed study shows that they are discontinuous and irregular in thickness when traced laterally, the result, probably, of submarine erosion during deposition (scour-and-fill) and later penecontemporaneous slumping and loading (Figure 15).

There are also definite sandstone lenses or channels up to five feet deep and 60 to 150 feet wide within the lower part of the section at Silver Point (Figure 15). Some of these sandstone channels contain climbing ripple laminations and parallel laminations in very well sorted, "clean", feldspathic, carbonaceous sandstones, suggesting continuous deposition from tractive currents (e.g., tidal currents) other than turbidity currents.

A few channel conglomerates within the lower Silver Point strata occur near the beach in a small headland associated with a Depoe Bay basalt sill, 100 feet north of the type Silver Point section. This channel is a maximum of 11 feet deep and pinches out northward and southward over a distance of 100 feet. The lower contact is sharp and truncates over 11 feet of laminated mudstones and very thin fine-grained sandstones. The lower eight feet of the channel contain a poorly sorted pebble conglomerate that lacks grading. The conglomerate is composed of rounded to subrounded quartz, chert, aphanitic basalt, andesite, and pumice pebbles averaging two inches in largest diameter and large angular blocks of imbricated laminated mudstone rip-ups (up to ten inches long) in a quartzose-feldspathic sandstone matrix. The conglomerate pebbles are very similar to those found in the Angora Peak conglomeratic sandstones near Hug Point (Appendix IV), suggesting a similar or the same source for both members of the Astoria Formation. The upper three feet of the channel fill consists of three graded conglomerate beds, each approximately one foot thick. Bottom contacts between the adjacent conglomerates are irregular and sharp, and load structures are common (Figure 16). Each grades upward from fine pebbles into a coarse sandstone. The third conglomerate bed grades upward into coarse-grained sandstone containing parallel laminations overlain by microtrough cross-stratification (typical of the A, B, and C divisions of turbidite sandstones defined by Bouma, 1962). The largest of these trough cross-beds is four inches deep and four feet wide with the average size about three inches deep and troughs three feet wide. Repeated graded bedding overlain by parallel laminations and rarely cross-stratification, abundant mudstone rip-ups in deep marine mudstones, suggest that these conglomerates were formed by a series of turbidity currents. Similar turbidite graded channelized conglomerates have been recognized in many deep-marine and flysch sequences throughout North America and Europe (Walker and Mutti, 1973). Comparable thin channelized pebbly conglomerates within the lower part of the Silver Point member are found inland along a logging road in the NE corner of section 17, T. 4 N., R. 10 W., and near Kidders Butte in the NE corner of

Figure 16. Graded conglomerate lenses in the Silver Point mudstone member near Silver Point. Note load casts along lower contact of the lower conglomerate lens.

section 9, T. 4 N., R. 9 W.

Other exposures typical of the lower Silver Point member are located along Arch Cape Creek in section 29, T. 4 N., R. 10 W., along the base of Kidders Butte in section 8, T. 4 N., R. 9 W., and in the NE 1/4 of section 19, T. 4 N., R. 10 W. in the eastern part of the thesis area. These localities contain nearly equal amounts of well-bedded, silty mudstones alternating with well-bedded, thinly-laminated, carbonaceous sandstones, with sandstone and pebble conglomerate channels much like the strata in the Silver Point sea cliff. In the lower 100 feet of Silver Point strata directly above the Angora Peak sandstones along the Hug Point mainline logging road, thin sandstone beds comprise nearly 60% of the unit. These even-bedded sandstone beds are less than 1.5 inches thick, averaging 0.5 inch (see measured section, Appendix III). More than half of the sandstones have sharp lower contacts and grade upward from medium-grained sandstone into the overlying mudstones. Microcross-laminations overlying micaceous, parallel laminations (Bouma's B and C divisions) are common to these beds. The occurrence of repeated graded bedding, overlying interpretive A, B, and C divisions defined by Bouma (1962), in deep marine mudstones indicate a probable turbidite origin for many of these lower Silver Point sandstones. There are many other outcrops of the lower part of Silver Point member along various logging roads in the thesis area similar in lithologies and sedimentary structures but more limited in exposure.

The Silver Point member generally becomes thinner bedded, finer-grained, and contains greater proportions of thin siltstones and mudstones and fewer sandstones upward over most of the thesis area. For example, high in the Silver Point type reference section approximately 200 feet below the Depoe Bay Basalt breccia contact and 100 feet above the base of the sea cliff, more than 100 feet of predominantly well-bedded mudstones are exposed. At the base of this road exposure above U. S. 101 at Silver Point, these silty, well-laminated, carbonaceous and very thin siltstones comprise nearly 70% of the section but increase to 90% of the section near the top of the road cut. Channel sandstones are absent here; however, channel fill features of subaqueous slump features are present. One large channel (40 feet wide and 6 feet deep) composed of mudstones and thin, fine-grained sandstones has truncated silty, dark mudstones and thin laminated and convolute sandstones immediately above the Silver Point highway view point on U.S. Highway 101. Bedded, carbonaceous sandstones and laminated siltstones in the upper part of the Silver Point member are lithologically similar to those in the lower part of the section; however, they are thinner (usually less than two inches thick) and finer grained. They are finely laminated, rarely micro-cross-laminated and convolute bedded. Graded bedding is also rare. Similar thin-bedded sandstones and siltstones are exposed in a quarry in section 6, R. 4 N., R. 10 W., stratigraphically higher than the type Silver Point section. Spherical calcareous concretions, ranging from three inches to one foot in diameter, occur in Silver Point mudstones in section 7, T. 4 N., R. 9 W. (sample locality 103, Plate I). These concretions contain fossilized fish bone fragments and scales, rolled up carbonized leaf prints, small mollusks, scaphopod shell fragments, and carbonized woody debris. The fish bones are composed of a phosphatic, clear reddish material. The shells, plant, and bone debris apparently acted as a nucleus, in which a microchemical environment developed that favored precipitation of microcrystalline calcite from permeating solutions soon after burial. Some concretions contain large "calcite" crystal pseudomorphis in their centers. The pseudomorphs are elongated (up to one foot long and two inches wide), crudely rhombic prisms. Boggs (1973), in a petrographic analysis of similar pseudomorph concretions in the Astoria Formation from Newport, Oregon, reported they are composed of interlocking calcite crystals with few terrigenous grains and microfossils. He hypothesized that the crystal pseudomorphs were formed by infilling a hollow (or mold), possibly a solutioned burrow, with calcite during diagenesis. The original crystal form may have been orthorhombic, possibly aragonite.

Petrology. Ten thin sections were prepared from sandstones distributed throughout the Silver Point member; modal analysis was completed on seven (Appendix VII). These sandstones are variously feldspathic and lithic arenites and wackes (see ternary classification diagram of Williams, Turner, and Gilbert, 1954, Figure 12).

The sandstones are composed mainly of quartz (17-40%), plagioclase feldspar (1-8%), potassium feldspar (2-7%), rock fragments (8-40%), muscovite (1-2%), and traces of glauconite and mafic minerals. Framework grains are angular to subrounded. They are texturally immature to submature. In thin section, laminations are a result of the concretion of tiny carbonaceous plant fragments, oriented micas, and other elongate grains alternating with lighter colored laminae composed of coarser grains of quartz, feldspar, and rock fragments.

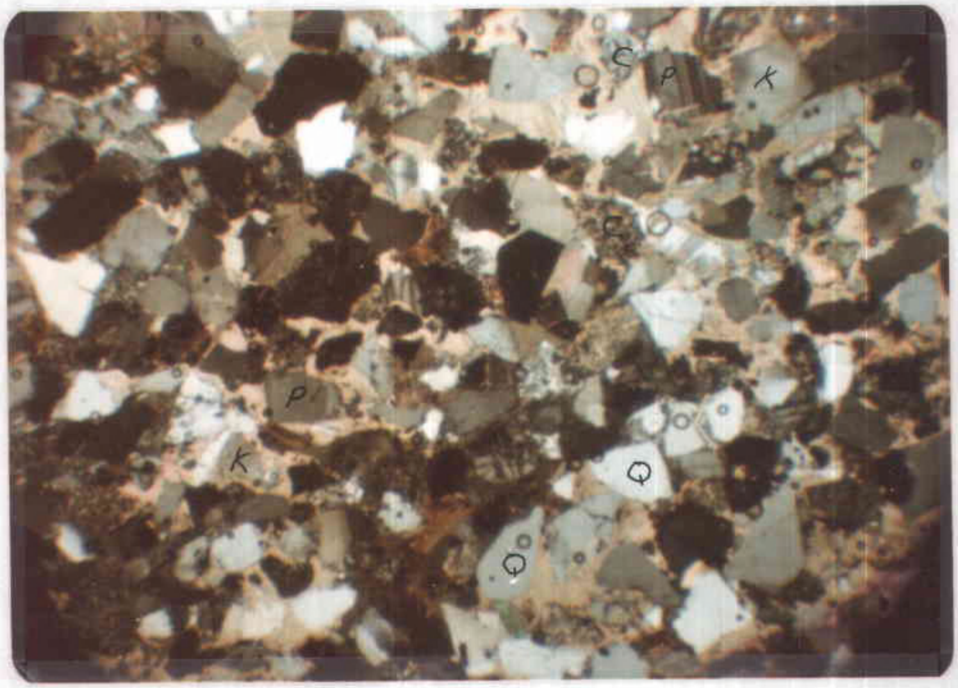
Silver Point sandstones are mineralogically and texturally similar to Angora Peak sandstones except that they are generally finer-grained, contain fewer volcanic rock fragments, and contain more detrital clay matrix, carbonized fossil plant material, plagioclase, and micaceous minerals (mainly muscovite). Coarse muscovite flakes are generally parallel to bedding planes and are not deformed or penetrated by adjacent framework grains, suggesting that only minor compaction of these strata occurred.

There is nearly an equal abundance of potassium and plagioclase feldspars in the Silver Point sandstones. Trace amounts of rounded glauconite pellets also occur.

Angora Peak and Silver Point sandstones contain similar amounts of subangular to subrounded quartz (both unstrained and strained), but there are smaller amounts of quartzite (2%) and chert (1-17%) in the Silver Point sandstones. Rock fragments in both members are of identical types. As in the Angora Peak sandstones, volcanic rock fragments, mainly porphyritic basalts (with intersertal and intergranular textures), andesites (with pilotaxitic textures), and rare pumice clasts are the most common rock types (up to 42% of the rock). Metaquartzite clasts are very rare. Some poorly sorted Silver Point sandstones contain dark angular mudstone chips (2-7%).

Calcium carbonate is the primary cement (1-48%) with minor amounts of hematite cement. Clear sparry calcite forms a substantial part of the thick, clean, channelized sandstones (up to 48%, Figure 17). In some samples, carbonate cement replaces carbonized wood fragments aligned along bedding planes.

The percentage of matrix varies greatly for Silver Point sandstones depending on their depositional origins. Thick, clean, channelized, current reworked sandstones contain only 1 or 2% clay matrix (Figure 17). These highly carbonaceous, well winnowed sandstones are composed of laminated, moderately to well-sorted, medium-grained sand cemented by sparry calcite. They also contain well-rounded, coarse sand-sized fecal pellets (up to 2%).



1 mm

Figure 17. Clean, carbonate cemented, channelized sandstone from the Silver Point member. Note well sorted character and angular altered potash feldspar (K), fresh twinned plagioclase (P), chert (C), and quartz (Q) in grain support; crossed nicols.

Four samples representative of the fine-grained, normally graded, "turbidite" sandstones of the Silver Point member contain abundant detrital dark clay matrix (34-62%). The angular framework grains are in matrix support. The dark, detrital clay forms very fine contorted laminae that are wrapped around sand grains. These "dirty" matrix-rich sandstones are probably the most common petrographic type in the Silver Point member and probably formed from currents in which there was little or no later winnowing or reworking of the fine detrital clay matrix due to rapid deposition and burial.

Silver Point sandstones, containing from 7 to 15% matrix, are petrographically very similar to Angora Peak sandstones in that they are medium- to coarse-grained sandstones, are poorly sorted, and contain an abundance of volcanic rock fragments (up to 40%). Much of the matrix in these sandstones is diagenetic in origin and was formed by the chemical breakdown of adjacent volcanic rock fragments after burial.

Carbonized wood fragments and finely disseminated dark organic, fibrous material concentrated along bedding planes are abundant in the Silver Point member, forming up to eight percent of the mudstone and over 12% of the sandstones.

One sample of a calcareous nodule in a siltstone located near the Silver Point-Depoe Bay basalt breccia contact in section 20, T. 4 N., R. 10 W., contains sponge spicules and foraminifera tests.

Nearly 20% of this sample is composed of finely disseminated, yellowish-brown organic material. This organic material is in the form of small anisotropic lumps and blebs scattered throughout the sample. Possibly, the organic material is "dead oil" that was trapped in the rock during the formation of the calcareous nodule or lumps of plant spores and pollen.

Heavy minerals comprise less than two percent of the Silver Point sandstones in the 3.5 to 4.0 phi size range. The types, the relative abundances, and the grain shapes of these heavy minerals in one Silver Point sample are similar to those found in the Angora Peak sandstone (see Appendix VI, and Petrology section of the Angora Peak sandstones). The primary difference is the much greater abundance of micas, primarily muscovite in the Silver Point sample (50% of the heavies), minerals which occur only in trace amounts in the Angora Peak sandstones.

The dark silty mudstones of the Silver Point member consist mainly of clay minerals and less abundant angular silt-sized grains of quartz, feldspar, and mica. The variations in the concentration of these silt-sized minerals and of carbonaceous fossil plant fragments is the reason for the well-bedded, laminated appearance of the mudstones. X-ray diffraction study indicates that the clay minerals in three Silver Point mudstones are montmorillonite, kaolinite, chlorite, vermiculite, mica, and mixed-layer clays (Appendix VIII). These clay minerals probably reflect the parent rock types and climatic conditions that occurred in the source areas in the Miocene, as well as later diagenetic changes. In the present upper Columbia River Basin (mountain terrains of Montana, Idaho, and British Columbia), and in the Willamette River basin drainage areas, illite, kaolinite, and chlorite form during weathering of igneous, sedimentary, and metamorphic rocks (Knebel and others, 1968). These clays develop in a relatively cool, subhumid climate, where there is extensive ground water circulation and subsequent leaching of metal cations of parent rocks by organic acids related to abundant vegetation. In contrast, the lower Columbia Basin of eastern Oregon and Washington, a predominantly basalt and volcanic tuff terrain, produces mainly montmorillonite or smectite under those semiarid conditions in which there is deficient water and poor ground water circulation for leaching of parent rock metal cations and little vegetation to produce abundant corrosive organic acids (Knebel and others, 1968). Both upper and lower Columbia Basin clay minerals are found in the Silver Point mudstones, suggesting possible Columbia River drainage basin sources. Mixed-layer clays indicate diagenetic changes and current weathering processes have degraded some of the well crystallized clay types (Carroll, 1970).

Contact Relations. Evidence for overlying and possibly interfingering relations between Silver Point mudstones and Angora Peak sandstones is discussed in the section on Contact Relations of the Angora Peak sandstones. The evidence for an unconformable relationship between Silver Point mudstones and the overlying Depoe Bay Basalt breccias is discussed in the section on Contact Relations of the Depoe Bay Basalt.

Age and Correlation. Stratigraphic and paleontological evidence suggest that the Silver Point member of the Astoria Formation in the thesis area is middle Miocene in age. The Silver Point mudstones overlie and possibly intertongue with middle Miocene Angora Peak sandstones in the thesis area and are, in turn, overlain by middle Miocene Depoe Bay Basalts. Although no diagnostic foraminifera were found in the thesis area, Neel (1975) collected well preserved foraminifera of Saucesian to Relizian age (middle Miocene) in Silver Point mudstones at several localities in the Cannon Beach-Seaside area, immediately north of the thesis area. He indicates that diagnostic genera, *Bulimina advena* Cushman, *Buliminella subfusiformis* Cushman, and *Clavulina* sp., commonly occur in the Silver Point mudstones there. His middle Miocene strata can be physically traced to the type Silver Point strata at Silver Point.

The Silver Point mudstone member correlates in age with the type Astoria Formation and may physically correlate with the middle mudstone and lower sandstone member of the Astoria defined by Howe in 1926 (Cooper, personal communication, 1974).

Wells and Peck (1961) mapped these strata in the thesis area as marine sedimentary rocks which included the Astoria Formation. Schlicker and others (1972) mapped Silver Point mudstones and Oswald West mudstones in the eastern parts of the thesis area as undifferentiated Oligocene to Miocene sedimentary rocks and in the western part of the thesis area as sandstone-rich Astoria Formation.

Depositional Environments. The Silver Point mudstones were deposited primarily in an open, marine quiet water environment of moderate depth. Neel (1975) collected foraminifera in Silver Point mudstones north of the thesis area that are indicative of deposition in cool marine water of sublittoral to upper bathyal depths (200-1000 feet). Molluscan fossils in these mudstones indicate middle to outer sublittoral (middle to outer shelf) depths (Neel, 1975). The abundance of laminated mudstones, siltstones, and preserved burrows indicates sedimentation occurred in a low energy environment where pelagic muds slowly settled from suspension. Microcross-laminations in some siltstone beds indicate the existence of weak bottom marine currents reworking these sediments into silt and mud layers. Repeated, normally graded sandstones in the lower Silver Point mudstones (marine foraminifera indicate 200-1000 feet depths) are interpreted to have been formed by turbidity currents. Neel (1975) also hypothesized a turbidity current origin for similar normally graded sandstones in the Silver Point member at Ecola State Park, six miles north of Silver Point. Microfaulting, flame, load structures, and convolute bedding suggest that there was a rapid deposition of denser sands over water-saturated muds and some downslope slumping of semicohesive sediments.

The few clean, channel sandstones that contain laminations and climbing ripples are thought to have been winnowed and deposited by strong marine tractive currents (e.g., tidal) other than turbidity currents. The writer believes these clean, well sorted sandstones underwent current winnowing and sorting, possibly as sands in the wave zone prior to final deposition. The clean, barrier sands were then transported by strong marine bottom currents downslope through channels previously cut by these currents in cohesive marine muds. The currents further winnowed the sand and produced climbing ripples, parallel laminations, and channel mud rip-ups.

The mineralogical and textural similarities of Silver Point graded conglomerates and coarse-grained, poorly sorted, graded sandstones to Angora Peak conglomeratic sandstones suggest there is a sedimentological association between the two members, e.g., lateral facies. Coarse-grained, poorly sorted pebble conglomerates and sandstones are hypothesized to have been derived from the transportation of shallow marine and fluvial Angora Peak sands and gravels into the deeper marine Silver Point basin by turbidity currents. The greater abundance of coarse muscovite in Silver Point sandstones may be explained by the fact that muscovite, being hydrodynamically lighter than most minerals, would have been preferentially transported farther by currents into the Silver Point basin of deposition than the coarse grains of quartz, feldspar, and rock fragments of the Angora Peak sandstones. The many thin, graded sandstones of the Onion Peak thesis area, as exposed (e. g., Hug Point mainline logging road) probably were transported by density currents formed during times of floods and large river discharge, and the resultant slumping into deeper water of unstable piles of Angora Peak sediments on a steep shelf.

The overall general decrease in abundant sand-sized material, and the increase of mudstone and thin siltstone in the upper part of the Silver Point mudstones, indicates possible basin deepening and/or progressive removal of the coarse sediment source.

Angora Peak Sandstone and Silver Point Mudstone Members

Conglomerate Pebble Lithologies. Pebble counts were conducted at five different conglomerate localities in the Angora Peak member and near Silver Point in the Silver Point member (Appendix IV, Figure 18). Pebble counts were made on 100 to 150 pebbles randomly collected over a two-square-foot area. Sample localities are on Plate I.

In the western part of the thesis area chert (31%), quartzite (15%), basalt (14%), and pumice (15%) are the dominant pebble lithologies with lesser amounts of intermediate volcanic, silicic volcanic, tuff, and rare plutonic clasts in both the Angora Peak and Silver Point members.

In the eastern part of the thesis area, chert and quartzite occur in quantities (a total of 10%), and intermediate volcanics (43%) and basalts (21%) form most of the conglomerate clasts (Figure 18).

Chert (12-31%) is one of the most common lithic types present. Red and green chert clasts containing small clear quartz veinlets are less common than white cherts. Much of the chert is of volcanic origin, probably from the alteration of silicic volcanic glass because many clasts in thin section contain small, euhedral phenocrysts of feldspar. Siliceous tuff and pumice pebbles are distinguishable by their white color. Altered pumice is soft and vesicular. Tuff pebbles are hard and rarely laminated.

Overall, an average of ten percent of the pebbles in these conglomerates are basaltic, suggesting there was only a small contribution from local Eocene Coast Range highs during the middle Miocene. Intermediate and silicic volcanic clasts are found in much greater overall abundance (average 15% and 20%, respectively). Included in these categories are andesite, dacite, and rhyolite flow rocks, welded tuff, tuff, and pumice. Chemical analyses (Appendix IX) of three porphyritic intermediate and silicic volcanic boulders from the unusual, Angora Peak boulder conglomerate shows that these volcanics are comparable to the Oligocene and Miocene andesite and dacite lavas of the Western Cascades (Taylor, personal communication, 1974). These boulders, ranging up to two feet in diameter, were among the five largest clasts found in the Angora Peak channel in section 24, T. 4 N., R. 10 W., in the eastern part of the thesis area (sample locality 54, Plate I) (Figure 11).

It is concluded that the primary volcanic source was probably the Oligocene Little Butte and Sardine Volcanics which contain andesite flows, tuffs, pumice, and ignimbrites, with a minor contribution from Coast Range pre-Miocene basalts such as the Tillamook and Goble Volcanics. The Oligocene tuffaceous John Day Formation of eastern Oregon could also be the source for some of the welded tuff and tuff clasts. Much of the pumice may have been freshly erupted by pyroclastics derived from ancestral Miocene Cascade volcanoes as thick ash fall tuffs have been recognized in the Astoria Formation in the Newport area (Snavely and others, 1969).

Figure 18 shows the areal distribution of pebble sizes (average diameter of the five largest clasts at each sample locality) and pebble compositions over the thesis area. Maximum pebble size decreases to the west and north and decreases upward in the section.

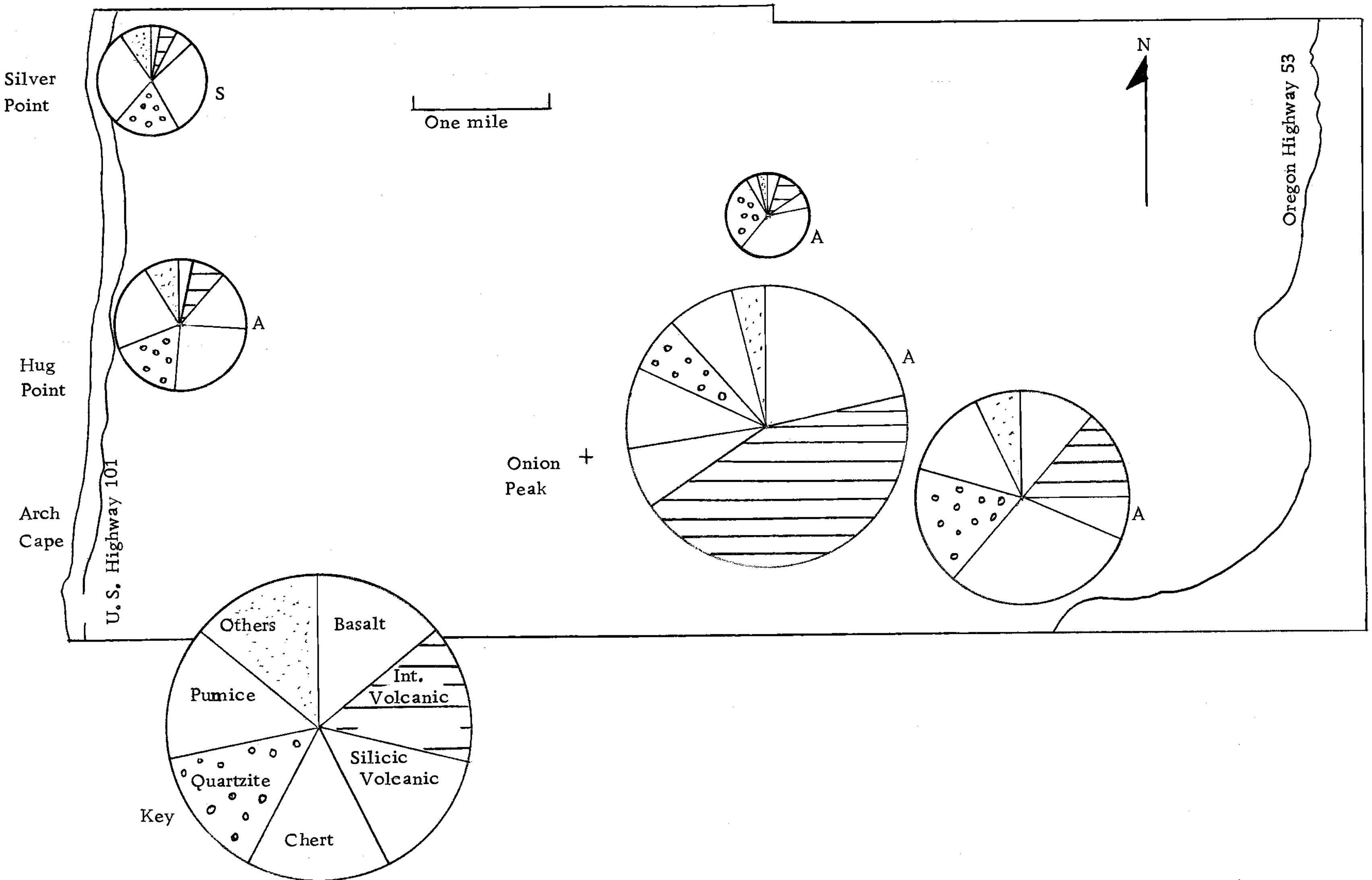


Figure 18. Relative abundance of pebble lithologies in Angora Peak (A) and Silver Point (S) conglomerates. Circle size represents maximum pebble size at each sample locality. For diagrammatic purposes, the diameter of each circle was calculated as one-half of the square root of the average of the five largest clast diameters at each sample locality.

The large andesite and dacite boulders found in the Angora Peak sandstones (locality 54, Plate I) are probably the result of floods. The competence and size of the river must have been great in order to move boulders from the Western Cascades over 100 miles away. The reason this deposit is thought to represent a unique event is that there are no other locations in the thesis area where the clast sizes approach those found here.

Exotic pebbles with no known sources in northwestern Oregon or the Western Cascades make up a significant percentage (20%) of the pebble counts. These pebbles suggest a more distant and different source area. The most abundant exotics are sedimentary and metamorphic quartzites (15%) and vein quartz. A typical metamorphic clast is illustrated in Figure 13. The elongate zones of aligned, strained, polycrystalline quartz with interlocking crenulated boundaries, suggest a metamorphic origin. Some quartzite pebbles contain zones of aligned muscovite flakes between polycrystalline quartz hinting at foliation. Sedimentary quartzite pebbles consist of well-rounded quartz grains, tightly cemented by secondary quartz overgrowths. Some light reddish sedimentary quartzites contain scattered disseminated hematite between quartz grains; however, most are white and grainy in appearance. Other exotic pebble types include weathered granite and black petrified wood. In thin section, granitic pebbles consist of interlocking quartz and highly altered feldspars.

Several rounded petrified wood pebbles (three to five inches in diameter) were collected (Cooper, personal communication, 1974). The pebbles are nearly black with abundant crenulated and concentric laminations that reflect an amazing preservation of the outline of the ring-like growth structure of ancient trees.

The Silver Point pebble lithologies are similar in types and abundance to those in the Angora Peak sandstones, particularly in the western part of the area, and are presumed to have been derived from the same sources (Figure 18, compare Hug Point and Silver Point localities).

Grain Size Analysis. Seven samples from the Angora Peak sandstones and one sample from the Silver Point member of the Astoria Formation underwent sieve and hydrometer grain size analysis (Appendix V). Samples from inland exposures are more deeply weathered and friable than samples from coastal cliffs (Plate I).

Statistical grain size parameters (mean, mode, standard deviation, skewness, and kurtosis) of Folk and Ward (1957) were calculated from cumulative weight percent graphs of data collected from sieving and hydrometer techniques. The size statistics were calculated once using the full range of size data and once calculated without the clay and silt matrix sizes (less than 4 phi). This was performed because most of the matrix sized material is believed to be secondary, the result of weathering of these strata, and does not represent the true size distribution of the clastics at the time of deposition.

The mean grain sizes for the Angora Peak samples range from 1.0 to 3.0 phi with an average mean of 1.86 phi (medium sand). The Silver Point sample mean grain size is 2.0 phi (medium sand).

Sorting in the Silver Point sample (0.85 phi) is slightly better than the average sorting in the Angora Peak sandstones. Sorting in Angora Peak sandstones ranges from poor to moderate (average 0.98 phi, moderate sorting).

Angora Peak grain size distributions are positively skewed, probably reflecting current winnowing of fines and subsequent concentration of coarse grains. Skewness ranges from +0.10 to +0.57 phi. The average skewness if +0.29 phi. The Silver Point sample is only very slightly positively skewed (+0.04 phi), reflecting a near normal size distribution.

Angora Peak size distributions are either mesokurtic (slightly excessively peaked curves) or normal curves with kurtosis values ranging from 0.94 to 2.70 phi. The Silver Point sample shows a near normal curve (kurtosis 0.95 phi).

These statistical parameters were plotted on Friedman's (1962) and Passega's (1957) graphs to aid in the determination of depositional environments. Because of the overall coarseness of the samples, many statistical size data plotted off the limits of the graphs. Both the Silver Point member and some Angora Peak sandstone statistical size data did plot on Friedman's (1962) graphs which suggest deposition occurred by tractive currents, either fluvial or marine. Plots on Passega's (1957) graphs also suggest deposition by tractive currents. This information correlates with similar depositional conclusions arrived at for the sandstones in the field according to lithologies, fossils, and sedimentary structures.

A Depositional Model. A deltaic origin for these members in the Astoria Formation, as proposed by Cressy (1974), is difficult to either prove or disprove. Sedimentary structures and lithologies, facies changes, and fossils can be interpreted as a deltaic environment. The interfingering of marine and non-marine environments, marine lateral facies to the north, south and west, and sediment dispersal patterns are all indicative of deltaic environments (see Transport Directions).

Sediments of various depositional environments of a deltaic complex possibly recognized in the Angora Peak sandstones include distributary channel conglomeratic sands and intervening swamp and overbank laminated, carbonaceous siltstones and mudstones. Clean, laminated, thick, shallow, marine sandstones may be delta front sheet sands formed by longshore and tidal currents. Farther offshore, sand and muds accumulating on the delta front may have become unstable, slumped, and formed turbidity currents. These current deposited sands slurried into a quiet, deeper water shelf basin to form the graded, laminated, carbonaceous and micaceous sandstones of the Silver Point member. Gentle currents reworked some of the transported sands and silts into cleaner cross-laminated sands and silts.

Similar features are found in deposits of modern deltaic complexes. The Silver Point member is analogous to the sediments of modern delta front platform (Allen, 1970) and delta slope deposits (Selley, 1970). The Niger delta has delta-front sheet sands (Allen, 1970) similar to the laminated sandstones in the upper part of the Angora Peak member. The interfingering of marine with non-marine sediments could be a consequence of the shifting of distributary channels by crevassing and abandonment.

A deltaic model need not be the only possible model to explain the different facies represented by the Angora Peak and Silver Point members.

Presently, there are no deltas along the Oregon Coast because longshore drift and shallow marine ocean currents are too vigorous to permit progradation of a delta. One can appeal to the present day fluvial, estuarine, shallow and deeper marine processes on the Oregon Coast for a model. The writer observed that the Columbia River today deposits coarse feldspathic and lithic sands and gravels in large-scale cross-bedded sequences in its estuarine channel. Along this channel extensive tidal mud flats and swamps contain abundant carbonaceous and micaceous silts and muds. Near the mouth of the river, the detritus is carried by strong longshore currents into large spits (Clatsop and Peacock Spits) of fine, well sorted sands, and probably carries the fine micaceous silts and muds oceanward. The ancient river that deposited the Angora Peak strata did not necessarily flow exactly like the Columbia today; however, many similarities do exist.

The cross-bedded conglomeratic sandstones in the Angora Peak member could have been deposited in a channel in an estuary with swamps and mudflats similar to the present-day Columbia. The burrowed, laminated sandstones could be analogous to the sands of Clatsop Spit which extend offshore into finer, pelagic sediments of the continental shelf. Shorelines much like this produce lithologies and sedimentary structures similar to those observed in the Astoria strata, with the possible exception of turbidite sandstones (Selley, 1970). Turbidites have not been observed on the Oregon shelf probably because there is not a steep enough shelf for their generation (Kulm, personal communication, 1974). The only turbidites are located in deep bathyal to abyssal depths in the Astoria submarine fan off the Columbia River (Kulm and Fowler, 1974b). However, it is possible that local, small deeper basins (perhaps fault produced) existed on the continental shelf during the Miocene. There could have been sediment build-ups along the steeper basin margins and subsequent slumping at these locations could have produced sand-rich turbidity currents that formed the graded "dirty" sandstones in the Silver Point member.

The Miocene river carrying the sediments probably was not as restricted by basaltic headlands as the modern Columbia. Constant river migration and swinging, and possible gradual basin downwarping led to interfingering of marine and nonmarine sediments. Additional conglomeratic and thick, shallow marine sandstones in the Angora Peak sandstones are found near Saddle Mountain 15 miles to the north of thesis area (Cooper, personal communication, 1974). Vigorous longshore currents could have redistributed these sands into spits and possible barrier bars.

The Basalts

Three basalt types exist within the thesis area. They are the middle Miocene Depoe Bay Basalt, the slightly younger Cape Foulweather Basalt, and rare intrusives of late Eocene basalt (Goble Volcanics). Snavely and others (1973) defined the first two basalt units near the town of Depoe Bay, Oregon, and at Cape Foulweather, both to the south of the thesis area. Depoe Bay Basalt is medium to dark gray, aphanitic to finely crystalline, and equigranular. Cape Foulweather Basalt is characterized by sparse, large plagioclase phenocrysts, a low content of SiO_2, and high content of total iron and

TiO_2 with respect to Depoe Bay Basalt. The late Eocene Goble Basalt is characterized by abundant (25%) small plagioclase phenocrysts, a low content of SiO_2 and total iron, and high contents of CaO, Al_2O_3, and MgO relative to Depoe Bay and Cape Foulweather Basalt types. These basalts form resistant headlands and steep, topographic highs and ridges in the Oregon Coast Range.

Depoe Bay Intrusive Rocks

Distribution. Depoe Bay intrusive basalts occur as dikes, thick and thin sills, and large irregular intrusive bodies. Thin dikes (less than five feet thick) to large sills (over 300 feet thick) occur at isolated exposures throughout the thesis area. Many thin, irregular sills and dikes are exposed along the coast (Figures 19 and 20). Outlines of intrusive bodies on Plate I are approximate because the contacts are commonly covered with talus and brush. Because of the highly irregular form of many of the intrusives (Figure 15), it is generally difficult to apply the strict definition of the geologic terms, dike or sill, to these bodies. Commonly the same intrusive may be sill-like and concordant with the sedimentary host rock at one locality and discordant with the same host rock at another locality. The intrusive bodies are differentiated through their topographic expression and contact relations with the host rock. Dikes are narrow, near vertical, elongate bodies that cut across topographic contour lines and strata,

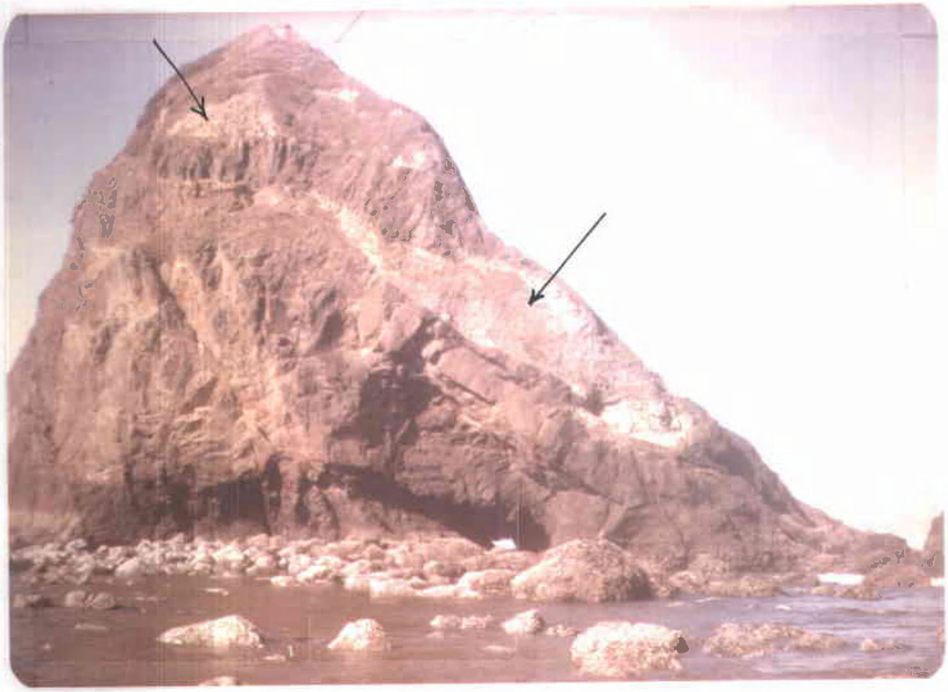


Figure 19. Sea stack of Depoe Bay Basalt at Silver Point. Note pods of Silver Point mudstones caught between irregular intrusive basalt (arrows).

Figure 20. Small, highly irregular, fractured intrusive of Depoe Bay Basalt intruding Angora Peak sandstone. Bedding is nearly horizontal. Located one mile above Hug Point on the Hug Point logging road.

whereas the generally thicker sills appear as near horizontal, tabular bodies that generally parallel strata and conform with the topographic contours (Plate I). Dikes and sills intrude and therefore post-date all the sedimentary rocks. Dikes within exposures of Depoe Bay extrusive breccias are commonly brecciated along their margins and thus are probably local feeders. On a logging road near the middle of the section line between sections 7 and 8, T. 4 N., R. 10 W., a 50-foot dike is brecciated near the margins, and the dike becomes completely brecciated 50 feet above the road.

Along the coast, Depoe Bay Basalt intrusives form headlands such as Arch Cape, Humbug Point, and Silver Point, and offshore rocky points such as Castle Rock, Lion Rock, and Jockey Cap (Plate I). Inland, many of the steep ridges are held up by intrusives. A 300-foot thick diabase sill forms a 500-foot high ridge in section 18 and the northern half of section 19, T. 4 N., R. 9 W. This sill intrudes both the Astoria Formation and the Oswald West mudstones. Dips on the top of the sill, interpreted from air photos, slope toward the center of the intrusive body where the Silver Point mudstone member crops out. These dips and the arcuate outcrop pattern suggest that the intrusive has an irregular dish or lopolith shape. One mile north of the lopolith-like sill, similar sills crop out: one under Kidders Butte, the other under Sugarloaf Mountain. These sills directly underlie extrusive Depoe Bay breccia. The similar thickness, lithologic character, stratigraphic and topographic position, and geographical proximity of the sills suggest that these sills were originally a single large intrusive body before erosion and faulting separated them. Many large and small dikes appear to be related to the sills. A 300-foot diameter, plug-like intrusive occurs within the extrusive breccia on Kidders Butte (Plate I) and is most likely an upper expression of the underlying sill.

Lithologic and Contact Characteristics. Depoe Bay Basalt intrusives are medium gray (N5) to dark gray (N2) in color and are composed of aphanitic to finely crystalline, columnar jointed basalt. Thick sills are medium crystalline and diabasic. The basalt weathers to iron-stained dusky yellowish brown (10 YR 4/2).

Well developed columnar jointing can be seen in most intrusives exposed in quarries, along logging roads, and in coastal exposures (Figure 21). Columnar jointing is well exposed in the intrusive body that forms the coastal cliff at Arch Cape. Near the borders of this intrusive, jointing is nearly horizontal. The jointing becomes more vertical toward the interior. Since columnar jointing develops perpendicular to cooling surfaces, this jointing pattern indicates a dome-shaped or cylindrical form to the intrusive body. The intrusive thickens inland and has irregular contacts with the surrounding strata. Large (up to 200 feet in diameter) blocks of Angora Peak sandstones are incorporated in the intrusive near its upper boundary in the sea

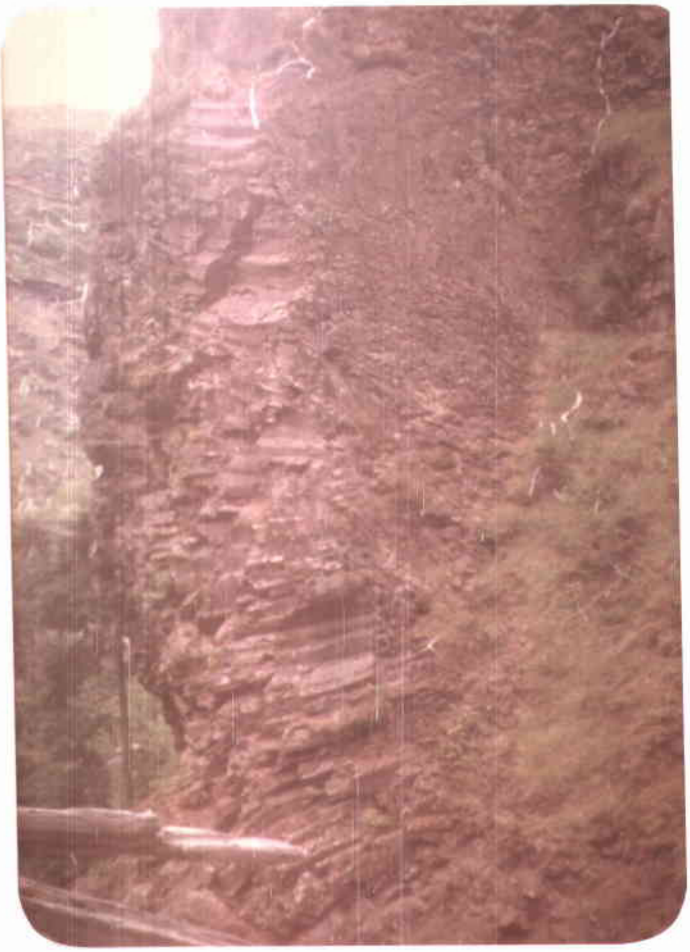


Figure 21. Horizontal, columnar jointing in a 20-foot thick Depoe Bay Basalt dike which intrudes Silver Point mudstone near Arch Cape Creek, in section 29, T. 4 N., R. 10 W.

sea cliff exposure. This large intrusive is typical of the irregularity of many of the intrusives exposed in the thesis area. Depending on the exposure, the intrusive may be called a sill or a dike, but it is most accurately described as an irregular intrusive body. The thick diabase sill that underlies Kidders Butte in the northeastern part of the thesis area exhibits irregular, vertical platy jointing. Joints are closely spaced (1 to 5 inch separation), with some platy joints bent and others irregular near the border of the sill.

Intrusives in the Oswald West mudstones are generally large (10 to several hundred feet thick) and more regular in shape than those found in the Astoria Formation. No brecciation of dike and sill contacts was found in Oswald West mudstones. The large sill in the southeast corner of the thesis area, and the sill which cuts across sections 15 and 16, T. 4 N., R. 9 W., are both concordant with the strata and have sharp, planar contacts with the host rock (Plate 1). Reddish baked zones are usually one inch thick or less. Dikes that intrude Oswald West mudstones have planar, discordant contacts with no brecciation.

In contrast to the planar, sharp, intrusive contacts found in the Oswald West mudstones, the intrusive contacts in the Angora Peak and Silver Point sedimentary units are irregular and commonly brecciated. Brecciation occurs locally over a zone several feet wide. More commonly, the contact consists of a thin, glassy chilled zone

one inch wide against a baked sedimentary zone one inch wide. Basalt contact surfaces have a fractured and undulating appearance.

The dikes and sills that intrude the Astoria strata are very irregular in shape and thickness (a few inches to hundreds of feet thick). The intrusives bifurcate and incorporate large blocks of strata (Figure 19).

A peperite dike occurs along the coast one-half mile north of Hug Point (Figure 31). This north-south trending dike is ten feet wide and can be traced 200 feet along the beach. The dike is composed entirely of a chaotic mixture of lapilli-sized angular blocks of tachylyte, finely crystalline basalt, and fine-grained, laminated, carbonaceous sandstone blocks in a sandstone matrix (Figure 22). The aphanitic basalt blocks are partly altered to a greenish clay mixture of montmorillonite, mica, and zeolites (Neel, personal communication, 1974). Laminated, fine-grained Angora Peak sandstones are vertical adjacent to the peperite dike. Petrographically, the tachylyte glass fragments have a hyaloophitic texture consisting of scattered microlites of plagioclase, minor phenocrysts of plagioclase, augite and magnetite in a dark turbid basalt glass. Sedimentary quartz and feldspar grains penetrate and occur within and between the turbid tachylyte fragments. The quartz grains contain embayed boundaries. The feldspars show little alteration. The basaltic magma incorporated sand grains from the host rock and was rapidly quenched, resulting in brecciation and

Figure 22. Close-up of peperite dike composed of angular basalt blocks (B) and angular, laminated mudstone and sandstone clasts (C) in an angular sandstone matrix one-half mile north of Hug Point.

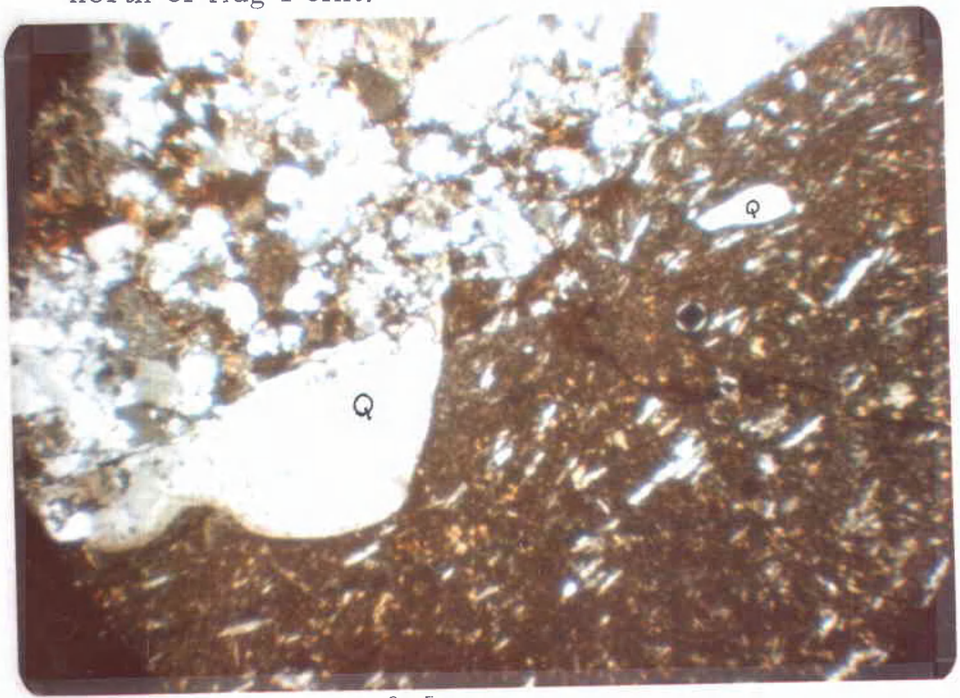


Figure 23. Basaltic glass fragment with pilotaxitic texture (lower half of photo) from the peperite dike near Hug Point. Note sheared-off, embayed quartz fragment (Q) and angular, quartz, lithic sandstone matrix; crossed nicols.

shearing of some quartz grains along the edges of glass fragments (Figure 23). Brecciation and alteration of basalt sills and dikes along contacts, and the peperite dike, probably resulted from steam blasting and quenching of hot magma intruding water-saturated semi-consolidated Angora Peak sediments. Field evidence suggests penecontemporaneously deformed Astoria sedimentary rocks must have been water-saturated and semi-consolidated at the time of intrusion, in contrast to the undeformed Oswald West mudstones. On the other hand, Oswald West mudstones were most probably lithified when intruded by Depoe Bay Basalt.

Petrology. Depoe Bay intrusives are composed of equigranular basalt. Brecciated intrusives have hyaloophitic textures; fine to medium crystalline basalts contain intersertal to intergranular textures, while diabases are subophitic in texture. Basalts are composed of 45 to 60% plagioclase, 20 to 25% clinopyroxene, 2 to 5% orthopyroxene, 5 to 10% opaque minerals, 10 to 20% glass and its alteration products (Appendix X).

Plagioclase occurs as subhedral laths usually less than 1 mm. in length. Labradorite (approximately An_{54}) is found both in the groundmass and in the centers of larger crystals. Larger crystals are progressively zoned with calcic andesine (approximately An_{45}) near the edges of some crystals. Plagioclase compositions were determined by the Michel-Levy method. Augite and pigeonite (2V = 25 to 50^{o}) occur in subhedral crystals, partially encasing the plagioclase crystals. Rarer orthopyroxenes, probably enstatite, occur as subhedral to anhedral interstitial crystals usually significantly smaller than the clinopyroxenes. Magnetite also is present as subhedral crystals between plagioclase crystals. Scattered deuteric alteration products are chlorophaeite and chlorite (Figure 24). A silicic residuum composed of quartz and alkali feldspar (?) is common in the groundmass.

The silicic residuum, chlorophaeite, and orthopyroxenes are lacking in the aphanitic basalt intrusives. Instead, dark, turbid basaltic glass (tachylyte) forms the groundmass between laths of plagioclase and pyroxenes. Zoned plagioclase crystals are also absent. Mineral compositions and volcanic textures of Depoe Bay Basalt intrusives in the thesis area (see modal analysis, Appendix X) are very similar to the type Depoe Bay Basalts described by Snavely and others (1973).

Depoe Bay Extrusive Rocks

Distribution. Depoe Bay Basalt extrusives crop out over approximately 20 square miles in the central part of the thesis area (Plate I). These resistant basalts form the highest and steepest, most rugged terrain within the thesis area (Figure 2). Natural precipitous cliff exposures of basalt with only thin soils are common. Onion Peak

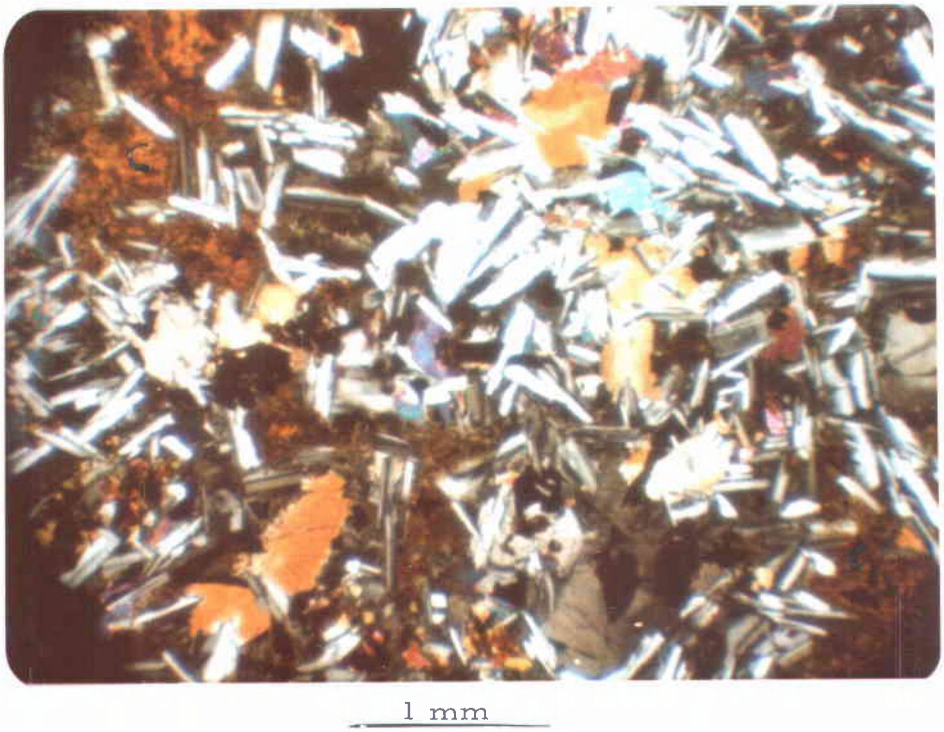


Figure 24. Depoe Bay Basalt dike rock showing intersertal texture of brown alteration products (mainly chlorophaeite (C)) filling voids around the plagioclase laths, colorful yellow and blue pyroxenes (mostly augite), and black magnetite; crossed nicols.

(elevation 3064 feet) and Sugarloaf Mountain are composed of submarine basalt breccias exceeding 2000 feet in thickness. An abrupt break in slope marks the contact between resistant basalt extrusive rocks and the softer sedimentary units.

Lithologic Characteristics. Depoe Bay Basalt extrusives are composed predominantly of submarine pillow breccias (Figure 25). Rare subaerial flows and pillow lavas also occur.

The breccias consist of well cemented, angular, grain-supported, lapilli-sized, dark glassy to aphanitic basalt fragments in a lighter ash-sized palagonitized matrix. Fractures and vesicles in the fragments are filled with radiating zeolites, chalcedony, and calcite. Where fresh, these fragments are medium dark gray (N4) with a resinous luster in a medium gray (N5) matrix. Weathered palagonite surfaces are moderate yellowish brown (10 YR 5/4) to an iron-stained red. These basaltic breccias are well exposed in the Double Peak area in section 7, T. 4 N., R. 10 W., and on the higher peaks such as Onion Peak and Sugarloaf Mountain.

Individual pillows and lapilli-sized broken pillow fragments make up small amounts of the brecciated flows. The pillow fragments can be distinguished as a dark rim of glassy material (sideromelane) partially surrounding an aphanitic basaltic interior. Fresh pillow rims are black (N1) while the interior of the pillows is medium dark gray (N4).

Figure 25. Pillow fragments of Depoe Bay Basaltic breccia from section 8, T. 4 N., R. 10 W. Note darker pillow rims and brecciated pillow interior in yellowish-brown palagonitic ash matrix.

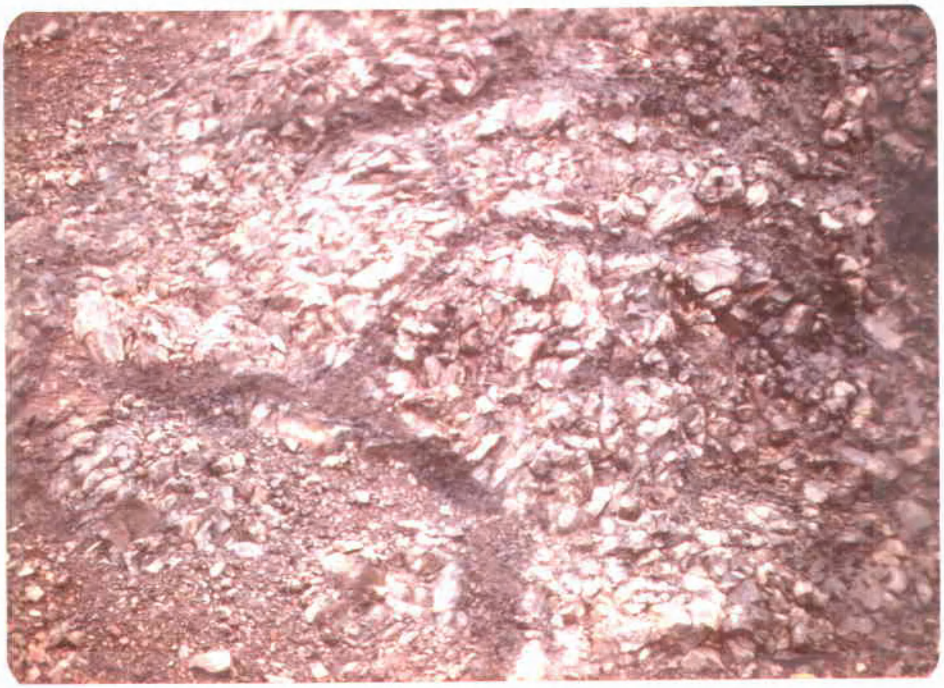


Figure 26. Fresh exposure of closely packed pillows of Depoe Bay Basalt near Kidders Butte in section 4, T. 4 N., R. 9 W. Pillows are two feet in diameter.

A 15-foot thick pillow lava and a possible subaerial flow occur near Kidders Butte in the SW 1/4 of section 4, T. 4 N., R. 9 W., near sample locality 10 (Plate I). The pillow lava consists of closely packed, ellipsoidal pillows with well developed tear-drop terminations (Figure 26). Pillows average two feet in diameter. Pillow rims, up to two inches thick, are glassy, darker, and have a resinous luster.

The subaerial flow (ten feet exposed) has a reddish, scoriaceous lower contact two to five inches thick (Figure 27). The upper contact is not exposed. The main mass of the flow is characterized by finely crystalline vesicular basalt. In thin section, basaltic glass comprises approximately 30% of the rock with calcic plagioclase microlites (55%), clinopyroxenes (10%), and magnetite (4%) forming the remainder. The vesicle fillings are radiating calcite crystals. The microlites are partially aligned in a pilotaxitic texture, indicating that a flow texture started to develop. The flow shows no brecciation.

In the lower 200 feet of basaltic breccias, immediately above the contact with Silver Point mudstones, there are incorporated contorted blocks of mudstone and siltstone. Some of these blocks are as much as 30 feet long and 10 feet wide. Blocks of strata were found along Arch Cape Creek in section 29, T. 4 N., R. 10 W., and along the West Fork of Elk Creek in sections 5 and 8, T. 4 N., R. 10 W. Traces of detrital sand grains occur in the palagonite matrix of the breccia. A few thin (4 to 30 inches thick) interbeds of dark mudstone

Figure 27. Reddish oxidized scoriaceous layer beneath possible subaerial flow of Depoe Bay Basalt which overlies breccia flow; hammer for scale. Near sample locality 10; section 4, T. 4 N., R. 9 W.

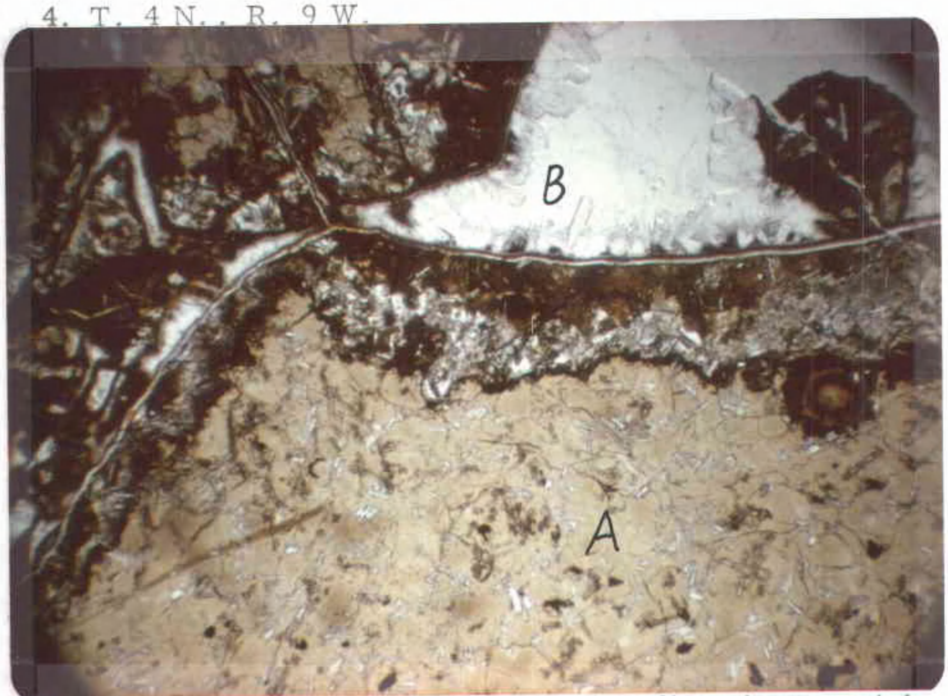


Figure 28. Perlitic cracks and plagioclase microlites in greenish basaltic glass fragment in Depoe Bay Basaltic pillow breccias. Note dark brown palagonitic alteration of glass along fractures, hyalo-ophitic texture of glass fragments (A) and zeolites (B) filling voids; plain light. 1 mm

also occur in the breccias.

Petrology. In thin section, the lapilli basalt fragments in the breccia are composed primarily of basaltic glass (70%) containing scattered microlites of calcic plagioclase in a hyaloophitic texture, and minor phenocrysts of plagioclase (20%), augite (3%), magnetite (2%), and the zeolite clinoptilolite (5%). Translucent light brown sideromelane and minor amounts of turbid tachylyte comprise the glassy constituents. Perlitic cracks are common in the fresh sideromelane (Figure 28). Edges and small fragments of the glass are altered to yellowish-brown palagonite. The matrix is primarily a mass of fine and coarse ash-sized palagonitized basalt fragments containing tiny plagioclase and augite crystals. Prismatic and fibrous zeolites including clinoptilolite also fill fractures and voids, partially cementing the angular basalt fragments (Figure 28).

Origin. The following features suggest that these basalts were extruded into a subaqueous environment in a deep, subsiding basin: (1) interbeds of deep marine mudstones from which foraminifera were recovered by Neel (1975), (2) pillow lavas, (3) accumulation of over 2000 feet of brecciated, quenched basalt lavas with sideromelane and tachylyte glasses, (4) palagonitic alteration of the glass, and (5) a lack of subaerial flow features. Locally, basalt accumulations may have formed small islands because a subaerial flow was found.

The basalts were supplied by local feeder dikes. The dikes were intruded over a period of time, feeding separate flows onto the ocean bottom. Some of these dikes are brecciated along their margins in the Angora Peak and Silver Point strata and become completely fragmented upward into the overlying extrusive breccias. Individual flow units are difficult to distinguish because the breccia is generally massive and continuous. However, a few thin mudstone interbeds indicate that there were periods of quiescence in volcanic activity.

Locally, the basaltic breccias are found topographically below Silver Point mudstones in areas where tectonic structures and slumping cannot entirely account for the difference in elevation. For example, an area of approximately one square mile that includes Double Peak (Plate I) contains unfaulted basaltic breccia, located 800 to 1000 feet below adjacent Silver Point mudstones which crop out on the surrounding slopes. Along the North Fork of Elk Creek, the extrusive breccias-Silver Point contact is 300 feet above sea level while on Sugarloaf Mountain and Kidders Butte the same unfaulted contact is 1600 feet above sea level.

These elevation irregularities in the contact relationship between Silver Point mudstones and Depoe Bay basalt breccias is attributed to eruption of the basaltic breccias onto a very irregular sea floor. The topography of the sea floor off the modern Oregon shelf is very irregular (Kulm and Fowler, 1974b). Various ridges, hills, canyons, and escarpments have as much as 4000 feet of relief. Several submarine banks (Nehalem, Stonewall, Heceta, and Coquille) in which bedrock is exposed, rise as much as 300 feet above the general slope. A similar relief may have existed during the Miocene when the Depoe Bay Basalts were extruded because an unconformity, with much relief between the Depoe Bay breccias and underlying strata, is known to occur (Snavely and others, 1969). The basalt breccias flowed down canyons and around hills, and were probably extruded at different elevations on the sea floor. The result was contact irregularities between the breccias and the Silver Point mudstones. Later uplift and local faulting of the Coast Range in the Pliocene may have further accentuated these topographic differences.

Baldwin (1952) suggested that the middle Miocene basaltic breccias of Sugarloaf Mountain, Onion Peak and nearby Saddle Mountain were originally part of a thick, continuous, widespread sheet of basaltic breccia and that subsequent erosion has highly dissected that sheet. Evidence from this investigation, however, suggests that some of the patchy outcrop distribution of the basaltic breccia in the thesis area is due, in part, to extrusion of lava over an irregular submarine topography. The writer believes from field evidence that the thick breccias at Sugarloaf Mountain and Onion Peak are more likely eroded remnants of local centers of volcanic activity fed by dikes and sills rather than eroded parts of a much larger 2000-foot thick breccia sheet. These breccias probably would not have flowed with the ease of subaerial flows. The possibility of a 2000-foot thick sheet of breccia covering all of Clatsop and Tillamook counties, that has been differentially eroded since the middle Miocene leaving mountain peaks composed of 2000 feet of breccia, does not seem probable.

Contact Relations. The extrusive Depoe Bay Basalts lie with angular unconformity on the underlying units. This relationship is exposed along the West Fork of Elk Creek and from Sugarloaf Mountain down to the East Fork of Elk Creek. The contact zone with Silver Point strata is a very irregular mixture of sedimentary rock and the basaltic breccias. Consistent strike and dip disparities between underlying Silver Point strata and less steeply dipping Depoe Bay Basalt breccias in these areas support the existence of an angular discordance. Regionally, Depoe Bay Basalt breccias unconformably overlie the Miocene Astoria Formation at Angora Peak (Cressy, 1974), and Oligocene strata at Saddle Mountain (Wells and Peck, 1961).

Age and Correlation. In the thesis area, Depoe Bay Basalt sills and dikes intrude the middle Miocene Angora Peak sandstones and Silver Point mudstones, and the extrusive breccias overlie these strata, indicating a middle Miocene or younger age from these basalts. A radiometric age of 15.5 $\pm$ 0.35 million years was obtained from the Neahkahnie Sill of Depoe Bay Basalt five miles south of the thesis area (Niem and Cressy, 1973). Other radiometric dates of intrusives in the general area range from 14.0 ± 2.7 to 16.0 ± 0.65 million years (Snavely and others, 1973). These absolute ages place the basalt at middle Miocene age (Turner, 1970).

Snavely and others (1973) correlate the Coast Range Depoe Bay Basalts to Yakima-type flows of the Columbia River Group on the basis of similar age and chemical composition.

Cape Foulweather Intrusive Rocks

Distribution and Lithologic Characteristics. A single example of Cape Foulweather Basalt is exposed in the thesis area in two quarries in section 6, R. 4 N., R. 10 W. (Plate I). This mass is a sill which intrudes the Silver Point mudstone member and cuts across Depoe Bay Basalt dikes. The sill varies in thickness from 30 to 60 feet and displays well developed vertical columnar jointing perpendicular to the sedimentary unit contacts. The small ridge on the west flank of Double Peak is held up by this sill.

The Cape Foulweather sill is characterized by sparse, large, yellowish plagioclase phenocrysts in a dark, dense aphanitic basalt. In outcrops, these phenocrysts comprise less than one percent of the basalt and are up to 0.5 inch in length. Fresh color of the basalt is medium gray (N5). The basalt weathers to grayish orange (10 YR 7/4) and forms large (up to 12 inches) blocks. The concordant contact with the sedimentary strata consists of a one inch glassy zone in the sill and a four-inch hardened, reddish baked zone in the sedimentary units.

Petrology. Petrographically, the coarsely crystalline plagioclase phenocrysts were determined to be labradorite (approximately An_{54}) using the Michael-Levy method of feldspar analysis. Snavely and others (1973) report similar but slightly more calcic plagioclase (An_{64}) phenocrysts in the type Cape Foulweather Basalts. Plagioclase microlites, which form 45% of the groundmass, are labradorite (An_{62}). Small subhedral crystals of the clinopyroxenes, augite and pigeonite (29%), partly surround the plagioclase microlites. Orthopyroxenes (7%) and magnetite (10%) infill the interstices between feldspar microlites. The crystals in the groundmass form an intersertal texture with alteration minerals and mineraloids (8%) partly filling interstices. Chlorophaeite is the most common alteration product with greenish celadonite and silicic residuum (an intergrowth of quartz and alkali feldspar) infilling the remainder of the interstices. Modal analysis of a sample of Cape Foulweather Basalt is summarized in Appendix X.

Age and Correlation. At the type section, Cape Foulweather Basalt overlies Depoe Bay Basalt and the sandstones of Whale Cove at Depoe Bay, Oregon (50 miles south of the thesis area; Snavely and others, 1973). The Cape Foulweather Basalt sill in the thesis area cuts middle Miocene Depoe Bay Basalt dikes and therefore is middle Miocene or younger. Radiometric ages of the Cape Foulweather

Basalt in the Oregon Coast Range fall within the middle Miocene (Snavely and others, 1973). On the basis of field, petrographic, and chemical characteristics, the Cape Foulweather basalt correlates with the type Cape Foulweather Basalt described by Snavely and others (1973). They correlate the Cape Foulweather Basalt with late-Yakima Basalts of the Columbia River Group of eastern Oregon and Washington on the basis of similar age and nearly identical chemical compositions.

Other Intrusive Basalts

Distribution and Lithologic Characteristics. An unusual north-south trending, porphyritic basalt dike exposed in sections 21 and 28, T. 4 N., R. 9 W., has distinctive weathering and outcrop patterns, and petrographic and chemical characteristics that differ significantly from both Depoe Bay and Cape Foulweather Basalts.

The basalt contains abundant (over 20%) plagioclase phenocrysts. Depoe Bay Basalt lacks phenocrysts and Cape Foulweather phenocrysts are much larger and more rare. Weathered exposures of this basalt are distinctive from those of Depoe Bay and Cape Foulweather Basalts. This basalt becomes soft and crumbly, losing its obvious basaltic characteristics upon weathering, whereas the Depoe Bay and Cape Foulweather Basalt rarely lose their resistant, steel black, hard nature even in more weathered outcrops. The porphyritic dike varies in thickness from 3 to 40 feet and forms a 200-foot high elongate ridge.

Fresh samples are dense, hard, and dark gray (N3) in color. The basalt weathers to a characteristic crumbly, chalky grayish yellow (5 Y 8/4) and iron-stained pale reddish brown (10 R 5/4) color with scattered black flakes in the yellow groundmass. The dike has an erosion-resistant interior containing both horizontal and vertical fractures. Near the contacts the dike is progressively altered, probably the result of more intense weathering as a result of being more closely fractured near the contacts.

One other porphyritic dike with similar weathering and outcrop characteristics was found cutting an Angora Peak channel conglomerate in the center of section 24, T. 4 N., R. 10 W.

Petrology. Petrographically, the rock is characterized by abundant subhedral phenocrysts of plagioclase (16%) approximately 0.2 inch long. Plagioclase phenocrysts are labradorite (An_{54}). Plagioclase microlites (44%) that form the groundmass are labradorite (An_{62}). A fresh sample consists of clinopyroxenes (28%), usually augite and pigeonite, orthopyroxenes (9%), and magnetite (3%). The orthopyroxenes, clinopyroxenes and plagioclase compositions are very similar to those in the Cape Foulweather Basalts. The texture is subophitic in fresh samples taken near the center of the dike and intersertal in samples near the contacts. Near the contacts, mineraloids and alteration products fill interstices between plagioclase microlites and replace the pyroxenes. These products are mainly chlorophaeite and celadonite which comprise as much as 10% of the rock. A silicic residuum of quartz and alkali feldspar (?) also occurs.

The primary petrographic differences between this basalt and the Depoe Bay and Cape Foulweather Basalts are the much greater abundance of plagioclase phenocrysts and the low magnetite (3% in this basalt as opposed to 10% in the other two basalts).

Chemical Compositions and Correlations

Chemical analyses were conducted on seven samples (Appendix IV). One sample (Ac) was from the Depoe Bay intrusive that forms Arch Cape. Another (Br 50) was from a fresh pillow fragment from Depoe Bay breccias near Onion Peak. A third sample (1) was from the tentative Cape Foulweather sill near Double Peak and the fourth (32) was from the unusual phenocryst-rich north-south dike in the southeastern part of the thesis area (Appendix IX). The other three samples were of volcanic boulders from an Angora Peak channel conglomerate (see discussion in the Pebble Lithology section). The Arch Cape intrusive and pillow fragment and the Cape Foulweather sill rock plotted on a silica variation diagram within the chemical ranges of Depoe Bay and Cape Foulweather Basalts determined by Snavely and others (1973), thus confirming the field and petrographic identifications of these igneous rocks (Figure 29).

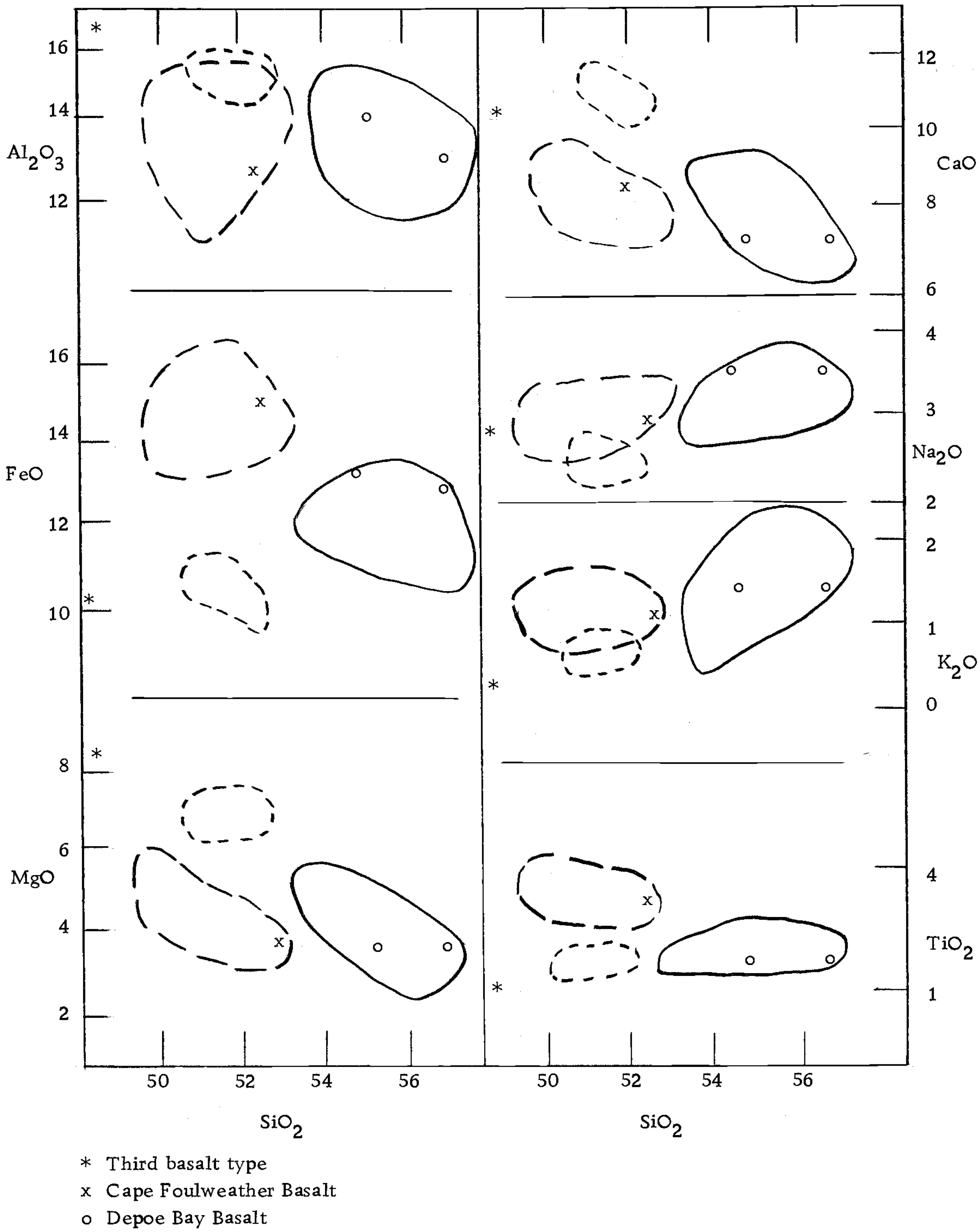


Figure 29. Silica variation diagram of basalts found in the thesis area. Solid lines enclose Depoe Bay and Yakima-type basalt; long dashes enclose Cape Foulweather and late-Yakima-type basalt; and short dashes enclose Pack Sack and Pomona Basalt (Snavely and others, 1973).

The Depoe Bay Basalt samples are distinguished from the Cape Foulweather Basalt sample by higher SiO_2 content and lower contents of total iron and TiO_2 (Appendix IX). The Depoe Bay and Cape Foulweather Basalts are chemically tholeiitic basalts when plotted on the silica variation diagram devised by Kuno (1968).

In contrast, the unusual porphyritic basalt from the north-south-trending dike in the southeast part of the thesis area (sample 32) plots as a high-alumina basalt on Kuno's silica variation diagram. The crystal-rich dike plots in the chemical ranges for neither the Depoe Bay nor the Cape Foulweather Basalts determined by Snavely and others (1973) (Figure 29). This third basalt is chemically distinct from both the Depoe Bay and Cape Foulweather Basalts in having lower SiO_2, total iron, and K_2O contents and higher CaO, Al_2O_3, and MgO contents.

Attempts were made to match this basalt with chemical analyses of older Eocene and Oligocene Coast Range basalts (summarized by Snavely and others, 1972). However, there is really no close chemical fit. The distinctive chemical differences are in the high Al_2O_3 and MgO content (16.8 and 8.5%, respectively) for this unusual porphyritic basalt. In general, older Coast Range basalts have high Al_2O_3 but rather low MgO contents (Table I). For example, the basalt at Yachats has 17.6% Al_2O_3 and only 3.6% MgO content. The only sample with comparably high MgO content is from the Siletz River

Table I. Average chemical composition of volcanic and intrusive rocks of the northern and central Coast Range, Picture Gorge and local basalt (32). (Averages recalculated water-free) (from Snavely and others, 1973).

	Volcanic Rocks							
	Lower & Middle Eocene		Uppermost Eocene			Middle Miocene		
	1	2	3	4	5	6	7	8
SiO_2	49.0	48.2	51.4	47.1	41.7	55.7	51.9	50.1
Al_2O_3	14.5	16.0	17.6	15.5	12.7	14.0	13.9	15.5
FeO + Fe_2O_3	11.6	12.0	10.9	12.0	16.5	12.3	14.5	11.2
MgO	8.3	6.1	3.6	6.6	7.8	3.6	4.1	6.7
CaO	12.2	7.4	8.7	10.3	10.3	7.1	7.9	10.6
Na_2O	2.3	4.3	3.6	3.0	2.1	3.3	3.0	3.0
K_2O	0.2	1.9	1.0	1.3	2.7	1.4	1.0	0.6
TiO_2	1.6	3.3	2.6	3.3	4.4	2.0	3.0	1.6
Number of Analyses	3	9	20	12	4	8	11	?

	Intrusive Rocks							
	Lower Upper Eocene?	Uppermost Eocene		Lower Oligocene		Mid-Oligocene	Middle Miocene	
	9	10	11	12	13	14	15	16
SiO_2	50.0	43.2	41.0	60.2	55.1	57.2	57.4	48.3
Al_2O_3	15.1	14.1	13.1	19.0	14.0	13.1	13.4	16.8
FeO + Fe_2O_3	12.3	14.8	16.5	6.0	13.5	14.3	14.7	10.3
MgO	5.2	4.5	7.5	0.2	2.0	1.3	1.5	8.5
CaO	10.0	10.7	10.0	1.2	5.7	5.3	5.2	11.0
Na_2O	3.6	3.7	3.6	8.6	4.9	3.7	3.0	3.0
K_2O	0.6	2.0	2.1	4.1	1.1	1.8	2.0	0.4
TiO_2	2.2	3.8	4.5	0.2	2.0	1.9	1.7	1.4
Number of Analyses	17	5	3	11	2	3	5	1

1. Tholeiitic basalt from lower part of Siletz River volcanics (Snavely and others, 1968).
2. Alkalic basalt from upper part of Siletz River Volcanics (Snavely and others, 1968).
3. Basalt near Yachats, Waldport, Tidewater, and Mapleton quadrangles (Snavely and others, 1969).

Table I. (Continued)

4. Basalt near Cascade Head, Hebo quadrangle (Snavely and others, 1969).
5. Camptonitic volcanic rocks, lower Siletz River (Snavely and others, 1969).
6. Depoe Bay Basalt, northwestern Oregon (Snavely and others, 1973).
7. Cape Foulweather Basalt, northwestern Oregon (Snavely and others, 1973).
8. High Mg Picture Gorge Basalt, eastern Oregon (Wright and others, 1973).
9. Albitized diabase sills and dikes, Euchre Mountain, Valsetz, and Grande Ronde quadrangles.
10. Hornblende camptonite sills and dikes, Euchre Mountain quadrangle.
11. Biotite camptonite dikes, Euchre Mountain quadrangle.
12. Nepheline syenite sills, dikes, and stock, Tidewater and Waldport quadrangles.
13. Chilled margin basalt, Marys Peak sill, Marys Peak quadrangle.
14. Chilled margin basalt, Cedar Creek sill, Euchre Mountain quadrangle.
15. Chilled margin basalt, Stott Mountain sill, Euchre Mountain and Valsetz quads.
16. Basalt sample 32, this thesis.

volcanics (Column 1, Table I) with 8.3%; however, the Al_2O_3 content is only 14.5%.

It is interesting that this unusual high alumina basalt closely matches the chemistry of the Picture Gorge basalt of the Columbia River Group of eastern Oregon (Wright and others, 1973); both have similar high MgO and Al_2O_3 content (Table I). The Picture Gorge Basalt type has not been previously recognized in the Oregon Coast Range. It is realized, however, that one chemical analysis of this porphyritic dike is insufficient to generalize and really compare with the total chemical ranges of Eocene and Oligocene Coast Range volcanics. Snavely (personal communication, 1974), after reviewing the chemical analysis and thin section of this unusual basalt, is of the opinion that it could fit with some of the variations he has seen in high alumina late Eocene Coast Range basalts (e.g., Siletz River, Goble or Nestucca Volcanics).

This is reasonable because stratigraphically the basalt intrudes possible late Eocene(?) lower Oswald West strata in the far southeastern part of the thesis where, a few miles away, Wells and Peck (1961) recognized late Eocene volcanic and sedimentary rocks. Thus, this basalt type is tentatively correlated with the late Eocene volcanics of the Oregon Coast Range, probably the Goble Volcanics.

Quaternary Deposits

Pleistocene and Recent deposits occur in a narrow strip along the coast as marine terraces, beach, and dune sand and along streams in the lower valleys as alluvium. There are several recent landslides along the coast, and a colluvium of breccia blocks cover part of the eastern part of the area.

Beach sands are continuous along the entire length of the shoreline. The widest beaches are found near the town of Arch Cape and north at Tolovana Park (Plate I). The sand is well-sorted and is composed predominantly of quartz and feldspar with minor amounts of volcanic fragments and ferromagnesium minerals. Grain sizes average medium sand with coarser sand to pebbles locally found near streams and headlands where there are local sources of detrital clasts. Summer beach sands are three to five feet thicker than winter beaches. Winter beaches characteristically contain rounded basalt cobbles, particularly around the headlands such as Arch Cape.

Pleistocene marine terrace deposits are relatively thin, less than 20 feet high, largely dissected, and poorly exposed. Only portions remain in the coves between headlands from Hug Point to Arch Cape and near Cannon Beach. The marine terrace on which the town of Arch Cape is built forms a nearly one-half mile wide flat surface. Beach exposures show these deposits to be crudely stratified and contain numerous partially carbonized tree trunks and limbs. The deposits are composed predominantly of beach sand and basalt pebbles. Some irregular buried soil horizons and mud and silt beds less than two feet thick also occur within these deposits. Further evidence of once higher ocean levels or lower coastline can be observed in the sea cliff at Hug Point State Park where the sea eroded steep notches into the Astoria conglomeratic sandstone cliffs which are now filled with terrace colluvium.

Most of the stream alluvium occurs as a strip up to one-quarter mile wide along the Nehalem River in the eastern part of the thesis area (Plate I). Along the river alluvium unconformably overlies Oswald West mudstones. The alluvium consists predominantly of coarse river basalt gravels and channel sands and silty flood plain deposits. River-cut exposures of deposits show they are at least 50 feet thick.

Other Quaternary deposits in the area include landslide deposits, colluvium, and talus. Landslides are outlined on Plate I. Landslides are recognized on aerial photos and on the ground by hummocky topography and recent pullaway scarps. The landslide deposits exposed between Hug Point and Silver Point along the beach consist of a mixture of angular rock fragments, blocks of basalt, and trees and brush suspended in a chaotically churned sand and mud matrix. Most of the angular basalt fragments were derived from the basaltic breccia and intrusives.

Deposits of colluvium derived from the breccia occur throughout the thesis area, particularly along the contact between Depoe Bay Basalt extrusive breccias and the Silver Point mudstone in the eastern part of the thesis area. Colluvium consists of blocks (up to 20 feet in diameter) of basaltic breccia and mud. The colluvium is partly covered by vegetation and forms a hummocky topography. The sliding of the breccia is caused by removal of support at the toe. For example, the "soft" Silver Point mudstones are easily removed from beneath the breccia by stream erosion allowing sliding to occur. Thick talus deposits occur around many of the intrusives. The talus deposits consist of angular blocks of basalt in a mud and silt matrix.

STRUCTURAL GEOLOGY

Regional Structure

The regional structure of the northern Coast Range is a north-plunging anticlinorium (Wells and Peck, 1961). Within the anticlinorium are a series of gentle folds with one to two mile wavelengths and with axes striking to the north and northwest (Niem and Van Atta, 1973). Eocene Siletz River and Tillamook Volcanics are exposed in the core of the anticlinorium. Surrounding the oldest rocks are younger late Eocene, Oligocene, and Miocene sedimentary rocks which dip (10 to 30°) away from the core to the east, west, and north. According to Braislin and others (1971), the folds are normal compressional type. The folds are cut by numerous high angle normal and reverse faults.

Structure of the Thesis Area

The largest structural feature of the thesis area is a broad north-plunging syncline (Figure 30, Plate I). The syncline axis strikes north-south through the basaltic breccia that forms Sugarloaf Mountain and Onion Peak. The limbs dip from 11° to 40° and are roughly symmetrical. The youngest extrusive unit in the thesis area, the Depoe Bay Basalt breccias, forms the core of the syncline with progressively older strata (the Silver Point mudstone, Angora Peak

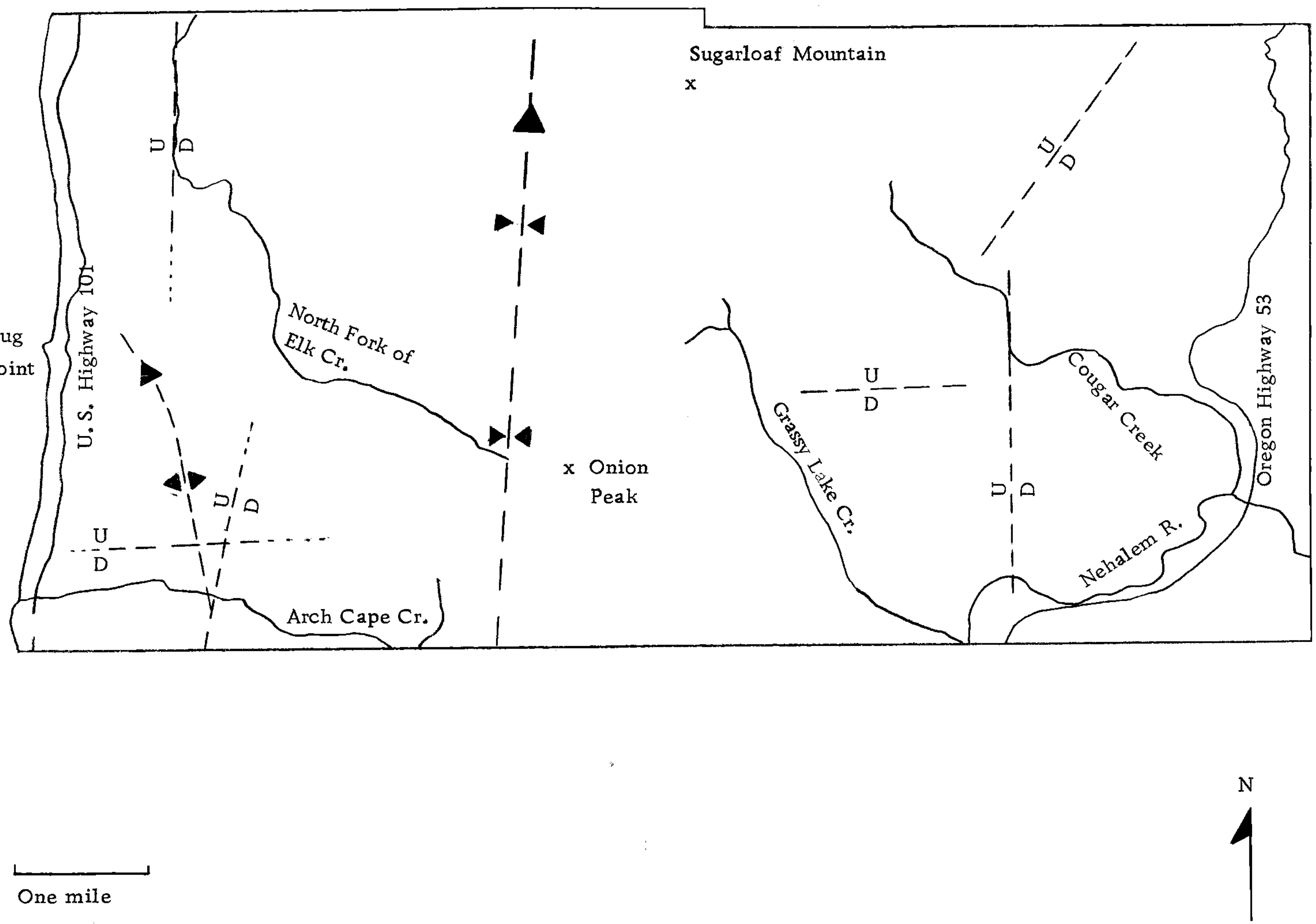


Figure 30. Structural map of the Onion Peak area.

sandstone, and Oswald West mudstone units) forming the flanks of the fold. This outcrop pattern is partly a result of topography with the youngest unit, the Depoe Bay Basalt breccia, forming the higher areas, the moderately resistant Astoria Formation forming intermediate elevations, and the least resistant Oswald West mudstones comprising the low lying area. However, topography cannot account entirely for the outcrop pattern because the contacts cut across topography (Plate I). The outcrop pattern of the Silver Point mudstones, Angora Peak sandstones, and Oswald West mudstones is consistent with the field interpretation having opposing dips on both sides of the basalts.

The nose of the syncline appears south of the thesis area. Cressy (1974) mapped the Depoe Bay Basalt extrusives, the youngest unit, in the core of the syncline and the older Astoria strata and Oswald West mudstones wrapped around the nose.

The axis of the syncline appears to be located in the area of thickest (1800 to 2000 feet) basaltic breccia. Depths of water indicated by foraminifera recovered from the Silver Point mudstone and from mudstone interbeds in the basaltic breccias did not exceed 600 feet (Neel, 1975). Yet, over 2000 feet of basaltic breccia and 1000 feet of strata accumulated in the submarine environment. Apparently rapid subsidence must have occurred during deposition of the sediments and eruption of the basalts in order to allow such a thick accumulation at such shallow depths. The symmetrical syncline may have formed during the middle Miocene as a result of local structural downwarping and the accumulation of basaltic breccias on top of a very compactible, thick section of semi-consolidated, water-saturated muds and sands. It is also possible that the syncline may have been formed or accentuated in the Pliocene when the general uplift of the Coast Range occurred (Baldwin, 1964).

Other smaller structural features in the thesis area include four north-south-trending high angle faults, two east-west-trending faults, and a small northwest-plunging anticline (Figure 30). The northwest-plunging asymmetrical anticline in the western part of the thesis area is delineated by opposing dips in the Angora Peak sandstones and the plunge by the outcrop pattern of Angora Peak sandstones surrounded by Silver Point mudstones (Figure 31, Plate I). The anticline is subparallel to the large synclinal axis, but it is difficult to prove if the two folds are definitely related. The west flank of this asymmetric fold dips more steeply (30° to 40°) than the east flank (10° to 20°). Near Hug Point, the west flank is indistinct because of faulting and soft sediment deformation of strata, distortion by intrusives, and recent landsliding. There is a small anticline and syncline (amplitude 50 to 100 feet, wavelength 700 to 1000 feet) near this locality (Figure 31). The western plunges of these small folds are at right angles to the large anticline. The small east-west folds and

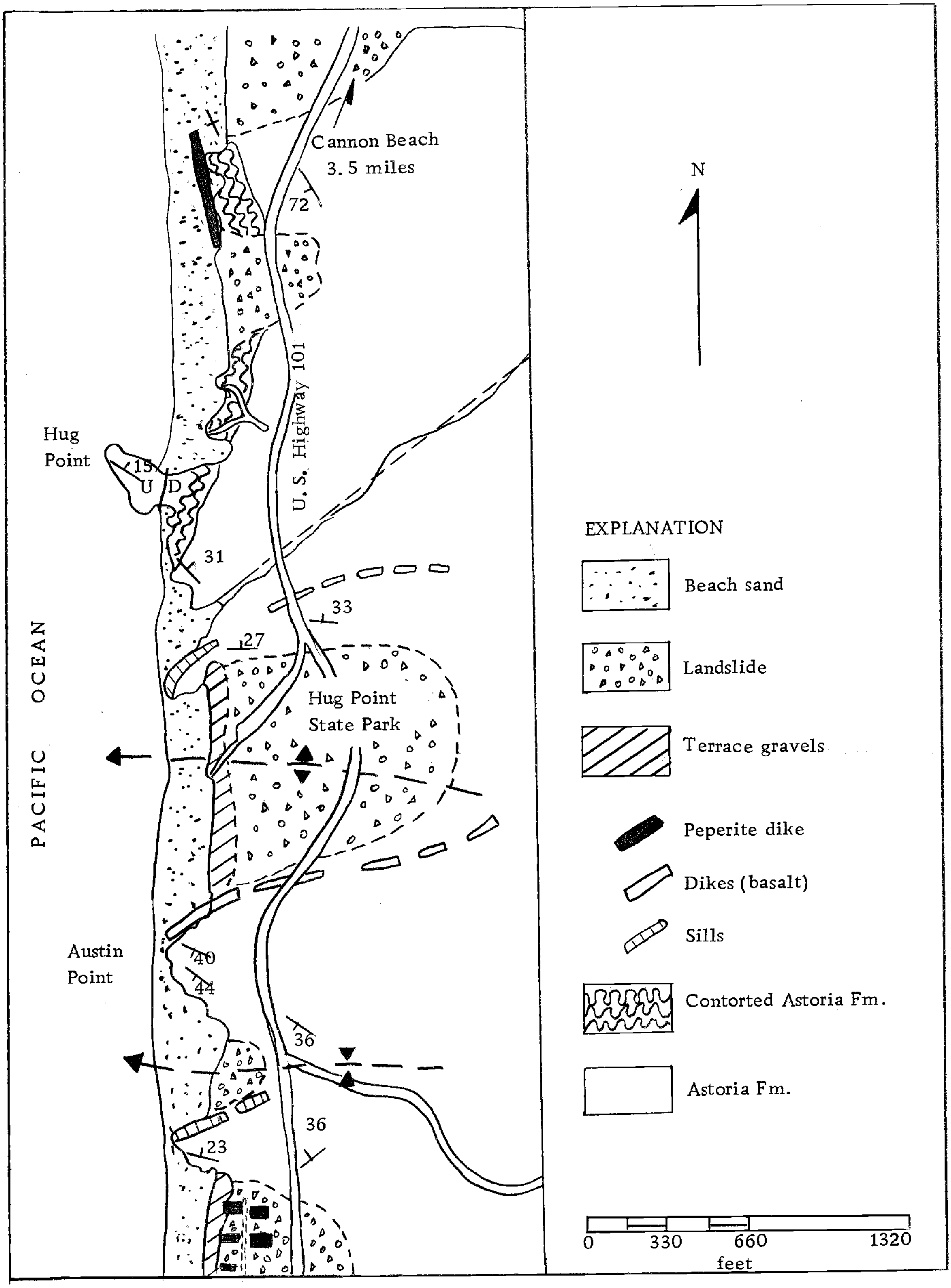


Figure 31. Geologic map of Hug Point State Park area.

structures near Hug Point are further discussed in the section on Soft Sediment Deformation Structures.

Although several small high-angle faults with displacements ranging from a few feet to several hundred feet are exposed along the beach cliffs, tracing the faults inland is difficult due to vegetation, soil, and landslide cover. Faults approximately strike north-south or east-west. Three of the faults appear as distinct lineations on ERTS infrared photographs. A major east-west trending fault which may cut across the entire thesis area, seen on ERTS photos, occurs about one mile above the southern boundary and converges with the east-west trending fault at Arch Cape Creek (Figure 30). The south block is down-dropped. Near Arch Cape Creek, Angora Peak sandstones are upthrown against Depoe Bay Basalt breccia. The rest of the length of the fault appears as a lineation through the breccia, mainly as saddles in ridges and linear creeks on aerial photos.

Two high angle faults trend north-south in the western part of the thesis area. One is a north-south trending fault that crosses Arch Cape Creek and continues northward displacing Angora Peak sandstones against downdropped Depoe Bay Basalt breccia on the western side of the fault (Plate I). Alignment of saddles on breccia ridges and offset extrusive breccia-Silver Point mudstone contacts delineate the continued trend of this fault. The other north-south striking fault is occupied by the straight, deep gorge of the North Fork of Elk Creek, a gorge which cuts through 500 feet of the resistant basalt breccia that forms Double Peaks (Plate I). The creek makes a 90^o bend through the resistant breccia as a result of this fault instead of flowing directly westward through "soft" easily eroded Silver Point mudstones (Plate I). The fault has also displaced eastward dipping Silver Point mudstones against a linear ridge of extrusive basaltic breccia. Displacements are probably greater than 500 feet, but the exact amount of displacement is difficult to determine because of limited exposures and incomplete knowledge of the thickness of the rock units present.

Other major faults occur in the eastern part of the thesis area. An east-west striking fault approximately one mile long down-drops the south part of a thick basaltic sill more than 800 feet in sections 18 and 19, T. 4 N., R. 9 W., near Grassy Lake Creek (Figure 30). Silver Point strata are preserved in the down-dropped block juxtaposed to the sill. Along a small possible northeast-southwest trending fault cutting Kidders Butte, Silver Point strata on the down-thrown block dip directly into the basaltic sill and the overlying extrusive breccia (Plate I). A small north-south trending fault(?) may occur along Cougar Creek (Figure 30). The only evidence for this fault is a north-south lineation between Cougar Creek and Buchanan Creek where Astoria strata on the postulated down-thrown block dip into adjacent Oswald West mudstones on the up-thrown block. Other small lineations that appear on aerial photographs and ERTS photographs are straight basalt ridges and cliffs and straight reaches of creeks that are not obviously related to faults.

Most of the faults in the thesis area truncate middle Miocene Depoe Bay Basalt breccias, indicating that the faulting post-dates middle Miocene. They are probably related to the general uplift of the Oregon Coast Range that occurred in late Miocene and Pliocene (Baldwin, 1964). The age of the faults that cut only sedimentary strata is more difficult to determine. They may have been formed after the middle Miocene basalts or were contemporaneous with the igneous events.

Soft Sediment Deformation Structures

The Angora Peak and Silver Point strata display many soft sediment deformation and penecontemporaneous gravity induced slump features. Small flame structures, load clasts (Figure 16), contorted bedding, and microfaulting (Figure 9) are all common and well-exposed along the sea cliffs from Silver Point to Hug Point. Unusual, large-scale, soft sediment deformation features include zones of vertical, contorted Angora Peak strata, massive sandstones with huge angular mudstone clasts (up to 15 feet in diameter), folds with wavelengths of several feet to 200 feet in the Angora Peak sandstones, and large sandstone blocks incorporated in the Depoe Bay Basalt intrusives as at Arch Cape. A 50-foot wide zone of vertical, contorted strata is exposed in Hug Point and continues in the 100-foot high sea cliff just north of Hug Point (Figure 31), where several thin unrelated basalt dikes (less than one foot wide) cut through the distorted sedimentary sequence.

The continuation of this zone of vertical strata parallels a 15-foot wide peperite dike about one mile north of Hug Point (Figure 31). Where disruption (probably slumping) of the vertical strata progressed further, only a few large, laminated sandstone or mudstone blocks (up to 15 feet in thickness) remain in the thoroughly mixed pebbly sandstone (Figure 8). There is also a 50-foot wide zone of a chaotic mixture of sedimentary breccia that occurs along both sides of a large basalt dike at Humbug Point (Figure 10). Inland, zones of contorted strata are exposed near the base of the sill in section 4, T. 4 N., R. 9 W., and near intrusives in section 17, T. 4 N., R. 10 W.

Sedimentary breccias are believed to be associated with the zones of vertical, plastically deformed, contorted strata. The sedimentary breccia near the intrusive at Humbug Point is composed of a chaotic mixture of angular blocks (2 to 10 feet long) of laminated, fine-grained, carbonaceous sandstones (90% of the rock) in a pebbly sandstone matrix (Figure 10). Many of the sandstone blocks are microfaulted (Figure 9).

In the Hug Point State Park area (Figure 31) a syncline and anticline (wavelength 700 to 800 feet) can be traced from the beach inland across U.S. Highway 101.

The origin of the sedimentary breccias and vertical contorted zones appears to be closely related to the intrusion of basalts into water-saturated, semi-consolidated strata. In all cases, there are basalt or peperite dikes parallel to the contorted zones. The relationship between igneous intrusions and sedimentary strata is particularly well-exposed in Ecola State Park five miles north of the thesis area. Isoclinal anticlines and synclines (with amplitudes up to 100 feet) occur in the sea cliffs at Ecola Point. These folds appear to be blocks of sedimentary strata dragged by or "squeezed" between adjacent dike-like apophyses associated with the upper part of the thick Tillamook Head sill in that area (Neel, 1975).

Radiometric dates for Depoe Bay basalts in the Tillamook Head area range from 14.0 $\pm$ 2.7 to 16.0 $\pm$ 0.55 million years or middle Miocene in age (Niem and Cressy, 1974). The host strata are also middle Miocene in age as indicated by mollusks and foraminifera. The overlapping ages of the sedimentary strata and the igneous intrusive bodies suggest that intrusion occurred shortly after deposition of the sedimentary sequence (Niem, 1974). Apparently the sediments were water-saturated and semi-consolidated at the time of intrusions as evidenced by the abundant microfaulting and folding of the sedimentary strata and the effects of alteration and rapid cooling displayed by the igneous rocks (e.g., peperites) (Niem, 1974).

Locally, the sediments were brittle when physically displaced by dikes, and they broke into blocks to form sedimentary breccias as at Humbug Point (Figure 10). Elsewhere, they deformed plastically to form zones of vertical contorted strata or became thoroughly disrupted and mixed to form pebbly sandstones (as at the cliff to the north of Hug Point).

The origin of the west-plunging anticline and syncline in Hug Point State Park is not clear (Figure 31). These structures do not conform to the general tectonic structure of the thesis area and the Oregon Coast Range, but they are not obviously related to soft sediment deformation caused by intrusion (Figure 31). Possibly the folds are related to a large, unexposed sill at depth (thin dikes and sills cut these structures) similar to the relationship between the isoclinal folds and intrusives at Ecola State Park (Niem, 1974); or possibly these folds were formed through submarine slumping of semi-consolidated "deltaic" strata deposited on unstable slopes. At present there are insufficient data to conclude which explanation is preferable.

ECONOMIC AND ENGINEERING GEOLOGY

The engineering and economic geology aspects of this area include landslide hazards and possible coal, petroleum, and crushed rock resources.

Coal

Although thin coaly lenses and wisps were noted in the Angora Peak sandstones, no economically thick coal seams were found. However, Cressy (1974) located two-foot thick coal beds in the Angora Peak sandstone in his thesis area immediately to the south. This coal is subbituminous to bituminous and crops out in Coal Creek two miles south of this thesis area. The thesis area contains incomplete exposures of Angora Peak sandstones; and therefore, unobserved coal seams may be present.

Petroleum

Petroleum possibilities in the Tertiary sedimentary rocks of the northwestern Oregon Coast inspired the first geologic expeditions made in this area by Diller in 1896. He noted "dead oil" trapped in carbonate concretions near Astoria, Oregon. He further observed that abundant clastic dikes in these strata lacked petroleum residue of the type contained in oil-producing rocks in California and concluded that either oil had long since drained off or it had never migrated to reservoir rocks. Warren and others (1945) produced one of the first reconnaissance maps. In the early 1960's, Shell Oil Company drilled an exploratory offshore oil well on the Nehalem Banks, several miles west of Seaside on the continental shelf, but did not obtain commercial production.

The petroleum potential of this area will be evaluted through an inventory of possible source rocks, reservoir rocks, capping rocks, entrapment structures, and time.

The dark, thick, organic-rich mudstones of the Silver Point member and Oswald West strata are possible petroleum source rocks. More than 1800 feet of Oswald West mudstones underlie the thesis area. The Oswald West mudstones contain a high abundance of organic carbon (3 to 5% by H_2O_2) and, along some bedding planes, a petroliferous odor was noted on fresh break.

Over 600 feet of dark mudstones of the Silver Point member comprise another potential source rock. The writer found in a thin section of a carbonate concretion from these mudstones small, scattered blebs of an amorphous, brown organic matter resembling an organic gel or "dead oil". This dark mudstone contains 3 to 5% organic carbon in H_2O_2. In addition, Silver Point mudstones could act as cap rocks for a petroleum reservoir as they overlie potential Angora Peak sandstone reservoir rocks. The mudstones are permeable, widespread, and thick.

Angora Peak sandstones and sandstone lenses in the lower part of the Silver Point member comprise possible reservoir rocks in that they are thick (20 to 1000 feet), clean sandstones. Unfortunately, porosity for most of these sandstones (determined from thin section) is low (1%). Thin section samples, however, were taken from predominantly well-indurated, carbonate-cemented sea cliffs or from inland outcrops where weathering processes and migrating fluids may have destroyed much of the original porosity by producing a secondary clay matrix. Permeability tests of unweathered core samples are needed to truly test the permeability of these rocks. However, some thick, clean, laminated, fine-grained, shallow marine sandstones appear to be very porous on outcrop whereas the lower Angora Peak coarse, lithic, channel cross-bedded, conglomeratic sandstones and conglomerates are generally tightly cemented.

Entrapment structures within the area include both east-west and north-south trending faults. Some of these faults may juxtapose Angora Peak reservoir sandstones against Silver Point mudstone source rocks, forming structural traps. A possibility for entrapment may also exist in a northward-plunging anticline located in the western part of the thesis area. However, the anticline has potential Angora Peak reservoir sandstones and faults exposed which would have allowed any oil accumulation to escape.

Stratigraphic traps probably afford the greatest possibility for oil entrapment. The greatest potential for stratigraphic traps lies in the near offshore where tongues of the Angora Peak sandstone probably interfinger with Silver Point mudstones. The Astoria Formation deltaic rocks should continue a few miles offshore because the facies dip offshore along the coast from Hug Point to Silver Point. The thin, clean, well-sorted channel sandstones in the lower part of Silver Point mudstones are potential migration routes for petroleum into Angora Peak sandstones. The Shell wildcat well, drilled near the Nehalem Bank several miles west of Seaside, failed to penetrate any permeable sandstones but encountered deep marine, impermeable mudstones. This well was probably drilled too far offshore to penetrate this deltaic facies. It is hypothesized that this delta probably extends only a few miles offshore, where it intertongues with Silver Point mudstones. The Silver Point mudstones and overlying Pliocene strata would form excellent cap rocks in this nearby offshore area. The area offshore is also extensively faulted (Kulm and Fowler, 1974b) which may also juxtapose the reservoir sandstones against source rock mudstones to form structural traps. It is believed that in the area a few miles offshore between Humbug Point and Seaside north of the thesis area where sandstones dip northwesterly under capping Silver Point mudstones affords the "best" petroleum potential. An extensive geophysical study of the nearby offshore area is needed to further evaluate these petroleum prospects. The subsurface petroleum potential beneath the thesis area is poor because of a lack of sandstone reservoir rocks in the underlying late Eocene-Oligocene mudstones and Eocene Tillamook Volcanic breccias.

Crushed Rock

A basic material necessity in any growing area is readily available crushed rock for road construction. Basaltic river gravels and quarry rock are both abundant in this area and are readily available for this purpose. Easily accessible thick (up to 20 feet), extensive basaltic river gravels occur along the Nehalem River in the eastern part of the thesis area (Plate I). Basalt quarries are scattered throughout the thesis area (Plate I). They are used primarily to produce crushed rock for nearby logging roads and highways. It is recommended that basalt dikes and sills and basaltic talus deposits shown on Plate I should be quarried first for road material because of their availability and high abrasional resistance. Basaltic breccias should be quarried only if the other rocks are not available, because it is generally softer, less resistant to abrasion, and breaks apart by weathering more easily. The two quarries in the Cape Foulweather Basalt sill in section 6, T. 4 N., R. 10 W. still contain a large volume of available rock for road building. Another such quarry is located next to State Highway 53, in section 16, T. 4 N., R. 9 W. The remaining quarries are smaller in size and contain much smaller volumes of available rock for logging road construction. Softer sedimentary rocks, such as Oswald West mudstones, are sometimes quarried for use as filler and topping material on road beds. This practice is not recommended because even short exposure to weathering causes rapid breakdown of these soft materials to form muds which are readily susceptible to landsliding.

Landsliding

Landsliding occurs primarily in Silver Point mudstones and Depoe Bay basalt breccias along the coastline and along oversteepened stream valleys (Plate I). Silver Point mudstones contain a high proportion of montmorillonite clays which expand during heavy winter rains, reducing the cohesiveness of the mudstones. These mudstones are quite unstable where located on steep slopes as along the coast between Hug Point and Silver Point. Landslide areas in the Depoe Bay Basalt breccias occur at points where Silver Point mudstones have been eroded from beneath, removing support for the overlying breccia. These areas are most prevalent in the eastern part of the thesis area.

Plate I outlines areas of recent landslides. Landslide areas in the thesis area were recognized by: (1) hummocky topography, (2) chaotic mixture of mudstone, basaltic rock, and plant debris, (3) live trees leaning in all directions, (4) scarps, and (5) other evidence of displacement such as cracks in highways, road beds, or house foundations.

A large (3000 feet wide) landslide displaced U. S. Highway 101 laterally by 30 feet, one-half mile south of Silver Point, in February, 1974 (Figure 32). A 100-foot high scarp was left above the highway and the toe of the slide was at beach level. The slide moved the highway, trees, a powerline, and houses 20 to 200 feet oceanward. Several summer homes were carried by the slide onto the beach where active wave erosion undercut their foundations. The Silver Point mudstones in the landslide were deeply weathered, soft, and were water-saturated by abundant winter rains which apparently lowered the internal friction of the rock mass enough to allow the slide to occur. The slope on which the slide occurred had been steepened by road cuts along U. S. Highway 101 and by undercutting by wave erosion along the beach. It was noted the previous summer that cracks had appeared in the highway in the slide area prior to the main movement. Present modifications by the Oregon State Highway Department to stabilize this slide include terracing the upper part of the slide to remove unnecessary weight, and installing a drainage system to remove excess water. Sections of Highway 101, forming several terrace levels at Silver Point, are evidence of recurrent movement of an older slide activity. Winter wave erosion and undercutting of cliffs at Silver Point on Highway 101 will probably continue to plague this area.

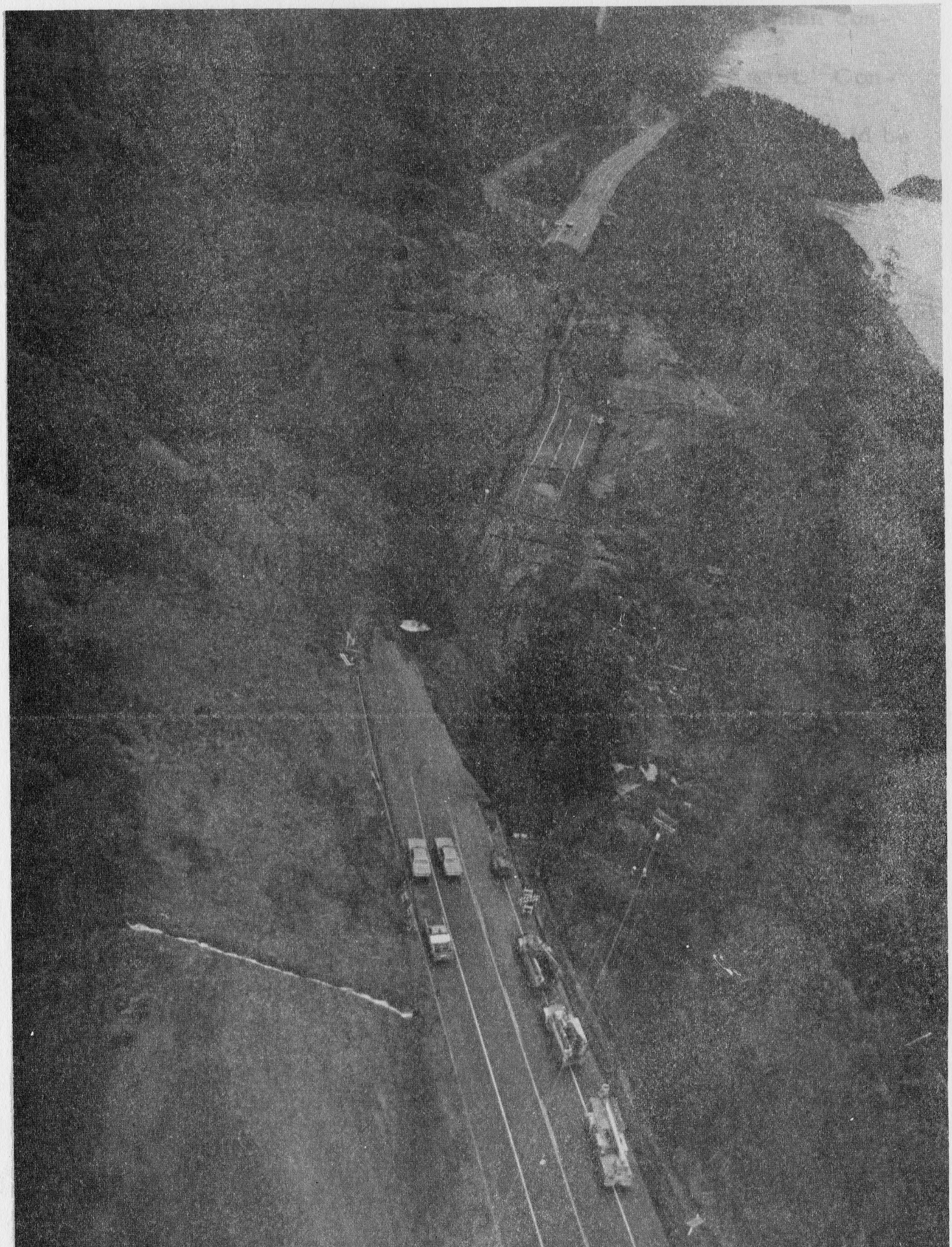


Figure 32. Landslide, February, 1974, in the Astoria Formation near Cannon Beach, Oregon. U.S. 101 in foreground.

Landsliding is a problem that should be considered when constructing roads and homes along the northwest Oregon Coast. Construction in areas of oversteepened Silver Point mudstones should be avoided because of their high susceptibility to sliding. Where it is necessary that roads be built across these mudstone areas, steep slopes must be avoided along the coast and care must be taken to avoid disturbance of the strata. Better suited construction areas, which lack old landslide scarps, are on marine terraces, on very stable, thick basaltic intrusives, and on Angora Peak sandstones (Plate I).

GEOLOGIC HISTORY

Transport Directions

Paleocurrent data were collected at six localities in the Angora Peak sandstone member in the western part of the thesis area and at Silver Point in the Silver Point member (Figure 33). One-hundred and twenty-seven measurements on planar and trough cross-bedding were used to obtain paleocurrent directions in the Angora Peak sandstones. Sixty-one measurements on microtrough cross-laminations, groove and flute casts, imbricated pebbles and mudstone clasts, and climbing ripples were recorded to determine paleocurrent directions in the Silver Point mudstones in the Silver Point area. The burrowed, fine-grained nature and a general lack of current formed sedimentary structures in the Oswald West mudstones prohibited data collection. All paleocurrent measurements were rotated back to original deposition orientation with the use of a stereonet to eliminate distortion by tectonic activity during the Coast Range uplift.

Paleocurrent data suggest that the sand and gravels of the Angora Peak sandstone member were transported to the west and northwest from the east and southeast. The grand mean for the measurements is west-northwest ($294^{\circ} \pm 31^{\circ}$). The individual means range from 284° to 354°. The large variance in paleocurrent directions ($\pm 31^{\circ}$) may be explained by meandering of delta distributary

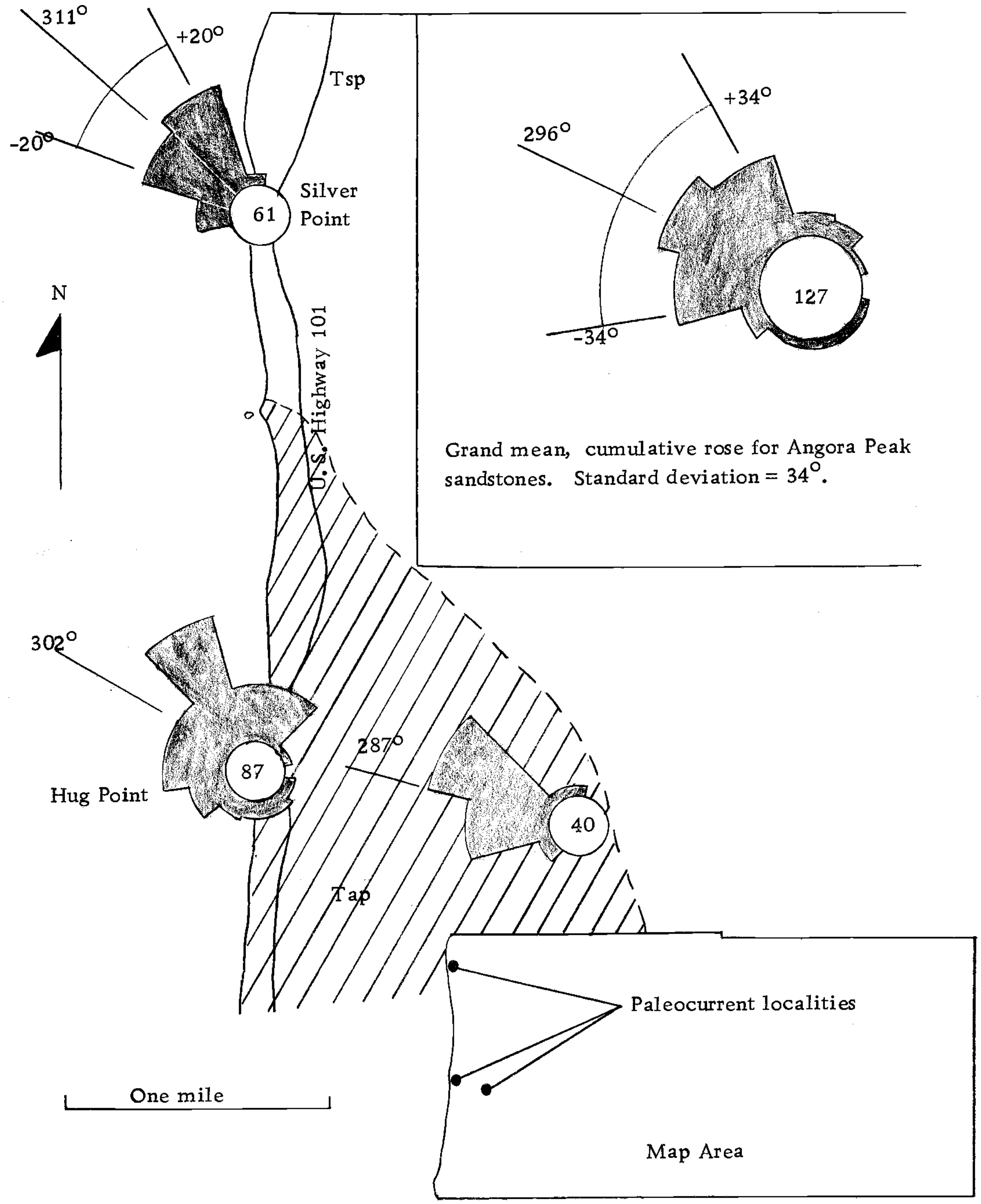


Figure 33. Rose diagrams of paleocurrent measurements from Angora Peak sandstones and Silver Point sandstones. Number of measurements and mean azimuth direction with roses.

stream channels and variations in direction in longshore drift. The general east to west dispersal pattern for Angora Peak sandstones is in agreement with an eastern source area postulated for these strata (see Provenance section).

The paleocurrent measurements of the Silver Point member are much more strongly oriented than those determined for the Angora Peak sandstones. The mean for these measurements is northwest (311°). The smaller variation (± 20°) in paleocurrent measurements may reflect restricted current transport over a long period of time, possibly down broad submarine channels cut into a delta front, similar to those in the Mississippi Delta (Gould, 1970). Neel (1975) found a similar northwestward paleocurrent dispersal pattern for Silver Point strata near Tillamook Head, five miles north of the thesis area.

The transport direction in Silver Point strata was more northward than in the Angora Peak sandstones. Similar mineralogies suggest that Silver Point strata are a probable offshore deep-water facies of the fluvial and shallow marine sandstones of the Angora Peak member found to the south. Cressy (1974) found a westward to southwestward paleocurrent pattern for Angora Peak sandstones in the Angora Peak area, ten miles south of the thesis area. These southwestward, west, and northwest dispersal patterns in the Astoria Formation support the concept of a delta prograding oceanward near present day

Arch Cape or slightly south of this point where the coarsest and thickest fluvial channels were found (Cressy, 1974). A delta with distributaries is more likely to have this three directional dispersal pattern than a long linear clastic shoreline of offshore sand bars.

Provenance

Few provenance data from the thesis area were observable from the Oswald West mudstones because of the very fine-grained nature of the unit, except for some reworked ash-fall tuffs probably derived from the ancestral Western Cascades during the Oligocene, and basalt clasts in the glauconitic sandstone. Cressy (1974) suggests from thin section study of a few sandstones that these strata were derived from uplifted basalt and sedimentary areas in the ancestral Coast Range and intermediate volcanic terrains of the Western Cascades. In addition, angular grains of garnet, staurolite, and microcline suggest metamorphic and acidic igneous sources. Cressy (1974) notes that these heavy mineral suites are similar to those found by Van Atta (1971) in the coeval Scappoose Formation of the northeastern Coast Range and postulated that the Oswald West mudstones represent a prodelta facies of the coeval Scappoose delta.

The mineral framework grains of the Angora Peak and Silver Point members of the Astoria Formation were derived from varied terrains consisting of acidic to basic volcanics, acid plutonic, metamorphic, and sedimentary rocks (Appendix VI). The primary source for much of the coarse constituents of these strata is local uplifted Coast Range basaltic terrains and andesitic and dacitic rocks of the Western Cascades. Metamorphic and plutonic terrains also contributed small amounts of clastics to this area. Possible source areas of these clastics are eastern Oregon, Washington, British Columbia, Idaho, Montana, and Wyoming.

With a mixed heavy mineral suite, it is difficult to pinpoint a single source area. However, generalizations about dominant source areas for the Astoria strata can be made by examining modern heavy mineral assemblages of major western Oregon river systems that drain different heavy mineral provenances.

It is assumed that a major river system transported Astoria sediments to the coast because of the occurrence of fluvial channel conglomerates with two-foot diameter boulders and an east to west paleocurrent pattern. The heavy mineral assemblages found in the modern Columbia River and the Astoria Formation are very similar. Pyroxenes are significantly more abundant than amphiboles in the bedload sediments of the Columbia River (Scheidegger and others, 1971), and in the Angora Peak sandstones (Appendix VI). In both, there are dominant contributions from basaltic and andesitic lava flows yielding hypersthene, augite, and many opaques. The same heavy mineral sources occur in the Willamette River drainage, which drains the hypersthene-rich Cascades, and the augite-rich Eocene Coast Range pillow lavas and breccias. The blue-green hornblende and monazite contained in the Angora Peak samples suggest some derivation from acidic intrusive sources and only a small contribution of high-rank metamorphics represented by epidote, garnet, rutile, and tourmaline. The Columbia River receives similar heavy minerals from sources in British Columbia, Montana, Idaho, and Wyoming. The Klamath Mountains of southwestern Oregon could provide relative large quantities of both low- and high-rank metamorphic heavy minerals such as blue-green hornblende, actinolite-tremolite, epidote, micas, and glaucophane (Scheidegger and others, 1971). Amphiboles compose possibly up to 75% of the heavy mineral suite in rivers draining the Klamath Mountains, while Angora Peak sandstones contain only minor percentages of amphiboles. Thus, it is likely that the Klamath Mountains were only a minor source, certainly not the principal one, for Astoria sediments.

Conglomerate pebbles indicate similar distribution of source areas. The major source areas indicated by pebble counts were andesites and dacite flows and tuffs (Figure 18), probably the Oligocene Little Butte and Sardine Volcanics of the Western Cascades. Pre-Miocene Coast Range basalts also made a local contribution during the middle Miocene (such as Tillamook and Goble Volcanics). Exotic pebbles in conglomeratic sandstones indicate more distant sources.

Granitic pebbles, potassium feldspar, microcline, and micas in the sandstones could have originated from Cretaceous batholiths in eastern Oregon, central and northeastern Washington, and Idaho. Sedimentary quartzites and recycled rounded grains of zircon from early Paleozoic rocks could have been transported by the Columbia via the Snake River. Metaquartzites and quartz mica schists are associated with low-grade metamorphic terrains in central and northeastern Washington, eastern Oregon, Idaho, British Columbia, and possibly the Klamath Mountains of southwestern Oregon. Welded tuff, tuff, and pumice could have also been derived from the John Day Formation of eastern Oregon as well as freshly erupted pyroclastics from Western Cascades volcanoes.

The Columbia River drainage system presently drains all these terrains. It is hypothesized on the basis of similar mineralogies between the present Columbia and the Astoria strata and the geologic principle of uniformitarianism that an ancestral Columbia River drainage or one similar to it, during the middle Miocene, was the main transporting agent for the minerals and rock fragments that comprise the Angora Peak and Silver Point members. The large Angora Peak fluvial channel conglomerates in the eastern part of the area, with the exotic two-foot diameter andesite boulders, may be a small deposit of such a major river. The Columbia River may have existed during the middle Miocene in an ancestral middle Miocene gorge now filled by Columbia River Basalts; this has been postulated as existing in the Cascade Mountains east of Portland (Taylor, personal communication, 1974).

Geologic Summary and Conclusions

Six distinct stratigraphic units exist in the Onion Peak area: the Oswald West mudstones (informal), the Angora Peak sandstone member (informal), the Silver Point mudstone member (informal) of the Astoria Formation, intrusive basalts of Depoe Bay basalt, extrusive pillow breccias of Depoe Bay Basalt, and intrusive basalts of Cape Foulweather Basalt.

The Oswald West mudstones comprise over 1600 feet of Oligocene to early Miocene well-bedded, burrowed, deep-water mudstones with local tuff and glauconitic sandstone beds. These mudstones may be a prodeltaic facies of the coeval Scappoose delta. During the middle Miocene, local uplift in the western Coast Range resulted in periods of non-deposition and possible erosion producing an eroded surface on the Oswald West mudstones.

The overlying Angora Peak sandstone member consists of over 1000 feet of predominantly well laminated, feldspathic, shallow marine sandstones and local cross-bedded, fluvial channel conglomerates, conglomeratic sandstones, and carbonaceous siltstones. Over 600 feet of interbedded, deeper marine dark mudstones, minor turbidite sandstones, and local sandstone and conglomerate lenses comprise the newly defined Silver Point mudstone member. These strata overlie the Angora Peak sandstones but also may represent lateral facies of the deltaic sequence. Sedimentary structures, fossils, and lithologies suggest that the Angora Peak sandstones represent fluvial distributary channel deposits with overbank and swamp deposits which were partly reworked by waves and longshore drift and other shallow marine currents into delta front sheet sands and barrier bars and inner to middle continental shelf sands. The Silver Point mudstones represent lower energy, deeper marine, deltaic environments, possibly delta front and prodelta facies. Rapid pelagic clay and silt sedimentation was often interrupted by turbidity flows which transported coarse clastics into the deeper (sublittoral to outer shelf), low energy marine basin. Paleocurrent data for these Astoria Formation members indicate an east to west dispersal pattern. Sandstone mineralogy and conglomerate clasts suggest the predominant sediment sources for the Astoria Formation were local Eocene Coast Range basalts and Oligocene and Miocene dacites and andesites from Western Cascades formations. Rarer quartzites, metamorphic and plutonic rock fragments, and heavy minerals were transported via an ancestral "Columbia River" drainage system from eastern Oregon, Washington, Montana, Idaho, Wyoming, and British Columbia.

Middle Miocene Depoe Bay Basalts intruded semi-consolidated, water-saturated Astoria strata at very shallow depths. As a result, some intrusives were brecciated (peperites), and locally the host Astoria strata were penecontemporaneously deformed into folds, sedimentary breccias, and contorted zones. Associated with these sills and dikes are over 2000 feet of extrusive Depoe Bay Basalt that forms the highest peaks in the area. These local volcanic accumulations of basaltic breccias and pillow lavas are postulated as forming on an irregular submarine topography and may have formed in a structural basin.

A few middle Miocene porphyritic Cape Foulweather Basalt dikes later intruded the aphanitic Depoe Bay Basalts and Astoria strata. Pliocene to Recent faulting and compressional folding uplifted the area and formed a large north-south syncline, a small anticline, and several east-west and north-south, high angle faults. Subsequent erosion has carved the present topography.

Recently, stream and winter wave erosion and man have undercut many Silver Point mudstone slopes resulting in several destructive landslides along the coast and inland. Contiguous source rocks (Oswald West and Silver Point mudstones), reservoir rocks (Angora Peak sandstones), capping rocks (Silver Point member), and possible structural and stratigraphic traps suggest possible petroleum potential in these strata, particularly in the nearby offshore areas.

Crushed rock from abundant basaltic intrusives for logging road and highway purposes is presently the most important geological economic resource for the area and probably will continue to be so in the near future.

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APPENDICES

APPENDIX I

Principal Reference Section A-B

Angora Peak Sandstone Member of the Astoria Formation

Initial point (A): SW 1/4 SW 1/4 of section 18, T. 4 N., R. 10 W. Section starts on the beach on the south limb of a syncline 1/4 mile south of Hug Point.

Terminal point (B): SW 1/4 SW1/4 of section 18, T. 4 N., R. 10 W. Approximately 40 feet below a house where the section is covered with brush. This house is directly below the junction of the Hug Point mainline logging road and U. S. Highway 101.

APPENDIX I

Principal Reference Section A-B

Unit	Description	Thickness Unit	(feet) Total
29	Siltstone: light gray (N7), weathers dark yellowish orange (10 YR 6/6); sandy, micaceous, moderately sorted silt; numerous woody fragments form laminations; limonite stained. Contact: gradational over 2 inches.	.5	133.0
28	Sandstone: grayish yellow (5 Y 8/4), weathers moderate yellowish brown (10 YR 5/4); normally graded over entire thickness from coarse, poorly sorted, angular sand into better sorted, medium-grained sand, and finally into a siltstone; planar cross-bedded and contains no pebbles. Contact: sharp, erosional; minor scour-and-fill	11	132.5
27	Sandstone: dark yellowish orange (10 YR 6/6); fine-grained, moderately sorted, finely laminated with carbonaceous layers 1 mm. thick; layers are irregular, discontinuous stringers up to 15 inches long. Contact: planar and sharp.	3	121.5
26	Pebbly sandstone: grayish orange (10 YR 7/4); medium to coarse-grained sand matrix; poorly sorted; pebbles average 1/8 inch in diameter, largest 1/4 inch; cross-bedded; beds are contorted and fracture offset; thin, silty laminations show smashed appearance with small mudstone dikes injected into the sandstone. Contact: sharp and planar, baked 1 inch.	19	118.5
25	Sill: Depoe Bay Basalt, trend N 70 W, 37 N. Contact: sharp and planar, baked over 6 inches.	18	109.5

Unit	Description	Thickness Unit	(feet) Total
24	Pebbly sandstone: grayish orange (10 YR 7/4); poorly sorted, medium- to coarse-grained sand matrix pebbles average 1/4 inch diameter, largest to 1/2 inch; cross-bedded; feldspathic. Contact: sharp and irregular, marked by pebble layer only 1 to 2 pebbles thick.	1	81.5
23	Sandstone: dark yellowish orange (10 YR 6/6); moderately sorted, fine- to medium-grained sand; feldspathic and micaceous; micro-trough and ripple laminated, trough cross-laminations 8 to 10 inches wide and 1 to 2 inches deep; contains scattered angular mudstone and siltstone clasts to 1-1/2 inches in diameter. Contact: sharp, irregular channel scour-and-filled surface.	9	80.5
22	Pebbly sandstone: grayish orange (10 YR 7/4); medium- to coarse-grained sand matrix; feldspathic, angular, and poorly sorted sand; 3 separate cross-bedded units; planar and sharp truncation by each; all units are normally graded with pebbles near the lower contact getting finer upward along cross-bedded surfaces; pebbles average 1/4 inch diameter, largest 1/2 inch. Contact: sharp, irregular channel scour-and-filled surface.	4.5	71.5
21	Sandstone: dark yellowish orange (10 YR 6/6); fine- to medium-grained sand; moderately sorted; feldspathic and quartz rich; semi-rounded to semi-angular grains; much carbonaceous debris increasing near the top of unit as carbonaceous stringers 10 to 15 inches long. Contact: sharp and planar.	1	67.0

Unit	Description	Thickness Unit	(feet) Total
20	Sandstone: grayish yellow (5 Y 8/4); very poorly sorted, coarse-grained, cross-bedded with scattered pebbles, same size as unit 22; crudely graded, carbonate cemented in a concretionary pattern. Contact: sharp, irregular scour-and-fill.	9	66.0
19	Mudstone: light gray (N7); thickens to the east, high silt content, finely laminated; conglomerate pebbles extend into unit. Contact: sharp and irregular.	.5	57.0
18	Pebbly sandstone: grayish orange (10 YR 7/4); medium- to coarse-grained sand with pebbles floating in matrix, average size 1/4 inch in diameter, largest to 1 inch; faintly laminated; contains abundant angular siltstone rip-ups; thins to the east. Contact: semi-planar to irregular surface due to loading; mudstone injections along contact.	.5	56.5
17	Mudstone to sandy siltstone: light gray (N7); no bedding evident; irregular mixture of mud and silt due to loading; conglomerate pebbles extend into unit. Contact: sharp and irregular.	1	56.0
16	Pebbly sandstone: grayish orange (10 YR 7/4); medium- to coarse-grained sand matrix, pebbles same size as unit 22; contains several cross-bedded units each planar truncated by the next, several thin (1 to 2 inches), discontinuous mudstone layers separate cross-bedded units. Contact: gradational over 1 foot.	2.0	55.0

Unit	Description	Thickness Unit	(feet) Total
15	Sandstone: grayish yellow (5 Y 8/4); medium- to fine-grained sand, moderate sorting, micaceous and feldspathic; well-defined climbing ripples and trough cross-bedding; troughs 6 to 8 inches wide, 1/2 to 1 inch deep. Two 1 inch thick silty interbeds contained within the unit; laminated muds and silts, medium gray (N5). Contact: sharp and irregular; loading evident, flame structures near contact.	2.5	53.0
14	Pebble conglomerate: Yellowish gray (5 Y 8/1), weathers to light brown (5 YR 5/6); average pebble 1/2 inch in diameter, with largest 1 inch; cross-bedded; unit forms rib, more resistant to weathering.	3	50.5
13	Covered by sand.	5	47.5
12	Pebbly sandstone: grayish orange (10 YR 7/4); very poorly sorted, coarse-grained sand matrix; pebbles average 3/4 inch in diameter with pebbles to 1-1/2 inches; cross-bedded, normal graded with a coarse pebble conglomerate at bottom of unit; pebble size and abundance decreases toward top of unit; grading also occurs laterally along cross-bed surfaces. Contact: sharp and irregular, scour-and-fill surface.	7	42.5
11	Mudstone: medium gray (N5); finely laminated with silts and carbonaceous debris, very irregular thickness, thins to the east; contains scattered pebble layers floating in the mudstone. Contact: sharp and irregular.	1	35.5

Unit	Description	Thickness Unit	(feet) Total
10	Pebbly sandstone: grayish orange (10 YR 7/4); poorly sorted, coarse-grained sand matrix; pebbles average 1/8 inch diameter; largest to 1/4 inch; irregular thickness, cross-bedded, normal graded along cross-bedding planes. Contact: sharp and irregular, scour-and-fill.	3	34.5
9	Mudstone: medium dark gray (N4); variable thickness, finely laminated mudstones and siltstones; very carbonaceous; contains scattered pebble layers with mudstone contorted or draped around pebbles. Contact: sharp and irregular, shows loading of sandstone into the mudstone and pebbles injecting into mudstone.	.5-1.0	31.5
8	Pebble conglomerate: grayish orange (10 YR 7/4); poorly sorted, coarse-grained sand matrix; pebbles at base of unit 1/2 inch in diameter, near top of unit average 1/4 inch in diameter; unit contains several cross-bedded units, each about 9 inches thick; grading in each is normal from coarse pebbles to coarse-grained sand; grading is along cross-bedding planes; planar truncation of each unit by the next. Contact: sharp and irregular.	7	30.5
7	Mudstone: brownish gray (5 YR 4/4) to medium light gray (N6); laminated carbonaceous layers; thickens to the east; underlying sandstone injects into mudstone. Contact: sharp and irregular.	.5	23.5

Unit	Description	Thickness Unit	(feet) Total
6	Pebbly sandstone: grayish orange (10 YR 7/4); very poorly sorted, coarse-grained sand matrix; pebbles average 1/2 inch in diameter, largest to 1 inch; cross-bedded; series of cross-beds show planar truncation and normal grading; contains mudstone layers to 1 inch thick, light gray (N6); layers are irregular and discontinuous. Contact: grading over 2 feet.	6. 5	23. 0
5	Pebbly sandstone: grayish orange (10 YR 7/4); discontinuous and irregular bed; coarse-grained sand matrix, very poorly sorted; contains angular mudstone rip-ups and pumice fragments up to 2 inches in diameter. Contact: sharp and irregular, scour-and-fill.	. 5	16. 5
4	Sandstone: moderate yellowish brown (10 YR 5/4); moderately sorted, coarse-grained sand; angular, feldspathic, micaceous; cross-bedded; no pebbles; carbonaceous material in the form of coaly lenses less than 1/4 inch thick. Contact: gradational over 1 foot.	2. 5	16. 0
3	Sandstone: moderate yellowish brown (10 YR 5/4); moderately sorted, medium-grained angular sand; quartz-rich; fine carbonaceous stringers mark laminations. Contact: sharp and irregular.	1	13. 5
2	Pebble conglomerate: yellowish gray (5 YR 8/1); pebbles in grain contact; coarse-grained sand matrix; very poorly sorted; pebbles average 1-1/2 inches in diameter, largest 2-1/2 inches; chert and quartzite pebbles abundant. Contact: sharp and irregular.	. 5	12. 5

Unit	Description	Thickness Unit	(feet) Total
1	Sandstone: grayish orange (10 YR 7/4); limonite stained to moderate yellowish brown (10 YR 5/4); pebble conglomerate lenses, some graded; lenses to 4 feet long and from several pebbles thick to 6 inches thick; pebbles average 1/2 inch in diameter, largest 1-1/2 inches; cross-bedded, planar truncations; calcareous cemented with sandy concretions up to 1 foot in diameter.	12	12.0

APPENDIX II

Principal Reference Section C-D

Silver Point Mudstones

Initial point: SW 1/4 SW 1/4 of section 6, T. 4 N., R. 10 W. Section measurement begins just above summer beach at base of sea cliff directly below U.S. Highway 101 southernmost view point at Silver Point.

Terminal point: SW 1/4 SW 1/4 of section 6, T. 4 N., R. 10 W. Ends approximately 100 feet above U.S. Highway 101 road cut near the southernmost view point at Silver Point. Covered zone thickness to the overlying Depoe Bay Basalts was estimated by the use of the thesis geological map and topographic maps.

APPENDIX II

Principal Reference Section C-D

Unit	Description	Thickness (feet) Unit	Total
33	Covered to Depoe Bay Basalt contact.	200	480.0
32	Mudstone: dark gray (N3); laminated unit gradational through extent; 90% mudstone; near lower contact, fine sandstone laminations are present becoming less frequent toward the top of the unit; large flame and load structures present; most laminations caused by silty, micaceous material; very carbonaceous rich. Contact: gradational over 5 feet.	85	280.0
31	Mudstone: dark gray (N3); sandstones light gray (N7), weathers dusky yellow (5 R 6/4); 70% mudstone; 10 8-inch sandstone layers present; sandstones, moderately sorted, quartz-rich, fine-grained; siltstones and sandstones very micaceous; some sandstone layers show sharp lower contacts and grade into mudstone, other sandstones show no grading and sharp lower and upper contacts; carbonaceous-rich and laminated; loading and flame structures present; abundant mudstone rip-ups in sandstones; mudstones finely laminated 18 to 20 per inch with siltstone and carbonaceous material; siltstones show micro-cross-laminations. Contact: gradational over 3 feet. Note: Colors the same as listed above unless otherwise stated.	47	195.0

Unit	Description	Thickness Unit	(feet) Total
30	Sandstone: medium- to fine-grained sandstone; moderately sorted, angular grains with laminations of mudstone, 8 laminations per inch; no sandstone layer is over 1/2 inch thick; varve-like appearance; sandstones show microcross-laminations and grade into mudstone with sharp lower contacts; 90% sandstone; loading and flame structures present; large, broad channels are incised into unit 31; truncating laminated mudstones and sandstones, channels filled with the same laminated sandstones and mudstones; largest channel, 60 feet wide and 10 feet deep. Contact: gradational over 2 feet.	10.5	148.0
29	Sandstone: fine-grained sandstone, laminated 10 per inch; limonite concretions to 2 inches in diameter; grades normally into mudstone. Contact: sharp and undulatory.	.5	137.5
28	Mudstone: 70% mudstone; carbonaceous-rich, laminated 6 per inch; feldspathic siltstones near top of unit as much as 1 inch thick. Contact: gradational over 2 feet.	6	137.0
27	Sandstone: 70% sandstones, grade normally into unit 28; very similar to unit 30; carbon-rich lenses in sandstones. Contact: sharp and undulatory.	6	131.0
26	Sandstone: very fine-grained, with 1/2 inch thick mudstone layers near lower contact of unit; mostly well sorted sandstone, laminated with carbonaceous material, 8 laminations per inch. Contact: gradational over 6 inches.	2	125.0

Unit	Description	Thickness Unit	(feet) Total
25	Mudstone: pure near lower contact, becoming micaceous and sandy into overlying unit. Contact: gradational over 2 feet.	3	123.0
24	Sandstone: medium- to fine-grained feldspathic sandstone, finely laminated with carbonaceous material and mudstones. Carbonized wood material abundant in unit; flame and load structures present.	7	120.0
23	Covered.	29	113.0
22	Alternating sandstone and mudstone: sandstones 6 to 8 inches thick, some crudely graded into mudstone units of equal thickness; contacts are generally sharp between sandstones and mudstones; sandstones moderately sorted and very micaceous; laminations 6 per inch. Contact: sharp and planar.	7	84.0
21	Mudstone: laminated nearly pure mudstone, no sandstone or siltstone lenses. Contact: gradational over 6 inches.	1	77.0
20	Sandstone: feldspathic, fine-grained sandstone; laminated; poorly sorted; grades into mudstone.	1	76.0
19	Covered.	13	75.0
18	Alternating sandstone and mudstone: sandstones medium- to fine-grained, moderately sorted, angular; micaceous and feldspathic; large scale channeling, similar to unit 30; sand to mud ratio is nearly 1:1; sandstones alternate with mudstones in varve-like manner. Contact: sharp and undulatory.	25	62.0

Unit	Description	Thickness Unit	(feet) Total
17	Sandstone: lens, thins to north and south; thickest about 6 feet, thins to nothing 60 feet from thickest point, to the south it is truncated by a fault; medium- to coarse-grained sandstone, moderately sorted, finely laminated with micas aligned along bedding and carbon material making laminations; microcross-bedding present; not graded; firmly carbonate cemented; cliff former. Contact: sharp and undulatory.	5	37. 0
16	Mudstone: laminated with siltstones and micaceous layers. Contact: gradational over 1 foot.	. 5	32. 0
15	Alternating sandstones and mudstones: similar to units 18 and 30; sandstones show sharp contacts with mudstones; mudstones are laminated, 1 inch thick beds, grading evident near top of unit. Contact: sharp and planar.	4. 5	31. 5
14	Sandstone: lens-shaped sandstone unit, well-sorted, medium-grained sandstone; contains minor mud rip-ups and coaly lenses to 1/8 inch thick; loaded into underlying unit; cliff former, firmly carbonate cemented. Contact: sharp and undulatory.	1	27. 0
13	Sandstone: fine-grained and finely laminated; feldspathic and micaceous; graded from nearly pure sand with only minor mudstone laminations to nearly pure mudstone with only minor sandstones near top of unit; contains mudstone rip-ups, loading and flame structures; firmly carbonate cemented. Contact: sharp and undulatory.	2	26. 0

Unit	Description	Thickness (feet) Unit	Total
12	Mudstone: finely laminated, 10 laminations per inch; nearly pure with only carbonaceous material marking laminations; sandstone above has loaded into this unit. Contact: gradational over 6 inches.	1	24.0
11	Sandstone: poorly sorted sandstone with mudstone matrix laminations to 1 mm. thick; sandstone is fine-grained and very micaceous. Contact: sharp and planar	1	23.0
10	Mudstone: nearly pure mudstone weathering out in small chips; contains only faint minor laminations of siltstone. Contact: gradational over 6 inches.	.5	22.0
9	Sandstone: sandstone with mudstone interbeds to 1-1/4 inches thick; 80% sandstones; contacts between mudstones and sandstones are sharp; sandstones are micaceous and finely laminated, 10 laminations per inch. Contact: gradational over 1 foot.	2	21.5
8	Alternating sandstone and mudstone: similar to units 18 and 30; sandstones 3 to 4 inches thick with equal amounts of mudstones; not graded; very carbonaceous and micaceous; loading and flame structures and mud rip-ups present. Contact: gradational over 1 foot.	1.5	19.5
7	Mudstone: weathering to chips similar to unit 10. Contact: gradational over 1 foot.	2	18.0
6	Sandstone: variable thickness, possible scour-and-fill structures; mudstone rip-ups mark bottom of unit; normally graded; microcross-bedded and micro-trough cross-bedded; firmly carbonate cemented. Contact: sharp, scour-and-filled into lower unit.	1.5	16.0

Unit	Description	Thickness Unit	(feet) Total
5	Mudstone: laminated with fine-grained silty layers to 1/2 inch thick; 85% mudstone; normally graded; very micaceous. Contact: sharp and planar	6	14. 5
4	Sandstone: very fine-grained, well sorted; fine mudstone layers 1 mm. thick mark laminations; sandstone is micaceous and quartz-rich; lower contact irregular because of loading, abundant flame structures; mudstone rip-ups abundant near lower contact; layer is lens-like. Contact: gradational with increasing mudstones over 2 feet, flute and groove casts present.	4	8. 5
3	Alternating mudstone and sandstone: 40% mudstones in 1/2 inch layers; sandstones very micaceous and finely laminated; flame structures and microfaults present. Similar to units 18 and 30; microcross-laminated. Contact: sharp and undulatory.	2	4. 5
2	Mudstone: chip-like weathering, nearly pure mudstone with some siltstone laminations. Contact: gradational over 5 inches.	. 5	2. 5
1	Alternating mudstone and sandstone: sandstones medium- to fine-grained, well-sorted, 2-1/2 inch thick lenses; 70% sandstone in well-laminated sequence; microcross-laminated.	2	2. 0

APPENDIX III

Principal Reference Section E-F

Angora Peak Sandstone Member and Silver Point Mudstone of the Astoria Formation

Initial point: NW 1/4 NW 1/4 of section 19, T. 4 N., R. 10 W. At junction of U.S. Highway 101 and Hug Point mainline logging road. Measurements were down section on the west limb of an anticline. Strata, where measurements were started, are the same as the strata measured in section A-B on the coast. Measurements were made up the Hug Point mainline over slumped and covered strata. Eleven hundred feet were measured to where the road turns southwesterly. At this point the section is offset along the road and estimated on topographic maps to be 600 feet stratigraphically. Measurements were started again in the cross-bedded unit exposed in the road cut in the NE 1/4 SE 1/4 of section 19, T. 4 N., R. 10 W. From these measurements, estimated thickness of Angora Peak Sandstones are 1100 feet on the west limb of the anticline, and 1156 feet on the east limb with 645 feet of Silver Point mudstones above this.

Terminal point: SE 1/4 SW 1/4 of section 17, T. 4 N., R. 10 W., near the road junction of the Hug Point mainline and a cross-over road at the saddle overlooking the West Fork of Elk Creek.

APPENDIX III

Principal Reference Section E-F

Unit	Description	Thickness Unit	(feet) Total
25	Covered: Terminated at first exposures of Depoe Bay Basaltic breccias; covered with talus and brush.	200	1191.0
24	Alternating sandstone and mudstone: equal amounts of each; sandstones are tuffaceous and very micaceous; show evidence of loading on beds and possible slumping; very similar to unit 22.	40	991.0
23	Covered.	160	951.0
22	Alternating sandstone and mudstone: fresh sandstones are grayish orange (10 YR 7/4), mudstones vary from medium gray (N5) to light olive gray (5 Y 6/1) with increasing silt content; outcrop weathers to dark yellowish orange (10 YR 6/6); from distance, outcrop is thinly laminated sandstones and mudstones, no single bed exceeds 3 inches in thickness, bedding appears to be continuous and planar; mudstones weather out as small chips, sandstones slightly carbonate cemented; carbonaceous rich; sandstones are in layers less than 1-1/2 inches thick averaging 1/2 inch; contain semi-rounded quartz grains; quartz-rich, moderately sorted, very fine- to medium-grained sandstones; very micaceous; possibly burrowed subparallel to bedding, sandstone fills burrows, interrupting laminations and making the bedding wavy; small sandstone dikes (0.1 inch thick) cut across structures; sandstones are normally graded; sharp lower contacts, grade into siltstones		

Unit	Description	Thickness Unit	(feet) Total
	and mudstones over the average 3-inch interval; no lensing of sandstones, micro-cross-laminations and trough cross-laminations are common; loading is evident by small flames; sandstones pinch out, possibly by loading and current action; the laminations are very irregular and discontinuous; elongate limonite concretions are present along some bedding planes; some sandstones grade up to fine-grained sandstone then another graded sandstone on top; sandstone 60%, about 1/2 showing grading, about 1/2 contacts sharp.	55	791.0
21	Covered.	190	736.0
20	Covered. Approximate location of contact between Angora Peak Sandstone and Silver Point mudstone.	370	546.0
19	Depoe Bay Basalt sill. Contact: baked 2 inches and planar.	15	176.0
18	Sandstone to mudstone: sandstone yellowish gray (5 Y 7/2), weathers dark yellowish orange (10 YR 6/6); mudstones very light gray (N8), weather light brown (5 YR 5/6); normally graded over entire unit; sands to very fine clay; faintly laminated but deeply weathered; pyrite concretions common near sill contact. Contact: sharp and irregular.	6	161.0
Note:	Colors the same as listed above unless otherwise stated.		
17	Pebbly sandstone: deeply weathered unit; spheroidal, iron-stained patterns; difficult to tell if unit is bedded or cross-bedded. Contact: gradational over 5 inches.	11	155.0
16	Mudstone: inversely graded from laminated mudstone into fine-grained sandstone into the next unit above. Contact: sharp and undulatory.	1	144.0

Unit	Description	Thickness Unit	(feet) Total
15	Sandstone: very poorly sorted, medium-to-coarse-grained sandstone, no pebbles; abundant woody and carbon matter; small concretions of pyrite; appears to be cross-bedded but weathering obscures bedding; grades finer upward into mudstone. Contact: sharp and undulatory	6	143.0
14	Mudstone: very light gray (N8), weathers to dark reddish brown (10 R 3/4); sharp contacts, overlying sandstone has loaded into mudstone; mudstone shows no laminations. Contact: sharp and planar.	.5	137.0
13	Pebbly sandstone: yellowish gray (5 Y 7/2), weathers to dark reddish brown (10 R 3/4); unit is very weathered; contains pebble layers to 3 inches thick; pebbles average 1/8 inch in diameter with largest 1/4 inch; thinly bedded; contains pyrite concretions. Contact: gradational over 2 feet.	8	136.5
12	Sandstone: doubly graded unit; fine-grained sandstone near center of unit grading both up and down to coarse-grained sandstone; moderately sorted. Contact: gradational over 1 foot.	2	128.5
11	Pebbly sandstone: poorly sorted, angular very coarse-grained sandstone; pebbles average 1/2 inch in diameter with largest to 1 inch; cross-bedded; abundant angular mudstone rip-ups; organic-rich; dark organic layer (dark gray (N3)) separates 2 cross-bedded units. Contact: sharp and undulatory.	2.5	126.5
10	Mudstone: no apparent laminations, or silt content, overlying unit has loaded into this unit and possibly scour-and-filled at contact; very organic-rich mudstone. Contact: sharp and planar.	1	124.0

Unit	Description	Thickness Unit	(feet) Total
9	Sandstone: moderately sorted, fine-grained sandstone; contains coarse-grained sandstone lenses up to 2 feet wide and 6 inches deep; laminated, appears to have vertical burrows filled with coarse sand; burrows 1/8 inch thick and round; unit contains three thin (4-inch thick) mudstone layers; mudstones are loaded into sharp, undulatory contacts; not bedded. Contact: gradational over 3 inches.	5.5	123.0
8	Interbedded mudstones and sandstones: low silt content in mudstones; sandstones are fine-grained and well sorted, feldspathic; contacts are sharp. Contact: sharp and planar.	1.5	117.5
7	Pebbly sandstone: poorly sorted, feldspathic, coarse-grained sandstone with pebble layers between cross-bedded units; pebbles up to 1/4 inch in diameter; carbonaceous rich layers and woody debris are common throughout unit; clay rip-ups present.	5	116.0
6	Covered.	75	111.0
5	Pebbly sandstone: very pale orange (10 YR 8/2), weathers to dark yellowish orange (10 YR 6/6); very poorly sorted, coarse-grained sandstone; pebbles average 1/4 inch in diameter, with largest to 1 inch; pebbles are scattered in unit; pumice-rich; 35 cross-bedded units present, each planar bed truncated by the next; cross-bedding amplitudes range from 5 inches to 1 foot; bedding and cross-bedding is planar and regular. Contact: sharp and planar.	15	36.0

Unit	Description	Thickness Unit	(feet) Total
4	Sandstone: yellowish gray (5 Y 6/2), weathers to dark yellowish orange (10 YR 6/6); medium-grained, moderately sorted sandstone; feldspathic; laminated by carbonaceous material; coarse sandstone lenses present. Contact: sharp and undulatory.	3	21.0
3	Siltstone: dark yellowish orange (10 YR 6/6), weathers dark reddish brown (10 R 3/4); laminated and very contorted from loading. Contact: sharp and undulatory.	1	18.0
2	Sandstone: laminated, fine-grained sandstone; moderate sorting, contorted and broken up; faintly cross-bedded, similar to unit 4. Contact: gradational over 1 foot.	9	17.0
1	Sandstone: similar to units 2 and 4; faintly laminated and cross-bedded, deeply weathered.	8	8.0

Appendix IV. Pebble lithologies of conglomerates in the Angora Peak sandstone member and "Silver Point" mudstones of the Astoria formation. (See Plate I for sample localities.)

Pebble Type	Angora Peak					Silver Point
	Hug	21	71	54	57	Spa
Chert	31	31	12	10	31	26
Quartz	2	10	--	--	2	8
Quartzite	15	12	10	7	16	14
Basalt	14	13	5	21	11	4
Intermed. volcanic	7	11	10	43	14	6
Rhyolite	3	3	5	5	5	3
Pumice	15	11	10	4	6	19
Tuff	5	4	10	7	8	8
Silicic tuff	2	--	32	--	--	2
Welded tuff	1	3	3	2	1	1
Metamorphic	1	1	1	--	3	1
Plutonic	1	1	1	1	2	1
Sedimentary*	3	--	1	--	1	7

* Includes: mudstone and quartz sandstone.

Appendix V. Size analyses of selected sandstone samples. Statistical parameters are of Folk and Ward's (1957). (See Plate I for sample locations.)

Sample	Sand %	Silt %	Clay %	Carbonate %	Organic %	Coursest 1%, mm	Median mm	Median phi	Mean phi	Sorting phi	Skewness phi	Kurtosis phi
Angora Peak												
1 H	83.6	8.3	8.1	3	1	2.00	0.38	1.40	1.9	2.10	0.55	1.70
1 H*	98.3	---	---			2.00	0.50	1.00	1.2	1.00	0.26	1.10
3 H	84.4	6.6	9.0	1	4	0.50	0.15	2.70	2.9	1.20	0.56	1.90
3 H*	98.3	---	---			0.50	0.17	2.50	2.7	0.62	0.29	1.10
5 H	80.9	9.4	9.7	2	4	0.75	0.15	2.70	3.0	1.60	0.54	1.70
5 H*	95.5	---	---			0.75	0.17	2.50	2.5	0.90	0.10	0.90
7 H	91.6	5.0	3.4	1	4	1.00	0.50	1.00	1.3	1.30	0.57	2.70
7 H*	98.8	---	---			1.00	0.60	0.90	1.0	0.72	0.42	1.60
Hug 1	95.5	---	---	5	9	0.75	0.38	1.40	1.6	1.30	0.39	0.95
Hug 2	90.0	---	---	4	15	0.65	0.21	2.30	2.4	1.10	0.18	1.10
Hug 3	97.0	---	---	7	3	0.85	0.38	1.40	1.6	1.30	0.38	0.94
Silver Point												
SP	98.2	---	---	10	2	0.75	0.25	2.00	2.0	0.85	0.04	0.95

* Parameters recalculated matrix free. Matrix is believed to be dominantly secondary due to the weathered nature of these strata.

Appendix VI. Heavy mineralogy of selected samples. (A = abundant, P = present, T = trace. See Plate I for sample locations.)

	Sample	Magnetite	Hematite	Leucoxene-Ilmenite	Pyrite	Green Hornblende	Basaltic Hornblende	Garnet	Augite	Hypersthene	Zircon	Monazite	Tourmaline	Enstitite	Epidote	Biotite	Muscovite	Corundum	Rutile
Angora Peak	1 H	A	A	A	-	P	-	A	A	P	T	A	-	P	T	A	-	-	P
	3 H	A	A	P	-	A	-	P	T	P	T	P	-	-	-	T	-	-	T
	5 H	A	A	A	-	A	A	A	P	A	A	-	-	P	-	P	-	-	-
	7 H	A	A	P	-	A	P	A	P	A	P	A	T	P	-	A	T	-	T
	Hug 1	A	P	P	A	A	P	P	-	A	A	P	-	-	T	-	-	T	T
	Hug 2	A	T	P	-	A	T	A	T	A	P	A	-	-	-	P	-	-	P
	Hug 3	A	T	P	-	A	-	A	P	A	P	A	-	-	-	P	-	-	P
Silver Point	SP	A	A	-	A	A	-	A	-	A	A	A	-	P	-	A	A	-	P

Appendix VII. Modal analyses of sandstone samples from "Silver Point Mudstones" and Angora Peak Sandstones. (See Plate I for sample localities.)

	Angora Peak			Silver Point						
Sample	Hug	Hug 1	57	SP	52	SP-1	52a	SP 2	19	11
Cement ($CaCO_3$)	4	Tr	7	48	24	2	3	4	--	--
Organics	--	--	Tr	8	1	--	12	--	5	4
Matrix	20	6	3	2	1	10	15	7	57	30
Grains	75	92	90	42	74	88	85	89	38	66
Stable Grains										
Quartz	35	44	15	25	37	39	37	17	25	40
Quartzite	2	4	10	2	1	Tr	1	2	1	2
Chert	1	1	14	2	3	Tr	2	17	2	1
Feldspars										
K-spar	9	5	1	5	7	5	5	2	3	6
Plagioclase	2	2	1	2	8	2	8	1	1	7
Rock Fragment										
VRF*	23	44	45	4	17	36	28	42	5	8
MRF*	1	2	3	Tr	Tr	Tr	Tr	Tr	Tr	Tr
SRF*	1	1	2	Tr	Tr	4	2	7	Tr	Tr
PRF*	Tr	Tr	2	--	--	Tr	--	Tr	--	--
Mica	--	--	--	2	1	2	2	1	Tr	2
Mafic	Tr	--	--	Tr	Tr	--	--	--	--	--
Glauconite	--	--	--	Tr	Tr	Tr	--	--	Tr	Tr
Porosity	1	2	--	--	--	--	--	Tr	--	--

* VRF - Volcanic Rock Fragment
* MRF - Metamorphic Rock Fragment
* SRF - Sedimentary Rock Fragment
* PRF - Plutonic Rock Fragment

Appendix VIII. Clay analysis of selected mudstone samples from Oswald West mudstones, Angora Peak sandstones, and Silver Point mudstones. (See Plate I for sample localities.)

	Oswald West			Silver Point			Angora Peak		
Sample No.	55	13	13a	SPa	6	103	Hug 1a	Hug 1b	58
Clay:									
Montmorillonite	-	X	-	X	-	X	-	X	X
Kaolinite	-	-	-	X	X	X	-	-	X
Chlorite	X	X	-	-	-	X	-	X	-
Vermiculite	-	-	-	-	X	-	X	-	-
Mica	X	-	-	-	X	X	X	-	-
Clinoptilolite	-	-	X	-	-	-	-	-	-
Mixed-layer clays	-	X	-	X	X	X	-	X	X

Appendix IX. Chemical analyses of selected samples of basalts and of Angora Peak pebbles. Calculated water free, total iron as FeO. (See Plate I and Appendix XI for sample localities.)

	Cape Foulweather		Depoe Bay		Eocene Dike	Angora Peak Pebbles		
Sample No.		Ac	Br 50	34*	32	54-1	54-2	54-3
SiO_2	52.5	56.4	54.4	56.4	48.3	64.3	73.2	73.0
Al_2O_3	12.6	13.1	13.8	13.9	16.8	19.3	17.2	13.4
FeO	15.0	13.5	12.9	12.4	10.3	1.8	3.3	3.3
MgO	4.2	3.4	3.4	3.3	8.5	0.6	0.6	0.2
CaO	8.3	7.0	7.2	6.9	11.0	5.3	0.1	2.2
Na_2O	3.0	3.6	3.4	3.4	3.0	4.9	1.0	5.0
K_2O	1.2	1.4	1.5	1.2	0.4	1.8	3.2	1.7
TiO_2	3.1	1.9	2.2	1.9	1.4	0.6	1.1	0.3

* From Snavely and others (1973), Sample SR 62-54, Pillow, SE 1/4, Section 20, T. 4 N., R. 10 W.

Appendix X. Modal analyses of basalt samples of Depoe Bay, Cape Foulweather, and a third basalt type.

Sample	Depoe Bay 10	Depoe Bay 17	Cape Foulweather 1	Third basalt 28	Third basalt 32
Plagioclase					
Groundmass	57	43	45	42	41
Phenocrysts	Tr.	--	1	16	15
Augite	24	26	29	29	19
Orthopyroxene	5	3	7	9	8
Chlorophaeite	2	7	6	1	14
*other alteration products	7	12	2	--	--
Magnetite	5	9	10	3	3

* Other alteration products include zeolites, silicic residuum, and chlorite.

Appendix XI. Sample localities. (see Plate I)

Member	Sample	Found in Appendix	Locality	Type of sample
Angora Peak member	Hug	IV, VII	SW 1/4 of section 18, T. 4 N., R. 10 W.	conglomeratic sandstone
	Hug 1	V, VI	NW 1/4 of section 19, T. 4 N., R. 10 W.	conglomeratic sandstone
	Hug 1a	VIII	same as above	clays from sandstone
	Hug 1b	VIII	same as above	mudstone interbed
	Hug 2	V, VI	SW 1/4 of section 18, T. 4 N., R. 10 W.	sandstone
	Hug 3	V, VI	SW 1/4 of section 19, T. 4 N., R. 10 W.	sandstone
	1H, 3H, 5H, 7H	V, VI	NW 1/4 of section 20, T. 4 N., R. 10 W.	sandstone
	21	IV	SE 1/4 of section 12, T. 4 N., R. 10 W.	conglomerate
	71	IV	SW 1/4 of section 18, T. 4 N., R. 10 W.	conglomerate
	54	IV	NW 1/4 of section 24, T. 4 N., R. 10 W.	conglomerate
	57	IV, VII	SW 1/4 of section 30, T. 4 N., R. 9 W.	conglomerate
Silver Point member	Sp	V, VI, VII	SW 1/4 of section 6, T. 4 N., R. 10 W.	laminated sandstone
	Spa	VIII	same as above	mudstone
	Spb	IV	same as above	conglomerate
	Sp-1	VII	same as above	channel sandstone
	Sp-2	VII	same as above	channel sandstone
	6	VIII	same as above	mudstone
	103	VIII	SW 1/4 of section 7, T. 4 N., R. 9 W.	mudstone
	52, 52a	VII	SW 1/4 of section 17, T. 4 N., R. 10 W.	laminated sandstone
	19	VII	NE 1/4 of section 19, T. 4 N., R. 10 W.	graded sandstone
	11	VII	NE 1/4 of section 8, T. 4 N., R. 9 W.	graded sandstone

Appendix XI. (Continued)

	Sample	Found in Appendix	Locality	Type of sample
Oswald West Mudstones	55	VIII	SW 1/4 of section 29, T. 4 N., R. 9 W.	mudstone
	13	VIII	NE 1/4 of section 9, T. 4 N., R. 9 W.	mudstone
	13a	VIII	same as above	tuff bed
Depoe Bay Basalt	Ac	IX	SW 1/4 of section 30, T. 4 N., R. 10 W.	basalt intrusive
	Br 50	IX	NE 1/4 of section 16, T. 4 N., R. 10 W.	pillow fragment
	10	X	SW 1/4 of section 4, T. 4 N., R. 10m W.	thick sill
	17	X	NW 1/4 of section 18, T. 4 N., R. 9 W.	thick sill
Cape Foulweather Basalt	1	IX, X	SW 1/4 of section 6, T. 4 N., R. 10 W.	thick sill
Other basalt	28	X	NE 1/4 of section 28, T. 4 N., R. 9 W.	thin dike
	32	IX, X	NE 1/4 of section 21, T. 4 N., R. 9 W.	thin dike