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AN ABSTRACT OF THE THESIS OF Kevin Blair Kelty for the Master of Science in Geology presented June 12, 1981.

Title: Stratigraphy, Lithofacies, and Environment of Deposition of the Scappoose Formation in Central Columbia County, Oregon.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

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Robert O. Van Atta, Chairman

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Gilbert T. Benson

The study area is located in central Columbia County and encompasses approximately 373 square kilometers. The purpose of the study was to map lithofacies to a scale of 1:31250, study the petrography of the lithofacies, determine the stratigraphy, and develop a model for environment of deposition of the Scappoose Formation.

Sediments of the Scappoose Formation consist of feldspathic sandstones, siltstones, and mudstones. Constituents of Scappoose Formation sediments are quartz, volcanic rock fragments, potassium feldspar and plagioclase feldspar, granite, chert, quartzite, and phyllite clasts. Large amounts of hypersthene, hornblende, and

volcanic and metamorphic rock fragments indicate that Scappoose Formation sediments were derived from a mixed volcanic and metamorphic provenance drained by the ancestral Columbia River.

The lower contact of the Scappoose Formation is a disconformity developed by erosion on the underlying Pittsburg Bluff and Keasey formations. The upper contact is an erosional surface that has been covered with Grande Ronde (low magnesium geochemical type), Columbia River Basalt Group lavas.

The oldest rocks within the Scappoose Formation are considered upper Oligocene in age and are predominantly tuffaceous, arkosic sandstones, siltstones, and mudstones deposited in a shallow marine to brackish water environment. Middle Miocene coarse grained, pebbly, arkosic fluvial sandstones were deposited in channels eroded through the Pittsburg Bluff and into the Keasey formations. Grande Ronde Basalt clasts from the Columbia River Basalt Group form gravel lenses and line channel bottoms. Early flows of Grande Ronde Basalt flowed into valleys in middle Miocene time and contributed palagonite and gravels as fluvial sedimentation and uplift continued.

Intertonguing marine and nonmarine lithofacies, fluvial cross-bedded sands, coal and abundant plant material, and numerous transgressive and regressive sequences reflect a deltaic shoreline dominated by a high energy wave and current marine environment during deposition of the Scappoose Formation. Predominantly marine lithofacies near the base, and shallow water fluvial lithofacies higher in the formation indicate a gradual shallowing environment of deposition. Finer grained structureless brackish water sandstones overlain by coarse grained fluvial sandstones demonstrate a westerly developing deltaic shoreline

receiving sediments from the ancestral Columbia River drainage. A middle Miocene period of uplift and transgression shifted the Columbia River drainage to the northeast while later flows of Columbia River basalt continued to build westward interfingering with the Astoria embayment and infilling the paleotopography.

STRATIGRAPHY, LITHOFACIES, AND ENVIRONMENT OF DEPOSITION OF THE
SCAPPOOSE FORMATION IN CENTRAL COLUMBIA COUNTY,
OREGON

by
KEVIN BLAIR KELTY

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University

1981

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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1. Geologic map of the east half of the Cathlamet
and Birkenfeld and west half of the
Clatskanie and Vernonia quadrangles pocket

INTRODUCTION

LOCATION AND ACCESSIBILITY

Townships 4-7 north, range 4 west include the study area in central and eastern Columbia County northwest Oregon (see Figure 1). The area is part of the Oregon Coast Range physiographic province and encompasses approximately 373 square kilometers in area.

Oregon Highway 47 traverses the area from north to south, and Highway 202 provides access from the west to the hamlet of Mist. The major population center in the area is the town of Vernonia located 27 kilometers north of the junction of Highway 47 with Highway 26. Several paved county roads and numerous unpaved logging roads provide access to exposures of bedrock in the area.

PURPOSE OF STUDY

The major purpose of this study is to examine the stratigraphic and lithofacies relationships of the Scappoose Formation and to present a model for environment of deposition of the Scappoose Formation. The nature of the basal contact with the Pittsburg Formation is examined as well as the upper contact with the Columbia River Basalt Group and a geologic map of the Scappoose Formation is produced. The lithofacies of the Scappoose Formation are also described petrographically.

Figure 1. Location sketch map of study area.

CLIMATE, VEGETATION, AND LAND USE

The climate of the study area is influenced by warm, wet marine air where the rainfall averages 127 centimeters annually. Summer temperatures average 20 degrees celsius, the winter climate is characterized by abundant rainfall.

Vegetation in the study area typically includes luxuriant dense growths of Douglas fir, white fir, hemlock, alder, birch, various species of cedar and maple, salal, choke cherry, numerous species of ferns, and non-edible and edible berries. The pioneer species to grow in new clear cuts and landslide scarps are alder, later supplanted by climax stands of Douglas fir, hemlock, and rare western red cedar.

Logging constitutes the major economic land use, and employment in the area. Numerous clear cuts provide excellent access to bedrock. Crown Zellerbach, Weyerhaeuser, and Longview Fiber are the larger companies and are contributors to an elaborate secondary logging road system. Private companies commonly consisting of from one to five partners, form smaller logging companies and are referred to locally as "gyppo" loggers.

GEOMORPHOLOGY

The study area is characterized by gentle topography to the west and generally more rugged topography to the east with a maximum relief of 300 meters. The highest elevation of 550 meters above sea level is in the Clatskanie Heights area where resistant flows of Columbia River basalt form prominent highlands. Many of the small and intermediate size streams form dendritic drainage patterns, although some trellis

type drainage generally occurs where stream direction is controlled by resistant beds. The largest river in the area is the Nehalem River, which flows from south to north. Warren and Norbistrath (1945) considered the geomorphology of the study area to be a result of rejuvenation from uplift due to the occurrence of accordant ridges in the east portion of the area. This conclusion is supported by Van Atta (1971) who noted the incision of the Nehalem River 2 to 3 meters into a broad meandering flood plain in the upper Nehalem River basin. Landslide topography predominates in areas of weakly consolidated mudstones, sandstones, and on the steep slopes below the contact between Columbia River basalt and the softer underlying sedimentary beds. Many landslide areas are dotted with sag ponds. Scout Lake, in the northeast corner of the study area, is just such a sag pond formed behind a large slide block of Columbia River basalt sliding over Scappoose Formation sandstones. Landslide topography is readily identifiable on high altitude aerial photographs.

PREVIOUS WORK

The Scappoose Formation was named by Warren and Norbistrath (1946) for a sequence of fossiliferous, tuffaceous sandstones and mudstones overlain by Columbia River basalt southeast of Scappoose, Oregon in Columbia County. Warren and Norbistrath also identified a megafauna which they regarded as distinctly different from that of the underlying Pittsburg Bluff Formation. They characterized the age of the Scappoose Formation as late Oligocene. Warren and Norbistrath also noted a similarity in lithology between the Scappoose and Pittsburg Bluff formations

but still considered the formations separable because of the difference in fossils. A basal pebble-boulder conglomerate was also identified within the Scappoose Formation that disconformably overlies the Pittsburgh Bluff Formation northwest of Buxton, where they estimated the thickness of the Scappoose Formation to be 457 meters. Detailed petrography by Van Atta (1971) delineated the mineralogical differences of the sandstones of the Scappoose Formation from the Pittsburgh Bluff Formation as well as the light and heavy mineral compositions of the mudstone and siltstone lithofacies. Van Atta substantiated Warren and Norbistrath's conclusions that the Scappoose Formation is a recognizable mappable formational unit.

Clark and Arnold (1923) correlated the beds near Scappoose, prior to Warren and Norbistrath's work, with the Sooke Formation of Vancouver Island, B.C. Snavely (1964) considered the Scappoose Formation equivalent to the Nye Mudstone and Yaquina Formation of central coastal Oregon, and the Blakely Formation in southwest Washington (Figure 2). Cressey (1973) suggested that the Oswald West Mudstone of the Astoria Formation represents a prodelta deep water sequence of a Scappoose delta identified by Van Atta.

FIELD WORK

Field work began in June of 1980 and continued until January of 1981. June to August 1980 was spent jointly mapping the study area and the western half of Columbia County with Moin Kadri, Betty Ordway, and Dale Timmons, under the auspices of a project financed by Diamond Shamrock Corporation, Northwest Natural Gas Company, and Reichold

SERIES	Foraminiferal Stages	Southwestern Washington (Kleinpell & Weaver, 1963)	Central Coast Range (Snively et. al., 1969, 1973)	Upper Nehalem River Basin (Warren and Norbistrath, 1946)	Upper Nehalem River Basin (Van Atta, 1971)	Upper Nehalem River Basin (This Report)
MIOCENE	Relizian	Astoria Formation	Astoria Formation	Columbia River Basalt	Columbia River Basalt	Columbia River Basalt
	Saucesian		Nye Mudstone	(?)		Middle Miocene Reds(?)
	Zemorrian	Blakely(?) Formation	Yaquina Formation	Beds of Blakely Age	Scappoose Formation	Scappoose Formation
NEHALEM GROUP						
OLIGOCENE			Siltstone of Alsea	Pittsburg Bluff Formation	Pittsburg Bluff Formation	Pittsburg Bluff Formation
	Refugian	Lincoln Formation		?	Keasey Formation	Keasey Formation
		Keasey Formation	Keasey Formation	Keasey Formation	Keasey Formation	Keasey Formation
Eocene	Narizian		Volcanic Rocks	?	?	?
		Cowlitz Formation	Nestucca Formation	Cowlitz Formation	Cowlitz Formation	Goble Volcanics Cowlitz Formation

Figure 2. Correlation chart of Tertiary formations northwestern Oregon, southwestern Washington Coast Range.

Chemical Corporation. During this period the Cowlitz, Keasey, and Pittsburg Bluff formations and the Columbia River Basalt Group were mapped to a scale of 1:31,250 on the Cathlamet, Birkenfeld, Clatskanie, and Vernonia quadrangles. In addition, all measured structural attitudes and trends were plotted. At the end of this joint mapping phase of the project detailed study of the Scappoose Formation began. Six detailed stratigraphic sections were measured using a clinometer, jacobs staff, and steel tape. All lithofacies, especially sandstones, were sampled for later petrographic analysis. All preserved fossils were collected for possible age determination to be included in the sampling program. Sedimentary primary structures were noted and described as indicators of environment of deposition. Such indicators included paleocurrent directions, style and type of bedding and stratification, geometry and extent of lithofacies, and spatial correlation of lithofacies. Basalt clasts were chosen at random from gravels within the Scappoose Formation for geochemical analysis.

LABORATORY WORK

A total of 25 samples were selected as possibly containing microfossils and were disaggregated, sieved, and the concentrate examined under a microscope. From the seven measured sections 11 representative samples were selected for grain mount feldspar staining. Grain mount techniques were determined as the best method to study the generally very friable Scappoose Formation sandstones. Another 29 samples were thin sections for petrographic study. In order to determine chemical composition and possible provenance, five basalt conglomerate clasts,

and five Columbia River basalt flows were sampled. The basalt samples were chipped and sent to Dr. Peter Hooper at Washington State University for whole rock major oxide analysis. In addition, the 10 basalt samples were also chipped and powdered, and one gram of the powder from each sample was placed in a polyethylene vial for Instrumental Neutron Activation Analysis. The vials were irradiated at the Reed College research reactor and then analyzed at Portland State University using the Tracor Northern multi-channel analyzer system. Data reduction was accomplished with the Honeywell 66/20 computer.

GEOLOGICAL SETTING

The Oregon Coast Range province contains over 7,600 meters of Tertiary marine and volcanic strata ranging in age from early Eocene to Pliocene (Snively and Wagner, 1964). Earliest Eocene rocks were deposited in a eugeosyncline located in the region of present day western Oregon and Washington State. Submarine volcanism concurrent with sedimentation in Eocene time formed basalt flows and breccias of the Siletz River and Tillamook Volcanics to the south and Goble Volcanics in the north. Other Tertiary units in the study area include the Cowlitz, Keasey, Pittsburg Bluff, Scappoose, and Astoria formations composed predominantly of feldspathic lithic sandstones and siltstones. The Astoria Formation is restricted to the west in a middle Miocene marine embayment (Figure 3). The Scappoose and Astoria formations are overlain by Columbia River Basalt Group flows. The Scappoose Formation was extensively eroded prior to the extrusion of the first basalt flows while to the west later basaltic lavas interfingered with upper Astoria Formation sandstones.

The northern Oregon Coast Range is part of a large anticlinorium (Snively, 1964). This large anticline has resulted in very gentle dips to the northeast and southwest. Faulting increases from south to north where the northwest trending Portland Hills structural trend intersects the northeast corner of the area. Structural deformation of the Oregon Coast Range is thought to have begun as early as Eocene time as a result of clockwise rotation. This rotation possibly

Figure 3. Paleogeologic map of western Oregon and Washington during early Eocene time, from Snively, 1963.

reached as much as 50-70 degrees by upper Eocene (Simpson and Cox, 1977).

STRATIGRAPHY AND PETROGRAPHY

INTRODUCTION

The Scappoose Formation is composed of arkosic sandstones, siltstones, and mudstones that contain a great deal of volcanic glass and carbonaceous material, especially in the finer grained lithofacies (see Figures 4-9).

LITHOFACIES AND THEIR RELATIONSHIPS

The most readily recognizable lithofacies within the Scappoose Formation is medium to coarse grained, moderately sorted, trough cross-bedded, lithic arkosic sandstone that crops out both near the base and at the top of the Scappoose Formation along the banks of the East Fork of the Nehalem River southeast of Pittsburg. In hand sample, generally all of the Scappoose Formation sandstone lithofacies are more abundant in lithic fragments and quartz than the underlying Pittsburg Bluff Formation.

In the mapped area between Lava Creek and the East Fork of the Nehalem River the middle portion of the Scappoose Formation is typically finer grained and very tuffaceous. The predominant lithofacies is a light gray, fossiliferous, tuffaceous siltstone. This siltstone is well exposed along the East Fork of the Nehalem River and in the Oak Ranch Creek area northeast of the Apiary-Highway 47 junction. In the Apiary-Highway 47 area the siltstone coarsens upward and

Unit	Column In Meters	Lithology
Columbia River Basalt Group	190	Dense, aphyric basalt. Well developed jointing. Low magnesium Grande Ronde Geochemical type.
	180	Disconformity
	180	Yellowish gray, fine grained, well sorted, micaceous, tuffaceous arkosic sandstone. Minor mudstone pebbles and tuffaceous siltstone lenses.
	170	Very pale orange, fine grained, micaceous, tuffaceous, slightly carbonaceous, siltstone. Dark yellowish orange tuffaceous streaks and patches.
	160	Cover
	150	
	140	Light brown, tuffaceous mudstone interbedded with white fine grained siltstone.
	130	
	120	Cover
	110	Grayish orange, micaceous, tuffaceous, sandy-pebbly mudstone. Minor angular-subangular quartz, rock fragments
	100	
	90	Grayish yellow, laminated, fine grained, well sorted, lithic, tuffaceous arkosic sandstone with interbedded white tuffaceous, micaceous mudstone. Yellowish orange streaks perpendicular to lamination.
	80	
	70	
	60	Rounded-subrounded, poorly sorted, matrix support, pebble, basalt, mudstone, granite, quartzite conglomerate with yellowish orange, medium-coarse grained, moderately sorted, lithic, quartzose, arkosic matrix. Larger size clasts at bottom.
	50	
	40	Yellowish gray, fine grained, well sorted, tuffaceous, micaceous, lithic arkosic sandstone.
	30	
	20	Cover
	10	
Pittsburg Bluff Formation	0	Very pale orange, tuffaceous, fine grained siltstone. Dark yellowish orange tuffaceous streaks and patches.

Figure 4. Measured Section I at Cedar Creek.

Figure 5. Measured Section II at Oak Ranch Creek.

Unit	Column In Meters	Lithology
Scappoose Formation	120	Yellowish gray, fine grained, well sorted, micaceous, carbonaceous, tuffaceous, arkosic sandstone. Minor discontinuous dark gray mudstone layers rich with carbonized plant fragments. Gradually coarsening to medium grained sandstone with pebbly layers associated with 1 meter diameter petrified log.
	110	
	100	Medium light gray, fine- medium grained, well sorted, micaceous, tuffaceous, siltstone. Minor fine grained, well sorted, micaceous sandy interbeds, thin tuffaceous layers. Abundant plant fragments on parting planes. Concretionary near base.
	90	
	80	Sub rounded-angular, siltstone, quartzite, basalt, mudstone, pebble-cobble, matrix support, poorly sorted, conglomerate. Coal, sandstone, petrified wood clasts rare. Clast size decreasing upward.
	70	
	60	Medium light gray, fine grained, well sorted, micaceous, tuffaceous siltstone. Bioturbated, weathered yellow orange pumice and tuffaceous patches.
	50	
	Cover	
	40	
	30	
	20	Medium light gray, fine grained, well sorted, micaceous, fossiliferous, tuffaceous siltstone. Bioturbated, rare fossil impressions (Solon). Weathered yellowish orange pumice and tuffaceous patches.
	10	
	0	

Figure 6a. Measured Section III at East Fork of the Nehalem River.

Unit	Column In Meters	Lithology
Scappoose Formation	240	Medium light gray, fine grained, well sorted, tuffaceous siltstone. Slightly carbonaceous.
	230	Light gray, tuffaceous, sandy siltstone. Scattered fossil impressions.
	220	Yellowish gray, moderately sorted, medium grained, lithic, arkosic sandstone. Interbedded with coal lense.
	210	Yellowish gray, medium-coarse grained, rounded-sub rounded, moderately sorted, micaceous, lithic, quartzose, pebbly sandstone. Alternating lamination and cross bedding. Paleocurrent direction N70W.
	200	
	190	
	180	Medium light gray, fine grained, well sorted, tuffaceous siltstone. Minor thin micaceous, lithic, arkosic sandstone lense. Scattered fossil impressions
	170	
	160	Yellowish gray, fine grained, well sorted, micaceous, carbonaceous, tuffaceous arkosic sandstone. Minor dark gray mudstone layers rich in plant fragments, and aligned fossil impressions. Coarsening upward with many burrows.
	150	
	140	
	130	

Figure 6b. Measured Section III at East Fork of the Nehalem River.

Figure 7. Measured Section IV at East Fork of the Nehalem River.

Figure 8. Measured Section V along Highway 67 northwest corner of study area.

Unit	Column In Meters	Lithology
Scappoose Formation	75	Yellowish gray, slightly carbonaceous, tuffaceous mudstone. Patches of dark yellowish orange weathered tuff.
	70	
	65	
	60	Light yellow brown, coarse grained, moderately sorted pumice, lithic, quartzose sandstone.
	55	Yellowish gray, fossiliferous, carbonaceous, tuffaceous, mudstone. Numerous burrows, minor laminated sandstone interbeds and fossil impressions.
	50	Medium gray, well rounded, coarse grained, pumiceous arkosic sandstone. Several concretionary layers.
	45	Greenish gray, fossiliferous, tuffaceous, muddy siltstone. Bioturbated, slightly carbonaceous.
	40	Moderate brown, well rounded, well sorted, coarse grained, calcareous, lithic, quartzose, arkosic sandstone.
	35	Light brown-moderate brown, tuffaceous, pebbly arkosic sandstone. Scattered pumice, well rounded basalt, and quartz pebbles. Large burrows, carbonized wood.
	30	Light yellow brown, fine grained, well sorted, micaceous, tuffaceous, lithic, quartzose arkosic sandstone. Rare fossil impressions and bioturbated mudstone lenses, slightly laminated with sporadic yellowish mottling.
	25	
	20	
	15	Yellowish gray, claystone. Minor burrows and slump structures. Chippy outcrop appearance.
	10	Yellowish gray, fine grained, well sorted, laminated, tuffaceous, micaceous, fossiliferous, arkosic sandstone. Numerous fossil pelecypod impressions (Mytilus, Panope, Solon, Macoma) aligned along bedding planes with much mica. Weathered dark yellow orange tuffaceous streaks.
	5	
	0	

Figure 9. Measured Section VI at Tolke Canyon.

intertongues with a coarse grained, trough cross-bedded, lithic arkose, very similar to the lithofacies observed near the base.

Associated with the basal cross-bedded sands are moderate to poorly sorted, pebble to boulder, framework-supported conglomerates occurring as lenticular shaped layers. These conglomerates are composed of mudstone, basalt, minor granite, metaquartzite, and phyllite clasts. A second distinctive conglomerate occurs locally below the Columbia River basalts and is composed entirely of rounded, well sorted, basalt clasts. Some of these clasts are very vesicular and are highly weathered. The clasts are supported in a matrix of fine grained arkosic sand. The contact between the gravels and the underlying beds is very gradual and discontinuous.

Mudstones occur as minor interbeds within sandstones and laterally adjacent to channel sandstones in overbank lithofacies. An exception to this is Tolke Canyon near Buxton where a carbonaceous yellowish gray mudstone intertongues upward with a fine grained silty arkose. Warren and Norbistrath used the terms "shale and shaley sandstone" for descriptions of Scappoose Formation units. Some fine grained laminated sands and mudstones do have a tendency to preferentially split along bedding planes rich with carbonaceous material but these units are less common than implied by Warren and Norbistrath. Sandstones make up between 25 and 95 percent of the stratigraphic sections.

Carbonized plant fragments are a ubiquitous part of all finer grained lithofacies ranging from thin lenses and leaf impressions to coaly seams and bedded lignite layers.

Cross-bedded, coarse grained sandstones are contained within

channel systems lined with lag gravel conglomerates and lenses, locally these sandstones are very pebbly. Mudstone ripups, rare petrified wood, terrestrial plant material, and large current-undermined slump blocks (Figures 10, 11) occur with this fluvial channel system in complex lateral and vertical relationships. Reading and others (1978) note such relationships as typical of an active fluvial floodplain drainage system. Channel lithofacies change abruptly laterally into overbank lithofacies of mudstones and fine grained sandstones rich with mica and delicate plant fragments. Overbank facies are interpreted by Walker (1979) as representing episodic flooding followed by quiet sedimentation. All of the channel sequences have a sharp upper erosional contact with fine grained, marine sandstones and siltstones (Figures 12, 13).

Marine sandstones are fine grained, thickly bedded, tuffaceous, well sorted units containing scattered concretions of shell material (Figure 14). Typically the marine lithofacies gradually decrease in grain size upward and intertongue with tuffaceous siltstones reflecting a gradual shallowing from marine lithofacies near the base into fluvial lithofacies higher in the formation. Between the coarse grained channel sandstones and the brackish water marine siltstone a transitional yellowish gray fine grained, micaceous, arkosic sandstone is common. This sandstone unit is more friable than the typical marine sands and contains broken disarticulated gastropod and pelcypod shells. Concentrations of broken shells in this sandstone represent mechanically reworked "death assemblages." Moore (1976) interprets such assemblages as the result of periodic storm cycles. Starfish

Figure 10. Mudstone ripups in cross-bedded channel sandstones near Camp 8, East Fork of the Nehalem River. Located southeast quarter section 36, township 5 north, range 4 west.

Figure 11. Large mudstone slump block in cross-bedded channel sandstone. Mudstone block contains coal lenses. Located northeast quarter section 1, township 5 north, range 4 west.

Figure 12. Idealized block diagram illustrating lateral facies changes in fluvial channel system, East Fork of the Nehalem River.

Figure 13. Contact between cross-bedded channel sandstone and marine siltstone with thin lignite coal lense between. Located on Columbia Forest Road northwest quarter section 15, township 4 north, range 2 west.

Figure 14. Fossiliferous concretions in fine grained glauconitic marine sandstone near Camp 8, East Fork of the Nehalem River. Located southeast quarter section 36, township 5 north, range 4 west.

Brisaster? occur locally with terrestrial plant fragments in similar situations aligned along bedding planes that are enhanced by the plant material.

Sandstone Petrography

Petrographic examination of 11 representative sandstone lithofacies shows that Scappoose Formation sands contain significant amounts of quartz, potassium feldspars, and both volcanic and granitic rock fragments. For the purpose of comparison, Scappoose Formation grain percentages were plotted on ternary quartz-feldspar-rock fragment and rock fragment-potassium feldspar-plagioclase feldspar diagrams. Using data from Van Atta (1971) for the Scappoose and Pittsburg Bluff formations and data from Cressy (1973), Neel (1975), and Penoyer (1976) for the Astoria Formation, the results were combined on the two diagrams (Figures 15, 16). The amount of overlap among the three formation grain composition percentages does not allow a precise definition of the fields occupied by each formation. In a general manner it can be seen that Scappoose Formation sands contain more total feldspar than the Astoria and Pittsburg Bluff formations. The amount of quartz and potassium feldspar is also greater in the Scappoose Formation sands than the Pittsburg Bluff Formation. This is also substantiated in part by Van Atta (1971, pp. 72-77). The Astoria Formation sands are richer in rock fragments and approximately equal in quartz composition compared to the Scappoose Formation. The compositional variations among the three formations allows at least a broad manner of separating the Scappoose Formation sandstones from the older Pittsburg Bluff and younger Astoria formations.

- Scappoose Formation
 This report ●
 Van Atta (1971) △
 Pittsburg Bluff Formation
 Van Atta (1971) ▲
 Astoria Formation
 Cressy (1973) ○
 Neel (1975) □
 Penoyer (1976) ■

Figure 15. Grain composition of Pittsburg Bluff, Scappoose, and Astoria Formation sandstones plotted on a ternary quartz-feldspar-rock fragment diagram.

Figure 16. Grain composition of Pittsburg Bluff, Scappoose, and Astoria Formation sandstones plotted on a ternary feldspar, rock fragment diagram.

Average mineralogic composition of Scappoose Formation sandstones are summarized in Table I. Quartz content of Scappoose Formation sandstones ranges between 6 to 25 percent with monocrystalline exceeding polycrystalline quartz (Appendix 1). Potassium feldspar is present in all sampled sandstones and in 45 percent of the samples potassium feldspar exceeds plagioclase feldspar. Plagioclase compositions are between oligoclase and andesine while andesine is generally more abundant.

Volcanic rock fragments are the only rock fragments present in significant amounts in the finer grained sandstones while microgranitic rock fragments make up between 13 and 15 percent of the coarser grained sandstone lithofacies (Table II). The discrepancy between greater abundance of microgranitic in the coarser sandstones than the finer grained sandstones is a result of the sediment size distribution. The finer grained sands contain the disaggregated grains from larger granitic rock fragments that are common in the coarser grained lithofacies. Microgranitic rock fragments are allotriomorphic, porphyritic, composed of orthoclase, microcline, quartz, and minor interstitial biotite. Larger cobbles of granite are found with cross-bedded channel sands and appear slightly metamorphosed. Volcanic rock fragments are rounded grains composed of plagioclase microlites intersertal opaque magnetite, ilmenite, and augite ranging from pilotaxitic to subophitic textures. Foliated metamorphic rock fragments and meta-quartzites are rare and are found as scattered grains although occasional angular cobbles of phyllite are found in the outcrop of the coarser grained sandstones.

TABLE I
AVERAGE MINERALOGIC COMPOSITION OF
SCAPPOOSE FORMATION SANDSTONES
BASED ON 11 SAMPLES

	Percent
Quartz	13
Plagioclase	28.5
K-Feldspar	29
VRF	24
GRF	tr.
SRF	3
Hypersthene	1.5
Biotite	tr.
Hornblende	tr.
Glass	tr.

VRF = volcanic rock fragments

GRF = granitic rock fragments

SRF = sedimentary rock fragments

tr. = less than 0.5%

TABLE II
PERCENTAGE OF ROCK FRAGMENT TYPES
IN COARSE GRAINED SCAPPOOSE
FORMATION SANDSTONES

Sample	Volcanic	Granitic	Sedimentary
82780st2-2	81	13	6
91680-1	85.5	14.5	-
102380-3	86.5	13.5	-
102380	85	15	-

Glauconite pellets are restricted to fine grained fossiliferous marine sandstones and are locally very abundant. Chert fragments are rare and are associated with coarse grained fluvial sands. A lense of diatomaceous coarse grained fluvial sand occurs below a mudstone bed in the Oak Ranch Creek area suggesting a temporary ponding of stagnant water. Palagonite is locally abundant in cross-bedded, coarse grained, pebbly channel sandstones in the Oak Ranch Creek area and also below Columbia River basalt flows in the Clatskanie Heights area north-east of Mist (Figure 17).

Heavy Minerals

Hypersthene and both blue-green, olive brown, and oxyhornblende are the most abundant heavy minerals found in siltstone, mudstone, claystone, and some of the sandstone lithofacies (Appendix 2). Blue-green, green, and olive brown hornblende range from 1.5 percent to trace amounts (Trace = less than 0.5 percent). Blue-green hornblende is interpreted by Deer and others (1963, p. 307) as a metamorphic mineral suggesting derivation from a metamorphic source. Hypersthene makes up between 50 and 85 percent of the heavy minerals in claystone, siltstone, and mudstone lithofacies. Hypersthene is common in intermediate volcanic rocks and further implies that Scappoose Formation sediments were in part derived from a volcanic source since andesite volcanic rock fragments are also common in the sandstone lithofacies. A one meter thick claystone bed in the Tolke Canyon area (Figure 8) contains a heavy mineral assemblage composed entirely of hypersthene and minor augite. The abundance of hypersthene suggests that

Figure 17. Cross-bedded, coarse grained, pebbly sandstone streaked with palagonite.

originally the claystone was volcanic ash that was diagenetically altered leaving the heavy mineral assemblage unaffected.

CONTACT RELATIONSHIPS

Basal Contact

The Scappoose Formation is separated from the underlying Pittsburg Bluff Formation by a disconformity. This contact is highly variable and characterized by pebbly mudstones, pebble-boulder conglomerates (Figure 18), and fluvial channel systems that rest on an irregular surface cut into the Pittsburg Bluff and Keasey formations. In the Oak Ranch and Cedar Creek areas northeast of Pittsburg a well-developed channel system of coarse grained, pebbly, fluvial sandstones has been cut deeply into the Pittsburg Bluff Formation.

Erosion and Deposition. On the west side of the Nehalem River in the northwest quarter of section 3, township 5 north, range 4 west there are isolated remnant patches of cross-bedded, coarse grained, pebbly Scappoose Formation sandstones resting in old channels eroded into the Pittsburg Bluff Formation. These remnant sands were once part of the extensive channel system observed on the east side of the Nehalem River prior to later stages of erosion. Paleocurrent directions from these sands on both sides of the Nehalem River indicate a southwest current direction. Some fluvial channeling within the upper Keasey Formation is easily mistaken for Scappoose Formation channeling where downcutting of the Scappoose Formation channels has eroded through the Pittsburg Bluff Formation and into the upper Keasey Formation. Another remnant channel sandstone is overlain by highly

Figure 18. Contact between lighter colored Pittsburg Bluff Formation siltstones below, and pebble-boulder, Scappoose Formation basalt conglomerate above.

weathered Columbia River basalt in the northwest quarter of section 7, township 5 north, range 4 west. The Pittsburg Bluff Formation in this area is approximately 30 meters thick and farther west and north thins out where trough cross-bedded, fine to medium-grained arkosic sands with scattered mudstone ripups cut into gray Keasey mudstones. These sands are distinctly finer grained than characteristically coarse grained quartzose sandstones of the Scappoose Formation that rest disconformably on gray Keasey Formation mudstones south of Mist. These finer grained, cross-bedded, arkosic sands are considered part of the upper member of the Keasey Formation for the following reasons. Van Atta (1971, p. 157) has demonstrated that the upper parts of the Keasey Formation locally contain abundant volcanic material, especially glass and rock fragments. Petrographically these fine grained, cross-bedded sands are composed entirely of volcanic rock fragments and likely represent a single episodic volcanic flood. Since volcanic rock fragments are common, and sorting and grain size are so different from typical Scappoose Formation fluvial sands, assigning these sands to the Keasey Formation is justified. Since the Pittsburg Bluff Formation is very thin in this area and downcutting and erosion can be demonstrated, it would be very easy to confuse the stratigraphic position of the fine grained, volcanic sands. Channeling is also common in the lower Pittsburg Bluff Formation southeast of Vernonia in Coal Creek so it might be possible that channeling has also occurred much closer to the base of the Pittsburg Bluff Formation than previously believed and the sands could be part of the lower Pittsburg Bluff Formation. This seems unlikely since the lower Pittsburg Bluff

Formation in the area is characterized by laminated dark gray black mudstones and fine grained arkosic sandstones in thinly bedded repeating sequences. It is apparent, then, that a cycle of erosion and downcutting during deposition of the Scappoose Formation has been partially superimposed on the upper Keasey Formation.

The Scappoose Formation demonstrably overlies the Keasey Formation south of Mist where a coarse grained sandstone containing mudstone pebbles overlies Keasey Formation mudstones. The nature of this basal contact is similar northwest of Mist where the same unit lies on top of the Pittsburg Bluff Formation.

Upper Contact

The Scappoose Formation is overlain disconformably by flows of Grande Ronde Basalt (low magnesium geochemical type). Associated with flows are sands and conglomerates which underly and are interbedded within the basalt. Erosion has removed varying amounts of the upper part of the Scappoose Formation with total removal in places south of Clatskanie. On Oregon Highway 47 just south of Clatskanie an angular unconformity separates Scappoose Formation sands from the overlying basalt. Locally the base of the basaltic lavas is highly weathered, brecciated, and the contact is partly subaerial to subaqueous in nature. Rounded, arkosic matrix-supported basalt gravels are localized below the lavas (Figure 19). Baldwin (1981) interprets these localized gravels as representing a slight folding of the sediments with development of topographic highs that shed gravels onto the pre Columbia River basalt surface. In the southwest corner of section 15, township 6 north, range 4 west, the Scappoose Formation is absent and the

Figure 19. Basalt conglomerate below Columbia River basalt near Oak Ranch Creek. Located northeast quarter section 1, township 5 north, range 4 west.

Columbia River basalts lie disconformably on the Pittsburg Bluff Formation. A sequence of three Grande Ronde Basalt flows are interbedded with yellowish orange, fine grained sandstone in two small quarries in the Clatskanie Heights area.

Channel systems are observable at the base and near the top of the Scappoose Formation with a siltstone member (informal) between. The basal channel system is traceable using the Pittsburg Bluff contact as a reference datum plane (Figure 20). The upper channel system is not readily traced laterally due to landsliding and heavy vegetation. The middle siltstone member of the Scappoose Formation demarcates the two channel regimes, and since it is observable immediately below the Columbia River basalts in the Cedar Creek and Oak Ranch Creek areas, the implications are that erosion has removed much of the Scappoose Formation in this area, including the channel system seen higher in the stratigraphic section along the East Fork of the Nehalem River. This premise is supported in part by the presence of rounded basalt gravels below the Columbia River basalt flows in the Oak Ranch and Cedar Creek areas, which suggests the area was a topographic low accumulating gravels from erosion of adjacent topographic highs.

The thickest measurable section of Scappoose Formation strata is approximately 240 meters measured along the East Fork of the Nehalem River (Figure 6). A supplemental section measured 0.5 kilometers east of the top of the East Fork of the Nehalem River can be correlated by a thin coal seam at the top of the section (Figure 21). The lateral variability of the channel lithofacies is well demonstrated in these two sections and also shows a facies change into a brackish

Figure 20. Correlation between Oak Ranch and Cedar Creek measured sections, base of Scappoose Formation northeast of Pittsburg.

Figure 21. Correlation of upper Scappoose Formation along East Fork of the Nehalem River.

water marine lithofacies of fossiliferous siltstones. By contrast, the upper Scappoose Formation is much sandier to the north, in the Clatskanie Heights area, where fine to medium grained sands are prominent below the Columbia River basalts. Some of these sands are structureless and massive and locally streaked with palagonite and have distinct bimodal ripple cross laminations suggestive of marine shoreface wave and tidal environment.

An estimate of the amount of Scappoose Formation strata present before erosion is made difficult by the amount of cover and lateral variability of lithofacies, especially of the subaerial channel facies. A second active channel cycle is also recognized near the top of the Scappoose Formation along the East Fork of the Nehalem River, however, though the lateral extent of this lithofacies cannot be discerned due to the paucity of outcrops. Both episodes of channeling could also represent the same channel system that has migrated laterally and vertically with time. The basal channeling is restricted to the area east and northeast of Pittsburg while north of Mist the base of the Scappoose Formation was deposited in a brackish water to marine environment similar to the environment of deposition of the upper Pittsburg Bluff Formation.

Basalt Geochemistry. Grande Ronde Basalt (low magnesium geochemical type) clasts are found within the Scappoose Formation that are chemically similar to flows interbedded with and on top of the Scappoose Formation. Five basalt clasts sampled from Scappoose Formation conglomerates and five basalt flows on top of the Scappoose Formation were analyzed for both major oxide and trace element composition. Four

basalt clasts were taken from the pebble-boulder basalt conglomerate resting on the Pittsburg Bluff Formation north of Buxton (Figure 20) and one clast was taken from a channel conglomerate lense in the Oak Ranch Creek area (Figure 22). The results of the analysis are listed in appendices 3 and 5. The chemistry of these 10 samples was compared with analysis of Tillamook and Goble Volcanics, and the Grande Ronde Basalt (low magnesium geochemical type) of the Columbia River Basalt Group flows.

Plotting the alkalis ($\text{Na}_2\text{O} + \text{H}_2\text{O}$) against TiO_2 and P_2O_5 using the methods described by Wright and others (1973), the three lava types are seen to have distinct chemical differences. The Tillamook Volcanics (Cameron, 1980) have a lower P_2O_5 content while the Goble Volcanics plot higher. The 10 samples plot in a very narrow range of TiO_2 and $\text{Na}_2\text{O} + \text{K}_2\text{O}$ and low P_2O_5 that typifies the Grande Ronde Basalt (low magnesium geochemical type) (Figures 23, 24).

Trace element concentrations of the 10 samples (Appendix 5) were chondrite normalized using the values established by Masuda and others (1973). The values for the elements Lanthanum, Cerium, Samarium, and Europium were plotted on semilogarithm paper for each of the 10 samples and compared against averaged chondrite concentrations of the same elements for the Tillamook and Goble Volcanics, and the (low magnesium) Grande Ronde Basalt of the Columbia River Basalt Group. Figure 25 illustrates the comparison of the five unknown basalt clasts with averaged normalized compositions from the Tillamook and Goble Volcanics, and Grande Ronde flows on top of the Scappoose Formation. The five unknown clasts compare favorably with the averaged

Figure 22. Pebble-boulder, conglomerate lense containing Columbia River basalt clasts. Current direction from right to left. Same outcrop shown in Figure 19. Located northeast quarter section 1, township 5 north, range 4 west.

Figure 23. Comparison of P_2O_5 versus $Na_2O + K_2O$ for the Goble and Tillamook Volcanics, Columbia River basalt flows on top of the Scappoose Formation and conglomerate clasts within the Scappoose Formation.

Figure 24. Comparison of P_2O_5 versus TiO_2 for the Goble and Tillamook Volcanics, Columbia River basalt flows on top of the Scappoose Formation and conglomerate clasts within the Scappoose Formation.

Figure 25. Averaged concentrations of Lanthanum, Cerium, Samarium, and Europium from Columbia River Basalt flows, the Goble and Tillamook Volcanics compared with the concentrations of five Scappoose Formation basalt clasts.

concentration of the Grande Ronde lavas although the Samarium concentrations exhibit a larger spread. An overlap in the Tillamook Volcanics Samarium and Europium values is also evident. In order to eliminate any experimental error in the analysis the five basalt clasts and the Grande Ronde flows on top of the Scappoose Formation were averaged using the methods described by Anderson (1978) and Beeson and others (1975). When these concentrations are plotted (Figure 26) the five clasts agree very well with the concentrations of the Grande Ronde Basalt flows on top of the Scappoose Formation and with the values given by Anderson and Beeson (Appendix 6). The Samarium concentrations in Figure 26 are also somewhat different, but it can be seen that the five basalt clasts from the Scappoose Formation are virtually identical to the low magnesium Grande Ronde Basalt flows that are interbedded with the upper Scappoose Formation.

Figure 26. Averaged concentrations of Lanthanum, Cerium, Samarium, and Europium from five Scappoose Formation basalt clasts compared with averaged concentrations from the Goble and Tillamook Volcanics and Columbia River basalt flows.

AGE AND CORRELATION

Based on marine megafossils Warren and Norbistrath placed the age of the Scappoose Formation as late Oligocene corresponding to the west coast Zemorrian Foraminiferal Stage. A total of 25 samples were examined for microfossils, but of these samples only one contained foraminifera and these were so poorly preserved and scarce as to be non-diagnostic. The lack of well preserved microfossils is due partly to weathering which locally extends as much as five meters into outcrops. The friable character of many lithofacies together with vigorous weathering leaves all larger fossils as delicate limonite stained calcite impressions. Microfossils could also be lacking in the Scappoose Formation due to the high energy shallow water environment of deposition of the Scappoose Formation, which would present an unfavorable environment for preservation or living situation for most foraminifera (R. E. Thoms, oral communication, 1981). For these reasons foraminifera could not be used for dating the Scappoose Formation.

Columbia River basalt clasts found within Scappoose Formation fluvial channels strongly imply an age correlative with the first Grande Ronde Basalt flows which occurred 15-16 million years ago, or in middle Miocene time. Locally, the uppermost sediments which have been included in the Scappoose Formation are interbedded within Grande Ronde Basalt flows. These uppermost sediments are actually related to erosion of valleys into which intracanyon Grande Ronde Basalts

flowed. Grande Ronde Basalt clasts are found in the conglomerate near Buxton identified by Warren and Norbistrath as the base of the Scappoose Formation. The type locality of the Scappoose Formation along Scappoose Creek (Bonnie Falls) and Dutch Canyon Road is composed of fine grained concretionary marine strata. Fluvial channeling and coarser grained sandstones typical of strata in the study area are not found at the type locality. The units described and dated by Warren and Norbistrath at the type locality of the Scappoose Formation are lithologically similar to the upper Pittsburg Bluff Formation in the study area. The confusion that results from Warren and Norbistrath's definition of the Scappoose Formation is also compounded by the fact that their formation definition applies not to lithology but to a fossil assemblage. A formation is defined as a rock stratigraphic unit with "distinct lithologic features" (Code of Stratigraphic Nomenclature, article 6a, p. 650). The definition given by Warren and Norbistrath applies to a biostratigraphic unit and not a formation.

Since the strata in the study area represent a different age and lithofacies than that of the type locality of the Scappoose Formation applying the name Scappoose Formation to the strata in the study area would be incorrect. An informal designation of "Middle Miocene Beds" is proposed for the strata in the study area (Figure 2). These beds might also be better defined as belonging to the middle Miocene upper Astoria Formation.

The vigorous fluvial channeling in the study area has added confusion to the stratigraphy and age relationships of the Scappoose Formation. The basal conglomerate identified at the base of the

Scappoose Formation near Buxton is actually a lag gravel deposit lining the bottom of a middle Miocene Fluvial channel that was cut into the Oligocene Pittsburg Bluff Formation. Laterally, other lithofacies within the Scappoose Formation would appear to lie at the same stratigraphic level as the channel gravels, giving the wrong impression of both age and stratigraphy.

ENVIRONMENT OF DEPOSITION AND PALEOGEOGRAPHY

The Scappoose Formation displays characteristics that typify a deltaic environment with lateral interfingering of marine and non-marine units, coal beds, and cross-bedded fluvial sandstones. Van Atta (1971) also believes a Scappoose delta began forming when subsidence ended in northwest Oregon in late Oligocene while high rates of sedimentation continued.

Different deltaic and marginal sedimentary regimes can be recognized in the Scappoose Formation (Figures 5-7, 9). Medium to coarse grained, cross-bedded, locally pebbly sandstones represent fluvial distributary channels carrying an abundant sediment supply. Laterally equivalent micaceous, carbonaceous mudstones are over bank facies resulting from periodic channel switching and flooding. The distributary channel sands transitionally overlies finer grained sandstones that are interpreted as delta front sands. Scouring into these finer grained sandstones is common (Figure 27). Broken and sorted shell material, locally bedded plant fragments, and glauconite, as well as the degree of sorting suggest that these sands were deposited in a high energy marginal environment and were possibly reworked into barrier bars and spits by wave and current action. Disarticulated layers of the bivalve Mytilus, a littoral zone rock dweller (Moore, 1976), preferentially oriented concave side down in outcrops in Tolke Canyon

Figure 27. Scour channel containing poorly sorted mudstone, basalt clasts overlying fine grained sandstone. Located southeast quarter section 27, township 6 north, range 4 west.

near Buxton indicate high energy, probably stormy, periods of mass mortality adjacent to a rocky shore and tidal flat environment to the southeast. Eroded non-marine beds overlain by fine grained fossiliferous marine sandstones display characteristics of periodic marine transgression (Figure 12). Localized ripple cross laminations are interpreted as representing beach shore face environment where combinations of tidal and wave current action were prevalent. Thick bedded tuffaceous, fossiliferous, siltstones were deposited in a low energy quiet brackish water lagoonal, and interdistributary environments. Rare chaotic, poorly sorted mixtures of coal, mudstones, and basalt clasts in matrix support layers resulted from periodic high energy flood influxes.

Coal occurs in a transitional environment between two lithofacies where organic material has accumulated (Figure 28). The lignite beds formed in stagnant marsh and swamp, possibly interdistributary environments, at the end of fluvial sedimentation and before the onset of transgressive brackish water marine sedimentation. The generally greater thickness of marginal to normal marine units versus the shallower water lithofacies suggests that a marine environment dominated by wave and current action was the predominant regime during sedimentation of the Scappoose Formation. The greater abundance of coarser sand to the north and east and finer sand and muds to the south and west suggests a southwestward flowing drainage system. A southwest flowing drainage system is also suggested by southwest oriented paleo current directions measured from cross-bedded fluvial sands (see map). The presence of granitic, metamorphic, and volcanic rock fragments in

Figure 28. Bedded lignite coal seam between sandstone below, and siltstone above. Note thinning of seam to left. Located on Columbia Forest Road northwest quarter section 15, township 4 north, range 2 west.

Scappoose Formation sandstones indicate a provenance of mixed volcanic and metamorphic sources for Scappoose Formation sediments typical of the ancestral Columbia River.

Summarizing the sedimentary features of the Scappoose Formation, a delta environment of deposition is an attractive explanation, but other limiting factors must be considered. Assuming that coastal conditions today represent a similar environment to that which existed in late Oligocene (Moore, 1976), a deltaic shoreline would be unable to construct a large delta seaward due to the vigorous wave and long-shore current action. Sediment would be distributed and reworked into bars, barrier islands, and spits adjacent to river mouths much in the same manner observed on the Oregon Coast today. The present day coastal river mouths are narrow localized outlets with estuarine margins flushed by periodic tidal, wave, and fluvial currents. Cressy (1973) believes that the middle Miocene Angora Peak sandstone member of the Astoria Formation was deposited in a deltaic high energy marine environment similar to the present day Niger Delta described by Allen (1970) where extensive sheets of fine grained delta front sand were reworked into barriers and spits. Additional work on the Astoria Formation by Penoyer (1976) confirms deltaic sedimentary affinities. A more likely model proposed by Penoyer for deposition of the Astoria Formation is that of a narrow deltaic shoreline that gradually builds seaward. Numerous transgressive and regressive marine cycles with marginal and intertributary brackish water environments are superimposed on active fluvial erosion channeling and deposition. The middle Miocene age of the Scappoose Formation suggested by the presence of Columbia River basalt

clasts, requires a correlation between the Scappoose and Astoria formations. Since Scappoose Formation sedimentation appears dominated by a high energy marine environment with fine-grained, reworked sands underlying non-marine fluvial sandstones in much the same situation as the upper Astoria Formation, a low relief deltaic coastal plain similar to present day Coos Bay, or a high energy marine dominated marginal delta front similar to the Niger Delta is proposed as a model for deposition of the Scappoose Formation.

COLUMBIA RIVER BASALT GROUP

Low magnesium Grande Ronde Basalt geochemical type flows of the Columbia River Group constitute the major portion of the basalt section overlying the Scappoose Formation. As stated earlier, clasts from the Grande Ronde lavas were contributed to the fluvial channel systems within the Scappoose Formation along with abundant palagonite. Many of the fluvial channels at the beginning of Scappoose time were choked with palagonite as these early low magnesium flows brecciated on contact with water. Rather than suddenly inundating the Scappoose topography the lavas apparently gradually built westward allowing weathering of the easily erodible flow tops to generate the partly vesicular gravels that were deposited in topographic lows.

In the Clatskanie Heights area the earliest flows entered the marine environment at the edge of the Astoria embayment producing local pillowed palagonite breccias. Much of the palagonite was eroded and reworked into coarse grained sands accentuating the bidirectional ripple cross laminations of these sands. Some of the earliest flows

of Grande Ronde Basalt also flowed onto the Pittsburg Bluff and Keasey Formations near the hamlet of Scofield (Van Atta, 1971, pp. 77-85) northeast of Highway 26 where earlier erosion had removed much of the Scappoose Formation.

Large blocks of underlying sediment were also incorporated into the lavas as the dense flows invaded the wet plastic sediments. This is demonstrated by Van Atta (1971, p. 77) who reports a lense of Scappoose Formation sandstone incorporated into Columbia River Group lavas on the east fork of Dairy Creek. Warren and Norbistrath (1946, pp. 233-34) report that "irregular dike-like masses" intrude Scappoose Formation sediments with "small well developed columns" formed in a fan pattern, that are feeders to the overlying Columbia River Group flows. No feeder dikes to the overlying basalt flows were observed in the study area. All of the flows examined rest on the Scappoose Formation in an intracanyon manner. It is probable that these "dikes" were the result of invasive and intracanyon flows similar to the features described by Beeson and others (1980). Judging from the description by Warren and Norbistrath, it appears the jointing type described more closely resembles the upper entablature typical of many Columbia River Group flows. Viewed in cross section with the base covered these intracanyon flows would very easily give the appearance of dike-like tabular bodies cutting across bedding. A check of the magnetic polarity of several intracanyon flows near Scofield and on the west side of the Nehalem River southeast of Mist (made with the aid of Terry Tolan, Portland State University) reveals that these early flows are reversed, placing them very low in the Columbia River Group

section below stratigraphically higher normally magnetized flows on the east side of the Nehalem River.

In the Clatskanie Heights area normally magnetized Grande Ronde Basalt flows are intercalated with sands that resemble marine sands of the Astoria Formation farther to the west which are also intercalated with Columbia River Basalt Group flows (Snively, 1973). Scappoose Formation sands in the Clatskanie Heights area stratigraphically below the Grande Ronde Basalt flows are medium grained, massive, with bidirectional ripple cross laminations indicative of a marine environment. In several places a dark partly lithified baked contact 50-60 centimeters thick below the basalts shows that these flows were subaerial and elsewhere where pillow lavas occur below the basalts in old channels partly lined with gravels show these flows were subaqueous. Slight weathering of the well developed flow tops suggests a hiatus between each flow during which the fine grained structureless interbedded sands accumulated. In other localities in western Oregon sedimentary interbeds are reported between Grande Ronde Basalt flows. Anderson (1978) describes interbeds of material derived from adjacent topographic highs in the Clackamas River drainage. Beeson (oral communication, 1981) found marine fossils between Grande Ronde Basalt flows near Amity, Oregon. The fine grained, well sorted structureless nature of the sandstone interbeds suggests that erosion and reworking of the sediment from adjacent topographic highs as well as a combination of normal marine and fluvial sedimentation then deposited these sandstone interbeds.

A middle Miocene episode of erosion and deposition with

simultaneous flows of Grande Ronde Basalt into stream valleys dominated the period during which the Grande Ronde Basalt lavas flowed onto the Scappoose Formation paleogeographic surface. Interbeds between later flows decrease in thickness upsection suggesting a decline in local topography and sedimentary influence as later flows built gradually westward. The sedimentary interbeds are better defined as belonging to the Astoria Formation due to their middle Miocene age.

The stratigraphy of the Columbia River Basalt Group in the study area was examined in a cursory manner mainly for indications of paleogeography. Most of the flows examined above the Scappoose Formation contact were intracanyon flows with interbeds of rounded gravels in topographic lows. Columnar jointing is well developed in the thicker flows as is a thin upper entablature and vesicular flow tops. Flows can be seen to thicken and thin over the old paleotopography demonstrating a dissected surface on the underlying Scappoose Formation surface. The thickest flows range between 40 and 50 meters and the thinnest flows are approximately one meter thick. Columbia River Basalt Group lavas extended farther to the west before removal by erosion and weathering. Since the Columbia River Basalt Group lavas rest on the Keasey, Pittsburg Bluff, and Scappoose Formations to the west of the Nehalem River and interfingered with the Astoria Formation to the northwest, the implications are that an embayment existed during middle Miocene to the northwest while the area around Scofield, Pittsburg, and further to the west of the Nehalem River was an eroded, moderate relief surface.

STRUCTURE

The Scappoose Formation in the study area forms the northeastern limb of a broad north plunging anticlinorium (see map cross section). Faulting is most common in the north and northeast portion of the study area near Clatskanie Heights, near the extension regional Portland Hills fault northwest structural trends. Most faults are northwest trending normal faults offsetting the resistant Columbia River basalts. A northeast trending fault is readily apparent on aerial photographs in Dog Creek canyon in the center of the study area where the Pittsburg Bluff Formation is faulted against the Scappoose Formation. Southeast of Vernonia in Dell Creek Canyon an older east-west normal fault has been offset by a younger northeast trending fault. The youngest episode of faulting in the study area is related to the Portland Hills northwesterly structural trend. A qualitative measure of the degree of fault offset in Scappoose Formation sediments can be interpreted by examination of fault breccia zones. Small displacement faults typically show a narrow, sharp fault zone usually between 15 and 50 centimeters wide with some sense of movement displayed such as bending or drag of bedding. Faults with large offsets are easily overlooked when lamination or bedding of the sediments is lacking. The fault zone of the larger faults is often 10 to 30 meters wide with blocks of the sediment incorporated into the fault zone in a chaotic mixture that makes determination of both amount and sense of fault

movement difficult. Many spurious dips which confuse the interpretation of structure are the result of sliding of Scappoose Formation beds.

GEOLOGIC HISTORY

By late Oligocene to early Miocene time a gradual shallowing of the continental margin basin began in northwest Oregon. At the end of Pittsburg Bluff time, in late Oligocene to early Miocene time, sediments with continental affinities began to be deposited with marine sediments in a shallow marine deltaic environment. At this time the ancestral Columbia River drainage system was flowing westward to the south of its present day course (Peck and others, 1964), supplying granitic, metamorphic, and volcanic sediments of the Scappoose Formation (Figure 29). By middle Miocene time a well established fluvial ancestral Columbia River drainage was supplying sediments to the Angora Peak Delta of Cressy (1973). The ancestral Columbia River flowed approximately east to west near present day Vernonia as paleocurrent trends indicate. A marine embayment north of the Columbia River extended as far east as present day Clatskanie (Figure 30). As a result of marine transgression (Penoyer, 1976), the ancestral Columbia River began a shift to the north during late middle Miocene time eroding deeply into the Pittsburg Bluff and Keasey Formations (Figure 31). During this period of erosion and readjustment of the Columbia River the first middle Miocene flows of low magnesium Grande Ronde Basalt erupted from fissures on the Columbia Plateau and flowed westward down the ancestral Columbia River. The lavas brecciated on contact with fluvial streams and the channels became choked with palagonite and

Figure 29. Paleogeographic map of northwestern Oregon in late Oligocene to early Miocene.

Figure 30. Paleogeographic map of northwestern Oregon in middle Miocene, from Penoyer, 1976.

Figure 31. Paleogeographic map of northwestern Oregon in late middle Miocene. Ancestral Columbia River drainage shifts to the northeast.

rounded basalt clasts that were carried westward and deposited in channels eroded into the Pittsburg Bluff Formation. A hiatus during middle Miocene time followed the readjustment of the ancestral Columbia River as Scappoose Formation sedimentation shallowed and the marine strand line moved to the west. This period was also accompanied by tectonic activity resulting in uplift, emergence, and erosion of the Scappoose Formation near Pittsburg while the marine embayment to the north near Clatskanie also began to gradually shallow. Grande Ronde Basalt lavas continued to build westward with intermittent periods of quiet between flows contributing palagonite and gravels to the shallowing Scappoose Formation shoreline. Gravels were also deposited in topographic lows on the dissected Scappoose Formation surface. Later subaerial flows of Grande Ronde Basalts moved down old canyons eroded into the Scappoose, Pittsburg Bluff, and Keasey Formations near Pittsburg across the present day Nehalem River. These low magnesium flows also entered the Astoria embayment near Clatskanie forming pillow palagonite breccias and interfingering with both marine and fluvial sands. Columbia Plateau derived basalts coincided with chemically similar intrusions of Depoe Bay and Cape Foulweather basalts of the present day Oregon Coast or were possibly the same Columbia Plateau derived basalts invading the wet plastic sediments (Beeson and others, 1980).

CONCLUSIONS

The Scappoose Formation ranges from late Oligocene to middle Miocene in age and is composed of intertonguing feldspathic sandstones, siltstones, and mudstones that are predominantly marine lithofacies lower in the formation and grade upward into brackish water, fluvial lithofacies higher in the formation, reflecting deposition in a high energy, marine wave and current dominated, westward developing coastline environment. Heavy mineral assemblages composed of hypersthene and blue-green hornblende, and metamorphic and granitic rock fragments demonstrate that sediments were derived from an ancestral Columbia River drainage system. Scappoose Formation conglomerates and cross-bedded sands rest on an irregular erosional surface cut into Oligocene Pittsburg Bluff Formation.

Late Oligocene to early Miocene marine to brackish water lithofacies are overlain by coarse grained fluvial channel sandstones, containing middle Miocene Grande Ronde Basalt clasts. Fluvial channel sandstones rest in channels eroded into the Keasey and Pittsburg Bluff Formations.

The presence of palagonite and low-magnesium type Grande Ronde Basalt clasts in fluvial channel sandstones illustrates that middle Miocene fluvial channeling was contemporaneous with early flows of Grande Ronde Basalt. Localized gravels below and sedimentary beds between Grande Ronde Basalt flows were derived from erosion of adjacent

topographic highs and early basalt flows. Pillow palagonite breccias above marine sands reflect extension of the basalt flows into a marine embayment that existed near present day Clatskanie.

The occurrence of middle Miocene fluvial sandstones in strata previously considered as late Oligocene in age requires a redefinition of the Scappoose Formation. The definition of the age of the Scappoose Formation must be extended either to include the middle Miocene fluvial sandstones or to place these middle Miocene beds in a separate formation.

REFERENCES CITED

- Allen, J. R. L., 1970, Sediments of the modern Niger delta: a summary and review; in Morgan, J. P. ed., Deltaic sedimentation modern and ancient: Society of Economic Paleontologists and Mineralogists, Special Publication No. 15, Tulsa, Oklahoma, pp. 138-151.
- American Commission of Stratigraphic Nomenclature, 1961, Code of stratigraphic nomenclature: American Association of Petroleum Geologists, Bulletin, v. 45, no. 5, p. 650.
- Anderson, J. E., 1978, The structure and stratigraphy of the Columbia River Basalt in the Clackamas River drainage: Portland State Univ. masters thesis, 141 p., unpub.
- Baldwin, E. M., 1981, Geology of Oregon, 3rd ed.: Eugene, Oregon, Univ. Oregon Cooperative Bookstore, 165 p.
- Beeson, M. H., Associate Professor Geology, Portland State Univ., personal communication.
- Beeson, M. H., Johnson, A. G., and Moran, M. R., 1975, Portland environmental geology-fault identification: Portland State Univ., Portland, Oregon, 107 p.
- Beeson, M. H., Perttu, R., and Perttus, J., 1980, The origin of Miocene basalts of coastal Oregon and Washington, an alternative hypothesis: Oregon Geology, v. 41, pp. 159-166.
- Cameron, K. A., 1980, Geology of the southcentral margin of the Tillamook Highlands, southwest quarter of the Enright Quadrangle, Tillamook County, Oregon: Portland State Univ. masters thesis, 87 p., unpub.
- Clark, B. L., and Arnold, R., 1923, Fauna of the Sooke Formation, Vancouver Island: Univ. California publication, Bulletin Dept. of Geological Science, v. 14, p. 125.
- Cressy, F. B., 1973, Stratigraphy and sedimentation of the Neahkahnie Mountain-Angora Peak area, Tillamook and Clatsop Counties, Oregon: Oregon State Univ. masters thesis, 148 p., unpub.
- Deer, F. R. S., Howie, R. A., and Zussman, J., 1963, Rock Forming Minerals, v. 4, Framework Silicates: John Wiley and Sons, New York, 435 p.

- Masuda, A., Nakamura, N., and Tanaka, T., 1973, Fine structures of mutually normalized rare-earth patterns of Chondrites: *Geochimica et Cosmochimica Acta*, v. 37, p. 243.
- Moore, E. J., 1976, Oligocene marine mollusks from the Pittsburg Bluff Formation in Oregon: U. S. Geol. Survey Professional Paper 922 66 p.
- Neel, R. H., 1975, Geology of the Tillamook Head-Necanicum Junction area, Clatsop County, northwestern Oregon: Oregon State Univ. masters thesis, 204 p., unpub.
- Nelson, M. P., 1977, Tertiary stratigraphy and sedimentation in the Lewis and Clark River-Youngs River area, Clatsop County, northwestern Oregon: Oregon State Univ. masters thesis, 242 p., unpub.
- Peck, D. L., Griggs, A. B., Schlicker, H. G., Wells, F. G., and Dole, H. M., 1964, Geology of the central and northern parts of the western Cascade Range in Oregon: U. S. Geol. Survey Professional Paper 449, 56 p.
- Penoyer, P. E., 1976, Geology of the Saddle and Humbug Mountain area, Clatsop County, northwestern Oregon: Oregon State Univ. masters thesis, 232 p., unpub.
- Reading, H. G. editor, 1978, Sedimentary environments and facies: Elsevier, New York, Blackwell Scientific Publications, pp. 32-60, 97-177.
- Rock-Coler Chart Committee, 1963, Rock-Coler Chart: Geological Society of American, New York, no pagination.
- Simpson, R. W., and Cox, A. U., 1977, Paleomagnetic evidence for tectonic rotation of the Oregon Coast Range: *Geology*, v. 5, pp. 585-589.
- Smith, T. N., 1974, Stratigraphy and sedimentation of the Onion Peak area, Clatsop County, Oregon: Oregon State Univ. masters thesis, 190 p., unpub.
- Snavely, P. D., and Wagner, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Division of mines and geology, report of investigations no. 22, 25 p.
- _____, 1964, Geologic sketch of northwestern Oregon: U. S. Geol. Survey Bulletin 1181-M, pp. 1-17.
- _____, 1973, Miocene tholeiitic basalts of coastal Oregon and their relations to coeval basalts of the Columbia Plateau: *Geological Society of American Bulletin*, v. 84, pp. 387-424.

- Tolson, P. M., 1975, Geology of the Seaside-Youngs River Falls area, Clatsop County, Oregon: Oregon State Univ. masters thesis, 191 p., unpub.
- Van Atta, R. O., 1971, Sedimentary petrology of some Tertiary formations, Upper Nehalem River Basin, Oregon: Oregon State Univ. doctoral thesis, 229 p., unpub.
- Walker, R. G. ed., 1979, Facies models: Ottawa, Canada, Geological Association of Canada, Geoscience Canada Reprint Series 1, pp. 1-32, 43-56, 75-90.
- Warren, W. C., and Norbistrath, H., 1946, Stratigraphy of upper Nehalem River Basin, northwestern Oregon: American Association Petroleum Geologists Bulletin, v. 30, pp. 213-237.
- Warren, W. C., Norbistrath, H., and Grivetti, R. M., 1945, Geology of northwest Oregon west of the Willamette River and north of latitude 45 degrees 15 minutes: U. S. Geol. Survey Oil and Gas Investigation Preliminary Map 42.
- Wright, T. L., Grolier, M. J., and Swanson, D. A., 1973, Chemical variation related to the stratigraphy of the Columbia River Basalt: Geological Society of America Bulletin, v. 84, pp. 371-386.

APPENDICES

APPENDIX 1
SANDSTONE GRAIN MOUNT PERCENTAGES

Sample	Monocrystalline Quartz	Polycrystalline Quartz	Potassium Feldspar	Plagioclase Feldspar	Granitic Rock Fragments	Volcanic Rock Fragments	Sedimentary Rock Fragments	Hypersthene	Biotite	Glass	Oxyhornblende	Blue Green Hornblende
102380-2a	17	3	26	43	tr.	9	-	2	-	-	-	-
93080-3	9	1	34	42	-	11	-	2	-	-	-	-
82780St1-1	6	-	35	46	-	13	-	-	-	-	-	-
92280-1	9	-	15	44	-	29	-	2	-	-	-	-
82780St3-3	20	5	26	18	tr.	29	-	-	-	-	-	-
82780St3-2	12	2	28	42	-	12	-	4	-	-	-	-
93080-2	6	-	30	18	tr.	45	-	-	-	1	-	-
91880-5	12	-	34	11	tr.	38	-	-	4	1	-	-
10980-4	15	3	30	15	-	35	-	tr.	-	1	tr.	tr.
82780St2-2	8	1	15	18	-	21	33	4	-	-	-	-
82780St3-1	11	2	39	20	tr.	22	1	2	1	1	-	2

APPENDIX 2
LIGHT AND HEAVY MINERAL PERCENTAGES

Heavy Minerals

Sample	Blue Green Hornblende	Brown Hornblende	Hypersthene	Augite	Pigeonite	Biotite	Zircon	Apatite	Garnet	Opaque
Siltstone 82880-2	-	tr.	57	tr.	-	1	tr.	1	-	40
Mudstone 91680-2	-	1.5	66	4.5	tr.	4.5	15	-	2.5	5.5
Siltstone 91880	-	tr.	85	-	-	1	1.5	-	-	12
Claystone 102380-1	tr.	tr.	65	tr.	-	7	-	1	-	24

Light Minerals

Sample	Rock Fragments	Plagioclase Feldspar	Potassium Feldspar	Quartz	Biotite	Glass
Siltstone 82880-2	-	17	10	47	26	-
Mudstone 91680-2	1	29	31	37	1	1
Siltstone 91880	3	43	29	18	5	2
Siltstone 102380-4	17	41	18	15	-	9

APPENDIX 3

	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	FeO	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅
BCR 900 ¹	56.21	13.96	2.17	5.70	6.53	0.17	6.49	3.22	1.79	3.38	0.38
KK 1 ²	57.49	14.41	2.10	4.90	5.61	0.20	6.74	3.15	2.07	2.94	0.38
KK 5 ²	56.51	14.35	1.98	5.41	6.20	0.18	6.82	3.36	1.85	3.00	0.35
KK 6 ²	55.00	13.91	2.22	6.08	6.96	0.20	7.02	3.41	1.93	2.94	0.36
KK 7 ³	56.53	14.27	2.02	5.21	5.96	0.19	7.05	3.41	2.04	2.97	0.35
KK 8 ³	56.07	14.00	2.14	5.51	6.31	0.19	7.02	3.21	1.99	3.17	0.38
KK 9 ³	56.76	14.23	1.98	5.20	5.95	0.19	6.98	3.37	2.09	2.91	0.35
KK 10 ³	56.81	14.11	1.94	5.22	5.98	0.19	6.91	3.39	2.06	3.05	0.35
KK 11 ³	56.25	14.19	1.95	5.51	6.31	0.20	6.94	3.48	1.93	2.89	0.34
KK 12 ²	56.68	14.50	1.95	5.31	6.09	0.17	6.92	3.44	1.76	2.83	0.35
KK 13 ²	57.38	14.65	2.03	4.52	5.18	0.19	7.07	3.52	1.96	3.15	0.35

¹Low Magnesium, Grand Ronde Columbia River Basalt Group Standard.

²Low Magnesium, Grand Ronde Columbia River Basalt Group on top of Scappoose Formation.

³Conglomerate Clasts from channels in Scappoose Formation.

APPENDIX 4

GAMMA SPECTRAL PEAKS AND COMPARATIVE VALUES USED IN CALCULATING CONCENTRATIONS

ISOTOPE	ENERGY KEV	BCR-1	COMPARATIVE VALUE (PPM) ARCHO-1	HALF-LIFE
Ce 141	145.4	53.9		781.0 hours
Co 60	1173.2	38		1925.0 days
Co 60	1332.5	38		1925.0 days
Eu 152	121.8	1.94		11.6 hours
La 140	328.8		46	40.2 hours
La 140	487.0	26		40.2 hours
La 140	815.8		46	40.2 hours
La 140	1596.2		46	40.2 hours
Na 24	1368.6	3.45 x 10 ⁴		15 hours
Sc 46	889.3	33		83.7 days
Sc 46	1120.5	33		83.7 days
Sm 153	103.2	6.6		47.1 hours
Yb 175	282.5	3.36		100.7 hours
Yb 175	396.3	3.36		100.7 hours
Lu 177	208.4		65	163.1 hours

APPENDIX 5

EXP7C 1ST COUNT SCAPPOOSE FM CRB FLOWS & CLASTS

SAMPLE	FE	CO	NA
ARCHO-1	8.80	0.20	2.00
BCR-1	9.40	0.30	3.00
82880L13	7.03	0.19	3.00
102480-2	8.70	0.20	3.00
102480-1	7.57	0.20	3.00
T6NR4W27	8.20	0.20	3.00
93080-47	8.60	0.20	3.00
9580-6	8.10	0.20	3.00
102480-4	8.20	0.20	3.00
102780-1	7.87	0.19	3.00
T6NR4NW6	7.70	0.20	3.00
102480-3	7.55	0.20	3.00

EXP7C 1ST COUNT SCAPPOOSE FM CRB FLOWS & CLASTS

SAMPLE	SM	EU	CE	LU	YB	LA	SC
ARCHO-1	9.70	0.40	3.60	0.70	75.00	12.00	0.65
BCR-1	6.60	0.30	2.00	0.50	54.00	11.00	0.63
82880L13	9.00	0.30	1.70	0.40	48.00	8.00	0.61
102480-2	4.90	0.50	1.60	0.30	40.00	7.00	0.57
102480-1	8.40	0.30	1.90	0.40	47.00	8.00	0.59
T6NR4W27	4.30	0.50	1.60	0.30	43.00	7.00	0.60
93080-47	8.50	0.30	1.90	0.40	42.00	7.00	0.67
9580-6	9.40	0.30	1.80	0.40	47.00	8.00	0.63
102480-4	9.30	0.30	1.80	0.40	55.00	9.00	0.59
102780-1	8.70	0.30	1.50	0.30	46.00	8.00	0.59
T6NR4NW6	8.60	0.30	1.60	0.30	46.00	8.00	0.60
102480-3	8.90	0.30	1.70	0.40	43.00	7.00	0.60

APPENDIX 6

Clackamas River-Anderson (1978)
Lo MgO 4/

Sc 34.0
Co 39.0
La 26.5
Ce 50.0
Eu 2.0
Sm 6.6

West Linn-Beeson et. al., (1975)
Lo MgO 1/

Sc 33.0
Co 36.0
La 25.4
Ce 48.0
Eu 1.7
Sm 6.1

On top of Scappoose Formation
Lo MgO 5/

Sc 32.8
Co 35.0
La 31.4
Ce 45.2
Eu 1.7
Sm 7.9

Conglomerate channel clasts
in Scappoose Formation
5

Sc 33.2
Co 37.6
La 32.6
Ce 46.2
Eu 1.7
Sm 8.0

n/ number of flows averaged
n number of samples averaged