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Title: STRATIGRAPHY AND SEDIMENTATION OF THE NEAHKAHNIE MOUNTAIN - ANGORA PEAK AREA, TILLAMOOK AND CLATSOP COUNTIES, OREGON

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Four distinct lithologic units compose the Tertiary rocks of the Neahkahnie Mountain - Angora Peak area, located along the northwest Oregon coast near the town of Nehalem. The Tertiary units are the late Oligocene to early Miocene Oswald West mudstones, the middle Miocene Angora Peak sandstone member of the Astoria Formation, and middle Miocene intrusive and extrusive rocks of the Depoe Bay Basalt. These units are unconformably overlain by Pleistocene and Recent beach and dune sands, alluvium, and tidal flat muds. The Oswald West mudstones and the Angora Peak sandstone member are informal stratigraphic units proposed in this study.

The Oswald West mudstones consist of over 1600 feet of well-bedded, highly burrowed, tuffaceous siltstones and silty mudstones interbedded with minor amounts of graded turbidite sandstones and submarine slump deposits. Foraminifera and trace fossils suggest deposition occurred in marine waters of upper bathyal depths.

The Angora Peak sandstone consists of over 1800 feet of thin- to thick-bedded, locally cross-bedded, fine- to coarse-grained arkosic sandstones, pumiceous and basaltic conglomerates, carbonaceous and micaceous siltstones, and local coal beds. The interfingering shallow marine and fluvial sandstones are interpreted to have been deposited in a high-energy, wave dominated, deltaic environment which reworked the sediments into extensive delta-front sheet sands similar to those observed in the modern Niger and Rhone deltas. Mineralogy, heavy minerals, and conglomerate clast lithologies indicate that most of the sediments were derived from local uplifted areas of Eocene basalts and early Tertiary sediments and from the Oligocene Little Butte Volcanics in the western Cascades. Rare metamorphic and plutonic clasts, sedimentary quartzite, heavy minerals, and sandstone mineralogy suggest that metamorphic, igneous, and Paleozoic sedimentary terranes in eastern Oregon and Washington, British Columbia, Idaho, and Montana supplied some of the sediments, possibly via an ancestral Columbia River.

Dikes, sills, and plugs of aphanitic to finely crystalline Depoe Bay Basalt intrude the older sedimentary rocks and locally are feeders for palagonitized pillow breccias which unconformably overlie the Angora Peak sandstone. The major intrusive body is a 1200-foot thick diabasic sill referred to as the Neahkahnie sill. The extrusive basalts formed in a subsiding marine basin in which over 1600 feet of pillow lavas, pillow breccias, and minor basalt flows were locally extruded.

The area is cut by a series of west-northwest and north-trending faults. Two synclines and an anticline strike subparallel to the west-northwest trending faults.

Stratigraphy and Sedimentation of the Neahkahnie Mountain - Angora Peak Area, Tillamook and Clatsop Counties, Oregon

by

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INTRODUCTION

Location and Accessibility

The area of investigation is located along the northern Oregon coast in the vicinity of Nehalem, approximately 60 miles west-northwest of Portland. The 34 square mile area, straddling northwestern Tillamook County and southwestern Clatsop County, occurs on the western side of the northern Coast Range of Oregon (Baldwin, 1964). The study area is naturally bounded on the east by the North Fork of the Nehalem River, on the south by Nehalem Bay, and on the west by the Pacific Ocean (Figure 1). The northern boundary lies one mile north of the Clatsop-Tillamook county line and extends six miles inland from Arch Cape to the North Fork of the Nehalem River. Prominent geographic features located within the area are Oswald West State Park, and the towns of Nehalem, Manzanita, and Neahka Neahkahnie Beach.

Access into the western part of the area is provided by U. S. Highway 101, the Oregon Coast Highway, from the north and south. Short Sands Cross Over Road, a gravel road maintained by Boise Cascade, provides access to the central part of the thesis area

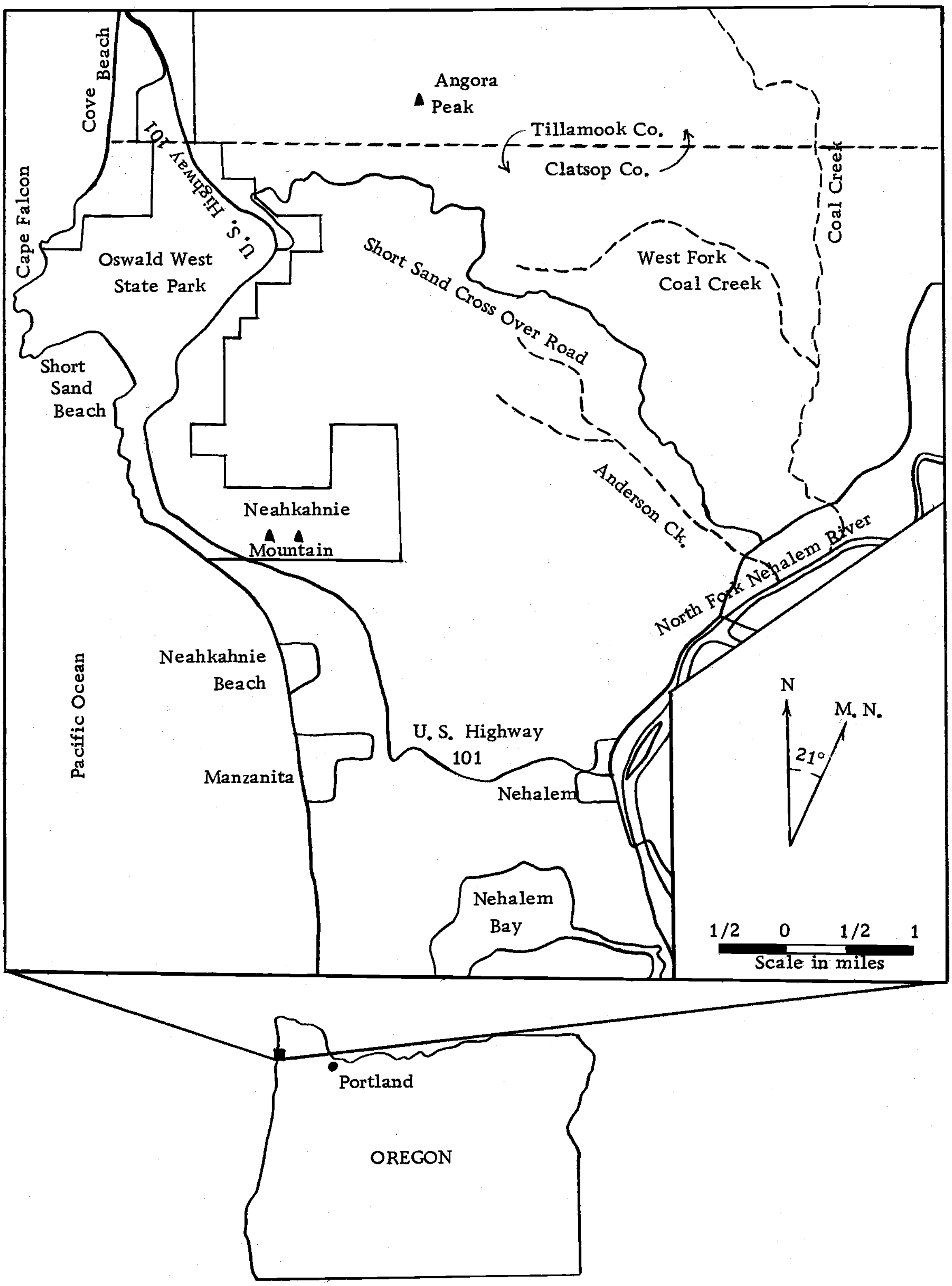

Figure 1. Index map showing the location of the Neahkahnie Mountain - Angora Peak area.

from both U. S. Highway 101 and a paved county road following the west bank of the North Fork of the Nehalem River. Numerous logging roads radiating from this mainline provide vehicular access to within two miles of any point. The quality of these roads is, however, deteriorating because of rapid growth of vegetation and landslides. The majority of the logging roads presently can be negotiated by 2-wheel drive vehicles in the summer, but heavy winter rainfall makes the roads almost impassable.

Purposes of Investigation

The objectives of this investigation are: 1) to construct a geologic map of the structure and stratigraphy of the area; 2) to determine the areal sedimentary, igneous, and tectonic history; 3) to describe the lithologies, lateral variations, sedimentary structures, contact relations, and fossils of the sedimentary units in order to determine their depositional paleoenvironments, probable source areas, and the paleogeography of this part of the Oregon coast; and 4) to evaluate the economic potential of this area.

Previous Work

A series of coal outcrops, exposed for approximately five miles in the eastern part of the area of investigation, was first recognized by Diller (1896) who described its occurrence and published chemical analyses on selected samples of coal. Diller also collected molluscan fossils at Short Beach (Short Sands Beach) in Oswald West State Park and assigned those strata an Oligocene age.

Washburne (1914) noted the presence of coal immediately south of Necarney (Neahkahnie) Mountain, about two miles west of the coal outcrops mentioned by Diller. Washburne suggested that these coal outcrops were equivalent and might be correlative with "the fresh-water sandstone above the marine rocks east of Astoria."

Few geologic investigations were conducted in northwestern Oregon until the early 1940's when war-time shortages of gas and oil forced a renewed interest in petroleum possibilities in the area. This renewed interest resulted in the publication of a small scale (1:143,000) reconnaissance map of northwest Oregon by Warren, Norbisrath, and Grivetti in 1945 in which they differentiated basalts and sedimentary rocks in the thesis area. They measured a 1500-foot section of siltstones and mudstones at Short Sand Beach, referring to those strata as "Beds of Blakely age," and noted that those strata represented unique sedimentary conditions for Blakely age (late Oligocene) strata in northwest Oregon. Although contacts between sedimentary units were not delineated on their map, Warren and others noted that the Astoria Formation occurred in northwestern Tillamook County and consisted of "mostly sandstone and tuffaceous sandy shale."

Cooper (1958), in his study of coastal dunes of Oregon and

Washington, found that the seaward part of the dune and beach complex of the Nehalem spit, located in the southwestern part of the study area, had been lost to erosion of the advancing sea.

Wells and Peck (1961) compiled a geologic map of western Oregon (scale 1:500, 000) which in the study area differentiates the Astoria Formation, the Oligocene strata, and those Miocene basalts which are equivalent to the Columbia River basalts. Formational contacts on the map are generalized and no structural features are shown.

Recently, interest in northwest Oregon coastal geology has increased. Geologic maps of Clatsop and Tillamook Counties (scale 1:62, 500) have been published by Schlicker and others (1972) in their report on environmental and engineering geology of the northwest coast. They differentiate extrusive basaltic breccias from intrusive basalts and indicate areas of potential geologic hazards. Snavely, MacLeod, and Wagner (1973) studied in detail Miocene volcanic rocks exposed in the thesis area and elsewhere along the Oregon coast, finding them to be petrologically and chemically similar to basalts of the Columbia River Group. They also refer to Neahkahnie Mountain as a sill over 1000 feet thick and note that submarine basaltic breccias of Depoe Bay Basalt form mountainous areas behind Neahkahnie Mountain.

Preliminary observations in an areal reconnaissance of sedimentary rocks of the northwest Oregon coast by Niem, which includes data from this study, have been published in a fieldtrip guidebook for the 1973 Geological Society of America Cordilleran Section meeting (Niem and others, 1973). He recognized deep water features in the strata at Short Sand Beach and refers informally to those strata as the "Oswald West mudstones." Foraminifera collected from these rocks by Niem indicate a Zemorrian (late Oligocene) age. He also informally referred to sandstones overlying the Oswald West mudstones as the Angora Peak sandstone member of the Astoria Formation.

Methods of Investigation

Field Methods

Field work was conducted during the summer of 1972 from July 6 to September 1 and also during periodic visits to the area later in that year and in early 1973. Field work consisted of geologic mapping, measurement and description of stratigraphic sections, paleocurrent determinations, and rock and fossil sampling.

Lithologic units and structural features were mapped on recent (May, 1971) Oregon State Department of Forestry aerial photographs at a scale of 1:12,000. These data were later transferred to enlarged (4" equals one mile) U. S. Geological Survey 15' topographic maps of the Nehalem (1955) and Cannon Beach (1955) quadrangles.

Stratigraphic sections were measured using a Brunton compass an Abney level mounted on a five-foot Jacobs staff. Paleocurrent structures were measured with a Brunton compass and then corrected for tectonic tilt with a stereonet. A 15X hand lens, sand gauge chart, and a Geological Society of America Rock-Color Chart (1963) aided in rock descriptions in the field.

Representative samples of major lithologies were collected for petrographic study, and additional sandstones were collected for size and heavy mineral analyses. Plant, invertebrate, and icnofossils (burrows) were collected for identification. Mudstone samples were collected for X-ray and microfaunal analyses. A minimum of 100 randomly selected pebbles were collected from eight conglomerate units and identified in the laboratory with the aid of a binocular microscope. Thin sections were made of exotic clasts to determine their composition more accurately.

Sediment size terminology used is that of Wentworth as modified by the National Research Council (Lane and others, 1957) and volcaniclastic size terminology used is that after Fisher (1961). The sandstone classification followed in this report is after Gilbert (Williams, Turner, and Gilbert, 1954). The volcanic and igneous rocks are also classified after Gilbert. Stratification and cross-stratification terminology used is in accordance with McKee and

Weir (1953).

Analytical Methods

Laboratory analyses of rock samples collected in the field consisted of size analysis, heavy mineral analysis, and modal analysis of the sandstones, and X-ray analysis of clay minerals from both sandstone and mudstone samples.

Size analyses were performed on 12 samples of sandstones using a combination of minimum diameter (sieving) and particle settling velocity (pipette) methods as standardized by Royse (1970). Most samples were easily disaggregated with the use of a rubber pestle. Those samples cemented by calcium carbonate were treated with dilute HCl. The disaggregated material was sieved through Tyler sieves at 1/2 phi intervals. Those samples with an abundant pan fraction (less than four phi) were dispersed in Calgon (sodium hexametaphosphate) and wet-sieved through a four phi sieve. The fine fraction (less than four phi) was placed in a 1000 ml. cylinder for pipette analysis. Dispersed mudstone samples were also analyzed by the pipette method. Inman's medium diameter, sorting, skewness, and kurtosis coefficients were calculated from cumulative weight percent curves of the 1/2 phi size fractions. These statistical parameters were then plotted on Friedman's (1962) and Passega's (1957) graphs in order to determine the depositional environments of the samples.

Heavy minerals were separated from the 3.0 phi to 3.5 phi size fractions (very fine sand) of ten selected samples with the use of tetrabromomethane (specific gravity 2.85). The heavy fractions were mounted on slides with Lakeside 70 for petrographic analysis.

Modal analyses of 15 thin-sections were performed by point counting approximately 600 points on a 0.5 mm. grid spacing at 80X magnification on a mechanical stage. Rock billets were stained for plagioclase and potassium feldspar using methods standardized by Laniz and others (1964).

A sample of Oswald West mudstone was treated with hydrogen peroxide (H_2O_2) to determine the percent of organic material.

REGIONAL STRATIGRAPHY

The present site of the Oregon Coast Range and adjacent continental margin was the locus of an elongate trough in which more than 25, 000 feet of Tertiary sedimentary and volcanic rocks accumulated (Snavely and Wagner, 1963). The strata in the northern Coast Range range in age from early Eocene to Pliocene and are thought to overlie oceanic crust (Snavely and others, 1968).

The oldest rocks exposed in the northern Coast Range are the early Eocene Tillamook Volcanics of Warren and others (1945) (Figure 2). These rocks are composed predominantly of tholeiitic and alkalic basaltic pillow lavas and volcanic breccias which interfinger complexly with minor amounts of marine tuffaceous siltstones and basaltic sandstones. Snavely and Wagner (1963) believe that the unit may be as much as 20, 000 feet thick near ancient centers of volcanism such as the Tillamook Highlands, located a few miles southeast of the thesis area. Correlative rocks in the central Coast Range are the Siletz River Volcanics (Snavely and others, 1968).

The late Eocene Cowlitz Formation unconformably overlies the Tillamook Volcanics in the northwest Coast Range (Warren and Norbisrath, 1946). This formation consists of more than 1000 feet of basaltic conglomerate, arkosic sandstone, and siltstone. The conglomerates commonly are fossiliferous, containing abundant

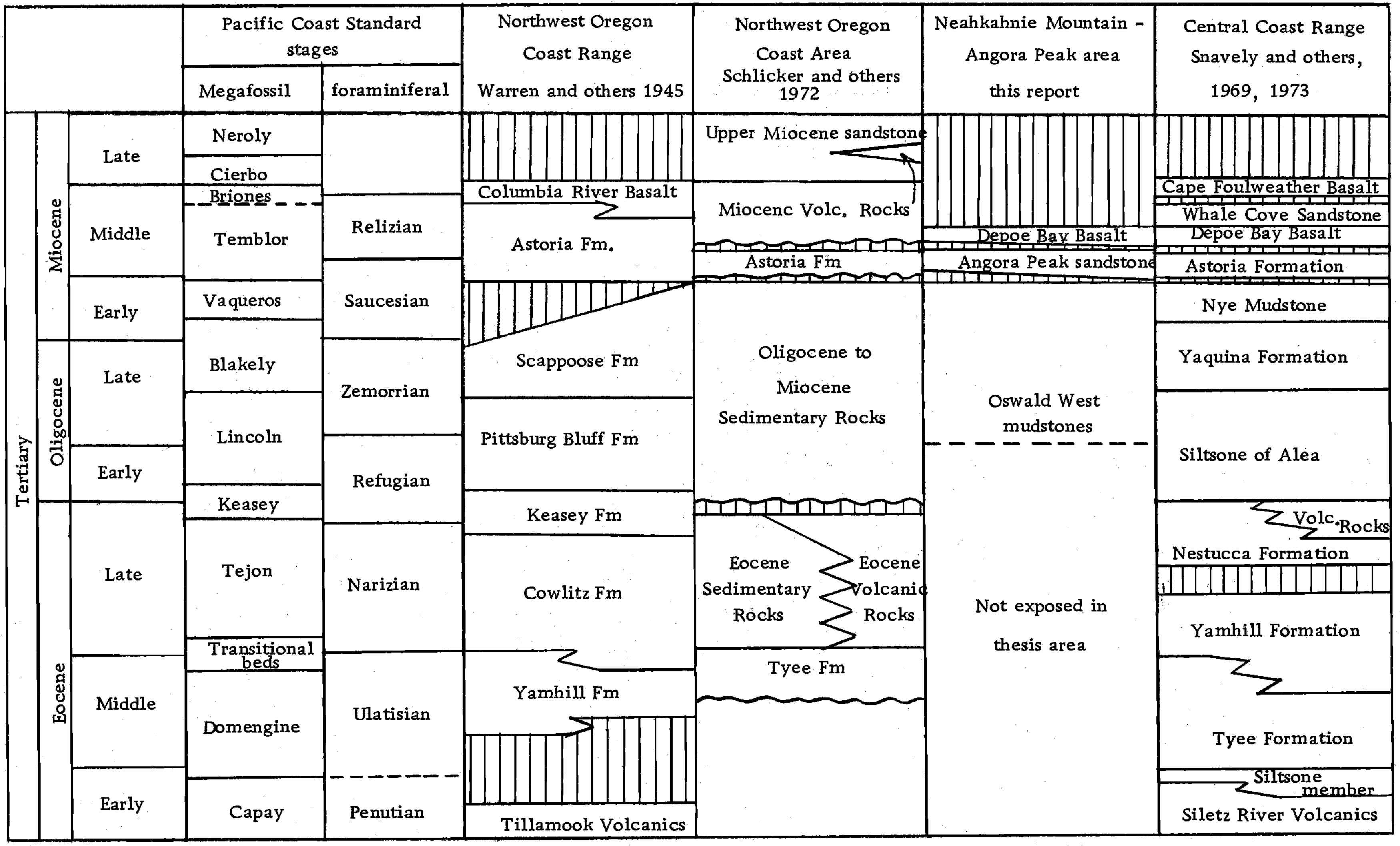

Figure 2. Correlation chart of Tertiary formations of the northern and central Oregon Coast Range.

mollusks, and the sandstones contain abundant plant debris. The Cowlitz is, in part, correlative to the Nestucca Formation in the central Coast Range.

In the north-central part of the Coast Range the late Eocene Yamhill Formation lies between the Siletz River Volcanics and the Cowlitz Formation, and interfingers southward with the Tyee Formation. The Yamhill Formation consists of 2000 feet of massive to thin-bedded siltstone which was deposited in bathyal depths (Snavely and others, 1969).

The late Eocene to Oligocene Keasey Formation conformably(?) overlies the Cowlitz Formation in the eastern part of the northern Coast Range (Warren and Norbisrath, 1946). Three members, totaling over 1800 feet, are recognized in the Keasey: 1) an upper member, 200 to 300 feet thick, consists of concretionary tuffaceous siltstone and mudstone; 2) a middle member, up to 1700 feet thick, consists of massive tuffaceous and fossiliferous siltstone; and 3) a lower member, 600 to 700 feet thick, consists of calcareous pebbly sandstone and dark gray glauconitic tuffaceous mudstone. The Keasey is correlated, in part, with the lower part of the "siltstone of Alsea" and the upper part of the Nestucca Formation (Snavely and others, 1969).

Interfingering with the Cowlitz and Keasey Formations in the northern Coast Range are a series of basalt flows, pillow basalts, flow breccias, and interbedded sedimentary rocks referred to as the

Goble Volcanics (Lowry and Baldwin, 1952). These rocks range in age from late Eocene to early Oligocene (Figure 2).

The middle Oligocene Pittsburg Bluff Formation conformably overlies the Keasey Formation on the eastern side of the northern Coast Range. The Pittsburg Bluff consists of thick-bedded laminated beds of arkosic and glauconitic sandstone and siltstone in the basal part of the unit. The upper part of the unit is composed predominantly of tuffaceous sandy siltstone and mudstone with local coal beds and cross-bedded, coarse-grained sandstone. Minor basaltic conglomerates also occur in the upper part of the formation. The Pittsburg Bluff is approximately 850 feet thick. In the central Coast Range rocks correlative with the Pittsburg Bluff Formation are the "siltstones of the Alsea" (Snavely and others, 1969). The Cowlitz, Keasey, and Pittsburg Bluff Formations have not been recognized on the west side of the northern Coast Range, but correlative units have been mapped as undifferentiated sedimentary rocks (Warren and others, 1945; Wells and Peck, 1961; Schlicker and others, 1972).

A maximum of 1500 feet of late Oligocene Scappoose Formation conformably(?) overlies the Pittsburg Bluff Formation. The Scappoose is composed of thick-bedded, yellowish to buff colored, micaceous and tuffaceous mudstone. Cross-bedded sandstones, commonly containing carbonized wood and leaf imprints and scattered pebbles of quartzite and basalt, are also common in the unit. Van Atta (1971) considers the Scappoose to be deltaic in origin. The Scappoose is correlative to the Yaquina Formation and, in part, equivalent to the Nye Mudstone in the central Coast Range.

Unconformably overlying the Nye Mudstone and older units along the Oregon and Washington coasts is the middle Miocene Astoria Formation. The Astoria consists predominantly of well- to moderately-sorted, arkosic, shallow marine sandstones and siltstones occurring in a series of embayments along the Oregon coast (Snavely and Wagner, 1963).

Two middle Miocene basaltic units, the Depoe Bay Basalt and the younger Cape Foulweather Basalt, locally intrude and unconformably overlie older strata in a belt along the present Oregon coast (Snavely and others, 1973). These units are composed of dikes and sills and as thick sequences of pillow basalts, pillow breccias, and fragmental water-laid tuff forming many of the headlands and highlands along the coast. The presence of yellowish plagioclase phenocrysts in the Cape Foulweather Basalt distinguishes it from the Depoe Bay Basalt.

Along the Columbia River in the eastern part of the northern Coast Range of Oregon, Columbia River Basalt flows lie unconformably upon the Scappoose, Pittsburg Bluff, Keasey, and Cowlitz Formations and on Goble and Tillamook Volcanics (Warren and

Norbisrath, 1946; Niem and others, 1973). The Columbia River Basalts are chemically and petrologically similar to and of the same age as Depoe Bay and Cape Foulweather Basalts (Snavely and others, 1973).

DESCRIPTIVE GEOLOGY OF THE THESIS AREA

The oldest rocks exposed in the thesis area belong to a late Oligocene to early Miocene unit informally referred to in this paper as the Oswald West mudstones. Unconformably overlying this unit is a middle Miocene sandstone unit correlative to part of the Astoria Formation. This sandstone unit is considered to be a member of the Astoria and is informally referred to in this report as the Angora Peak sandstone member of the Astoria Formation. Middle Miocene Depoe Bay Basalts, divided into extrusive and intrusive units, unconformably overlie the Angora Peak sandstones. Intrusive Depoe Bay Basalts consist of dikes, sills, and other irregular shaped bodies which locally intrude older strata, and extrusive basalts which are composed of palagonitic pillow breccias and minor pillow lavas and basalt flows. Quaternary sediments unconformably overlie these older rocks and are divided into two units for mapping purposes: one unit includes beach and dune sands, and the other includes alluvium, tidal flat muds, and estuarine sediments.

Oswald West Mudstones

The seacliffs in the cove at Short Sand Beach in Oswald West State Park are composed of a well-exposed sequence of silty mudstones and tuffaceous siltstones over 1600 feet thick that are informally referred to in this paper as the "Oswald West mudstones." Warren and others (1945) referred to this unit as the "beds of Blakely age" and noted that it represented conditions of sedimentation that were unique for strata of this age in northwest Oregon.

Oswald West mudstones weather readily and characteristically form topographic lows covered with colluvium. The unit occurs in low-lying areas in the vicinity of Short Sand Beach and north from there in the vicinity of Cove Beach, in an area west of U. S. Highway 101 (Plate I). An arcuate outcrop belt of these mudstones extends from the town of Neahkahnie Beach on the coast, northeastward along the North Fork of the Nehalem River (Plate I).

Lithologies and Structures

The dominant lithologies of this unit are interbedded mudstones and less abundant tuffaceous siltstones. Roadcut and streambank exposures consist of weathered, iron-stained, crumbly silty mudstone. Thick, continuous exposures of Oswald West mudstones occur at the proposed type section in the seacliffs along Short Sand Beach in Oswald West State Park (see measured and described section A-B, Appendix I). At this locality the unit is composed of well-bedded, extensively burrowed, silty mudstone and tuffaceous siltstone (Figure 3). Graded sandstones, sandstone dikes, convoluted bedding, and apparent submarine slump deposits are also exposed in the unit.

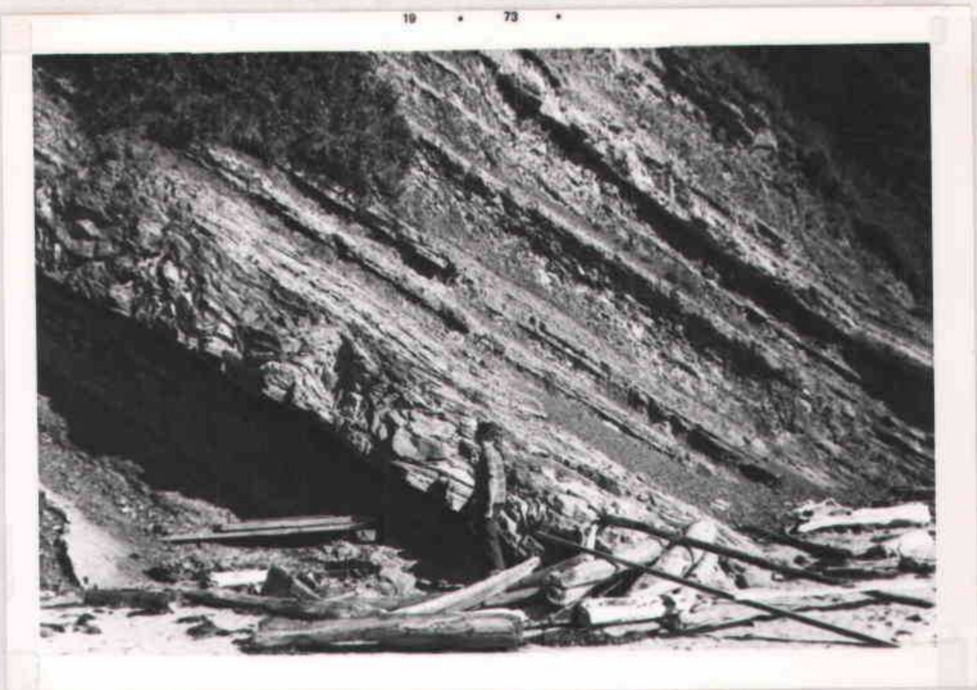

Figure 3. Well-bedded siltstones (resistant ribs) and mudstones of the Oswald West mudstones. Note convoluted sandstone bed in center of photograph. North end of Short Sand Beach, Oswald West State Park (NE 1/4 of section 12, T. 3 N., R. 11 W.).

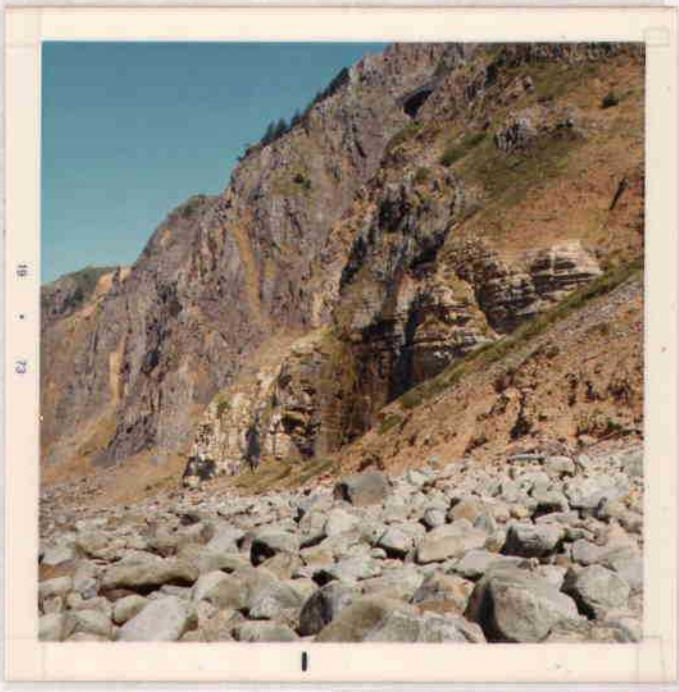

Figure 4. Well-bedded tuffaceous siltstones of the upper part of the Oswald West mudstones. Neahkahnie sill lies discordantly above the siltstones. In seacliffs south of Neahkahnie Mountain (SW 1/4 SE 1/4 of section 18, T. 3 N., R. 10 W.).

Tuffaceous siltstone beds are most abundant in the lower 500 feet of the strata exposed at Short Sand Beach. The middle part of the unit is predominantly mudstone with a few interbeds of siltstone and sandstone. The upper 300 feet of the unit, exposed in the sea-cliffs at the south end of Short Sand Beach, consist of interbedded tuffaceous siltstone and silty mudstone (Figure 8). A 50-foot thick sequence of bedded tuffaceous siltstones (Figure 4) which occurs beneath the Neahkahnie sill along the coast one mile north of Neahkahnie Beach (section 18, T. 3 N., R. 10 W.), may be correlative to the siltstone-rich upper part of the Oswald West mudstones exposed in the seacliffs at the south end of Short Sand Beach. This unit beneath the sill is much lighter in color than other exposures of Oswald West mudstones, typically having a yellow gray color (5Y 7/2). These siltstones contain abundant burrow structures, the most notable being Lophoctenium, which is one of the better recognized deep-water burrow forms (Chamberlain, written communication, 1972).

The Oswald West mudstones consist of thick- to very thick-bedded mudstones, ranging in thickness from two to 24 feet, inter-bedded with thin-bedded siltstones which range in thickness from six inches to two feet. Sandstone beds in the unit are thick-bedded, ranging in thickness from two to ten feet.

Mudstones range in color from medium gray (N5) to medium light gray (N6) whereas siltstones are medium light gray (N6) in seacliff exposures. Both lithologies are slightly darker on a freshly broken surface. The tuffaceous siltstones contain very fine carbonaceous laminations and rare micro-trough cross-laminations. Well-indurated siltstones are more resistant to erosion than the fractured mudstones and form ribs in the seacliff exposures. The siltstones, particularly in the lower part of the formation at the north end of Short Sand Beach, are extensively burrowed. Burrows are composed of darker fecal pellets and pelitic material in the light colored siltstones (Figures 6 and 7). Burrows vary in shape from small spiral-shaped burrows cutting through the bedding to elongate tubes 1/2-inch in diameter to intricate meandering patterns on bedding surfaces (Figure 6). Scalarituba, Planolites, Chondrites, and Zoophycos are the most commonly occurring trace fossils (Chamberlain, written communication, 1972).

The thicker mudstone beds appear massive or mottled as the result of burrowing which has obliterated the original bedding. Calcareous concretions up to six inches in diameter are common in some mudstone units. Molluscan fossils, preserved as molds or casts or as original material, occur in the Oswald West mudstones, and foraminifera are common in some mudstone beds. Contacts between mudstone and siltstone units are gradational over an interval of less than one inch.

Several "graywacke" sandstone beds are present in the Oswald

Figure 5. Submarine slump deposit in the Oswald West mudstones. Note poorly sorted nature and chaotic appearance of sediment. Arrows point out thinning of overlying sandstone bed over large clasts in top of slump. Clastic dike may be observed in upper left-hand corner (arrow). Short Sand Beach, Oswald West State Park.

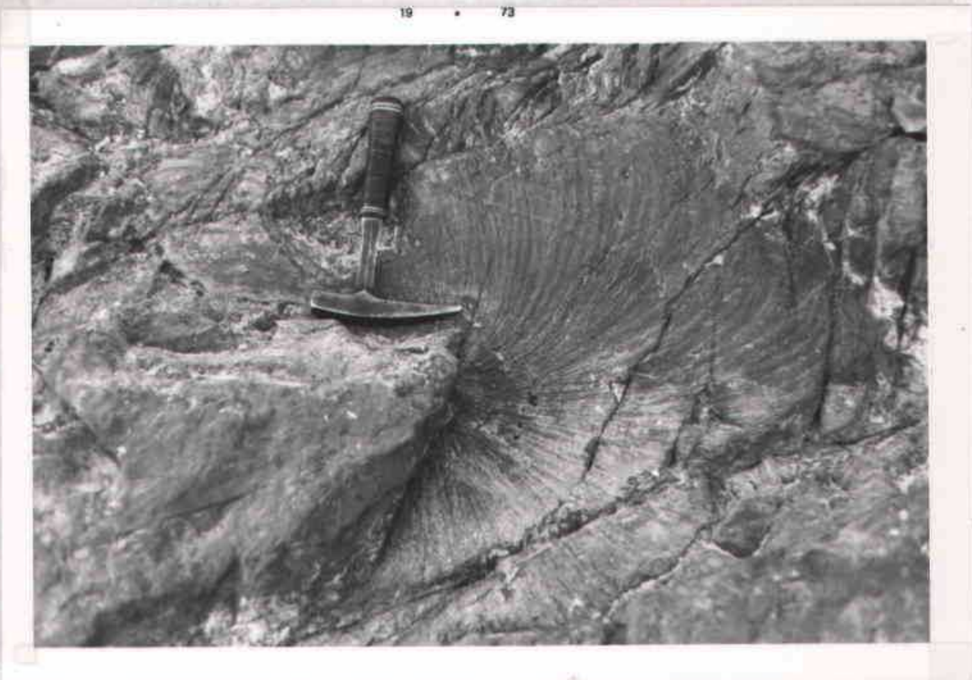

Figure 6. Burrowing pattern of <u>Zoophycos</u> on bedding plane in the Oswald West mudstones. Located near waterfall at north end of Short Sand Beach, Oswald West State Park.

West mudstones. The well-indurated sandstones are calcareous and form resistant ribs or ledges in the mudstone and siltstones (Figure 5). They range in thickness from a few inches to nine feet and typically are graded, from coarse- to medium-grained sandstone at the bases to medium- to fine-grained sandstone at the top of the beds. Basal sandstone contacts are sharp and slightly undulatory. The top contacts are gradational into the overlying siltstones and mudstones. The upper parts of the sandstone beds display tubular burrows and burrow mottling whereas the lower parts of the sandstones appear massive. Parallel laminations, cross-laminations, and convolute laminations typical of the a, b, and c divisions of the Bouma (1962) turbidite sequence are found in some of these sandstone beds (Figures 3 and 5). These matrix-rich sandstones are poorly sorted and dirty, having an olive gray (5Y 4/1) color and weathering to lighter or darker shades of this color. The sandstones are feldspathic and lithic wackes, and commonly contain abundant small mud rip-ups less than one inch long. Deep-water marine foraminifera, graded bedding, ripped-up mud clasts, the poorly sorted appearance, convolute and parallel laminations, and sharp bottom contacts, suggest these sandstones were deposited by turbidity currents.

Two pebbly mudstone units, interpreted as submarine slump deposits, were also observed in the Oswald West mudstones. The two units range from 13 to 50 feet thick, and are separated by 20 feet of well bedded siltstone and mudstone. These units are composed of a poorly sorted mixture of pebble- to boulder-sized clasts of mudstone, siltstone, and minor sandstone suspended in a silty mudstone matrix. Clast sizes range from one inch to ten feet in diameter. Basal contacts of both conglomeratic mudstone units, although obscured, appear gradational over one foot with the underlying bedded mudstones and siltstones. The upper contacts are gradational or very irregular (Figure 5) as where one slump is overlain by a two foot thick sandstone bed. Large clasts near the top of this slump deposit protrude almost entirely through the overlying sandstone which deposited around the clast.

Sandstone dikes are associated with the interval in which the submarine slump deposits occur. The dikes cut both the slump deposits and the intervening strata and can be traced over 100 feet. They range from one to seven inches thick and can be observed, locally, to bifurcate into two dikes. The clastic dikes are composed of fine-grained, feldspathic sandstone which appears identical in hand specimen to the feldspathic sandstones in the unit from which it may have originated.

Contact Relations

The base of the Oswald West mudstones is not observable in the thesis area. In the seacliffs at Cape Falcon the bedded mudstones and siltstones are overlain by the Neahkahnie sill, which intrudes the unit

Figure 7. Highly burrowed tuffaceous silty mudstone from the Oswald West mudstones. Such a pattern is typical of Scalarituba (fecal ribbon form) (Chamberlain, written communication, 1972).

(Figure 17). Measured from this contact with the Neahkahnie sill, Oswald West mudstones extend stratigraphically upward 1600 feet to the base of the Angora Peak sandstone member of the Astoria Formation.

An angular unconformity occurs between the Oswald West mudstones and the overlying Angora Peak sandstones. This relationship is not readily observed in exposures in the thesis area, but unconformity is suggested by four lines of evidence.

1) Regional observations along the Oregon coast indicate that the middle Miocene Astoria Formation lies unconformably on older rocks, as in the Newport area, where the unit can be observed overlapping both the Nye Mudstone and the Yaquina Formation (Snavely and others, 1969). At Cape Kiwanda the Astoria Formation lies unconformably upon Eocene mudstones (Snavely and Vokes, 1948). Snavely and Wagner (1963) noted that in the early part of the middle Miocene "the older Tertiary strata were folded and faulted . . . . and erosion of the land areas elevated by this period of deformation furnished the coarse clastics that characterize much of the sedimentary rocks of middle Miocene age."

2) The contact between Oswald West mudstones and Angora Peak sandsones is well exposed and accessible in Neahkahnie Creek in the NW 1/4 of section 21. The contact between the two units is sharp and abrupt. Attitudes differ by as much as 50 degrees in strike above and below the contact suggesting an unconformity. However, slumping of the mudstone could also explain the differences in strike if this were the only evidence in favor of an unconformity.

In the seacliffs south of Short Sand Beach in the SW 1/4 of section

Figure 8. Contact (arrow) between well-bedded Oswald West mudstones (bottom) and Angora Peak sandstones (top) in seacliffs south of Short Sand Beach (SW 1/4 SW 1/4 section 7, T. 3 N., R. 10 W.).

7 the contact between Oswald West mudstones and Angora Peak sandstones is well exposed but unfortunately inaccessible (Figure 8).

3) In the measured section along Short Sand Beach, foraminifera and trace fossil samples indicate that the Oswald West mudstones were deposited in water of upper bathyal depths (1000 to 2000 feet) (Rau, written communication, 1972; Chamberlain, written communication, 1972). In Short Sand Creek in the SW 1/4 of section 5 (T. 3 N., R. 10 W.), shallow marine or fluvial Angora Peak sandstones overlie deep-water mudstones from which foraminifera were collected approximately 50 feet below the contact. These fossils indicated an upper bathyal water depth and a Saucesian or early Miocene age (Rau, written communication, 1972). This rapid shallowing of the depositional environment is indicative of rapid uplift sometime during or immediately after the early Miocene.

4) Lastly, an unconformity is suggested by the ages of megafossils collected from both units. The Oswald West mudstones have yielded only Blakely (late Oligocene) age megafossils (Table 1) whereas the Angora Peak sandstones have yielded only Temblor (middle Miocene) age fossils. Fossils indicative of a Vaqueros (early Miocene) age were not found in either unit. Admittedly, the absence of Vaqueros fossils could be a result of sampling, but together with the data previously presented, it seems valid to hypothesize an unconformity representing a period of uplift and erosion that existed from the erly Miocene to middle Miocene.

Table 1. Paleoecology of fossils reported from the Oswald West mudstones.

Fossil	Probable environment as indicated by modern genera
Pelecypoda	
Acila	30 to 4,200 ft.
Lima	intertidal to 210 ft., free-swimming
Macoma(?)	intertidal to 1,800 ft., in mud or sand
Nuculana	18 to 12,000 ft.
Solen(?)	intertidal to 240 ft. sand
Volsella	intertidal to 240 ft., attached to rocks or in sand
Yoldia	intertidal to 6,000 ft.
Gastropoda	
Echinophoria	?
Priscofusus	?
Scaphopoda	
Dentalium	30 to 3,900 ft., shallowly buried on sea floor
Foraminifera	
Anonalina	?
Bolivina	200 to 700 ft., sandy bottoms
Buccella	?
Buliminella	?
Cassidulina	shallow to moderate depths (1500 ft. Baja Calif.)
Dentalina	?
Elphidium	inner shelf
Eponides	100 to 400 ft. (Calif.)
Globigerina	planktonic, typically offshore, open marine
Gyroidina	greater than 600 ft., variable bottom
Nonion	0 to 900 ft., brackish to marine
Pseudoglandulina	greater than 450 ft.
Robulus	120 to 1,100 ft.
Uvigerina	200 to 8,000 ft.
Uvigerinella	?
Ichnofossils (burrows)	
Chondrites	?
Helminthopsis	?
Lophoctenium	deep-water, bathyal
Planolites	?
Scalarituba	intermediate depths (1,500 to 2,000 ft. (?))
Taenidium	deep-water
Teichichnus	shallow- to deep-water
Zoophycos	deep-water (bathyal to abyssal)

Faunal sources:
- Warren and others (1945)
- Addicott (written communication, 1973)
- Chamberlain (written communication, 1972)
- Rau (written communication, 1972)

Ecological sources:
- Chamberlain (written communication, 1972)
- Keen (1963)
- Phleger (1960)
- Rau (written communication, 1972)
- Stanley (1970)

Age and Correlation

A late Oligocene to early Miocene age is assigned to the Oswald West mudstones based upon microfaunal and megafaunal evidence and stratigraphic considerations.

Diller collected molluscan fossils from rocks at Short Beach (Short Sand Beach) in 1896 and assigned the strata an Oligocene age. In 1914 Washburne correlated these rocks with the "Astoria shales," agreeing with Diller's determination of the age. Warren and others (1945) collected Blakely age molluscan fossils (late Oligocene - early Miocene) from the same area and noted that the Echinophoria rex and Echinophoria apta megafossil zones of Durham (1944) occurred there.

Additional megafossils, collected at Short Sand Beach by the writer and identified by Warren Addicott (U. S. Geological Survey) confirm a Blakely age for the Oswald West mudstones. Furthermore, foraminifera collected at the same locality indicates a Zemorrian (late Oligocene) age (Rau, written communication, 1972). Saucesian (early Miocene) age foraminifera were also identified by Weldon Rau from the uppermost part of the Oswald West mudstones in the vicinity of Short Sand Creek in section 5 (T. 3 N., R. 10 W.).

Since the lower contact of the Oswald West mudstones is not defined in the thesis area, the late Oligocene to early Miocene age of the unit is only a minimum age. In the field Oswald West mudstones appear identical to rocks exposed outside the thesis area on the east side of the North Fork of the Nehalem River. These other rocks were mapped by Peck and Wells (1961) as undifferentiated late Eocene and Oligocene sedimentary rocks. It is therefore conceivable that the Oswald West mudstones may be older than late Oligocene outside the thesis area. In recent mapping of the northwest coastal area of Oregon, Schlicker and others (1972) include all the sedimentary rocks between the Astoria Formation (Angora Peak sandstone) and the Eocene volcanics as undifferentiated "Oligocene to Miocene sedimentary rocks." This unit would include the Oswald West mudstones.

It is thought that even though the basal contact of the Oswald West mudstone is not visible in the thesis area, this unit is a viable mappable unit with a well-exposed type section that can be studied for future reference. It is a first attempt to define the coastal stratigraphy of this part of the Oregon coast and it is suggested that in the future the Oswald West mudstones be assigned formational status.

Strata considered coeval with the Oswald West mudstones are the Scappoose Formation, located 40 miles to the east, and the Yaquina Formation and the Nye Mudstone, both located in the Newport area.

Depositional Environment

The sequence of lithologies, sedimentary structures, and fossils suggest that the strata represented by the Oswald West mudstones were deposited in a deep-water, normal marine environment, possibly in a pro-delta or delta-slope environment seaward of the delta that deposited the coeval Scappoose Formation.

The predominance of silty mudstone and siltstone in the unit suggests quiet water deposition sporadically interrupted by an influx of turbidite sands. Structures such as convoluted bedding, flame structures, clastic dikes, and other load structures; submarine slump deposits; and deep-water sandstones suggest rapid deposition of the Oswald West sediments.

Evidence of minor bottom-current reworking is suggested by micro-cross-laminations in some siltstone beds. The magnitude of the currents probably was not great as indicated by the rarity of these structures and the fine size of the material. The current activity was also not continuous for any length of time because of the many undisturbed burrow structures found on bedding surfaces.

The variety of burrow types and the abundance of many deep-water mollusks and benthonic foraminifera suggest a diverse benthonic fauna and open marine conditions. Within the sediments, somewhat restricted environment is thought to have existed in that the sediments contain an abundance of organic matter and minor authigenic pyrite.

Water depths and environments of modern molluscan and foraminifera genera whose counterparts were collected from the unit are shown in Table 1. Molluscan faunas show a wide depth range and are not too useful, but benthonic foraminifera genera, notably Gyroidina and Cassidulina, suggest moderate to deep water. Weldon Rau (written communication) considers the foraminiferal assemblages collected here to be indicative of cold water in upper bathyal depths (1000 to 2000 feet). C. K. Chamberlain (written communication) considers the ichnofossils (burrows), notably Zoophycos, Taenidium, and Lophoctenium, also to be indicative of an upper bathyal depth.

The alternating siltstone and mudstone lithologies, deep water environment, high sedimentation rate, sedimentary structures, slump structures, turbidite sandstones, diverse fauna, and the highly burrowed nature of the sediments are similar to sediments deposited in a pro-delta environment as envisioned by Visher (1965), Gould (1970), and Selley (1970). Shallow marine and fluvial sandstones and siltstones of the coeval Scappoose Formation have been interpreted to be deltaic in origin by Van Atta (1971). The Oswald West mudstones may represent the deeper water pro-delta environment of that delta. An alternative model is a marginal deep-water basin adjacent to the Oregon coast. Minor micro-cross-laminations in the unit indicates a northeasterly source. Flame structures and convolute bedding indicate a paleoslope to the southwest. Both are in accord with the proposed models.

Astoria Formation

The Astoria Formation crops out in western Oregon in a series of marine embayments from the type area at Astoria south to Newport (Wells and Peck, 1961). Some middle Miocene rocks in western Washington have also been mapped as Astoria Formation by Pease and Hoover (1957) and by Snavely and others (1958). However, confusion about the Astoria Formation has arisen among Northwest geologists since the rocks were first described in 1880. The following review of the general history of the name "Astoria" presents the stratigraphic and nomenclative problems of this unit. In addition, excellent summaries of the geologic investigations of the Astoria Formation have been published by Moore (1963) and Dodds (1969).

Rocks mapped as Astoria Formation have been known since 1848. In that year Conrad identified fossils from the beds at Astoria in one of the first papers published on the Pacific Coast Tertiary. The following year Conrad assigned a Miocene age to fossils collected by Dana in 1849. However, it was not until 1880 that these rocks were described in print by Cope (from unpublished notes of Condon) who referred to them as the "Astoria shales." Dall and Harris (1892) referred to a series of sandstones on both sides of the Columbia River overlying the "shales" as the "Astoria sandstones" and included them, together with the "Astoria shales," in the "Astoria group." These terms have since been abandoned by the U. S. Geological Survey (Keroher and others, 1966).

Howe (1926) divided the Astoria Formation in the city of Astoria, the type area, into three members: a lower sandstone approximately 150 feet thick which is overlain by a middle "shale" member approximately 1000 feet thick, overlain in turn by an upper sandstone. Although Howe described three members of the Astoria Formation, he did not specify a type section or stratigraphic limits of the unit with other formations. The original exposures along the Columbia River from which Dana collected fossils in 1849, and the exposures described by Howe, have been covered by urban growth of the town of Astoria and are no longer available for study.

Lowry and Baldwin (1952) and Baldwin (1964) have indicated that the upper sandstone member of Howe interfingers with middle Miocene basaltic breccias east of the town of Astoria. Based on geological mapping and microfaunal evidence, Dodds (1969) suggested that the upper sandstone member of Howe lies unconformably over the middle "shale" unit in the vicinity of Svensen, ten miles east of the city of Astoria.

The age of the Astoria Formation is now considered to be middle Miocene based on foraminiferal and molluscan faunas (Moore, 1963). Some earlier workers had assigned all or part of the Astoria Formation to the Oligocene or even to the Eocene. This occurred because the unit was defined before ages of Pacific Coast index fossils had become clearly established.

Since 1926 when Howe described the type area of the Astoria Formation, the unit has been extended north into western Washington (Pease and Hoover, 1957; Snavely and others, 1958; Wolfe and McKee, 1968, 1972) and south into the Newport area (Volkes and others, 1949; Snavely and Volkes, 1949; Snavely and others, 1969). Durham (1953) has referred to strata as far south as Cape Blanco, in southern Oregon, as the "Astoria formation."

However, correlation of the Astoria Formation into these other areas has not been accomplished by rock-stratigraphic procedures as defined by the Code of Stratigraphic Nomenclature (1961) but by time-stratigraphic procedures. Thus, the rock-stratigraphic definition of the unit varies in different areas in Oregon and Washington because correlation with the type area has been determined on a faunal basis, not on a lithologic or cartographic basis (Moore, 1963). The term "Astoria Formation," in addition to its use as a formational name, has, in effect become a time-stratigraphic unit referring to strata deposited during middle Miocene time in western Oregon and southwestern Washington. This use has avoided the clutter of many formational names in the literature, but at the same time it has confused rock-stratigraphic terminology with paleontologic zonation (Moore, 1963).

Attempts have been made to restrict the usage of the term "Astoria," but a restriction would only further confuse the problem as the term is already so ingrained in the literature. As of 1963 there had been over 75 papers published that dealt in some way with the "Astoria formation" (Moore, 1963). Mapping of the Astoria on the basis of lithology only is difficult because of poor exposures and the fact that the formation exhibits rapid facies changes from shallow marine sandstones to deep marine sandstones, siltstones, and mudstones in the northwest coastal area (Niem, personal communication, 1972-73) and in the Newport area (Snavely and MacLeod, personal communication, 1973).

Perhaps the best alternative is to retain the name, Astoria Formation, for middle Miocene sandstones and mudstones thusly mapped, but to refer to those rocks of obvious differing lithologies in various embayments as members of the Astoria.

Angora Peak Sandstone Member

The name, Angora Peak sandstone member of the Astoria Formation, is herein informally proposed for a thick sequence of sandstones and minor conglomerates that occur in the thesis area. In the coastal area between Nehalem and Cannon Beach, strata mapped as Astoria Formation are dominantly thick-bedded, thinly laminated to cross-bedded, buff, arkosic sandstones that are locally conglomeratic (Wells and Peck, 1961). Schlicker and others (1972), in remapping the northwestern coastal area of Oregon, restricted the Astoria Formation to this distinctive unit. However, because the Astoria in the type area is a mudstone, this restriction of the term confuses the situation. It is suggested, therefore, that the name, Astoria Formation, be retained, but that the name, Angora Peak sandstone member, be used for this distinctive sequence of rocks. This 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 normally are in vertical sequence, laterally equivalent parts of a formation that differ recognizably may also be considered members."

The Angora Peak sandstone member is areally the most extensive unit in the thesis area. The member underlies extrusive Depoe Bay Basalts that form the heights of Angora Peak and Rock Mountain in the central part of the area (Plate I). The Angora Peak sandstone is exposed along the coast at Arch Cape and in precipitous seacliffs at the south end of Short Sand Beach where it unconformably overlies late Oligocene to early Miocene Oswald West mudstones. Along the coast north of Neahkahnie Beach the member is covered by terrace deposits and colluvium, but is exposed in places along U. S. 101. A 100-foot thick boulder conglomerate in the member is exposed at the north end of Cape Falcon.

The type section of the Angora Peak sandstone is located southeast of Angora Peak in the east half of section 3, T. 3 N., R. 10 W. It is a partial measured section approximately 950 feet thick (Appendix II).

Lithologies and Structures

The Angora Peak sandstone consists of fine- to coarse-grained sandstone with subordinate amounts of micaceous and carbonaceous siltstone and silty mudstone, coal, and conglomeratic beds. The member forms intermediate slopes and hilly topography between low, flat-lying areas underlain by the Oswald West mudstones and steep, rugged peaks formed by the overlying Depoe Bay Basalts. Weathered sandstones are typically iron-stained pale yellowish orange (10YR 8/6) to light brown (5YR 5/6). Fresh sandstones have a greenish gray color (5GY 5/1). Sandstones are poorly-sorted to well-sorted, and are composed of subangular to subrounded (visually estimated) grains of quartz, feldspar, rock fragments, and mica. They are predominantly arkosic in composition.

Sedimentary structures associated with the coarser grained sandstones (medium- to coarse-grained) differ from those that occur in fine-grained sandstones. Large channels, scour-and-fill, conglomerate lenses, and large-scale, high-angle, trough cross-bedding are associated with the coarser grained sandstones (Figure 9). These sandstones are thin- to thick-bedded, and commonly contain pebbles, locally abundant mud rip-ups, coalized wood fragments, and minor pyrite nodules.

Fine-grained sandstones are ubiquitously very thinly laminated or cross-laminated; the laminations are defined by concentrations of carbonaceous material and mica. The cross-bedding is large-scale, planar, and at low angles to the bedding (less than 15°). These sandstones are very thick bedded, although thin- and very thin-bedded units occur locally. Climbing ripple lamination (Figure 10) and convolute lamination were infrequently observed. The fine-grained sandstones are locally truncated by channels of coarse-grained sandstone (Figure 9). Shallow marine molluscan fossils, preserved either as original material or as molds and concentrated in two- to three-inch beds, and calcareous concretions have been observed only in fine-grained sandstones and coarse siltstones. These sandstones appear compositionally the same in hand sample as the coarser sandstones, but lack any pebbles and contain abundant mica and carbonaceous material.

Beds up to 30 feet thick of tuffaceous and argillaceous siltstones

Figure 9. Fluvial channel in the Angora Peak sandstone. Yellow tacks delineate the base of the channel, 3 1/2-foot scale parallels bedding of the lower fine-grained sandstone. Note large-scale cross-bedding in coarse-grained channel sandstone to right of scale and iron-stained liesegang weathering bands below scale. Located in NE 1/4 of section 6, T. 3 N., R. 10 W.

Figure 10. Alternating beds of climbing ripple lamination (arrows) and parallel lamination in fine-grained Angora Peak sandstone. Unit is exposed in seacliff 1/4-mile south of Short Sand Beach, Oswald West State Park (SW 1/4 SW 1/4 of section 7, T. 3 N., R. 10 W.). Brunton compass for scale.

and silty mudstones are common between sandstone units in the lower and upper parts of the Angora Peak sandstone. Siltstones and mudstones are medium gray (N5) to medium light gray (N6) but greenish hues also occur. The tuffaceous units are grayish yellow (5Y 8/4) in color. These fine-grained strata are carbonaceous, micaceous, and very thinly-laminated. Thin subbituminous to bituminous coal beds are associated with carbonaceous silty mudstones (Figure 11). For example, in section 36, T. 4 N., R. 10 W. a two-foot thick subbituminous coal bed is interbedded with carbonaceous mudstones.

In the upper 200 feet of the Angora Peak sandstones dark gray (N3) silty mudstones are interbedded with very thin- to thin-bedded sandstones (1/4"-1 1/2 feet). Convolute bedding, load structures, large mud rip-ups, and micro-cross-laminations occur in this unit. Sandstones are fine-grained and are commonly platy.

Two types of conglomeratic units were recognized in the Angora Peak sandstone: 1) thin-bedded, pebbly sandstones and pebble conglomerates which are associated with channels and cross-bedding, and 2) very thick-bedded, graded conglomerates.

Thin-bedded, pebbly conglomerates and pebbly sandstones are composed of coarse sand and pebbles, with only rare cobbles. These intervals, up to 30 feet thick, are interbedded with coarse-grained, large-scale, planar, cross-bedded sandstones (Figure 12). The conglomerates occur in lens-shaped channels, and contain

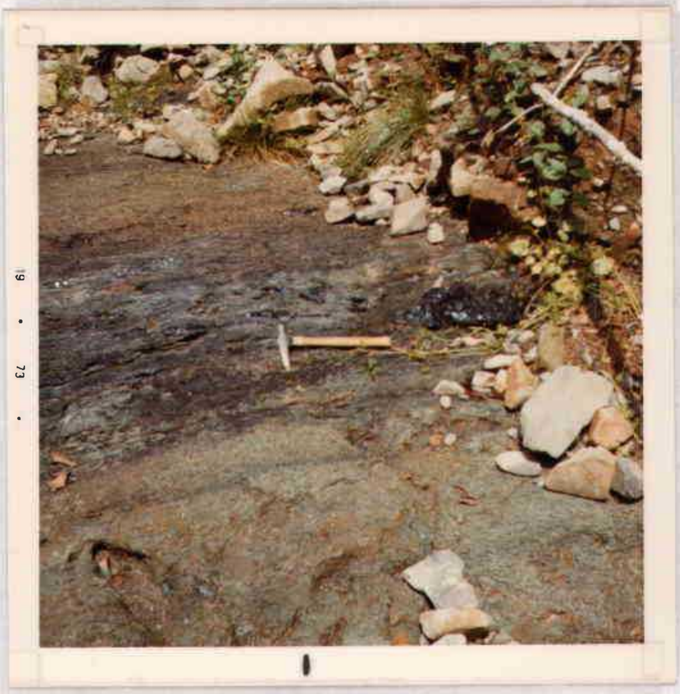

Figure 11. Coal bed in the lower part of the Angora Peak sandstone. (Includes units 12, 13, 14 of reference section C-D, SE 1/4 NE 1/4 of section 3, T. 3 N , R 10 W.).

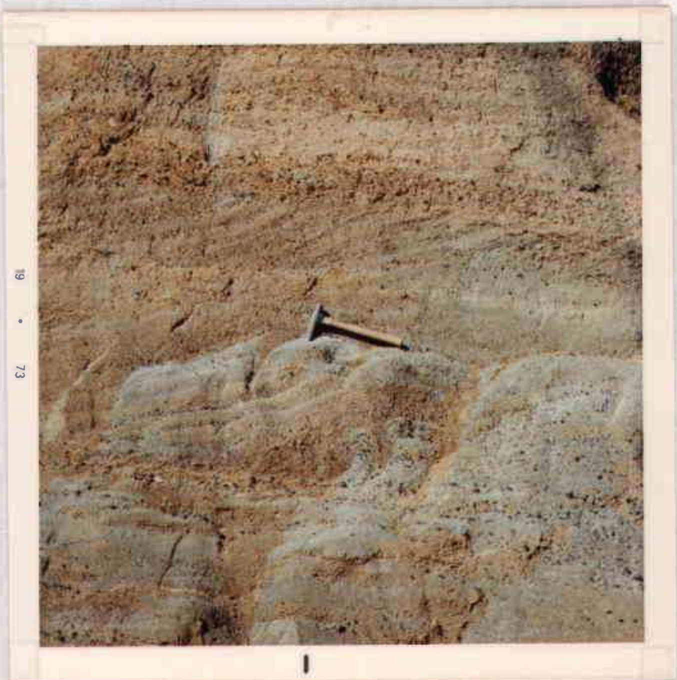

Figure 12. Cross-bedded pebbly sandstone in a fluvial sequence in the Angora Peak sandstone. Current from right to left. Located in SE 1/4 NW 1/4 of section 3, T. 3 N. , R. 10 W.

scour-and-fill structures at their bases.

Graded, basaltic conglomerates approximately 100 feet thick occur along the coast north of Cape Falcon (NE 1/4 of section 1, T. 3 N., R. 11 W.) and along the drainage of the West Fork Coal Creek (SW 1/4 of section 2, T. 3 N., R. 10 W.). The conglomerates north of Cape Falcon are well exposed in the seacliffs and consist of rounded to subrounded cobble- and boulder-sized clasts up to 11 feet in diameter (Figures 13 and 14). These conglomerates occur in 30 to 40 feet thick beds. Some of the poorly sorted conglomerates are graded. The clasts are in grain support near the base of the beds, but higher in the beds, the units grade into finer material with isolated cobbles and boulders floating in a medium- to coarse-grained sand matrix (Figure 14).

Clasts are predominantly basalt, but quartzite, andesite, schist, welded tuff, and pumice clasts were noted. The largest clasts (up to 11 feet) are composed of mudstone and fine-grained arkosic sandstone, some of which contain molds of gastropods and pelecypods. The conglomerates are tightly cemented by calcium carbonate. No sedimentary structures were observed in these conglomerates other than scour-and-fill features (relief to one foot) between the beds (Figure 14).

Although the exact stratigraphic position of the conglomerate north of Cape Falcon cannot be determined accurately as the base is

Figure 13. Graded conglomerate beds in the Angora Peak sandstone. Note local scour-and-fill at base of overlying bed (arrow). Clasts are "floating" in a sand matrix in the lower bed which grades downward (out of picture) to conglomerate resembling the upper bed. In seacliffs at north end of Cape Falcon (SE 1/4 of section 1, T. 3 N., R. 11 W.).

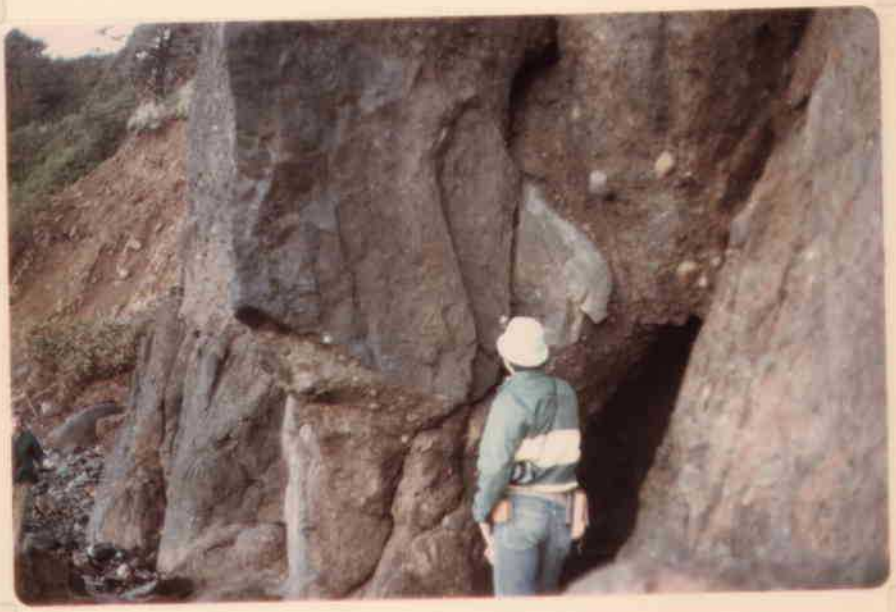

Figure 14. Large sandstone boulder in a poorly sorted conglomerate in the Angora Peak sandstone. Five hundred feet north of above location.

covered and the upper part is cut by a thick sill of Depoe Bay Basalt, it is believed to be correlative with a similar carbonate-cemented, basaltic conglomerate of a like thickness in the West Fork of Coal Creek. The conglomerate in the West Fork of Coal Creek stratigraphically lies in the lower 500 feet of the Angora Peak sandstone.

Contact Relations

The Angora Peak sandstone unconformably overlies the Oswald West mudstones and is, in turn, unconformably overlain by Depoe Bay Basalts (Plate II). Evidence for the unconformable contact with the early Miocene mudstones has been presented earlier in the section on Contact Relations of the Oswald West mudstones.

An unconformity between the Astoria Formation and Depoe Bay Basalts was noted by Snavely and others (1969, 1973) where it is well exposed in the inner harbor at Depoe Bay, some 40 miles to the south. Schlicker and others (1972) suggest that an unconformable relationship between the same units exists in northwest Oregon just north of the thesis area.

The contact between the two units is not exposed in the thesis area because it is covered by landslide debris of Depoe Bay Basalt. There is, however, structural evidence for the existence of an unconformity. Dips in the Angora Peak sandstone reach 40° and the beds are folded into a series of west-northwest-trending synclines and anticlines (Plate II, section A-A'). The overlying Depoe Bay pillow breccias are almost horizontal indicating an angular unconformity between the two units. This relationship is especially evident in the vicinity of Angora Peak where the underlying sandstones dip at 35° to 40° to the northeast beneath Depoe Bay Basalts which dip 5° to the north (Plate I).

Age and Correlation

A middle Miocene or "Temblor" age is assigned to the Angora Peak sandstone member in the thesis area on the basis of fossils collected and on stratigraphic relationships. The unit unconformably overlies late Oligocene to early Miocene Oswald West mudstones and is unconformably overlain by Depoe Bay Basalts which have been radiometrically dated at 14.5 to 16.0± 1.0 million years (Turner, 1970). These dates fall within the middle Miocene according to Turner (1970).

Megafossils collected in the sandstone by the writer and identified by Warren Addicott (USGS) are indicative of a middle Miocene (Temblor) age. *Vertipecten fucanus*, *Spisula albaria*, *Litorhadia astoriana*, *Cancellaria oregonensis*, and *Cryptonatica oregonensis* are the most characteristic fossils of the member. *Mytilus middendorffi* (Figure 15), a geographically wide-ranging species of middle Miocene age, and *Solen perrini*, which ranges from rocks of middle

Figure 15. Mytilus middendorffi (lower left) and Spisula albaria in a concretion, Angora Peak sandstone. This is only the second occurrence of Mytilus middendorffi in Oregon. (collected from roadcut, SE 1/4 NE 1/4 of section 4, T. 3 N., R. 10 W.).

to late Miocene age in California, also support this age assignment (Addicott, written communication, 1973).

A poorly preserved microfauna with a number of specimens of Bolivina cf. B. advena suggests a Miocene age (Rau, written communication, 1972) correlative with either the Astoria Formation or Nye Mudstone in the Newport area. However, on the basis of the megafossil ages the Angora Peak sandstone member is considered equivalent to the Astoria Formation at Astoria, the type area, at Ecola State Park, and south in the Tillamook and Newport embayments. Vertipecten fucanus suggests correlation with exposures of the lower part of the Astoria Formation in the Newport area and, therefore an age no younger than late Saucesian (early to middle Miocene) in terms of foraminiferal ages (Addicott, written communication, 1973).

The graded conglomerate north of Cape Falcon contains clasts of sandstone which contain molluscan fossils dated as middle Miocene (Addicott, written communication, 1973). Addicott further stated that the clasts contained Vertipecten fucanus which is indicative of the lower part of the Astoria section at Newport. That the conglomerate is intruded by middle Miocene Depoe Bay Basalts indicates a middle Miocene "Astoria" age, suggesting contemporaneous faulting and uplift during deposition of the lower part of the Angora Peak sandstone.

Depositional Environment

Sedimentary structures and lithologies, lateral and vertical facies changes, and fossils suggest that deposition of the Angora Peak sandstone occurred in a westerly prograding deltaic environment. A deltaic environment is suggested for the Angora Peak sandstone member because it contains in vertical succession interfingering marine and non-marine strata. The non-marine strata consist of pebbly, coarse-grained, cross-bedded channel sandstones and conglomerates and minor amounts of carbonaceous silty mudstones and coal deposits. The marine strata, composing over 60 percent of the section, consist of fine-grained, laminated, molluscan-bearing and glauconitic sandstones. A delta is further suggested because laterally to the north, south, and west equivalent age strata are only marine. To the north only deep-water mudstones have been reported in the type area of the Astoria Formation (Howe, 1926; Niem and others, 1973). Also, ten miles to the north at Ecola State Park the Astoria Formation consists of a deep-water turbidite facies which may be laterally correlative or overlie the Angora Peak sandstone (Niem and others, 1973). To the south at Cape Meares the equivalent Astoria Formation is composed of shallow marine sandstones. Offshore, on the continental shelf, the Astoria Formation consists of a thick fine-grained marine facies (Braislin and others, 1971).

Deposition of Angora Peak sediments took place in a variety of recognizable environments within the delta complex, ranging from shallow marine delta-front sheet sands to distributary channel sands and swamp deposits. Fine-grained Angora Peak sandstones were deposited, in part, in a shallow, normal marine environment as indicated by an abundant molluscan fauna (Appendix V). Interpretation of the paleoecology of the molluscan fossils from their modern counterparts indicates that they lived in shallow marine waters at depths greater than 90 fee (Table 2). Addicott (personal communication, 1973) considers the molluscan fauna indicative of an inner shelf environment in water depths from five to 25 fathoms (30 to 150 feet).

The majority of the fine-grained sandstones are unfossiliferous. However, because of the similarity in lithologies and sedimentary structures to the fossiliferous sandstones that are interbedded with them, the unfossiliferous sandstones are believed to have been deposited in water depths similar to or shallower than the depths indicated by the fossils. These sandstones are inferred to have been deposited as delta-front sheet sands in a wave-dominated delta system. In high energy, wave-dominated deltas the sands are well-sorted and commonly contain beds of well-sorted shell detritus (Scott and Fisher, 1969). Small amounts of glauconite are also common. Low-angle, large-scale, planar cross-stratification and parallel, horizontal laminations are the dominant sedimentary

Table 2. Probable paleoecology of fossils reported from the Angora Peak sandstone.

Fossil	Probable environment as indicated from modern genera
Mollusca	
Pelecypoda	
Acila	30 to 4, 200 ft.
Anadara	intertidal to 420 ft., in sand
Cyclocardia	60 to 6, 000 ft.
Litorhadia	?
Mytilus	intertidal, attached to rocks
Nuculana	18 to 12, 000 ft.
Panopea(?)	intertidal, buried in sand or mud
Solen	intertidal to 240 ft., in sand
Spisula	intertidal to 150 ft., in sand
Tellina	intertidal to 450 ft., in sand or mud
Vertipecten	?
Yoldia	intertidal to 6, 000 ft.
Gastropoda	
Bruclarkia	?
Cancellaria	90 to 1800 ft.
Cryptonatica	intertidal to 5, 400 ft.
Natica	intertidal to 5, 400 ft.
Ophiodermella	30 to 240 ft.
Xenuroturris	?
Foraminifera	
Bolivina	200 to 700 ft., sandy bottom.

Faunal identification:
Addicott (Written communication, 1973)
Rau (Written communication, 1972)

Modern ecological sources:
Keen (1963)
Stanley (1970)

structures. The shallow-marine, fine-grained Angora Peak sandstones contain these same sedimentary characteristics. Allen (1970) noted that the delta-front sheet sands of the modern Niger delta were deposited in depths up to 60 feet, which is comparable to the depths determined by fossils for the Angora Peak sandstone.

Coastal processes during the middle Miocene are inferred to have been similar to those today. The high wave energy would quickly have redistributed and reworked the fluvial sands forming extensive coastal barriers and an extensive delta-front sand sheet. The configuration of the ancient delta may have been similar to the modern sand-rich Rhone, Niger, or Orinoco deltas which empty into high energy marine environments and have developed extensive coastal barriers (Dott, 1966; Oomkens 1967; Scott and Fisher, 1969).

Medium- to coarse-grained, locally pebbly, fluvial sandstones are inferred to represent distributary channels within the ancient delta complex. Local scouring is common where these sandstones overlie finer grained delta-front sandstones or carbonaceous mudstones (Figure 9). In the measured section of the Angora Peak sandstone (Appendix II) two non-marine intervals containing coal beds and fluvial sandstones were recognized interfingering with three marine intervals. Within the non-marine intervals are subbituminous coals and dark carbonaceous mudstones and siltstones containing abundant plant fragments. These lithologies are indicative of inferred marsh and swamp deposits.

The middle Miocene age boulder conglomerate exposed at the north end of Cape Falcon suggests that local highs and seacliffs existed due to the contemporaneous tectonic activity. The local highs contributed large clasts of Eocene Tillamook basalts and pene-contemporaneously lithified sandstones containing middle Miocene age molluscan fossils. The occurrence of the pelecypod Mytilus (mussel) in the Angora Peak sandstone also suggests local rocky highs in the middle Miocene as this fossil needed a rocky substrate to survive (Keen, 1963).

Depoe Bay Basalt

Middle Miocene Depoe Bay Basalts were described by Snavely and others (1973) for tholeiitic basalt flows, pillow lavas and breccias and associated intrusive rocks exposed along the central and northern Oregon coast. These basalts have a similar composition, age, and petrology to the Yakima Basalts of the Columbia River Group of Waters (1961). Depoe Bay Basalts occur along the Oregon and southern Washington coasts, forming many of the resistant headlands. Topographically high areas in the thesis area are composed of resistant Depoe Bay Basalt as are the headlands at Cape Falcon and Arch Cape. The basalts were divided into two units in the study area: 1) intrusive dikes, sills, and other irregularly shaped bodies, and

2) equivalent extrusive pillow basalts, pillow breccias, and minor flows.

Intrusive Rocks

Occurrence and Distribution. Exposures of intrusive Depoe Bay Basalt occur throughout the study area wherever dikes, sills, and other bodies locally intrude the older rocks. The shapes of these intrusions are generalized and the contacts approximated as shown on the geologic map of the area (Plate I) due to heavy vegetation in the area. The most prominent body is a sill-like intrusion over 1200 feet thick referred to as the Neahkahnie sill which composes the bulk of Neahkahnie Mountain (Figure 4) and the headland at Cape Falcon (Figure 17). Other large intrusive bodies include a dike forming Arch Cape, Round Mountain, a small plug, and a plug north of the West Fork Coal Creek in section 3, T. 3 N., R. 10 W) (Plate 1). A thin but areally extensive sill occurs south of Angora Peak where it intrudes Angora Peak sandstones. Large dikes also occur along two faults 1/4-mile north and east of Rock Mountain.

These basalts intrude both Oswald West mudstones and Angora Peak sandstones. Locally these dikes were feeders for the overlying extrusive basalts (Figure 18).

The Neahkahnie sill occurs in the central part of the thesis area along the coast at Oswald West State Park and is thought to lie

Figure 16. Extrusive pillow breccias and pillow lavas of Depoe Bay Basalt forming Angora Peak on sky line. Unit overlies Angora Peak sandstone member of the Astoria Formation in foreground.

Figure 17. Neahkahnie sill intruding well-bedded Oswald West mudstones at Cape Falcon. Contact is locally discordant; small headland in background is Arch Cape, a large dike of Depoe Bay Basalt. Photograph courtesy of P. D. Snavely, Jr., U. S. Geological Survey.

under much of the western part of the area (Plate II). It is called a sill-like body in that it is essentially flat-lying or dipping gently to the northeast or to the south, and is commonly concordant with the adjacent strata. At other places it intrudes the rocks in a discordant manner, commonly cutting the strata at a low angle to the bedding (Figure 18). Schlicker and others (1972) refer to this intrusive body as a plug composing only Neahkahnie Mountain, but more detailed mapping has shown it to be a tabular, flat-lying sill including both Neahkahnie Mountain and Cape Falcon as previously stated by Snavely and others (1973).

Lithologic Character. The intrusive rocks are aphanitic to fine-grained basalts except in the interior of the Neahkahnie sill where these rocks grade into medium- to coarse-grained diabases which compose the central few hundred feet of the sill. Fresh basalt ranges from a dark gray (N3) to a medium gray (N5) color, weathering to an iron-stained dark yellowish orange color (10 YR 6/6). Columnar jointing in the basaltic dikes and sills is common where these intrusive bodies are well exposed in quarries as in the plug in section 3, T. 3 N., R. 10 W. The basalt is highly fractured and brecciated at the borders of the intrusive bodies between the columnar jointing and the sedimentary strata. The brecciation also occurs near the contact of the Angora Peak sandstone and extrusive Depoe Bay basalts where dikes begin to bifurcate and splay outward into fan-shaped bodies, incorporating large blocks of sediment. The brecciation and extensive bifurcation of the dikes suggest the basalt was intruded at very shallow depths into semi-consolidated wet sediments which resulted in extensive steam blasting and quenching of the hot magma. Some of these brecciated dikes can be traced over a few hundred feet through Angora Peak sandstones into the overlying submarine pillow breccias indicating feeders for the overlying extrusive basalts.

Other than columnar jointing, no obvious structures were observed within any of the intrusive bodies. However, at the end of Cape Falcon, wave action has removed the less resistant Oswald West mudstones overlying the top of the Neahkahnie sill, exposing several hundred yards of the sill's surface. Flow structures, referred to here as "pseudo-pahoehoe" structures, were observed in small areas on the sill's surface (Figure 19). These structures, resembling pahoehoe or ropy lava flow structures, are thought to have formed in gas pockets trapped beneath sediments in contact with the sill's upper surface (Snavely and MacLeod, personal communication, 1972). The same structures have also been observed by Snavely and MacLeod on surfaces of sills in the Eocene Siletz River Volcanics.

Petrology. Intrusive Depoe Bay Basalts are equigranular, and depending on their degree of crystallinity, have intersertal, intergranular, or subophitic textures. These basalts are composed of

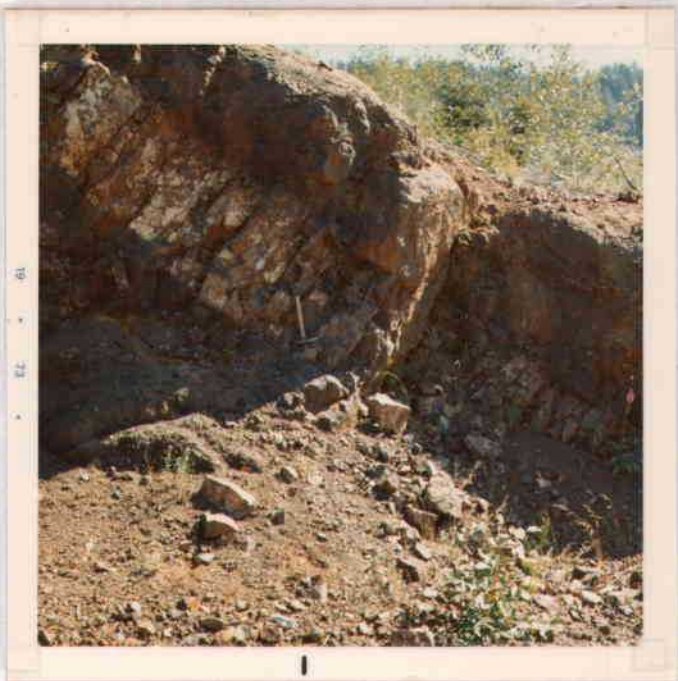

Figure 18. Small dike of Depoe Bay Basalt intruding pillow breccias of extrusive Depoe Bay Basalt. Southwest of Rock Mountain (NW 1/4 of section 17, T. 3 N., R. 10 W.).

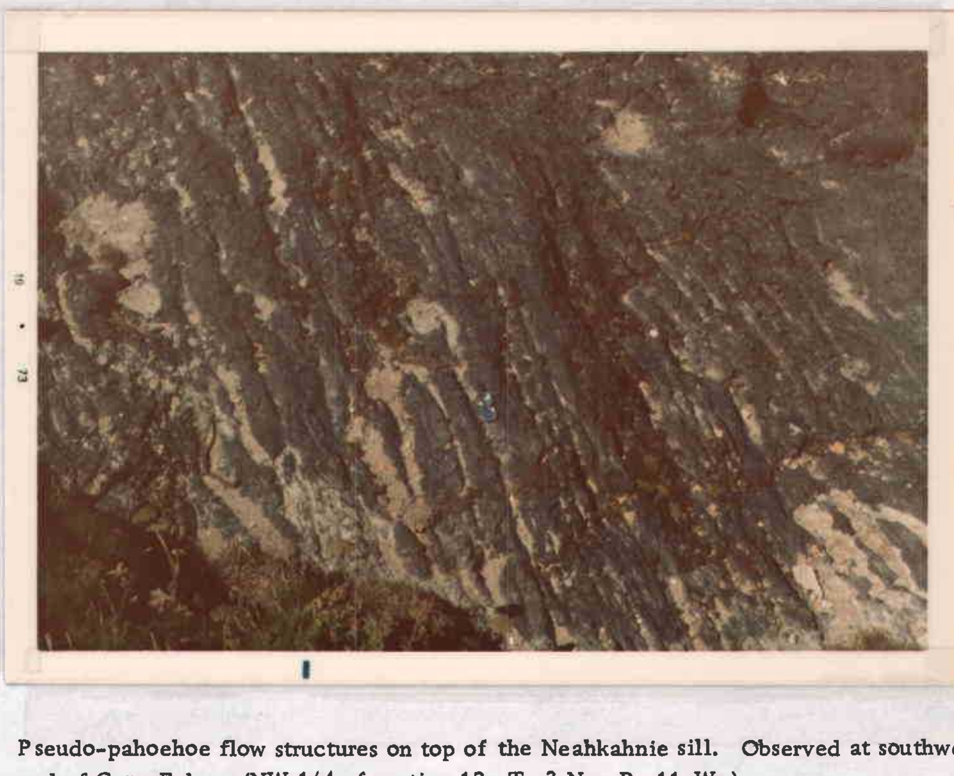

Figure 19. Pseudo-pahoehoe flow structures on top of the Neahkahnie sill. Observed at southwest end of Cape Falcon (NW 1/4 of section 12, T. 3 N., R. 11 W.).

plagioclase, clinopyroxene, and opaque minerals plus glass or its alteration products and mineraloids. Minor amounts of apatite and olivine also occur.

Modal analysis of a typical well-crystallized, medium-grained diabase from the interior of the Neahkahnie sill shows the following minearlogy:

Plagioclase	56%
Clinopyroxene	21%
Opaques (magnetite and ilmenite)	4%
Apatite	Tr.
Chlorophaeite	6%
Hornblende	4%
Biotite	Tr.
Silicic residual	7%
Chlorite	Tr.

Plagioclase ranges from calcic andesine to sodic labradorite (An_{45} to An_{55}) using the Michel-Levy method, and occurs in subhedral laths ranging from one to three millimeters in length. Subhedral pyroxene consists of augite to subcalcic augite (2V = 40°), some of which has deuterically altered to brownish to greenish hornblende and to green biotite (Figure 20). Brown to green chlorophaeite occurs in interstices between grains as does a silicic residual composed of intergrown quartz and alkali feldspar (orthoclase and albite(?)).

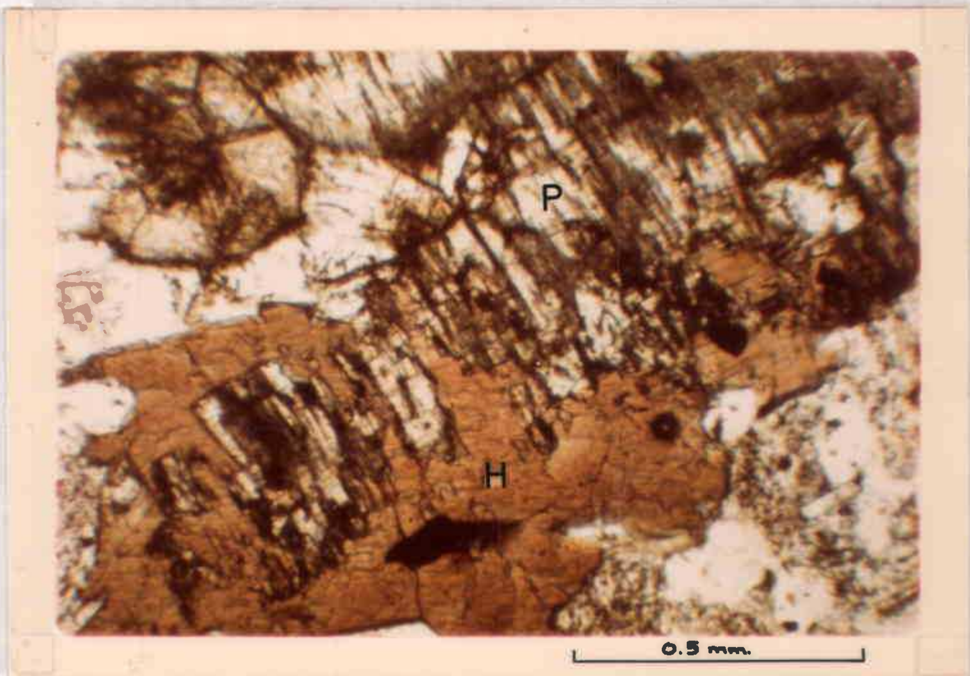

Figure 20. Deuteric alteration of light green pyroxene (P) to dark green hornblende (H) in tholeiitic diabase of Depoe Bay Basalt. Sample from center of Neahkahnie sill; plain light.

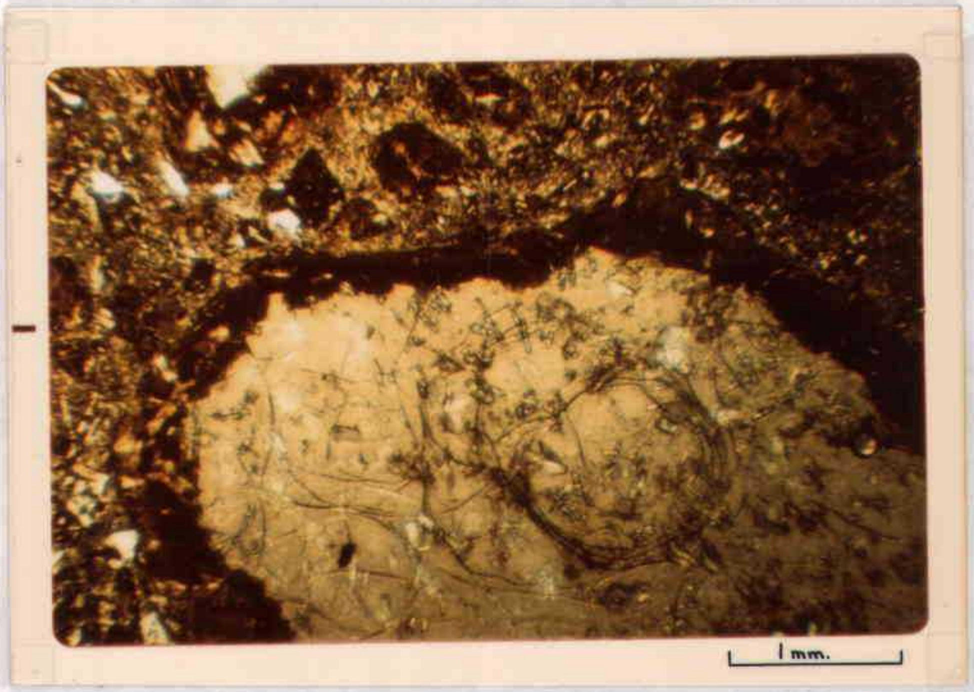

Figure 21. Perlitic cracks in basaltic glass fragment from extrusive pillow breccias of Depoe Bay Basalt. Note the hyalo-ophitic texture of the fragment and the brown palagonite alteration of the glass fragment edges and the ash-sized matrix; plain light.

Minor chloritic alteration of pyroxene, hornblende, and biotite, and sericitic alteration of feldspars amounts to less than one percent of the rock.

Basalts other than the rocks that compose the Neahkahnie still are aphanitic to finely crystalline and have hyalo-ophitic to intersertal textures. Mineralogically these rocks differ from the diabases at Neahkahnie Mountain in that they lack hornblende, biotite, chlorophaeite, and the silicic residual. Instead the less crystalline rocks contain plagioclase, clinopyroxene (probably augite or subcalcic augite) and opaque minerals (magnetite and ilmenite) in a groundmass of light- to dark-brown glass which is altering to a nearly opaque paste.

The above petrographic observations of the intrusive Depoe Bay Basalts are in agreement with those summarized by Snavely and others (1973) for other Depoe Bay Basalts found along the coast. They found that the basalts typically were composed of 45 to 55 percent plagioclase, 25 to 35 percent pyroxene, 3 to 10 percent opaque minerals, and less than one percent apatite and olivine. Snavely and others (1973) also noted that the well crystallized basalts contain a glassy silicic residual and chlorophaeite whereas less crystalline rocks contain light- to dark-brown basaltic glass.

No differentiation of the Neahkahnie sill was noted in thin section observations, however Snavely and others (1973) noted that minor chemical differentiation, including the development of pegmatitic schlieren, was found to occur in the Depoe Bay Basalt. Chemically the Depoe Bay Basalt is characterized by a high SiO_2 content (54% to 56%), and high total iron oxides and alkalies (Snavely and others, 1973).

Contact Relations. Except near the upper part of the Angora Peak sandstone where dikes of Depoe Bay Basalt have incorporated large blocks of sediment, the contacts between the basaltic intrusives and the sedimentary units are sharp. There is some alteration of the sedimentary rocks, and the basalt is frequently highly brecciated adjacent to these contacts. There is only minor alteration of the surrounding sedimentary rocks that are in contact with the intrusive rocks. The alteration consists of a six-inch to one foot wide "baked" zone of iron-stained, indurated mudstones along the lower sill contact with the Oswald West mudstones in the seacliffs south of Neahkahnie Mountain (section 18, T. 3 N., R. 10 W.). Further evidence of the intrusive effects of the sill surrounding strata is found in a small cove south of Short Sand Beach in the NW 1/4 of section 18 (T. 3 N., R. 10 W.) where columnar jointing in the Neahkahnie sill continues into the overlying strata for a distance of 20 feet.

Extrusive Rocks

Occurrence and Distribution. In the study area extrusive rocks of Depoe Bay Basalt form resistant highlands such as Rock Mountain and Angora Peak. The best exposures of the rocks are in the north-central part of the area where steep, cliff-forming exposures over 1600 feet thick form the heights of Angora Peak (Figure 16). Exposures in the central part of the area in the vicinity of Rock Mountain are half as thick and are covered by vegetation.

These basaltic rocks unconformably overlie less resistant Angora Peak sandstones. The contact between the two units is almost everywhere covered by talus blocks of basaltic breccia and vegetation and in many places only an abrupt break in slope delineates the contact. Along the eastern margin of Angora Peak the less resistant sandstones have been eroded from beneath the basalt breccias, removing their support, and resulting in the formation of the landslide blocks (Plate I).

Lithologic Character and Petrology. The dominant lithology of extrusive Depoe Bay Basalt is a palagonitized, submarine pillow breccia. Minor amounts of pillow basalts and subaerial basalt flows are also present in the unit.

The pillow breccias are well cemented forming resistant cliffs. The breccias weather a dark yellowish brown (10 YR 4/1). Pillow rims weather to a darker yellowish orange color (10 YR 6/6) than the surrounding palagonitic matrix or pillow interior (Figure 22). Fresh hand samples are dark greenish gray (5 GY 4/1) to greenish black (5 GY 2/1) in color. Fresh sideromelane or tachylite fragments in these samples have a resinous luster and a blacker color than the matrix which is slightly greenish (greenish black, 5 G 2/1).

The breccias are composed of whole pillows or fragments of pillows, angular lapilli-sized fragmental material, a palagonitized ash-sized matrix, and minor amounts of zeolites. The pillow breccias vary in texture, ranging from whole pillows suspended in a lapilli- and ash-sized matrix to broken pillows and angular pillow fragments in an ash matrix. These textures have been termed "isolated-pillow breccia" and "broken-pillow breccia" respectively by Carlisle (1963).

Pillows are elliptical in shape and range from one foot to two feet in diameter. Sideromelane and/or tachylite rims from 1/4-inch to two inches wide define the pillows (Figure 23). Interiors of pillows consist of aphanitic to fine-grained basalt similar in texture and mineralogy to fine-grained intrusive basalts described previously.

In thin section the color of the basaltic glass that forms pillow rims and angular lapilli-sized fragments ranges from translucent, light yellowish-brown sideromelane to dark brown, turbid tachylite. The glass is altered to yellowish and brownish palagonite around

Figure 22. Weathered boulder of basaltic pillow breccia of Depoe Bay Basalt. Note darker pillow rims above and to the left of lens cover.

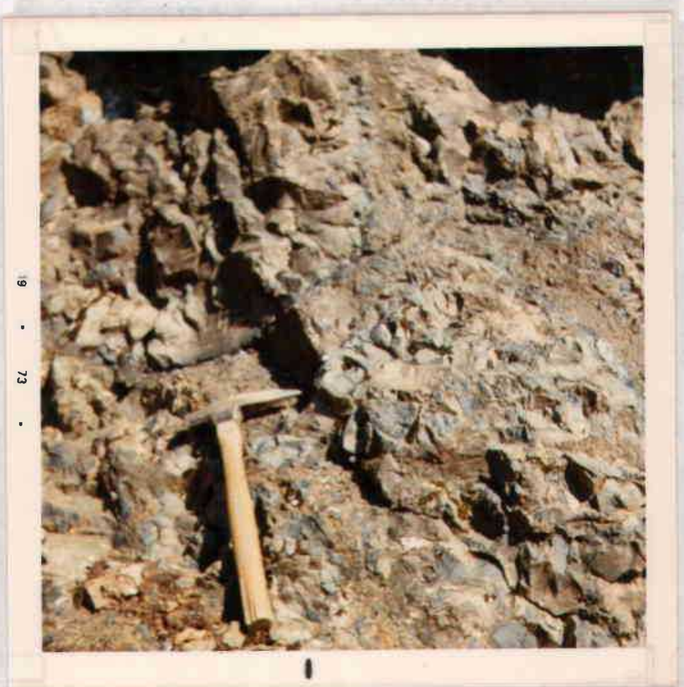

Figure 23. Fresh outcrop of basaltic pillow breccia of Depoe Bay Basalt. Note pillows and pillow rims above hammer.

fragment edges and along fractures (Figure 21). The matrix consists predominantly of palagonitized ash-sized fragments of sideromelane and tachylite glass intermixed with minor amounts of aphanitic to fine-grained basalt, and plagioclase and augite crystals. The glass fragments are texturally hyalo-ophitic in thin section, consisting of microlites of plagioclase and minor phenocrysts of plagioclase and augite to 0.5 millimeters in length. Perlitic cracks are common in the fresh sideromelane (Figure 21). Minor amounts of fibrous zeolites infill voids in the rock.

Near the base of the unit the breccias contain clasts of sandstone and siltstone and scattered grains of detrital quartz and feldspar in the matrix. However, this sedimentary material is absent one to two hundred feet above the base of the breccia.

Within the thick basaltic pillow breccia sequence a pillow lava and a subaerial flow were observed on the north slope of Angora Peak in section 34, T. 3 N., R. 10 W. The pillow lava consisted of closely-packed basalt pillows, one to one and a half feet in diameter. There is a lack of a palagonitic glass matrix characteristic of the pillow breccias. The subaerial flow consists of a fine-grained, highly vesicular basalt. The vesicles range in diameter from one to twelve millimeters and are commonly partly filled with zeolites and chalcedony. Both of these units are poorly exposed because of a deep soil cover and vegetation.

Contact Relations. Pillow breccias, composed of Depoe Bay Basalt, lie on Angora Peak sandstones at an angular unconformity as previously discussed. Intrusive basaltic dikes feed the breccias and may be observed cutting both Angora Peak sandstones and adjacent parts of the overlying breccia. In the SW 1/4 of section 4, T. 3 N., R. 10 W. dikes of Depoe Bay Basalt in the Angora Peak sandstones were observed to become brecciated near the contact with the overlying rocks. Within the breccias these dikes, although brecciated and resembling the breccias which it cut, was still visible as a resistant ridge cutting the lower 50 feet of the breccia. No evidence of an overlying Tertiary unit was observed in the thesis area.

Origin. The occurrence of pillow lavas and breccias, sideromelane and tachylite glass fragments, and alteration of these to palagonite is indicative of rapid quenching of a basaltic lava in an aqueous environment (Carlisle, 1963; Cucuzza-Silvestri, 1963). The presence of subaerial flows and baked zones in the pillow breccias in the study area, north in the Onion Peak area, and south at Cape Meares, indicates the presence of local volcanic highs. This would suggest a shallow water origin for the majority of the breccias and pillow lavas. The extensive areal occurrence of Depoe Bay breccias in northwestern Oregon (Snavely and others, 1973), together with paleogeographic maps constructed by Snavely and Wagner (1963) suggests that the breccias formed in a marine environment, and the great thickness of the unit (over 1600 feet thick) suggests formation in a rapidly subsiding basin.

Age and Correlation

Turner (1970) obtained a middle Miocene age for Depoe Bay Basalts based upon radiometric dating and stratigraphic interpretations of these basalts elsewhere along the coast. Donald Parker, an Oregon State University graduate student, obtained a radiometric age of 15.5 ± 0.35 million years for a sample of the Neahkahnie still using whole rock potassium/argon dating techniques (Niem and Cressy, in press). This date compares favorably with other radiometric ages of Depoe Bay Basalt (14.0±2.7 to 16.0±0.65 million years) obtained by other workers (Snavely and others, 1973). According to Turner (1970) these ages fall within the uppermost Saucesian and Relizian (middle Miocene) foraminiferal stages of Kleinpell (1938).

In the thesis area Depoe Bay Basalts unconformably overlie Angora Peak sandstones which contain middle Miocene or Temblor age megafossils (Addicott, written communication, 1973) indicating a late Temblor or younger age for the basalt unit.

Snavely and others (1973) correlate Depoe Bay Basalts with middle Miocene Yakima-type basalts of the Columbia River Group on the basis of similar chemical composition, age, and petrology.

Quaternary Deposits

Extensive deposits of Pleistocene and Recent age sediments unconformably overlie the older Tertiary rocks in the study area. The Quaternary deposits were divided into two units for mapping purposes: one unit includes beach and dune sands and gravels, and the other unit consists of alluvium, estuarine, and tidal flat sediments.

The distribution of beach and dune sands are interrupted along the coast by resistant basaltic headlands. Three areas of thick, mappable sand deposits occur on the Nehalem sandspit (Figure 24), in the cove at Short Sand Beach, and at Cove Beach (Plate I). The beach and dune sands are quartzose, well-sorted, and contain an immature heavy mineral assemblage consisting of magnetite. ilmenite, augite, hypersthene, garnet, and epidote. Locally, in the vicinity of headlands, the beach consists of large blocks and boulders of basalt as at the southern end of Neahkahnie Mountain (Figure 4) and at Cape Falcon. The character of the beaches changes with the seasons. In winter the beach is chiefly basalt pebbles and cobbles with minor amounts of sand, whereas the summer beach consists of abundant sand covering the majority of the cobbles.

The sand deposits are not thick (less than ten feet thick). However, on the Nehalem spit an abandoned well in section 32, T. 3 N., R. 10 W. penetrated 60 feet of beach and dune sand (Appendix III) and

Figure 24. Panoramic view of Nehalem Bay and sandspit. Dune and beach sands overlie Oswald West mudstone in the foreground.

dunes at the northeast corner of the spit are at least that high, suggesting a greater maximum thickness for the unit.

Beach sands overlie Oswald West mudstones at Short Sand Beach and Cove Beach. The dune sands that compose the Nehalem spit overlie terrace material to the northwest and tidal muds to the east (Cooper, 1958). In the vicinity of Neahkahnie Lake dune sands overlie stream alluvium and partially block the drainage of Neahkahnie Creek. The abandoned well mentioned previously penetrated 200 feet of interbedded Pleistocene(?) tidal muds, beach sands, and estuarine sediments below the dune sands. Bedrock in all the above instances consists of Oswald West mudstones.

River and stream alluvium of Coal Creek and the North Fork of the Nehalem River compose most of the sediments mapped as Quaternary alluvium and estuarine sediments (Qae). Tidal flat muds and estuarine sediments of Nehalem Bay are also included in this category. The alluvium and estuarine sediments occur along the eastern and southern boundaries of the thesis area (Plate I) and unconformably overlie Oswald West mudstones and older mudstone units outside the thesis area.

The unit is composed of varying amounts of poorly sorted, subangular and rounded alluvial gravels and sands with lenses and interbeds of silts and muds. Tidal muds and estuarine sediments interfinger with these gravels and sands in the lower part of the Nehalem

River and Bay. The tidal muds and estuarine sediments are fine-grained, highly carbonaceous, dark gray (N3) muds and silts.

PETROLOGY OF THE SEDIMENTARY UNITS

A total of 107 sedimentary samples were collected from Oswald West mudstones and Angora Peak sandstones from which representative samples were prepared for laboratory analysis. The location of these samples is shown on Plate I. Fifteen of 41 thin sections were point counted. Of those, 13 were from Angora Peak sandstones. Size analyses were performed on 12 Angora Peak samples, and heavy mineral analyses were performed on ten samples. Because of the well-cemented nature and scarcity of sandstones in the Oswald West mudstones, size and heavy mineral analyses were performed on only one sample from that unit. X-ray analyses were done on four samples by John Hudson (graduate student, Oregon State University; personal communication, 1973), three of which were from the Angora Peak sandstone. Detailed petrologic descriptions of the above samples were found in Appendices VI, VII, VIII, and IX.

Sandstones

Terminology and Classification

Sandstones were classified using the scheme of Gilbert (1954). This classification is based on a ternary plot of the percent of stable grains (quartz, quartzite, and chert), feldspar, and rock fragments, and on the percent of matrix. Sandstones containing less than ten percent matrix are arenites; those with greater than ten percent matrix are wackes. Matrix is defined in this study as clay and fine silt-sized material with an upper limit of about 0.015 mm (very fine silt).

Thin to thick sandstone beds occur at various intervals within the Oswald West mudstones. Two point counted sandstones from this unit are arkosic wackes (Figure 25).

Angora Peak sandstones are arkosic arenites and wackes, many of which plotted very close to the feldspathic arenite or wacke boundary (Figure 25). The dominant feldspar is an intermediate to calcic plagioclase (andesine and labradorite). The "arkoses" were found to occur in fine- to medium-grained sandstones collected from predominantly shallow marine intervals. Sandstones collected from the coarser, fluvial sandstones contain a higher percentage of volcanic rock fragments, and as a result are classified as lithic or volcanic arenites and wackes.

Textural Aspects

Sand-sized framework grains of both Oswald West and Angora Peak sandstones are predominantly subangular (visually estimated). Pebbles and cobbles in the coarse- and very coarse-grained sandstones and conglomerates are subrounded to well rounded. Sand-sized grains of the same mineral species display a wide range of angularity. For instance, hypersthene, zircon, and quartz range from euhedral

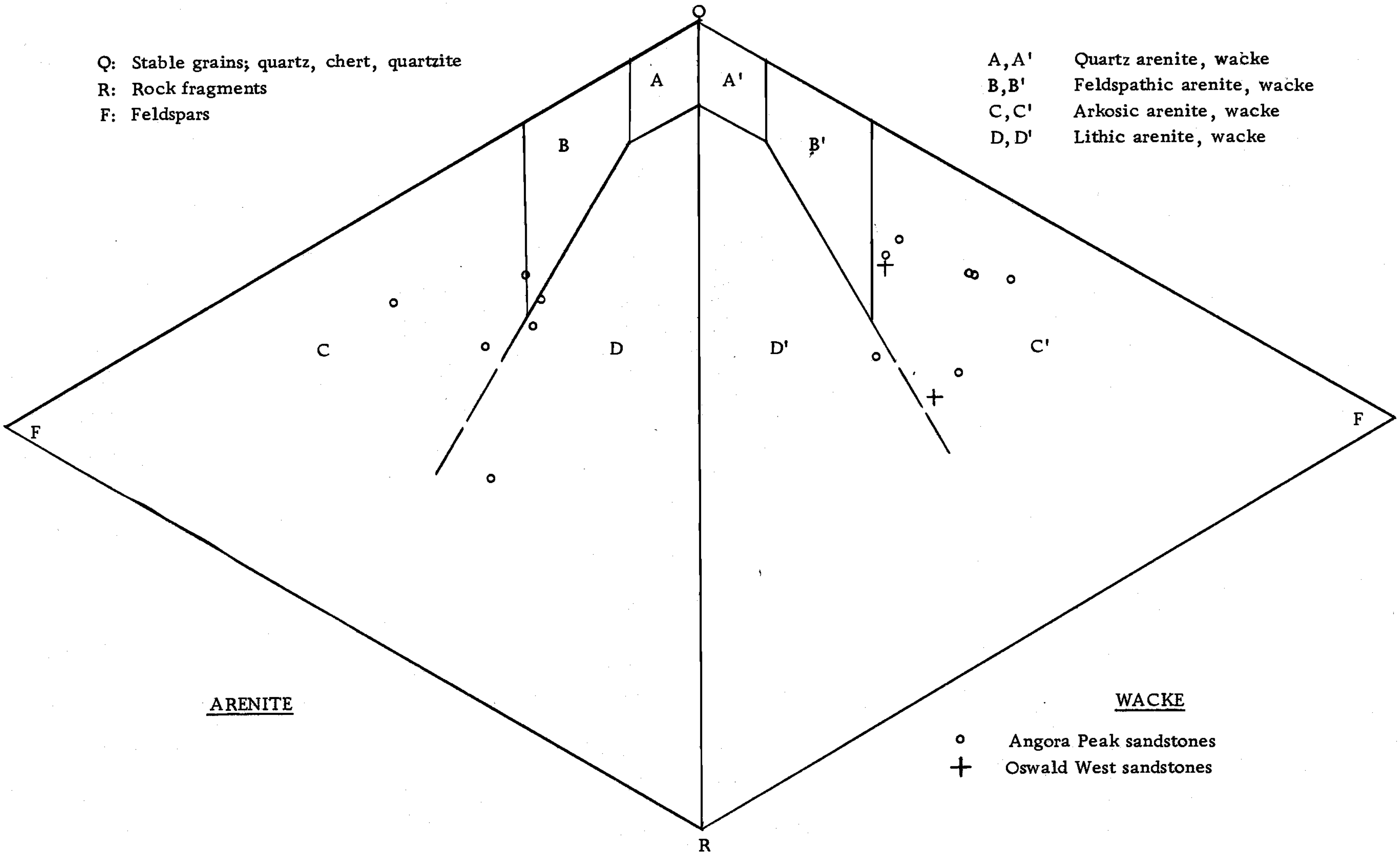

Figure 25. Classification of Angora Peak and Oswald West Sandstones (Classification after Gilbert, 1954)

or angular grains to rounded or well rounded grains in the same sample (Figure 28).

Inman's (1952) statistical size parameters were calculated from cumulative weight percent graphs of data collected from sieving and pipette techniques. The data are summarized in Table 3 and are presented in detail in Appendix VIII. The mean grain size for one sample of sandstone from the Oswald West mudstones is 4.32∅ (coarse silt) which reflects the large amount of matrix in the sample. Mean grain size for Angora Peak sandstone samples ranges from 4.85∅ to 0.14∅ (coarse silt to coarse sand). The average mean for these sandstones is 2.84∅ (fine sand). The most common rock type in the measured section of the Angora Peak sandstone (Appendix II) is also a fine-grained sandstone.

Table 3. Summary of size parameters.

Oswald West sandstone		Angora Peak sandstones (11)	
		range	average
Mean*	4.32	0.14 to 4.84	2.94
Sorting*	1.98	0.61 to 1.75	1.09
Skewness*	0.53	-0 92 to 0.61	0.26

*Inman's (1952) size parameters in phi (∅).

The terminology and phi limits set for sorting and skewness are those defined by Folk and Ward (1957). The sandstone sample from the Oswald West mudstones is poorly sorted (1.98Ø). It almost could be called very poorly sorted as the limits for a poorly sorted sediment, according to Folk and Ward, range from 1.00Ø to 2.00Ø. Angora Peak sandstones are better sorted, ranging from moderately sorted to poorly sorted (0.61Ø to 1.75Ø) with the average of the samples being poorly sorted (1.09Ø). This average is again very close to the limits set by Folk and Ward between a moderately and a poorly sorted sediment.

The Oswald West sandstone is very positively skewed (enriched in coarse grains). The skewness obtained from this sample is not thought to be typical of other Oswald West sandstones. Because of the high amount of matrix these sandstones should be negatively skewed. However, because the coarsest one percent of that sample is only 1/4 mm in diameter, a positive skewness is reasonable. All but one sample of the Angora Peak sandstones are positively to very positively skewed (-0.92Ø to 0.61Ø). The average Angora Peak sandstone is positively skewed (0.26Ø) (enriched in coarse grains). These data suggest that there was winnowing of the fine sediment during transportation.

Based on Folk's (1968) criteria for determining textural maturity in sediments, the Oswald West sandstones are texturally immature, that is, they contain significant amounts of primary matrix (greater than 10%), are poorly sorted, and contain chiefly angular clasts. This textural immaturity would suggest rapid deposition and burial of these sandstones with little or no current reworking, such as that in deep-water turbidity current deposits.

The textural maturity of Angora Peak sandstones ranges from immature to mature; the majority of the sandstones are submature. That is, they lack the primary matrix, are moderately sorted, and contain subangular clasts. The textural maturity of the Angora Peak sandstones suggests some winnowing of the primary matrix and sorting of the clasts before final deposition. However, the relative immaturity suggests deposition was rapid without extensive reworking.

The statistical size parameters of the sandstones were plotted on binary graphs of Passega (1957) and Friedman (1962) to aid in the determination of depositional environments. The interpretative value of these graphical plots is limited because of diagenetic addition of clay minerals to the matrix of the sandstones. Also the overall coarseness resulted in data being plotted off the graphs. Friedman's (1962) graphs clearly suggest deposition by tractive currents, either marine or fluvial. Passega's (1957) graph also suggests deposition by tractive currents for Angora Peak sandstones.

Framework Mineral and Rock Components

Framework grains that compose the Oswald West mudstones and the Angora Peak sandstones consist of quartz, plagioclase, potassium feldspar (orthoclase and microcline), volcanic rock fragments, mica, and in one Angora Peak sandstone, glauconite (Table 4). Minor amounts of sedimentary, metamorphic, and igneous rock fragments, heavy minerals, chert, and mafic minerals (pyroxene and amphibole) also occur in the sandstones. Detailed descriptions of the grain mineralogy are given in Appendices VII and IX.

Quartz. Quartz ranges from 19% to 21% in two sandstones from the Oswald West mudstones at Short Sand Beach. In Angora Peak sandstones quartz ranges from 15% to 43%, averaging 30% (13 samples). No recognizable changes in the quartz content of Angora Peak sandstones were observed higher in stratigraphic section. In both Angora Peak and Oswald West sandstones there are nearly equal amounts of undulatory (strained) and nonundulatory (normal) quartz. Polycrystalline quartz is common, especially in the coarser grained sandstones, but it constitutes only a minor part of the total quartz content. Quartz grains in both units are subangular to subrounded. However, a few rounded and well-rounded quartz grains were observed in the Angora Peak sandstone, and one of these contained quartz overgrowths on a well-rounded grain (Figure 28). No rounded or well-rounded grains were observed in sandstones within the Oswald West mudstones.

Feldspar. Feldspar grains are abundant in both sedimentary units with plagioclase being the dominant feldspar (Figure 26). Microcline and orthoclase occur in all samples, but are more abundant in Angora Peak sandstones (Figure 27). Potassium feldspar ranges from 1% to 2% in Oswald West sandstones, whereas Angora Peak sandstones contain 3% to 6% potassium feldspar, averaging 4%. Although an increase in the content of microcline and orthoclase was noted between the two sedimentary units, no variation trends were noted vertically within the Angora Peak sandstone.

Plagioclase content averages 14% for Oswald West sandstones and 17% for Angora Peak sandstones. In both units plagioclase ranges in composition from oligoclase to labradorite (An_{15} to An_{64}) with andesine being the most abundant feldspar variety (An_{30} to An_{50}).

Feldspars in both units range from unaltered to highly altered grains. Orthoclase and microcline are commonly unaltered or only slightly altered to sericite and kaolin(?). Plagioclase feldspars range from unaltered to highly altered grains in the same thin section (Figure 28), both in grains of the same composition and in grains of widely differing compositions. For example, in the same thin section unaltered and highly altered andesine grains may be found or some labradorite grains may be unaltered whereas oligoclase or andesine

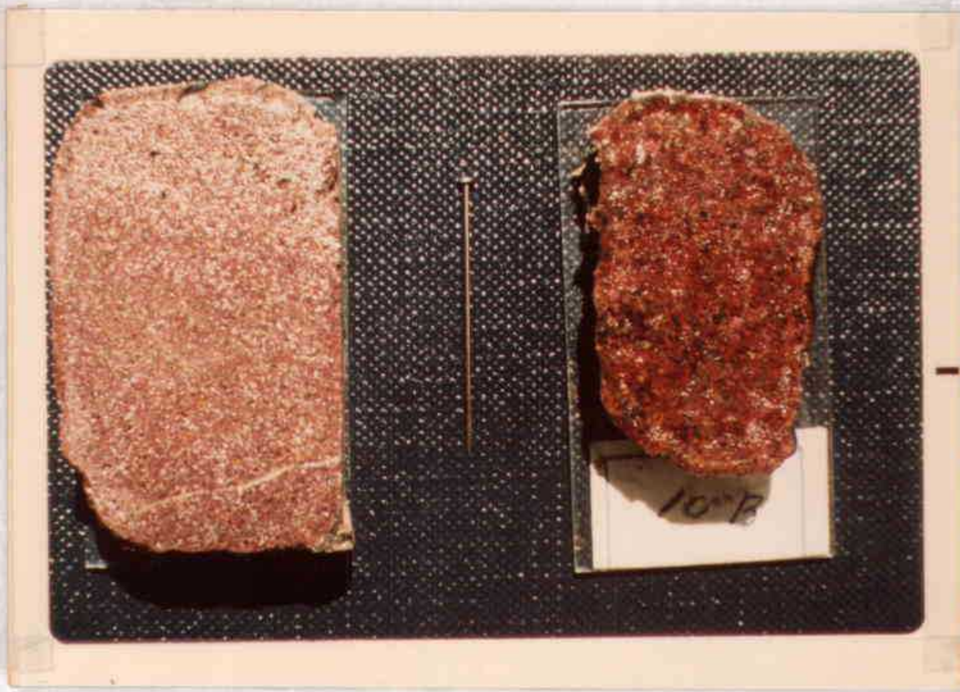

Figure 26. Stained rock billets from the Angora Peak sandstone. Potassium feldspar is stained yellow; plagioclase is red. Quartz is clear. Note one-inch long pin for scale.

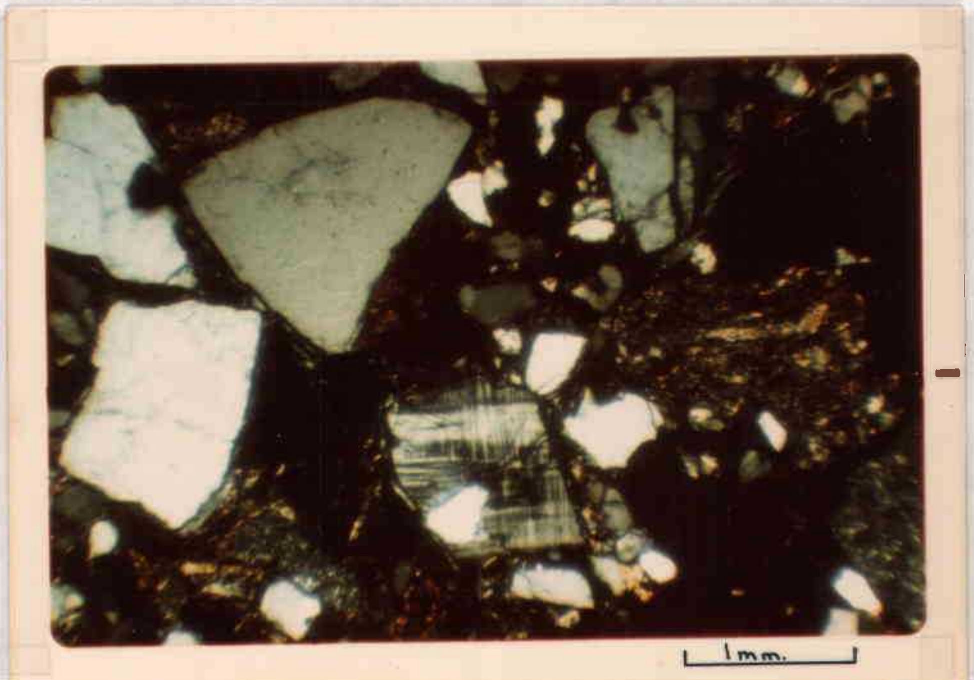

Figure 27. Angular and subangular quartz and microcline in a poorly sorted Angora Peak sandstone, crossed nicols.

grains may be highly altered. The marked range of alteration of the feldspars suggests mixing of fresh and weathered feldspars from the source area(s) or recycling of feldspars from locally uplifted strata. Folk (1968) suggests that this type of feldspar admixture is indicative of a source area with steep relief which is undergoing chemical weathering. Kaolin, sericite, and calcium carbonate are the common alteration products of the plagioclase grains.

Rock Fragments. Rock fragments, common in sandstones of both sedimentary units, range from 7% to 26% in the Oswald West mudstones and from 5% to 24% in Angora Peak sandstones. The large variation in the percentage of rock fragments is dependent upon the relative grain size of the sandstones. Rock fragments are more common in the coarse- and very coarse-grained sandstones.

Basic volcanic rock fragments make up the majority of the lithic constituents (Table 4). Although many of these fragments are so highly altered as to make their identification impossible, the majority appear to be basalts with a pilotaxitic texture of calcic andesine and labradorite microlites in an altered (celadonite?) groundmass. These lithic fragments have textures and mineralogy similar to Eocene Siletz River Volcanics described by Snavely and others (1968) and are thought to have been derived from similar volcanic areas in northwest Oregon. Andesite fragments which occur in minor amounts in the sandstones are thought to have been derived

Table 4. Average mineralogic composition (in percent) of Oswald West and Angora Peak sandstones.

Mineral	Oswald West*	Angora Peak**
Quartz	20	30
Quartzite	Tr.	Tr.
Chert	1	2
Plagioclase	14	17
K-feldspar	1	4
VRF	14	14
MRF + IRF + SRF	3	Tr.
Mica	4	3
Mafic	2	1
Opaque	2	2
Other	Tr.	2
Alteration minerals	--	7
Matrix	35	11
Cement (carbonate)	4	6
Porosity	--	1

*Based on two samples.

**Based on 13 samples.

VRF = volcanic rock fragments.

MRF + IRF + SRF = metamorphic, igneous, and sedimentary rock fragments.

Alteration minerals = iron oxides, celadonite, nontronite.

Tr. = less than 0.5%.

from the western Cascades.

Other rock fragments occurring in minor amounts (less than 5%) are chert, quartzite, quartz mica schist, granitic, and mudstone fragments. Chert is the most common of these fragments, ranging to 4%. Much of the chert is thought to be a devitrification product of silicic volcanic fragments because a few chert grains contain phenocrysts of feldspar. Those chert fragments with phenocrysts were included with the volcanic rock fragments in point counting the sandstones. Quartz mica schist fragments and metaquartzite fragments composed of interlocking, stretched quartz crystals with sutured borders and aligned micas were noted in eight of 15 samples. These fragments range in abundance from a trace to 1% in the eight samples. Granitic fragments, consisting of composite grains of quartz and feldspar, were observed in three samples in the coarser Angora Peak sandstones. Mudstone clasts occur most frequently in sandstones from the Oswald West mudstones, ranging from 1% to 4%. These fragments are thought to be mud clasts ripped from the bottom by current scour.

Mica. Muscovite and green and brown biotite are ubiquitous in Oswald West and Angora Peak sandstones, ranging from 1% to 8% in these units. Mica averages 4% in Oswald West sandstones and 3% in Angora Peak sandstones. In both units muscovite occurs more frequently than biotite. The mica flakes are commonly oriented parallel to the bedding of fine- to medium-grained wackes. Ragged and frayed edges of the grains are common. Compaction of the sandstones was not extensive because the mica flakes are not strongly contorted or crushed, and the framework did not penetrate them.

Heavy Minerals. Heavy minerals (specific gravity greater than 2.96) were separated from one Oswald West sandstone and from nine samples of Angora Peak sandstone. The results are presented in Appendix IX. Heavy mineral abundance ranges from a trace to 5% by weight of the total grains in the 3.0ø to 3.5ø size class. Opaque minerals, predominantly pyrite, leucoxene, ilmenite, and magnetite, account for over half of the heavy minerals in most samples.

Other than the opaque minerals, the most common heavy minerals are clear and pink garnet, green hornblende, augite, and mica. Others noted include basaltic hornblende, hypersthene, epidote, zircon, apatite, tourmaline, staurolite, and rutile. Augite, garnet, and zircon were observed in all but one sample. Hornblende, hypersthene, epidote, zircon, and tourmaline occur both as well-rounded and angular grains. Hypersthene and zircon commonly occur as euhedral crystals. Garnet and staurolite always were found as angular or subangular grains.

Authigenic Minerals. Pyrite and leucoxene are abundant in Oswald West sandstones where they compose over half of the opaque minerals. Pyrite and leucoxene occur as small irregular-shaped sand-sized grains or spherulitic masses. These minerals also occur in the same forms in fine-grained, marine Angora Peak sandstones. Rarely, pyrite fills the inside of a foraminifera test. Pyrite is also found as large, irregular-shaped nodules up to two inches in diameter in medium- to coarse-grained channel sandstones. Some fine-grained marine sandstones in the Angora Peak sandstone contain rounded or irregular, sand-sized pellets of glauconite (Figure 29). Some of the pellets are oxidized to an orangish color (limonite(?)). Glauconite is present in these shallow marine sandstones in trace amounts, but in one sample it composes 20% of the rock (Figure 29).

Conglomerate Pebbles

Pebble counts of eight conglomerate beds in the Angora Peak sandstone were made, and the composition of the five largest clasts was noted. Sample localities are located on Plate I. Clasts ranged from fine pebbles to small boulders (1/4 to 14 inches in diameter) with coarse pebbles (1/2 to 3/4-inches in diameter) being most abundant. The only exception is the conglomerate north of Cape Falcon (locality 13) where boulders up to 11 feet in diameter were noted (Figure 14).

The results of the pebble counts are presented in detail in Appendix VI, and are summarized in Figure 30 which shows a graphic

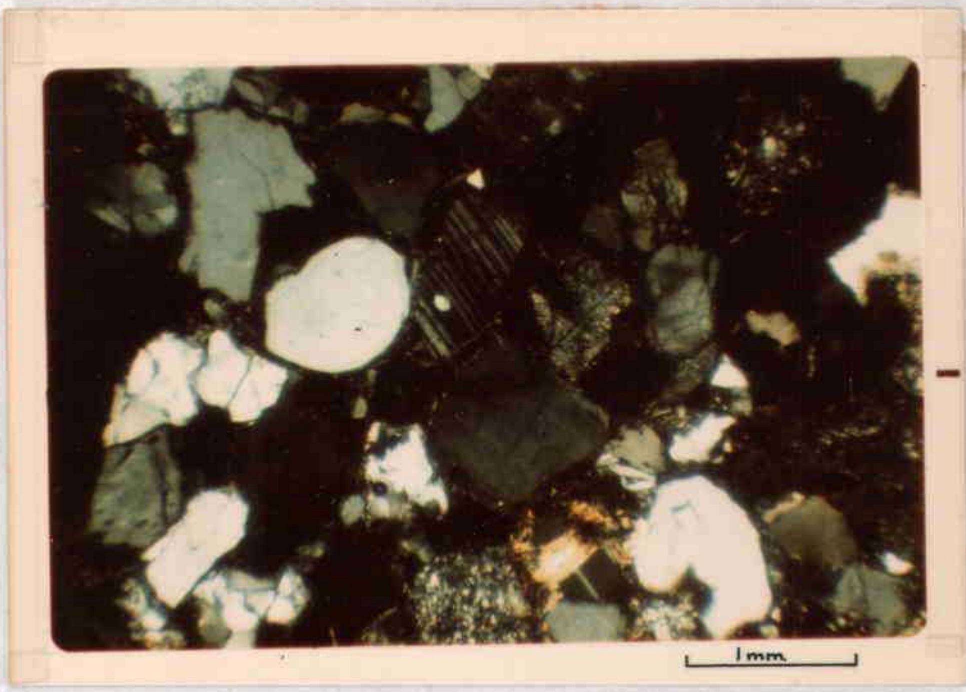

Figure 28. Unaltered and highly altered plagioclase grains in an Angora Peak sandstone. Note large, well-rounded quartz grain with rounded overgrowths (left center) and polycrystalline quartz grain (lower left). Crossed-nicols.

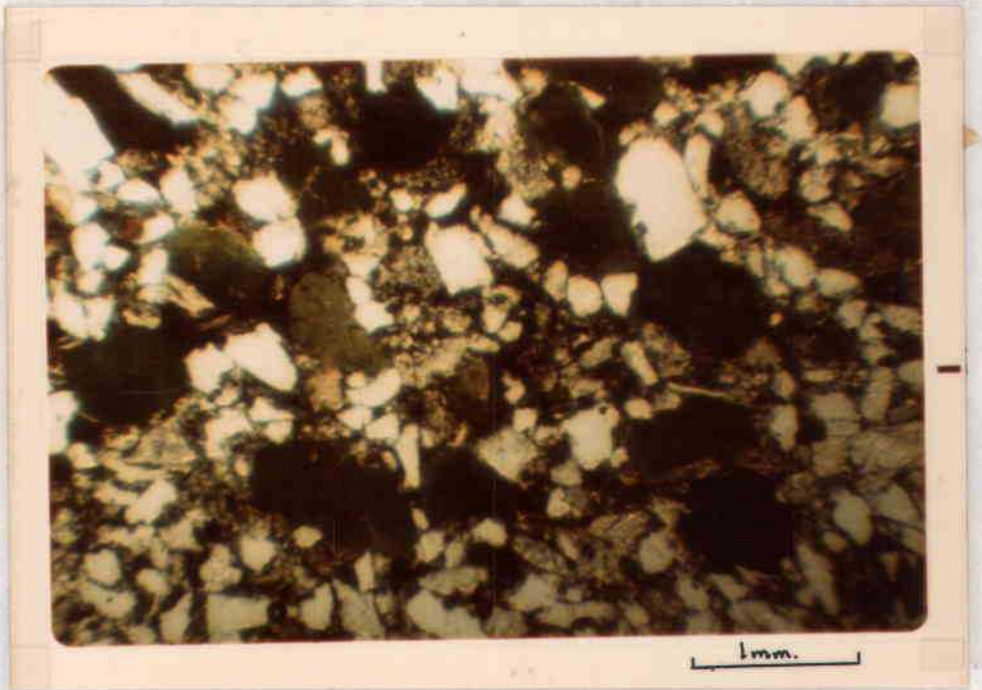

Figure 29. Dark green glauconite pellets in fine-grained Angora Peak sandstone. Note very fine-grained sparry calcite cement. Plain light.

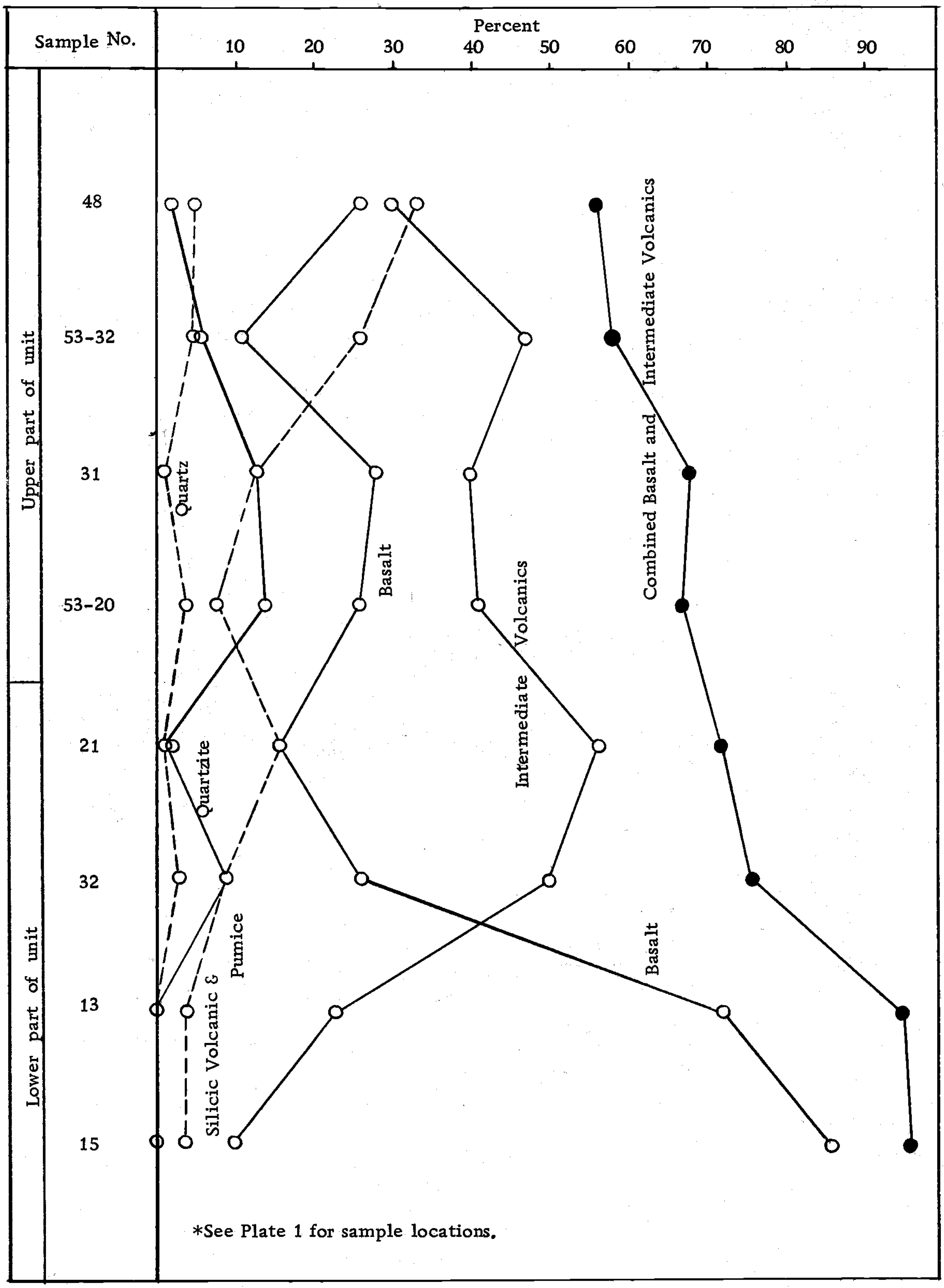

Figure 30. Percent variation in pebble lithologies in conglomerates of the Angora Peak Sandstone (sample localities in stratigraphic order)*

relationship between stratigraphic position and the abundance of selected pebble compositional types in Angora Peak conglomerates. In order to eliminate abnormal variations caused by high concentrations of mudstone rip-ups, the result of penecontemporaneous bottom scour, the data used for Figure 30 were recalculated without the sedimentary clasts. Figure 30 shows that clasts of intermediate (rhyodacite to andesite) and basaltic volcanics are dominant, composing 56% to 96% of the clasts. Other pebbles, in order of their relative are pumice, sedimentary and metamorphic quartzite, rhyolite, quartz, welded tuff, chert, silicic plutonic, and foliated metamorphic clasts.

Stratigraphically upward in the unit, there is a significant decrease in basaltic and intermediate volcanic clasts and an increase in combined rhyolite and pumice clasts. In the lower third of the unit (localities 15, 13, and 32) there is an upward decrease from 86% to 26% of basalt pebble abundance which may be related to erosion lowering local Eocene basaltic volcanics uplifted in the early middle Miocene. The percentage of basaltic clasts remains fairly constant higher in the unit implying an equilibrium condition between erosion of these local basaltic sources and contributions of sediment from other sources. The largest basalt clasts occur in the lower third of the Angora Peak sandstone also suggesting that a higher relief may have existed in local basalt sources whose sediment contribution overwhelmed contributions from other sources.

Exotic Pebbles. Conglomerate clasts which were collected in the Angora Peak sandstone and have no known source in western Oregon are referred to as "exotic" clasts. Exotic pebbles are rare, amounting to less than 5% of the total clasts counted, and most are either sedimentary or metamorphic quartzite. Other exotic pebbles are vein quartz, silicic plutonic, and schist fragments (Figure 31).

Exotic sedimentary and metamorphic quartzite pebbles range from traces to 14% of the total clasts counted. Sedimentary quartzite clasts are composed of medium-grained, very well-rounded and well-sorted quartz grains cemented by quartz overgrowths. Some grains in the pebbles are coated with an iron oxide, giving the pebble a reddish hue. Metaquartzie pebbles appear the same in hand specimen, but in thin section they are composed of parallel aligned, elongated and stretched, crystalline quartz grains with undulatory extinction. The interlocking quartz grains contain sutured boundaries. One hypabyssal, porphyritic microgranite (Figure 31) was collected. This cobble consisted of phenocrysts of quartz, oligoclase, and microcline in a glomeroporphyritic texture. The groundmass is finely crystalline and hypidiomorphic-granular, consisting of quartz, microcline, oligoclase, biotite, and magnetite. The potassium feldspar phenocrysts commonly have cores of oligoclase. A schistose metamorphic clast was also found. It is composed of a quartz-epidote-albite-muscovite-biotite mineral assemblage, characteristic

Figure 31. Exotic pebbles from conglomerates in the Angora Peak sandstone. Stained (1a) and fresh (1b) samples of a porphyritic microgranite with phenocrysts of K-spar (cores of plagioclase); stained schist fragment (2); welded tuff (3); and sedimentary quartzite pebbles (4).

of a high greenschist facies (Williams and others, 1954).

Matrix

The amount of matrix is variable in Angora Peak sandstones, ranging from 3% to 30%. In 13 samples the amount of matrix averaged 11% as compared to 35% for two sandstone samples collected from the Oswald West mudstones.

The matrix in the wackes of the Oswald West mudstones is composed of clays and carbonaceous material which appear as a nearly opaque to brown, translucent paste under the microscope. In these sandstones the matrix is detrital in origin. The detrital origin of the matrix is suggested by the large amount of matrix in the samples (23% and 47%) and by the presence of abundant mudstone rip-ups of similar composition in the sandstones. Indistinct boundaries between the matrix and altered volcanic rock fragments and plagioclase grains suggest minor diagenetic origin of some of the matrix.

A similar argillaceous and carbonaceous matrix occurs in the Angora Peak sandstones. X-ray analysis of the clay-sized fraction from these sandstones indicates that most of the clay-sized material, other than fine quartz and feldspar, is composed of illite and mixed-layer illite-smectite (Hudson, personal communication, 1972). Hudson also found trace amounts of chlorite, biotite, glauconite, clinoptilolite, and kaolinite(?). The zeolite, dinoptilolite, is a common alteration product of intermediate to acidic volcanic glass suggesting that at least some of the matrix may be diagenetic. Some altered volcanic framework grains have indistinct boundaries with the matrix, also suggesting minor diagenetic origin of the matrix. Thus, some Angora Peak sandstones may have been deposited as arenites, but because of the alteration of volcanic glass and framework grains to clay-sized matrix material, they are now classified as wackes. The matrix content in the Angora Peak sandstones classified as wackes commonly only slightly exceeds the 10% limit of Gilbert (1954) (Appendix VIII).

Cement

Sandstones in the Oswald West mudstones are tightly cemented by calcium carbonate which composes 3% to 4% of the rocks (2 samples). In both samples the calcite has, in part, replaced the matrix, plagioclase grains, and volcanic rock fragments.

Angora Peak sandstones are commonly friable and incompletely cemented by iron oxides and alteration products of volcanic glass(?) such as celadonite, saponite, and nontronite. Calcite occurs as a cement in concretions and in sandstones associated with fossil horizons. Sparry calcite forms the cement in the thick conglomeratic units at the north end of Cape Falcon and in the West Fork of Coal Creek.

STRUCTURAL GEOLOGY

Regional Structure

The Coast Range of Oregon structurally is a north-plunging anticlinorium with the core composed of early Eocene Siletz River and Tillamook Volcanics in the central and northern parts of the range. Late Eocene to middle Miocene strata dip homoclinally away from the core, both to the east and west. In the northern Coast Range the anticlinorium plunges northward exposing late Eocene to late Miocene strata wrapping around the nose of the structure. Smaller folds and faults are common within this larger structure. Smaller structures delineated on the "Geologic map of Oregon west of the 121st meridian" (Wells and Peck, 1961) show a general northwesterly trend in the northern Coast Range. Folds in most of the area are thought to be of a normal compressional type and normal and reverse faults are commonly high angle (Braislin and others, 1971).

Structure of the Thesis Area

Three west-northwest-trending folds, two synclines separated by an anticline, are recognized in the thesis area (Figure 32). Two sets of faults occur in the area: a west-northwest trending set of faults which is subparallel to the fold axes, and a north-south-trending set (Figure 32; Plate I).

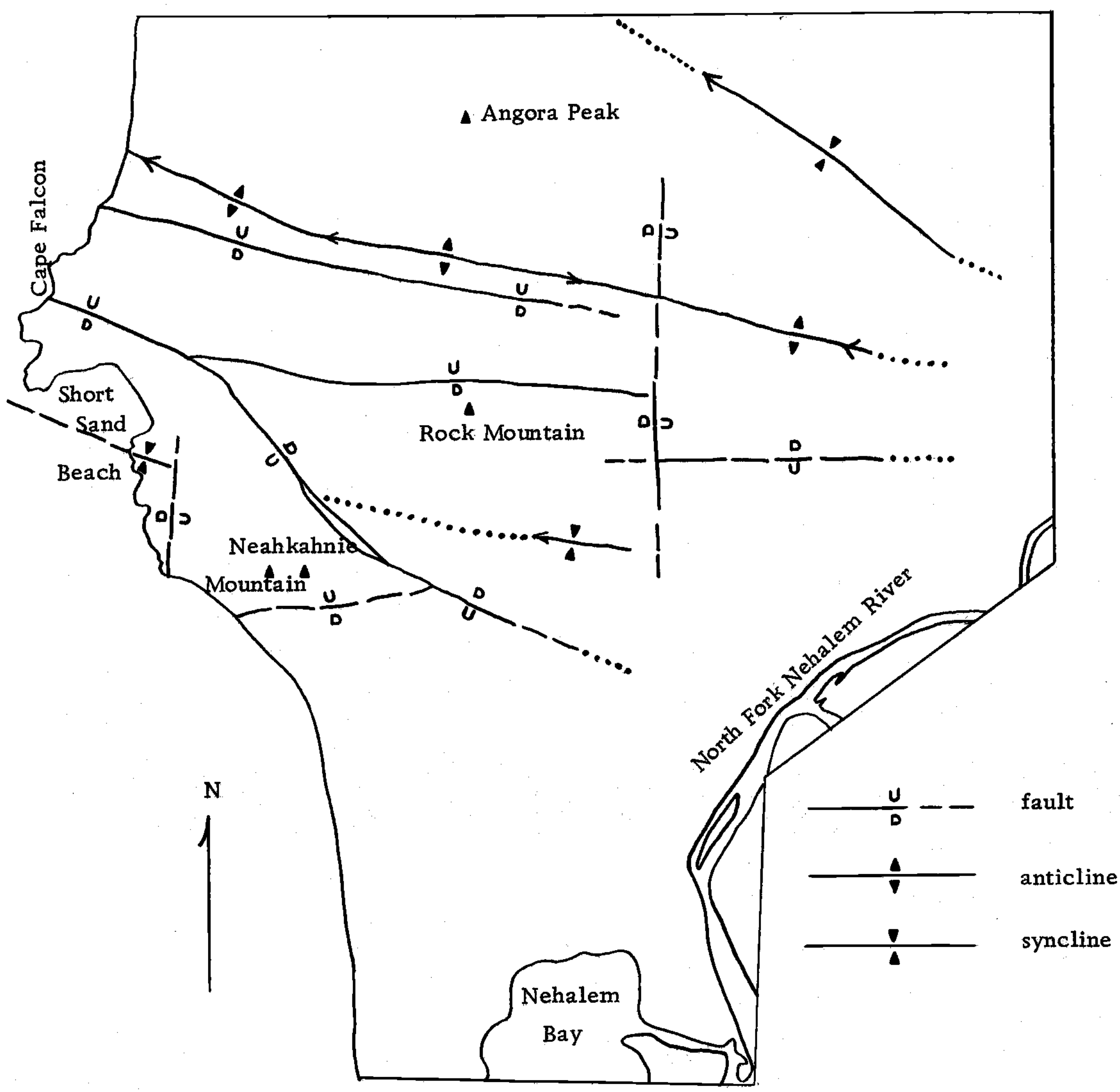

Figure 32. Structural map of the Neahkahnie Mountain - Angora Peak area.

Folding in the sedimentary rocks is recognized by persistent reversals in dip over large areas on both the east and west sides of the thesis area, by outcrop patterns, and by direct observation. Direct observation of the folding occurs in the seacliffs 1/2 mile south of Short Sand Beach (Figure 33) where the axis of a large syncline is exposed. The folding is partly responsible for the formation of the cove at Short Sand Beach as the top of the Neahkahnie sill is folded so that it lies below sea level and the overlying Oswald West mudstones are easily eroded by wave action. The sill dips northeast in the seacliffs immediately south of the fold axis (Figure 33) and dips southwest at the end of Cape Falcon.

The folds appear to be symmetrical. Locally, however, the folds are asymmetrical where the strata of one limb have been disturbed by slumping, faulting, or by nearby intrusions. The limbs of the folds range in steepness from 10° to 40°, but commonly dip from 25° to 40°. The folds generally plunge toward the west-northwest, but local reversals in plunge occur. The locations of fold axes are approximate because of heavy vegetation and cover. Extrusive Depoe Bay basaltic breccias are only slightly warped and unconformably overlie more intensely folded Angora Peak sandstones suggesting more than one episode of folding. Most of the folding took place after deposition of the Angora Peak sandstone but before extrusion of the Depoe Bay Basalt. Minor warping of these basalts

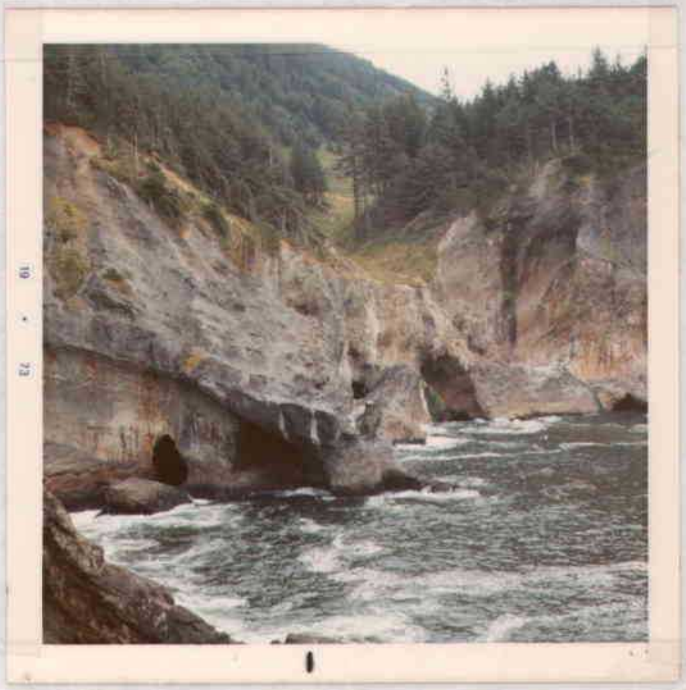

Figure 33. Looking southeast along the axis of a syncline in the lower part of the Angora Peak sandstone. In seacliffs 1/4 mile south of Short Sand Beach, Oswald West State Park (NW 1/4 NW 1/4 of section 18, T. 3 N., R. 10 W.).

occurred after their extrusion.

Faults with displacements ranging from a few feet to over 1000 feet are abundant in the thesis area. Seven major faults are delineated on Plate I. Faults are readily recognized in seacliff exposures where offsets of bedding may be easily observed. Faulting may well be more prevalent, but is obscured by heavy vegetation and the extreme difficulty in tracing faults in the Oswald West mudstone in inland exposures. Offset contacts, juxtaposed rock types which are not stratigraphically in contact, linear ridges and dikes, and shear zones delineate faults. Supporting evidence of the presence of faults are saddles on ridges and local abnormal dips and strikes.

West- and northwest-trending faults form a "N-shaped" pattern in the western half of the thesis area (Figure 32). This fault pattern has uplifted the thick basaltic sill that now forms Neahkahnie Mountain. The major fault in this system is a near-vertical fault to the northeast of Neahkahnie Mountain which juxtaposes Depoe Bay pillow breccias and the Neahkahnie sill. A sliver of highly sheared Angora Peak sandstone is caught between these resistant units. This less resistant sliver of sandstone forms a saddle near the top of the ridge in the center of section 17 of T. 3 N., R. 10 W. and the valley to the northwest (Plate I). On the south side of Neahkahnie Mountain an east-west trending normal fault down-drops a block of Angora Peak sandstone. The north block is composed of the Neahkahnie sill. This fault may be observed in a road cut along U. S. Highway 101 (Plate I). Displacements on both these faults exceed 1000 feet.

North of Cape Falcon another northwest trending fault forms a long parallel ridge striking for four miles from the coast inland to the southeast. This fault is the northern boundary of the exposed Neahkahnie sill. The fault also juxtaposes Oswald West mudstones against Angora Peak conglomerate at the north end of Cape Falcon. The fault brings Oswald West mudstones and Angora Peak sandstones against the Neahkahnie sill, and is the locus for many small basalt dikes which occur along it. South of this fault and north of Rock Mountain (Figure 32) a west-northwest-trending fault is associated with two large dikes of Depoe Bay Basalt that parallel the strike of the fault. The fault displaces extrusive Depoe Bay pillow breccias 100 to 200 feet.

Two major north-south faults were mapped in the study area. One is located to the west of Neahkahnie Mountain and down-drops the western side of the Neahkahnie sill approximately 1400 feet. The top of the Neahkahnie sill abruptly drops in elevation from about 1600 feet at the top of the mountain to a little over 200 feet at U. S. Highway 101 which follows a north-south-trending valley at this location, suggesting a possible fault in this saddle. A north-south fault in the eastern half of the area is mapped because of anomalous attitudes in the Angora Peak sandstone in the northeast corner of section 3,

T. 3 N., R. 10 W. In this same area upper Angora Peak sandstones are in juxtaposition with middle Angora Peak sandstones. Several dikes are also abruptly terminated along this trend (Plate I).

The ages of the faults are difficult to determine, but movement on some of them may have occurred at different times in the geologic past. Faulting is thought to have been contemporaneous with deposition of the lower part of the Angora Peak sandstones (see Depositional Environment section, Angora Peak sandstone). Some faulting occurred prior to or contemporaneous with intrusion of the dikes of Depoe Bay Basalt as dikes follow the strike of some faults. Faulting also occurred after intrusion and extrusion of the pillow breccias. For example, the large fault to the northeast of Neahkahnie Mountain cuts both intrusive and extrusive basalts.

GEOLOGIC HISTORY

Transport Directions

Paleo-sediment dispersal patterns and the paleoslope directions for the Oswald West mudstones are difficult to determine because of the fine-grained, highly burrowed nature of the sediment. However, minor micro-cross-laminations in tuffaceous siltstones suggest a paleocurrent direction to the south or southwest. A paleoslope direction to the south or southwest was also determined by small-scale (one inch high) flame structures and large-scale (to 1 1/2 feet) convoluted bedding. These sediment dispersal patterns and paleoslope directions are in agreement with Snavely and Wagner (1963) who postulated an uplifted area to the east of the thesis area during the late Oligocene.

Paleocurrent directions for the Angora Peak sandstone were determined in four areas by measuring the orientation and direction of planar foresets and trough cross-bedding together with, in one instance, the imbrication of mudstones rip-ups. The four areas show sediment dispersal patterns of the fluvial intervals of the Angora Peak sandstone from the east to the southwest, west, and northwest (Figure 34).

The cumulative mean paleocurrent direction for the four areas is west-southwest ($252° \pm 61°$). The individual means range from

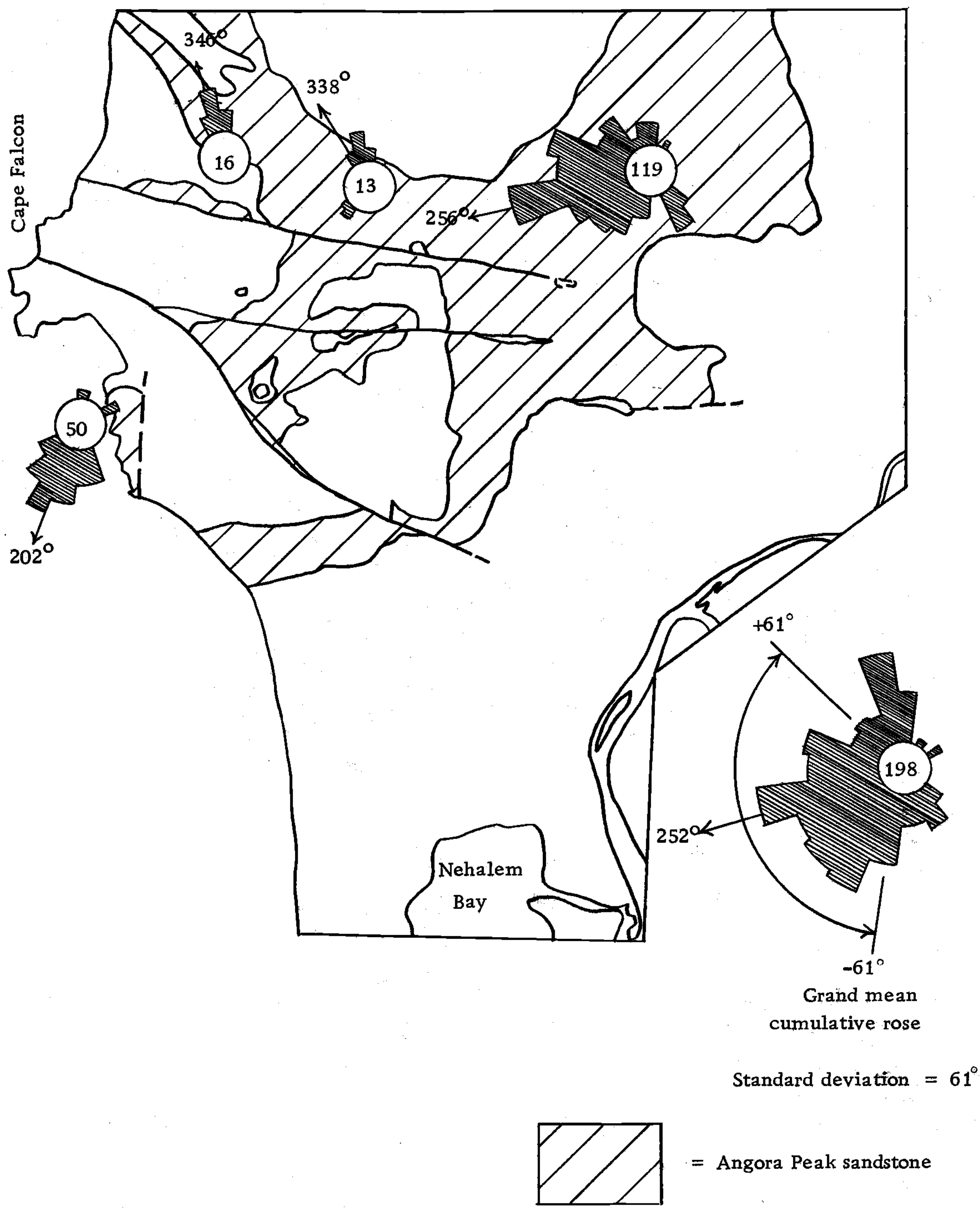

Figure 34. Rose diagrams of paleocurrent measurements from the Angora Peak sandstone. Number of measurements and mean azimuth direction with roses.

northwest (346°) to southwest (202°), a 144° change in the predominant transport direction. The wide variation in the measured transport directions is to be expected in the subaerial parts of deltaic sequences due to the lateral migration and abandonment of distributary channels. At Hug Point, ten miles to the north of the thesis area, preliminary reconnaissance of Angora Peak sandstones exposed there shows a sediment dispersal pattern to the northwest, which also supports a deltaic origin for the unit.

Provenance

Most of the sediment composing the Oswald West mudstones and Angora Peak sandstones was locally derived from uplifted areas in the ancestral Coast Range and from the Western Cascades. However, petrographic and heavy mineral analyses and conglomerate clast lithologies indicate contributions from more distant source areas which may have been carried to the depositional site by an ancestral "Columbia River."

Because of limited sampling and the very fine-grained nature of the Oswald West mudstones, the source areas for this unit are difficult to determine. Basic volcanic rock fragments in the sandstones of the unit suggest a local source, but these rock fragments are so highly altered as to mask their exact composition. A local volcanic high is thought to have existed to the east and southeast of the thesis area during the Oligocene and Miocene (Snavely and Wagner, 1963), and this may have contributed rock fragments. Euhedral hypersthene and zircon grains in the heavy mineral suite suggest derivation from the Western Cascades. Also the abundance of tuffaceous siltstones in the lower part of the Oswald West mudstones suggests contemporaneous volcanic activity from the western Cascades. Snavely and Wagner (1963, 1964) and Goodwin (1972) also hypothesized late Oligocene volcanism in the Western Cascades as a source for the abundance of tuffaceous siltstones and pumice in the Yaquina Formation, the southern lateral equivalent of the Oswald West mudstones.

Angular grains of garnet, staurolite, and microcline in Oswald West sandstones suggest a metamorphic and acidic igneous source. These minearals were also found in the coeval Scappoose Formation by Van Atta (1971) who hypothesized an ancestral Columbia River draining metamorphic and plutonic terranes in eastern Oregon, Washington, and Idaho to supply some of the sediments of that formation. This evidence also supports the hypothesis presented earlier that the Oswald West mudstones may represent a prodelta environment for a coeval Scappoose delta.

The mineral grains of the Angora Peak sandstone were derived from varied sources ranging from acidic and basic volcanics to plutonic, metamorphic, and Paleozoic sedimentary rocks. Most of the sandstone grains, however, were derived from local uplifted basaltic volcanic terranes and from the western Cascades. The dominance of basaltic pebbles and sand-sized rock fragments, especially in the lower part of the unit, reflects the large contribution of sediment from locally uplifted Eocene Siletz River and Tillamook Volcanics to the southeast. The abundance of intermediate volcanic (rhyodacite to andesite) and dacitic pumice clasts in Angora Peak conglomerates indicates that the Western Cascades were a major contributor of the sediments that now compose the Angora Peak sandstone, especially higher in the unit after local uplifted basaltic areas had been eroded to lower relief. The Oligocene Little Butte Volcanics in the Western Cascades of Oregon contain abundant dacitic and andesitic tuff, rhyodacitic welded tuff, and andesitic and basaltic flows (Peck and others, 1964). This unit may have been the source for this material. Euhedral hypersthene and zircon crystals in the heavy mineral suite of the sandstones also support this source. The occurrence of tuff beds elsewhere in the Astoria Formation is suggestive of freshly erupted material from the Cascades during the Miocene (Snavely and others, 1969).

A major river system, such as the present day Columbia River, is hypothesized to have supplied much of the sediment of the Angora Peak sandstone rather than a large coastal river from the Western Cascades. A broad valley existed through the Cascades in the Miocene just south of the present day Columbia River and it is believed to be the valley of an ancestral Columbia River (Lowry and Baldwin, 1952; Peck and others, 1964). An ancestral Columbia River is hypothesized to account for the presence of heavy minerals, rock fragments, and conglomerate pebbles that have no known sources in western Oregon. Data from Snavely and Wagner (1963, 1964) show that "the arkosic sandstone of the Astoria Formation contains a heavy mineral suite indicating that much of the coarser detritus was transported from igneous and metamorphic terranes in north-central Washington and southern British Columbia." The modern Columbia River and its tributaries drain such an area today.

The abundance of microcline in the Angora Peak sandstones, the hornblende, tourmaline, staurolite, rutile, and abundant garnet and mica in the heavy mineral suite, and the silicic granitic, greenschist, and metaquartzite clasts are indicative of the metamorphic and acid igneous sources.

The abundance of sedimentary quartzite pebbles in Angora Peak conglomerates suggests a Paleozoic source in Idaho and Montana. A major tributary of the Columbia which presently drains this area is the Snake River. The presence in the sandstones of well-rounded quartz grains with rounded overgrowths and rounded grains of zircon and tourmaline also suggests a recycled origin from texturally supermature Paleozoic sandstones. An ancestral Columbia River also could have supplied volcanic material from eastern Oregon such as rhyolitic welded tuff and pumice from the John Day Formation.

Summary and Conclusions

Four distinct stratigraphic units exist in the Angora Peak-Neahkahnie Mountain area: the Oswald West mudstones, the Angora Peak sandstone member of the Astoria Formation, intrusive basalts and diabases of Depoe Bay Basalt, and extrusive pillow breccias and lavas of Depoe Bay Basalt. The two sedimentary units are informally described for the first time from this area.

During late Oligocene and early Miocene time, over 1600 feet of Oswald West mudstones were deposited in a deep-water (upper bathyal) marine environment along the western side of the northern Coast Range. The relatively rapid accumulation of fine-grained silts and muds was interrupted by turbidite sandstones and submarine slump deposits, and the sediments were highly burrowed by organisms. The position of the Oswald West mudstones with respect to a possible coeval delta represented by the Scappoose Formation suggests a prodelta environment of deposition for the former.

The Oswald West mudstones were uplifted in the early Miocene exposing the upper part of the unit to subaerial erosion. Intermittent uplift continued during the deposition of the lower part of the Angora Peak sandstone. Relatively continuous subsidence and progradation over the Oswald West mudstones in middle Miocene resulted in deposition of over 1800 feet of shallow marine and fluvial sandstones of the Angora Peak sandstone. Paleocurrent data, sandstone mineralogy, and conglomerate clasts suggest that most of the sediment was derived from local basaltic and sandstone sources and from intermediate volcanics from the western Cascades, but other material was derived from igneous, metamorphic, and sedimentary sources in eastern Oregon and Washington, British Columbia, Idaho, and Montana via an ancestral Columbia River system. Interfingering fluvial and shallow marine sandstones, coal beds, sedimentary structures, and fossils suggest that these sediments were deposited in a deltaic environment dominated by high wave energy reworking the sediments into extensive delta-front sheet sands.

After deposition of the Angora Peak sandstone in the middle Miocene, the area was again uplifted and folded into a series of west-northwest-trending synclines and anticlines. During this time dikes, sills, and plugs of Depoe Bay Basalt intruded the sediments. Extrusion of the basalt over the eroded surface, coupled with renewed subsidence and marine transgression, resulted in localized buildups of palagonitized pillow basalts and breccias of Depoe Bay Basalt. These buildups, over 1600 feet thick, were primarily submarine but periodically reached the surface permitting local subaerial basalt flows.

Uplift and erosion, accompanied by vertical north-south- and northwest-southeast-trending faulting and warping, have continued from post-middle Miocene deposition until the present.

ECONOMIC GEOLOGY

Coal

In the 77 years since Diller (1896) discussed the occurrence of coal in the extreme northwestern corner of Tillamook County, few investigations have been made of these beds. Other authors (Smith, 1900; Washburne, 1914; Allen, 1940; Mason and others, 1955) have only cited Diller or simply mentioned that coal occurs in the area.

Several coal beds, ranging in thickness from nine to 24 inches, occur in the lower part of the Angora Peak sandstone member of the Astoria Formation. In outcrop the coals are black, have a waxy luster, and are fairly well indurated. Thinner layers of silty coal, lignitic coal, and highly carbonaceous beds are found higher in the member, but they are of a limited extent. The higher grade coals are commonly interbedded with highly carbonaceous silty mudstones which contain many small stringers of coal and are associated with medium- to coarse-grained, cross-bedded fluvial sandstones.

In Coal Creek in the SW 1/4, SW 1/4 of section 36, T. 4 N. R. 10 W. a seam of coal ranges from 18 to 24 inches in thickness (analyses 47A and 13) and extends 100 feet along the creek. Similar coal seams, exposed on a more limited scale, occur in the SE 1/4 NE 1/4 of section 3 (Figure 11) and in the SW 1/4 NE 1/4 of section 9 in T. 3 N., R. 10 W. (analysis 17A). Diller (1896) described similar coal seams from sections 2, 10, and 16 in the same township. Washburne (1914) noted that coal crops out in section 18. Thus, in general, the coal seams occur along a northeast-trending belt from section 16 to section 36 as shown on Figure 35.

Laboratory analyses by the U. S. Bureau of Mines Coal Analysis Laboratory in Pittsburg, Penn. indicate that coals found in the thesis area are subbituminous to bituminous in grade (Walker, written communication, 1973). Samples of two coals in Table 5 were classified using procedures standardized by the American Society for Testing Materials. Sample 47A is a subbituminous "A" grade coal (highest grade subbituminous), and sample 17A is a high volatile "C" bituminous grade coal (lowest grade bituminous). BTU's are high, ranging from 11,280 to 12,080 in the field sample, and 12,970 to 13,520 in the moisture and ash-free samples. Comparison with analyses of other coals from the thesis area in Table 5 (Diller, 1896) suggests that these coals are high rank subbituminous as Diller's samples 11, 12, and 13 compare favorably with sample 47A. The coals have high ash and sulphur content and are comparable with Eocene coals of the Coos Bay area (Yancey and Geer, 1940). The coals in the thesis area have higher BTU's than the Eocene coals (Snavely, personal communication, 1973) which may reflect a thermal overprint on these coals from the proximity of the underlying Neahkahnie sill.

Although the quality of the coal is good, its position in the lower

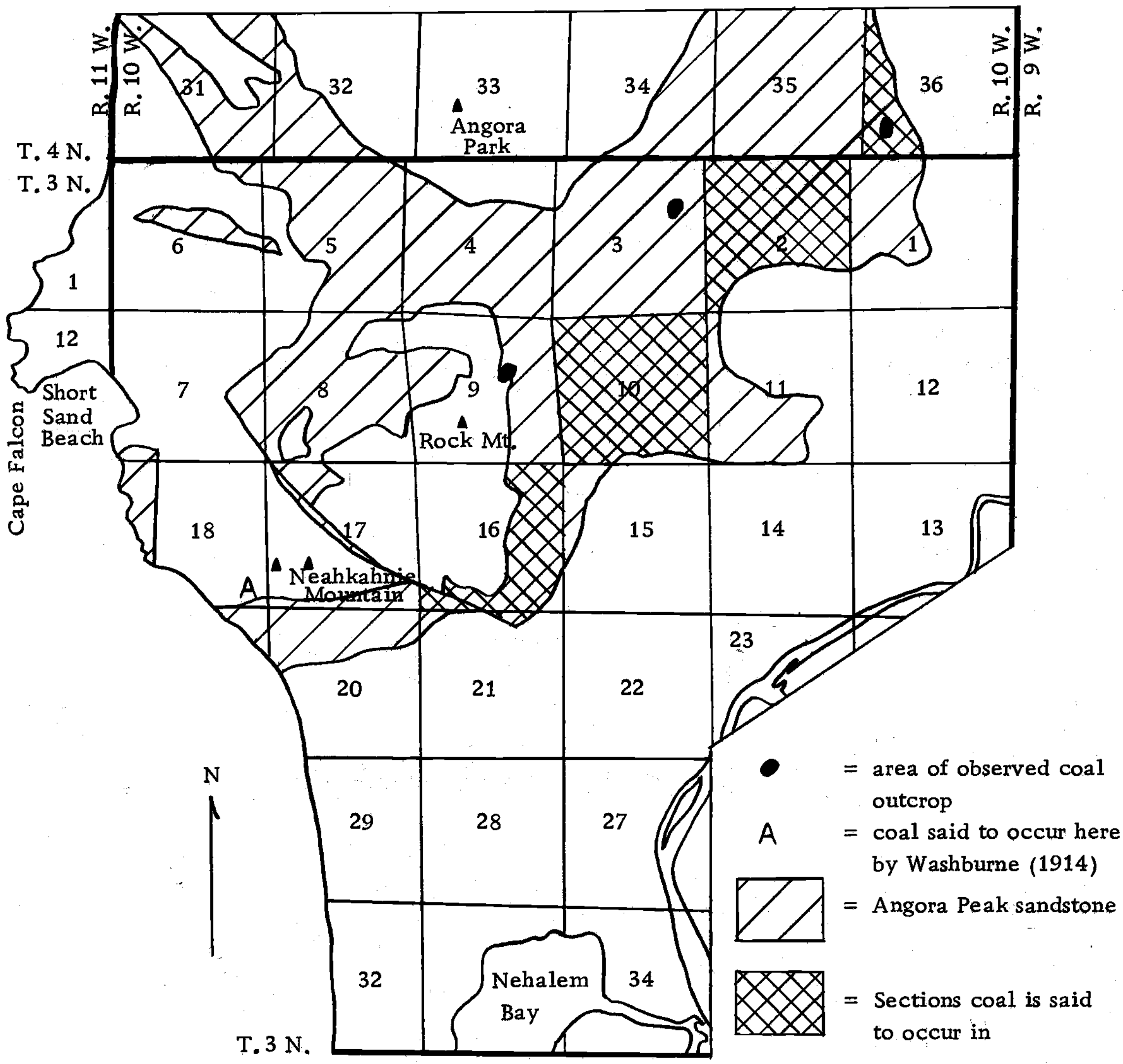

Figure 35. Map of reported coal occurrences in the Neahkahnie Mountain - Angora Peak area. Data from Diller (1896), Washburne (1914), and this work.

Table 5. Laboratory analysis of coals from the Angora Peak sandstone, data from Walker (written commun. 1973) and Diller (1896).

		Sample 17A			Sample 47A			Samples from Diller (1896)		
		as received	moisture free	moisture and ash free	as received	moisture free	moisture and ash free	11	12	13
Proximate analysis	Moisture	5.1	--	--	10.4	--	--	8.08	8.86	8.91
	Volatile matter	23.9	25.1	26.7	39.8	44.4	45.7	41.26	40.06	41.54
	Fixed carbon	65.4	69.0	73.3	47.2	52.7	54.3	46.81	46.79	47.23
	Ash	5.6	5.9	--	2.6	2.9	--	3.85	4.29	2.23
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ultimate analysis	Hydrogen	4.2	3.8	4.1	5.8	5.1	5.3	--	--	--
	Carbon	72.2	76.0	80.7	65.2	72.7	74.9	--	--	--
	Nitrogen	1.2	1.3	1.4	1.3	1.5	1.5	--	--	--
	Oxygen	15.8	11.9	12.7	24.6	17.3	17.8	--	--	--
	Sulphur	1.0	1.1	1.1	0.5	0.5	0.5	1.30	1.31	0.38
	Ash	5.6	5.9	--	2.6	2.9	--	3.85	4.29	2.23
	Total	100.0	100.0	100.0	100.0	100.0	100.0			
	British Thermal Units (BTU's)	12080	12720	13520	11280	12590	12970	--	--	--

part of the Angora Peak sandstone, dipping beneath the hilly and mountainous terrain in the central part of the thesis area, limits the coals development as an economic resource. Because of the large amount of overburden and the limited thickness and lateral extent of the coals, strip mining would be uneconomical. The coal could be mined through shafts, but the soft overlying strata would require extensive timbering which again would be uneconomical because of the small amount of coal available for mining. There is still economic interest in the coal, however, as several coal prospects, dated as recently as April, 1972, were observed in the area.

Petroleum

The necesary requirements for accumulation of petroleum are the combination of reservoir rocks, source beds, entrapment structures, and time. Potential reservoir rocks for petroleum are the fine- to coarse-grained shallow marine and channel sandstones of the middle Miocene Angora Peak sandstone which make up over 70 percent of the unit. Sandstones collected from surface outcrops have very little porosity (1-2%) because of weathering of abundant volcanic rock fragments and feldspars to clay minerals and other alteration products. At depth, below the zone of weathering, the sandstones may be potential reservoirs.

The dark gray color of the underlying Oligocene to early Miocene

Oswald West mudstones suggests the mudstones have a high organic content and may serve as a source rock. One sample of mudstone was treated with 30% hydrogen peroxide (H_2O_2) to remove the organic matter and a three percent weight loss occurred. Washburne (1914) noted that traces of gas were detected in a 1500-foot exploratory oil well drilled by the Necarney Hydrocarbon Oil Company in 1910 on the Nehalem sandspit in section 32, T. 3 N., R. 10 W. From the location of the well and from the sketchy description of the well log (in Washburne) it seems probable that the well was drilled through about 260 feet of estuarine and littoral sediments overlying at least 1200 feet of Oswald West mudstones from which some gas was detected.

Although potential reservoir and source rocks are exposed in the thesis area, the possibility of petroleum accumulation there is not likely because of extensive faulting and intrusion of numerous dikes and sills in the map area. The dikes and sills of Depoe Bay Basalt and the extensive faulting which accompanies the intrusions, occur in a belt along the present Oregon coast (Snavely and others, 1973). If the unit extends far offshore, away from this belt, the Angora Peak sandstone is probably less faulted and therefore more conducive for the accumulation of gas and oil.

The map area has west-northwest-trending folds which, if they continue offshore, might be traps for petroleum. The large anticline exposed in the Cove Beach vicinity north of Cape Falcon is such a structure. Also, rapid lateral and vertical facies changes from channel and littoral sandstones to fine silty mudstones represent possible stratigraphic traps. Braislin and others (1970) are of the opinion that the continental shelf offers the greatest potential for oil in the Pacific Northwest and that "the middle Miocene Astoria Formation . . . offers excellent offshore objectives." However, so far wells drilled offshore have only encountered a fine-grained facies of the Astoria Formation which had very little permeability. The Oswald West mudstones, which are a possible source rock of hydrocarbons, are of the same age as other mudstones exposed along the coast which have a petroliferous odor on a fresh surface. The Nye Mudstone, exposed in the Newport area, is one such formation (Snavely and others, 1969), and Braislin and others (1970) state that similar beds are present offshore on the continental shelf.

Thus, the fact that the Angora Peak sandstone member of the Astoria Formation seems to represent a middle Miocene delta, and the fact that it is associated with source beds and possible stratigraphic and structural traps, indicate that possible petroleum accumulations lie a few miles offshore area from Nehalem to Cannon Beach.

Crushed Rock

The most important mineral resource in the study area is basaltic gravel and crushed rock (Schlicker and others, 1972). Sandstones of the Astoria Formation and Oswald West mudstones are unsuitable, being too soft and being readily decomposed upon weathering.

Two quarries in the study area, located along a large dike of Depoe Bay Basalt in the SE 1/4 of section 10 and in the NE 1/4 of section 15, T. 3 N., R. 10 W., are presently being worked by Tillamook County (Plate I). These quarries appear to meet the requirements necessary to be economically successful. The quarries provide excellent road material (Schlicker and others, 1972), are close enough to population centers, and have a minimum of overburden. The dike containing the quarries appears to be offset a half-mile to the north by faulting and presents another site for a future quarry. Other quarries are located in the SE 1/4 of section 17 and the NE 1/4 of section 3, T. 3 N., R. 10 W.; and although they contain large reserves of material, the amount of overburden is too great or they are too far from a population center to be successful at this time. They are not presently being worked.

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APPENDICES

APPENDIX I

Principal Reference Section A-B

Oswald West Mudstones

Initial point (A): SE 1/4 NE 1/4 of section 12, T. 3 N., R. 11 W. Section starts at base of distinctive convoluted sandstone bed in the seacliffs at the north end of Short Sand Beach, Oswald West State Park, approximately 300 feet southeast of waterfall at north end of cove.

Section trends south along the seacliffs in the cove. Below convoluted sandstone bed lies 200 feet of mudstones and siltstones in contact with the Neahkahnie sill. These rocks have been cut by numerous small faults and have slumped.

Terminal point (B): NW 1/4 SW 1/4 of section 7, T. 3 N., R. 10 W. Section ends at base of inaccessible seacliffs at the south end of Short Sand Beach, Oswald West State Park, approximately 150 feet south of Necarney Creek. Stratigraphically point B lies 200 feet below the base of the Angora Peak sandstone exposed in the seacliffs south of Short Sand Beach (at the SW corner of section 7).

APPENDIX I

Principal Reference Section A-B

Unit	Description	Thickness (feet) Unit	Total
42	Pleistocene alluvium, partially covered by vegetation and Recent alluvium of Short Sand and Necarney Creeks: weathers dark yellowish orange (10YR 6/6); semi-consolidated; clasts are subrounded to rounded pebbles and cobbles (to one foot) of Miocene volcanic rocks (Tidb and Tedb) and older mudstone, siltstone, and sandstone; poorly sorted. Contact: erosional, angular unconformity.	390	1034
41	Argillaceous siltstone: medium light gray (N6), weathers light gray (N7) to very light gray (N8); thin bedded (1-1 1/2 feet); highly burrowed, burrows are tubular and flat-lying; nonresistant; unit contains one 3-inch tuffaceous mudstone bed; laminated. Contact: gradational over 3 inches.	19	644
40	Sandstone: olive gray (5Y 4/1), weathers light olive gray (5Y 6/1); normally graded; coarse-to fine-grained; poorly sorted; feldspathic; top third of unit is mottled by burrowing; resistant, ledge-former. Contact: sharp, planar.	9	625
39	Sandstone: olive gray (5Y 4/1), weathers light olive gray (5Y 6/1); poorly sorted; fine-grained. Contact: gradational over one inch	0.3	616
38	Mudstone and silty mudstone: medium gray (N5) to medium light gray (N6), weathers light gray (N7); thin bedded; concretions (calcareous) found in upper half of unit; contains several very light gray (N8) tuff beds 3 to 5 inches thick; also contains four 4 to 6-inch fine-grained sandstone beds, resistant, forming ribs in the interbedded mudstone; sands are fairly well-sorted, well-cemented by calcium carbonate; interbeds of tuff and sandstone are separated by 5 to 8-foot thicknesses of mudstone. Contact: gradational over six inches.	108	616
37	Sandstone: medium greenish gray (5GY 5/1), weathers greenish gray (5GY 6/1); graded, medium- to fine-grained upward; very poorly sorted, clay matrix throughout; feldspathic; slightly calcareous; mud rip-ups and clasts common near base of unit; horizontal, tubular burrows, 3/4 to one inch diameter to one foot long near top of unit; resistant, ledge former. Contact: sharp and planar.	5	508

Unit	Description	Thickness Unit	(feet) Total
36	Mudstone: medium gray (N5) to medium light gray (N6), weathers light gray (N7); very thinly bedded; rhythmically bedded, two-inch thick calcareous mudstone beds alternate with less resistant, crumbly, one- to two-inch mudstone beds, very slightly calcareous; minor silty mudstone beds and one tuffaceous, very light gray (N8) mudstone bed, three inches thick; entire unit is fossiliferous, contains scaphopods, gastropods, pelecypods, abundant fish scales (Fossil locality 53-39); small-scale (1/2-inch) flame structures in mudstone bed indicate paleoslop to west or southwest. Contact: sharp and planar, lower 10 feet cut by a 1 to 3-inch sandstone dike.	24.5	503
35	Sandstone: light olive gray (5Y 6/1), weathers yellowish gray (5Y8/1); graded, coarse- to medium-grained near base, fine- to medium-grained near top; angular to subangular grains; feldspathic, contains large (1 to 2 mm) muscovite flakes; thinly laminated, in places large-scale, low angle, thin, cross-laminations are present but poorly defined; lower half of unit contains abundant pebble-sized (1/4 to 3 inches) mudstone rip-ups oriented parallel to bedding; clasts grade in size upward; thickness of unit is variable, 8 inches to two feet; resistant, ledge-former. Contact: very irregular, large clasts from underlying slump protrude into and in places almost project through this sandstone unit; 1 to 3-inch sandstone dike leaves unit into overlying unit; sharp bottom contact.	1-2	478.5
34	Mudstone conglomerate: (submarine slump); medium light gray (N6), weathers light gray (N7); clasts range from one inch to seven feet in diameter; clasts variable in lithology, chiefly mudstone, minor siltstone, tuffaceous mudstone, calcareous mudstone, sandstone; clasts both in grain support and floating in silty mudstone matrix; sparsely fossiliferous, minor mollusks. Contact: gradational over one foot, obscured.	13	476.5
33	Mudstone: medium gray (N5) to medium light gray (N6), weathers light gray (N7); thin bedded, well-bedded 3-inch beds; slightly calcareous; contains minor silty mudstone and two sandstone dikes cutting bedding at high angles; sandstone like unit 35; individual dikes bifurcate and rejoin, range in thickness from 1 1/2 to five inches, thicker at base of unit, one dike continues through 34 into unit 36; sparsely fossiliferous, containing mollusks, foraminifera. Contact: gradational over one foot.	20	463.5

Unit	Description	Thickness Unit	(feet) Total
32	Siltstone and mudstone conglomerate: (submarine slump); very similar to unit 34; contains clasts of fine-grained sandstone, siltstone, and mudstone to 10 feet in diameter; clastic dike described in unit 33 observed in upper two feet of unit. Contact: appears even but is obscured.	50	443.5
31	Sandstone: light gray (N7), weathers medium olive gray (5Y 5/1); fine-grained; thinly laminated with carbonaceous material; micaceous; slightly calcareous; forms resistant rib; variable thickness. Contact: sharp and planar.	0.8	393.5
30	Silty mudstone: medium light gray (N6), weathers light gray (N7); slightly calcareous; fossiliferous, contains pelecypod impressions along bedding (Yoldia longissima); non-resistant; (Fossil locality 51-36).	4	392.7
29	Covered by colluvium and vegetation; probably mudstone or silty mudstone.	55	388.7
28	Mudstone: yellowish gray (5Y 7/2), weathers dark yellowish gray (5Y 6/2); contains two 10-inch, well laminated sandstone beds (at 15 and 18 feet above base) like unit 31; unit is not resistant, sandstone beds form ribs. Contact: gradational over one foot.	18	333
27	Mudstone: as unit 38; contains a 2 1/2-inch sandstone bed at 5 feet above base of unit; very fine-grained sandstone, thinly laminated and convoluted, pinches out toward top of cliff. Contact: gradational over two feet.	20	315
26	Mudstone: medium light gray (N6), weathers light gray (N7); highly burrowed, mottled; non-resistant, breaks into very small angular chips; unit is partially covered. Contact: sharp, even and planar.	32	295
25	Silty mudstone: medium light gray (N6), weathers light gray (N7); slightly calcareous; forms a resistant rib. Contact: sharp, even and planar.	0.8	263
24	Mudstone: like unit 26; contains a two-inch tuffaceous mudstone bed, very light gray (N8) in lower part of unit. Contact: gradational over 1/2 inch, even and planar.	23	262
23	Siltstone: light gray (N7), weathers olive gray (5Y 4/1); very thinly laminated; calcareous, well cemented; well sorted; forms resistant rib. Contact: sharp and planar	1.5	239

Unit	Description	Thickness Unit	(feet) Total
22	Mudstone: as unit 26	3	237.5
21	Covered by vegetation and colluvium; probably mudstone or silty mudstone.	35	234.5
20	Mudstone: as unit 26; contains one four-inch tuffaceous mudstone bed, very light gray (N8); burrowed; unit contains a few 2- to 3-inch calcareous concretions.	30	199.5
19	Covered by vegetation and colluvium; probably mudstone.	27.5	169.5
18	Mudstone: as unit 26; contains a few very thin (one inch thick) tuffaceous mudstone beds, very light gray (N8); burrowed.	10	142
17	Covered by vegetation and colluvium; probably mudstone.	19	132
16	Mudstone and sandy siltstone: three siltstone beds separated by mudstone beds like unit 26; siltstone is very light olive gray (5Y 4/1), weathers olive gray (5Y 4/1); coarse-grained siltstone to very fine-grained sandstone; very thinly laminated with carbonaceous material; micaceous; mudstone partings; calcareous; sharp, planar bases of silts and sands, tops gradational over 1/2-inch; beds 1 1/2 to 2 feet thick; located at base, middle, and top of unit.	13	113
15	Covered by vegetation and colluvium; probably mudstone.	11.5	100
14	Mudstone and siltstone: mudstone like unit 26; siltstone like those in unit 16; unit contains five tuffaceous siltstone beds, 5 to 9 inches thick; evenly spaced with mudstone beds approximately four to five feet thick; some siltstone beds contain micro-cross laminations.	24	88.5
13	Covered by vegetation and colluvium; probably mudstone.	9	64.5
12	Siltstone and mudstone: light gray (N7), weathers yellowish gray (5Y 8/1); very thinly to thinly laminated, 1 to 2-inch beds of siltstone alternate with 1/2-inch or less mudstone beds; siltstone is very thinly cross-laminated; intensively burrowed, burrows are tubular and horizontal, also radial; burrows are differentially weathered, give unit a mottled to lumpy surface; resistant, ledge-former. Contact: sharp and planar.	1.2	55.5

Unit	Description	Thickness Unit	(feet) Total
11	Mudstone: same as unit 26; but slightly calcareous; contains six very thin, tuffaceous siltstone beds; very light gray (N8); very fine-grained; highly burrowed, commonly by tubular burrows oriented parallel to bedding; abundant foraminifera fauna (Fossil locality 51-13); non-resistant. Contact: planar, gradational over two inches.	13.5	54.3
10	Siltstone and mudstone: as unit 12.	3	40.8
9	Mudstone: as unit 26; contains three siltstone beds 3 to 5 inches thick like those described in unit 16. Contact: gradational over 1/2 inch.	12.8	37.8
8	Siltstone: very light gray (N8), weathers yellowish gray (5Y 8/1); fine-grained; tuffaceous; very thinly laminated and cross-laminated; well-cemented; contains large tubular burrows parallel to bedding; also thin 1/4-inch mudstone partings; resistant, rib-former. Contact: sharp and planar.	1	25
7	Mudstone: medium light gray (N6), weathers light gray (N7); grades from very thinly laminated mudstone and siltstone near base to a highly burrowed mudstone like unit 26 at the top; non-resistant. Contact: planar, gradational over three inches.	8	24
6	Sandstone: very light gray (N8), weathers yellowish gray (5Y 8/1); well-bedded, laminated; well-cemented; calcareous; well-sorted; fine-grained; feldspathic; middle three inches contain thin mudstone partings. Contact: sharp, planar.	1.3	16
5	Mudstone: as unit 26. Contact: sharp, planar.	1.4	14.7
4	Siltstone: as unit 8. Contact: sharp, planar.	1	13.3
3	Mudstone: as unit 26; contains patchy areas containing small burrows. Contact: planar, gradational over two inches.	1.8	12.3
2	Sandstone and mudstone: alternating thin beds of sandstone and mudstone; sandstone like unit 6, occurs in 2 to 3-inch beds; mudstone as unit 26, occurs in 1/2-inch beds; abundant Scalarituba burrows and long tubular burrows. Contact: gradational; there is a loss of the convoluted nature of the underlying bed.	3.5	10.5

Unit	Description	Thickness Unit	(feet) Total
1	Sandstone: convoluted bed; sandstone like unit 6; unit contains large-scale convoluted bedding; large synclinal troughs to two feet in diameter, sharp anticlinal crests; mudstone laminae between two-inch sandstone beds; calcareous cement; many tubular burrows in lower part; unit is resistant, ledge-former. Contact: sharp and planar above mudstone like that of unit 26.	7	7

APPENDIX II

Principal Reference Section C-D

Angora Peak Sandstone Member of the Astoria Formation

Initial point: NE 1/4 SE 1/4 of section 3, T. 3 N., R. 10 W. At junction where southeast-flowing creek meets the West Fork of Coal Creek. Section is located up the southeast-flowing creek along the sides and bottom of the creek. Stratigraphically the initial point (C) is located about 400 to 500 feet above the base of the Angora Peak sandstone.

The section is accessible by walking approximately one mile up the West Fork of Coal Creek from Coal Creek or from a large gravel quarry in NW 1/4 NE 1/4 of section 3, T. 3 N., R. 10 W.; the quarry is reached from a logging road that leaves Short Sands Main Line at NE 1/4 NW 1/4 of section 10, T. 3 N., R. 10 W. Take right fork to the northwest.

Terminal point: NE 1/4 NE 1/4 of section 3, T. 3 N., R. 10 W., approximately 200 feet south of northwest bend in stream trending toward large intrusion. "D" is located approximately 800 feet due east of quarry mentioned above. Stratigraphically, point D lies approximately 200 to 300 feet below top of unit.

APPENDIX II

Principal Reference Section C-D

Unit	Description	Thickness Unit	(feet) Total
33	Sandstone: yellowish gray (5Y 7/2), weathers dark yellowish orange (10YR 6/6); fine-grained; fairly well-sorted; very thinly laminated; carbonaceous material forms laminations; contains minor siltstone interbeds.	33	938
32	Covered by colluvium and vegetation.	40	905
31	Sandstone: yellowish gray (5Y 7/2), weathers dark yellowish orange (10YR 6/6); coarse- to fine-grained; fairly well-sorted; lower part of unit contains coarse-grained sandstone lenses to two feet wide and six inches thick in medium-grained sand; upper part is fine- to medium-grained, lacks lenses; thinly laminated; contains minor silty interbeds 1/4 to 1/2 inch thick; sands are feldspathic, micaceous. Contact: gradational over three feet.	90	865
30	Sandstone and pebbly sandstone: greenish gray (5G 6/1), weathers to a moderate yellowish brown (10YR 5/4); sand is medium- to coarse-grained, pebbles average 1/2 inch diameter, range to one inch; pebbles composed predominantly of intermediate volcanics and pumice (see Appendix VI, sample 53-32); poorly sorted; thin-bedded, beds range from three inches to one foot thick; some beds contain (lower part of unit) large-scale trough (?) cross-beds with pebbles, cross-beds are normally graded; conglomerate lenses common, to three feet across, eight inches thick; unit contains minor thin (2-3 inches) silty mudstone beds, medium dark gray (N4), carbonaceous; also minor calcareous concretions to three inches in diameter and minor coalized wood; resistant, well indurated. Contact: gradational over one foot.	26	775
29	Sandstone: greenish gray (5G 6/1), weathers dark yellowish orange (10YR 6/6); fine-grained; fairly well-sorted, appears massive; feldspathic, micaceous.	4	749
28	Covered: appears to be a two-foot wide cleft between sandstone units on either side of the creek; filled with colluvium; appears to be something soft (mudstone(?)) which has eroded.	2	745

Unit	Description	Thickness Unit	(feet Total
27	Sandstone: light olive gray (5Y 6/1), weathers dark yellowish orange (10 YR 6/6); coarse-grained; contains scattered pebbles; poorly sorted; pebbles to 1/4 inch; pumiceous; feldspathic; micaceous; thin bedded to thinly cross-bedded, large-scale trough cross-beds common (coarser material concentrated here), resistant, forms steep sides of creek. Contact: gradational over five feet.	35	743
26	Sandstone: greenish gray (5GY 6/1), weathers dark yellowish orange (10YR 6/6); fine-grained; well- to fairly well-sorted; very thinly laminated and cross-laminated, cross-laminations are large scale and appear planar; sand is feldspathic, micaceous; fairly resistant unit.	95	708
25	Covered by colluvium and vegetation.	11	613
24	Sandstone: as unit 22; fossiliferous, fossils appear to be thin-shelled, many leached, gastropods and pelecypods; fossils occur at distinct horizons, beds 2-3 inches thick, shell hash; beds at 20 feet, 30 feet, and 32 feet above contact with unit 23; only scattered fossils outside of these thin beds. Contact: sharp and planar, at fossil horizon.	50	602
23	Sandstone: minor mudstone and siltstone, similar to unit 21; many structures present, predominantly small scale cross-laminations, to two inches; parallel laminations; convolute bed six inches thick at 8 feet from base; small channels present approximately one foot deep, six feet wide, cut into sandstone and mudstone inter-beds; unit grades upward into clean sand, last five feet like unit 22. Contact: sharp and planar, at two inch shell bed.	20	552
22	Siltstone and sandstone: medium greenish gray (5GY 5/1), weathers dark yellowish orange (10YR 6/6); sandstone is very fine-grained; poorly sorted; very thinly laminated; contains fossil beds at top and bottom of unit (fossil sample 53-22), gastropods and pelecypods. Contact: even and planar; at shell bed 2-3 inches thick.	7	532
21	Sandstone, siltstone, minor mudstone: medium greenish gray (5GY 5/1), sandstone weathers yellowish orange (10YR 6/6); mudstone is dark gray (N3); unit is very thinly laminated and cross-laminated, bedding is disrupted by burrowing and soft sediment deformation (minor convoluted bedding), in cross-stratifications are festoons small-scale troughs, 2-12 inches wide; sandstone and siltstone are muddy; mudstones are very carbonaceous with some coaly seams; mudstone surfaces are undulatory, beds are unevenly thick and are cut and filled by sandstone and siltstone channels,		

Unit	Description	Thickness Unit	(feet) Total
21	1/2-1 inch deep; bedding is 1-2 inches thick; units are thinly laminated. Contact: gradational over one foot.	21	525
20	Pebble conglomerate: light olive gray (5Y 6/1), weathers dark yellowish orange (10YR 6/6), pebbles to 1 1/2 inches in diameter, average 1/2 inch; composed predominantly of basalt, intermediate volcanics, and quartzite (see Appendix VI, sample 53-20). Contact: scour-and-fill, maximum 1- 1 1/2 feet wide by 6-8 inches deep.	1-2	504
19	Sandstone: medium gray (N5), weathers dark yellowish orange (10YR 6/6); medium-grained; fairly well-sorted; contains scattered pebbles in lower third of unit; sand is feldspathic, micaceous; thinly laminated and cross-laminated, trough (large-scale) cross-beds, 1-2 feet wide, 4-8 inches deep. Contact: sharp and planar.	35	502
18	Siltstone: medium dark gray (N4), weathers grayish black (N2) (wet) or light brown (5YR 5/6) (dry); muddy; contains abundant plant material in the form of leaf and plant fragments; also contains large (to 3 mm.) muscovite flakes. Contact: sharp and planar.	0.3	467
17	Pebbly sandstone: light olive gray (5Y 6/1), weathers light brown (5YR 6/1); medium- to coarse-grained matrix; poorly sorted; pebbles average 1/4-inch diameter, range to 1/2-inch; variable thickness of unit, lens(?). Contact: large (4-foot) scour-and-fill (6 inches deep).	1-1.5	466.5
16	Sandstone: medium gray (N5), weathers dark yellowish orange (10YR 6/6); medium- to coarse-grained; fairly well sorted; feldspathic, micaceous.	2	465
15	Covered by colluvium and vegetation.	70	463
14	Muddy siltstone: greenish gray (5GY 6/1), weathers dark yellowish orange (10YR 6/6); very thinly laminated with carbonaceous layers, in places these layers are disrupted as if by roots, burrows; local very small coaly seams in lower part of unit (1/4-inch thick by 4 inches long maximum). Contact: gradational over five inches, amount of carbonaceous material decreases upward.	9	393

Unit	Description	Thickness Unit	(feet) Total
13	Carbonaceous siltstone: dark gray (N3) to grayish black (N2), weathers medium dark gray (N4) to dark gray (N3); muddy; highly carbonaceous, unit contains many thin (1/4-1/2 inch) subbituminous coal seams 3-6 inches long, it also contains one large 6-inch by 1 1/2-foot subbituminous coal lens in center of unit; siltstone is very thinly laminated. Contact: gradational over 4 inches, amount of carbonaceous material increases upward abruptly over this interval.	3.5-4	384
12	Muddy siltstone: greenish gray (5GY 6/1), weathers moderate yellowish brown (10YR 5/4); contains very small coal seams in upper two feet; carbonaceous. Contact: gradational over 4 to 5 feet, upward increase of finer material, loss of coarser material.	5	380
11	Sandstone: medium gray (N5), weathers dark yellowish orange (10YR 6/6); medium- to coarse-grained with scattered pebbles to 1/4-inch diameter; poorly sorted; unit contains many 2- to 3-foot wide lenses, 4 to 8 inches thick; coarser grained at base of unit (coarse to very coarse sand and pebbles), finer grained at top (fine and medium sand); unit is thinly cross-laminated in places; sand is feldspathic, micaceous, contains minor pumice; upper 5-7 feet is fine- to medium-grained sand, very thinly laminated to cross-laminated, abundant carbonaceous material.	33	375
10	Covered by colluvium and vegetation.	95	342
9	Sandstone: greenish gray (5G 6/1), weathers light brown (5YR 5/6); fine-grained; fairly well-sorted; unit is partially covered, non-resistant.	20	247
8	Covered by colluvium and vegetation.	45	227
7	Sandstone: greenish gray (5G 6/1), weathers light brown (5YR 5/6); fine-grained; fairly well sorted; very thinly laminated to cross-laminated; low-angle, large-scale planar cross-laminations; micaceous; resistant unit, forms steep sides of creek; carbonaceous layers near top. Contact: erosional, undulatory, minor scour-and-fill (1 1/2 feet by 6 inches).	35	182
6	Sandstone: medium gray (N5), weathers moderate yellowish brown (10YR 5/4) to moderate yellowish orange (10YR 6/4); fine- to very fine-grained; very micaceous; very thinly laminated to cross-laminated; cross-laminations are planar, low-angle; carbonaceous material common along laminations. Contact: obscured, appears planar and even.	13.5	147

Unit	Description	Thickness Unit	(feet) Total
5	Siltstone and sandstone: medium gray (N5), weathers moderate yellowish orange (10YR 6/4); sandstone is fine- to very fine-grained; fair sorting; carbonaceous, micaceous, feldspathic; siltstone and sandstone are very thinly laminated and interbedded; unit contains minor mudstone interbeds 1/4-inch wide, dark gray (N3); small sandstone channels are present in unit 1 to 2 feet wide and 3-5 inches thick; unit is partially covered by colluvium. Contact: sharp and undulatory, minor scouring (3 inches by 1/4-inch deep).	5.5	133.5
4	Sandstone: as unit 6. Contact: gradational over three inches.	2	128
3	Siltstone: dark olive gray (5Y 5/1), weathers light olive gray (5Y 5/2); carbonaceous, contains abundant impressions of twigs, leaf fragments on bedding planes; micaceous; very thinly laminated; contains scattered fine-grained sand grains; unit is non-resistant.	6	126
2	Covered by colluvium and vegetation; probably siltstone, minor mudstone and sandstone; at 50 feet above base of this unit colluvium contains abundant poorly sorted, medium- to coarse-grained arkosic sandstone weathering a yellowish orange (10YR 6/6).	90	120
1	Siltstone: olive gray (5GY 4/1), weathers same (wet) to light olive gray (5Y 5/2) (dry); argillaceous, poorly sorted; contains scattered 1/2-inch diameter tubular burrows(?) or root casts(?) aligned in groups along a bedding plane, infilled with a lighter colored sediment; contains minor calcareous concretions, these are also aligned in groups along bedding planes; when dry, the siltstone breaks into small fragments; non-resistant, found in stream bottom.	30	30

APPENDIX III

LOG OF NECARNEY HYDROCARBON OIL COMPANY WELL

Date drilled: 1910
Depth: 1500 feet
Elevation: 35 feet
Location: section 32, T. 3 N., R. 10 W.

Description	Thickness	Depth
Sand, yellow	60 feet	60 feet
Clay	5	65
Sand, gray	10	75
Clay, blue	10	85
Sand, gray	10	95
Clay, with clamshells	15	110
Sand, gray	5	115
Clay, with clamshells	135	250
Beach boulders, with traces of gas	5	255
Sand, black	5	260
Hardpan	45	305
Shale	5	310
Hardpan	20	330
Shale	15	345
Clay and shale	30	375
Sandstone	10	385
Shale, light colored	10	395
Shale, dark brown	10	405
Shale, light colored	55	460
Shale, brown	50	510
Slate, white	10	520
Shale, brown	30	550
Shale, loose, caving	10	560
Shale, blue	15	575
Shale, loose, caving	10	585
no log, record to bottom, a little gas reported	915	1500

Log from Washburne (1914)

Interpretation of log with respect to units reported in thesis:

0-60 feet	Quaternary beach and dune sand
60-260 feet	Quaternary alluvium and estuarine, minor amounts of beach and dune sand
260-1500 feet	Late Oligocene to early Miocene Oswald West mudstones

APPENDIX IV

CHECKLIST OF FOSSILS FROM THE OSWALD WEST MUDSTONES

	Locality							
BIVALVIA	A	B	C	D	E	F	G	H
Acila gettysburgensis (Reagan)	X	-	-	-	-	-	-	-
Lima cf. L. twinensis Durham	X	-	-	-	-	-	-	-
Lima n. sp.	X	-	-	-	-	-	-	-
Macoma lorenzoensis arnoldi Tegland	X	-	-	-	-	-	-	-
Macoma twinensis Clark	X	-	-	-	-	-	-	-
Nuculana alkiensis (Clark)	X	-	-	-	-	-	-	-
Solen cf. S. clallamensis Clark & Arnold	?	-	-	-	-	-	-	-
Volsella cf. V. restorationensis (Van W.)	X	-	-	-	-	-	-	-
Yoldia cf. Y. longissima Slodkewitsch	-	-	-	-	-	X	-	-
GASTROPODA								
Echinophoria apta (Tegland)	X	-	-	-	-	-	-	-
Echinophoria rex (Tegland)	X	-	-	-	-	-	-	-
Priscofusus cf. P. stewarti (Tegland)	-	-	X	-	-	-	-	-
SCAPHOPODA								
Dentalium sp.	-	-	-	X	-	-	-	-
FORAMINIFERA								
Anonalina californiensis Cushman & Hobson	-	X	X	-	-	-	-	-
Bolivina cf. B. advena Cushman	-	-	-	-	X	-	-	-
Buccella mansfieldi oregonensis (Cushman & Stewart)	-	-	-	-	X	-	-	-
Buliminella subfusiformis Cushman	-	-	-	-	X	-	-	-
Cassidulina cf. C. crassipunctata Cushman	-	X	X	-	-	-	-	-
Dentalina spp.	-	-	X	-	-	-	-	-

APPENDIX IV (Continued)

	Locality							
FORAMINIFERA (continued)	A	B	C	D	E	F	G	H
Elphidium cf. E. minutum Cushman	-	-	X	-	-	-	-	-
Eponides cf. E. umbonatus (Reuss)	-	-	X	-	-	-	-	-
Globigerina sp.	-	-	-	-	X	-	-	-
Gyroidina orbicularis planta Cushman	-	X	X	-	-	-	-	-
Nonion costiferum (Cushman)	-	-	-	-	X	-	-	-
Pseudoglandulina inflata (Bornemann)	-	X	X	-	-	-	-	-
Robulus spp.	-	X	X	-	-	-	-	-
Uvigerina cf. U. garzaensis Cushman & Siegfus	-	X	-	-	-	-	-	-
Uvigerina obesa impolita Cushman & Laiming	-	-	-	-	X	-	-	-
Uvigerinella cf. U. obesa impolita Cushman & Laiming	-	-	X	-	-	-	-	-
TRACE FOSSILS								
Chondrites	-	-	-	-	-	-	X	-
Helminthopsis labyrinthica (fecal back-filled)	-	-	-	-	-	-	X	-
Lophoctenium	-	-	-	-	-	-	-	X
Planolites	-	-	-	-	-	-	X	-
Scalarituba (fecal ribbon form)	-	-	-	-	-	-	X	-
Scalarituba (radial meniscate form)	-	-	-	-	-	-	X	-
Taeinidum annulata	-	-	-	-	-	-	X	-
Teichichnus	-	-	-	-	-	-	X	-
Zoophycos	-	-	-	-	-	-	X	-

APPENDIX IV (Continued)

LEGEND

Locality	Field No.	USGS Cenozoic Loc.	Section	Twp.	Rng.
A*	--	--	--	--	--
B	51-13	--	12	3N.	11W.
C	51-37	M5805	7	3N.	10W.
D	51-39	M5806	7	3N.	10W.
E	30B	--	5	3N.	10W.
F	51-36	M5804	12	3N.	11W.
G	51-Tr.	--	12	3N.	11W.
H	1-Tr.	--	18	3N.	10W.

*reported from Warren and others (1945)

Note: see Plate I for fossil localities, measured section for 51-13, 51-36, 51-37, and 51-39

APPENDIX V

CHECKLIST OF FOSSILS FROM THE ANGORA PEAK SANDSTONE MEMBER OF THE ASTORIA FORMATION

	Locality					
BIVALVIA	A	B	C	D	E	F
Acila conradi (Meek)	-	-	-	-	-	X
Acila gettysburgensis (Reagan)	-	-	-	-	?	-
Acila sp.	-	X	-	-	-	-
Anadara sp.	-	X	-	-	-	-
Anadara spp.	-	-	X	X	-	-
Cyclocardia sp.	-	-	-	X	-	-
Katherinella sp.	-	-	-	-	-	?
Litorhadia astoriana (Henderson)	-	-	-	X	-	-
Mytilus middendorffi Grewingk	-	-	X	-	-	-
Nuculana sp.	-	-	-	-	-	X
Nuculanid	-	-	-	X	-	-
Panopea	-	-	-	X	-	-
Securella cf. S. ensifera (Dall)	-	-	-	-	-	X
Solen curtus Conrad	-	-	-	-	-	X
Solen perrini Clark	X	-	-	-	-	-
Spisula albaria (Conrad)	-	X	X	X	-	-
Spisula cf. S. albaria (Conrad)	-	-	-	-	-	X
Tellina emacerata Conrad	-	-	X	-	-	-
Vertipecten fucanus (Dall)	-	-	-	X	-	X
Yoldia (Megayoldia) sp.	-	-	-	-	-	X
Yoldia cf. Y. cooperi Gabb	-	X	X	-	-	-
GASTROPODA						
Bruclarkia oregonensis (Conrad)	-	-	-	X	-	X
Cancellaria oregonensis (Conrad)	-	-	X	-	-	-
Cancellaria cf. C. oregonensis (Conrad)	-	-	-	X	-	-

APPENDIX V (Continued)

	Locality					
	A	B	C	D	E	F
GASTROPODA (Continued)						
Cryptonatica oregonensis (Conrad)	-	-	X	-	-	-
Naticid	-	X	X	X	-	-
Ophiodermella workensis (Etherington)	-	-	-	X	-	-
Turrid	-	X	-	-	-	-
Xenuroturris antiselli (Anderson and Martin)	-	-	-	?	-	-
FORAMINIFERA						
Bolivina cf. B. advena Cushman	-	-	-	X	-	-

Locality	Field No.	USGS Cenozoic Loc.	Section
A	41	M5802	11*
B	18	M5803	3*
C	19	M5807	4*
D	53-22	M5808	3*
E	16	M5809	10*
F	13B	M5816	1**

*T. 3 N., R. 10 W.

**T. 3 N., R. 11 W.

Note: see Plate I for fossil localities.

APPENDIX VI

PEBBLE LITHOLOGIES OF CONGLOMERATES IN THE ANGORA PEAK SANDSTONE MEMBER OF THE ASTORIA FORMATION

Pebble type	Sample 15 (sec. 10)**	Sample 13* (sec. 1)		Sample 32 (sec. 1)	Sample 21 (sec. 8)	Sample 53-20 (sec. 3)	Sample 31 (sec. 3)	Sample 53-32 (sec. 3)	Sample 48* (sec. 5)	
Basalt	86%	66%	72%*	26%	16%	26%	28%	11%	21%	26%*
Intermed. volcanic	10%	21%	23%	50%	56%	41%	40%	47%	24%	30%
Rhyolite	--	3%	3%	2%	8%	--	2%	5%	5%	6%
Pumice	4%	1%	1%	6%	8%	8%	11%	21%	22%	27%
Weld. tuff	--	1%	1%	4%	3%	1%	1%	2%	1%	1%
Chert	--	--		1%	6%	4%	1%	5%	2%	2%
Quartz	--	Tr.		3%	2%	4%	1%	5%	4%	5%
Quartzite	--	Tr.		9%	1%	14%	13%	6%	2%	2%
Metamorph.	--	Tr.		--	--	--	--	1%	--	
Plutonic	--	--		--	--	--	--	--	1%	1%
Sediment.	--	8%	--	--	--	2%	3%	2%	19%	--

*recalculated without sedimentary clasts

**see Plate I for sample locations (samples in T. 3 N., R. 10 W., except sample 13, in T. 3 N., R. 11W.)

Tr. - trace, observed in outcrop but not counted.

APPENDIX VII

MODAL ANALYSES OF SANDSTONE SAMPLES FROM "OSWALD WEST MUDSTONES" AND "ANGORA PEAK SANDSTONES" IN APPROXIMATE STRATIGRAPHIC ORDER

	Oswald West mudstones			Angora Peak sandstones			
Sample No.	51-1	51-36	54-2	54-4	33A	10B	21C
Cement ($CaCO_3$)	1	4	--	--	32	--	--
Matrix	47	23	3	30	2	4	12
Grains	50	73	95	70	66	94	88
Stable Grains							
Quartz	19	21	32	23	15	38	31
Quartzite	--	Tr.	--	--	Tr.	--	--
Chert	1	2	1	1	1	3	4
Feldspar							
Plagioclase	8	21	17	21	14	15	15
K-spar	2	1	6	4	3	5	5
Rock Fragments							
VRF	6	22	18	16	23	22	21
IRF	--	--	--	--	--	Tr.	1
MRF	Tr.	--	--	--	1	Tr.	1
SRF	1	4	--	Tr.	Tr.	--	--
Mica	5	4	4	1	1	1	1
Mafic	4	--	1	Tr.	2	Tr.	1
Opaque	3	1	3	1	4	1	Tr.
Other	1	--	1	Tr.	2	Tr.	1
Glauconite	--	--	--	--	--	--	--
Alteration minerals	--	--	12	3	--	9	7
Porosity	--	--	2	--	Tr.	2	--

Tr. - less than 0.5%

See Plate I for sample locations

Sample No.	47	53-8	53-22	53-28	35	6A	6B	6C
	Angora Peak sandstones							
Cement C_aCO_3	--	--	39	--	--	11	--	--
Matrix	9	13	8	10	18	15	13	9
Grains	89	86	52	89	82	74	86	87
Stable Grains								
Quartz	43	26	17	32	37	21	36	38
Quartzite	Tr.	--	--	--	Tr.	--	--	--
Chert	3	2	--	1	4	1	1	1
Feldspars								
Plagioclase	17	23	14	22	15	16	12	16
K-spar	3	6	3	4	5	3	6	4
Rock Fragments								
VRF	19	6	5	9	10	5	8	13
IRF	--	--	--	--	1	--	--	--
MRF	1	--	--	--	--	--	--	1
SRF	--	--	Tr.	--	Tr.	--	--	--
Mica	1	4	1	5	1	3	8	6
Mafic	Tr.	1	1	Tr.	1	Tr	1	2
Opaque	1	5	7	1	Tr.	Tr.	2	1
Other	1	1	1	Tr.	--	Tr.	2	1
Glauconite	--	--	Tr.	--	--	20	--	--
Alteration minerals	--	12	3	15	7	5	10	6
Porosity	2	1	1	1	--	--	1	2

Tr. - less than 0.5%

See Plate I for sample locations

APPENDIX VIII. SIZE ANALYSES OF SELECTED SANDSTONE SAMPLES. Samples in approximate stratigraphic order. Statistical parameters are those of Inman (1952); (See Plate I for sample locations.)

Sample	Sand %	Silt %	Clay %	Coarsest 1%, mm	Median mm	Median phi	Mean phi	Sorting phi	Skewness phi	2nd Skewness phi	Kurtosis phi
Angora Peak sandstones											
48	78	17	5	0.24	0.10	3.30	3.84	1.12	0.48	--	--
19	84	--	--	0.23	0.11	3.27	3.39	0.61	0.20	--	--
53-28	82	--	--	0.20	0.10	3.33	3.46	0.64	0.20	--	--
53-13	91	4	5	0.35	0.18	2.45	2.67	0.69	0.32	2.70	2.90
46	94	--	--	1.23	0.41	1.27	1.56	0.95	0.30	0.86	1.08
47	86	2	0	3.74	1.15	-0.20	0.14	1.04	0.33	0.78	1.09
41	83	12	5	0.24	0.12	3.12	2.34	0.85	-0.92	1.95	2.09
10	94	4	2	0.53	0.36	1.49	1.96	1.24	0.38	1.08	0.96
3	59	33	8	0.19	0.07	3.78	4.85	1.75	0.61	--	--
13	89	--	--	1.73	0.31	1.70	2.15	1.37	0.33	--	--
49	76	15	9	0.19	0.07	3.78	4.85	1.75	0.61	--	--
Oswald West mudstones											
51-36	66	25	9	0	0.10	3.27	4.32	1.98	0.53	--	--

APPENDIX IX

HEAVY MINERALOGY OF SELECTED SAMPLES. SAMPLES IN APPROXIMATE STRATIGRAPHIC ORDER

(A = abundant, P = present, T = trace), see Plate I for sample locations.

	Sample	Green hornblende	Basaltic hornblende	Garnet	Augite	Hypersthene	Epidote	Zircon	Apatite	Tourmalene	Staurolite	Rutile	Mica	Opaque	Other
Angora Peak sandstones	19	T	-	P	T	P	-	T	T	T	-	-	A	A	-
	53-28	P	T	T	-	-	T	T	T	T	-	T	A	A	-
	53-13	-	-	A	P	T	-	P	-	T	T	T	A	A	T
	46	P	-	T	-	-	P	T	T	T	T	T	A	A	-
	47	T	T	P	T	-	T	T	-	-	-	-	A	P	-
	41	T	-	-	T	T	-	P	-	-	-	-	P	A	-
	10B	P	T	A	T	-	T	T	-	T	-	T	A	A	-
	3	-	-	T	T	P	T	P	-	-	-	-	A	A	-
	13	-	-	T	A	T	-	-	-	-	-	T	T	-	-
Oswald West mudstones	51-36	-	-	A	T	T	T	T	-	T	T	T	A	A	-