AN ABSTRACT OF THE THESIS OF

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Title: GEOLOGY OF THE SEASIDE-YOUNG'S RIVER FALLS AREA, CLATSOP COUNTY, OREGON

Abstract approved: Alan R. Niem

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Eight Tertiary geologic units crop out in the Seaside-Young's River Falls area, including late Oligocene to early Miocene Oswald West mudstones; Angora Peak sandstone and Silver Point members of the middle Miocene Astoria Formation; and middle Miocene Depoe Bay and Cape Foulweather Basalts. Three new lithologically distinct units, the 'J' and Airplane units of the Astoria Formation and the middle Miocene Dump sandstones, are described and named informally. The Silver Point is subdivided into lower and upper tongues. These units are locally overlain by Quaternary beach ridges (Clatsop Plains) and two alluvial terraces.

The 250-meter thick Oswald West mudstones are poorly stratified, yellowish orange tuffaceous burrowed mudstones. The upper part of the unit contains glauconitic sandstones, local fine-grained, well-bedded arkosic sandstones, and tuff beds. The unit was deposited in an open, deep-marine (outer shelf to upper slope)

environment. Broad uplift following deposition of the Oswald West formed a minor angular unconformity with the overlying Astoria Formation.

The Angora Peak sandstones are composed of over 120 meters of fossiliferous arkosic wackes and arenites deposited in a high energy, wave-dominated beach or bar environment. Gradual transgression is indicated by the gradation of pebbly coarse-grained sandstones upward into deeper marine clay-rich bioturbated fine-grained sandstones.

The lower Silver Point tongue is a "flysch-like" sequence of interbedded very fine-grained arkosic wackes and gray mudstones. It was deposited in a sublittoral environment by both turbidity and tidal currents on a delta slope or outer delta platform.

The 'J' unit, which conformably overlies the lower Silver Point tongue, consists of approximately 150 meters of well-laminated micaceous, carbonaceous mudstones of lagoonal origin. A sequence of arkosic, coarse-grained pebbly delta distributary channel sandstones of the 'J' unit gradually prograded westward into the lagoonal environment.

Rapid subsidence, perhaps by abandonment of the 'J' deltaic lobe, resulted in transgression over the study area. Over 250 meters of well-laminated yellowish brown mudstones of the Airplane tongue were deposited in an upper slope or outer shelf environment as suggested by an abundant foraminiferal assemblage. The Airplane mudstones grade into the overlying upper Silver Point tongue which is composed of approximately 120 meters of very thin interbedded dark gray mudstones and very fine-grained micaceous sandstones and siltstones. The upper Silver Point tongue was deposited at bathyal depths, possible in a low-energy pro-delta slope environment.

Broad, open folding and extensive erosion occurred soon after deposition of the upper Silver Point. The 50-meter thick Dump sandstones overlie several members of the Astoria Formation in apparent angular unconformity. These clay-rich very fine-grained arkosic sheet sandstones and siltstones possibly formed from erosion and redeposition of older sedimentary units.

Numerous dikes, irregular sills, peperites, and submarine pillow lavas of the Depoe Bay Basalt and younger sparsely porphyritic Cape Foulweather Basalt intrude or overlie all Tertiary sedimentary units. These tholeiitic basalts are locally 150 meters thick, but pinch out within several kilometers, possibly due to lava ponding on an irregular ocean floor and/or accumulation around local volcanic centers. Sedimentary interbeds between flows suggest intermittent volcanic activity.

Folding and faulting of these Oligocene and Miocene units probably coincides with uplift of the present Coast Range which resulted from convergence of the Juan de Fuca and North American plates during late Miocene time. This deformation formed northwest trending folds and two major sets of high angle faults striking northwest and northeast.

The Angora Peak sandstones are potential hydrocarbon reservoirs in the nearby continental shelf. Well logs and cores from three nearby wells suggest that Eocene and Oligocene sedimentary units are too impermeable for significant hydrocarbon production.

Geology of the Seaside-Young's River Falls Area, Clatsop County, Oregon

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INTRODUCTION

Purpose of Investigation

The geology of northwestern Oregon is known only in a regional sense. Early reconnaissance mapping, however, revealed many fascinating unstudied sequences of Tertiary deltaic and deep-marine sedimentary units, submarine volcanics, and intrusive rocks in the region. The Young's River Falls-Seaside area is of special interest because all of these units are exposed in the study area. The purposes of this investigation are: 1) to map and describe in detail the sedimentary and volcanic rock units; 2) to determine the stratigraphic and facies relationships of these units; 3) to determine paleoenvironments of deposition; 4) to interpret the geological history; and 5) to evaluate potential economic, especially hydrocarbon, resources of this area. This study, when combined with other recent investigations by Oregon State University geology graduate students, will help define the overall geology of northwestern Oregon.

Geographical Setting

The Seaside-Young's River Falls area is a C-shaped area of approximately 150 km^2. The coastal strip along the Pacific Ocean side to Cullaby Lake consists of a series of low-lying north-south beach ridges, interdune lakes and swamps, and a modern beach/dune area. This strip forms the southern part of the Clatsop coastal plane and varies from one to several kilometers in width. Coastal streams flow northward parallel to the beach ridges which are breached in several places allowing the streams to flow into the Pacific Ocean. Several lakes, of which Cullaby Lake is the largest (approximately 5 km. long), have formed in interdune troughs where the local water table has been intersected (Frank, 1970).

Inland, much of the area consists of low hummocky hills less than 150 meters in elevation. They are separated by the northward-flowing Lewis and Clark River and Young's River (Plate I). Fine-grained sedimentary rock units commonly underlie the low hills which are characterized by numerous slumps and landslides.

The greatest relief in the area occurs where there are thick accumulations of resistant intrusive and extrusive Tertiary basalts. For example, Lone Ridge, formed by a circular intrusive basalt dike in the northeastern part of the area (Plate I) has 200 meters of relief. The elevation of the area increases from north to south. Irregular, extensive bodies of basalts locally form steep narrow ridges and cliffs in the southern part of the area. The two highest points in the area, approximately 460 meters in elevation, are in the southwest (secs. 14 and 27, T. 6 N., R. 9 W.) (Figure 1).

Figure 1. Scenic view looking south across the Lewis and Clark River valley. Hills in background are held up by intrusive and extrusive basalts.

Two flat-lying Quaternary stream terraces occur along the Lewis and Clark River. The highest terrace is approximately 30 to 45 meters above the modern river valley.

Climate and Vegetation

The climate of the area is cool and dry in the summer and mild and wet in the winter. Temperatures are moderated by onshore winds from the Pacific Ocean. These moist winds cause high rainfall in winter and morning fog in the summer. The high rainfall, up to 200 cm. per year, and overall temperate climate is ideal for rapid forest growth, mostly Douglas fir, hemlock, spruce, and alder. Thick groundcover hinders off-trail walking. Exposures of sedimentary units are commonly deeply weathered because of the warm, wet climate and the unstable tuffaceous mineralogy of the units.

Access

Two main highways, U. S. 26 and U. S. 101, provide easy access to the Seaside-Young's River Falls area from Portland and Astoria. The north-south U. S. 101 traverses the western part of the area along the Clatsop Plains. From Seaside, the Lewis and Clark County Road and well-maintained Crown Zellerback Corporation logging roads, including Lewis and Clark Mainline, 400 line, and Young's River Mainline, provide access to the interior parts of the area.

Numerous logging spurs off these roads provide ample roadcut exposures for detailed mapping (Plate I shows these logging roads).

Previous Work

The earliest geological investigations in northwestern Oregon were descriptions of the Miocene molluscan assemblages collected from mudstones near the city of Astoria, Oregon (Conrad, 1848). Most of the early work in the 1800's was conducted along the Columbia River and Pacific coast because of the inaccessibility of the forested interior. Diller (1896) noted the regularity and asymmetric shapes of modern beach ridges that form the Clatsop Plains. He also recognized a "radiolarian" tuff (probably foraminiferal) on the north side of Tillamook Head which he postulated was Miocene in age. Washburne (1914) reported a large dike formed Young's River Falls (in the northwestern part of the study area) and that immediately to the north of this feature were several poor exposures of freshwater sandstones. He concluded that there must be at least 60 meters of the sandstones and that they appeared to overlie the Astoria shales. The first measured section near the study area was described by Howe (1926) in his pioneering study of the type middle Miocene Astoria "shales" at Astoria. He recognized lower and upper sandstone units separated by a middle mudstone member.

Since Howe's work in the 1920's, only limited reconnaissance mapping was done in northwestern Oregon. An oil and gas investigation map by Norbisrath and others (1945) delineated several large Tertiary basaltic masses from undifferentiated Tertiary sedimentary strata. Wells and Peck's 1961 "Geologic Map of Oregon West of the 121st Meridian" recognized a major north-south fault in the study area and improved earlier reconnaissance maps by differentiating the middle Miocene Astoria Formation and Columbia River basalts from two unnamed Eocene-Oligocene mudstone units. Schlicker and others (1972), in an environmental and engineering geology study of Tillamook and Clatsop Counties, distinguished middle Miocene submarine basaltic breccias from intrusive basalts and mapped a sandstone unit of the middle Miocene Astoria Formation separately from undifferentiated Oligocene-Miocene mudstones. These distinctions were drawn to accentuate the varying engineering qualities of the rock units.

Snavely and others (1973) recognized two distinct middle Miocene petrographic basalt types, the Depoe Bay and Cape Foulweather basalts, on the basis of chemical and petrologic differences of basalts in northwestern Oregon and southwestern Washington. Results of this study indicate that the older non-porphyritic Depoe Bay Basalt can be distinguished in the field from Cape Foulweather Basalt which contains sparse large plagioclase phenocrysts.

In the past four years, Oregon State University geology students have mapped the area from the Nehalem River north to Seaside (Cressy, 1974; Smith, 1975; and Neal, 1976). These students, in unpublished master's theses, have named and described the Oligocene-early Miocene Oswald West mudstones and have differentiated two members within the middle Miocene Astoria Formation, the Angora Peak sandstones and Silver Point mudstones. Presently, two other students, Peter E. Penoyer and James W. Carter, are working in the nearby Saddle Mountain and Astoria areas. David M. Cooper is preparing a regional stratigraphic correlation and paleoenvironmental study of the Astoria Formation in western Oregon as part of an overall geologic study of northwestern Oregon initiated by Dr. Alan R. Niem of the Department of Geology, Oregon State University.

Several onshore and offshore geophysical surveys have been undertaken in the past 15 years which have included northwestern Oregon. Bromery and Snavely (1964) noted a large gravity low over the Seaside-Astoria area which suggests that about 2500 meters of strata have been deposited in the Astoria embayment since Eocene time. Positive magnetic anomalies (Emilia and others, 1968) and seismic profiles (Kulm and Fowler, 1974b) suggest that middle Miocene basalts extend from Tillamook Head south of Seaside to approximately 14 kilometers offshore.

Field and Laboratory Methods

Field work was conducted over a period of three months during the summer of 1974 and on several weekends through spring 1975. Geologic mapping, description of stratigraphic sections, and collection of rock and fossil samples was accomplished during this time. Initial field mapping was noted on State of Oregon Forest Service aerial photographs taken in 1971 at a scale of 1:12, 000. These data were then transferred to Crown Zellerback Corporation topographic maps (1:12, 000, see Plate I).

Three stratigraphic sections were described and measured using Jacobs staff and Abney level (Appendices I-III). McKee and Weir's (1953) stratification terminology and Wentworth's grain size scale were used in the field. Representative rock samples, pebble counts, and paleocurrent measurements were obtained from measured sections and other localities in the field (see locations in Appendices IV-X).

Grain size analysis of seven disaggregated sandstones (Appendix VII) was performed by sieving techniques (see Royse, 1970, for procedure) and analyzed quantitatively using the statistical parameters developed by Folk and Ward (1957). Calcium carbonate and organic carbon abundance were determined for several sandstone and mudstone samples by saturation in 1 N. HCl and 30% H_2O_2, respectively.

Petrographic analysis included thin section study of 10 igneous and 31 sedimentary rocks. Modal analysis was performed on 16 sandstone and siltstones (Appendix VI). These rocks were then classified using the classification of Williams and others (1954). Feldspar staining was performed on 16 sandstones to aid their identification using the method suggested by Bailey and Stevens (1960). Eight heavy mineral analyses were performed on representative samples from each sedimentary unit in the area (Appendix V) using tetrabromoethane (S. G. = 2. 95) as the separation medium (see procedure in Royse, 1970). Clay mineralogy of disaggregated mudstones was analyzed using a Norelco X-ray diffractometer. Pretreatment techniques are described in Appendix IX. Diffraction patterns were compared with known clay diffraction patterns obtained by Grim (1958), Carroll (1970), and Brown (1969).

Paleocurrent data were corrected for tectonic tilt by the stereonet method discussed by Potter and Pettijohn (1963) and were statistically analyzed using the method outlined by Royse (1970).

Four basalt samples were chemically analyzed by X-ray fluorescence, atomic absorption spectrophotometry, and visible light spectrophotometry. Buttons for the analyses were prepared in accordance to Taylor's Cookbook for Standard Chemical Analysis (1974).

Microfossils were separated from more than 50 mudstones by boiling in a Calgon solution, mounted, and sent to Dr. Weldon W.

Rau, Washington Department of Natural Resources, for identification. Trace fossils and molluscs were collected and sent to Dr. C. Kent Chamberlain of Ohio University and Dr. Warren O. Addicott of the U.S. Geological Survey, respectively, for identification and paleo-environmental interpretation. Assemblages and fossil localities are listed in Appendix IV.

REGIONAL GEOLOGY

The thesis area is located on the northwest limb of the northward-plunging Coast Range Anticlinorium (Baldwin, 1964) (Figure 2). The core of this structure consists of early to middle Eocene-age Tillamook Volcanics which are age and lithological equivalents to the Siletz River Volcanics of the central Coast Range. The Tillamook Volcanics are largely tholeiitic pillow basalts and submarine breccias intertonguing with minor tuffaceous siltstones and basaltic sandstones (Snavely and Wagner, 1964). These Eocene volcanics are postulated to be oceanic basalt formed at a spreading ridge and may have a thickness of over 6,000 meters (Snavely and others, 1968). Younger late Eocene to middle Miocene units dip gently away from the volcanic core. Six Tertiary formations which overlie the Tillamook Volcanics have been defined in the northeastern part of the Oregon Coast Range. They are the Cowlitz Formation, the Goble Volcanics, the Keasey, Pittsburg Bluff, and Scappoose Formations, and the Columbia River Basalts (Figure 2). The 300-meter thick Cowlitz Formation consists of dark deep-marine mudstones and subordinate arkosic sandstones and basaltic conglomerates which interfinger with the Goble Volcanics (Norhisrath and others, 1949). Undifferentiated Tertiary strata, in part equivalent to the Cowlitz Formation, have been mapped on the western side of the Coast Range (Figure 2).

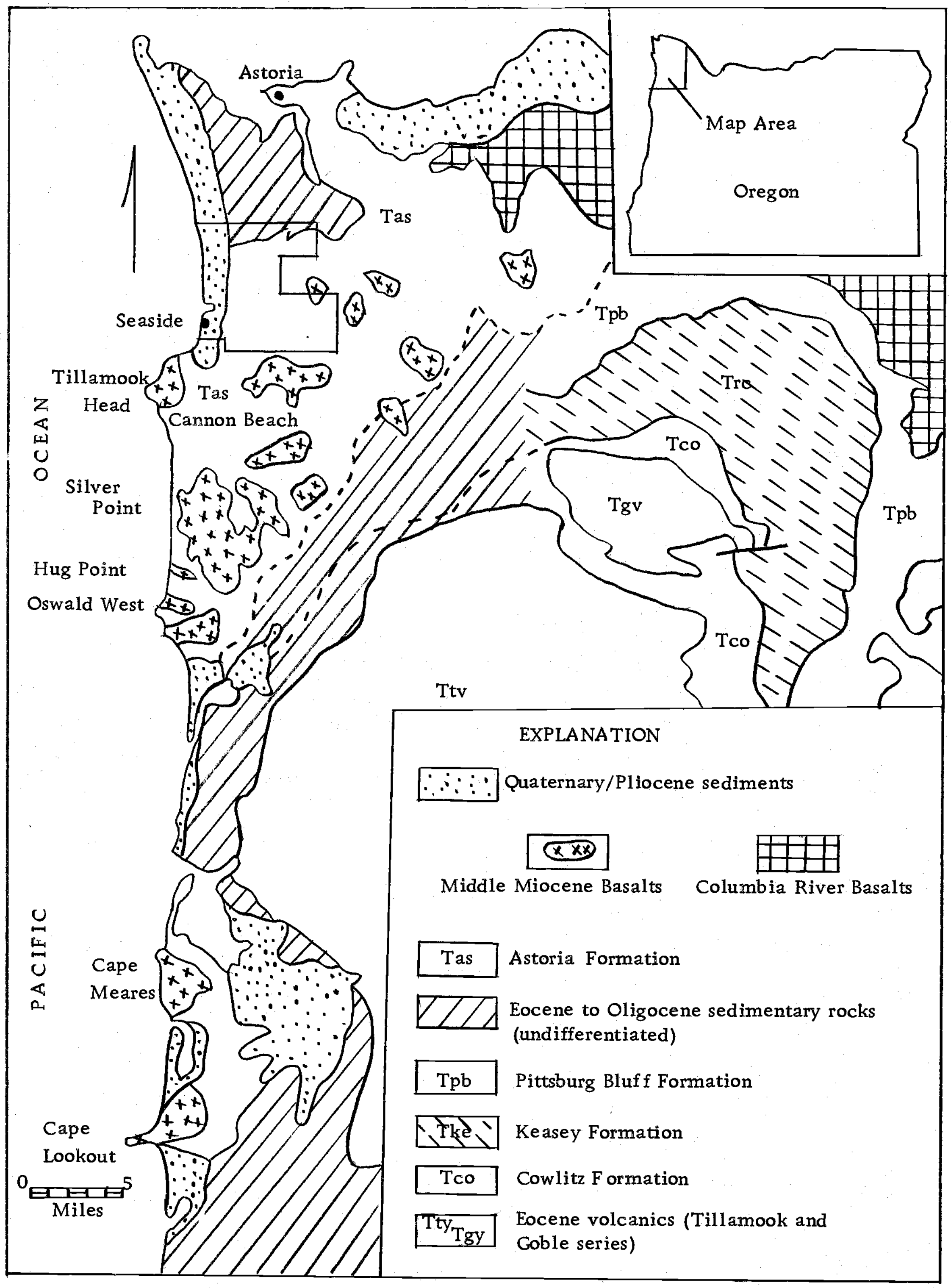


Figure 2. Regional geologic map of the northwest Oregon Coast Range. (Map after Wells and Peck, 1961).

In the northeastern Coast Range, the Cowlitz Formation is unconformably overlain by the late Eocene to early Oligocene Keasey Formation which is approximately 500 meters thick. The Keasey consists predominantly of light colored tuffaceous mudstones and siltstones (Van Atta, 1971). It is also one of the more fossilerous units in the northern Coast Range, containing many molluscan genera and locally well-preserved crinoids.

The overlying 250 meter thick, ridge-forming middle Oligocene Pittsburg Bluff Formation is dominantly a structureless to well-bedded fine-grained sandstone unit with minor mudstones and conglomerates (Niem and Van Atta, 1973). Undifferentiated tuffaceous mudstones of Keasey and Pittsburg Bluff age are found on the western side of the Coast Range (Wells and Peck, 1961).

The Pittsburg Bluff Formation is conformably overlain by the 450 meter thick late Oligocene Scappoose Formation composed of coarse-grained arkosic sandstones, and subordinate tuffaceous mudstones and basalt conglomerates (Niem and Van Atta, 1973). This unit, which is thought to be deltaic in origin, is equivalent to the 500 meter thick Oswald West deep-marine mudstones of the northwestern Coast Range (Cressy, 1974).

The middle Miocene Astoria Formation is restricted to the western side of the Coast Range in a series of marine embayments from Newport to Astoria, Oregon. The unit consists of deltaic and shallow-marine arkosic and lithic sandstones with local coal seams, turbidite sandstones, and deep-marine mudstones (Niem and Van Atta, 1973). The 600 meter-thick Astoria Formation lies with angular unconformity over the Oswald West mudstones.

The Astoria Formation is angularly overlain by Depoe Bay and Cape Foulweather Basalts which are considered to be coeval with the subaerial Columbia River Basalts of the eastern Coast Range and eastern Oregon (Snavely and others, 1973) (Figure 3). Both the Depoe Bay and younger Cape Foulweather basalts occur as irregular intrusive dikes and sills and extrusive pillow basalts and breccias. These basalts now form the steepest and highest topography in the northern Oregon Coast Range.

These basalts, as well as older Tertiary units, are locally overlain by Pliocene-Pleistocene fluvial and shallow-marine terrace deposits (Niem and Van Atta, 1973). Some of these deposits may be equivalent to the Troutdale gravels of the Portland area (Schlicker and others, 1972).

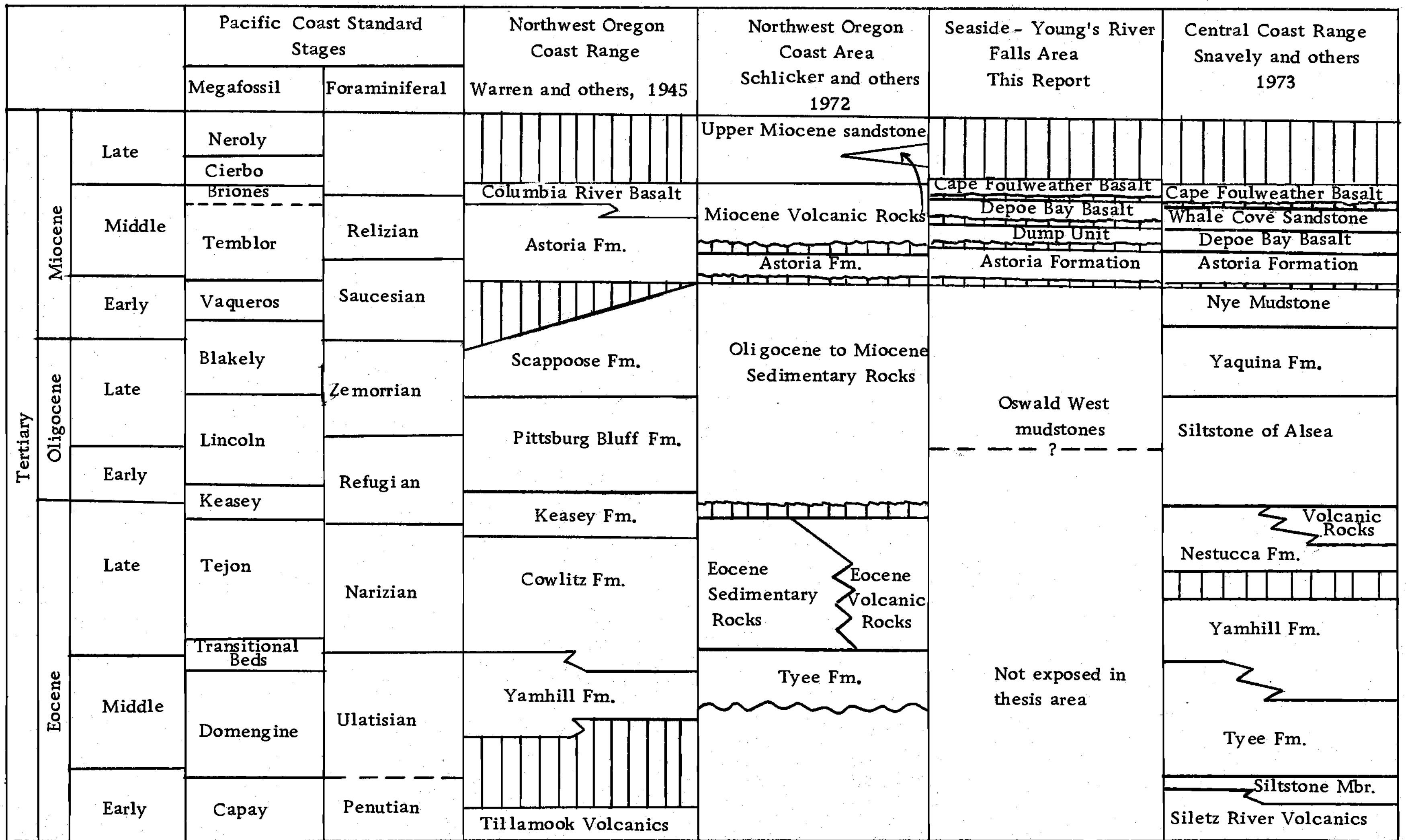


Figure 3. Tertiary correlation chart of the northern and central Oregon Coast Range.

DESCRIPTIVE GEOLOGY

Introduction

During the past four years, many of the lithologic units of the northwest Oregon Coast Range have been named and described in detail by graduate students in the Department of Geology, Oregon State University. Many of these units, or their age equivalents, have traced into this study area. A brief history of this development is given below.

The oldest rocks in this area are the late Oligocene-early Miocene Oswald West mudstones (informal). Cressy (1974) first described this 490 meter thick unit along Short Sands beach in Oswald West State Park approximately 30 km. south of this area. This unit has been extended to the north by Smith (1975) and Neal (1976) to the Seaside area. The Oswald West mudstones have been traded continuously into this study area.

Cressy (1974) determined that the Oswald West mudstone is overlain by a 300 meter thick middle Miocene fluvial to shallow marine sandstone unit he named the Angora Peak sandstone member (informal) of the Astoria Formation. A limited exposure of Angora Peak sandstone crops out in the southeastern part of this study area (Plate I). Smith (1975) further differentiated the Astoria Formation in his area into the Angora Peak sandstones and an overlying 180 meter thick fine-grained unit which he named the Silver Point member (informal). Neal (1976) has traced extensive exposures of the Silver Point member to the Seaside area, adjacent to this study area.

Field mapping in this area has determined that the middle Miocene Astoria Formation is a complex, intertonguing sequence of several informal mappable units (Figure 4). Two new units of the Astoria Formation have been distinguished in this area; the 'J' unit and the Airplane tongue. The Silver Point member has been subdivided into a lower and upper tongue separated by the 'J' and Airplane units (Figure 4). The 'J unit is probably a lateral facies of the Angora Peak sandstones (Figure 4). The Airplane mudstone is probably correlative to the middle mudstone member of the type Astoria Formation at Astoria, Oregon (Howe, 1926). Formalization of these two new units is not recommended because they may not be laterally extensive and further differentiation of lateral facies could lead to a confusing stratigraphic picture.

The Airplane and upper Silver Point members of the Astoria Formation are angularly overlain by a thin, discontinuous sheet sandstone informally named the Dump sandstones (Figure 4). The Dump sandstone unit is of middle Miocene age and is preserved only where covered by extrusive middle Miocene basalts.

Two petrographically distinct middle Miocene basalt units crop out in the study area; the Depoe Bay and Cape Foulweather Basalts.

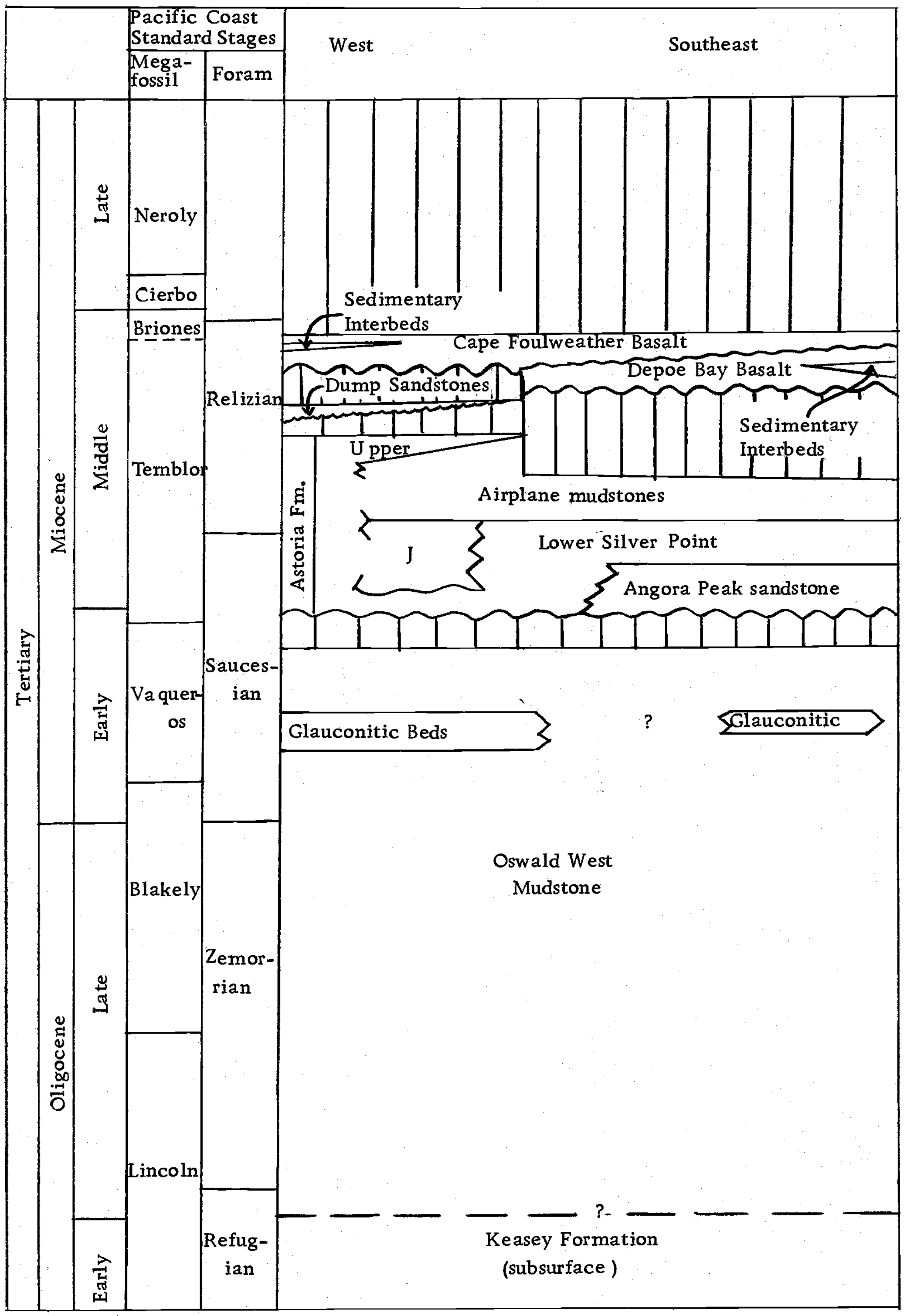


Figure 4. Tertiary stratigraphy of the thesis area.

Intrusive and extrusive equivalents of each basalt type occur in the thesis area. Thin marine sedimentary interbeds also occur between individual pillow basalt flows.

An angular unconformity separates Miocene and older rock units from Pleistocene and Holocene beach and alluvial deposits. Two terrace levels of alluvial deposits occur along the Lewis and Clark River.

Oswald West Mudstones

Late Oligocene to early Miocene Oswald West strata crop out extensively in the study area and are up to 250 meters thick near Cullaby Lake (Figure 5 and Plate I). Along the eastern boundary of the area, most outcrops are exposed were faulting has brought the unit to the surface. Low hills formed of light colored, burrowed mudstones and local galuconitic sandstones of the Oswald West are commonly dissected by small streams. Glauconitic sandstones are noted by Smith (1975) and Neal (1976) in the Oswald West mudstones near Onion Peak to the south. Glauconitic sandstone beds were also noted by me directly beneath middle Miocene Angora Peak sandstones in the sea cliffs above the Oswald West type section described by Cressy (1974) at Oswald West State Park.

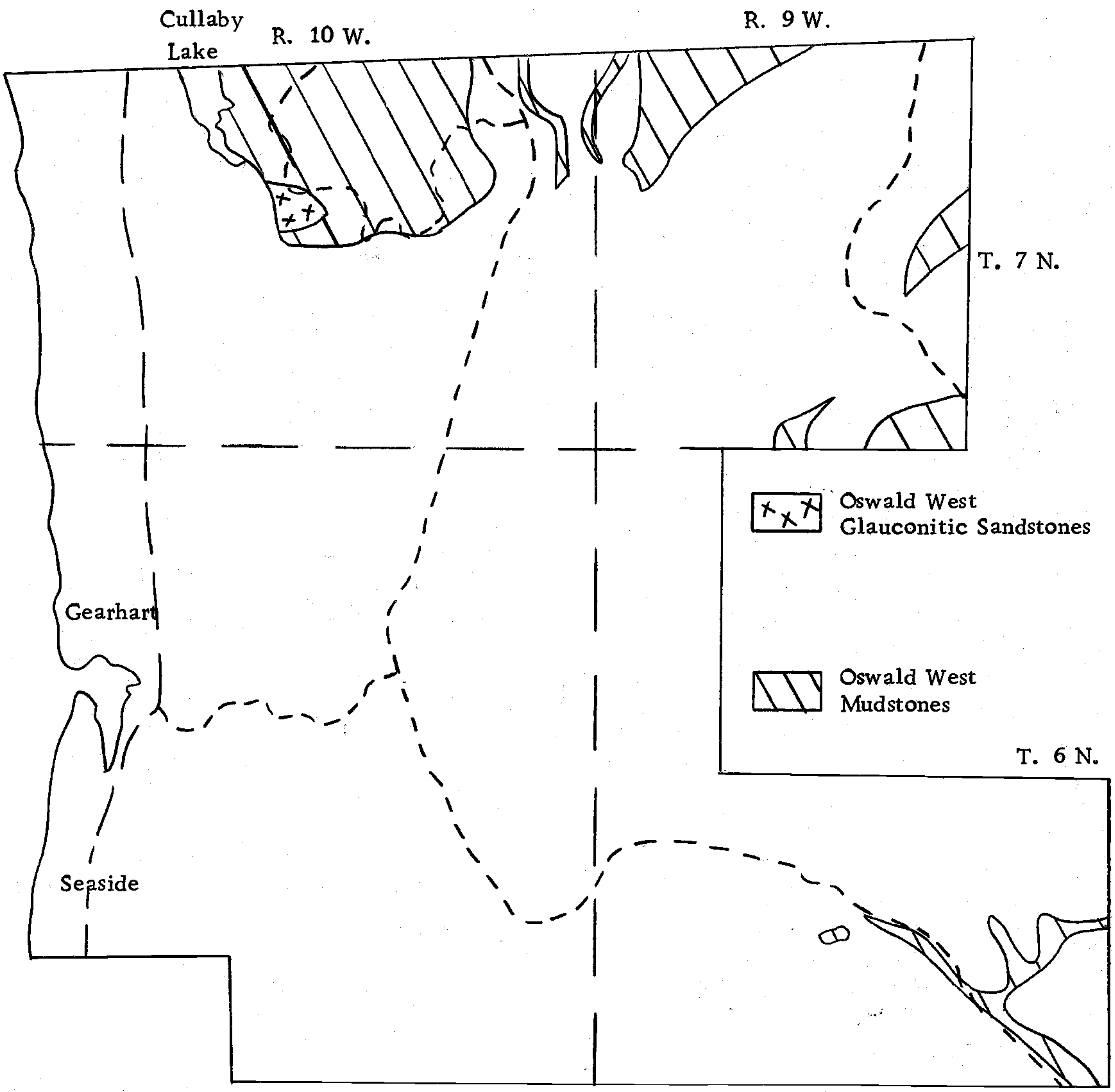


Figure 5. Outcrop location of the Oswald West mudstones.

Lithological Characteristics

The Oswald West can be divided into lower and upper units. The lower unit consists of poorly indurated, grayish orange weathered claystones. Fresh exposures of these claystones are generally olive gray (5Y7/2) and show vague bedding but are more commonly structureless (Figure 6). Thin lighter colored tuffaceous mudstone beds, tuff lenses, and concretionary layers define bedding. Rare water-laid tuff interbeds up to 15 cm thick are yellowish gray (5Y7/2). Small spheroidal calcareous concretions are common in the lower Oswald West mudstones and rarely have nucleii composed of fossilized crab or shrimp fragments.

Weathered outcrops are moderate brown (5Y4/4) to moderate yellowish brown (10YR5/4) and are spheroidally weathered. Iron stained reddish orange Liesegang rings are associated with the weathered surfaces. The bases of most Oswald West mudstone exposures are littered by talus composed of angular blocks 8 to 10 cm. wide and smaller (2-6 mm.) irregular chips of mudstone.

Trace fossils are abundant in the lower part of the Oswald West mudstones. Helminthoida, which appear as light meandering ribbons in the darker mudstones, have been identified by Chamberlain (1974, written comm.). Coiled foraminifera, some as large as 3 mm. in diameter are common, but because of weathering are usually

Figure 6. Typical outcrop of Oswald West mudstones. Note the structureless, weathered surfaces and the chippy talus at the base of outcrop.

unidentifiable.

The lower Oswald West mudstones grade into an upper unit composed of mudstones and local thinly bedded clay-rich siltstones and very fine-grained sandstones. The upper unit may be as thick as 150 meters as calculated from dip measurements and outcrop patterns. Trace fossils identified as Helminthoida (Chamberlain, 1975, written comm.) and coarse-grained glauconitic sandstones are ubiquitous in the upper Oswald West unit.

Fresh exposures of the muddy siltstones are dark yellowish brown (10YR4/2), but most exposures commonly weather to a yellowish brown (10YR5/4). A 9 meter sequence of well-stratified, thinly bedded silty sandstones is exposed on logging spur Fletcher 12C (W$\frac{1}{2}$, sec. 24, T. 7 N., R. 10 W.). These fine-grained sandstone beds (approximately 7 cm. thick) may grade upward into clayey siltstones and are slightly bioturbated. Rarer lenticular sandstone beds may contain erosional bases. Weathering produces a disaggregated sandy clay talus at the base of roadcut exposures.

Approximately 60 meters of fine- to coarse-grained glauconitic sandstones in the upper Oswald West mudstone crop out in the northern half of section 26, T. 7 N. R. 10 W. (Plate I). Fresh glauconitic sandstones are light olive gray (5Y8/2), but are usually weathered to brownish gray (5YR4/1) resistant calcite-cemented lenses and nodules. The coarser fraction of the sandstones is composed of glauconite pellets. Individual glauconite beds up to 1 meter thick are common within the sequence and are medium- to coarse-grained at the bottom grading upward into fine-grained muddy sandstone. Contacts between beds are generally sharp. The beds are bioturbated and contain small scaphopods, Dentalium sp. (Addicott, 1975, written comm.), and unidentifiable gastropod fragments.

In the northeastern part of the study area, the Oswald West is well indurated due, in part, to baking by nearby middle Miocene Cape Foulweather dikes. These light bluish gray (5B7/1) mudstones contain wispy laminae of siltstone and very fine-grained sandstone. The baked beds are similar in lithology and color to the type Oswald West mudstones defined at Oswald West State Park by Cressy (1974). Some Oswald West mudstones contain carbonaceous layers up to 15 cm. thick. Small isolated, disarticalated blocks of fine- to medium-grained sandstones suspended in the mudstones were probably formed by soft sediment deformation.

Gastropods, scaphopods, and bivalved shells are scattered throughout the upper unit. The gastropods and bivalves are usually small, thin-shelled, and unbroken. The molluscan assemblage identified by Addicott (1975, written comm.) include: naticid gastropods, the scaphopod Dentalium sp., and bivalves Acila sp., Nuculana sp., and Propeamussium/Pilarense (Slodkowisch) (Appendix IV).

Contact Relations

No contacts between the Oswald West mudstones and older Tertiary rock units crop out in the thesis area. Early Oligocene Keasey-age mudstones were reported in the Standard Oil Company of California's (Socal) Hoaglund Unit #1 well 5 km. northeast of Cullaby Lake and are presumed to underlie the Oswald West mudstone in the study area. Upper contacts are described in Contact Relationship sections of the Angora Peak sandstones and lower Silver Point tongue of the Astoria Formation.

Age and Correlation

The bivalve *Propeamussium/Pilarense* indicates a late Oligocene-early Miocene age for the Oswald West mudstones (Addicott, 1975, written comm.). This age and similarity of lithologies suggests that the Oswald West in this area is equivalent to the type Oswald West mudstones as defined by Cressy (1974) at Oswald West State Park. The type Oswald mudstones are better indurated than those in this study area; probably due to baking from thick basalt sills which surround the type area. Smith (1975), Neal (1976), Penoyer (1975, personal comm.), and Cooper (1975, personal comm.) have mapped Oswald West mudstones of similar age and lithologic character adjacent to the study area.

Petrology

In thin section, the Oswald West mudstones contain scattered silt and sand grains set in a clay rich matrix. Sieve analysis of several samples indicates that only 10 to 15% (maximum) of the mudstones is of sand size. X-ray diffraction analysis of the clay matrix shows the presence of chlorite and mixed layered chlorite, montmorillonite, and muscovite (Appendix IX). Montmorillonite and glauconite form the greatest proportion of the clay matrix. The zeolite, clinoptilolite, is present, but not volumetrically important.

Sandstone interbeds in the upper Oswald West unit are arkosic and glauconitic wackes (Williams and others, 1954). Modal analyses (Appendix VI) of five sandstones determined that approximately 70% of the sand-size grains are glauconite pellets (Figure 7). These pellets are medium- to coarse-grained ovals and are in grain support (Figure 8). Other sand-size framework grains include fine to very fine, angular monocrystalline quartz, chert, plagioclase, and minor polycrystalline quartz, K-feldspar, micas, and lithic rock fragments.

Plagioclase is commonly oligoclase, but ranges from andesine to labradorite (An_{16} to An_{65}). These, as well as K-feldspar grains, are partially altered to sericite and clay minerals. Lithic fragments are dominantly basalts and andesites with groundmasses altered to green micaceous clays, possibly celadonite or nontronite. Biotite

AVERAGE MINERALOGIC COMPOSITION OF SANDSTONES

Mineral	Oswald West	Angora Peak	Silver Point Lower	Silver Point Upper	'J'
Quartz	2.0	10.3	12.0	8.7	5.3
Quartzite*	Tr	11.1	21.0	17.5	18.6
Chert	1.3	4.6	6.5	5.5	5.0
Plagioclase	1.8	24.0	26.5	26.7	30.6
K-feldspar	Tr	4.0	7.5	5.7	1.5
VRF	Tr	10.0	5.0	9.8	5.0
MRF+IRF+SRF	-	2.7	Tr	3.7	6.0
Mica	0.5	7.4	4.0	7.0	2.7
Mafic	-	0.8	Tr	Tr	Tr
Opaque	3.8	0.7	Tr	Tr	Tr
Other	-	Tr	Tr	Tr	-
Authigenic** minerals	66.2	6.3	3.5	4.9	2.0
Matrix	21.5	12.4	15.0	10.2	16.6
Cement (Carbonate)	-	5.3	Tr	Tr	2.0
Porosity	1.2	3.7	3.0	3.0	3.0

*Quartzite = strained ± polycrystalline quart

Authigenic Minerals = celadonite, zeolite, and glauconite

Tr = less than 0.5%

Figure 7. Average mineralogic composition of sandstones in Tertiary units.

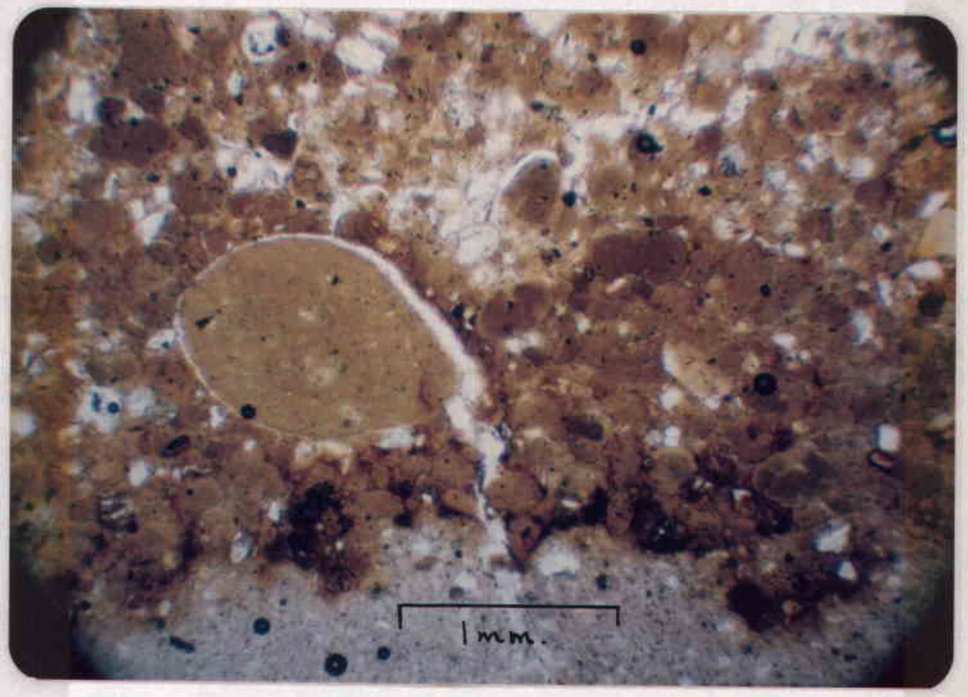


Figure 8. Photomicrograph of glauconitic sandstones in the upper Oswald West mudstones. Note large green glauconite pellets, colorless small silt-size detrital quartz grains, and burrowed layer (B) below glauconite (Uncrossed Nicols).

and chlorite are the most common detrital micas.

Heavy minerals (specific gravity greater than 2.95) in the 3.5-4.0 size range indicate a variety of source terranes for the Oswald West sandstones. The opaque minerals, magnetite, hematite, and authigenic pyrite are the most abundant heavy minerals. Other heavy minerals include green hornblende, biotite, and pink to colorless garnets with rare chlorite, zircon, and glaucophane (Appendix V). Glaucophane is particularly important because it is indicative of a high-grade metamorphic source area, possibly the Klamath Mountains, the Cascades of southern British Columbia and northern Washington, or the Blue Mountains of eastern Oregon. Augite, magnetite, and green hornblende occur in many Eocene and Oligocene volcanic rock units of the Coast Range and Cascades. Colorless to pink garnets are possibly spessartite or grossularite which may have been derived from acid igneous or metamorphic rocks of eastern Oregon and Washington and Idaho.

Authigenic and detrital clays and rare calcite act as the most common cementing agents of the Oswald West sandstones. Non-pelletal glauconite, which was probably formed by compaction of original glauconite pellets, may comprise up to 50% of the clay matrix.

Finely disseminated carbonaceous plant debris comprises 1-3% (determined by H_2O_2 treatment) of the mudstones. The abundance of unbroken molluscan shells, carbonaceous material, clay minerals, authigenic pyrite, and glauconite suggests that the Oswald West mudstones were in a low energy, reducing marine environment.

Oswald West sandstones are texturally immature (Folk, 1968). Sand grains are generally angular to subangular. The sandstones average 30% clay matrix and are poorly sorted (s_i=1.65, Folk and Ward, 1957) (Appendix VII). The fine grain size also suggest that the sandstones were deposited in a low energy environment.

Angora Peak Sandstones

The middle Miocene Angora Peak sandstone member of the Astoria Formation is restricted to an area of 4 square kilometers in the southeastern corner of the thesis area in sections 20, 21, 22, and 23, T. 6 N., R. 9 W. (Figure 9 and Plate I). A 133-meter section of shallow-marine, fine- to coarse-grained Angora Peak sandstones was measured and described from outcrops along logging spur 85 in section 23, T. 6 N., R. 9 W. (Appendix I). Twenty kilometers south of this area near Angora Peak, the type area, the unit thickens to over 300 meters and is fluvial and shallow-marine in origin (Cressy, 1974; Smith, 1975).

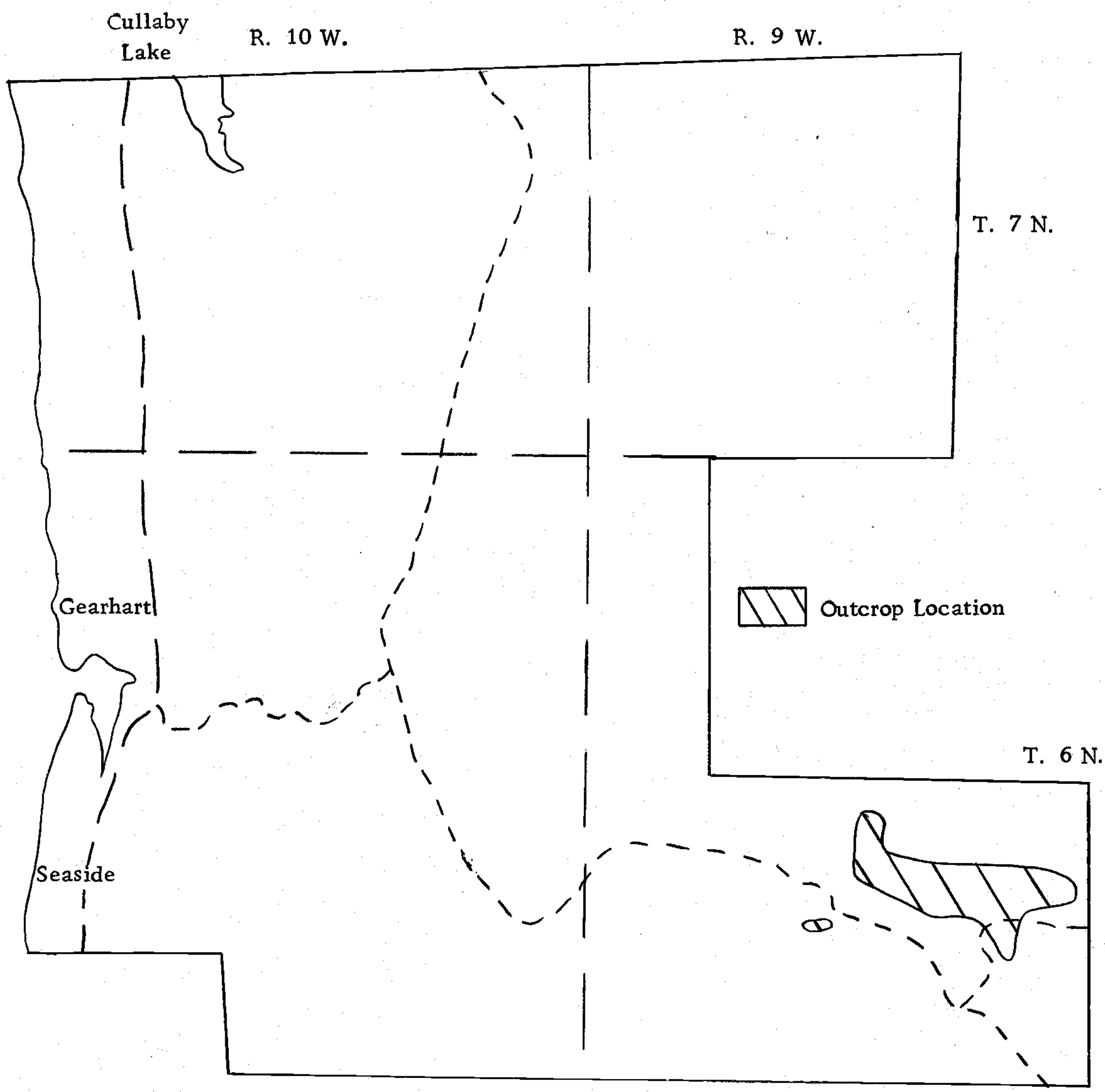


Figure 9. Outcrop location map for the Angora Peak sandstones.

Lithological Characteristics

The Angora Peak is composed of well-sorted, structureless to thickly bedded sandstones. The resistant sandstones form several ridges within the outcrop area. The 133-meter measured section on logging spur 85 is typical of Angora Peak sandstones exposed in the study area.

The lower 55 meters of this section (Appendix I) consists of friable, medium-to coarse-grained arkosic sandstones (Figure 10). The sandstones are composed of well sorted, angular to subangular quartz, feldspar, mica, and volcanic rock fragments. Lithic pebble lenses up to 15 cm. thick are interstratified with the sandstones. The lenses consist of well-rounded medium-size pebbles (maximum 1.5 cm diameter) which are dominantly quartzite, dark chert, basalt, and mudstone ripups (up to 6 cm. in length). The sandstones are medium bluish gray (5B5/1) to olive black (5Y2/1) in fresh exposures. When weathered, they are iron-stained dark yellowish orange (10YR6/6).

The lower part of the Angora Peak sandstones is generally structureless. Pebble conglomerate lenses and rare carbonaceous laminae define the stratification. Some sandstone beds (up to 1.5 meters thick) contain indistinct low-angle planar cross-beds. Surface weathering has commonly destroyed most stratification, however.

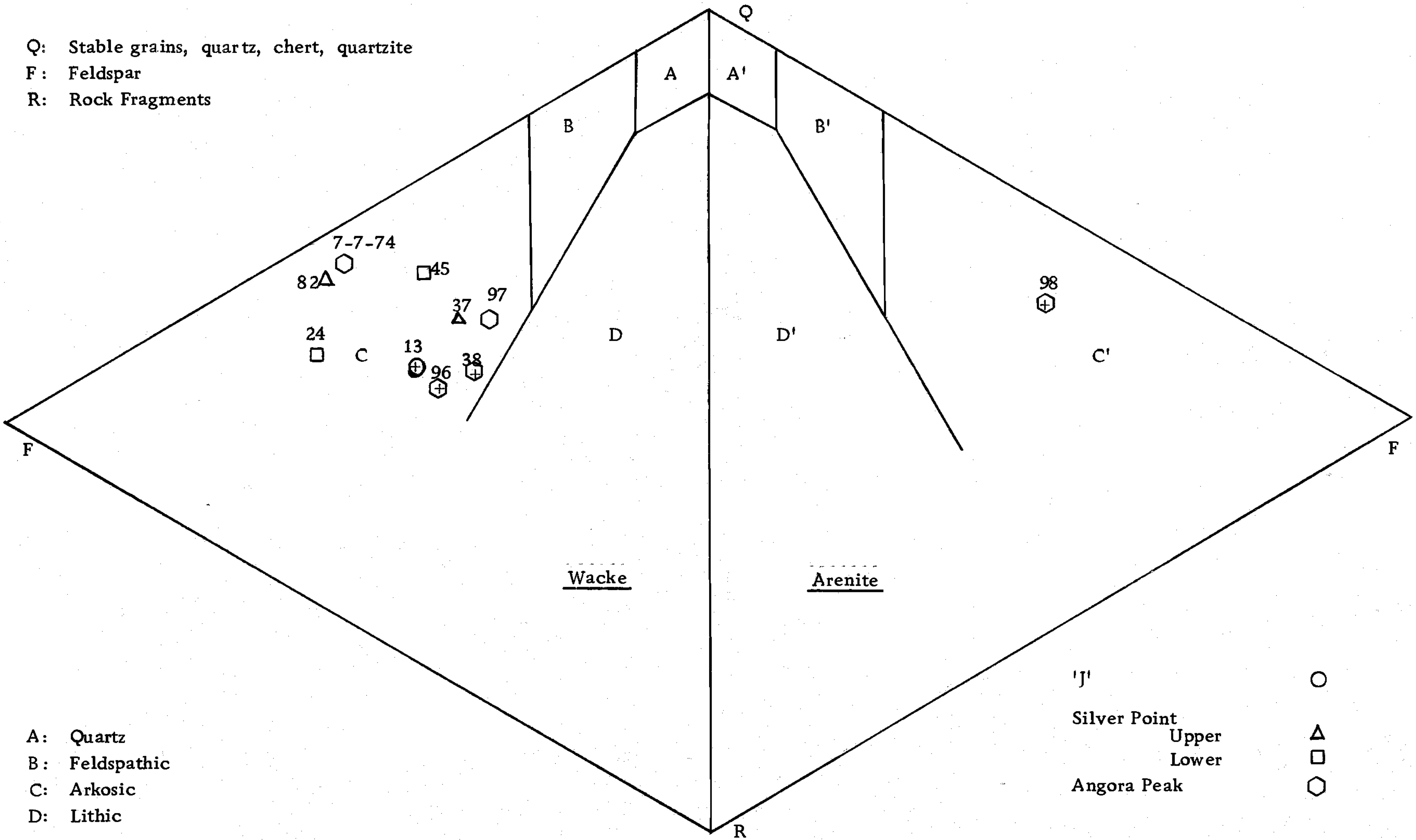


Figure 10. Classification of Astoria Formation sandstones (After Williams and others, 1955).

The upper 67 meters of the Angora Peak section show an overall fining upward, well-defined parallel bedding, and a noticeable lack of pebbles. Medium-grained arkosic sandstones grade upward into muddy fine-grained sandstones. This unit is light olive gray (5Y6/2) to dusky yellowish brown (19YR2/2) in fresh samples but is commonly weathered to dark yellowish orange (10YR6/6) to grayish olive (10Y4/2). These poorly cemented sandstones are friable and contain stringers of disseminated carbonaceous plant debris. Bedding in this part of the section varies from 3 cm. to 10 meters thick. Planar parallel bedding is ubiquitous, with bedding planes commonly defined by concentrations of mica flakes.

The uppermost 21 meters of the Spur 85 Angora Peak measured section contains many resistant calcareous concretionary layers (Figure 11). The layers contain molds of broken and unbroken molluscs and, less frequently, calcareous shells. The calcite which cements these resistant ribs was probably derived by diagenetic dissolution of calcareous molluscan shells with later reprecipitation in pore spaces along the layers where the shells are most concentrated. The molluscs, of which Solen sp., Mytilus, and Yoldia are the most common (see Appendix IV for complete listing) are indicative of a very shallow-marine (5 to 20 meters) inner shelf environment (Addicott, 1975, written comm.).

A 30- to 60-meter sequence of grayish orange (10YR7/4)

Figure 11. Outcrop of typical Angora Peak sandstones. Note the resistant calcareous concretionary layers (arrow) which contain abundant mollusc shells and molds.

clay-rich very fine-grained sandstones overlies the clean sandstones of the measured section. These structureless sandstones are extensively bioturbated and mottled. An abundant molluscan fossil assemblage (Appendix IV) including Anadara and Nuculana is indicative of neritic (5 to 140 m.) deposition (Addicott, 1975, written comm.). The unbroken, thin-shelled nature of this molluscan assemblage is indicative of quiet, deeper-marine deposition away from the influence of wave or tidal current agitation.

Other Angora Peak sandstone exposures in the area can be correlated to the Spur 85 measured section. A series of resistant calcite cemented sandstone outcrops which probably correlate with the upper part of the measured section occur along logging spur 134 (secs. 22 and 23, T. 6 N., R. 9 W.) (Plate I). These fine-grained, well-bedded arkosic sandstones have been offset by several small faults. Some exposures along this logging road contain vertical bedding caused by drag along these faults. Stratification in the sandstones is determined by concentrations of molluscan fossils along bedding planes. Rare, planar cross-beds occur along Spur 134.

A well-exposed 13-meter high roadcut of indurated calcite cemented Angora Peak sandstones occurs along an unnamed logging spur south of Spur 85 at SE$\frac{1}{4}$, SW$\frac{1}{4}$, section 23, T. 6 N., R. 9 W. Large-scale trough cross-beds up to 5 meters wide and with amplitudes up to 0.3 meters have been measured for paleocurrent orientations.

Megaripples with wave heights of 0. 6 meters are exposed in this outcrop. Large talus blocks (up to 1 m.) containing molluscan fossils have broken loose along bedding surfaces. The molluscan assemblage is similar to that collected in the upper 67 meters of the Spur 85 measured section. The fauna includes unbroken razor clams (Solen) up to 11 cm. long, Vertipecten, and Spisula (see Appendix IV for complete assemblage) which are indicative of shallow-marine (5-20 m.) deposition (Addictott, 1975, written comm.).

A small outcrop on logging spur 141 (NE$\frac{1}{4}$, SW$\frac{1}{2}$, sec. 21, T. 6 N., R. 9 W.) is composed of structureless muddy fine-grained sandstones. These are extensively bioturbated and contain an unbroken molluscan assemblage, including Patinopecten, Anadara, and Katherinella (see Appendix IV for complete assemblage), typical of a neritic (5-140 m.) environment (Addicott, 1975, written comm.). This outcrop is probably correlative to the muddy, fine-grained Angora Peak sandstones found directly above the Spur 85 measured section.

Contact Relationships

The stratigraphic contact with the underlying Oligocene-early Miocene Oswald West strata is covered across the Angora Peak outcrop area. Along logging spur 85 the covered interval is only 7 meters thick and the dips between the two lithologies are nearly conformable. However, the change from deep-marine Oswald West mudstones to well-bedded, coarse-grained, pebbly, very shallow marine Angora Peak sandstones implies a rapid change in depositional regimes. These lithological and environmental differences may also represent a possible disconformable relationship. Cressy (1974), Smith (1975), and Neel (1976) have noted discordance in dips between the units and have suggested the existence of an angular unconformity between the two units within their thesis areas to the south. During reconnaissance surveys outside the study area, I have observed that a sharp angular unconformity exists between the Oswald West mudstones and the overlying Angora Peak sandstones near the type Oswald West mudstone section in the sea cliffs south of Short Sands Beach at Oswald West State Park.

The upper contact is described in Contact Relationships of the lower Silver Point tongue.

Age and Correlation

The Angora Peak sandstones in this area are age equivalents to the type middle Miocene Astoria Formation at Astoria, Oregon. The molluscan faunal assemblage from this unit is correlative to the Temblor molluscan stage (middle Miocene) of California. The assemblage includes *Mytilus mittendorfi* Grewink and *Patinopecten propatulus* (Conrad) which are restricted to the middle Miocene on the Pacific Coast (Addicott, 1975, written comm.). However, the occurrence of Vertipecten fucanus (Dall) in sample PMT-51-74 (see Appendix IV), which are in sandstones lithologically correlative to the upper 67 meters of the Spur 85 section, is suggestive of possible correlation with the early Miocene Nye Mudstone of the Newport, Oregon, area (Addicott, 1975, written comm.).

The Angora Peak sandstone member crops out extensively south of the study area near Onion Peak and Angora Peak (Cressy, 1974; Smith, 1975). However, the Angora Peak member there contains minor fluvial channel conglomerates and local coal seams, as well as the dominant shallow-marine sandstones. Neel (1976) has mapped Angora Peak sandstones to within 8 km. of the study area.

Petrology

The Angora Peak sandstones are fine- to coarse-grained arkosic wackes to arkosic arenites (Williams and others, 1954) (Figure 10). The sandstones contain approximately 12% clay matrix, most of which is thought to be of diagenetic origin.

Modal analysis of six Angora Peak sandstones determined that quartz and plagioclase are the dominant framework minerals (Figure 7). Volcanic rock fragments, micas, K-feldspars, chert, and minor amounts of pyroxene, amphibole, iron oxides, lithic rock fragments, and zircon constitute the remaining framework grains (Figure 12).

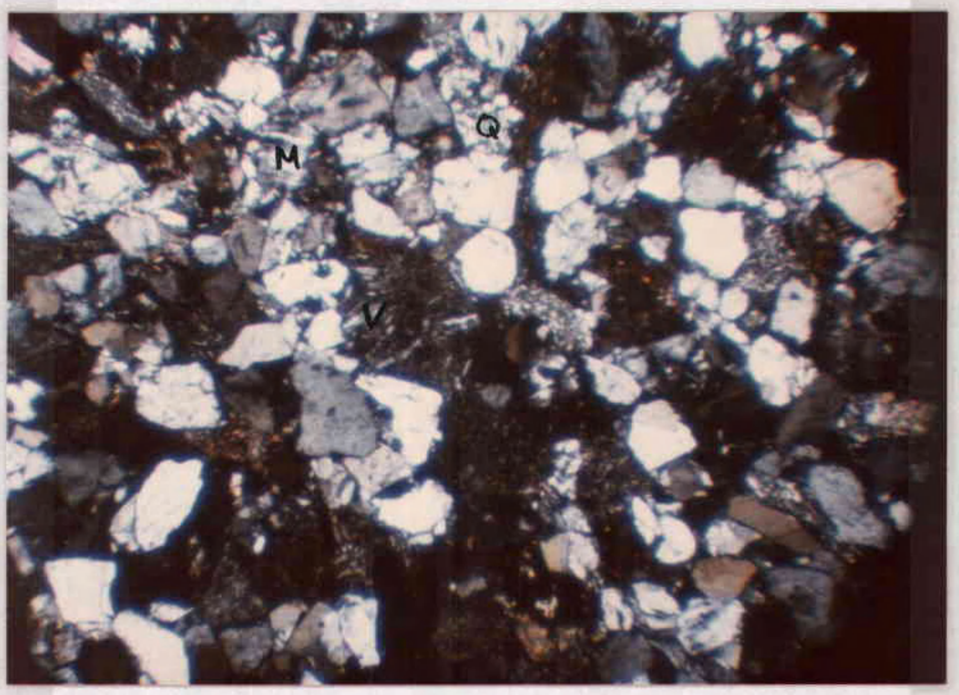


Figure 12. Photomicrograph of Angora Peak sandstone containing volcanic rock fragments (V), polycrystalline quartz (Q), and microcline (M). (Crossed Nicols) Field of vision = 4 mm

Normal (unstrained quartz), strained quartz, and polycrystalline quartz are equally abundant and compose approximately 22% of the sandstones. Plagioclase averages 24% and is dominantly andesine (average An_{36}). However, extremes of plagioclase composition range from oligoclase (An_{20}) to bytownite (An_{73}). The intermediate to basic composition suggests that much of the plagioclase was derived from gabbroic or porphyritic andesitic and basaltic provenances. Trace amounts of perthite are found. K-feldspar, predominantly orthoclase and minor microcline, forms about 4% of the sandstones. K-feldspars are usually unaltered while many plagioclase feldspars are extensively altered to sericite and calcite.

Volcanic rock fragments (10%) are generally intersertal to intergranular porphyritic basalts. Rare pumice and tuff fragments occur in many samples. The groundmass of many volcanic fragments is altered to green clays, probably celadonite or nontronite, which commonly grades into the surrounding, compositionally similar, clay matrix. Chert clasts average 5% in the sandstone samples.

Brown and green biotite are commonly twice as abundant as muscovite. The undeformed nature of the detrital mica flakes suggests minor post-depositional compaction of the sandstones. Angular, elongate mudstone ripups and rare grains of glauconite are also found in the sandstones.

Garnet, biotite, clino- and orthopyroxenes, zircon, and the opaque minerals magnetite, hematite, leucoxene, and pyrite are the most common heavy minerals (Appendix V) and form 1% to 3% of the sandstones. Garnets are salmon pink, colorless, or pale yellow and are possibly spessartite or grossularite which indicate a low-rank metamorphic or acidic igneous provenance for the sandstones (Milner, 1940). Augite occurs in all samples. Other pyroxenes, including hypersthene, enstatite, and pigeonite, comprise from 0 to 15% of the total heavy mineral assemblage. Hornblende is ubiquitous and is extremely abundant in some samples. These mafic minerals are common in intermediate to basic igenous rocks which form extensive parts of the pre-Miocene ancestral Coast Range and western Cascade Mountains. Other minerals include rare apatite, chlorite, sphene, monazite, epidote, siderite, and olivine(?). These minerals indicate acidic to ultramafic igneous and/or metamorphic source rocks. Siderite was probably a minor cementing agent in the sandstone which became mixed with the heavy mineral assemblage during disaggregation.

Authigenic clay matrix constitutes from 5% to 35% of the Angora Peak sandstones. Most is derived from diagenetic alteration of volcanic rock fragments which are partly or completely altered to clays. Celadonite and nontronite are common and finely crystalline zeolites may be present. Neel (1976) identified vermiculite, chlorite (may or may not be diagenetic), and the zeolite clinoptilolite, in the clay matrix of Angora Peak sandstones by X-ray diffraction. The diagenetic clays may act as the cementing agent in many friable Angora Peak sandstones. Other pore-filling cements include hematite and calcite (up to 30%). Calcareous sandstones locally form resistant ribs. The sparry calcite cement seems to have retarded the development of diagenetic clays from the volcanic rock fragments in the sandstones.

Angora Peak sandstones are texturally mature to immature (Folk, 1968). Most are submature to mature, suggesting extensive sorting by tractive currents or waves prior to final deposition. Sieve analysis demonstrates that Angora Peak sandstones are moderately sorted even when including the diagenetic clay matrix (s_i=0.63 Ø, Folk and Ward, 1957) (Appendix VII). Individual framework grains vary from angular to subrounded. Some zircon grains are euhedral crystals while others are rounded, suggesting derivation from multiple source areas and possibly recycling from pre-existing sedimentary strata. Rare quartz overgrowths on quartz grains are also indicative of recycled sedimentary strata for some of the Angora Peak sandstones. Porosity, determined by modal analysis, is generally less than 4% due to the large quantities of diagenetic pore-filling clay matrix and/or carbonate cement.

Silver Point Member

The Silver Point member of the Astoria Formation is a thick sequence of interbedded marine mudstones and fine-grained laminated sandstones. The member can be divided into lower and upper tongues in the study area (Figure 13). The lower tongue crops out in all parts of the study area with exception of the southwest part (Figure 14 and Plate I) and ranges from approximately 30 to 75 meters in thickness. The upper tongue is restricted to the southwestern part of the study area and is up to 120 meters in thickness. The two tongues are separated by the 'J' and Airplane units in the western part of the study area (Figure 13). The 'J' and Airplane members apparently pinch out in the Tillamook Head area to the southwest where Neel (1976) has mapped a continuous sequence of lithologies comparable to the upper and lower Silver Point tongues. Neel (1976) further determined that the total thickness for the Silver Point in the Tillamook Head area is approximately 300 meters thick.

Lower Silver Point

Lithological Characteristics. The lower Silver Point tongue consists of laterally persistent, rhythmically interbedded, thin fine-grained sandstones, coarse-grained siltstones, and dark gray mudstones. This lithology is well exposed in steeply dipping strata at

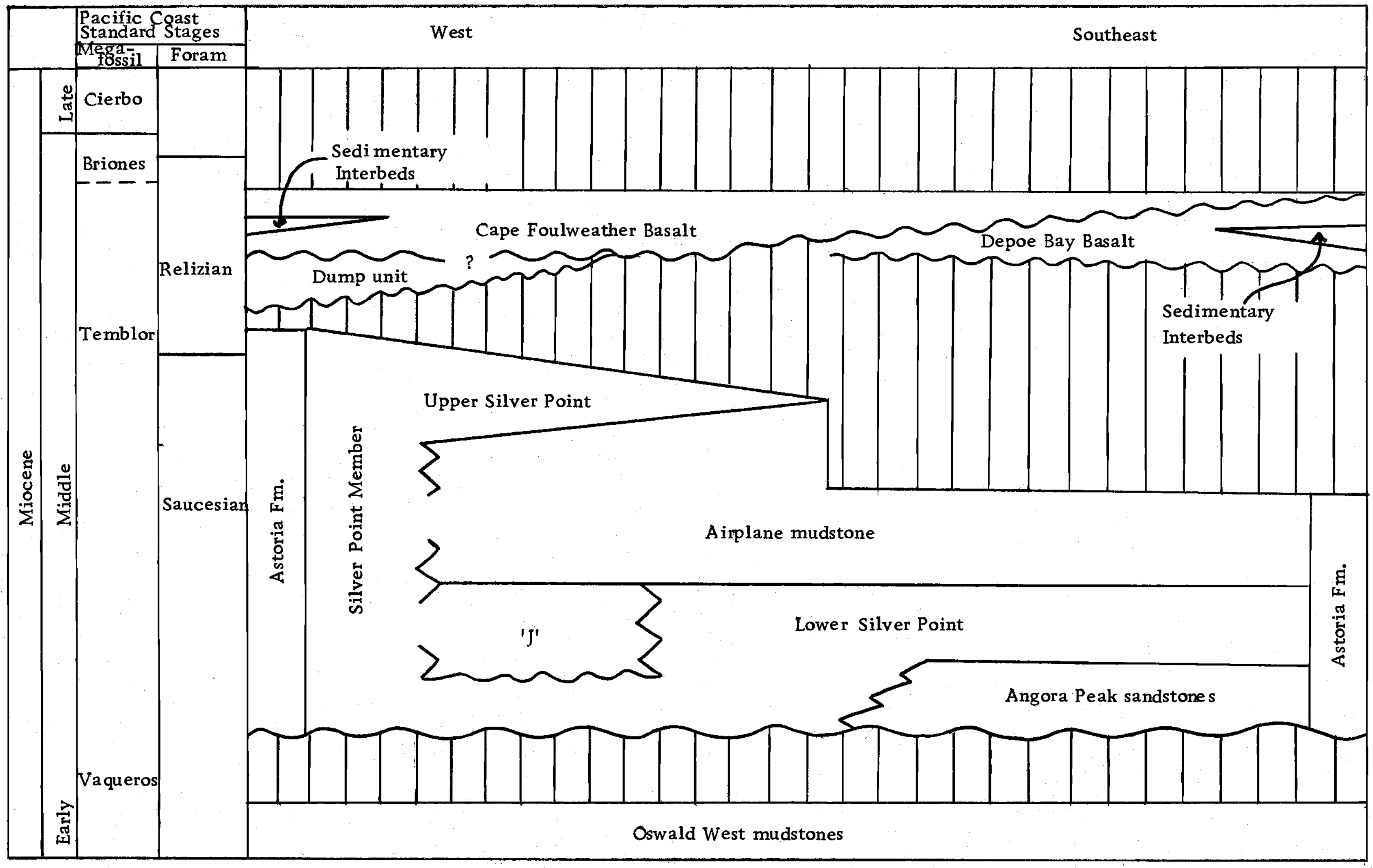


Figure 13. Miocene stratigraphy of thesis area.

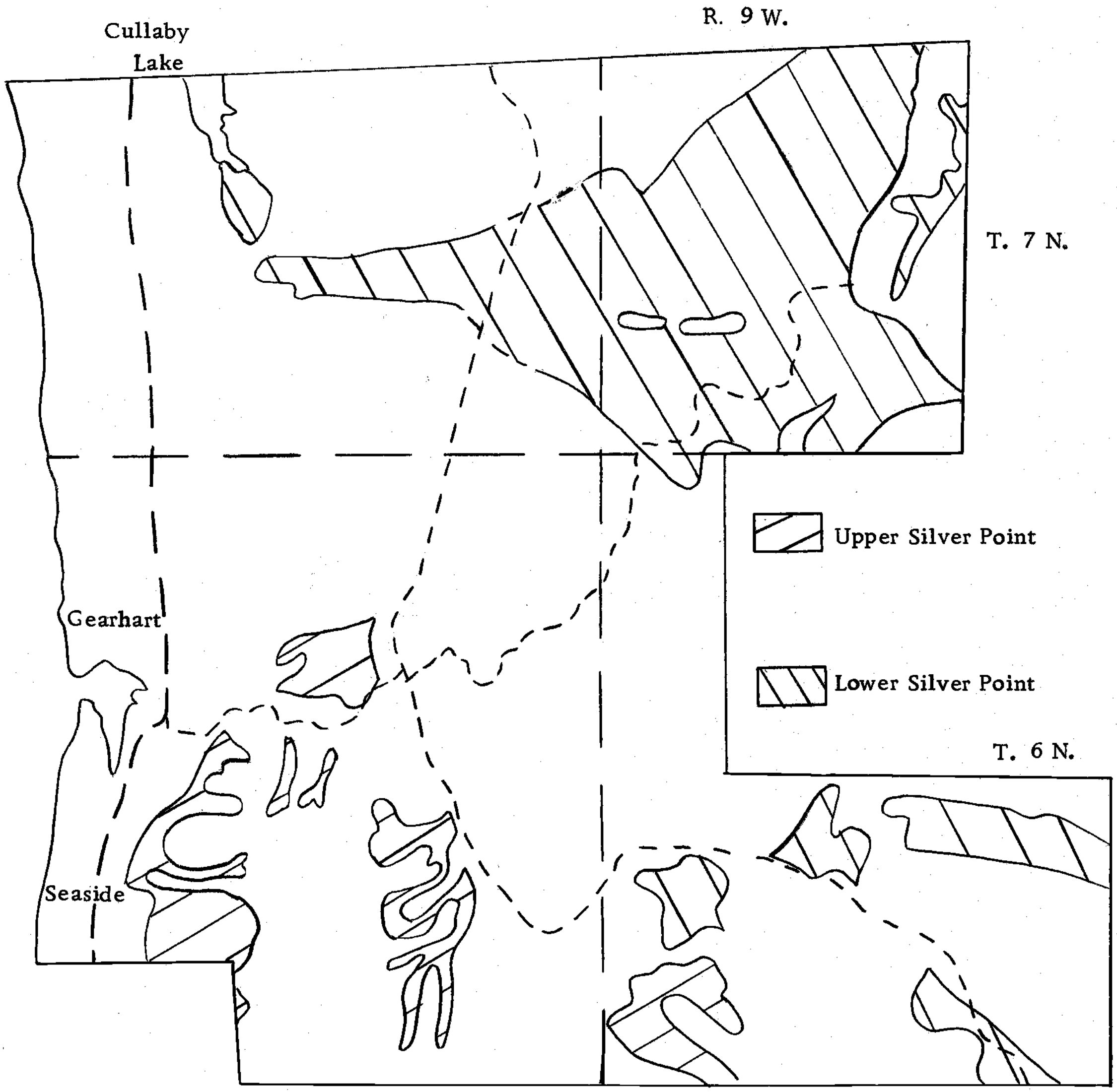


Figure 14. Outcrop distribution map of Silver Point member.

Young's River Falls (580 meters east of NW corner, sec. 27, T. 7 N., R. 9 W.) and along the 400 line between Spur 490 and Young's River Mainline (SW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 28, T. 7 N., R. 9 W.). The lower Silver Point tongue forms a low-lying hummocky topography except near basaltic intrusions where the unit is commonly well-indurated due to baking.

Lower Silver Point mudstones are medium light gray (N6) to light olive gray (5Y6/1) in color and contain very fine mica flakes and disseminated carbonaceous plant debris. The mudstones are very thinly to thinly bedded (1-10 cm.). Very thin light gray, wispy, planar and ripple laminated siltstones are commonly interstratified within the mudstones. The upper contacts of mudstone beds with the overlying coarser-grained interbeds are commonly very irregular. Load casts, flame structures, and scour features typically occur at these interfaces. Many mudstone layers have a mottled appearance due to intense bioturbation. Burrow forms include Helminthoida and Siphonites which are associated with water depths of 9 to 25 meters (Chamberlain, 1975, written comm.).

Two types of sandstones commonly occur in the lower Silver Point tongue. Both types are laterally persistent, "flysch-like" in appearance, and are pale yellowish brown (10YR6/2) in color. The most common type (approximately 60%) is non-graded very fine-grained sandstones and/or siltstones. They are characterized by parallel lamination, Flaser bedding, ripple cross-lamination, and micro-trough lamination (Figure 15). Trough cross-lamination orientations suggest deposition by series of tractive currents with highly variable flow directions (almost 360). Carbonaceous and micaceous debris commonly delineates laminae surfaces within these sandstone and siltstone beds. The sandstones are 3 to 13 cm. thick and have sharp upper and lower contacts with adjacent mudstone interbeds (Figure 16).

The other, less common, coarse-grained bed-type in the lower Silver Point tongue is normally graded fine-grained sandstones and coarse-grained siltstones which form 8 to 13 cm. thick beds. Sedimentary structures in composite order of occurrence in these beds include a normally graded interval, planar lamination, current ripple lamination, and upper parallel lamination which correspond to the A, B, C, and D intervals of the Bouma (1962) sequence. The Bouma E, or pelitic, interval is rarely observed in continuous sequence with the lower four intervals. Incomplete Bouma sequences, commonly T_{ab}, T_{bc}, T_{ac}, and T_{b-d} are typical of these lower Silver Point sandstone layers. Only one sandstone layer containing the complete, uninterrupted Bouma sequence (T_{a-e}) was found in the lower Silver Point (SE$\frac{1}{4}$, NE$\frac{1}{4}$, sec. 27, T. 6 N., R. 9 W.). Sharp basal contacts with underlying mudstones are sharp, undulatory, and many contain load casts. Some flame structures are visible in slabbed sandstones.

Figure 15. Closeup view of Flaser bedding in lower Silver Point tongue. Sample from outcrop shown in Figure 16.

Figure 16. Well-bedded lower Silver Point exposure. Light gray beds are tuffaceous sandstones. Note lateral continuity and sharp bedding contrasts.

Sandstone-filled horizontal and vertical burrows also occur in slabbed samples. The combination of the above features, especially repeated graded bedding, laterally persistent layers, and the presence of the Bouma sequence is suggestive that these beds were deposited by turbidity currents. The origin of these turbidite beds is further discussed in the Tertiary Geologic History section.

Other lithologic variations occur in the lower Silver Point tongue. On logging road Fletcher 16 (SW$\frac{1}{4}$, SE$\frac{1}{4}$, NW$\frac{1}{2}$, sec. 25, T. 7 N., R. 10 W.), structureless non-turbidite, fine- to medium-grained, micaceous sandstones are interbedded with dark mudstones approximately 15 meters above the contact with the underlying Oswald West mudstones. The sandstone beds, up to 26 cm. thick, contain scour-and-fill structures at contacts with the underlying mudstone interbeds.

Lenticular bedding is locally well developed within the lower Silver Point tongue along the 400 Line logging road (center, sec. 33, T. 7 N., R. 9 W.). One such fine-grained sandstone bed has a maximum thickness of 50 cm. and can be traced for approximately 15 meters before pinching out laterally. Other, less extensive, lenticular sandstone beds at this location are interbedded with dark mudstones and predominantly structureless sandstone beds.

Several lower Silver Point outcrop areas contain structureless, thick- to very thick-bedded micaceous, fine- to coarse-grained sandstone layers 0.6 to 4 meters thick (e.g. 100 line logging road, 600 meters south of NE corner, sec. 21, T. 7 N., R. 9 W. and logging Spur 101F, SE$\frac{1}{4}$, NE$\frac{1}{4}$, sec. 20, T. 6 N., R. 9 W.). Interbedded mudstone layers at these locations are relatively thin, usually less than 5 cm. thick. Along Spur 101F, these beds are fine pebble conglomerates and contain abundant mudstone ripups up to 10 cm. long. The structureless fine- to coarse-grained sandstone layers within this sequence contain abundant quartzite, chert, and basaltic pebbles up to 4 cm. diameter (Appendix VIII).

Because of deep weathering, much of the lower Silver Point strata are highly friable. However, near contacts with intrusive dikes or sills, such as at Young's River Falls, the strata are well-indurated and bleached due to baking by the basalt magma. Local carbonate cemented resistant sandstone beds commonly form irregular blocks up to 15 cm. (maximum dimension) in the talus below the outcrops.

Contact Relationships. The lower Silver Point tongue overlies the upper Oligocene-lower Miocene Oswald West mudstones in the north and the middle Miocene Angora Peak sandstones in the southeast part of the study area (Figure 13 and Plate I). Because the contact between the Oswald West mudstones and the lower Silver Point tongue is covered at all locations, the contact relationship cannot be precisely determined. However, in the northwestern part of the study area, the orangish weathering Oswald West mudstones contain molluscan fossils and trace fossils indicative of outer neritic to bathyal conditions. The Oswald West is directly overlain by shallow-marine grayish lower Silver Point sandstones and mudstones (see Geologic History for interpretation). Although no disparities in dip and strike are apparent between the two units, this rapid change in rock types and depositional environments suggests the presence of a possible disconformity in this area.

In the southeastern part of the area, the middle Miocene Angora Peak sandstones and the overlying lower Silver Point tongue form a conformable gradational sequence. Fine-grained, thickly bedded, arkosic Angora Peak sandstones fine upward and incorporate increasing numbers of mudstone interbeds over approximately 15 meters into the very fine-grained, thinly bedded micaceous sandstones and carbonaceous mudstones of the lower Silver Point tongue. This relationship is observed locally in outcrops between logging Roads 134 and 110 in sections 15 and 22, T. 6 N., R. 9 W.

Based on stratigraphic position, the lower Silver Point tongue is thought to intertongue laterally with the Angora Peak sandstones in the south (Figure 13). This relationship is probably present only in the subsurface beneath the Green Mountain Sister volcanic complex.

The upper contact between the lower Silver Point tongue and overlying units is described under the Contact Relations sections of the 'J' and Airplane units.

Age and Correlation. The lower Silver Point tongue is an informal unit within the middle Miocene Astoria Formation as it is underlain by and probably intertongues with the Angora Peak sandstones which contain a middle Miocene molluscan assemblage. The lower tongue is overlain, in part, by the Airplane mudstones which contain a middle Miocene foraminiferal assemblage. No diagnostic fossils are present in the lower Silver Point tongue, but Neel (1976) obtained a middle Miocene age from foraminiferal assemblages in the lower part of the Silver Point member (a lateral equivalent) at Ecola State Park approximately 11 km. southwest of this study area. The lower Silver Point tongue is a well bedded sandstone/mudstone sequence similar to the lower part of the type Silver Point mudstones 15 km. southwest of the study area. However, Smith (1975) noted the sandstones at the type locality are thicker bedded (up to 2 m.) than in this area and are predominantly of turbidite origin.

The lower Silver Point tongue lithology has been traced northward within 3 km. of the type Astoria Formation at Astoria, Oregon (Cooper, 1975, pers. comm.). The lower tongue may be stratigraphically equivalent to the lower Sandstone member of the type Astoria Formation (Howe, 1926) which also contains interstratified dirty, fine-grained sandstones and dark mudstones. The lower Silver Point tongue may also be, in part, equivalent to the middle "Shale" Member at Astoria. Better age control of fossil assemblages and petrologic studies are needed before correlations to the type Astoria Formation can be made.

Upper Silver Point Tongue

Lithological Characteristics. The 120-meter thick upper Silver Point tongue is composed of well-laminated to thinly bedded dark gray mudstones and light gray very fine-grained silty sandstones and siltstones. The upper tongue is easily weathered and slump-prone which causes the unit to form low hummocky, dissected hills. The upper Silver Point crops out only in the southwestern part of the study area beneath late middle Miocene Cape Foulweather and Depoe Bay Basalts (Figure 14). Deep ravines have been cut into the Silver Point once the capping basalts are eroded. A 12-meter section of typical upper Silver Point lithology is well exposed in a ravine 10 meters east of the Necanicum Mainline logging road (NW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 26, T. 6 N., R. 10 W.).

The mudstone interbeds are olive gray (5Y4/1) and rapidly weather to small yellowish gray (5Y7/2) chips. The fresh dark color is caused by very finely disseminated carbonized plant debris. Concentrations of sand-size foraminifera in some mudstone laminae locally give the mudstones a sandy appearance.

The very light gray (N8) to light bluish gray (5B7/1) sandstone beds are commonly tuffaceous, micaceous, and feldspathic. Rare white (N9) discontinuous tuff nodules and lenses are interbedded with the sandstones and mudstones.

Small ellipsoidal limonite concretions are locally abundant in the upper Silver Point tongue. The concretions are 2 to 8 cm. in length and commonly have soft tuffaceous, or even hollow, cores. Limonite/hematite staining and hemispheroidal weathered surfaces cross, and commonly destroy, the usually well-defined bedding of the upper tongue. Similarly, deep weathering in the poorly indurated strata causes many outcrops to appear structureless. Talus and outcrop surfaces are commonly composed of a very fine clay-rich sand.

Wavy laminations in both mudstones and the coarser silty sandstones are ubiquitous (Figure 17). Mudstone beds are commonly cut by small scour-and-fill troughs in the mudstone beds. Flame structures and pull-aparts suggest that small-scale penecontemporaneous soft sediment deformation occurred due to rapid loading, differential compaction, or post-depositional down-slope movement. Rare small sandstone dikes (up to 20 cm. thick and 3 m. long) are present near contacts with intrusive basalts.

Foraminifera are abundant in the upper Silver Point tongue. Common forms include Siphogenerina, Globigerina, Virgulina sp., Buliminella sp., and Nodosarie lonniscata (d'Orbigny) (Rau, 1975, written comm.). This microfossil assemblage is indicative of deposition on the upper continental slope at depths of 500 meters or less.

Contact Relations. The upper Silver Point tongue is in gradational contact with the underlying Airplane mudstones of the Astoria Formation in the west-central part of the area (Figure 13). This relationship is best exposed along the 500 Line logging road (S$\frac{1}{2}$, NE$\frac{1}{4}$, sec. 11, T. 6 N., R. 10 W.) where thinly laminated Airplane mudstones gradually incorporate more thinly interlaminated sandy siltstone lenses over a distance of approximately 25 meters until a typical interbedded upper Silver Point sequence is encountered.

The unconformable relationship between the upper Silver Point tongue and overlying rocks is discussed in the Contact Relations sections of the Cape Foulweather Basalts and Dump sandstones.

Age and Correlation. A Saucesian, or middle Miocene, age for the upper Silver Point tongue is indicated by the foraminiferal assemblage from several samples within the unit (Rau, 1975, written comm.) (Appendix IV). The upper Silver Point tongue in this study area correlates lithologically and stratigraphically with the upper part of the Silver Point first described by Smith (1975) at the type Silver Point locality 15 km. to the south. This unit has been mapped by Neel (1976) from Silver Point to the southwestern corner of the study area.

Petrology of the Lower and Upper Silver Point Tongues

Modal analysis was performed on five fine- to medium-grained Silver Point sandstones. Since most beds in the upper and lower Silver Point tongues are composed of sandy siltstones or silty, very fine-grained sandstones, there will be a bias in the analysis results. Finer grained siltstones were studied but not point counted. They appear to be mineralogically similar to the coarser sandstones but contain more detrital matrix and fewer lithic and opaque minerals. Silver Point sandstones are arkoses to arkosic wackes (Williams and others, 1955) (Figure 10).

Quartz and plagioclase form from 47% to 76% of the framework grains within the Silver Point sandstones. Total quartz, of which strained and polycrystalline quartz form the greatest amount, averages 39.5% for lower Silver Point sandstones and 31.7% for upper Silver Point sandstones (Figures 7 and 18). Lower Silver Point sandstones generally contain greater percentages of quartz than the upper Silver Point sandstones, although quartz ranges overlap in individual thin sections in both units.

Plagioclase averages 27% for sandstones in both tongues. Andesine is the most common plagioclase with extremes being represented by oligoclase (An_{24}) to labradorite (An_{63}). K-feldspars are less common (5-8%) and are dominantly orthoclase with minor

Figure 17. Wavy bedding in interbedded upper Silver Point tongue. Light layers are sandstone, dark layers are carbonaceous mudstones (NW 1/4, SW 1/4, sec. 26, T. 6 N., R. 10 W.)

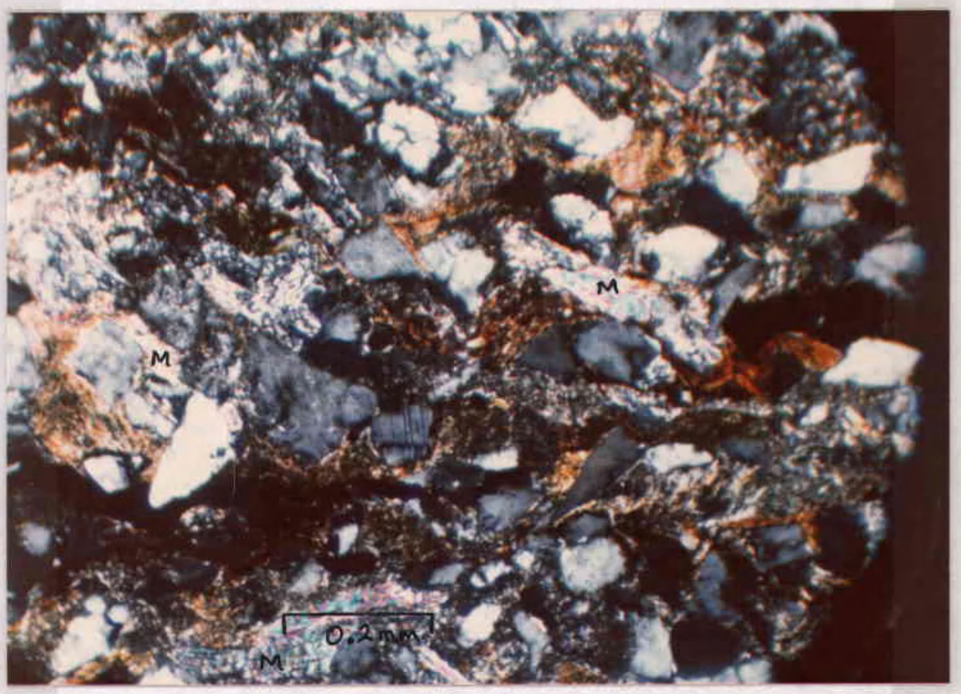


Figure 18. Photomicrograph of upper Silver Point quartzose-feldspathic sandstone. Note concentrations of mica (m) and dark brown carbonaceous plant debris. (Crossed Nicols)

microcline and rare sanidine. Many feldspar grains are partially altered to sericite and/or calcite. K-feldspar is generally less altered than plagioclase.

Lithic rock fragments are not abundant (10% or less) in the Silver Point sandstones, probably because the sandstones are so fine-grained. Folk (1968) indicates that unstable rock fragments break down chemically before physically reaching fine or very fine sand size. Basalt, andesite(?), and rare pumiceous fragments are the most common lithic types. These volcanic rock fragments are generally highly altered to green clay minerals. Basalt clasts have intersertal to intergranular textures.

Detrital micas form 2 to 13% of the Silver Point rocks. Brown and green varieties of biotite are commonly two to three times as abundant as muscovite. Small detrital micas comprise a large portion of the sandstone matrix.

Biotite and the opaque minerals magnetite and ilmenite are the most abundant heavy minerals in a Silver Point sandstone sample (Appendix V). Pink and translucent garnets, possibly spessartite, are very common. The pyroxenes, augite, pigeonite, and enstatite are abundant. Heavy minerals comprise less than 1% of this sample. The heavy mineral assemblage suggests that the source for the Silver Point was largely intermediate to mafic igneous terrane which is also confirmed by the presence of basalt and andesite rock fragments.

Garnets and micas probably come from a low-rank metamorphic, acid plutonic, or pegmatitic terrane.

Diagenetic clays and calcite are the most common cements. Iron oxides are generally not important cementing agents, but color many weathered samples. X-ray diffraction analysis determined that the dominant clay matrix minerals are montmorillonite, chlorite, and mixed-layered clays. Celadonite and sericite were identified microscopically. Very finely disseminated carbonaceous plant debris is also present in amounts varying from 1% to 7% as determined by treatment with hydrogen peroxide.

Because of the high percentage of unstable rock fragments and plagioclase, the Silver Point sandstones are compositionally immature (Folk, 1968). The sandstones are texturally immature, as well, since they contain well over 5% matrix and angular to subrounded grains, most of which are subangular. Most sandstones appear to be poorly to moderately sorted.

The pebble conglomerates in the lower Silver Point sandstones on logging Spur 101F, sec. 20, T. 6 N., R. 9 W., are composed predominantly of dark brown and green chert (42%) and quartzite (43%) (Appendix VIII). Tuff (5. 7%) and porphyritic rhyolite (3. 1%) pebbles occur in minor amounts. Agate, andesite or basalt, vein quartz, and diorite(?) individually compose less than 1% of the sample. Some pebbles are as large as 3. 2 cm. (maximum diameter) and almost all are well-rounded.

'J' Unit

The 'J' unit crops out over a 10 km^2 elongate area across the northern part of the study area (Figure 19 and Plate I). Although not areally extensive, it is a well-defined, mappable unit with a total thickness of approximately 150 meters. The type 'J' unit is described in a 107 meter measured stratigraphic section (Appendix II) on logging Spur 16N ($N\frac{1}{2}$, $SE\frac{1}{4}$, $SE\frac{1}{4}$, sec. 26, T. 7 N., R. 10 W.). A 25 meter measured section in the northeast part of the study area along logging spur 470 ($NW\frac{1}{4}$, $NW\frac{1}{4}$, sec. 33, T. 7 N., R. 9 W.) illustrates a lithologic variation in the 'J' unit (Appendix III).

Lithologic Characteristics

In the northwestern part of the area, the type 'J' unit consists of a well-bedded sequence of laminated (1-2 mm.) highly carbonaceous and micaceous mudstones and muddy siltstones (Figure 20). Rare very fine sandstone laminae and light colored tuff beds (up to 20 cm. thick) are interbedded with the finer mudstone layers. The distinctive rhythmic dark laminations, formed by concentrations of carbonaceous plant fragments and mica flakes, differentiate this unit from other members of the Astoria Formation. The carbonaceous plant debris comprises up to 25% of some layers and a 10% plant fragment

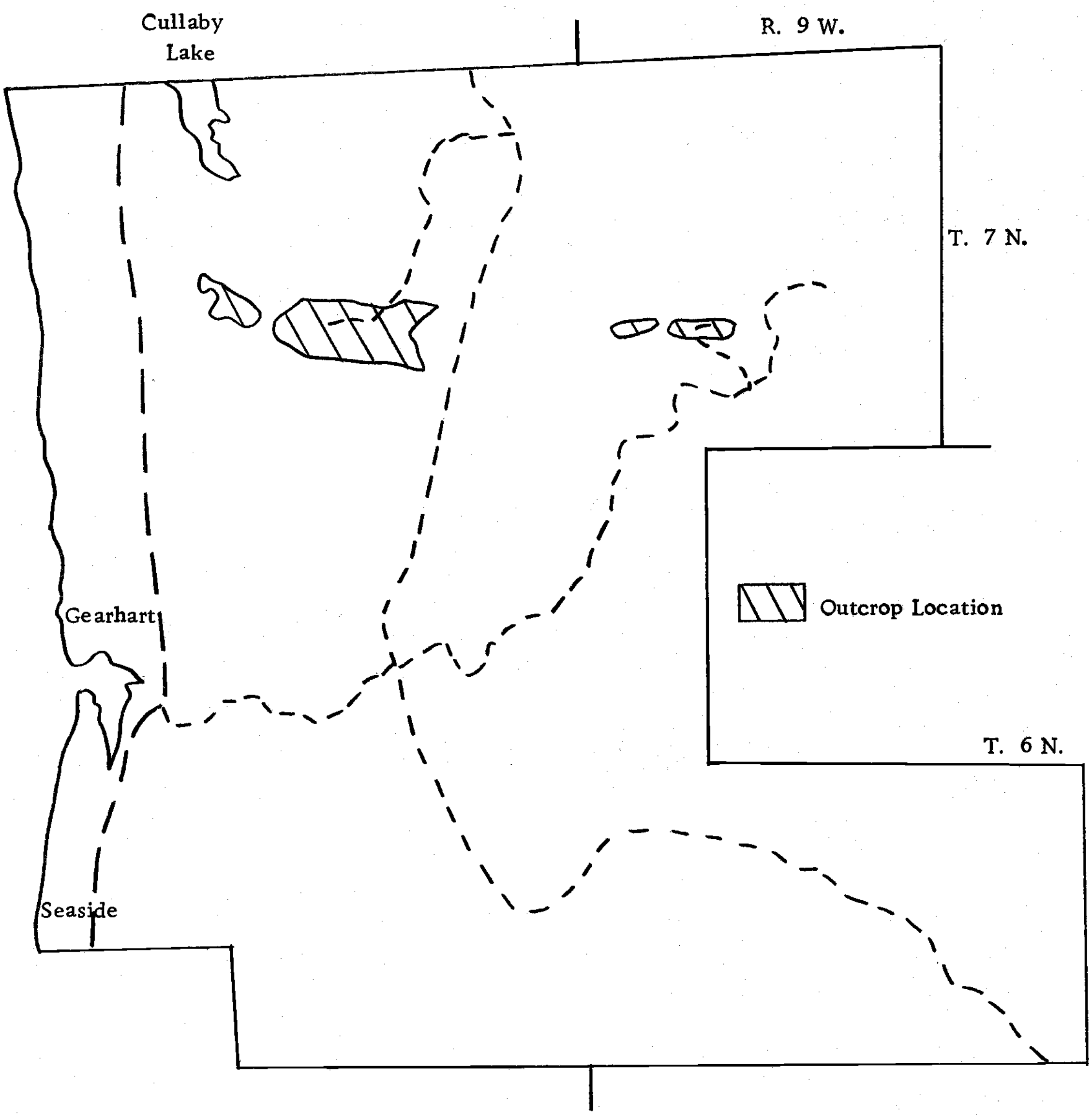


Figure 19. Outcrop distribution of the 'J' unit.

Figure 20. Outcrop of laminated carbonaceous, micaceous mudstones of the 'J' unit. (Reference section C-1), unit 97, N 1/2, SE 1/4, SE 1/4, sec. 26, T. 7 N., R. 10 W.

content in the mudstones is not uncommon. In parts of the unit, elongate plant fragments have been oriented by currents in a northeast-southwest direction. Rare, large deciduous leaf fragments were collected from the lower part of the unit ($N\frac{1}{2}$, $SE\frac{1}{4}$, $SE\frac{1}{4}$, sec. 26, T. 7 N., R. 10 W.) but because the leaf margins were destroyed they could not be identified (Dennis, 1974, pers. comm.). Carbonaceous debris is generally less abundant and randomly oriented in the upper 50 meters of the unit but still comprises 1% to 4% of the rock layers.

Fresh exposures of 'J' laminated mudstones are olive black (5Y2/1) to dusky brown (5YR2/2). Light olive gray (5Y7/1) to dark yellowish orange (10YR6/6) weathered mudstone outcrops are far more common, however. Weathered surfaces are composed of small mudstone chips and iron stained spheroidal Liesegang rings commonly occur in the roadcut exposures. Hematite concretions, 2 to 10 cm. diameter, are abundant in the lower 60 meters of the 'J' unit. The concretions commonly contain cylindrical cores of pyrite or marcasite.

Several ridge-forming channelized sandstones cap the top of the 'J' unit in the northwestern part of the study area. These medium- to coarse-grained arkosic carbonate cemented sandstones range in thickness from 0.5 to 1.4 meters. The sandstone channels are lenticular in shape and are approximately 6 meters in width. In a roadcut along logging Spur 16J2 ($S\frac{1}{2}$, $SE\frac{1}{4}$, $SW\frac{1}{4}$, sec. 25, T. 7 N., R. 10 W.), a 0.6 meter-thick erosional channel is completely enclosed by typical 'J' laminated carbonaceous mudstones. The channel sandstones, which form the ridge along logging Spur 16 and its side roads in the southwestern corner of section 25, T. 7 N., R. 10 W., contain planar cross-beds and imbricated carbonaceous mudstone ripups up to 8 cm. long.

Channel sandstones, found only in the uppermost part of the 'J' unit in the northwest, are the dominant features of the 'J' unit in the northeastern part of the study area (Figure 19). Individual channels range from 1. 0 to 3. 5 meters in thickness and grade upward from fine pebbly sandstones and pebble conglomerates to moderate yellowish brown (10YR5/4) carbonaceous, laminated sandy siltstones. Carbonized leaf fragments and whole leaves are found in the finer-grained sandstones and siltstones above the conglomeratic channels. Carbonaceous debris is concentrated along bedding planes of the fine-grained sandstones and mudstones in a manner similar to that of the type 'J' unit measured section along logging spur 16N. This plant material may constitute 3% to 10% of the rock.

The pebble conglomerates contain trough cross-beds with amplitudes up to 0. 6 meters. Lenses of imbricated elongate pebbles and mudstone ripups are interstratified in the lower parts of the conglomerate channels (Figure 21). Pebbles are dominantly rounded quartzite and intermediate and basic volcanics up to 1 cm. diameter. Carbonaceous mudstone ripups range from 0. 5 to 5 cm. in length.

Figure 21. Channel sandstones of the 'J' unit. Note scour-and-fill channel and mudstone ripup lens (arrow).

Loose weathered sands and blocks of mudstone compose thick talus deposits at the base of most of these outcrops.

Contact Relations

The contact with the underlying lower Silver Point tongue is covered in all parts of the thesis area. However, in the northeast part of the map area (N$\frac{1}{2}$, sec. 33, T. 7 N., R. 9 W.), the sandstones of the lower Silver Point tongue become coarser, thicker bedded, and lenticular upward. Since these lithologic and bedding characteristics are also common in the 'J' unit, it is probable that a gradational contact exists between the two units over approximately 30 meters. Laterally, the 'J' unit pinches out to the southeast (Figure 13). The upper contact is described in the Contact Relations section of the Airplane mudstones.

Age and Correlation

Since the 'J' unit occurs conformably between the lower Silver Point tongue and Airplane tongue of the Astoria Formation, both of which contain late Saucesian (middle Miocene) foraminiferal assemblages, the 'J' unit is also middle Miocene in age.

The 'J' unit in the northeastern part of the study area is correlative to the type 'J' unit in the northwest based on similar stratigraphic position above the lower Silver Point, lithological similarities between channel sandstones and fine-grained carbonaceous siltstones and mudstones, and that they are on strike with one another.

The fluvial arkosic sandstones and laminated carbonaceous mudstones of the 'J' unit may be, in part, correlative to the Angora Peak sandstones south of the study area based on similar stratigraphic position. Cressy (1974) and Smith (1975) report outcrops near Onion Peak and Angora Peak 30 km. to the south consisting of channelized fluvial and shallow-marine arkosic sandstones and isolated exposures of laminated carbonaceous mudstones which were mapped within the Angora Peak sandstone member.

Petrology

Modal analysis of two sandstones from the 'J' unit were made (Appendix VI). Quartz (29%) and plagioclase (39%) compose the largest fraction of detrital grains (Figure 7). An unusually large amount of strained and polycrystalline quartz (19%) was noted in the 'J' sandstones. Unstrained quartz and chert are equally abundant and comprise approximately 10% of the total rock volume. Plagioclase ranges from oligoclase (An_{20}) to labradorite (An_{70}) and is dominantly andesine (average An_{31}). Both twinned and untwinned plagioclase are abundant. Other feldspar types include the K-feldspars, orthoclase and microcline (1.5%), and rare perthite. Plagioclase is commonly partially altered to sericite and/or calcite while many of the K-feldspars remain unaltered.

Volcanic rock fragments (5%) are dominantly basalt in composition with porphyritic, intersertal, and intergranular igneous textures. The groundmass of most volcanic rock fragments are altered to celadonite and other green clays. Other rock fragment types include rare quartz-mica schist, pumice, granitics, and andesite(?). Mudstone ripups comprise approximately 6% of the sandstones. Zircon, garnet, augite, and glauconite occur as minor heavy mineral constituents. Carbonaceous plant fragments and very fine-grained detrital mica matrix forms about 17% of the sandstones (Figure 22). The 'J' sandstones are generally cemented by clays and minor calcite. X-ray diffraction analysis of the clay matrix shows the presence of montmorillonite, mixed layered chlorites, mica and possibly chlorite and kaolinite (Appendix IX).

'J' sandstones are compositionally immature because of the abundance of chemically unstable feldspars and lithic rock fragments (Folk, 1968). In addition, the channel sandstones are texturally immature as they are poorly sorted, contain dominantly angular to subrounded framework grains, and have an abundant silt-clay matrix (averaging 17%) (Folk, 1968). This textural immaturity suggests the sandstones were deposited rapidly with little or no current reworking.

The laminated mudstones and siltstones which compose most

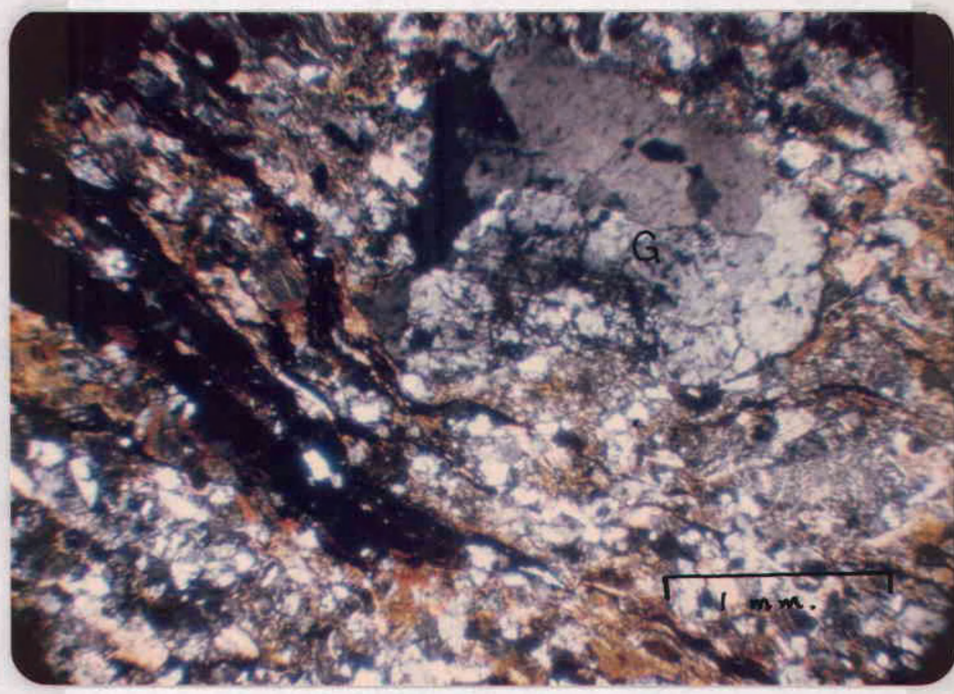


Figure 22. Photomicrograph of channel sandstone showing poor sorting, angular grains, and abundance of matrix. Note dark carbonaceous debris deformed around granitic rock fragment (G). (Crossed Nicols)

of the 'J' unit are cemented by calcite and hematite. The dark mudstones contain up to 25% disseminated carbonaceous plant material. Fine-grained authigenic pyrite is commonly associated with the carbonaceous laminae.

Airplane Mudstone Tongue

The Airplane mudstones of the Astoria Formation crop out in an east-west band across the central part of the study area (Figure 23 and Plate I). The unit, which consists entirely of laminated mudstones, may be as thick as 250 m. based on calculations from outcrop distribution and dip relations. Typical exposures can be observed along Airplane Apur logging road (western half, sec. 36, T. 7 N., R. 10 W.) which is the type area. Most of the Airplane unit is poorly exposed because the mudstones are easily weathered. Much of the outcrop area consists of low, hummocky, rounded hills.

Lithological Characteristics

The Airplane mudstone unit consists of weathered yellowish gray (5Y7/2) to dark yellowish brown (10YR4/2) very well-laminated (less than 1 mm. thick) mudstones. The mudstones are commonly iron stained and form small platey chips. Foraminiferal molds are characteristically well preserved along bedding planes. Rare fresh exposures are olive gray (5Y3/2) to olive black (5Y2/1) in color.

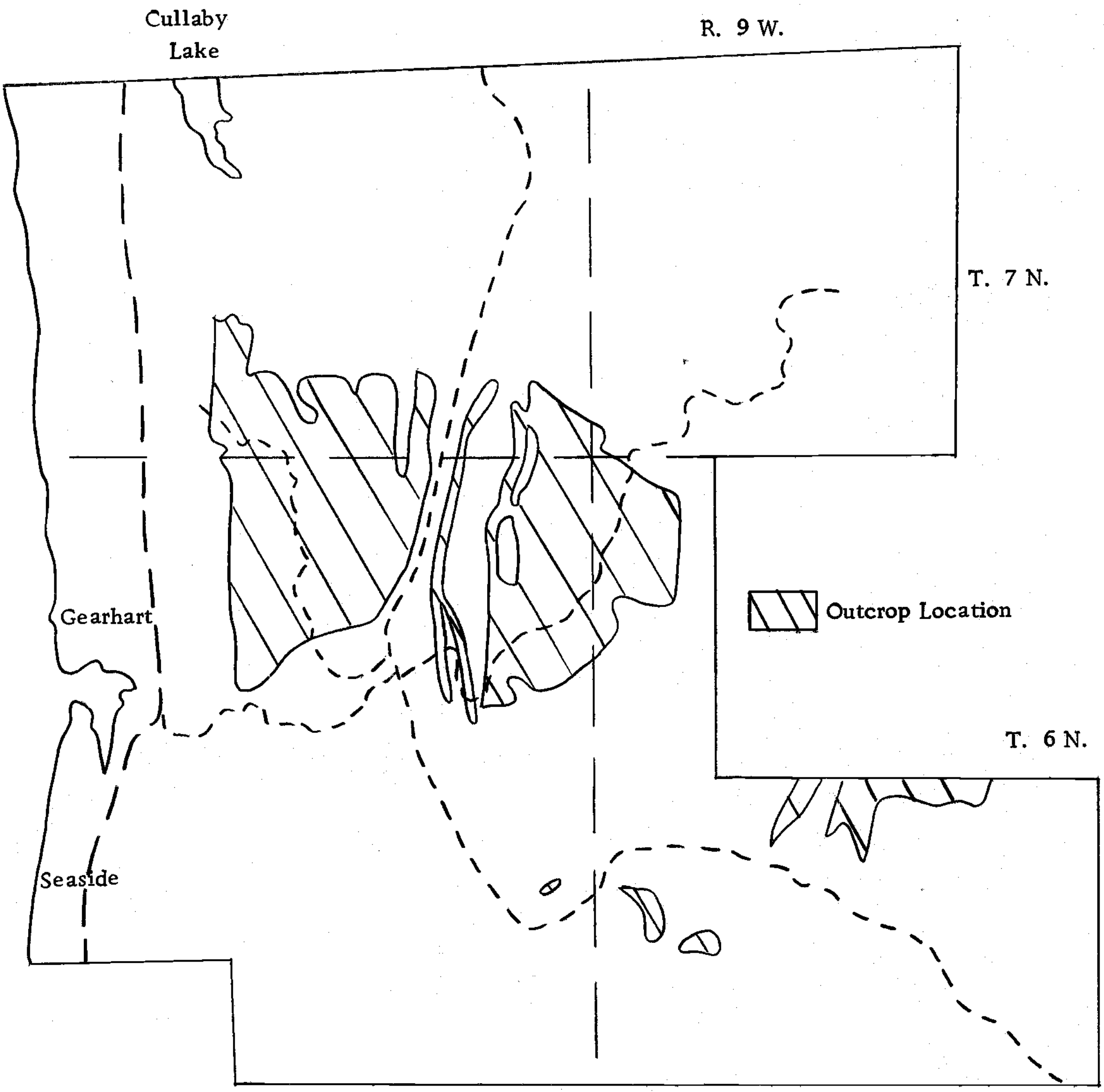


Figure 23. Outcrop distribution of the Airplane mudstones.

The Airplane unit can be roughly divided into lower and upper units. The lower part consists of approximately 45 meters of tuffaceous and carbonaceous laminated mudstones. The basal 15 meters contains from 2% to 5% disseminated plant fragment debris concentrated along lamination boundaries. Rare wispy siltstone laminae (less than 0. 1 mm. thick) occur in this part of the unit. Within the lower 45 meters, rare light colored 8 to 22 cm. thick tuff beds, which are slightly more resistant are interstratified with the darker brown mudstones (Figure 24). The tuff beds weather to blocks up to 8 cm. in maximum dimension.

The upper part (approximately 200 m.) of the Airplane unit is a monotonous sequence of well-laminated mudstones containing no tuff beds. The uppermost 15 meters becomes coarser grained and incorporates wispy laminae of micromicaceous siltstone and very fine-grained sandstone as it grades upward into the overlying upper Silver Point tongue.

A local lithologic variation of the Airplane mudstone crops out along logging Spurs 410F and 451 in sections 5 and 6, T. 6 N., R. 9 W. The small outcrops consist of very well-indurated and resistant tuffaceous, silicified laminated mudstones. Foraminiferal molds remain as small holes in the cherty mudstones.

Figure 24. Roadcut exposure of lower Airplane mudstones containing resistant tuff beds (light color). Note small platey weathering and hammer in center for scale.

Contact Relations

The Airplane mudstone tongue is conformable with the underlying lower Silver Point tongue in the southeast and the 'J' unit in the northwest part of the study area (Figure 13). The contact with the lower Silver Point tongue is covered but dips of the two units are conformable.

The contact between the Airplane and 'J' units in the northwest is gradational over approximately 30 meters. This sequence is partially exposed along Warrenton Pipeline Road (sec. 37, T. 7 N., R. 10 W.) where carbonaceous, thick-bedded, very fine-grained silty sandstones of the 'J' unit underlie the Airplane mudstones. These sandstones gradually become thinner bedded, less numerous, and less carbonaceous as the abundance of laminated mudstone increases upward. This lithologic change also correlates with a gradual color change from the light grays typical of the 'J' unit to the weathered yellow browns of the Airplane mudstones.

The contact between the Airplane and overlying upper Silver Point tongue is discussed in the Contact Relations section of the upper Silver Point tongue.

Age and Correlation

The Airplane mudstones are of Saucesian, or middle Miocene, age and are age equivalent to the type Astoria Formation based on the foraminiferal assemblage collected at several localities over the outcrop area (Rau, 1975, written comm.). The forams include Dentalina spp., Globigerina spp., Siphogenerina sp., and Virgulina sp. (Appendix IV). Because of the age, similarity in lithology, and its stratigraphic position, the Airplane mudstones probably correlate to the middle "shale" member of the type Astoria Formation described by Howe (1926) at Astoria, Oregon (Cooper, 1975, personal comm.). The Airplane unit appears to thicken towards the city of Astoria where it may be as thick as 400 meters (Carter, 1975, pers. comm.). Apparently the Airplane mudstones pinch out rapidly to the south into the Silver Point mudstones. Neel (1976) did not recognize an Airplane mudstone lithology in the Tillamook Head-Necanicum Junction area where there is a continuous section of lower and upper Silver Point units which grade into one another.

Petrology

In thin section, the Airplane mudstones consist mainly (approximately 90%) of detrital clays or very fine silt. Scattered coarse-grained silt- and rare very fine sand-size grains of quartz and plagioclase constitute the remaining 10% of the mudstones. A few sand-size elongate and planispiral foraminifera are found (Figure 25). Calcite, clay minerals and pyrite are the main cementing agents.

Finely disseminated carbonaceous plant debris is commonly concentrated along bedding plane boundaries and comprises up to 5% of some samples, as determined by H_2O_2 treatment. Pyrite has replaced this fine plant material along some bedding planes. X-ray diffraction analysis of the clay matrix determined that the Airplane mudstone clays are predominantly of montmorillonite, chlorite, chlorite intergrades, mica, and kaolinite(?).

Thin section study of the silicified Airplane mudstones collected from sections 5 and 6, T. 6 N., R. 9 W., shows that these mudstones have been completely cemented and partially replaced by very finely crystalline chalcedony and chert. Minor blebs of calcite, which was probably the original cement, still remain. Two hypotheses are proposed for the origin of these silicified mudstones. (1) Pore waters in the mudstones became saturated with silica due to nearly total devitrification and solution of tuffaceous material from the Airplane and surrounding units. The silica then precipitated as chert and chalcedony after migration to this locality. (2) The locality is within 0.5 km. of a group of middle Miocene basaltic intrusions which may have had excess deuteric silica. This deuteric silica could have been dissolved by percolating pore waters which permeated into the

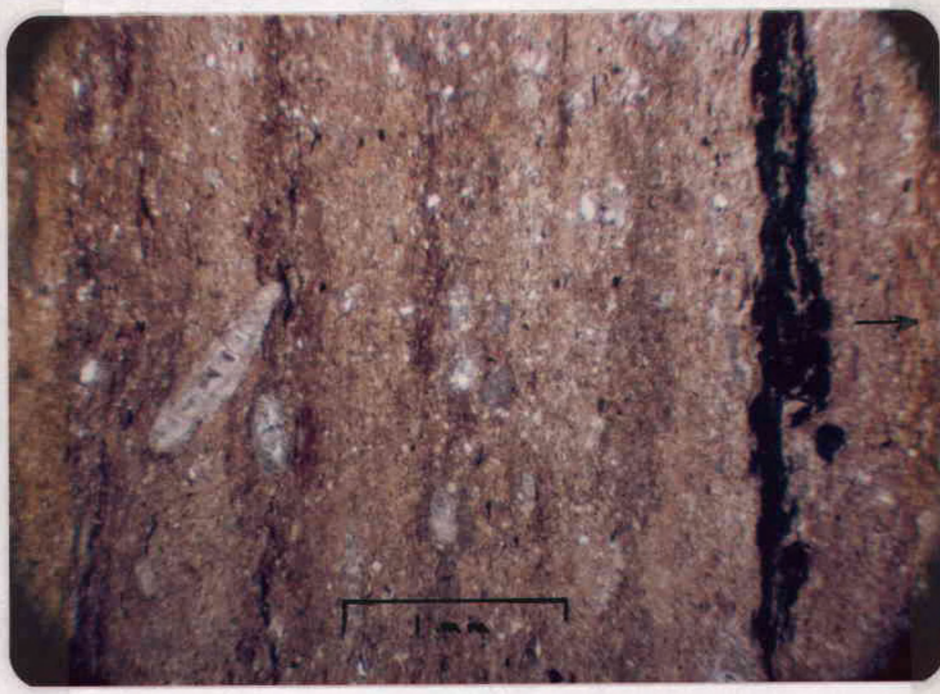


Figure 25. Photomicrograph of laminated Airplane mudstones. Note the pyrite layer at top of photo, several foraminiferal tests, and brown carbonized plant debris forming lamination boundaries. Stratigraphic up is to right (arrow)

surrounding mudstone where it precipitated. The first proposal seems most likely since the mudstones contain tuff beds and abundant tuffaceous material which can easily devitrify to more stable components almost in situ.

The Airplane mudstones are well-laminated, with the laminations due to layers of clay separated by finely disseminated carbonaceous plant fragments. These fine laminations suggest that the mudstones were deposited in a cyclic manner in a very low energy environment. The lamination could have been formed by the influx of fine material by periodic floods along the nearby coast or by reworking by very weak fluctuating bottom currents. Abundant pyrite is suggestive of deposition under reducing conditions. Minor bioturbation is observed in thin section which suggests that some bottom life existed. The foraminiferal assemblage is indicative of deposition in water about 500 meters or less in depth (Rau, 1975, written comm.).

Dump Sandstone

The Dump unit is an informal middle Miocene sandstone unit defined in this thesis which lies with probable angular unconformity over the Airplane and upper Silver Point tongues of the Astoria Formation. The Dump sandstone is best exposed at the type area in a series of discontinuous roadcuts along the Lewis and Clark County

Road near the city of Seaside sanitary landfill site (Figure 26) where it is conformably (?) overlain by Cape Foulweather pillow basalts and breccias. Approximately 25 meters of Dump sandstones are exposed in a road cut and ravine along the Lewis and Clark County Road 540 meters east of the southwest corner, section 11, T. 6 N., R. 10 W. The Dump unit is commonly preserved in small faulted blocks or where it is overlain by Cape Foulweather basalts (Plate I). Apparently, the unit was either eroded where not covered by capping basalt flows or was not deposited in the rest of the study area. In the faulted blocks, the faintly bedded sandstones contain highly variable dips, some nearly vertical, probably as a result of drag along fault planes. The total thickness of the Dump unit is unknown because the unit is structurally deformed. However, based on trigonometric calculations of observed outcrop thickness and outcrop pattern the Dump unit has a maximum thickness of approximately 50 meters.

Lithology and Petrology

The Dump unit is composed of poorly bedded to thick structureless dirty, very fine-grained sandstones and coarse-grained siltstones. Rare fine-grained thin sandstone beds define bedding. Crude stratification can be discerned from a distance due to color differences as a result of varying amounts of iron staining along bedding planes. The thick-bedded sandstones are grayish orange (10YR7/4) with thin

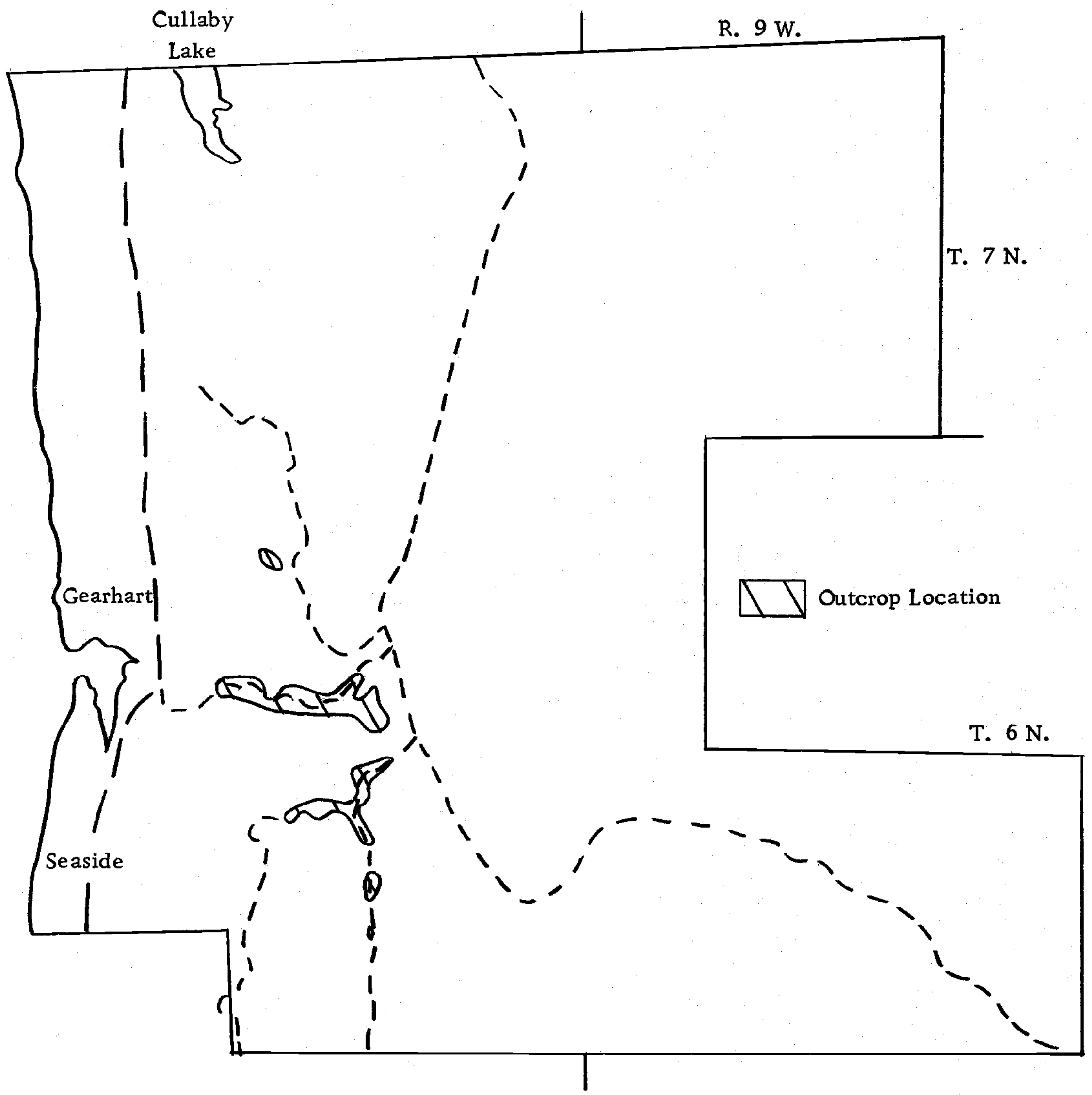


Figure 26. Outcrop distribution of the Dump sandstones.

light bluish gray (5B7/1) to yellowish gray (5Y8/1) siltstone interbeds.

Most exposures consist of friable, poorly cemented sandstones. A thick, loose clayey-sand talus with small chips of iron oxide cemented siltstone accumulates at the base of most outcrops.

Dump sandstone bedding thicknesses vary from 10 cm. to several meters. Surface weathering has destroyed part of the bedding. Locally, the structureless sandstones appear mottled, suggesting that disruption of original stratification was caused by extensive bioturbation.

Rare molluscan fossils are scattered in layers in nearly vertical beds at a roadcut along Necanicum Mainline logging road at NW$\frac{1}{4}$, NE$\frac{1}{4}$, NE$\frac{1}{4}$, section 23, T. 6 N., R. 10 W. These very fragile, thin-shelled unbroken pelecypods indicate that deposition occurred in a sublittoral environment below strong wave and tidal influence.

The sandstones are predominantly composed of subangular to subrounded quartz, subangular feldspars, and micas. The feldspars are partially altered to sericite and clay minerals. The micas, biotite and muscovite, comprise approximately 7% of the total rock volume. Mafic and opaque minerals are rare. Dark green glauconite pellets form much of the coarse fraction (1-2 $\emptyset$) of sieved samples. Hematite, limonite, and clay minerals are the cementing agents in the Dump sandstones. Since the unit contains few rock fragments but abundant chemically unstable feldspars and micas, the Dump sandstones are compositionally submature (Folk, 1968).

Texturally, the Dump sandstones are fine-grained based on sieve analysis of a sandstone sample. This is, however, slightly misrepresentative because many grains in the 1 to 2.5 ϕ (fine-grained sand) range consisted of well-cemented aggregates of smaller sand- or silt-size grains. Thus, the sandstones are probably very fine-grained. When Folk and Ward's (1957) sorting coefficients and mean grain size are calculated adjusting for the aggregation, the sandstones are well to moderately sorted and have a mean grain size of 3.5 ϕ (very fine sand) (Appendix VII). The high degree of sorting, lack of detrital matrix, and subangular to subrounded grains suggest that the Dump sandstones are texturally submature to mature (Folk, 1968). This maturity suggests some sorting and winnowing of the sands prior to final deposition.

Age, Correlation, and Contact Relationships

The Dump sandstones are middle Miocene in age because they lie with angular unconformity over the Silver Point and Airplane members of the middle Miocene Astoria Formation and are conformably (?) overlain by the middle Miocene Cape Foulweather Basalt.

Sandstones lithologically similar to the Dump sandstones have been described by Neel (1976) interbedded within the Silver Point member in the Tillamook Head area, approximately 3 km. to the southwest. Their relationship to the Dump unit is unclear, but they are thought to be of similar origin and age as the Dump sandstones (Neel, 1975, pers. comm.).

The exact contact relationships between the Dump sandstones and overlying and underlying units are unknown. However, the Dump unit in this study area is exposed overlying the gently southerly dipping Airplane tongue at several locations (SE$\frac{1}{4}$, NW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 1, and N$\frac{1}{2}$, SE$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 2, T. 6 N., R. 10 W.) and the upper Silver Point tongue along Lewis and Clark County Road (secs. 11, 12, 13, and 14, T. 6 N., R. 10 W.), Necanicum Mainline (northeast corner, sec. 23, T. 6 N., R. 10 W.), and 300 line logging road (western half, sec. 24, T. 6 N., R. 10 W.). The unit is conformably(?) overlain by resistant Cape Foulweather basalt flows or in association with fault blocks, at each of the above locations (Plate I). Because of the above relationships, I believe that the Dump unit was deposited unconformably over the previously deformed Astoria Formation.

Depoe Bay Basalt

Middle Miocene Depoe Bay Basalts are limited to the southeastern part of the study area (Figure 27). They occur as isolated dikes cutting older Tertiary sedimentary rocks, as thick irregular sills, and as submarine breccias and pillow basalt flows. The sills locally form steep cliffs where stream erosion has cut away the surrounding sedimentary rocks. Both intrusive and extrusive

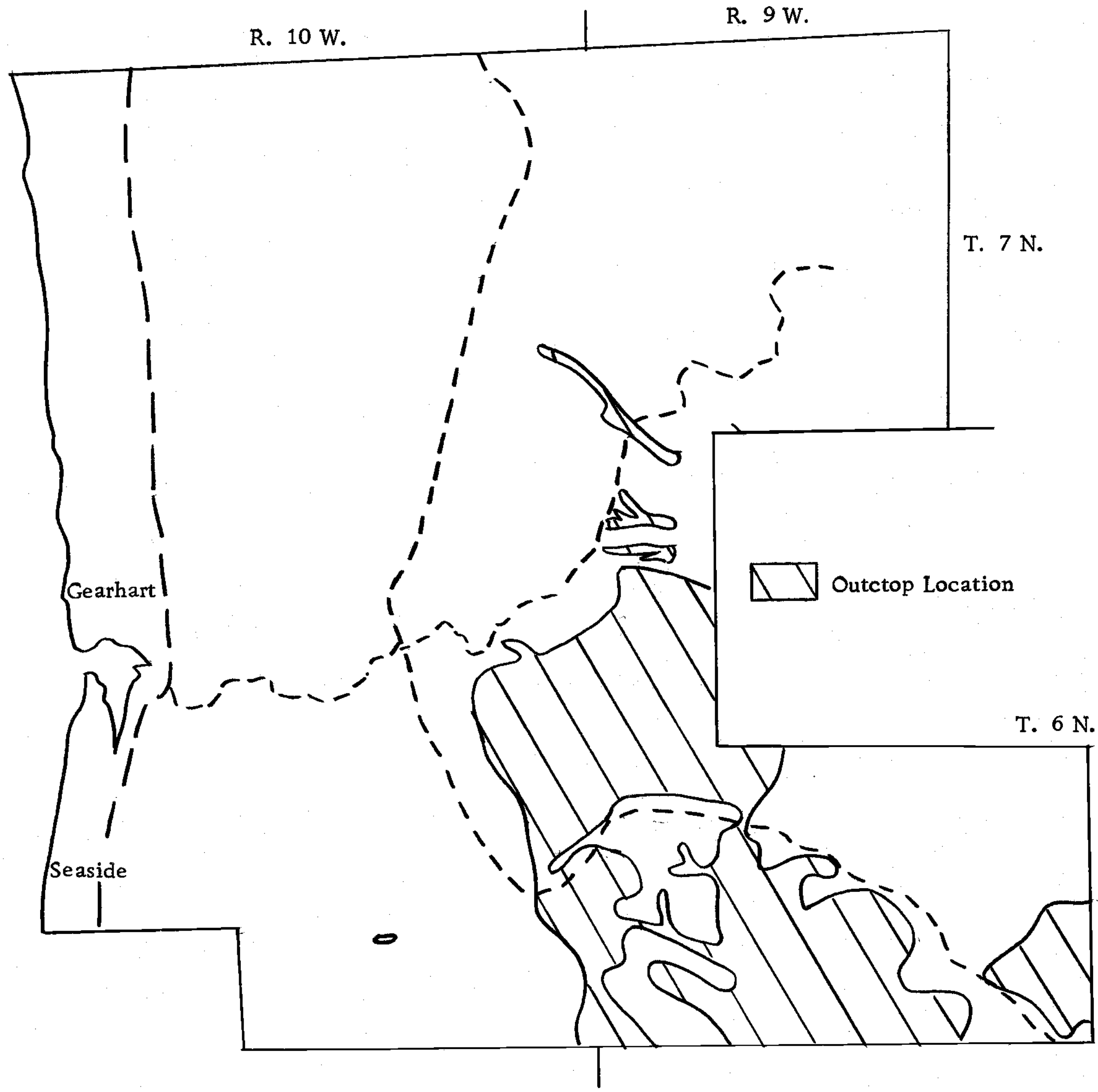


Figure 27. Outcrop distribution of the Depoe Bay Basalts.

basalts cap high hills in the study area. One of the highest points in the study area ($SE\frac{1}{4}$, $SE\frac{1}{4}$, sec. 27, T. 6 N., R. 9 W.) is held up by a thick Depoe Bay sill. This sill is thought to underlie much of the southeastern part of the area (see B-B', Plate II) and extend southward for several kilometers (Penoyer, 1975, pers. comm.). Local thick accumulation of extrusive basalts may have been caused by ponding of flows on an irregular submarine floor or by local buildup of volcanic centers.

Intrusives

Two intrusive forms of Depoe Bay Basalt are common; breccias and structureless to columnar jointed basalts. Both forms can occur within the same pluton. No spatial relationships were noted between the intrusive breccias and columnar jointed basalts in this area. Penoyer (1975, pers. comm.), however, has observed that intrusive breccias commonly overlie the massive, columnar jointed basalts suggesting that the breccias were formed as a result of rapid quenching and fragmentation when the upper part of the basalt pluton came in contact with the overlying water-saturated sedimentary rocks.

Intrusive breccias are olive black (5Y2/1) in fresh outcrops. The breccia fragments consist of aphanitic to very finally crystalline basalt and are enclosed in a palagonitic, glassy matrix. The angular fragments range in size from 1 to 20 cm. in diameter. Many breccia fragments have a vitreous luster along their margins due to a high glass content. Weathered breccia fragments are coated with a dark yellowish orange (10YR6/6) crusty, iron-stained powder, which is probably palagonite. Weathered breccias, in general, are easily broken into angular fragments along weathered fragment boundaries.

Depoe Bay peperite dikes occur along the Lewis and Clark River in the western parts of sections 7 and 18, T. 6 N., R. 9 W. (Plate I). The dikes consist of highly brecciated fingers of basalt approximately 3 to 6 meters thick incorporating blocks of angular baked mudstones and siltstones, some up to 5 meters across (Figure 28).

Southward along the Lewis and Clark River the breccias grade laterally into a thick columnar jointed Depoe Bay Basalt sill which is exposed in a 30-meter deep, narrow gorge along the Lewis and Clark River (NW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 19, T. 6 N., R. 9 W.). The sill here is typical of large Depoe Bay intrusions. The basalt weathers moderate brown (5YR4/4) to dark yellowish orange (10YR6/6) in color. Fresh basalt is dark gray (N3). Some intrusive basalts in quarries display radial columnar jointing patterns. Most massive Depoe Bay sills and dikes are finely crystalline to aphanitic. Small aggregates of quartz, agate, calcite, and zeolites fill vugs and fractures in the basalts.

Figure 28. Depoe Bay peperite dike. Light colored angular blocks are xenoliths of Airplane mudstones. Hammer on large xenolith at bottom left for scale.

Extrusives

Depoe Bay basalt pillow lavas and breccias cover approximately 23 km^2 in the southeastern part of the thesis area (Figure 27 and Plate I). Individual submarine flows are 3 to 12 meters thick and total accumulated thickness may exceed 150 meters.

Most flows contain brecciated isolated broken pillow lavas. Closely packed pillow lavas are rare. Individual pillows range from 0.5 to 1.5 meters in diameter. Pillow rims are composed of fractured fragments of lustrous, greenish black (5G2/1) tachylyte or sideromelane glass. The 1 to 10 cm. breccia fragments are partially altered to soft, moderate brown (5YR4/4) to pale yellowish orange (10YR8/6) palagonite. Pillow cores are olive black (5Y2/1) to greenish gray (5GY4/1) aphanitic or very finely crystalline basalt which is similar in texture to the intrusive Depoe Bay massive basalts.

Locally, these extrusive flows are separated by thin (less than 6 m.) mudstone and clay-rich fine-grained arkosic sandstone interbeds which are lithologically similar to those in the upper Silver Point strata, however. A possible submarine channel containing arkosic clayey sandstones is exposed between two Depoe Bay basalt flows in S½, section 26, T. 6 N., R. 9 W.

Petrology

Depoe Bay Basalt sills and dikes are glassy, aphanitic, or finely crystalline depending upon the thickness of the individual plutons. Glassy intrusive basalt breccias are found in thin sills and dikes (1-20 meters thick) or near sedimentary/intrusive contacts. Finely crystalline basalt comprises the center of larger sills and dikes.

Intrusive holocrystalline basalts are formed predominantly of calcic plagioclase (45-55%), pyroxene (30-40%), and the opaque minerals magnetite and ilmenite (5-10%). Labradorite is the only plagioclase present and varies from An_{63} to An_{67} in composition. Rare phenocrysts of faintly zoned plagioclase are visible in some thin sections. Anhedral augite is the dominant pyroxene although enstatite is present in all thin sections. Minor constituents (less than 3%) include apatite, tachylyte glass, and the alteration products caladonite and palagonite. These basalts have intergranular to intersertal textures. Snavely and others (1973) noted that some Depoe Bay basalts contain ophitic textures.

Depoe Bay intrusive breccias contain hyalo-ophitic to intersertal textures. Angular basaltic glass fragments and alteration products of glass comprise 30 to 70% of the total rock volume. Sideromelane, which is, in part, perlitic, and dark turbid tachylyte are the major types of glass (Figure 29). Yellow-orange palagonite

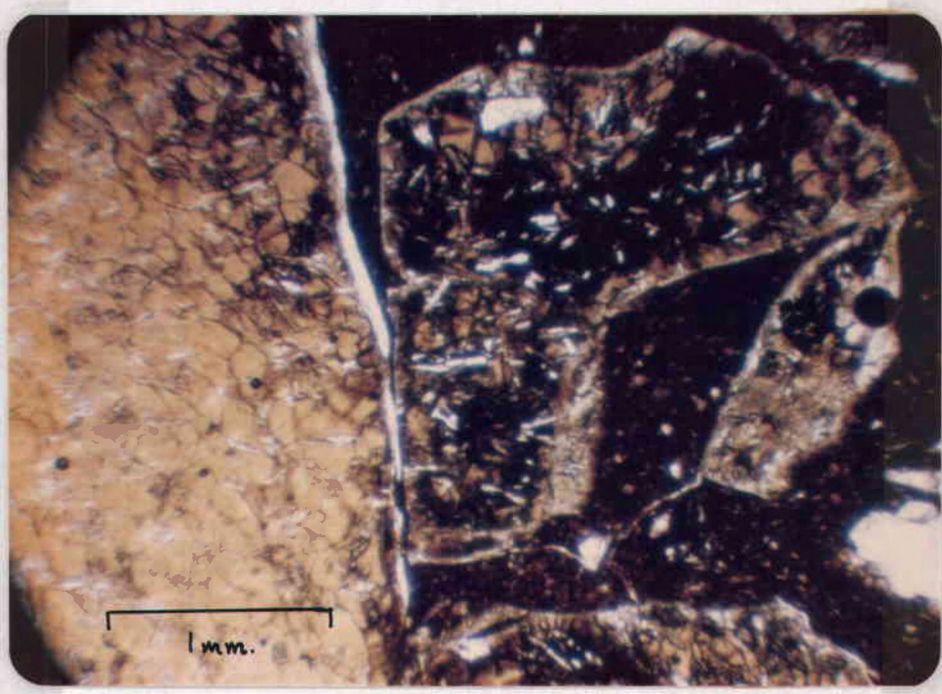


Figure 29. Photomicrograph of Depoe Bay Basalt breccia. Sideromelane with perlitic fractures on right, breccia fragments in tachylyte matrix at left (uncrossed Nicols).

and pore-filling zeolites, possibly natrolite or clinoptilolite, are common alteration products of the glass. Plagioclase microlites (10-30%) and tiny pyroxene crystals (10-30%) are scattered throughout the glass matrix. Small chalcedony crystals and hematite occur along breccia fragment margins and are possibly of deuteric origin. Calcite is a common alteration product of calcic-plagioclase microlites.

Depoe Bay pillow basalts are texturally hyalopilitic consisting of scattered plagioclase microlites, rare plagioclase micro-phenocrysts, and small anhedral pyroxene crystals in a groundmass of sideromelane glass and palagonite. Extrusive basalt breccia fragments are cemented by calcite, chalcedony, and zeolites.

Contact Relations

Intrusive contacts between Depoe Bay dikes and sills and enclosing sedimentary units are sharp and undulatory where exposed in quarries. Baked zones in the sedimentary rocks, which are well-indurated and bleached, vary from a few centimeters to many meters in thickness.

Depoe Bay submarine basalt flows generally dip northward in apparent angular unconformity with the older underlying southerly dipping Miocene sedimentary units in the southeastern part of the study area (Plate I). The contacts between the extrusive basalt and underlying sedimentary units are generally covered by basalt talus and soil, but a sharp break in slope between the steep hills of basalt and the gently sloping sedimentary rocks delineate approximate contact locations.

Age and Correlation

The Depoe Bay Basalt in the study area is of middle Miocene age. A foraminiferal assemblage collected in a mudstone interbed between Depoe Bay flows on Sugarloaf Mountain, approximately 8 km. south of this area, is late Saucesian or early Relizian (middle Miocene) in age (Neel, 1976). Turner (1970) and Niem and Cressy (1973) obtained ages of 14. 2±2. 7 to 16. 0±0. 65 million years and 15. 5±0. 4 m. y. (middle Miocene) respectively, for Depoe Bay Basalt by K-Ar radiometric dating in the Tillamook Head area.

Based on similar chemical composition and stratigraphic position, the Depoe Bay Basalts of this area are petrologic equivalents to the type middle Miocene Depoe Bay Basalt defined at Depoe Bay, Oregon by Snavely and others (1973). The Depoe Bay Basalts along the northern Oregon coast are lithologic, chemical, and age equivalents of the Yakima-type basalts of the Columbia River Basalt Group of eastern Oregon and Washington.

Cape Foulweather Basalt

Middle Miocene Cape Foulweather Basalt is the most widespread rock unit in the study area. Cape Foulweather pillow basalts cover approximately 23 km^2 in the southwestern part of the study area (Plate I and Figure 30) and vary from approximately 20 to 250 meters in thickness. Thin intrusive dikes (less than 4 m. thick) are commonly associated with the extrusive flows and may represent a feeder system. A network of thin Cape Foulweather dikes and sills intrude sedimentary strata in the eastern part of the area (secs. 12, 13, 14, 22, and 23, T. 6 N., R. 9 W.) and are probably related to the Green Mountain Sister volcanic complex (Figure 30). A small extrusive section of Green Mountain Sister crops out in section 14, T. 6 N., R. 9 W. The largest Cape Foulweather intrusive bodies are two concentric steeply inclined silled sheets or "ring dikes" in the northeastern part of the study area (Plate I and Figure 30).

Cape Foulweather Basalts are differentiated in the field from Depoe Bay Basalt by the presence of scarce large (up to 1 cm.) yellowish plagioclase phenocrysts in the finer crystalline groundmass (Snavely and others, 1973).

Intrusives

Cape Foulweather intrusives are generally thin (less than 4 m.)

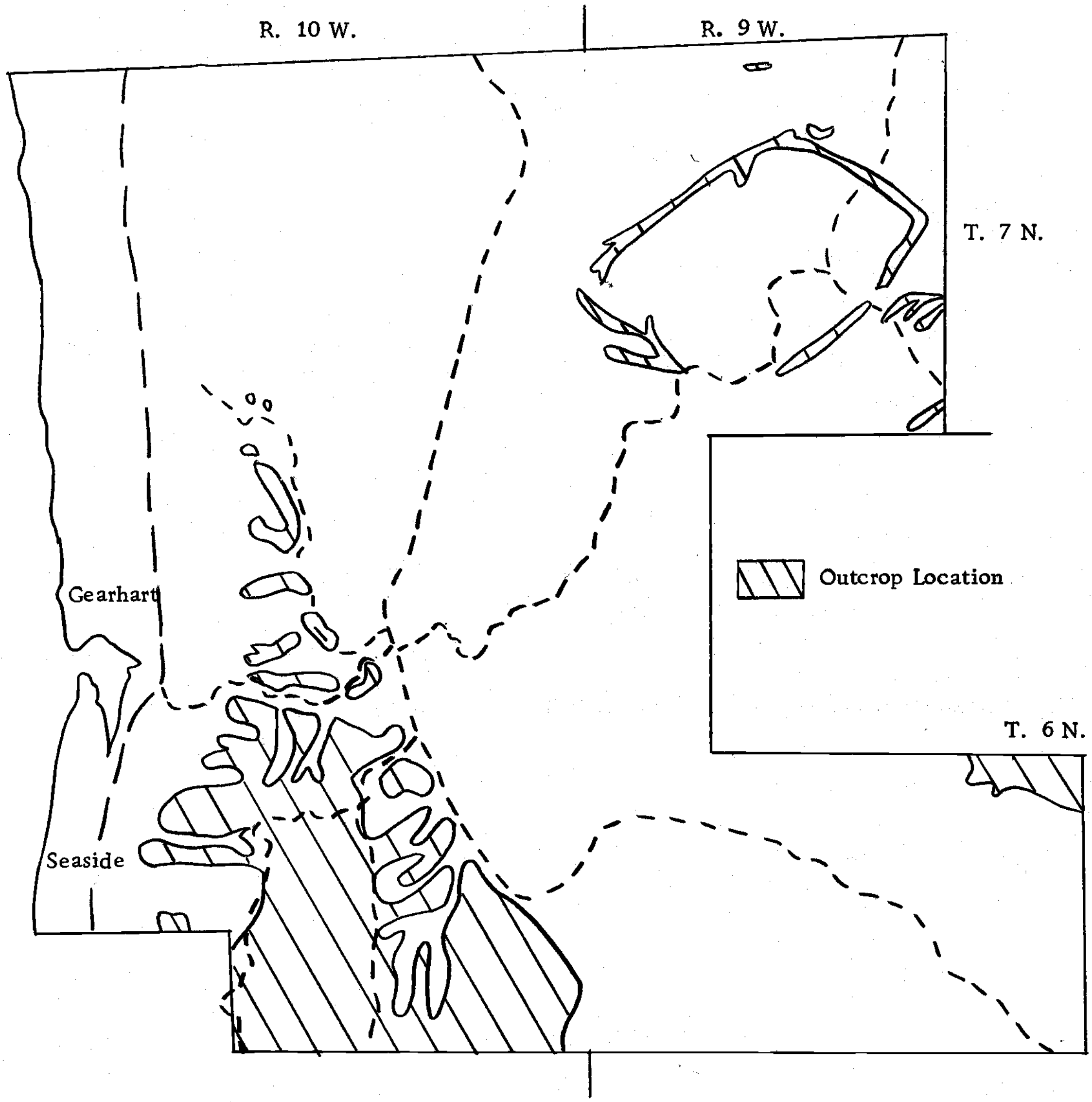


Figure 30. Outcrop distribution of the Cape Foulweather Basalts.

basalt dikes. Thicker dikes, 2 to 10 meters thick, locally contain columnar jointing, but in general are structureless and irregularly fractured. Thinner dikes are commonly brecciated, consisting of angular, glassy aphanitic basalt fragments in a palagonitic clay matrix. Thick Cape Foulweather sills commonly contain well-developed columnar jointing. Contacts between sills and sedimentary rock units are irregular but are generally concordant with sedimentary stratification.

Fresh samples of Cape Foulweather basalt are aphanitic to finely crystalline basalt with sparse light yellow plagioclase phenocrysts. Weathered Cape Foulweather intrusive breccias are moderate brown (5YR4/4) to dark yellowish orange (10YR6/6). The powdery palagonite weathering rims around the breccia fragments are generally thicker than those in Depoe Bay basalt breccia.

The double "ring dike" of Cape Foulweather basalt which forms Lone Ridge and other nearby ridges in the northeastern part of the map area are readily visible on topographic maps and aerial photographs as elongate ridges. Lone Ridge has the most spectacular relief in the thesis area, causing a rise in elevation of over 200 meters in 0. 4 km. distance. At Young's River Falls, the 25-meter thick Lone Ridge dike forcibly displaced the intruded Silver Point strata into nearly vertical orientation (Figure 31). The Silver Point strata adjacent to the intrusion were baked and bleached by the heat

Figure 31. Dark Cape Foulweather Basalt "ring dike" which upturned lower Silver Point strata (on right) during intrusion. Photographed on logging road west of Young's River Falls.

of the intrusion and are very well-indurated.

A small granophyric gabbroic intrusion is associated with the Cape Foulweather ring dike in NE$\frac{1}{4}$, NE$\frac{1}{4}$, NE$\frac{1}{4}$, sec. 29, T. 7 N., R. 9 W. The coarsely crystalline gabbro is composed predominantly of euhedral plagioclase crystals up to 1 cm. long and subhedral pyroxene. The gabbro is dark greenish gray (5G5/1) weathering olive gray (5Y4/1) to yellowish gray (5Y7/2).

Extrusives

Cape Foulweather extrusives are pillow and isolated pillow lavas. Pillows are generally better developed than in Depoe Bay extrusives and are commonly 0.5 to 1.5 meters in diameter. Individual flows have a maximum observed thickness of 13 meters (Figure 32). Locally (e.g. NW$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 23, T. 6 N., R. 10 W.), the basalts are slightly vesicular suggesting extrusion in shallow water and/or release of large quantities of volatile material during extrusion.

Thin mudstone and very fine-grained arkosic sandstone interbeds, which are lithologically indistinguishable from the upper Silver Point tongue are intercalated between some flows. These sedimentary strata are poorly exposed. A sequence of these sedimentary interbeds occurs along logging Spurs 34, 42, and 44 off Necanicum Mainline (Western part of sec. 26, T. 6 N., R. 10 W.) and may represent a

Figure 32. Cape Foulweather pillow basalts in quarry on Lewis and Clark County Road (NE 1/4, NE 1/4, Sec. 14, T. 6 N., R. 10 W.). Axe in center for scale.

single layer approximately 20 meters thick. The sedimentary beds suggest sporadic extrusion of Cape Foulweather Basalt followed by quiescent periods during which marine sediments were deposited.

The edge of Green Mountain Sister, a possible volcanic center composed of feeder dikes and extrusive flows of Cape Foulweather Basalt, is partly exposed in sections 14 and 15, T. 6 N., R. 9 W. (Plate I). Because of the elongate nature and parallel alignment of the main part of this complex, which lies immediately east of the study area, with the Lone Ridge ring dike, this submarine volcanic center may be a southern extension of the Lone Ridge system.

Petrology

Cape Foulweather Basalt differs from Depoe Bay Basalts by being sparsely porphyritic and containing a slightly more calcic plagioclase groundmass.

Cape Foulweather intrusive basalts have porphyritic intergranular to sub-ophitic igneous textures. Subhedral plagioclase laths (35-45%) intergrown with subhedral pyroxene (30-38%) are the most abundant mineral constituents. The plagioclase groundmass is labradorite (An_{52-58}) while the rare euhedral plagioclase phenocrysts (less than 1%) are a more calcic labradorite (An_{64}). The clinopyroxene, augite, is the most abundant pyroxene, whereas the orthopyroxenes, largely enstatite, comprise less than 2% of the rock. Anhedral to subhedral magnetite (5-10%), chlorophaeite (4-7%), and zeolites, possibly clinoptilolite, (0-2%) are minor consitutents.

The granophyric intrusive body at the top of Lone Ridge has a distinctive composition and microscopic phaneritic intergranular texture. Labradorite (An_{66}) (40%) and clinopyroxene (30%) are the most abundant minerals. The pyroxene is almost entirely pigeonite, which is uncommon in the finely crystalline and aphanitic Cape Foulweather basalts, with very little augite. Myrmekitic quartz intergrowths occur along the margins of many plagioclase crystals (Figure 33). Magnetite (8%) is common while deuteric(?) biotite and apatite form less than 1% of the total rock volume. Alteration products and late stage magnetic minerals including myrmekitic quartz, zeolite (natrolite), chlorite, and celadonite form the remaining 15% of the gabbro.

The presence of myrmekitic quartz suggests that this intrusion was an isolated, volatile-enriched finger of magma. High volatile content may have caused an overall decrease in magma viscosity and slow cooling which allowed larger crystals to grow compared to the surrounding aphanitic to finely crystalline basalt intrusives of Lone Ridge.

Cape Foulweather extrusive basalts are largely composed of plagioclase microlites and laths (28-35%) in a groundmass of sideromelane and tachylyte glass (55-65%). Rare, euhedral plagioclase

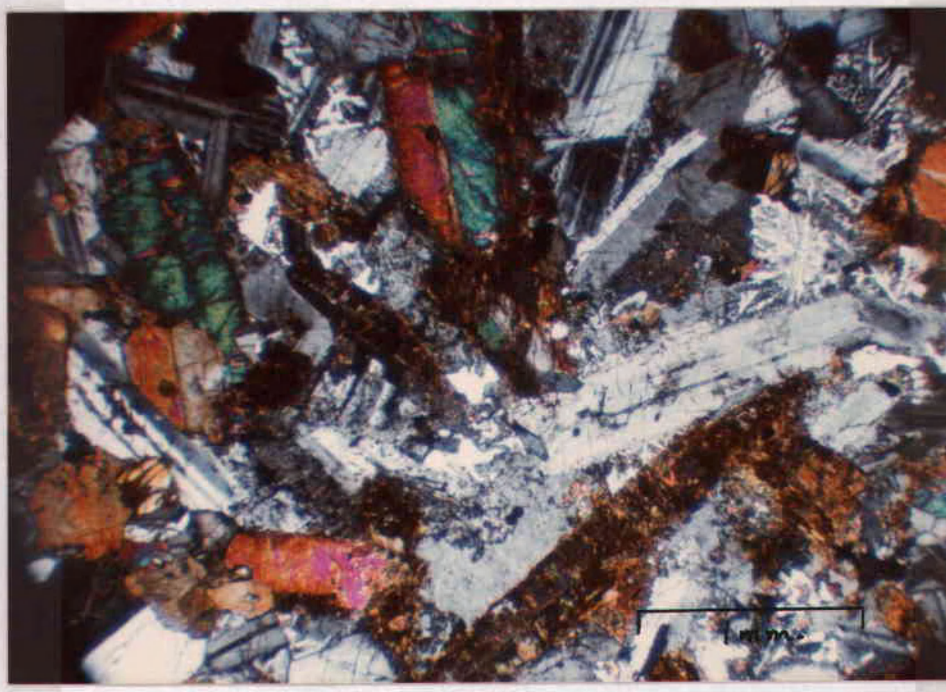


Figure 33. Myrmekitic quartz gabbro of granophyric dike in Cape Foulweather "ring dike." Note colorless quartz and twinned bright colored pigeonite.

phenocrysts are labradorite (An_{64}). The smaller groundmass plagioclase is less calcic labradorite (An_{50-58}) which may exhibit oscillatory zoning. Some sideromelane has been partially replaced by palagonite. Magnetite (1-3%) and the clino- and orthopyroxenes (1-3%), augite and enstatite, respectively, are rare. Alteration and deuteric products are widespread. These include hornblende and chlorophaeite after pyroxene, calcite replacing plagioclase, zeolite (analcime), and caladonite. Pillow basalts have porphyritic intersertal to hyalo-ophitic textures.

Contact Relations

Geologic mapping suggests that extrusive Cape Foulweather basalt overlies older Tertiary sedimentary strata in angular unconformity. The basalts in the southeastern part of the area dip slightly to the north or are horizontal while the underlying Silver Point and Airplane units of the Astoria Formation dip 10° to 20° southward. The contact between the Dump sandstone and Cape Foulweather is nearly conformable, where exposed (SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 12, T. 6 N., R. 10 W.).

Age and Correlation

Cape Foulweather Basalts along the northwest Oregon coast have been dated as middle Miocene in age by both radiometric techniques and by fossil data collected from sedimentary interbeds. Cape Foulweather Basalts have been dated by K-Ar techniques to be 13.4±0.4 to 16.8±million years (Snavely and others, 1973). Because of errors inherent within the K-Ar dating technique, there is a complete overlap of radiometric age between Cape Foulweather and Depoe Bay Basalt (14.2±2.7 to 16.0±0.65 m.y.).

Stratigraphic and intrusive cross-cutting relationships provide the main evidence by which relative ages of the two basalt types can be discerned in the study area. Cape Foulweather Basalt is the younger unit because its sills and dikes cut both extrusive and intrusive Depoe Bay Basalt. For example, Cape Foulweather dikes cut an older Depoe Bay sill along logging Spur 101 (center, sec. 20, T. 6 N., R. 9 W.) and intrude diagonally across a sequence of Depoe Bay pillow basalts and sedimentary interbeds on Logging Spur 2E (SE corner, sec., T. 6 N., R. 9 W.) (Figure 34). These intrusive relationships appear to apply for the entire middle Miocene basaltic outcrop area of the western Oregon Coast Range (Snavely and others, 1973).

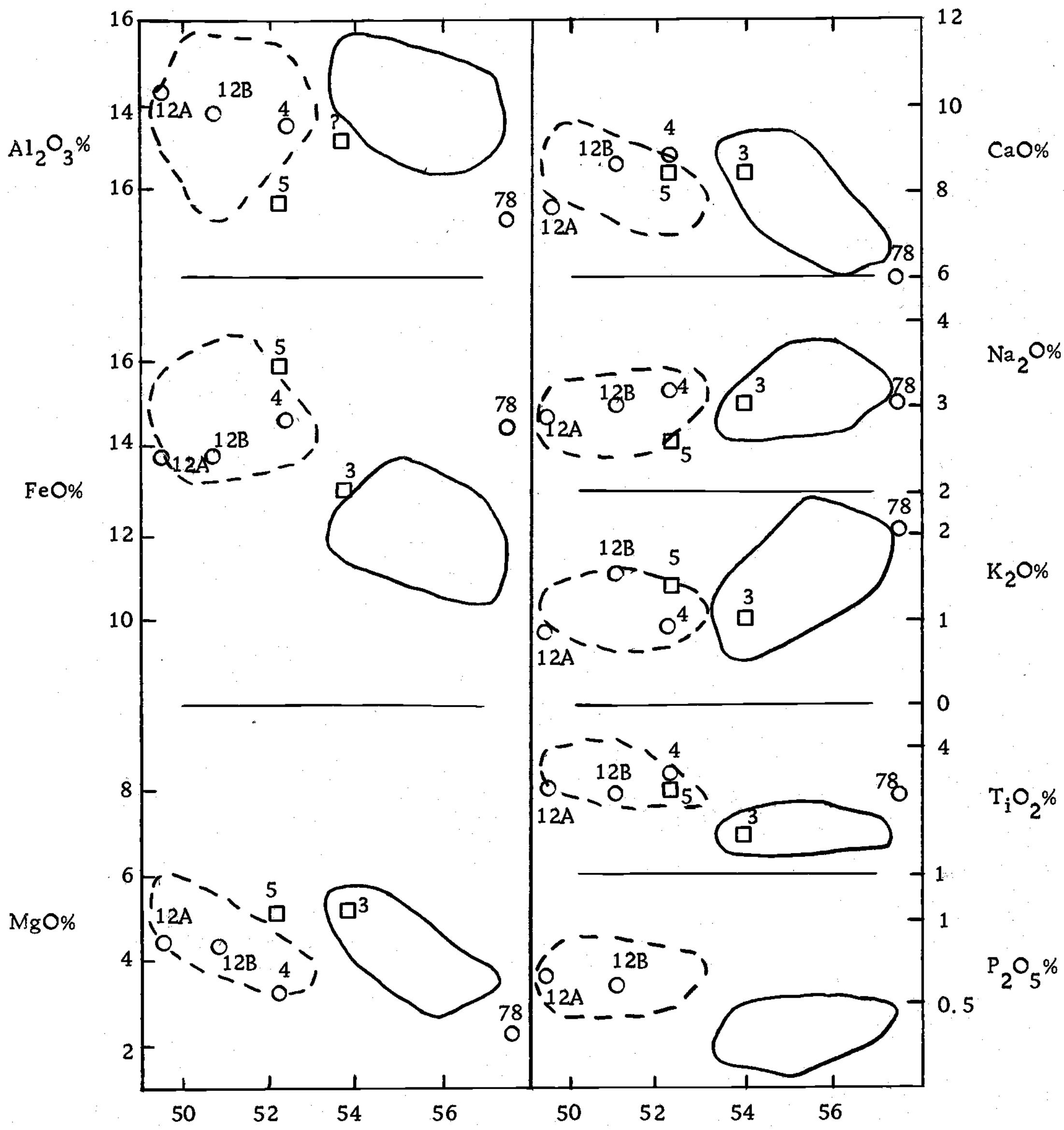
Based on similar petrology, stratigraphic position, and chemistry, the Cape Foulweather Basalt in this study area is tentatively correlated to the type Cape Foulweather petrologic-type basalt at Cape Foulweather on the central Oregon coast. Snavely and others (1973) also suggest that Cape Foulweather basalts are coeval with late Yakima-type basalts of eastern Oregon and Washington.

Figure 34. Large Cape Foulweather dike cutting perpendicularly across bedding of Depoe Bay extrusive basalt and sedimentary interbeds (bedding outlined). Axe (arrow) for scale (SE corner, sec. 28, T. 6 N., R. 9 W.).

Basalt Chemistry

The Depoe Bay Basalt and Cape Foulweather Basalt which crop out along the western Oregon and southwestern coasts were named and described as distinct petrologic types by Snavely and others (1973) on the basis of age, petrographic, and chemical variations between the basalt units. Chemical analyses determined that the basalts are tholeiitic in composition; and as a group, the Cape Foulweather Basalt can be differentiated from the older Depoe Bay Basalt by lower percentages of SiO_2 and higher percentages of total iron, TiO_2, and P_2O_5 (Snavely and others, 1973). Field criteria and whole-rock chemical analyses from the northwest Oregon coast suggest that the characteristics differentiating the basalts are generally valid (Smith, 1975; Neel, 1976).

Four whole-rock chemical analyses were preformed on selected mafic igneous samples from the study area to confirm the presence of the two basalt types. Sample PMT-4-75, from a pillow basalt sample (see Plate I and Appendix XI for location), was mapped as Cape Foulweather Basalt. Sample PMT-3-75 was collected from an extensive Depoe Bay sill (Plate I and Appendix XI). Chemical analyses of the two samples plotted on a silica variation diagram confirmed the preliminary field and petrographic identifications (Figure 35). Two samples from the Lone Ridge "ring dike" were determined by Snavely



——Depoe Bay petrologic-type basalt
— —Cape Foulweather petrologic-type basalt
○ SR66-12A
○ SR66-12B
○ PMT-4
○ PMT-78
□ PMT-3
□ PMT-5

○ mapped as Cape Foulweather Basalt

□ mapped as Depoe Bay Basalt

Figure 35. Silica variation diagram of selected basalt samples. Note anomalous compositions of PMT-5 and PMT-78. SR66-12A and SR66-12B from Snavely and others (1973). Precise sample locations shown in Appendix XI and Plate I. Diagram from Snavely and others (1973).

and others (1973) to be chemically and petrographically similar to typical Cape Foulweather Basalt.

However, chemical analysis of a basalt sill sample (PMT-5-75) from the southern part of the study area which was mapped as Depoe Bay Basalt based on the lack of plagioclase phenocrysts contains a low SiO_2, very high total iron, and high TiO_2 percentages which are more typical of Cape Foulweather Basalt (Figure 35). This sill can be traced southward where Penoyer (1975, pers. comm.) has also found a similar non-porphyritic basalt with Cape Foulweather chemistry. Due to the presence of a non-porphyritic Cape Foulweather chemical-type basalt, it appears that the presence or lack of plagioclase phenocrysts noted in the field may not be a totally reliable means of differentiating Miocene basalt types.

The deviation from the typical chemistry and texture established for Depoe Bay and Cape Foulweather basalts by Snavely and others (1973) may be caused by one or more factors including: 1) sample contamination during preparation for analysis; 2) analysis of chemically altered or weathered basalt sample; 3) calibration variations in analytical equipment; and 4) an actual textural and chemical variation from the original scheme. Further petrologic and chemical studies will be needed to determine if this variation is real.

The percentage of metal oxides of 3 samples (PMT-3, -4, and -5) when plotted on Kuno's (1968) alkali-silica and alkali-alumina-silica diagrams suggests that these basalts are tholeiitic in composition.

Sample PMT-78-74 is a granophyric gabbro from an intrusion in the Lone Ridge "ring dike") (See Appendix X and Plate I for location). It is unusual in that it contains coarsely crystalline myrmekitic free quartz, abundant magnetite, and the clinopyroxene pigeonite; and thus is probably a late stage magmatic differentiate. Chemical analysis indicates that this gabbro contains higher SiO_2 (58%) and K_2O (2.05%) and lower CaO (5.9%), Al_2O_3 (11.6%), and MgO (2.4%) than typical Cape Foulweather Basalt which comprises most of the Lone Ridge dike (Figure 35 and Appendix X, samples SR66-12A and SR66-12B). The microscopic analysis has been described in the Cape Foulweather Petrology section.

Quaternary Deposits

Two types of Quaternary deposits occur in the thesis area: beach ridges and associated inter-ridge swales and lakes which parallel the modern coast (Clatsop Plains) and river terrace and flood plain alluvium which are well-developed along Young's River and the Lewis and Clark River (Plate I and Figure 36).

The Clatsop Plains occur along the western edge of the study area and extend approximately 3 km. inland. They are composed of a series of nine sub-parallel north-trending beach ridges which have a maximum relief of 22 meters. Individual ridges can be easily

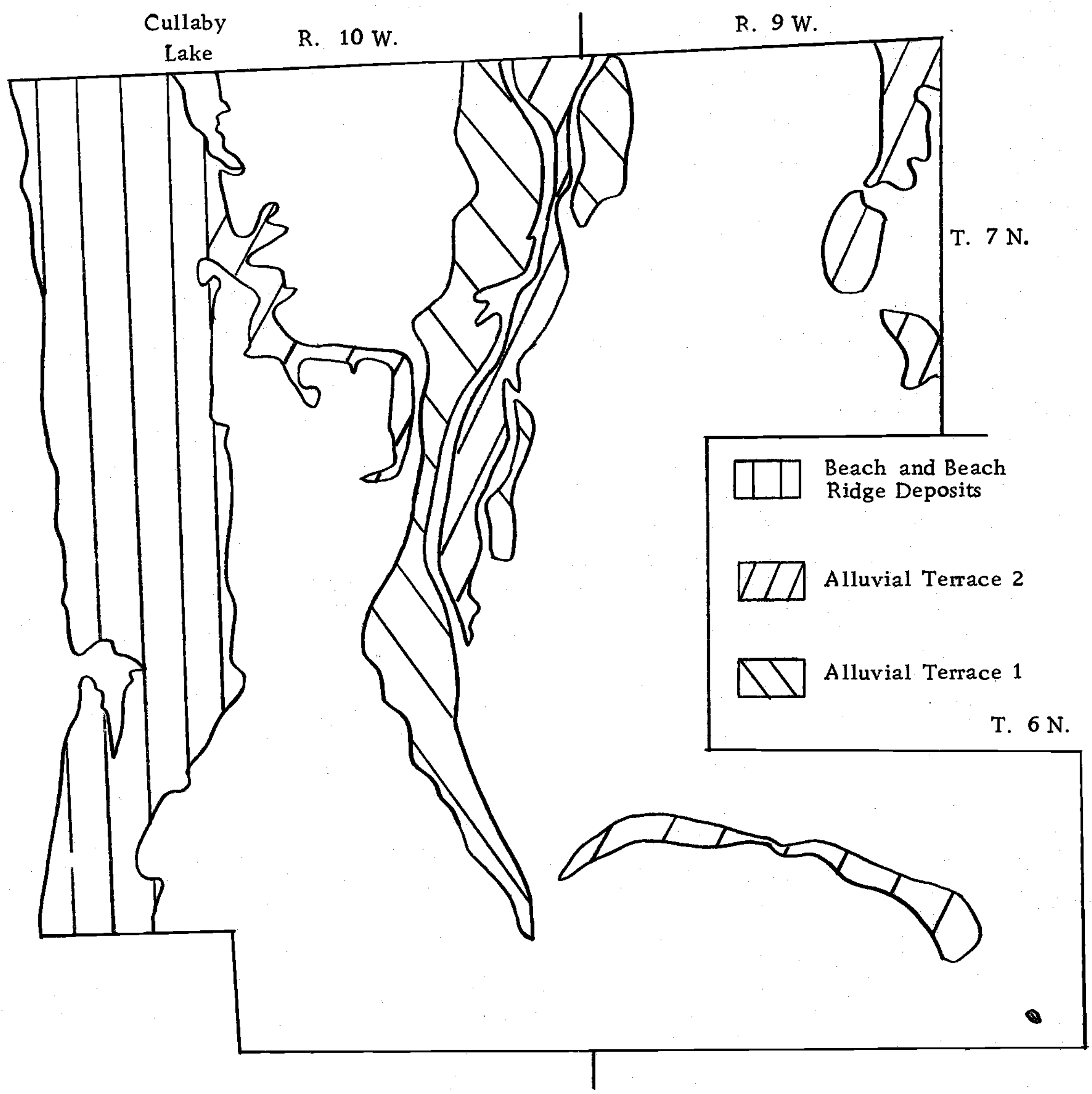


Figure 36. Outcrop distribution of Quaternary deposits.

recognized in the field, on aerial photographs, and on topographic maps. Several of the ridges coalesce in the southern part of the study area. Diller (1896) was the first to recognize the extent and asymmetry of the ridges. Cooper (1958), who studied the Clatsop Plains as part of a larger study of coastal dunes in Oregon and Washington, suggests that the ridges were built on a wide wave-cut marine terrace formed approximately 18,000 to 6,000 years B. P. during Wisconsin glaciation, when sea-level was nearly 60 meters lower than today. The coastal plain has been prograding seaward since 6,000 years B. P. (Cooper, 1958). The ridges are largely transverse dunes formed by transported beach sands from dominantly onshore winds. Much of the beach sand is in turn probably derived from longshore drift from the Columbia River. The dunes are composed of well-sorted quartz- and feldspar-rich fine-grained sands with local heavy mineral placers. Marsh and lake deposits, such as those in Cullaby Lake in the extreme northwestern part of the study area, are forming at the present time in swales between beach ridges.

Stream alluvium is present along most major streams and rivers in the study area. At least two river terrace levels are present along the Lewis and Clark River and possibly along the Young's River (Plate I) indicating at least two periods of flood plain development and river entrenchment. The higher, and older, river terrace covers a much larger area and is approximately 45 meters above the present flood plains (Figure 36). Evidently, Pleistocene(?) and Holocene drainage patterns were similar to those of today because terraces parallel the present courses of the Lewis and Clark River and Young's River.

Terrace deposits are well exposed along the Lewis and Clark Mainline logging road (SE$\frac{1}{4}$, sec. 13, T. 6 N., R. 10 W.). The terraces are composed of well-bedded lenticular gravel- and boulder-filled channels and finer-grained horizontally bedded sands and silts (Figure 37). Well-rounded grain-supported boulders, commonly 15 to 45 cm. in diameter, are composed predominantly of locally derived Cape Foulweather and Depoe Bay Basalt. Smaller quartzite and chert pebbles in the terrace deposits indicate that erosion and recycling of older Tertiary deposits, such as the Angora Peak pebbly sandstones, has taken place.

River entrenchment following development of the oldest flood plain appears to have been episodic. A small local terrace level occurs approximately 4 meters below the oldest level immediately east of the terrace locality described above. The present Lewis and Clark River and its alluvial deposits forms a valley which is 0.8 km. wide on older Tertiary sedimentary units. The river also forms a picturesque deep (80 m.) narrow gorge where it flows through the Depoe Bay sill along the Lewis and Clark Mainline (NW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 19, T. 6 N., R. 9 W.) Young's River forms an 18 meter-high water

Figure 37. Roadcut exposure of lenticular Quaternary river terrace deposits 50 meters above Lewis and Clark River (SE 1/4, sec. 13, T. 6 N., R. 10 W.). Boulders and cobbles are locally derived Depoe Bay and Cape Foulweather basalt.

falls at Young's River Falls County Park ($N\frac{1}{2}$, $N\frac{1}{2}$, sec. 27, T. 7 N., R. 9 W.). where the river crosses the Cape Foulweather ring dike and has downcut the adjacent less resistant Silver Point sandstones and mudstones.

Structural Geology

Regional Structure

The northern part of the Oregon Coast Range is a northward-plunging anticlinorium (Baldwin, 1964). The core of this structure consists of early Eocene Tillamook Volcanics with younger Tertiary sedimentary and volcanic units around the nose and flanks of the anticlinorium. Pliocene and younger beach and alluvial deposits overlie the older Tertiary strata with angular unconformity (Snavely and Wagner, 1964). Several unconformities occur within the Tertiary strata indicating periods of regional and local eustatic changes. A significant unconformity in early Miocene time may be traceable throughout much of the Circum-Pacific area (Dott, 1969; Moore and others, 1974).

At least three structural embayments were formed during late Eocene time along the western edge of the present Coast Range (Snavely and Wagner, 1964), and allowed pre-Pliocene marine sediments to accumulate in excess of 2,500 m. (Bromery and Snavely, 1964). Bouguer gravity anomalies (Bromery and Snavely, 1964) show that the study area is located in the southern part of the Astoria Embayment.

Regional geologic maps of northwestern Oregon (e. g. U. S. Geological Survey, 1961; Wells and Peck, 1961) show northwesterly folding and faulting trends associated with the west side of the Oregon Coast Range. Zietz and others (1972) noted no dominant tectonic trend onshore but suggest that linear offshore magnetic anomalies against irregular onshore anomalies may indicate that a major fault zone lies parallel to the coast along the study area. Kulm and Fowler (1974b) show that faulting and folding on the nearby continental slope and shelf is generally oriented in a north-south trend. The Nehalem Banks which lie about 45 km. west of the study area is a folded, and possibly faulted, submerged ridge of Pliocene strata (Kulm and Fowler, 1974b). Several less prominent anticlines are located on the continental slope and shelf near the Nehalem Banks (Figure 38).

Thesis Area Structure

The folds on faults delineated in the study area (Figure 39), although partly obscured by ground cover and slumping in the sedimentary rock units, follow general structural trends defined by earlier studies by Wells and Peck (1961) in the Oregon Coast Range and more recent studies by Smith (1975) and Neel (1976) immediately

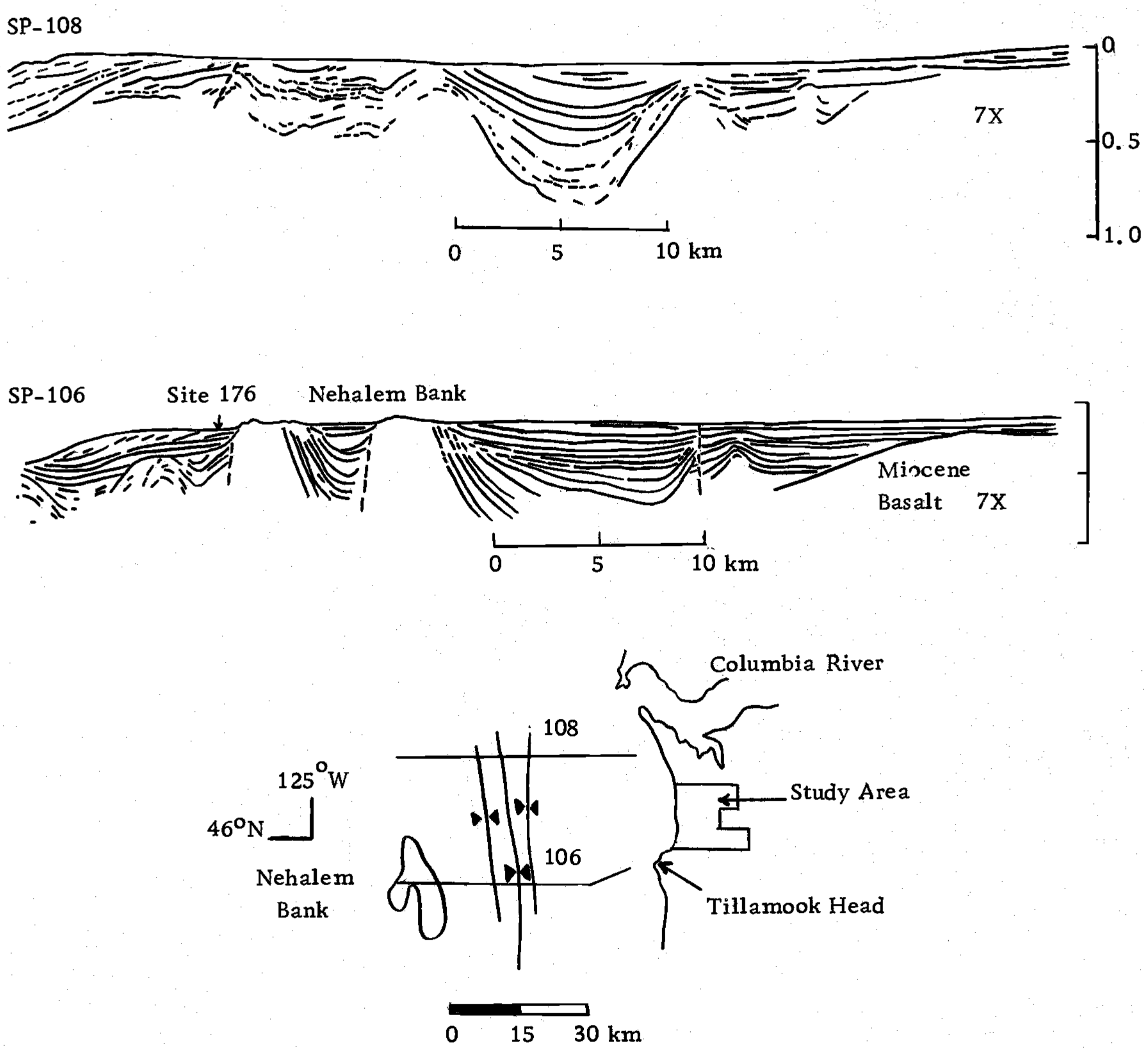


Figure 41. Line drawings of seismic reflection profiles and structural map of the northern Oregon continental margin. SP-106 crosses Location of Deep Sea Drilling Project. Leg 18, site 176. (SP-106 and structural map after Kulm and Fowler, 1974b; SP-108 unpublished data courtesy of L. D. Kulm, School of Oceanography, Oregon State University).

south of the study area. In the study area, high angle normal or reverse(?) faults trend northwest and northeast, with smaller associated faulting at oblique angles to the major trends (Figure 39). Major faults crosscut all Tertiary sedimentary and volcanic units. Folding immediately prior to middle Miocene basaltic activity followed by later post-middle Miocene folding is evident. The younger episode resulted in broad northwest-trending folds.

Northwest-trending faults appear to show small displacement since juxtaposition of different stratigraphic units does not occur at fault contacts. Six of these small faults occur in the western half of the area (Plate I and Figure 39). The faults are defined by a series of aligned ravines or straight stream valleys which cut across the sedimentary strike and are evident on low altitude aerial photographs. Several of these faults are also visible as faint lineations on NASA radar (SLAR) imagery (Missions APQ 96 and 98, flown on 10-25-65, 10-27-65, respectively). A discordance in dip on both sides of some faults was probably the result of drag along the faults.

Five major faults in the area have northeast trends and are apparently restricted to the eastern half of the area (Figure 39). Field evidence for faulting includes juxtaposition of different stratigraphic units and anomalous steep dips and varying orientations of stratification caused by drag along the fault plane. Lineations on aerial photographs, side-scanning radar imagery, and/or

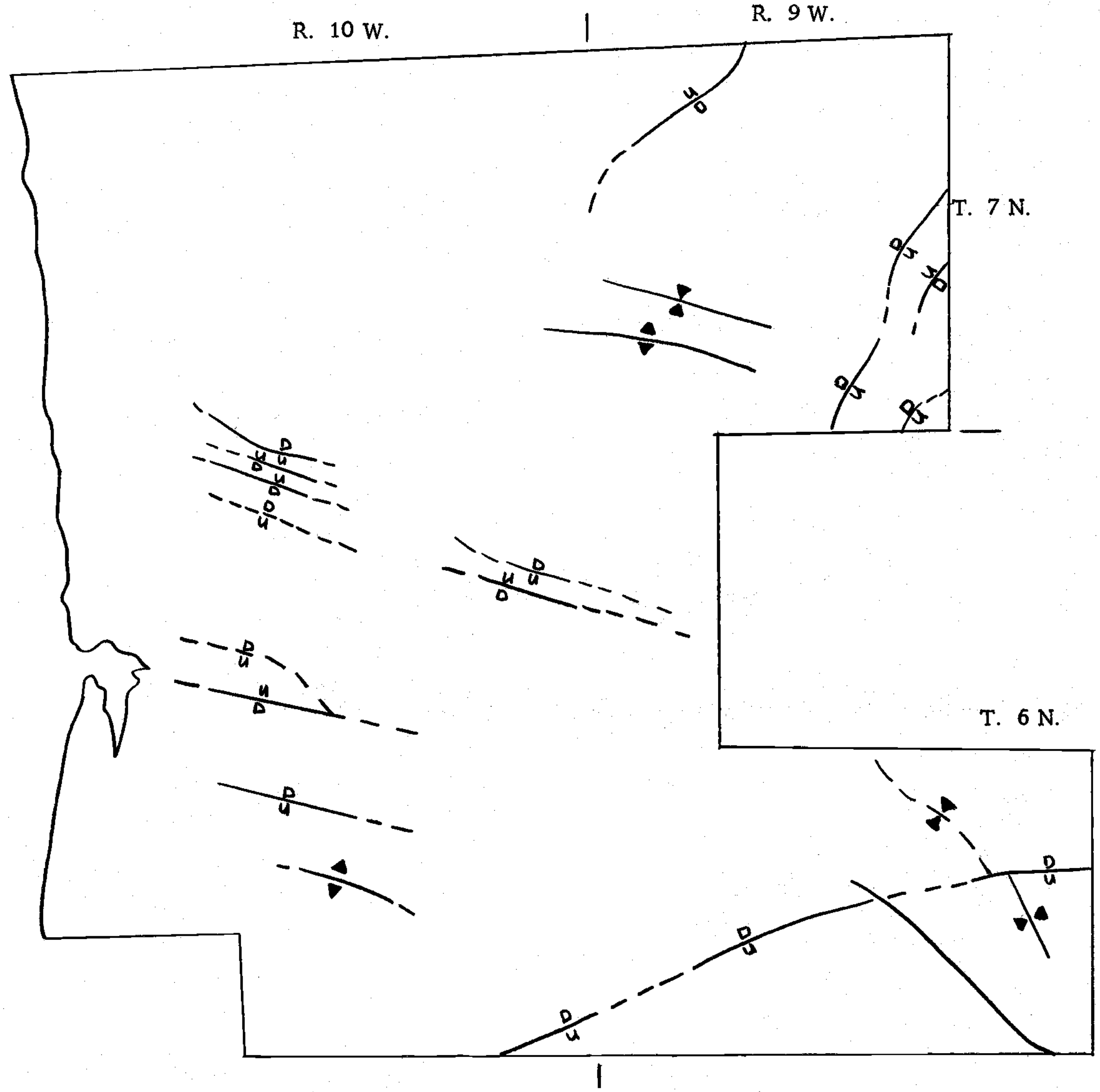


Figure 39. Structure map of the Seaside-Young's Falls Area.

aeromagnetic data confirm the presence of these faults. The faults may have displacement up to 250 m. The large northeast-trending fault crossing the southeastern part of the study area (Figure 39) has down-dropped the Angora Peak sandstone a minimum of 150 m. against Oswald West mudstones along Logging Spur 85 (W½, sec. 23, T. 6 N., R. 9 W.). A roadcut exposure at NW¼, NW¼, sec. 26, T. 7 N., R. 9 W., which is approximately 0.4 km. outside the northeastern part of the study area, contains a high angle normal fault which has displaced Oswald West mudstones against lower Silver Point sandstones and mudstones. The Silver Point at this location has been folded and overturned by drag along the fault plane (Figure 40). Other faults in the northeastern part of the study area juxtapose lower Silver Point against Oswald West mudstones. No estimates of displacement can be made due to the lack of stratigraphic marker beds within the Oswald West and lower Silver Point units. All faulting in the area is probably post-middle Miocene/pre-Quaternary in age because all middle Miocene units are cut by the faults.

Two episodes of folding are evident. The older episode occurring before deposition of the Dump sandstones consists of a large broad fold with east-west trending axis. This southward tilting, followed by erosion, allowed Cape Foulweather Basalt in the southwestern part of the area to flow northward over the exposed southward dipping upper Silver Point and Airplane tongues.

Figure 40. Overturned anticline in Silver Point strata on right, faulted against upthrown Oswald West mudstones. Water jug approximately at plane of normal fault.

Post-middle Miocene folds with northwest-southeast axes were delineated in the northeast part of the map area. Here, two anticlines have been mapped on the basis of consistent opposing strike and dips and outcrop patterns (Figure 39, Plates I and II).

Intense folding occurs locally adjacent to contacts between some intrusive basalts and the surrounding country rock. At Young's River Falls (sec. 27, T. 7 N., R. 9 W.), the Cape Foulweather Basalt ring dike forming Lone Ridge has dragged lower Silver Point sandstones and mudstones into near vertical orientation. Within 100 m. to the north, the Silver Point strata dip only 20° to 30°. At other locations, small-scale faulting (less than 0. 2 m.) in adjacent sedimentary units with little or no drag folding accompanies basalt emplacement.

Aeromagnetic Data

A large structural (?) discontinuity shown by aeromagnetic data (unpublished data supplied by Parke Snavely, U. S. Geological Survey) separates the southeastern part from the rest of the thesis area (Figure 41). Short wavelength, high amplitude anomalies south of the discontinuity are probably caused by large irregular middle Miocene basaltic sills, dikes, and volcanic centers. North of the lineation, long wavelength magnetic anomalies are suggestive of a deep regular magnetic basement (probably the Eocene Siletz River or Tillamook Volcanics). This regular pattern is interrupted only by the Lone Ridge

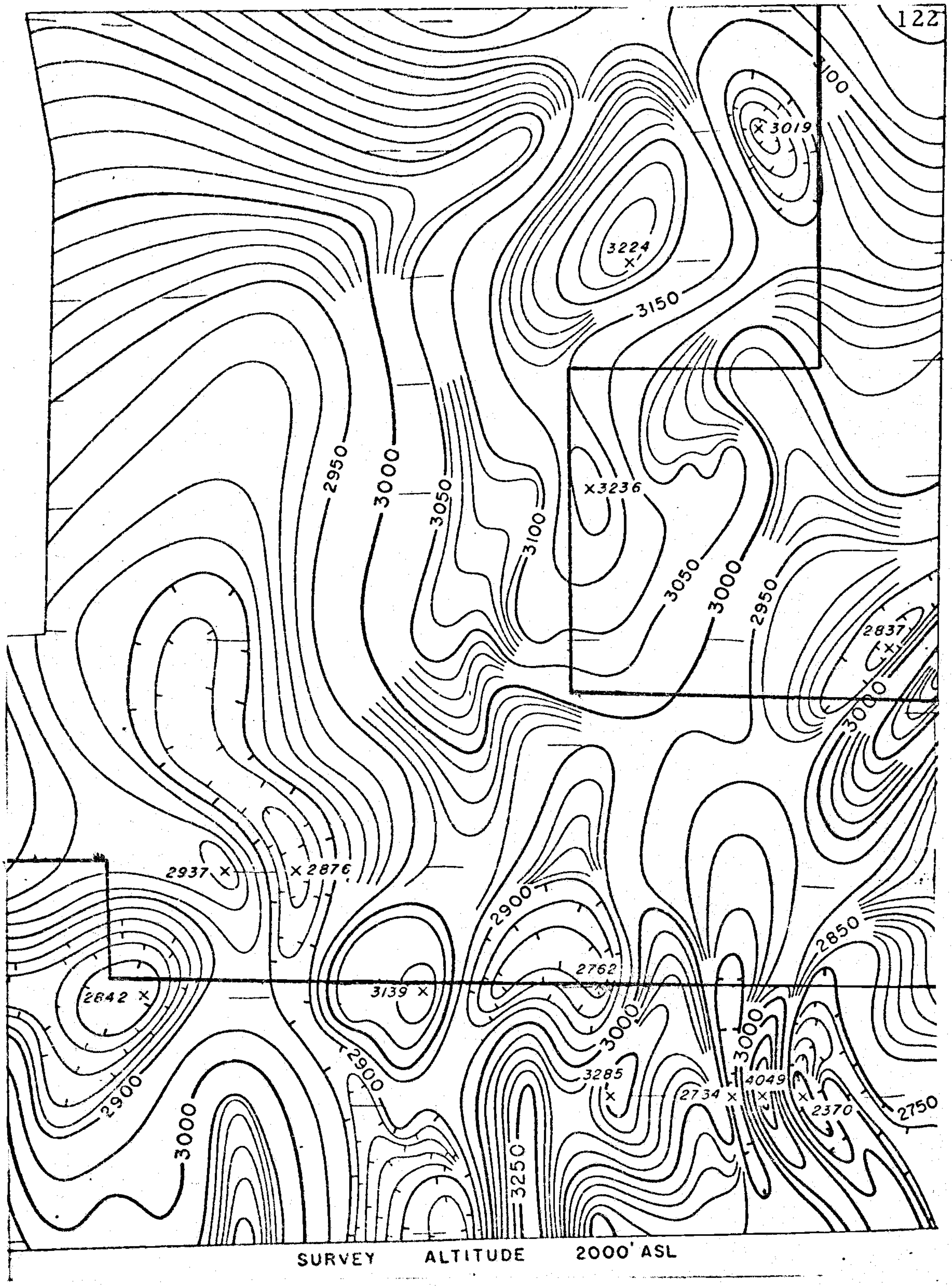


Figure 41. Aeromagnetic anomaly map. Thesis area outlined. (Unpublished U. S. Geological Survey data, courtesy of P. D. Snavely, Jr.)

'ring dike'. Snavely (1975, written comm.) has suggested that the aeromagnetic discontinuity represents a major northeast-trending fault. A lineation on topographic maps follows the approximate strike of the magnetic discontinuity, but no field evidence for faulting was obtained along this path since it was outside the study area. However, the 8 km. long northeast-trending fault in the southeast part of the area (located on Figure 39) parallels the discontinuity and may be related to it.

Snavely and others (1973, p. 419) indicate that the general north-trending belt of middle Miocene volcanic rocks in coastal Oregon and Washington ". . . was offset by a major northeast-trending zone that also controlled the emplacement of Miocene intrusive rocks." I believe that the northeast-trending faults in the study area, probably late Miocene or Pliocene in age, were possibly controlled by the earlier basement faulting noted by Snavely and others (1973). These faults appear to control emplacement of middle Miocene basalt sills and dikes from the Seaside area to Astoria and may also have marked the hinge line for the Astoria Embayment.

Tertiary Geologic History

Tholeiitic Tillamook Volcanics form the geological basement of northwestern Oregon. These early Eocene submarine basalts are thought to be original oceanic crust formed at a spreading ridge and subsequently accreted to the North American plate (Snavely and others, 1968). This accretion may have been caused by migration of the pre-Eocene subduction zone from an unknown location, probably in west-central Oregon, to a location west of the study area. The Socal Hoagland Unit #1 well, 3 km. north of the study area, encountered 460 meters of Tillamook basalts, which are assumed to underlie the study area (see Appendix XI for well data; data and cores supplied by Oregon Department of Geology and Mineral Industries).

Incipient formation of the Astoria embayment probably began soon after accretion of the basalts to the continent (Snavely and Wagner, 1964). The edge of this structural embayment stretches from Astoria, Oregon, southward past the study area and inland approximately 20 km. This basin received over 2, 500 meters of sediment before its destruction.

The Socal Hoaglund well also penetrated 1, 517 meters of middle Eocene to middle Oligocene slightly carbonaceous claystones with subordinate interbedded thin siltstones and fine-grained sandstones. Pyrite is a common authigenic mineral in several core samples. Based on the very fine-grained nature of the strata, fine wavy or horizontal laminations, and the appearance of pyrite, it is suggested that these Eocene to Oligocene units were deposited in a quiet, deep marine basin (probably continental slope) in a slightly reducing environment.

The late Oligocene to early Miocene Oswald West mudstones in the study area are age equivalents of the Scappoose Formation of the northeastern Coast Range which is interpreted to be a subaerial deltaic plain (Niem and Van Atta, 1973; Cressy, 1974). Most of the Oswald West mudstones are slightly laminated, but are more commonly structureless. Abundant bioturbation has destroyed original stratification and the trace fossil Helminthoida (Chamberlain, 1975, written comm.) indicates bathyal to abyssal depositional conditions. Microscope and sieve analyses of the mudstones shows that the silt and sand fraction composes less than 15% of the rock samples. All of the above conditions are typical of hemipelagic deposition (Bouma and Hollister, 1973) in a deep-marine basin, possibly a pro-delta extension of the Scappoose delta or outer continental slope environment. Glauconite, occurring as scattered pellets and as glauconitic sandstone beds, in the upper Oswald West mudstones suggests deposition in a cool, slightly reducing, deep-marine environment (Porrenga, 1967).

Rare blocks of coarse sandstones in mudstone matrix suggests that slumping into the basin was intermittent. Convolute bedding in Oswald West sandstone beds south of this area (Cressy, 1974) is typical of base-of-slope slumping and deposition (Stanley, 1969). Local zones of well-laminated to micro-cross-laminated very fine-grained sandstones up to 20 meters thick crop out in the upper part of the Oswald West. These well-sorted, slightly bioturbated sandstones indicate increasing energy within the Oswald West depositional environment and are typical of delta-slope deposition (Selley, 1970).

A minor angular unconformity or disconformity is developed between the deep-marine (bathyal) Oswald West mudstones and the overlying middle Miocene very shallow marine (littoral) Angora Peak sandstones and the sublittoral lower Silver Point tongue of the Astoria Formation. The shoaling effect could have been produced by broad uplift near the end of early Miocene time and/or by rapid progradation across the deep continental shelf by a deltaic flood plain facies.

The lowest part of the Angora Peak sandstones in the southeastern part of the area contain moderately sorted arkosic medium- to coarse-grained sandstones, abundant plane parallel bedding with subordinate trough cross-beds and pebble lenses locally containing mudstone ripups and wood fragments. Based on the overall coarse-grained nature, pebble lenses, and sedimentary structures, this part of the Angora Peak was probably formed in a very high energy wave and/or tidal influenced beach or bar environment. The middle part of the Angora Peak sandstones is characterized by moderately sorted fine- to medium-grained sandstones and horizontal, trough cross-beds, and rare megaripples. Several sandstone layers contain a remarkably unbroken, articulated molluscan assemblage including <u>Mytilus</u>, <u>Spisula</u>, and <u>Solen</u>. The whole assemblage is characteristic of a very shallow marine environment, probably 5 to 20 meters in depth (Addicott, 1975, written comm.). The unbroken nature of the molluscs suggests that the sandstones were deposited in areas away from maximum wave or tidal influence. Further deepening of the marine environment is shown by the clay-rich, mottled and burrowed, very fine-grained sandstones in the upper part of the Angora Peak member. The upper sandstones contain thin-shelled molluscs, such as Anadara, suggesting a sublittoral (5-140 m.) depositional environment (Addicott, 1975, written comm.). The combination of the above factors and the linear, arcuate shape of the outcrop area, indicates that the Angora Peak sandstones were deposited as a beach or barrier bar (Shelton, 1973).

The transgressive sequence noted here, from foreshore deposits in the lower Angora Peak to lower foreshore deposits in the upper part, is rarely described in the geological literature. Most beaches form under regressive conditions while most transgressive sequences contain thin destructive sheet sandstones since rapid landward movement of the sea reworks all deposited sediments as it advances (Selley, 1970). Thus, the Angora Peak sequence must have been caused by slow subsidence with accompanying marine transgression within the Astoria depositional embayment.

The Angora Peak sandstones in the study area were apparently spread northward by longshore currents from a thick (over 300 m.)

fluvio-marine deltaic complex approximately 24 km. to the south (Cressy, 1974; Smith, 1975). Paleocurrent measurements of medium-scale trough cross-bedding indicate a northerly (355 mean azimuth) dispersal pattern (Figure 42). Clifton and others (1971) noted trough cross-bedding of similar amplitude (1-2 m.) parallel to the shoreline in the surf zone along the present Oregon coast. These modern cross-beds were formed by longshore currents. Megaripples immediately above the cross-beds lie nearly normal to the cross-beds and were probably formed by wave backwash. The megaripples indicate a westerly paleoslope.

The Angora Peak sandstones grade upward and laterally into the interbedded thin sandstones and mudstones of the lower Silver Point tongue (Figure 13). Transgressive marine conditions continued for the rest of Astoria time in the southeastern part of the study area as exemplified by the lower Silver Point and the overlying Airplane tongues (see Figure 13, southeast part, for facies relationships). Abundant interbeds of very fine-grained micaceous sandstone up to 30 cm. thick at the base of the lower Silver Point tongue gradually become thinner and less common in the upper part of the unit. Sandstone beds in the upper part are 2 to .6 cm. thick and are separated by 5 to 10 cm.-thick carbonaceous mudstone layers. The lithologic and bedding changes noted in the Silver Point are similar to those described by Howard (1972) of shoreface-offshore transition

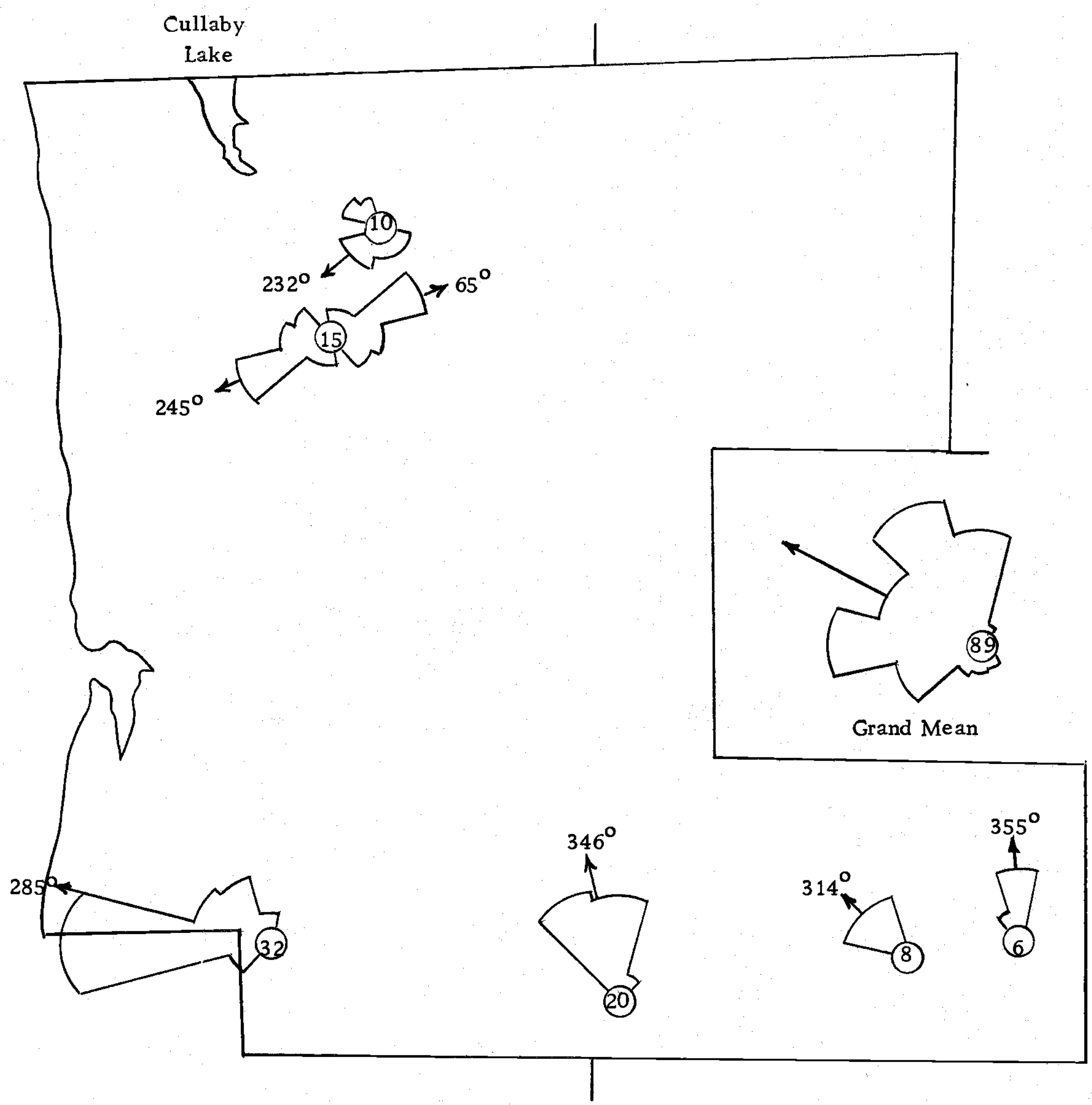


Figure 42. Rose diagrams showing paleocurrent directions in the Seaside-Young's River Falls area.

in the Upper Cretaceous Blackhawk Formation of east-central Utah and the change from outer delta-front platform to pro-delta slope noted by Allen (1965) for the modern Niger Delta.

The overall fine-grained (mostly claystone), laminated character of the Airplane tongue which gradationally overlies the lower Silver Point tongue suggests deposition in a very low energy, deep-marine environment. A water depth of 500 meters or less, corresponding to upper slope or outer shelf conditions, is indicated by the foraminiferal assemblage, which includes Globinerina and Uvigerina (Rau, 1975, written comm.). Abundant carbonaceous layers, some of which have been replaced by pyrite, commonly divide individual laminae and indicate that the bottom waters were stagnant and anaerobic. Thus, the overall depositional character of the Astoria Formation in the southeastern part of the study area is characterized by marine transgression probably controlled by basin subsidence.

The oldest Astoria strata in the northern part of the study area are the shallow marine deposits of the lower Silver Point tongue. The lower Silver Point tonge is composed of laterally continuous, rhythmically alternating carbonaceous, very fine-grained sandstone and mudstone interbeds. The sandstone interbeds contain normally graded bedding, ripple cross-lamination, horizontal lamination, flaser bedding, coarse load casts, and sharp lower and upper mudstone/sandstone contacts. Some of the sandstones contain incomplete

Bouma (1962) sequences, most frequently T_{ab}, T_{bc}, and T_{ac}. These sedimentary structures suggest that the beds were deposited by cyclical turbid currents carrying sediment into the depositional area. Flaser bedding and orientation of trough cross-lamination within the more common non-graded sandstone layers suggests that other multidirectional fluctuation (almost 360°) currents were also active in this shallow marine environment and were possibly of tidal origin. The above features are common in shallow offshore marine and/or interdistributary estuarine deposits (Dott, 1966; Heckel, 1972; and Shelton, 1973) but with exception of the multidirectional cross-lamination and Flaser bedding, are also typical of deep-marine turbidite deposition. Bioturbation is common in many mudstone layers within the lower Silver Point tongue. The burrows have been identified as the shallow to very shallow marine genus siphonites (Chamberlain, 1975, written comm.). There is a marked lack of fauna, both molluscan or foraminiferal, in the lower Silver Point tongue.

The appearance of turbidite sandstone beds is somewhat anomolous in shallow-marine deposits. Similar deposits have been described by Dott (1966) in the Eocene Coaledo Formation in southwestern Oregon, by McBride and others (1975) in Cretaceous deltas of Mexico, and by Walker (1969 and 1971) in Pennsylvanian deposits of England and the Devonian Catskill clastic wedge of Pennsylvania. These writers suggest that the turbidites were formed by flooded turbid rivers debouching large quantities of sediment into a depositional basin. In each of these examples, the turbidite-bearing facies is overlain by prograding delta distributary channels.

In the northern part of the study area, the lower Silver Point tongue is overlain by the 'J' unit. In the northwest, the 'J' is composed of laminated very carbonaceous and micaceous mudstones with rare siltstone and sandstone laminae. Measurement of elongate carbonaceous plant stems shows a southwest-northeast (245^{o}-65^{o}) mean current dispersal pattern (Figure 42) throughout the unit. Locally, the carbonaceous laminae grade into coaly seams up to 1 cm. thick. The upper part of the 'J' unit in the northwestern part of the area contains several lenticular, scoured channel sandstones surrounded by the dominant laminated mudstones. These cross-bedded fine- to coarse-grained sandstones commonly contain mudstone ripups and small pebbles. Thus, the 'J' unit in the northwest appears to be a 150 meter thick low energy, lagoonal or interdistributary sequence, based on the consistent laminated structure of the carbonaceous and micaceous mudstones. The shallow backwater sequence was cut by fluvial or tidal currents which deposited channel fill sandstones.

In the northeastern part of the study area, the 'J' unit is composed of a sequence of normally graded arkosic sandstone channels, none more than 5 meters thick. The bases of each channel are irregular and are in sharp erosional contact with underlying finer carbonaceous mudstones. The initial deposits of each layer consist of rougly bedded to lenticular and trough cross-bedded pebbly coarse-grained sandstones. These sandstones commonly contain poorly imbricated elongate mudstone ripups, pebbles, and wood fragments. Finer-grained, horizontally bedded clay-rich sandstones gradationally overlie the coarser material. Laminated to thinly bedded carbonaceous mudstones form the top part of each unit. The laminated texture and abundance of whole and partial leaf fragments in the mudstones suggests deposition in quiet water. The fining upwards sequence together with sedimentary structures indicative of high to lower flow regimes suggest that the 'J' unit in the northeastern part of the area was formed by a multi-storied meandering fluvial system (Fisher and Brown, 1972; Shelton, 1973) with each layer representing a point bar-channel fill sequence. Thickness of each channel unit, which corresponds to maximum water depth at flood stages (Shelton, 1973), indicate that the streams forming the 'J unit were generally less than 3 meters deep. The few lenticular sandstone bodies occurring near the top of the 'J' unit in the northwestern part of the study area are probably river or tidal channels which locally prograded into the 'J lagoonal facies. The 'J lagoonal sequence in this model is thought to be bounded by a down-dip, subsurface offshore bar, which may be laterally continuous with the Angora Peak sandstones of the southeastern part of the study area.

Rapid transgression occurred across the entire study area after deposition of the 'J' lagoonal/fluvial sequence. Either a lateral shift of the 'J' system by deltaic lobe abandonment or increased subsidence within the depositional basin resulted in deposition of the overlying deeper marine Airplane mudstones. As discussed previously in this section, the laminated Airplane mudstones with abundant forams were deposited in a low energy slope or outer shelf environment. The mudstones are similar in the organic-rich, laminated, olive gray offshore clays (classical bottom-set beds) noted by Scruton (1960) in the Mississippi River Delta and laminated claystones containing abundant pelagic forams in the open shelf environment of the Niger River Delta (Allen, 1965). Some interbedded tuff layers within the Airplane mudstones suggests that intermittent acidic volcanic activity, possibly in the ancestral Cascades to the east, was occurring simultaneously with deposition of the Airplane mudstones.

The interbedded wispy mudstone and very fine-grained sandstone and siltstone layers of the upper Silver Point tongue gradationally overlie the Airplane mudstones. Small scour-and-fill troughs in the mudstone layers suggest that the fine-grained sandstones were deposited by fairly low energy traction currents. Rare flame structures and pull-aparts indicate that the upper Silver Point was deposited on an unstable moderate slope which resulted in minor penecontemporaneous deformation of the water-saturated sediments. The foram assemblage, which includes Dentalina and Globigerina, is associated with deposition in water at bathyal depths (Rau, 1975, written comm.). The trace fossil, Helminthoida, which is rarely seen in the upper Silver Point tongue, is well known from Deep-Sea Drilling Project (DSDP) cores in abyssal waters (Chamberlain, 1975, written comm.). Very fine, disseminated carbonaceous plant material occurs in both sandstone and mudstone layers, but is more concentrated in the darker mudstones. The above features suggest that the upper Silver Point tongue was deposited in a slope or outer shelf environment. Similar interbedded, carbonaceous ring-grained sandstones and mudstones have been observed on the pro-delta slope and outer delta-front platform on the modern Niger Delta (Allen, 1965) and delta-front silts and sands (classical topset beds) of the Mississippi River Delta (Scruton, 1960). Westerly (mean direction = 285°) and northerly (mean = 346°) paleocurrent measurements in the upper Silver Point tongue (Figure 42) indicate a wide range of current transport in the depositional basin.

Broad, late middle Miocene east-west-trending folding resulted in mild deformation and erosion of the Oswald West mudstones and Astoria Formation. Continued subsidence probably followed this short period of deformation. The Dump sandstones were formed by redeposition of the sediments eroded from the older exposed Tertiary sedimentary units.

Deposition of the Dump sandstones was followed by intrusive emplacement of basaltic dikes and sills, and periodic submarine volcanism of the Depoe Bay and then the Cape Foulweather Basalts. A possible localized Depoe Bay shallow submarine volcanic center exists in the northwestern part of section 19, T. 6 N., R. 9 W. The complex consists of abundant intrusive dikes, vesicular and frothy basalt breccia, and local pillow basalts. Large angular blocks of Airplane mudstones(?) are scattered throughout the breccias. This complex is well-exposed along log spurs 108 and 108-A off Lewis and Clark Mainline (northwestern quadrant of sec. 19, T. 6 N., R. 9 W.).

Extrusive submarine pillow basalts and breccias with angular unconformity overlie older Tertiary units in the study area with exception of the Dump sandstones. In the western part of the area, an extensive series of Cape Foulweather pillow basalt flows dip at low angles to the north over southerly dipping sedimentary units of the Astoria Formation. Marine sedimentary beds between individual Cape Foulweather and Depoe Bay basalt flows suggests that volcanism was episodic with marine sediments deposited during times of volcanic quiescence. Sedimentary processes controlling deposition of these sedimentary interbeds and the underlying upper Silver Point tongue apparently remained unchanged because of the lithological similarities between both units.

Major normal and possible (?) reverse faulting and broad, open folding took place after late middle Miocene basaltic activity ended as evidenced by northeast- and northwest-trending high angle faults and northeast-trending folds which disrupt the basalts and all older strata in the area. At this time, the Astoria marine embayment was destroyed.

The difference between altitudes of present outcrops and paleo-ecological depth criteria for trace fossils and forams in the Airplane mudstones and upper Silver Point tongue indicates that at least 700 meters of uplift has taken place since late Miocene time. The result of this uplift has been the subaerial erosion of extensive amounts of Tertiary sedimentary and basaltic rocks.

Deposition and Tectonics

The study and knowledge of sediment deposition associated with outer shelf and upper slope environments of modern continental margins has increased greatly during the past 15 years. However, it is difficult to relate working depositional and tectonic models of modern active continental margines to older uplifted margin sequences onshore. Ancient sedimentary rocks deposited at this position are usually covered by thick layers of younger rocks or have been subject to extensive erosion. The following argument is based largely on sedimentary facies mapped in this study area compared to facies on the modern Oregon continental margin as described by Kulm and Fowler (1974a; 1974b).

During late Oligocene and early Miocene time, there was a shallow shelf, or fore-arc basin, approximately 80 km. wide stretching from what is now the most eastern part of the Coast Range to the area near the eastern border of the study area. The Scappoose Formation of the northeastern Coast Range is the only remnant of this shelf; the rest has been removed by erosion of the Coast Range Uplift. The Scappoose is thought to be of deltaic origin (Van Atta, 1971) and forms the easternmost boundary of this shelf.

The study area was part of a large, upper slope basin during late Oligocene and early Miocene time which was filled with hemipelagic muds and glauconitic sands of the Oswald West mudstones at a depth of nearly 500 meters (Figure 43). Evidently, most of the coarse sediments issuing from the Scappoose delta were trapped in the fore-arc basin. The upper slope basin was similar, but probably more extensive, than the basins formed on the modern continental slope off northern Oregon. These modern troughs are currently being partially filled by Holocene muds (Kulm and Fowler, 1974a). These modern troughs are formed by compressional folding and faulting as a result of imbricate thrusting at the juncture of the

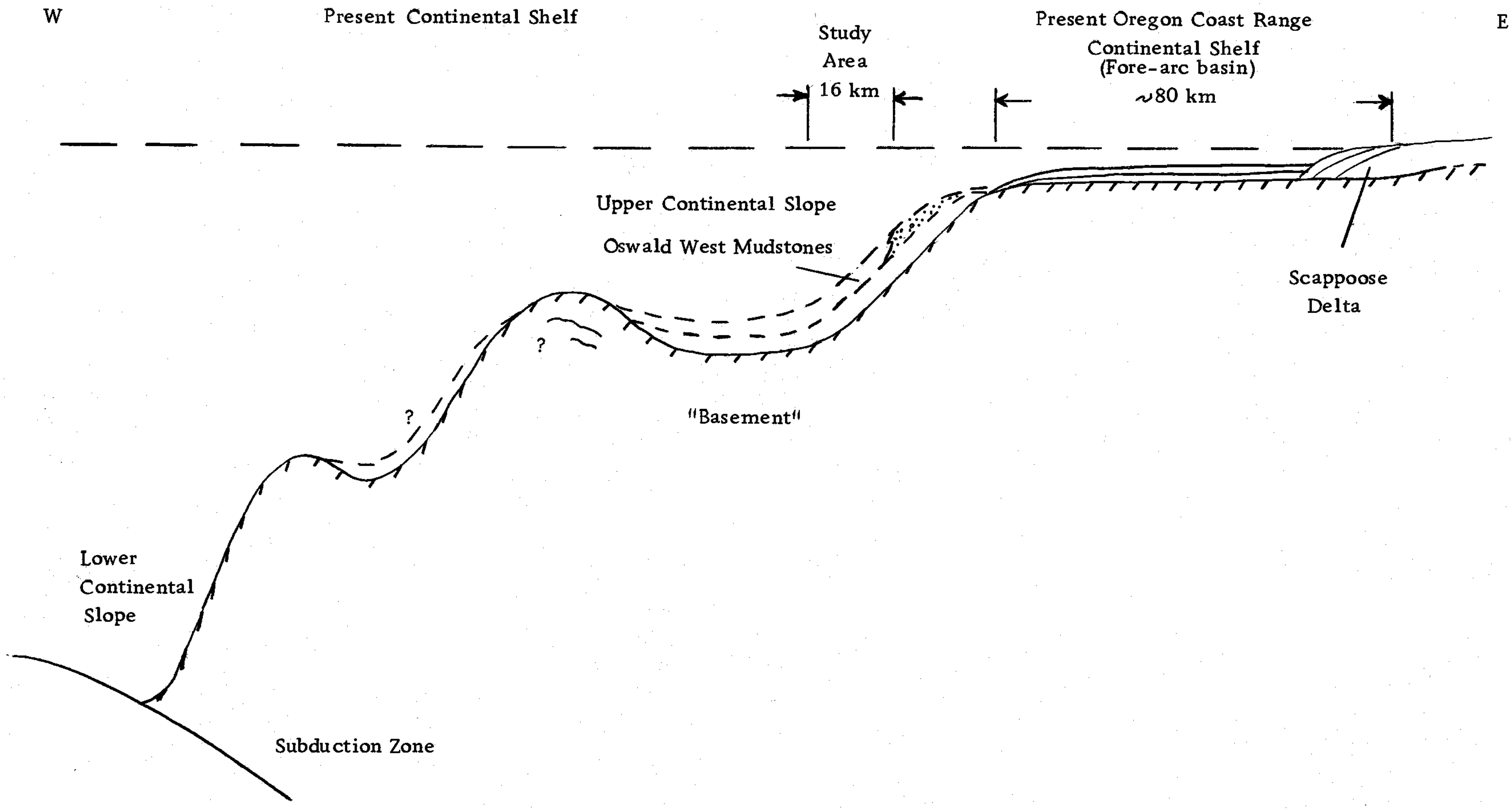


Figure 43. Idealized east-west cross-section of early Miocene sediment distribution along the northern Oregon continental margin. "Basement" consists of several thousands of meters of pre-Miocene sedimentary rocks and unknown thickness of Eocene oceanic Siletz River Volcanics. Not to scale. Volcanic arc represented by intrusive and extrusive igneous rocks in present western Cascades. (General basinal setting inferred from data given in Kulm and Fowler, 1974a).

Juan de Fuca and North American plates. Figure 43 illustrates an idealized cross-section across the Oregon margin during deposition of the Oswald West-Scappoose units in early Miocene time.

Broad uplift of the upper slope-outer shelf combined with major Antarctic glaciation during the Late early Miocene (Kennett and others, 1974) produced a large eustatic lowering of sea level. The uplift was probably caused by shallow imbricate thrusting of abyssal deposits of the Juan de Fuca Plate under the North American Plate (Kulm and Fowler, 1974b; Seely and others, 1974). Late Cenezoic broad uplift of the upper slope/outer shelf near the Nehalem Bank occurring at a rate up to 100 meters/million years (Kulm and Fowler, 1974b) is similar in cause and rate to the proposed Miocene uplift. This shoaling allowed rapid progradation of coarser sediments across the continental shelf to the edge of the continental slope.

The coarsening upward Astoria sequence from marine to fluvial, tidal flat and lagoonal conditions in the northern part of the study area (lower Silver Point tongue to 'J' unit); formation of complex intertonguing shallow-marine and fluvial deposits underlain by the deep-marine Oswald West mudstones; and a highly variable, but dominant westerly, paleo-dispersal pattern suggests that the middle Miocene Astoria Formation was of deltaic origin. This deltaic complex which rapidly filled the upper slope basin appears to have had its main depositional locus in the Angora Peak-Neahkahnie Mountain area some 30 km. south of the study area. In that area, there are over 300 meters of complexly intertonguing fluvial, intertidal or inter-distributary swamp mudstones with local low-grade coal seams up to 0.8 meters thick, and littoral sheet sandstones (Cressy, 1974; Smith, 1975). Laterally, to the north and south of the Angora Peak area, most of the Astoria Formation consists mainly of deep-marine turbidite sequences of the Silver Point member with subordinate littoral sandstones, most of which are inland relative to the Angora Peak outcrops (Neel, 1976; Cooper, 1975, pers. comm.). Thus, the Angora Peak area represents a localized lobe of non-marine buildup.

In this study area, a similar complex of less magnitude is found. The 'J' unit, composed of intertidal or lagoonal carbonaceous mudstones with very thin peat or low-grade coal seams and fluvial channel sandstones and conglomerates, is hemmed in by the Angora Peak beach or bar sandstones to the southeast, deep-marine mud-stones in the offshore area to the west, and lower Silver Point sub-littoral to bathyal mudstones and sandstones to the northeast. Thus, because of the facies relationships with other members of the Astoria Formation in this study area, the 'J' unit represents a relatively small deltaic lobe building into a deep upper slope basin (Figure 44).

Cressy (1974) suggested that an ancestral Columbia River with a drainage basin similar to the modern Columbia River was respon-sible for the deltaic progradation into the study area. He based this

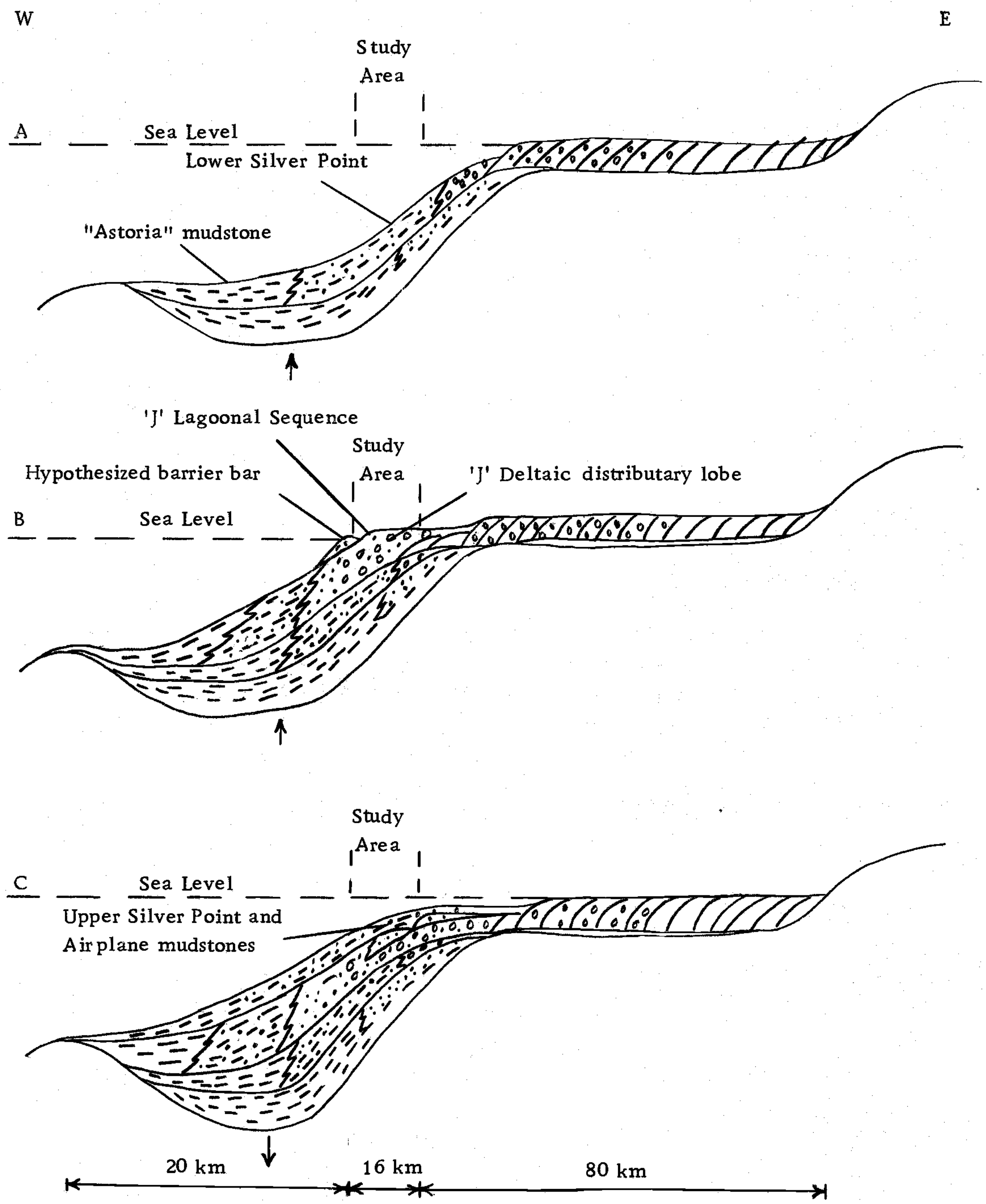


Figure 44. Idealized east-west cross-section of middle Miocene Astoria Formation sediment distribution.

A. Deposition of Lower Silver Point tongue on delta front.

B. Deposition of progradational subaerial deltaic plain including 'J' lagoonal and fluvial sediments and Angora Peak bar sands.

C. Deposition of pro-delta Airplane muds and delta slope upper Silver Point sands and muds.

hypothesis on the exotic pebble composition and heavy mineral composition of Astoria Formation sandstones. Studies of pebbles and heavy mineral suites from the Astoria Formation of this study area further confirms that the sources of material must have included western Idaho, eastern Washington and Oregon, or southern British Columbia, as well as the western Cascade Mountains.

Subsidence of the upper slope trough caused by the accumulation of large amounts of clastic material accompanied by downbending and seaward migration of the Juan de Fuca oceanic plate (Seely and others, 1974) and sea level rise from melting of part of the Antarctic glaciers (Kennett and others, 1974) again allowed deposition of deeper water (500 meters or less) sediments as part of a delta slope sequence during the latter part of middle Miocene time represented by the Airplane mudstones and upper Silver Point. Figure 44 shows the hypothesized depositional setting during Astoria time.

Renewed thrusting at the trench after deposition of the upper Silver Point tongue caused broad gentle folding of the upper slope and outer shelf. Sediments from the anticlinal crests were eroded into synclinal lows forming the Dump sandstones.

Submarine volcanism and intrusive emplacement of the Depoe Bay and Cape Foulweather Basalts may have been caused by westward migration of magma along thrust planes in the subduction zone. The magma then advanced vertically along high angle faults to the ocean floor surface (Snavely and others, 1973). It is hypothesized that these high angle faults were tensional features formed along a hinge line marking the continental shelf/slope boundary.

Uplift of the present Coast Range probably began during late Miocene time (10 m. y. B. P.) (Kulm and Fowler, 1974b). Although Kulm and Fowler (1974b) further suggest that intense underthrusting along the Oregon margin occurred at this time, uplift of a feature as large as the Coast Range anticlinorium would seem to be a product of isostatic uplift and associated with high angle normal faulting after a period of prolonged thrusting or higher subduction rates (Seely and others, 1974). The subduction zone probably migrated oceanward from a position probably near the modern continental shelf/slope boundary to its present position off the Oregon continental margin during late Miocene time with possible isostatic rebound of the detached plate.

Since late Miocene time, large quantities of sediment have been accumulating on the continental shelf, in north-south troughs along the continental slope, and in Cascadia Basin.

ECONOMIC GEOLOGY

A few geologic resources have been developed in the study area. Dense, columnar jointed intrusive basalts are commonly crushed and used as road-building material. Logging companies use large quantities of basalt as road base and, as a result, have many quarries in the area. Several of the larger quarries, which are usually located in large sills or dikes are identified on Plate I. Reserves in inactive and active quarries are large. Other possible sites for new quarries include many locations along South Fork Spur and South Fork Spur 1 (secs. .019, 29, and 30, T. 6 N., R. 9 W.) where a large columnar jointed Depoe Bay sill crops out.

Another, as yet unexploited, source of gravel is the Pleistocene stream terrace deposits along the Lewis and Clark River. These deposits may be 1.5 to 9 meters thick and include a wide size range of gravels composed mainly of Depoe Bay and Cape Foulweather basalts.

Groundwater in the Quaternary beach ridges of the Clatsop Plains along the western margin of the study area is an ample source of good quality fresh water (Frank, 1973). Relatively few wells have been drilled to tap this water supply because abundant streams and rivers provide sufficient potable water for this non-industrial area. Schlicker and others (1972) suggest that because of the high porosity and permeability of the Clatsop Plains sands, the groundwater may be susceptible to contamination by waste dumping and other types of surface sewage disposal. Tertiary units generally have low yield rates and contain water of poorer chemical quality than the beach ridges.

No significant hydrocarbon reserves have been discovered in the Tertiary deposits in the area. Three wells have been drilled near the study area since 1955 including Standard Oil Co. of California's (Socal) onshore Hoaglund Unit #1 well (5 km. northeast of Cullaby Lake at SE$\frac{1}{4}$, sec. 11, T. 7 N., R. 10 W.) and two wells drilled approximately 25 kilometers offshore on the continental shelf, the Shell OCS PO75 1ET (46°09'08" N., 124°24'30" W.) and Shell OCS PO78 1ET (46°02'50" N., 124°29'55" W.). These wells have total depths reaching 2,160, 3,097, and 2,505 meters, respectively. The wells drilled through a total geologic column of Pleistocene sedimentary strata to Eocene volcanic basement (see Appendix XI for well data).

The Socal Hoaglund #1 well was spudded in Oligocene strata and drilled through a thick sequence of Eocene mudstones and subordinate interbedded thin siltstones and very fine-grained sandstones (all rock units and ages are from Socal scout tickets of the well) and bottomed in early Eocene volcanics. It is generally assumed that these volcanics form the economic basement in the area. Core samples from the Hoaglund well (Appendix XI) from middle Eocene "Tyee-age" rocks are very fine-grained deep-marine siltstones and claystones. Electric log spontaneous potential (S. P.) curves indicate that no porous zones are developed within these mudstones. Although the Tyee-age strata are probably not potential reservoir rocks in this area they are organic-rich in places and could be considered a possible hydrocarbon source.

Approximately 590 meters of late Eocene Cowlitz-age rocks overlying Tyee-age mudstones were encountered in the Hoaglund well. S. P. curves from the electric log suggest that most of the unit appears to have almost no porosity; indicative of a mudstone lithology. Some very thinly bedded (maximum 3 cm.) very fine-grained sandstones are observed in core samples (Appendix XI). Two 12- to 15-meter intervals with well developed porosities can be seen on the electric logs. These intervals may contain fairly thick sandstones although core samples from the 1028.7 to 1041.8 meter interval contain shattered claystones. The sandstone layers and shattered claystones could be reservoir rocks elsewhere if hydrocarbons were present.

Late Eocene-early Oligocene interbedded mudstones and silty sandstones of Keasey age occur from the surface to a depth of 526 meters in the Hoaglund well and overlie the Cowlitz-age mudstones. Sandstones recovered from cores at 332.2 to 335.3 meters gave a field porosity of 22.6% and 1 millidarcy permeability. Electric log characteristics show that approximately 15 meters of probable sandstones and interbedded mudstones with moderate porosity and permeability are developed immediately under the cored interval noted above. The remainder of the Keasey unit is largely composed of low porosity/permeability mudstones or tight sandstones. Very fine plant material is abundant in the cored mudstones. Under high enough pressure-temperature conditions, these mudstones may have the capability of being a source of light hydrocarbons.

Approximately 1523 meters of Oligocene to Eocene sedimentary rock were encountered in the Socal Hoaglund well before the Eocene volcanics were struck. In the offshore Shell OCS PO75 1ET well only 108 meters of Oligocene to Eocene sedimentary rocks were drilled before encountering a volcanic unit. If this small interval represents the entire Oligocene-Eocene sedimentary deposition then there is over 1400 meters of east to west thinning in a distance of less than 32 km. Because several areas of folding occur between the Standard and offshore Shell wells as determined by offshore seismic data (Figure 38, unpublished data, School of Oceanography, Oregon State University, and Kulm and Fowler, 1974b), there is a possiblity that up-dip porosity/permeability pinchout stratigraphic traps may be found offshore in the Eocene-Oligocene interval.

The Oswald West mudstones which crop out extensively in the study area probably have almost no hydrocarbon production potential. Most of the unit is mud-rich with very low apparent porosity and permeability. The Oswald West mudstones are a possible cap rock for underlying units and contains from 3 to 5% disseminated organic material, which, under deep enough burial conditions could be a hydrocarbon source for overlying more porous and permeable units in the area, such as the Angora Peak sandstones.

The middle Miocene Astoria Formation has the best potential for containing hydrocarbon reserves onshore and in the immediate offshore areas. If encountered in the subsurface, possible reservoir rocks include much of the Angora Peak sandstones and thicker beds and channel deposits in the lower Silver Point tongue and 'J' units. Many beds in these units are well-sorted, friable, feldspathic-quartzose sandstones with porosities approaching 5% as determined in thin section. Porosity in these sandstones is largely dependent upon cementation, diagenetic alteration, and surface weathering of volcanic rock fragments. It is possible that at depth little or no alteration has occurred in the rocks and higher porosities may be expected.

The best subsurface target in the surrounding area is the Angora Peak sandstones which consist of approximately 120 meters of fine- to coarse-grained fairly porous, moderately sorted sandstones. The Angora Peak is overlain and underlain by thick sequences of fine-grained carbonaceous mudstones and thin, silty sandstones which could act as potential source rock. The overlying Silver Point and especially the Airplane mudstones would make good cap rocks. The linear distribution, shallow-marine fossils, sedimentary structures, interfingering facies relationships, and texture suggest that the Angora Peak is a long, linear beach or barrier bar deposit. If the Angora Peak continues along depositional strike to the northwest from its outcrop location in the southeast part of the study area (Plate I), it will probably be found in the subsurface downdip from the 'J' lagoonal sequence in the western part of the study area and adjacent offshore areas.

Offshore production targets have included Miocene to Pliocene sedimentary deposits which have an aggregate thickness of approximately 1800 meters (well data supplied through courtesy of Shell Oil Company). Major prospects include the lower to middle Miocene Hoh Formation (as named by Shell scout tickets) and the middle Miocene Astoria Formation (Braislin and others, 1971). Several hydrocarbon shows were detected in the offshore Shell PO72 1ET well.

Onshore mapping of the Astoria Formation in the study area and offshore well data suggest that there is an overall rapid westward fining of this unit. Thus, the best possible area for drilling would be in the offshore area within 5 to 15 km. of the coast. However, seismic reflection profiles (Kulm and Fowler, 1974b) show that middle Miocene basalts occur directly west of Tillamook Head and may be encountered in other places offshore as well (Figure 38). Beyond the distance noted above, thin interbedded mudstones and dirty sandstones, similar to those in the upper Silver Point, or mudstones, like the Airplane mudstones should be expected. Shell's two offshore wells have encountered only impermeable middle Miocene siltstones and mudstones, which tends to confirm the suggested offshore fining.

GEOLOGIC HAZARDS

Landsliding, flooding of lowlands, and less frequent events such as earthquakes and high storm waves are the most notable geologic hazards in the area. The primary hazard is landsliding. Landslides occur when overburden weight on a rock unit becomes greater than the shear strength of the weakest plane in the rock. Clay-rich rock units are extremely slump-prone because of low shear strength of water-saturated clay beds where dips of strata parallel hillslopes. Fine-grained rock units in the study area, such as the Oswald West and Silver Point mudstones, commonly underlie areas of recent slumping. Many logging roads are frequently damaged or destroyed by sliding during the rainy winter season. A large slump on Lewis and Clark Mainline (SE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 23, T. 6 N., R. 9 W.) has been so continuously active that a special alternate route has been built around the slump area. Many areas underlain by fine-grained mudstone units have tilted trees and hummocky topography attesting to the size and frequency of recent landslide activity.

Schlicker and others (1972) and Carter (1976) speculate that earthquake vibrations may trigger massive slope failure, especially if slope stability is already low because of water-saturated ground conditions. Although not common, at least 16 minor earthquakes with magnitudes generally less than 4.0 have occurred within 160 km.

of the study area within the past 150 years. The largest of these was in 1957 with an epicenter near Beaver, Oregon, which is approximately 80 km. southeast of this area. The magnitude of this earthquake, calculated from maximum observed intensity, was 5.0 (Couch and others, 1974). Larger earthquakes with epicenters outside the 160 km. radius have been felt in the Seaside area. Two of these, in 1962 and 1965, have had modified Meccali intensities of VI in the Seaside area (Couch and others, 1974). Damage to chimneys and plaster, furniture moved, and objects overturned are typical effects occurring at this intensity.

Flooding, although not as common in this area as in other northwestern Oregon locations, is a problem in some of the low-lying flood plains of the Young's River and the Lewis and Clark River. Because these valleys are sparsely populated in the study area, flood damage to buildings has been minimal. Comparison of recent (1971) aerial photographs and Crown zellerbach maps (1960) suggests that course changes caused by meander cutoffs along the Lewis and Clark River in the northern part of the area have occurred in the past 15 years.

Infrequent catastrophic events have damaged areas along the coast. A tsunami generated by the Good Friday Alaska earthquake in March, 1964, damaged or destroyed several bridges and houses in the Seaside area (Schlicker and others, 1972). Storm waves caused by high winds have caused damage to bridges and business areas along the coast. Flooding and damage by large water-rafted logs caused $7,000 damage to Seaside in December, 1967, as a result of large storm waves (Schlicker and others, 1972).

CONCLUSIONS

Studies of sedimentary structures, trace fossils, foraminifera, and grain-size distribution in the sedimentary units suggest that the study area was situated in an upper continental slope basin during late Oligocene to middle Miocene time. Late Oligocene to early Miocene sedimentary rocks are of hemipelagic origin. These Oswald West mudstones are overlain by a coarsening upward deltaic rock sequence of the Astoria Formation. Fluvial, lagoonal, littoral beach or bar, and delta front facies are observed in the Astoria Formation which prograded into the deep upper slope depositional basin. The upper part of the Astoria Formation consists of a transgressive marine sequence of prodelta and delta slope fine-grained sandstones and mudstones.

Local broad folding allowed buildup of thin pockets of eroded sheet sandstones of the Dump unit and localized accumulations of Depoe Bay and Cape Foulweather extrusive basalts. Folding and faulting of all the above units, probably during late Miocene time, was associated with rapid convergence of the Juan de Fuca and North American plates. Since middle Miocene time the study area has been uplifted a minimum of 700 meters based on present elevations and peleoecological interpretation of trace fossils and foraminifera in the Tertiary strata.

Little hope is held for production of hydrocarbons near the Seaside-Young's River Falls area. Although the Angora Peak sandstones and lower Silver Point tongue contain potentially good reservoir rock, poor hydrocarbon shows in several nearby wells suggest that economically recoverable reserves may never be found in northwestern Oregon.

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APPENDICES

APPENDIX I

Principal Reference Section A-B

Angora Peak Sandstone Member of the Astoria Formation

Initial Point (A): NE 1/4, NE 1/4, SW 1/4, section 23, T. 6 N., R. 9 W.
Section starts in ravine at first sandstone unit seen above mudstones along Crown Zellerbach log Spur 85. Stratigraphically at erosional, possibly angular, unconformable contact with Oswald West mudstones.

Below the initial point lie about 250 meters of slumped and very weathered Oswald West mudstones.

Terminal Point (B): NE 1/4, NW 1/4, SW 1/4, section 23, T. 6 N., R. 9 W.
Section ends at last outcrop of sandstone on east side of Junction Spur 85 and south-bound unnamed log spur.

Unit		Thickness (meters) total	unit
12	very fine-grained silty sandstone; dark greenish gray (5G4/1); angular to subangular; poorly sorted; no bedding noted due to complete bioturbation; contains pods of pebbly siltstone up to 15 cm. diameter; pebbles are basaltic, quartzose, and quartzitic; surrounding sandstone is finely micaceous, feldspathic, quartzose. basal contact gradational over .6 meters	132.74	1.52
11	fine-grained sandstone; dark greenish gray (5G4/1); angular to subangular; well sorted; no bedding noted; mottled color probably caused by complete bioturbation; very micaceous, feldspathic, quartzose. basal contact sharp	131.22	6.10
10	fine- to medium-grained fossiliferous sandstone; dark yellowish brown (10YR4/2) to dusky yellow (5Y6/4) with local color variation at 97.84 meters of grayish olive (10Y4/2); fairly well sorted; subangular to subrounded grains; well bedded up to 1 meter; most beds 5-10 cm.; fossiliferous beds (5-15 cm.) at 103.48 m. and 104.39 m. containing well preserved pelecypods (see Appendix IV); other fossiliferous beds contain broken and abraded pelecypods; fossiliferous beds commonly form highly resistant calcareous cemented concretionary layers that are pale brown (5YR5/2); feldspathic, quartzose. basal contact sharp and planar megafossil samples: Cooper 10-7-74 Tolson PMT-12-74 U. S. G. S. Cenozoic location M6381	125.12	32.31

Unit	Description	Thickness (meters) total	unit
9	medium-grained sandstone with alternating light and dark beds 3 to 15 cm. thick. light beds moderate yellowish brown (10YR5/4) medium-grained sandstone; well-sorted; subangular to subrounded; feldspathic, quartzose with minor muscovite. dark beds dusky yellowish brown (10YR2/2); same lithology as light beds but contain much disseminated carbonaceous debris and dark minerals. basal contact sharp and planar	92.81	.91
8	medium-grained sandstone; light olive gray (5Y6/2) weathering to dark yellowish orange (10YR6/6) to grayish orange (10YR7/4); well-sorted; subangular to subrounded; no bedding noted; feldspathic, quartzose with minor muscovite. basal contact covered	91.90	8.38
7	covered	83.51	18.59
6	fine-grained sandstone; olive black (5Y2/1) weathering to moderate yellowish brown (10YR5/4); poorly sorted; subangular to subrounded; quartzose; very thick bedded (1-2 m.) basal contact sharp and planar	64.92	7.01
5	medium-grained sandstone as in Unit 6 but well bedded; beds 1-35 cm. thick; possible low angle cross-bedding; random floating pebbles up to 1.5 cm. diameter. basal contact gradational over .9 m.	57.91	5.64
4	medium-grained sandstone as in Unit 6 but with pebble lenses. sharp basal contact, planar	52.27	3.05
3	medium-grained sandstone as in Unit 6 with notable thin (1-3 mm.) carbonaceous stringers; grayish olive (10Y4/2) carbonaceous layers. basal contact sharp and planar	49.22	0.46
2	medium- to coarse sandstone to pebble conglomerate; olive black (5Y2/1) weathering to moderate yellowish brown (10YR5/4); poorly sorted; structureless but contains pebble lenses and thin carbonaceous stringers; pebble lenses up to 15 cm. thick; pebbles up to 2.5 cm. with mudstone ripups to 7 cm.; lenses fine upward into coarse sandstone; round to subround pebbles composed of quartzite, pumice, and chert; rare carbonaceous plant fragments up to 10 cm. in length. sandstone matrix fines from coarse sand at base to medium sand at top; subangular to subrounded; quartzose. basal contact sharp and planar. pebble count AP-1	48.77	21.49

Unit	Description	Thickness (meters) total	unit
1	medium-grained sandstone; fresh medium bluish gray (5B5/1) weathers to dark yellowish orange (10YR6/6); well sorted; subangular to subrounded grains; irregular, poorly bedded; quartzose, feldspathic, slightly micaceous.		
	basal contact covered	27.28	27.28

APPENDIX II

Principal Reference Section C-D

'J' Unit of the Astoria Formation

Initial Point (C): N 1/2, SE 1/4, SE 1/4, section 26, T. 7 N., R. 10 W. Section starts at bottom of gully on northeast part of log landing on Zellerbach log Spur 16P. Stratigraphically the initial point is approximately 60 meters above the upper Oligocene-lower Miocene Oswald West mudstones. The initial point is about 15 meters stratigraphically above the lower Silver Point-'J' contact.

Terminal Point (D): about 130 meters East of NW corner of section 36, T. 7 N., R. 10 W. Section ends in poorly exposed roadcut approximately 12 meters north of log landing at end of Crown Zellerbach log Spur 16N. Point D lies about 9 meters stratigraphically below the 'J'-Airplane contact found along Warrenton Pipeline log Road (NW 1/4 of section 36).

Unit	Description	Thickness (meters) total	unit
11	interbedded sandy coarse siltstone and rare wispy very fine-grained muddy sandstone; fresh olive black (5Y2/1), weathered dark yellowish orange (10YR6/6) to light olive gray (5Y7/1); poorly sorted; angular to subangular; bedding massive or very poorly bedded at base grading up to fair very thin bedding (less than 1 cm. at top of unit); small blocky weathered appearance; many iron-cemented concretions; much carbonaceous debris; feldspar and mica dominant; rare leaf imprints found on bedding surfaces in upper part of unit. basal contact covered; first in-place outcrop	112.18	15.24
10	covered	96.94	15.24
9	sandy mudstone, fresh dusky brown (5YR2/2) weathering to moderate yellowish brown (10YR5/3) to light olive gray (5Y6/1); very fine sand in silty matrix; poorly sorted; angular to subangular; extremely well-laminated (1-2 mm.) to slightly interlaminated; light laminae of micaceous mudstone and dark carbonaceous, common mudstone concretions up to 4 cm. possibly from cemented with pyrite/marcasite (?) cores; iron staining of unit is common; partial fossil leaves found between laminae; extremely rich in micas (up to 2 mm.) and carbonaceous plant debris (up to 5 mm. long). Subunit A: thin layers from 10 cm. to 30 cm. thick as in unit 9 but more carbonaceous debris; plant fragments show good current orientation; extremely fissile; color variation moderate brown (5YR3/4) fresh to light brownish gray (5YR6/1) weathered; Subunit A at 72.24 m., 71.94 m., 71.63 m., 71.02 m. and 70.41 m. Subunit B: thin layers of interlaminated (1 mm.) highly fissile carbonaceous mudstone and very fine- to fine-grained sandstone;		

Unit	Description	Thickness (meters) total	unit
	same fresh color as unit but weathers to yellowish gray (5Y8/1); laminations not as well developed as in most of Unit 9; Subunit B at 67.36 m., 66.03 m., and 65.54 m. basal contact covered	81.70	21.03
8	interlaminated (1 mm.) tuffaceous very fine-grained sandstone and micaceous and carbonaceous plant material (current oriented); dusky brown (5YR2/2) fresh to very pale orange (10YR8/2) weathered; sandstone laminae are poorly sorted; angular to subangular; quartz, feldspathic, and mica; chippy extremely friable on weathered surfaces. basal contact sharp and planar	60.67	0.3
7	Same as Unit 9. basal contact sharp, planar	60.37	1.83
6	roughly interlaminated as in Unit 9 but light sandy mudstone layers become prevalent; dusky brown (5YR2/2) fresh to moderate yellowish brown (10YR5/3) weathered; plant fragments are highly diffused and randomly oriented; contains 25 cm. bed at 53.04 meters with same lithology as Unit 9 Subunit B basal contact; gradational over 0.3 m. offset 70 m. on attitude S 70 E at 55.78 m. of section	58.54	12.20
5	sandy mudstone; moderate brown (5YR3/4) fresh to moderate yellowish brown (10YR5/3) weathered; very fine; poorly sorted; angular sand framework; well-laminated (1-2 mm.) with laminae separated by thin micaceous and plant fragment layers; tuffaceous laminae rarely found as interlaminae; contains 15 cm. bed at 66.45 m. with same description as Unit 9 Subunit A highly fissile with platey weathering contact gradational over 0.3 meters.	46.34	1.22
4	interlaminated sandstone and mudstone; mudstone olive gray (5Y4/1) fresh to yellowish gray (5Y8/1) weathered; sandstone pale yellowish brown (10YR7/2) fresh to yellowish gray (5Y8/1) weathered; where highly carbonaceous, sandstone laminae are light brown (5YR6/4) and where iron-stained are light brown (5YR5/6); poorly sorted; planar laminae (1-2 mm.); very fissile to blocky weathering sandstone is highly micaceous with flakes up to 1 mm. 1 contains many iron concretions. basal contact gradational over 15 cm. offset 208 m. @ S 70 E at 41.46 m. in section New orientation N 75 W, 20 SW offset 19.2 m. @ S 75 E at 39.93 m. in section offset 12.8 m. @ S 75 E at 36.88 m. in section	45.12	14.33

Unit	Description	Thicknes (meters) total	unit
3	mudstone; moderate brown (5YR3/4) fresh weathering light yellowish brown (10YR7/4) to grayish orange (10YR7/4); poorly sorted; poorly to roughly bedded (1-3 cm.); very micaceous and abundant disseminated carbonaceous plant debris; rare iron-cemented concretions; spheroidal weathering common. basal contact gradational over . 60 m.	30. 79	6. 10
2	covered	24. 69	32. 19
1	Same as Unit 3 basal and upper contacts covered	12. 50	12. 50

APPENDIX III

Principal Reference Section E-F

'J' Unit of the Astoria Formation

Initial Point (E): NW 1/4, NW 1/4, section 33, T. 7 N., R. 9 W.
Section starts half way to end of second short spur from 40 line road along Crown Zellerbach log spur 470. Initial point starts at first uncovered, non-slumped conglomerate bed. Stratigraphically approximately 60 to 90 m. above the top of the Oswald West mudstones.

Terminal Point (F): NE 1/4, NW 1/4, NW 1/4, section 33, T. 7 N., R. 9 W.
Section ends at east end of log spur (described above) at last uncovered part of roadcut.

Unit	Description	Thickness (meters) total	unit
16	Interlaminated fine- to medium-grained muddy sandstone and carbonaceous debris; grayish red (10R4/2) to light brownish gray (5YR6/1); poorly sorted; angular; laminae up to 2 mm.; feldspar, carbonaceous material, biotite and muscovite; grades sharply at 24.28 m. to very fine muddy sandstone; moderate brown (5YR4/4); poorly sorted; angular; laminae from 1 mm. to 10 mm.; same lithology as lower part of unit. basal contact - sharp, planar	24.99	1.48
14	Interbedded very muddy medium- to coarse-grained granulite sandstone and medium- to coarse-grained muddy sandstone, dark yellowish brown (10YR5/4); very poorly sorted; angular to subangular; conglomerate units; thin bedded up to 11 cm.; granules up to 3 cm. and mudstone ripups up to 6 cm. that are commonly layered; commonly grade upward into fine-grained muddy sandstone; abundant carbonaceous debris content; possibly very roughly trough cross-bedded; quartz, feldspar, lithic rock fragments, mafics, biotite and muscovite; Sandstone units; extrememly abundant carbonaceous debris content; mudstone ripups up to 3 cm.; irregular bedding up to 13 cm.; lithology similar to conglomeratic units; extreme iron staining; grades sharply at 21.56 m. into fine- to medium-grained sandstone; medium light gray (N6) to dark reddish brown (10YR3/4); poorly sorted; angular to subangular, planar laminated (1 mm. to 10 mm.) to possibly poorly defined micro-trough cross-laminated; laminae surfaces marked by carbonaceous debris and/or micaceous material; lithology as in upper parts of unit but no lithic rock fragment of granule size; extremely iron stained. Sample PM T-101-74 basal contact - sharp, erosional, relief up to 13 cm.	23.55	3.66

Unit	Description	Thickness (meters) total	unit
13	Coarse silt to fine-grained sandstone; grayish orange (10YR7/4); poorly sorted; angular; mostly well bedded 1 mm. to 1 cm. thick marked by carbonaceous and micaceous material; rare laminae of fine-grained sandstone; feldspar, quartz, biotite and muscovite, som iron-staining. basal contact - covered	19.89	2.70
12	Covered Change in bedding attitude to N20W, 30 NE	17.83	4.58
11	Roughly interbedded medium- to coarse-grained muddy conglomeratic sandstone and medium-grained sandstone; moderate brown (5YR4/4); very poorly sorted; framework angular to subangular; granules and pebbles subangular to subrounded; very irregular; poor bedding; conglomeratic units contain basalt, quartz, and quartzite pebbles up to 1 cm.; mudstone ripups to 11 cm.; wispy carbonaceous debris layers; feldspar, quartz, lithic rock fragments, biotite and muscovite; grades sharply at 12.07 m. to fine- to medium-grained sandstone; moderate yellowish brown (10YR5/4) to light brown (5YR5/6); very poorly sorted; angular; common very thin (less than 0.5 mm.) carbonaceous debris laminate and rare lenses of mudstone ripups, ripups up to 3 cm. long; iron staining common; at upper covered surface grades to laminated very fine- to fine-grained muddy sandstone. basal contact - very sharp, irregular with relief up to 13 cm.	13.26	1.62
10	Medium- to coarse-grained conglomeratic sandstone; light brown (5YR6/4); very poorly sorted; angular to subangular; irregularly bedded with rare wispy fine- to medium sandstone laminae; mudstone ripups up to 3 cm.; extremely abundant, finely disseminated carbonaceous debris; feldspar, mafics, quartz, biotite and muscovite; grades upward into very fine- to medium-grained muddy sandstone; very pale orange (10YR8/2); planar laminated to micro-cross-laminated with wispy carbonaceous debris layers; rare mudstone ripups up to 2 cm.; similar lithology as lower part of unit. basal contact - erosional, undulatory, sharp with relief up to 8 cm.	11.58	2.23
9	Interbedded medium- to coarse-grained extremely muddy conglomeratic sandstone and muddy very fine-grained sandstone; Conglomeratic units; beds up to 8 cm.; light brown (5YR6/4); very poorly sorted; angular to subangular; granules subangular to subrounded; quartz, feldspar, lithic rock fragments, mafics, biotite and muscovite; extremely carbonaceous; Fine units; beds up to 30 cm.; laminated (0.5 to 10 mm.) marked by carbonaceous debris accumulations; yellowish gray (5Y7/2); very poorly sorted;		

Unit	Description	Thickness (meters) total	unit
	subangular; lithology similar to conglomeratic beds. basal contact - very sharp, erosional with relief up to 11 cm.		
8	Interbedded medium- to coarse grained muddy conglomeratic sandstone and medium-grained muddy sandstone; light brown (5YR5/6); very poorly sorted; angular to subangular framework; mudstone ripups up to 3 cm. and pebbles up to 1 cm.; well-bedded (3 to 10 cm.); conglomerate beds to 6 cm. marked by carbonaceous debris accumulations; feldspar, quartz, biotite, mafics, lithic rock fragments (basalt or andesite); grades upward into interbedded fine- to medium-grained muddy sandstone; dark yellowish orange (10YR6/6) and thin (1 cm.) carbonaceous debris beds; black (N 1); sandstone beds faintly cross-laminated; lithology same as lower part of unit. Sample PMT-100-74 basal contact - sharp, undulatory with relief up to 60 cm.	8.54	.46
7	Coarse- to very coarse-grained conglomeratic sandstone; grayish red (5R4/2); very poorly sorted; angular to subangular; interbedded (3 to 13 cm.) conglomerate and mudstone; bedding marked by abundant carbonaceous debris; mudstone ripups up to 8 cm.; conglomeratic beds; pebbles up to 1.5 cm.; matrix is feldspar, quartz, biotite and muscovite, mafics, and lithic rock fragments; granules and pebbles are basalt or andesite porphyries and extremely weathered unknown lithic fragments; grades sharply at 8.46 m. into interbedded medium- to coarse-grained muddy sandstone and very fine-grained muddy sandstone; grayish orange (10YR7/4); interbeds (3 to 8 cm.) marked by carbonaceous debris accumulations; rare conglomeratic beds; feldspar, quartz, muscovite and biotite, lithic rock fragments; iron stained. basal contact - sharp generally planar.	8.13	1.44
6	Fine- to medium-grained muddy sandstone; dusky yellow (5Y6/4) to dark yellowish brown (10YR5/4); poorly sorted; angular to subangular; irregular bedding; mudstone ripups to 10 cm. long and slightly imbricated; feldspar, quartz, mica, extreme carbonaceous debris, minor mafics; grades sharply at 8.37 m. into very fine-grained muddy sandstone; pale greenish yellow (10Y8/2) to pale reddish brown (10YR5/4) where iron stained; very poorly sorted; subangular; irregular bedding marked by carbonaceous debris; lithology similar to lower part of unit; minor fold with approximately 15 cm. relief noticed in outcrop. basal contact - sharp planar	7.06	2.27

Unit	Description	Thickness (meters) total	unit
5	Medium- to coarse-grained sandstone; yellowish gray (5Y7/2); poorly sorted; subangular; well laminated (less than 2 cm.) with minor small-scale planar cross-laminations at 4.42 m.; quartz, feldspar, minor lithics, rare coarse quartz grains; laminations and cross-laminations marked by accumulations of carbonaceous debris; grades sharply at 4.72 m. into fine- to very fine-grained silty sandstone; yellowish gray (5Y7/2); very poorly sorted angular to subangular; well laminated (less than 1 cm.); same lithology as above; extreme iron staining. basal contact - sharp, planar.	5.69	2.03
4	Coarse-grained to granulite sandstone; light brown (5YR4/6); mud matrix; poorly sorted; angular to subangular with granules sub-angular to sub-rounded; irregularly bedded with wispy layers containing mudstone ripups, feldspar, lithics, minor quartz, and up to 20% mud matrix; grades sharply into interbedded (1 to 2 cm.) fine-grained sandstone and coarse sandstone; grayish orange (10YR7/4); some cross-trough lamination; tuffaceous; feldspar, pyroxene, quartzites and lithic rock fragments. basal contact - sharp, erosional, relief up to .3 m.	3.66	1.07
3	Medium- to coarse-grained muddy sandstone; pale yellowish brown (10YR6/2); poorly sorted; angular to sub-angular; mostly thinly bedded (1 to 5 cm.) with minor possible trough laminations; some iron staining; feldspar, lithic fragments, quartz; mudstone ripups up to 3 cm. length; grades upward into coarse siltstone or very fine-grained sandstone; moderate brown (5YR4/4); abundant contorted bedding in finer part. basal contact - sharp and planar	2.60	0.76
2	Medium-grained muddy sandstone; dusky yellow (5Y6/4); poorly sorted; subangular to subrounded; irregularly bedded with some interbedded muddy sandstone layers up to 0.5 cm.; rare micro-trough cross-lamination; quartz, feldspar, biotite and muscovite; abundant carbonaceous plant debris; mudstone ripups up to 5 cm. length; grades upward into sandy mudstone; with thin interbedded fine- to very fine-grained sandstone stringers. basal contact - erosional with relief up to 15 cm.	1.83	0.91
1	Conglomeratic sandstone; muddy medium- to coarse-grained sand matrix with 15% granules; moderate yellowish brown (10YR5/4); poor sorting; matrix grains subangular; framework subangular to subrounded; irregular bedding generally less than 5 cm.; lithology same as unit 2; grades sharply into interbedded medium-grained muddy sandstone (as above) and mudstone; mudstone moderate brown (5YR4/4). Sample PMT-99-74 basal contact - covered	0.91	0.91

APPENDIX IV

FOSSIL CHECKLIST AND LOCATION OF SAMPLES

Oswald West Mudstones

Sample	26	29	48	60	68	71
Gastropod						
Naticid		X			X	
Scaphopod						
Dentalium sp.	X					
Bivalve						
Acila sp.		X			X	
Katherinella?		X				
Nuculana sp.		X			X	
Propeamussium Pilarense (Slodkewitsch)				X		
Yoldia ?					X	
Trace Fossil						
Helminthoida			X			X

Sample Number	USGS Cenozoic Number	Location
PMT-26-74	M6434	Roadcut: 440 ft N., 1990 ft W. of SE corner, sec. 23, T. 7 N., R 10 W.
PMT-29-74	M6435	Roadcut: NW 1/4, NE 1/4, SW 1/4, sec. 23, T. 7 N., R. 10 W.
PMT-48-74		Roadcut: NE 1/4, NW 1/4, NW 1/4, sec. 25, T. 7 N., R. 10 W.
PMT-60-74	M6436	Roadcut: E 1/2, sec. 26, T. 7 N., R. 9 W.
PMT-68-74	M6433	Roadcut: W 1/2, W 1/2, sec. 22, T. 6 N., R. 9 W.
PMT-71-74		Roadcut: NE 1/4, SE 1/4, NE 1/4, sec. 26, T. 7 N., R. 10 W.

Identification of molluscan fauna by W. O. Addicott, U. S. Geological Survey

Identification of trace fossils by C. K. Chamberlain, Ohio University

APPENDIX IV (Continued)

Sample	Angora Peak Sandstones 12	38	52	9/13
Gastropod				
Bruclarkia oregonensis (Conrad)			X	
Calliostoma ?		X		
Echinophoria n. sp. aff. *E. cornosa* Kuroda & Habe			X	
Naticid	X			
Natica sp.	X			X
Searlesia sp.			X	
Bivalve				
Acila sp.				X
Anadara sp.		X		X
Clinocardium aff. *C. nuttali* (Conrad) Moore			X	
Dosinia whitneyi (Gabb)			X	
Katherinella sp.		38		?
Mytilus mittendorfi Grewingk	X			
Nuculana sp.		X		
Patinopecten propatulus (Conrad)	X	X		
Pectinid				X
Securella ensifera (Dall)			X	
Securella?	X			
Solen cf. *S. clallemansis* Clark and Arnold			X	
Solen sp.	X			X
Spisula albaria (Conrad)	X		X	
Vertipecten fucanus (Dall)			X	
Yoldia cf. *Y. tenuissima* Clark	X		X	

Sample Number	USGS Cenozoic Number	Location
PMT-12-74	M6381	Roadcut: NW 1/4, SW 1/4, sec. w3, T. 6 N., R. 9 W.
PMT-38-74	M6383	Roadcut: NE 1/4, SE 1/4, sec. 21, T. 6 N., R. 9 W.
PMT-52-74	My385	Roadcut: SW 1/4, sec. 23, T. 6 N., R. 9 W.
Cooper 9/13	M5988	Roadcut: NE 1/4, NE 1/4, sec. 22, T. 6 N., R. 9 W.

APPENDIX IV (Continued)

Sample	Silver Point lower		Silver Point upper			Airplane		
	62	9/20	6	14	44	36	64	9/22
Foraminifera								
Bathysiphon sp.	X							
Bulimina alligata Cushman and Laiming								X
Buliminella sp.								
Bolivina cf. *B. advena* Cushman					X			X
Bolivina marginata adelaidana Cushman & Kleinpell								X
Cassidulina cf. *C. laevigata carinata* Cushman								X
Dentalina spp.						X	X	
Globigerina spp.				X	X	X	X	X
Nodogenerina advena Cushman and Laiming								X
Nodosaria longiscata (d'Orbigny)					X			
Nonion costiferum (Cushman)								X
Siphogenerina kleinpelli Cushman								X
Siphogenerina sp.								X
Uvigerinella obesa Cushman								X
Uvogerina californica Cushman								X
Valvulineria cf. V. arancana (d'Orbigny)								X
Virgulina sp.					X	?		
Trace Fossil								
Helminthoida		X	X					
Siphonites		X						

Foraminifera identified by W. W. Rau, Washington State Department of Natural Resources

Trace Fossils identified by C. Kent Chamberlain, Ohio University, Atkins, Ohio

APPENDIX IV (Continued)

Sample number	USGS Cenozoic Number	Location
PMT-6-74		Roadcut: NW 1/4, NW 1/4, sec. 23, T. 6 N., R. 10 W.
PMT-14-74		Ravine: NW 1/4, SW 1/4, sec. 26, T. 6 N., R. 10 W.
PMT-44-74		Hillside: NE 1/4, NE 1/4, NW 1/4, sec. 19, T. 6 N., R. 9 W.
PMT-36-74		Roadcut: NW 1/4, sec. 20, T. 6 N., R. 9 W.
PMT-64-74		Roadcut: S 1/2, N 1/2, SE 1/4, sec. 20, T. 6 N., R. 9 W.
Cooper 9/22		Roadcut: 1320 ft N. of SW corner, sec. 7, T. 6 N., R. 9 W.
PMT-62-74	M6436	Roadcut: 1500 ft S. of NE corner, sec. 33, T. 7 N., R. 9 W.
Cooper 9/20		Streamcut bank: N 1/2, N 1/2, N 1/2, sec. 27, T. 7 N., R. 9 W.

APPENDIX V

Heavy Mineralogy of Selected Samples

	Oswald West		Astoria Formation					
			Angora Peak			'J'		Upper Silver Point
Samples	25	28	55	96	38	13	99	82
Minerals								
Hornblende								
Green / Basaltic	R	F	-	C	R	F	C	R
Glaucophane	R	-	-	-	-	-	-	-
Augite	R	R	F	R	C	C	C	F
Hypersthene	-	-	-	R	C	-	C	F
Enstatite	-	-	-	F	-	-	-	C
Pigeonite	-	-	-	-	-	F	-	-
Garnet	F	F	A	F	C	A	F	C
Zircon	R	-	R	R	R	F	F	-
Apatite	-	-	R	-	-	-	F	-
Biotite	C	C	F	F	C	A	C	A
Chlorite	-	R	-	R	-	-	R	-
Sphene	-	-	R	-	-	-	-	-
Monazite	-	-	C	-	-	-	-	-
Carbonate	-	-	R	-	R	-	-	-
Epidote	-	-	R	R	-	R	-	-
Olivine	-	-	R	-	-	R	-	-
Rutile	-	-	-	-	-	R	-	-
Staurolite	-	-	-	-	-	-	F	-
Opaques	A	A	A	A	A	A	A	A

R 1% F = 1-5% C = 5-15% A = 15%

APPENDIX V (Continued)

Sample	Location
Oswald West mudstones	
PMT-25	Roadcut: W 1/2 NE 1/4, sec. 26, T. 7 N., R. 10 W.
PMT-28	Roadcut: SW 1/4 NE 1/4 NW 1/4, section 23, T. 7 N, R. 10 W.
Angora Peak sandstones	
PMT-55	Roadcut: W 1/2 SW 1/4 SE 1/4, section 26, T. 6 N., R. 9 W.
PMT-96	Roadcut: NW 1/4 SW 1/4, section 23, T. 6 N., R. 9 N.
PMT-38	Roadcut: NE 1/4 SE 1/4, section 21, T. 6 N., R. 9 W.
'J' unit	
PMT-13	Roadcut: N 1/2 N 1/2 NW 1/4, section 36, T. 7 N., R. 10 W.
PMT-99	Roadcut: NW 1/4 NW 1/4, section 33, T. 7 N., R. 9 W.
Silver Point tongue	
(upper)	
PMT-82	Roadcut: SW 1/4 SW 1/4 SW 1/4, section 23, T. 6 N., R. 10 W.

APPENDIX VI

Modal Analyses of Sandstone Samples from Oswald West mudstones and Astoria Formation in approximate stratigraphic order

	Oswald West Mudstones			Angora Peak Sandstones					
Sample No.	PMT-24	PMT-25	PMT-49	PMT-38	PMT-74	PMT-96	PMT-97	PMT-98	7-7-74
Stable Grains									
Quartz	8	-	-	7	3	18	9	8	17
Quartzite	1	-	-	12	11	6	14	12	12
Chert	5	-	-	9	5	1	5	4	4
Feldspar									
Plagioclase	7	-	-	21	29	22	16	19	37
K-spar	1	-	-	4	5	6	4	3	2
Rock Fragments									
VRF	1	Tr	-	19	8	19	12	9	5
IRF	-	-	-	-	1	Tr	Tr	1	1
MRF	-	-	-	-	-	Tr	-	Tr	Tr
SRF	-	-	-	-	-	-	-	-	-
Mica	2	-	-	10	6	7	13	7	1
Mafic	-	-	-	1	Tr	2	Tr	1	Tr
Opaque	10	1	-	1	Tr	1	1	1	Tr
Other	-	-	-	1	Tr	Tr	-	1	Tr
Glauconite	60	85	95	2	2	-	-	1	Tr
Alteration Minerals	Tr	-	-	10	4	15	5	1	1
Cement ($CCaCO_3$)	-	-	-	Tr	-	2	-	30	-
Porosity	1	Tr	Tr	1	1	3	4	2	3
Matrix	6	10	5	5	31	5	19	~	19

Tr = less than 0.5%

See Plate I for sample locations

APPENDIX VI (Continued)

Sample No.	Lower Silver Point PMT-45	PMT-62	J PMT-13	Upper Silver Point PMT-37	PMT-65	PMT-82
Stable Grains						
Quartz	12	12	5	11	10	6
Quartzite	17	25	19	10	26	17
Chert	5	8	5	6	4	7
Feldspar						
Plagioclase	22	22	84	20	29	31
K-spar	7	8	2	1	6	9
Rock Fragments						
VRF	19	-	-	8	6	15
IRF	-	-	-	4	2	1
MRF	-	-	Tr	Tr	1	-
SRF	-	-	6	1	Tr	-
Mica	7	1	3	13	6	2
Mafic	Tr	-	Tr	1	Tr	Tr
Opaque	1	Tr	Tr	1	Tr	Tr
Other	1	-	-	1	-	Tr
Glauconite	-	-	Tr	-	-	-
Alteration Minerals	4	3	2	3	7	5
Cement ($CaCO_3$)	-	-	2	-	-	-
Porosity	1	4	4	2	3	4
Matrix	10	20	17	10	8	13

Tr = Less than 0.5%

See Plate 1 for sample locations

APPENDIX VII

Sample	Oswald West PMT-25	Angora Peak PMT-96	Angora Peak PMT-33	'J' (fluvial) PMT-13	'J' (fluvial) PMT-99	Upper Silver Point PMT-22	Dump PMT-1
Sand (%)	72	87	75	97	70	99	82
Silt & Clay (%)	28	13	25	3	24	1	13
Coarsest 1% (mm)	1	0. 35	0. 30	0. 72	2. 70	0. 85	0. 76
Median (mm)	0. 20	0. 11	0. 09	0. 17	0. 20	0. 28	0. 10
Mean (Ø)	2. 40	7. 20	2. 60	2. 60	2. 10	2. 25	3. 20
Sorting	2. 63	3. 20	2. 13	2. 53	2. 02	1. 65	3. 10
Skewness	1. 655	0. 667	0. 63	0. 804	2. 094	0. 864	0. 761

See Plate I for sample locations

APPENDIX VIII

Pebble C Unit

Sample	Angora Peak AP-1	Lower Silver Point SP-1
Quartzite*	43%	42%
Chert	42	17
Pumice	5.7	12
Granitic/Rhyolite	3.1	8
Basalt	1	5
Mudstone	1	6
Welded Tuff	-	3
Andesite (?)	-	2
Petrified Wood	-	2
Diorite (?)	1	-
Vein Quartz	1	-
Metamorphic schist	-	1

Sample Number	Location
AP-1	Hillside: SE 1/4, NE 1/4, section 20, T. 6 N., R. 9 W.
SP-1	Roadcut: NW 1/4, SW 1/4, section 23, T. 6 N., R. 9 W.

*Includes sedimentary and metamorphic varieties

APPENDIX IX

Clay Mineralogy of Selected Samples

Procedure

Pretreatment of mudstones and clays from the matrix of the sandstone samples included disaggregation by gentle grinding and soaking in water, wet sieving through a 4Ø sieve, soaking in 0.1 N hydrochloric acid to remove calcium carbonate, addition of 30% hydrogen peroxide to remove organic matter, and soaking with sodium dithionite ($Na_2S_2O_4$) to remove iron. The fine-grained disaggregated samples were then dispersed in a calgon solution and centrifuged to separate the clays from the silt fraction. The clay size fraction was smeared onto glass slides for X-ray analysis. The runs were made on each sample 1) dried at room temperature; 2) treated with ethylene glycol overnight; 3) heated to 400°C for one hour; and 4) heated to 600°C for one hour.

APPENDIX IX (Continued)

Clay Mineralogy of Selected Samples

(locations are shown on Plate I)

Sample	Oswald West mudstones 22	Oswald West mudstones 29	'J' 99	Airplane mudstones 20	Airplane mudstones 34	Upper Silver Point 11
Montmorillonite	X	-	X	?	X	X
Chlorite	X	X	?	-	-	X
Chloritic intergrades	-	X	X	X	X	X
Kaolinite	-	?	?	X	-	-
Mica	X	X	X	X	X	X
Zeolite	?	-	-	-	-	-

S = Present

Sample Locations

PMT-22	Glauconitic mudstone outcrop in roadcut: SW 1/4, NW 1/4, section 25, T. 7 N., R. 10 W.
PMT-29	Mudstone outcrop in roadcut: NW 1/4, NE 1/4, SW 1/4, section 23, T. 7 N., R. 10 W.
PMT-99	Matrix of sandstone in roadcut: NW 1/4, NW 1/4, section 33, T. 7 N., R. 9 W.
PMT-20	Tuff bed in roadcut: NE 1/4, NW 1/4, SW 1/4, section 11, T. 6 N, R. 10 W.
PMT-34	Tuff bed in roadcut: NW 1/4, SW 1/4, section 36, T. 7 N., R. 10 W.
PMT-11	Tuff nodules in ravine: NW 1/4, SW 1/4, section 26, T. 6 N., R. 10 W.

APPENDIX X

Chemical Analyses of Selected Basalt Samples

Sample	PMT-3	PMT-5	PMT-4	PMT-78	SR65-12A*	SR66-128*
SiO_2	53.9	52.2	52.3	57.7	51.5	51.4
Al_2O_3	13.1	11.6	13.4	11.6	15.0	14.0
FeO	12.9	15.9	14.6	14.3	14.4	14.0
MgO	5.3	5.1	3.3	2.4	4.6	4.4
CaO	8.3	8.1	8.4	5.9	7.2	8.3
Na_2O	3.0	2.5	3.1	3.1	2.8	2.8
K_2O	0.95	1.15	0.65	2.05	0.71	1.5
TiO_2	1.80	2.85	3.30	2.80	2.8	2.7
P_2O_5	--	--	--	--	0.66	0.61

*From: Snavely and others, 1973

Sample locations

Depoe Bay Basalts:

PMT-3:	Sill: NE 1/4 NW 1/4, section 26, T. 6 N., R. 9 W.
PMT-5:	Sill at dam: NW 1/4 NW 1/4 NE 1/4, section 30, T. 6 N., R. 10 W.

Cape Foulweather Basalts:

PMT-4:	Pillow basalts: N 1/2 NE 1/4, section 14, T. 6 N., R. 10 W.
PMT-78:	Granophyric dike at top of Lone Ridge: NE 1/4, NE 1/4 NE 1/4, section 29, T. 7 N., R. 9 W.
SR66-12A:	Sill: SW 1/4, section 22, T. 7 N., R. 9 W.
SR 66-12B:	Sill: SW 1/4, section 22, T. 7 N., R. 9 W.

APPENDIX XI

Oil Well Data

Standard Oil Company of California (Socal) Hoaglund Unit #1
Location: SE 1/4, section 11, T. 7 N., R. 10 W.

Scout Ticket Paleontological Markers as of 8/23/55

Top of late Eocene-early Oligocene Kessey	1085' 330.7 m.
Top of middle to late Eocene Cowlitz	1725' 525.8 m.
Top of middle Eocene McIntosh (Tyee)	3650' 1112.5 m.
Top of early to middle Eocene Metchosin Volcanics	7101'2164.4 m.

Note: As of 1961, mapping by Wells and Peck (1961) shows surface rock at wellsite to be Keasey age. It has also been reported that Cowlitz, not McIntosh rock may rest on the volcanics. I prefer to call the volcanic unit part of the Tillamook Volcanics rather than Metchosin Volcanics, which underlie the sedimentary rocks of the Olympic Peninsula of northern Washington.

Descriptions of well cores obtained from Department of Geology and Mineral Industries, State of Oregon (Reported in feet to conform with original data). (Described by author unless noted)

Core 2: 988-1800 ft. - medium greenish gray, interbedded (0.5-1 cm.) silty fine sandstone and claystone; non-calcareous, slight mica.

Core 3: 1083-1100 ft. - greenish gray very finely interlaminated (0.1-1 mm.) claystone and very fine sandstone, slightly lenticular, few green mudstone ripups (0.3 mm.), slight fine mica, non-calcareous: Socal notes 1097 ft. 22.6% porosity and 1 md. permeability.

Core 4: 1297-1307 ft. - grayish green vaguely bedded (0.5-1 cm.) very fine silty sandstone, slightly calcareous, mica up to 0.3 mm.

Core 5: 1512-1522 ft. - grayish green laminated (.1-.3 mm.) very fine sandstone, boundaries marked by clay and carbonaceous partings, slightly micaceous.

Core 6: 1727-1737 ft. - light olive green poorly laminated (parting?) claystone, structureless, well bioturbated.

Core 7: 1971-1981 ft. - olive gray poorly bedded (1-3 cm.) fine silty sandstone, micaceous, green mudstone ripups of amphibole (?), small light olive gray claystone, in part very calcareous.

Core 8: 2188-2198 ft. -light olive gray structureless silty mudstone to claystone, oriented carbonaceous debris, few forams, few green claystone ripups, burrowed (one long burrow = 8 mm. x 70 mm.).

Core 9: 2408-2418 ft. - greenish gray feldspathic very fine dirty sandstone, very micaceous compared to above cores, rare forams, locally slightly calcareous, interlaminated with light olive gray carbonaceous claystone, burrows filled with sandstone similar to above - sharp contacts between sandstone and claystone.

APPENDIX XI (Continued)

Core 10: 2653-2663 ft. - light brownish gray carbonaceous claystone with few carbonaceous stringers and possibly microfaulted, greenish gray muddy siltstone, slightly micaceous, carbonaceous, burrowed filled with claystone as above; both very slightly calcareous, forams in both.

Core 11: 2904-2914 ft. - light olive gray laminated to micro-cross-laminated silty mudstone, slightly carbonaceous and micaceous, very calcareous in some layers, rare forams, well-indurated.

Core 12: 3143-3153 ft. - light olive gray faintly laminated (?) silty mudstone, locally calcareous.

Core 13: 3393-3400 ft. - light olive gray claystone, shattered possibly by drilling (Note: SP on electric log indicates good porosity so fractures may be in situ).

Core 14: 3455-3465 ft. - missing

Core 15: 3652-3662 ft. - olive gray poorly laminated (?) claystone, slightly carbonaceous, rare forams.

Core 16: 3844-3854 ft. - light olive gray fine silty claystone, poorly defined wavy lamination, slightly micro-carbonaceous, some carbonaceous material replaced by very fine pyrite.

Core 17: 4087-4097 ft. - light olive gray structureless stily claystone, slightly micaceous and carbonaceous, some pyrite replacement as in Core 16, fish scales (?), formas (?), shell fragment (?), green mudstone ripups, fissile.

Core 18: 4328-4338 ft. - no recovery.

Core 19: 4338-4349 ft. - brownish gray claystone, slight parting or fissibility, very slight carbonaceous debris and mica, rare pyrite, fish scales. Socal notes thinly bedded, very tuffaceous with fine to medium sand-size grains, several foram-rich layers.

Core 20: 4583-4593 ft. - no recovery.

Core 21: 4790-4795 ft. - sample missing; Socal notes bentonitic texture, interbeds of tuff and tuffaceous graywacke.

Core 22: 5048-5058 ft. - grayish olive basalt (?), very finely crystalline, amygdules with calcite and zeolite, disseminated crystalline pyrite common.

Core 23: 5357-5364 ft. - olive black aphanitic to finely crystalline basalt, amygdules (up to 6 cm.) filled with crystalline calcite.

Core 24: 5388-5398 ft. - core missing.

Core 25: 5464-5471 ft. - medium light gray fine, clean, very micaceous feldspathic sandstone, minor carbonaceous debris, rare pyrite replacement; surrounded by dense aphanitic black basalt (?) or siliceous cement.

APPENDIX XI (Continued)

Core 26: 5772-5781 ft. - olive black fine to medium crystalline basalt, spherules of black glass, calcite filled veins, zeolite, rare well-developed amphibole crystals, biotite, palagonite (?), all in glassy matrix with some elongation of spherules.

Core 27: 6269-6281 ft. - light gray spherulitic basalt, spherules appear to be green silica, pyrite in nodules, calcite in few spherules.

Core 28: 6410-6420 ft. - olive black amydgoidal finely crystalline basalt, amphibole and feldspar crystals, amygdules appear silica filled and partially flow-aligned.

Shell Oil Company Offshore Continental Shelf well PO72 1ET
Location: 46°02"50'N., 124°29"55'W.

General Description and Tops (in feet)

Recent - Pliocene Siltstone with minor silty sandstone	538-2360
lower Pliocene Siltstone and shale (no sandstone)	2360-4880
upper Miocene Siltstone and shale (no sandstone)	4880-5100
middle Miocene Siltstone and shale (no sandstone)	5100-5340
middle- lower Miocene (Hoh) TD: Siltstone with argillaceous sandstone	5340-8219

Significant Results:

Hydrocarbon odor on sidewall cores from Recent to Pliocene strata.

Middle- lower Miocene (Hoh):

Core 5870-6881 ft. - strong fluorescence, slight odor on core; 4 feet of low porosity, low permeability fine to medium grained sandstone.

Core: 7000-7005 ft. - strong fluorescence, slight hydrocarbon odor; 3 3/4 feet of low porosity, low permeability fine to medium grained argillaceous sandstone with possible fracture porosity.

APPENDIX XI (Continued)

Shell Oil Company Offshore Continental Shelf well PO75 1ET
Location: 45°09'08" N., 124°24'30"W.

General Description and Tops (in feet)

Plio-Pleistocene Siltstone, sandy silt, sandstone	477-3270
Pliocene Siltstone, silty sandstone, shale, claystone	3270-7930
Upper Miocene Claystone	7930-8950
Middle-lower Miocene (Hoh) Silty claystone	8950-9410
Oligocene-upper Eocene Siltstone	9410-9765
Eocene (?) TD: Volcanics	9765-10160

Significant Results:

Drilled complete sequence of Recent to Volcanic basement for stratigraphic control.