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Upper Eocene and lower Oligocene marine clastic beds are exposed in the upper Nehalem Basin. The rocks are predominantly sandstones, siltstones and mudstones of the graywacke suite and locally contain a considerable admixture of tuffaceous material.

The oldest rock exposed in the upper Nehalem Basin is the middle Eocene Tillamook volcanic series which locally forms the core of the Coast Range. Upper Eocene sandstones and siltstones of the Rocky Point formation lie unconformably on the Tillamook volcanic series and have a thickness of 1,000 feet. The overlying lower Oligocene Nehalem formation contains beds of coarse sandstone, tuffaceous siltstone, mudstones, and one local basalt flow and has a thickness of some 500-600 feet. The lower Oligocene Keasey formation lying above the Nehalem formation consists predominantly of tuffaceous, sandy siltstone and subordinately of tuffaceous sandstones, with a partial thickness of 1,700 feet.

Much of the structural detail is not known because of concealment by soil and vegetation and the consequent lack of continuity between outcrops. Generally the sedimentary beds lie on the easterly flank of the Coast Range anticlinorium and dip with low to moderate angles to the east. Structural deformation of the early Tertiary beds was probably brought about by the Coast Range uplift which occurred at the close of the Pliocene.

Eugeosynclinal deposition with an Eocene volcanic archipelago lying to the west is suggested. By early Oligocene the westerly landmass, if present, had subsided or was covered by encroaching waters and sediments derived from an easterly source became finer grained and more uniform in character.

A REVISION OF UPPER EOCENE AND LOWER OLIGOCENE STRATIGRAPHIC UNITS IN THE UPPER NEHALEM RIVER BASIN, NORTHWEST OREGON

by

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A REVISION OF UPPER EOCENE AND LOWER OLIGOCENE STRATIGRAPHIC UNITS IN THE UPPER NEHALEM RIVER BASIN, NORTHWEST OREGON

INTRODUCTION

Marine Tertiary strata in northwestern Oregon have been of interest to geologists for about sixty years because of the abundant and well preserved fossils in certain beds; the stratigraphy of these rocks, however, has been largely neglected. Several formations have been defined principally on the basis of their fossils by Schenck, Weaver and others. It is the purpose of this paper to re-examine the definitions of two of these formations, the Eocene Cowlitz formation and the Oligocene Keasey, and to re-define these on the basis of correct stratigraphic usage.

Weaver in 1912 (11, p. 13) proposed the name Cowlitz formation for beds containing a molluscan fauna exposed one and one-half miles east of Vader, Lewis County, Washington, along the west bank of the Cowlitz River. In 1937 (13, p. 94) he expanded the type Cowlitz formation to include strata exposed along Olequa Creek between the towns of Winlock and Vader, and described the formation as consisting essentially of 4,200 feet of marine sandstone and shales. In 1943 Beck (1) described Eocene foraminifera from Weaver's original type section of the Cowlitz

formation and criticized Weaver's emendation of the Cowlitz formation because the Olequa Creek section was not included in the original definition and the addition would necessitate two type localities for the Cowlitz formation. Beck limits the type Cowlitz to beds exposed on the Cowlitz River.

In 1946 Warren and Norbisrath in an oil and gas reconnaissance of northwest Oregon for the U. S. Geological Survey mapped the Eocene beds above the Tillamook volcanics as the Cowlitz formation in the upper Nehalem Basin on the basis of comparison of its fauna with that of the Washington Cowlitz formation. They did not however compare the lithology of the Oregon upper Eocene to the type Cowlitz lithology in Washington. The map boundary between the "Cowlitz" and "Keasey" formations of Warren and Norbisrath on the Sunset Highway was drawn within the Keasey formation between the lower and middle members because the fauna contained in the lower Keasey member was thought to be Eocene. In their report they pointed out that this contact may also be the boundary between the lower and middle Keasey members, but they apparently reached the conclusion that lithologically the lower Keasey beds at this locality could be included within the Cowlitz map-unit. Hence, it would appear that the Keasey formation was not a clearly defined map-unit inasmuch as Warren and

Norbisrath included the lower portion of the Keasey formation within their Cowlitz map-unit.

The Keasey formation first was described in 1927 by Schenck (7) in a preliminary report on marine Oligocene of Oregon. In 1928 Schenck (8) extended his definition of the Keasey formation to designate the "sandy, tuffaceous, bluish, fossiliferous shales that outcrop on the banks of Rock Creek 0.7 miles below Keasey Station." In 1937 Weaver summarized existing knowledge of the Keasey formation and divided the formation into a lower dark colored sandy shale member and an upper shaly sandstone member which comprised two-thirds of the formation. He gave an approximate thickness of 1200 feet on Rock Creek. Warren and Norbisrath (10) divided the Keasey formation into three members: a lower member whose composition and thickness varies from place to place; a thick, widespread, fairly uniform middle member of massive, silty, tuffaceous shale with cemented beds; and an upper member of stratified, tuffaceous, sandy shales. They gave a total thickness of 1700 feet for the formation along the Sunset Highway near the Sunset Tunnel.

In an attempt to resolve stratigraphic problems in this area, approximately 8 weeks were spent in the field in the summer and fall of 1952. Two main stratigraphic sections were measured, one near Keasey Station along Rock

Creek and the other along the Sunset Highway between Sunset Camp and Sunset Tunnel. Along the Nehalem River between Sunset Camp and Vernonia nine partial sections were measured and in the vicinity of Glenwood one partial section was measured. Location of sections and methods of measurements will be described in section descriptions. Petrographic study was made in the laboratory on a number of samples, both disaggregated fragments and thin sections. Several macro- and micro-fossil collections were made and worked up in the laboratory. Mr. Harold A. Boyd Jr. identified the foraminifera.

Plate 1 shows the general location of the studied area in Oregon; plate 2 shows the specific location of stratigraphic sections. Access to the area is facilitated by several paved roads. The Sunset Highway, which extends from Portland to the Pacific Coast, cuts through the southwest part of the area approximately 25 miles from Portland. The southern part of the area is located some 15 miles southwest of Forest Grove and is serviced by the Tillamook cut-off highway. Keasey Station in the northerly part of the area may be reached by a gravel road from Vernonia.

Geologic work in this area is seriously hindered by a heavy cover of second growth timber and undergrown brush. Northwest Oregon is conditioned by a temperate

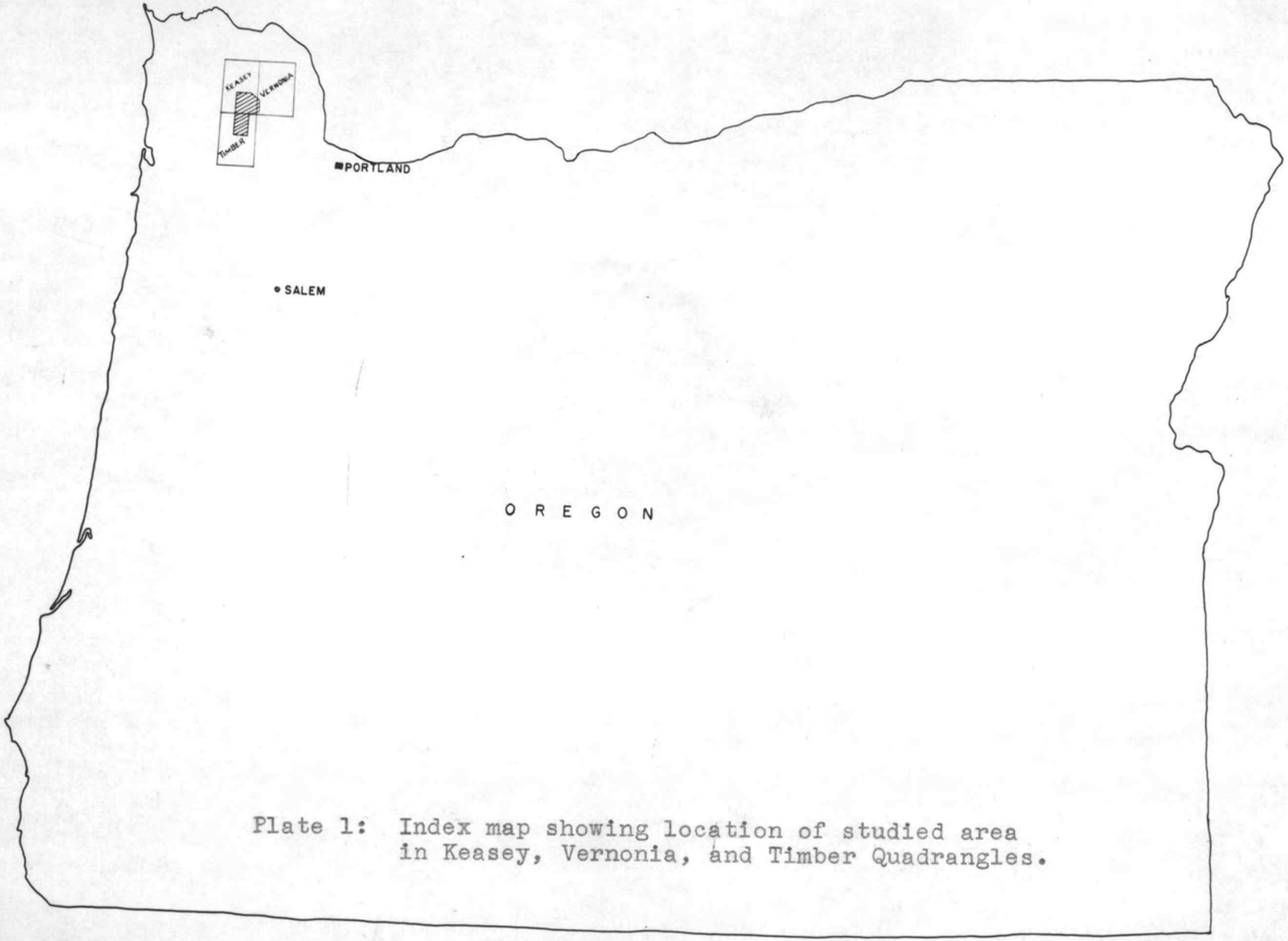
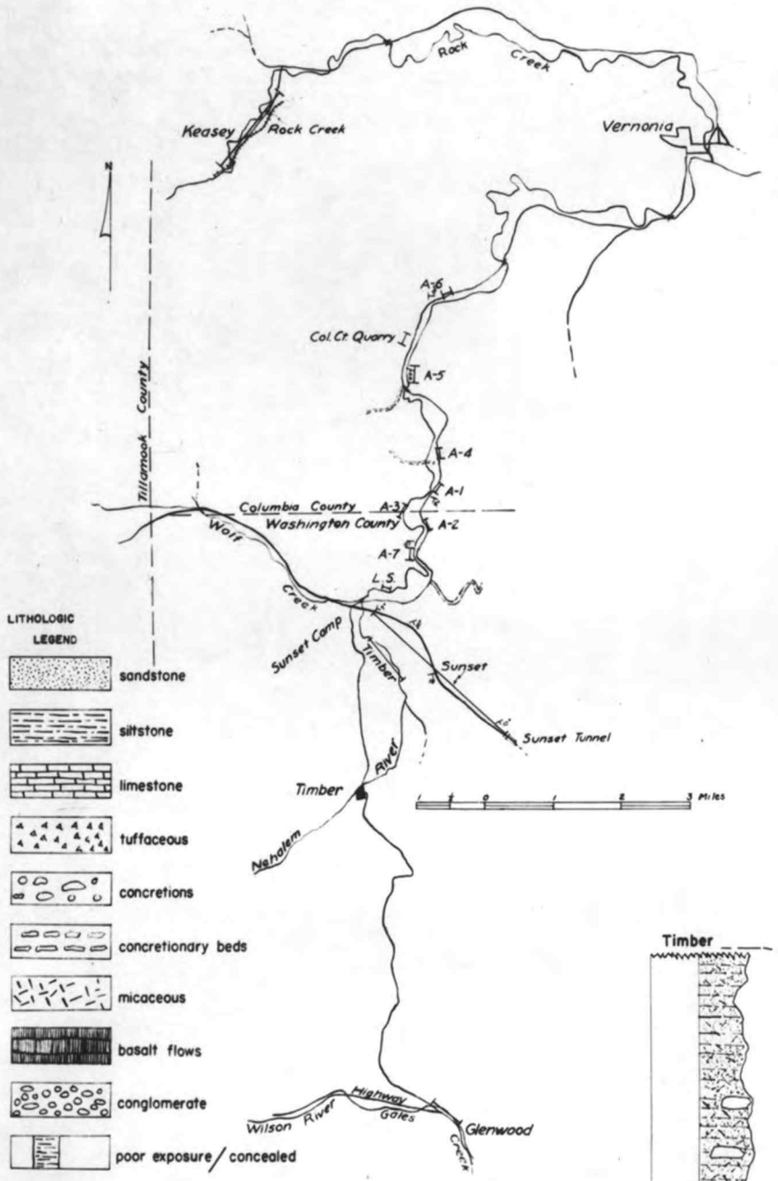


Plate 1: Index map showing location of studied area in Keasey, Vernonia, and Timber Quadrangles.

LOCATION OF MEASURED SECTIONS—UPPER NEHALEM BASIN



COLUMNAR SECTION CORRELATION

Plate 2

coastal climate with heavy rainfall conducive to the development of a relatively thick soil mantle. The soil cover is commonly 5 to 10 feet thick. Slump and landslides are also common and where movement has been considerable, good exposures are sometimes found, although as a rule slump blocks add to the confusion of structural problems. Exposures available for study are generally limited to stream banks and roadcuts and these are not plentiful. Where roadcuts have been exposed for a number of years the rock is generally weathered to such an extent that good samples are obtained with difficulty.

The Nehalem River flowing through the area in a northerly direction has cut a deep moderately steep valley oriented generally parallel to the strike of the rocks. It has now reached a temporary base level and is forming broad flood plains. Small creeks, mostly intermittent, entering the Nehalem River as lateral consequents, have cut steep valleys ranging in depth from 300 to 400 feet. The moderately steep mountain topography varies from 1200 to 1500 feet in elevation. The lowest point in the area is near Vernonia, where the elevation is between 450 and 500 feet.

STRATIGRAPHY

The oldest rocks exposed in the upper Nehalem Basin are the Tillamook volcanic series of middle Eocene age. Upper Eocene sandstones and siltstones of the Rocky Point formation lie unconformably on the Tillamook volcanic series and have a thickness of 1,000 feet. Past authors have referred to these beds as the Cowlitz formation, chiefly on the basis of faunal comparison with the type Cowlitz in Washington.

The Nehalem formation lying above the Rocky Point formation is composed of coarse sandstones, tuffaceous siltstones, mudstones and one local basalt flow and is 500 to 600 feet thick. These beds have been considered to lie within the lower part of the Keasey formation by previous workers.

The Keasey formation lying above the Nehalem beds consists predominantly of tuffaceous, sandy siltstone and subordinately of tuffaceous sandstones, with a partial thickness of some 1700 feet. The Keasey formation is considered to be lower Oligocene in age.

The Pittsburg Bluff and overlying Scappose formations are exposed in this area but will not be discussed further in this report except to mention that the middle Oligocene Pittsburg Bluff formation has an abundance of well preserved fossils in its lower part and is composed

Plate 3
CORRELATION CHART

		West Coast Standard	U.S.G.S. Prel. Map #42	This Report
TERTIARY	OLIGOCENE	Blakeley	Scappose fm.	Not involved in this Report
		Lincoln	Absent (?)	
			Pittsburg Bluff formation	
			Keasey formation	Keasey formation
		Keasey		Nehalem fm.
	EOCENE	"Tejon"	Goble Vol. Series / Cowlitz	Rocky Point formation
		"Transition Beds"	Tillamook Volcanic Series	Tillamook Volcanic Series
		"Domengine"		
		"Capay"		
	PALEOCENE	"Meganos"	Base not Exposed	Base not Exposed
		"Martinez"		

essentially of tuffaceous sandstones that are 700 to 850 feet thick (10), whereas the Scappose formation is upper Oligocene or lower Miocene in age and comprises 1500 feet of fossiliferous, tuffaceous sandstone (10).

The formations of this area are shown on plate 3.

ROCKY POINT FORMATION

The type locality of the Rocky Point formation is on Rock Creek about a quarter of a mile downstream from Keasey Station, extending from an exposure of stratified argillaceous sandstone containing large calcareous concretions up Rock Creek approximately three-quarters of a mile to the Pacific Railway trestle where the basal conglomerate rests unconformably on Eocene Tillamook volcanics. The formation is named from a prominent physiographic feature called Rocky Point Lookout that occurs about a mile west of the Columbia County Quarry. The formation consists of sandstone and siltstones which Warren (10, p. 221) referred to as the Cowlitz formation. Previous use of the name "Cowlitz formation" in this area has been based on faunal correlation with the type section of the Cowlitz formation in Washington rather than on a lithologic basis.

The writer, accompanied by Mr. Harold Boyd, instructor in geology at Oregon State College, visited the type section of the Cowlitz formation in the fall of 1952. A reconnaissance was made along Olequa Creek between Vader and Winslow, where the amended type section of Cowlitz strata as designated by Weaver (12, p. 94) occurs, and although the strata are essentially sandstone and shales, there is little resemblance to the Eocene strata of the Rock Creek section. If one regards Weaver's original type

locality on the Cowlitz River to be the type Cowlitz section, then there is no similarity whatsoever between the northwest Oregon Eocene beds and the type Cowlitz formation of Washington. Three-quarters of a mile east of Vader, a roadcut has exposed stratified, concretionary, micaceous sandstone that closely resembles sandstone in the Rock Creek section. Nonetheless, the conclusion was reached that, despite the resemblance of this one outcrop to the Oregon section, the major portion of the Winslow-Vader amended type Cowlitz and the original type Cowlitz on the Cowlitz River in Washington is not sufficiently similar to the Oregon upper Eocene to enable extension of the name "Cowlitz" into northwest Oregon. Hence, it is proposed that the name "Cowlitz" be dropped for Eocene strata in this part of northwestern Oregon and that the name "Rocky Point formation" be employed to designate the late Eocene strata of the upper Nehalem Basin.

Three major lithic units of the formation are: a lower member, consisting of basaltic conglomerate and medium grained sandstone; a micaceous siltstone member containing resistant, coarse sandstone beds near the middle; and an upper micaceous, concretionary sandstone member that weathers light brown.

Lower Member

The lower unit consists of a moderately to well

Figure 1. Rock Creek section - massive boulder and cobble conglomerate, base of Rocky Point formation.

Figure 2. Columbia County Quarry cobble conglomerate, base of Rocky Point formation.

indurated brown boulder conglomerate resting unconformably upon Tillamook volcanics (Fig. 1). Composition of the pebble and boulder constituents exposed on Rock Creek is entirely basaltic. A large percentage of these have been altered to serpentine and chlorite. Along the strike about 7 miles to the south, the basal contact is picked up at a small quarry and at this locality an investigation of the pebbles revealed a few andesitic types (Fig. 2). Warren (10, p. 222) reported a thickness of approximately 200 feet for the conglomerate 3 miles southwest of Timber and also suggested a predominantly basaltic pebble and cobble composition. A minimum thickness of 60 feet was computed for the conglomerate on Rock Creek, although the unit is largely concealed and may be much thicker.

Medium to fine grained greenish brown sandstone overlies the conglomerate. The sandstone is composed of angular to subrounded basalt fragments, moderately cemented by a brown ferruginous matrix. Near the top the sandstone is fine grained, takes on a dark green color, weathers evenly to light shades of brown, and contains small, round, sandy concretions. The top of the unit is concealed by soil mantle just beneath which a 2-foot bed of basaltic pebble conglomerate is noted to grade up to a gray, micaceous, brown weathering, carbonaceous, sandy siltstone. The sandstone is exposed only in the Rock Creek section

a few hundred feet south of the railroad trestle along a new logging road where it is largely concealed; it controls relatively steep mountainous topography.

An undeterminable concealed thickness separates the lower unit from the next member; it would be necessary to assume the amount of throw of the southern fault on Rock Creek (see plate #8) in order to compute the thickness of this interval.

Middle Member

The sandstone is overlain by 100 feet of gray, micaceous, concretionary siltstone which weathers light gray or locally spotty reddish brown. It alternates with resistant gritstone beds every 2 to 3 feet for a thickness of approximately 40 feet near the middle portion, and then grades back again toward the top to a gray, micaceous siltstone. This member is exposed best along the Nehalem River below the Sunset Highway bridge less than a quarter of a mile east of Sunset Camp. It may be followed south along the strike for more than a mile. Small nodular 3 to 5 inch concretions are common and often in alignment. Macrofossils are locally common but are generally poorly preserved. Microfossils are not common but are present locally.

Thickness

A minimum thickness of 100 feet was measured for this

member in the Rock Creek section. However, it is quite probable that a greater thickness exists. A minimum thickness of 56 feet was measured in the Sunset section. A much greater thickness is possible, however, because neither the base nor top is exposed.

Upper Member

Approximately 500 feet of massive to well stratified sandstone forms a conspicuous part of the upper part of the Rocky Point formation. The top of this member was selected as the top of the Rocky Point formation as it is the most widespread and easily recognized horizon in the formation as exposed in the upper Nehalem Basin. The sandstone is best exposed along Rock Creek in outcrops a few hundred feet both upstream and downstream from Keasey Station (plate #8) but it also appears at two places along the Nehalem River (Unit 17 in Section A-5) as well as in the top part of the Timber section. The Nehalem River exposures are poor, however, with only a few feet exposed at both localities. Calcareous concretions typical of the upper member in the Rock Creek section occur as float and identify the unit in both outcrops.

The sandstone member is variable in sedimentary structure but varies only slightly in composition. Near the base the member is massive, micaceous, and quartzose and contains the typical large calcareous concretions in 2 to 3 foot

Figure 3. Upper member Rocky Point formation. Note stratification in lower right corner.

discoidal forms. The medial part of the member is argillaceous and well stratified, and weathers light brown (Fig. 3). Stratification is represented locally by lamination of coarse and fine material, locally showing irregular cut-and-fill structures. In places the alternating layers of coarse and fine clastics attain thicknesses of 3 to 8 inches, but generally the individual beds are less than one inch thick. This portion of the member is characterized by conspicuous resistant concretionary beds that weather to discontinuous ledges. A thin section of a typical concretion exhibits the following characteristics:

50-60% calcite: partially finely divided calcite crystals with variable orientations, structureless calcite predominates as cement.
7-10% biotite

10-15% feldspars, angular
5% quartz, angular
1% pyrite
1- 2% glass

The top portion is massive and retains the same composition but lacks the concretions and weathers light rust brown. Approximately 3 miles west of Sunset Camp the member is exposed on a hillside a few hundred feet north of Wolf Creek. Here it is gray brown, micaceous, massive and resistant, and locally cross bedded. Cross bedding was absent in the other exposures. So far as known, fossils are completely lacking in this member.

A thin section of a specimen taken from the middle portion of the member reveals a graywacke composition as defined by Pettijohn (6, p. 244). The author realizes that one thin section hardly is representative of the whole member, but in the field very little essential change in mineralogy was noted. Examination of the thin section revealed a composition predominantly of medium to acid plagioclase feldspars, quartz, micas, and a small amount of basaltic rock fragments cemented by a calcareous matrix of feldspathic silt. The feldspars are predominantly angular to subhedral, with a few euhedral forms. Quartz is milky and subangular to subrounded. Biotite is more common than muscovite and is typically oriented along bedding planes with many of the crystals bent. Basaltic rock fragments represent a minor percentage and are

generally subrounded. One crystal of green hornblende was noted.

Thickness

A minimum thickness of 550 feet was measured for this member on the Rock Creek section but probably the true thickness may exceed this figure considerably. Minimum thickness of the member in the Sunset Highway section is 450 feet.

Structure

Structural interpretation of the Rocky Point formation exposed on Rock Creek is clearly shown by a cross section included in plate 8. In general the formation has been folded into a moderate anticlinal structure and broken later by two high angle reverse faults. The anticline plunges to the northwest; the axis has been plotted on plate 8. Elsewhere in the area the structure is not thought to be as complex, although it is probable that faulting has been the basic cause of stratigraphic confusion along the Nehalem River.

Attitudes are generally low, ranging from 10 to 15 degrees in the Rock Creek section. At the base of the Sunset section along the Nehalem River, dips were recorded of as much as 22 degrees.

Age Relations

Strata belonging to the Rocky Point formation exposed

on Rock Creek and along the Nehalem River have been referred to by Warren (10, p. 221-225) and Weaver (12, p. 172) as upper Eocene. The writer made two macrofossil collections from the lower member but they were nondiagnostic. Foraminiferal collections from the lower unit of the Nehalem formation that lies immediately above the upper member of the Rocky Point formation were determined by H. A. Boyd Jr. (personal communication) to be either upper Eocene or lower Oligocene. The lower member of the Rocky Point formation lies above unquestionably Eocene Tillamook volcanics. In conclusion the stratigraphic relations and microfossils point to an upper Eocene age for the Rocky Point formation.

NEHALEM FORMATION

The name "Nehalem formation" is proposed to designate the heterogeneous lower Oligocene strata lying between the more homogeneous uppermost Rocky Point strata and lowermost Keasey strata. The type section of the Nehalem formation is on Rock Creek approximately one quarter of a mile northwest of Keasey Station extending from an exposure of mudstones down Rock Creek in a northwesterly direction approximately 700 feet to an exposure of micaceous sandstone. The lithology is variable over the area studied; in no two sections are the details of lithology the same. The chief basis of mappability of the Nehalem formation is its field occurrence between the easily recognizable overlying Keasey formation and the underlying equally recognizable Rocky Point formation. Since the variable strata cannot be included logically within either of the previously named map-units, it was decided that these admittedly poorly exposed and diverse sedimentary rocks might better be separated from the Keasey and Rocky Point formations and be given separate formational status. Somewhat similar Pacific Coast examples of lithologically heterogeneous but cartographically real units include the Franciscan formation (upper Jurassic of California) and the Clarno formation (Eocene of central Oregon).

In discussing the stratigraphy of the Nehalem formation,

the units will be described at each of the three main areas of study in which they occur.

Rock Creek Section

The beds designated as belonging to the Nehalem formation in this section lie above the upper member of the Rocky Point formation and are interpreted as being in fault contact with the lower Keasey formation (see plate 8). Lithologically they cannot be included within either the overlying Keasey or underlying Rocky Point formation. With the exception of the fault mentioned above, there is no unusual structural complexity apparent in the field at this locality.

The major portion of the formation in this section is represented by a minimum of 230 feet of compact, stratified, dark gray mudstones that weather to a light gray, crumbly surface (Fig. 4). Near the base there are a few thin glauconitic sandstone interbeds. Sand seams, less than a quarter of an inch thick, are common. The fauna is dominated by the pelecypod, Amussium sp., found primarily on bedding planes. Foraminifera are common; a collection from the upper part of the unit yields the following forms:

Cyclammina sp.
Spiroloculina sp.
Robulus sp.
Robulus welchi Church
Nodogenerina sp.
Uvigerina garzaensis Cushman & Siegfuss
Cibicides hodgei Cushman & Schenck
Cibicides sp.

Figure 4. Rock Creek Section lower Nehalem formation mudstones

According to Mr. H. A. Boyd Jr. (personal communication) the assemblage is indicative of either upper Eocene or lower Oligocene age.

The next higher unit is represented by approximately 15 feet of dark grayish black, fine, sandy siltstone commonly weathering light gray and locally to a spotted reddish brown. The contact between the lower mudstone and this siltstone unit is concealed so that contact relations are not known. Furthermore, the bed is poorly exposed and was seen in only a few low creek banks. Approximately 10 feet above the base of the exposure a conglomerate bed is intervalated within the main siltstone unit. Thickness of the conglomerate was estimated to be about 7 feet although the top has been truncated by stream erosion.

Lateral extent of the conglomerate is not known because it is exposed in only one outcrop. The bed is dark brownish gray, contains many yellowish calcite veinlets, is well indurated, and weathers to a pitted, light grayish green surface. A thin section cut from a rock collected near the middle of the bed has been considered in the treatment of this unit in the discussion of the measured section (page 71). The composition is represented on page 23 in tabular form to demonstrate the similarity between this unit and a coarse sandstone unit in Section A-4 on the Nehalem River.

Macrofossils are absent in the siltstone and foraminifera are locally common. A collection of foraminifera contains the following forms:

Nodosaria grandis Reuss
Pseudoglandulina sp.
Guttulina irregularis Cushman & Ozawa
Bulimina cf. pyrula d'Orbigny
Plectofrondicularia packardi Cushman & Schenck
Planulina haydoni Cushman & Schenck
Pullenia salisburyi Stewart & Stewart
Cibicides sp.
Cibicides aff. perlucida Nuttall

According to Mr. H. A. Boyd Jr. (personal communication) the assemblage is diagnostic of Refugian (lower Oligocene) Age.

The top portion of the Nehalem formation along Rock Creek is composed of approximately 20 feet of fine to medium grained micaceous, gray black, concretionary

sandstone that weathers light gray or locally light gray with yellow spots. Fossils are lacking in this bed but at the top a three-foot bed of nodular sandy limestone contains an abundance of medium sized pelecypods which, however, cannot be identified because they cannot be broken free of the rock matrix in which they are contained. The limestone bed makes an irregular contact with the lower sandstone; it is light blue gray and weathers to a nodular gray surface. Two unidentifiable fish teeth were found.

Faulting prohibits estimation of the true thickness of this unit and necessarily prohibits description of the nature of the Keasey-Nehalem boundary along Rock Creek.

Nehalem River Partial Sections

Uncertainty regarding structure and the discontinuity of exposures make it difficult to classify units in the several fragmentary stratigraphic sections along the Nehalem River. In light of the present structural interpretation, the writer has assigned two sections (A-4 and A-2) to the Nehalem formation in this vicinity.

Section A-4 has been included within the Nehalem formation at this locality because the beds are lithologically dissimilar from the Keasey lithology and if their attitude may be interpreted at face value, the projected continuation of these beds below the surface of the ground

Figure 5

Minerals	THIN SECTIONS	
	Nehalem River A-4	Rock Creek B-12
Calcite	Primary 5% Secondary 55%	Primary 3% Secondary 47%
Glauconite	1-2%	30%
Basaltic Rock Fragments	15%	10%
Plagioclase Feldspars	10% Albite Oligoclase Labradorite Bytownite	10% Albite Andesine Labradorite
Mafics	1% Hornblende Augite	1% Augite

would bring them beneath the lower Keasey beds in Section A-1. Likewise, the projected attitude of the Rocky Point formation as exhibited in Section A-5 would indicate that the Rocky Point formation occurs beneath the Nehalem beds in Section A-4.

In Section A-4 the lower unit consists of a coarse grained, blue gray, pebbly, calcareous sandstone. The unit weathers to brown resistant ledges. It is found only in one 15 foot outcrop. Petrography of a single thin section from each locality suggests correlation with the conglomerate bed of the Nehalem formation on Rock Creek by the similarity in components of basaltic rock fragments, the wide variation in plagioclase species (albite to labradorite) and percent of calcite as matrix.

A tabular representation of thin sections of each unit shows a direct comparison of the two lithologies (Fig. 5).

A roadcut less than 100 feet southeast of the Columbia County line and approximately 3.5 miles north of Sunset Camp has exposed a deeply altered basalt flow intercalated between two lithologically dissimilar sandstone units. Section A-2 is interpreted as being in fault contact with the lower Keasey formation in this locality. An extension of these beds southward, toward Section A-7, would find them dipping below lower Keasey lithology in Section A-7, and if interpretation of Section A-7 is correct, the actual contact of the Nehalem and Keasey formations may be seen at the base of this section (see discussion page 34). One may also consider the probability that the basalt represented in Section A-2 is actually Tillamook Volcanics brought to its present position by a major fault. However, in view of the present interpretation in projecting the dip of Section A-2 beneath the beds at Section A-7, without any indication of structural disturbance between the two sections, it is plausible to consider the basalt flow as a local flow within the lower Oligocene of the Nehalem formation, but the correlation of Section A-2 with the Nehalem formation remains uncertain.

The basalt weathers to a dirty grayish green but on

fresh fracture it is dark gray. Its crystalline texture rarely is preserved. Vesicularity is common and many of the vesicles have been filled with amygdules of calcite, quartz and zeolites; brown chalcedonic vein fillings are common. The position of the flow between marine sandstone beds and its high degree of alteration and accompanying secondary mineralization point to a submarine origin.

The sandstone bed that lies unconformably beneath the basalt is largely concealed by the Nehalem River at the point of contact with the basalt but less than 100 feet downstream it is better exposed in the stream bed. The sandstone is medium grained, brownish gray, partly micaceous and moderately indurated. Plagioclase laths are occasionally seen with the hand lens as are a few disseminated pellets of glauconite. A thin section description of this unit is included in the section description on page 61.

The overlying sandstone makes an irregular contact with the basalt and grades from extremely coarse grained sand near the base to a medium grained sand about 2 feet up from the base and continues upward 10 feet in this phase until it is concealed. The sandstone is brownish gray, glauconitic, weathers light brown and is moderately indurated. Its lithology is similar to that of the lower sandstone but not identical.

Thickness of the Nehalem formation as exposed in Section A-2 is 55 feet.

Sunset Section

Supposed Nehalem beds occur in a continuous, apparently uncomplicated sequence between the middle member of the Rocky Point formation and lower Keasey lithology although the actual contacts of both units are concealed. Interpretation (see plate 9) has led to the insertion of a part of the upper Rocky Point member in the concealed interval between the middle Rocky Point member and Nehalem lithology. It is conceivable that these beds are in fault contact with the lower member of the Keasey formation. However, there is no physiographic evidence for faulting, and beds similar in lithology to this facies of the Nehalem formation are not known to occur higher in the section in this area. Hence, it is unlikely that younger Oligocene strata, such as the similarly tuffaceous Eugene formation, have been dropped down into the Sunset Highway section along a hypothetical fault. So these problematical beds are here included with the Nehalem formation.

The Nehalem formation is represented in this section by a dominant lithology of gray brown siltstone and fine grained sandstone alternating with thin beds of waterlaid tuffs. The base and top of the section are both concealed.

Approximately eight coarse to medium coarse sandy tuff beds varying in thickness from slightly less than one foot to 4 feet break the sedimentary continuity at 15 foot to 45 foot intervals up the section. The ash beds are generally yellowish gray, grayish white and rarely a clean white and are composed of angular to subangular black rock fragments, plagioclase feldspars and/or quartz and fresh to deeply altered glass shards. Induration is generally moderate to poor; some units are subdued and friable, others, although not well indurated, stand out as partially resistant ledges.

The intermittent siltstones have essentially the same composition and vary only locally in texture and degree of sorting. They are generally gray brown and vary in color from light gray to greenish gray and brown; the weathered surface shows medium shades of yellowish brown. An irregular joint system has developed in most of the units but the orientation of joints is not well defined. Joint planes commonly weather to reddish brown iron residuals, black carbonaceous stains are also common. The sandstones and siltstones are partially composed of materials of volcanic origin i.e., glass shards and volcanic rock fragments. The components are generally angular to subangular with a small proportion showing subrounded forms. Stratification is usually lacking

although faint stratification is seen locally. Fossils are absent.

Thickness

The thickness of the Nehalem formation in the Sunset section is 554 feet.

Stratigraphic Problems

Placement of units of the Nehalem formation in correct position with respect to regional stratigraphy becomes a problem that can be resolved only on an interpretative basis because of structural complexity and paucity of exposures. The following discussion is presented in order to account for the lithologic variation from the Rock Creek section to the Sunset section.

On Rock Creek the Nehalem formation is in fault contact with the lower member of the Keasey formation. This position has resulted from movement along a reverse fault that has brought the Nehalem formation up to its present position. Beds that should overlie the uppermost unit of the Nehalem formation at this locality have been removed by erosion. Such beds are present both along the Nehalem River and in the Sunset section.

Interpretation has led to insertion of a part of the upper sandstone member of the Rocky Point formation to occupy most of the concealed interval below the Nehalem formation within the Sunset section. The 400 foot concealed

interval between the uppermost Nehalem beds and lower Keasey lithology conceivably may contain Nehalem units of either the Rock Creek or Nehalem River sections. Part of this interval probably contains lower Keasey lithology as the lower member of the Keasey formation is between 400 and 500 feet thick (10, p. 225) at its type locality on Rock Creek as compared to less than 100 feet of exposed lower Keasey lithology in the Sunset section. There is no suggestion that the lower Keasey member thins toward the south as that member is well exposed along the Nehalem River northeast of Sunset Camp and is computed to be at least 400 to 500 feet thick at this locality. It is plausible, too, that units present on Rock Creek may be represented by still different rock types on the Sunset Highway. The distance of some 12 miles separating the two sections can allow considerable variation in local environments of deposition.

In conclusion, the strata that are included in the formation occupy an interval between two known horizons, lower Keasey sandy siltstones and upper Rocky Point concretionary sandstones and in none of the areas studied was lithology of the Nehalem formation sufficiently similar to be included in either the Rocky Point or Keasey formations. Therefore, the term, Nehalem formation, has been employed to refer to all the sedimentary rocks and the basalts between these two definite horizons.

KEASEY FORMATION

The Keasey formation furnishes the most distinctive lithology of the upper Nehalem Basin. It is best exposed along the Sunset Highway in highway cuts westerly along the highway for almost two miles from the Sunset Tunnel. Elsewhere in the area excellent exposures may be seen sparingly in high creek banks along the Nehalem River between Sunset Camp and Vernonia. Excellent exposures also may be seen in highway cuts along the road between Buxton and Vernonia. About a mile and a half below Keasey Station, Keasey lithology is well exposed in high creek banks.

Schenck in 1928 designated the type section of the Keasey formation on Rock Creek 0.7 miles below Keasey Station at an exposure of "dark bluish gray, fossiliferous, tuffaceous, sandy siltstone." Weaver in 1937 and Warren in 1945 enlarged the definition of the Keasey formation to include younger beds that crop out farther down Rock Creek from Schenck's type section and assigned these beds to the middle and upper member of the Keasey formation.

The writer has recognized two major lithologic divisions of the Keasey formation and has assigned them to a lower and middle member; the upper member of Weaver and Warren apparently is higher in the section than the writer worked. The lower member includes lithology of Schenck's

type section and similar lithology exposed in other areas. The middle member includes beds that Weaver and Warren assigned to middle Keasey. Lithology of the middle member is described from the measured Sunset section which exhibits the best continuous exposures of middle Keasey lithology to be found in the area.

Lower Member

The lower member is typically dark bluish gray, tuffaceous, fossiliferous, sandy siltstones. It characteristically weathers to light and dark shades of reddish brown. Concretions generally form a conspicuous part of most exposures and are present as round and nodular forms which average about 6 inches in diameter but range from 2 inches to 3 feet in diameter. Concretionary beds are also common and where present weather to resistant ledges. Lenses of glauconitic sandstone are characteristic of this member. They are not known to occur at any particular horizon in the member and glauconite is not limited to the sandstone phases but may be found locally disseminated in almost any part of the member. Worthy of mention is a 15-25 foot lens that occurs in Section A-1 along the Nehalem River (Fig. 7). It is medium grained and dark gray in fresh rock and weathers to a light green surface. A thin section of the rock reveals the following approximate mineral composition:

75% glauconite: green to yellow pellets, composed largely of microlitic silt particles. A few take on deformed shapes when grown around feldspars.
5% plagioclase feldspars: assigned to species andesine and oligoclase; predominantly subhedral with notable rounding of corners; few show marked angularity. Kaolinization is minor.
7-10% rock fragments: predominantly basaltic; limestone fragments represent about 2% of volume; two quartzite fragments were noted; all components subrounded to well rounded.
1% quartz: angular and subrounded
7% calcite: matrix
<1% pyrite: authigenic
volcanic glass shards
biotite

Limestone is absent in most exposures but a notable exception is one sandy limestone lens that occurs in Section A-1 (plate 4) immediately above the glauconitic sandstone bed. The limestone lens contains an abundance of medium sized venerid clams.

The main siltstone units are composed largely of unidentifiable silt particles, glass shards, occasional plagioclase laths, variable amounts of glauconite, and a minor amount of mafics, pyrite and mica; a slight carbonate reaction with acid was noted in some samples. The siltstone is not bedded although faint stratification is common locally. Concretionary ledges and alignment of concretions generally serve to mark stratification. In the Sunset section near the contact with the middle

Figure 6. Lower member, Keasey formation, located 0.3 miles west of Sunset Camp. Note concretionary beds.

Figure 7. Lower member, Keasey formation; line drawn on contact of glauconitic sandstone lens above.

member of the Keasey formation stratification is notable. Alternations of fine and slightly coarser material has produced a shaly structure with bedding less than 1/4 inch thick. Microscopic study of fragments broken down from a sample taken at this locality reveals the following approximate composition:

50-60% basalt fragments: subrounded and well rounded.
15-20% plagioclase feldspars: subhedral and subrounded.
albite
oligoclase
andesine
1- 2% quartz: subrounded.
5-10% volcanic glass: green and brown.
5- 8% glauconite: yellowish green, pleochloric felt-like mass of silt particles.

The base of the lower member was not positively found. There is some evidence however that the contact between the conglomerate and underlying siltstone unit in Section A-7 (plate 6) may mark the base of the Keasey formation. This contact was poorly exposed, being almost entirely covered by slope talus or vegetation and consequently samples of the siltstone were difficult to obtain in fresh condition. The evidence to suggest that this may be the Keasey-Nehalem contact is: (1) the siltstone does not resemble lower Keasey lithology and may therefore be a part of the Nehalem formation, (2) the conglomerate grades up into typical lower Keasey lithology and furthermore this section is the only section in which

conglomerate lithology is found in the lower member, and (3) according to structural interpretation the Nehalem-Keasey contact should occur in this vicinity.

Typical exposures of this member are located 0.7 miles west of Sunset Camp (Fig. 6), 0.3 miles northeast of the Columbia County line along the Nehalem River (Fig. 7), approximately 6 miles from Vernonia toward Keasey along Rock Creek, and on the Sunset Highway near the top of the grade east of Sunset Camp.

Thickness

The writer measured only a part of this member in the Rock Creek section, where it was computed to be 170 feet thick. Warren estimated this member to be between 400 and 500 feet thick on Rock Creek. A few miles north of Sunset Camp and along the Nehalem River the lower member is exposed in several places and was computed to be at least between 400 and 500 feet thick. In the Sunset area a section of 55 feet was measured. The base of the exposure here is followed by a 400 foot concealed interval so that an estimate of the true thickness is impossible.

Middle Member

The middle member is lighter in color in fresh rock, contains a higher percentage of tuffaceous material than the lower member, and weathers to light shades of brown and buff. Lithology of the middle member is described in

detail from the Sunset measured section. Excellent exposures of the member occur along the Sunset Highway near the Sunset Tunnel and in the Empire Light Rock Quarry a few hundred feet southwest of the Sunset Tunnel. Good exposures may also be seen along the Nehalem Highway between Buxton and Vernonia.

The base of this member is exposed on the Sunset Highway east of Sunset Camp near the top of the grade and is marked by a sharp lithologic contact of pebble conglomerate overlying dark bluish gray sandy siltstones of the lower member (Fig. 8). Microscopic study of fragments of the conglomerate matrix reveals the following estimate of its composition:

70-80% rock fragments: igneous types (basaltic) subangular, few subrounded forms.
10-15% plagioclase feldspars: euhedral angular and subrounded, zoning of labradorite.
oligoclase
labradorite
andesine
1- 2% quartz: subrounded
<1% hornblende
2- 4% volcanic glass

The conglomerate contains polished and well rounded pebbles that range in diameter from 1/4 to 3 inches. The pebbles are dominantly basaltic, although a few are composed almost entirely of a pyroxene mineral. The pebbles are embedded in a coarse sandstone matrix that contains

Figure 8. Contact between base of middle member and top of lower member, Keasey formation, Sunset section.

nearly 25 percent of a green structureless material that under the microscope was seen to be composed of microlitic particles embedded in an amorphous green matrix. The green material is believed to be a low grade type of glauconite. Two feet below the top the conglomerate bed begins to grade to sandstone. Pebbles become progressively smaller upward until the lithology is dominantly sandstone. The conglomerate bed is 5 feet thick.

Eighteen feet of medium to fine grained, greenish gray sandstone overlies the conglomerate member. It is moderately indurated, generally non-stratified and weathered light grayish buff. Stratification is present locally and is expressed by thin bedding planes less than 1/2 inch apart. Carbonaceous material is seen locally. Approximately 4 feet below the upper contact lenses and

stringers of coarse sand are common. The contact between this unit and the unit above involves a sharp change in color from light greenish gray in the lower unit to medium gray in the upper unit. The contact is marked by a resistant concretionary ledge about 15 inches thick where typical middle Keasey lithology begins.

This next sandstone unit is more uniform in texture than the lower sandstone and is predominantly fine grained, giving way locally to medium grained phases. The sandstone is uniformly medium gray but weathers to a light blue gray or in spots to reddish brown. A few small 3- to 4-inch subrounded and nodular concretions were noted. Microscopic study of fragments of the sandstone reveals the following approximate composition:

50-60% rock fragments
15-20% plagioclase feldspars: not identifiable
15-20% volcanic glass
<1% biotite and muscovite

The rock is composed essentially of sharply angular igneous fragments with minor amounts of feldspars and glass in equal proportion; a few pieces of biotite and muscovite were noted. In the hand specimen feldspars, glass and occasional flakes of mica may be identified. A concealed interval of 62 feet separates it from the next higher unit.

Approximately 146 feet of greenish gray, tuffaceous siltstone overlies the medium gray sandstones. Lenses and stringers of medium grained sandstone are common,

concretions are small and rarely seen and fossils are absent.

The remaining 1228 feet of measured Keasey lithology is represented by medium gray, tuffaceous, sandy siltstones, generally non-stratified to faintly stratified with concretions and well preserved macro- and micro-fossils locally abundant. The siltstone is compact, generally shows a well developed irregular joint system, and weathers to light shades of brown and reddish brown. Sand seams from 1/2 inch to 1 inch thick locally mark stratification and are composed of angular feldspars, quartz, calcite and minor amounts of basaltic rock fragments. Two sandstone dikes are exposed in a 12 foot roadcut located about a mile and a half east of the Sunset Tunnel; they cut the siltstone almost vertically. Both dikes are approximately 18 inches wide at the top of the exposure and taper to 6-inch branches at the base of the exposure. They are dirty grayish white in color and are composed of angular fragments of quartz, feldspar and dark igneous rock fragments (probably basalt). In one of the dikes unoriented siltstone fragments ranging in size from 1 inch to one 2-foot angular block were noted. Near the base of both dikes a black carbonaceous residue appears as a secondary stain.

A thin section was made from a concretion that is

considered representative in composition of other Keasey concretions. It was found to be composed of the following approximate percentage of minerals:

70% matrix: calcite, extremely fine grained.
15-20% glass
5% feldspars
2- 3% pyrite
<1% biotite
<1% mafic
1% glauconite
minerals all angular

The top of this member was not included within the measured section. Warren has indicated a faunal boundary between the Keasey formation and the overlying Gries Ranch beds in the close vicinity of the Sunset Tunnel. A cursory investigation of this area did not show a lithologic change between the two formations. East of the Sunset Tunnel excellent exposures are afforded by high road cuts for a distance of about a mile. A section measured along here would probably pick up the Keasey-Gries Ranch boundary if the boundary is lithologic and not merely faunal.

Thickness

The partial section of middle Keasey, measured on the Sunset Highway is 1653 feet thick.

STRUCTURAL GEOLOGY

General Structure

Fundamental structure of the area studied is controlled by the anticlinal deformation of the Oregon Coast Range. The uplift is said by Weaver (13, pp. 1397-1398) to have occurred at the close of the Pliocene epoch. Structural deformation of the major portion of the Tertiary sediments probably may be related to activity during this time or shortly thereafter. The sedimentary beds included in this report lie on the easterly flank of the Coast Range anticlinorium in northwestern Oregon.

Although the structure of the upper Nehalem Basin is not clearly known, folding and faulting have produced structures that have complicated the local stratigraphy. Between Sunset Camp and Vernonia and farther east along the Sunset Highway between Sunset Camp and the Sunset Tunnel, the strata dip generally to the east with moderate to low dips. This homocline has been broken locally by normal and reverse faults, mostly with minor throw. However, at places along the Nehalem River faults with major displacement must be proposed in order to explain the stratigraphy. A cross section (plate 9) has been prepared to show structural interpretation between Sunset Camp and the Sunset Tunnel.

Farther to the north along Rock Creek, near Keasey

Station, the structure is more complex. Structural interpretation of the area in which the Rock Creek section was measured appears in cross section on plate 8. The structure includes a rather broad anticline and the southwest limb of a syncline that has been faulted in three places. Two of the faults are high angle reverse faults. The Tillamook volcanics have been brought up by a reverse fault, the southernmost of the faults shown in the cross section. The fault in the middle of the section has brought middle Rocky Point up and in fault contact with the upper member of the Rocky Point formation. The effects of drag on the down throw block are expressed by a number of small faults for a distance of some 30 to 50 feet from the fault contact. It is not known whether the northern fault is normal or reverse as the fault was drawn primarily to explain the stratigraphy but by analogy with the other faults in the section it probably is reverse too. This fault has brought the Nehalem formation up and in fault contact with the Keasey formation.

GEOLOGIC HISTORY

General Statement: The oldest exposed marine rocks in northwestern Oregon were deposited in late Eocene. Deposition probably continued uninterruptedly into the lower Oligocene. To presume that the sea retreated after the latest Eocene and then swept back into the area in lowest Oligocene is unlikely and not necessary to explain the stratigraphy. Warren's (9, p. 235) suggestion that the sea retreated and then re-invaded the area at the Eocene-Oligocene boundary is a more complicated solution than to assume continuous deposition across that time boundary. The writer suggests that the sea during late Eocene was transgressive westerly as the depositional basin was filling and that sedimentation was continuous through late Eocene into the lower Oligocene. Sufficient evidence to prove either a continuation or a break in sedimentation is lacking.

The major portion of the Eocene sediments were deposited in a near shore or shore environment under conditions of rapid deposition and subsidence. The initial Eocene record of basaltic boulder and cobble conglomerate and basaltic sandstone suggests that these sediments were derived largely from a volcanic terrain, probably exposed areas of the Tillamook volcanic series. Later in the Eocene the sediments became fine grained and micaceous as the basaltic

contributions became almost negligible. A marine fauna was incorporated in the lower part of this phase but not in the final sediments of the Eocene.

Initial Oligocene deposition was marked by extreme variability that gave rise to such diversified rocks as mudstones, coarse sandstones and waterlaid tuffs. Succeeding Oligocene sedimentation was more uniform as fine-grained clastic facies predominated although fluctuations intermittently produced coarser units, particularly near the base of the middle Keasey. Volcanic materials constituted a major source of the Oligocene sediments.

The position of the landmass that was a source area for Eocene sediments has received considerable discussion in geologic literature of northwestern Oregon and Washington, particularly with reference to a westerly landmass. On the basis of areal distribution and lithic character of Eocene and Oligocene sediments in Washington and of an Oligocene overlap to the west, Weaver (13, pp. 1407-1409) visualizes a peninsula-like orogenic belt to the west forming a north-south trough that extended from Vancouver Island to some unknown place west of Coos Bay, Oregon. Eardley (3, pp. 451-452) suggests that this may have been a continuation of the theoretical Paleozoic and Mesozoic West Coast Volcanic Archipelago. Stratigraphic information is yet too meager in Oregon to prove a westerly landmass

as a source of Eocene sediments.

In support of the existence of a westerly landmass is the position of an Eocene shoreline in the upper Nehalem Basin. The sedimentary record is indicative of an active landmass, whose location is unknown, composed almost entirely of volcanic rocks. There is some suggestion that the Eocene conglomerate becomes finer towards the east, for if a north-south strike may be assumed, the boulder conglomerate exposure less than a mile south of the Keasey section may be tied in with the boulder conglomerate described by Warren, three miles southwest of Timber, Oregon. The exposure of the finer pebble and cobble conglomerate at the Columbia County Quarry would be 2.5 to 3 miles down dip. Secondly, the sediments become finer grained up the section so as to suggest either that the sea may have been transgressive to the west or that the water was becoming deeper and the landmass lay farther away from the depositional site. It is probable, however, that if a westerly landmass was present during the Eocene it had subsided before early Oligocene because an Oligocene shoreline has been located clearly some 30 to 40 miles to the east (4).

Summary

The late Eocene and early Oligocene rock suite is composed almost entirely of clastics that vary from

graywacke types to rocks with a considerable admixture of tuff; one local basalt flow was noted. Eugeosynclinal (4) deposition with an Eocene volcanic Archipelago lying to the west is suggested. By early Oligocene the westerly landmass, if present, had subsided or was covered by encroaching waters and sediments derived from an easterly source were fine grained, tuffaceous, and more uniform in character.

MEASURED SECTION DESCRIPTIONS

General Statement: Rock description and designation of rock names has been patterned largely after Pettijohn (6). Rock sample numbers included in the sections have been designated in the following manner: the letter preceding the numbers designates the section, the middle number designates the exposure and the last number designates the sample number at the exposure. Sections were designated during field work as follows: Section A, Nehalem River partial sections; Section B, Rock Creek section; Section C, Sunset section. The rock samples are located in the geology storeroom at Oregon State College.

Fossil collections and location are included in Appendix I, page 82.

SUNSET SECTION

This section was measured along the Sunset Highway starting from an outcrop a few hundred feet east of a bridge crossing the Nehalem River about 0.2 miles east of Sunset Camp and extending easterly for a distance of 3.1 miles to the western edge of the Sunset Tunnel. The section contains strata of the Rocky Point, Nehalem, and Keasey formations in the most continuous section to be found in the area. Unfortunately, all contacts between formations were concealed. The section is located on plate 2. It was measured by using a state highway profile map with a horizontal scale of 1 inch to 100 feet and a vertical scale of 1 inch to 10 feet; a cloth tape and hand level were used on individual outcrops.

Keasey formation: middle member

Unit		Feet
12	Siltstone, sandy, tuffaceous, uniform light gray, weathers yellowish brown, induration moderate; joint system well developed with surfaces brownish red, fracture harsh; 2-4 inch spherical concretions uncommon. Sand lenses locally mark stratification with dominantly angular to subrounded feldspars, quartz and calcite, minor amount subrounded basaltic rock fragments. Fossils uncommon. (Sample C-11-2). Dip 10° S30E.	69
	Concealed.....	44
11	Siltstone, sandy, tuffaceous, massive to faintly stratified, medium gray, weathers uneven brownish buff to reddish brown, wet surface uniform light bluish gray, fracture	69

Unit		Feet
	irregular; joint system well developed, surface weathers deep reddish brown, induration moderate, concretions common. Macrofossils common (Acila nehalemensis), foraminifera common (Sample C-10-2). Unit becomes darker and streaky upward; faintly stratified, large spherical concretions, up to 2 feet in diameter and carbonaceous fragments appear locally; near upper contact unit weathers light yellowish brown, tuffaceous content particularly noticeable, soil mantle brownish yellow, about 2-3 feet thick, concretions absent in upper 15 feet of weathered zone (Sample C-10-4).	
	Concealed.....	406
10	Siltstone, sandy, tuffaceous, dark gray, streaky, weathers bluish gray and reddish buff, induration moderate; two concretionary beds near middle of unit weather to resistant ledges; macrofossils rare, well preserved (Sample C-9-1). Dip 10° S55E.	128
	Concealed.....	47
9	Siltstone, sandy, tuffaceous, faintly stratified, weathers gray brown, induration moderate; spherical and nodular 5-7 inch concretions common; 1 foot thick concretionary bed weathers to resistant ledge near base of unit. Pelecypods (Nemocardium weaveri) common and well preserved.	95
	Concealed.....	90
8	Same as Unit 9, two coarse grained sandstone dikes cut the siltstone diagonally; number 1 dike contains unoriented siltstone fragments ranging in size from 1 inch to one 2-foot angular block with lithology similar to host unit but badly altered. Both dikes thin from approximately 18 inches at the top to less than 6-inch branches near base of 12-foot exposure; fresh color dirty gray white, weathers same, near base black residue appears as secondary stain. Dip 5° S40E.	95

Unit		Feet
	Concealed.....	185
7	Siltstone, tuffaceous, greenish gray, weathers light grayish buff, induration moderate; lenses and stringers of sand common, concretions rare, fossils absent (Sample C-6-1).	146
	Concealed.....	62
6	Sandstone, fine to medium grained, tuffaceous, medium gray, smooth fracturing, weathers light blue with uneven reddish brown iron stains about 10 feet above base; resistant 1-foot concretionary ledge stands out to show stratification, few small spherical concretions, induration moderate, fossils uncommon, mostly gastropods in good preservation (Sample C-5-11).	195

Petrography (fragments)

Composition

50-60% rock fragments
15-20% plagioclase feldspars: not identifiable
15-20% volcanic glass
<1% biotite and muscovite

Composition mostly sharply angular igneous rock fragments with minor amounts of feldspars and glass in equal proportion; a few pieces of biotite and muscovite were noted.

5	Sandstone, tuffaceous, greenish gray, weathers light gray; stratification generally absent, thin beds less than 1/2 inch thick express stratification; sandstone becomes pebbly near base, lower 2 feet stands out as resistant ledge, carbonaceous locally (Sample C-5-8). Grades to poorly sorted sandy siltstone approximately 4 feet below upper contact; tuffaceous sandstone lenses and stringers common, fresh surface uniform greenish gray, weathers even grayish buff (Sample C-5-9). Contact phenomena: unit grades to sandstone within 3 feet of upper	18

Unit		Feet
	contact, black carbonaceous stain on joint surfaces; contact sharp (Sample C-5-10). Dip 18° S20E.	
4	Conglomerate, well rounded, dominantly discoidal pebbles, cemented by coarse green sandy matrix, pebble size range from less than 1/4 inch up to 3-inch diameters, composition dominantly shale or sandstone, small percent basaltic pebbles and a few pebbles composed almost entirely of a pyroxene, weathers irregular reddish brown to light green; induration moderate, sorting poor, becomes finer upward (Sample C-5-7). Dip 18° S20E.	5

Petrography (fragments of matrix)

Composition

70-80% basalt fragments: subangular, few subrounded forms.
10-15% plagioclase feldspars: euhedral angular and subrounded, zoning of labradorite
oligoclase
andesine
labradorite
1- 2% quartz: subrounded
<1% hornblende
2- 4% volcanic glass

Keasey formation: lower member

3	Siltstone, sandy, partly tuffaceous, grayish blue, massive to well stratified; local dominance of tuff imparts streaky appearance; lower part of unit is gray blue, faintly stratified; near middle fresh color changes to lighter gray brown and siltstone has excellent stratification expressed by thin, less than 1/4 inch, alternations of fine and medium fine components; unit grades upwards into flaggy structure, with alternations of light brown and gray blue, fine and medium grained siltstones, lenses and stringers of sand common (Sample C-5-5). Near top of 3 foot stratified zone, unit grades up into massive to faintly stratified blue gray	30

Unit Feet

concretionary sandy siltstone, upper phase is in sharp contact with upfaulted sandy, pebble conglomerate; near upper contact glauconite pellets disseminated in small percentage, subspherical and nodular 2-8 inch concretions common, much of outcrop surface covered with reddish brown hematite stains (Sample C-5-6). Fossil collection, located near middle in coarse sand lens, is listed below:

Macrofossils: No. 4125

Nuculana sp.
Echinoid sp.
Pecten (Patinopecten) sp.
Acila cf. *A. nahalemensis*
Unidentifiable Gastropods

Microfossils: No. 4125

Bulimina sp.
Globobulimina sp.

Petrography (fragments) Sample C-5-5
Composition

40-50% volcanic glass: green and brown.
15-20% plagioclase feldspars: subhedral to euhedral.
andesine
microcline: sharply angular.
10-15% quartz
<1% lamprobolite: basaltic hornblende.
<1% biotite
10-20% matrix: tuffaceous silt, containing iron oxide as hematite and limonite.

Petrography (fragments) Sample C-5-6
Composition

50-60% basaltic fragments: subrounded and well rounded.
15-20% plagioclase feldspars: subhedral and subrounded.
andesine
oligoclase
albite

Unit		Feet
	1- 2% quartz: subrounded. 5-10% volcanic glass: green and brown. 5- 8% glauconite: yellowish green, pleochloric felt-like mass of silt particles.	
2	Claystone, silty, partly tuffaceous, massive structure, extremely fine grained, fresh surface greenish gray, weathers light shades brown to dull, dirty white; induration moderate to hard, breaks pseudo-concoidal fracture. Fossil collection from 1/2 inch lens that pinched out within 2 feet, forms include pelecypods and echinoids, badly altered (Sample C-5-3). Fossil listing follows:	4
	Macrofossils: No. 4125 Solena sp. Pecten (Patinopecten) sp. Echinoid sp.	
1	Siltstone, tuffaceous, light gray to dull white, weathers light buff shades, well stratified with partings uniformly 1/4 inch intervals; detrital particles on bedding planes give unit coarse texture; induration fair to poor, local accumulation of badly altered mollusk forms (Sample C-5-1); grades up into light greenish gray, massive sandy tuff, weathering light shades gray brown, on joint surface rich yellow brown; texture slightly more coarse than upper unit, detrital particles can be seen with unaided eye; with hand lens angular glass fragments can be detected, induration low, fossils not common, few decomposed mollusks noted (Sample C-5-2a). Lateral texture change, down dip about 25 feet, unit becomes tuffaceous sandstone; sand spotty, appearing in dominant percentage but spread irregularly in small lenses, pockets and stringers; tuff, calcite, quartz, feldspars, black subrounded components compose essential mineralogy, no stratification, tight well developed joint system control fracture of "brickbat" fragments, fossils rare (Sample C-5-2b).	21

Unit		Feet
	Total thickness of lower and middle Keasey formation.....	1709
	Concealed interval not assigned to either formation.....	418
Nehalem formation		
12	Sandstone, fine grained and highly tuffaceous, exposure mostly concealed by residual talus and soil, few fine flakes of mica, wet surface grayish buff, weathers light shade yellow brown, induration low (Sample C-4-1).	35
	Concealed.....	45
11	Siltstone, sandy, tuffaceous, grayish brown, weathers yellow brown, induration low, mostly concealed by cut slope talus, sandy tuff interbeds near base; outcrop deeply weathered (Sample C-3-1).	117
	Concealed.....	93
10	Interbedded sandstone and sandy ash beds, six moderately resistant medium to coarse sandy ash beds break sandstone phase every 15-25 feet and average one foot to 15 inches in thickness to end of outcrop. Sandstone, very fine grained, tuffaceous, faint stratification locally, fresh surface light gray brown, weathers light brown; irregular joint system, deep limonite stains on joint surfaces; induration low to moderate, sorting fair to locally poor, texture slightly more coarse than siltstone, particles irregular fragments in unoriented fabric, outcrop poor, deep weathering on slope surface makes sample collection difficult (Sample C-2-7). Dip 18-25° S20E.	121
9	Siltstone, tuffaceous, fresh surface dirty light brown, weathers uniform yellowish gray; tuff is present in amounts of 50-60%. Tight, irregular joint system with surface stains of dark reddish brown and black iron residuals, induration low to moderate (Sample C-2-6).	1

Unit		Feet
8	Sandstone, tuffaceous, as described under Unit 10.	30
7	Sandy ash bed, fine to medium grained, dirty gray, weathers yellowish gray, soft and easily disintegrated, friable; near 30% tuffaceous material, particles irregular, except for small percent subrounded sand grains (Sample C-2-5).	4
6	Siltstone, sandy, fine grained, highly tuffaceous, with small percent black detrital component; fresh surface light uniform gray, weathers light yellow brown, with some green tinting, locally becomes more sandy, massive with good to poor sorting, induration moderate (Sample C-2-4).	45
5	Unit is similar to Unit 10.	15
4	Siltstone, fine grained, tuffaceous, brownish gray, weathers light buff gray to irregular rust brown and gray, small percentage of dark detrital components near lower contact; faint stratification suggested, joints irregularly developed, induration low (Sample C-2-3).	5
3	Sandstone, fine grained, highly tuffaceous, with black detrital component appearing in higher percentage than Unit 6, gives texture more granularity; fresh surface medium to mottled green gray, weathers light brownish green, limonite stain on joint surfaces, induration low to moderate, surface of outcrop finely pitted where detrital components have been removed (Sample C-2-2).	12
2	Sandstone ledge, highly tuffaceous with finely disseminated subrounded black particles (which may be glauconite); fresh surface light gray green, weathers lighter uniform shades of tan brown with fine angular sandstone texture, induration low and partly friable, medium to coarse grained (Sample C-2-1).	1.3
1	Siltstone, sandy, grayish brown, tuffaceous, weathers uniform rust brown, induration moderate; contact sharp with above sandstone ledge, base concealed, exposure poor.	30

Unit		Feet
	Total thickness of Nehalem formation.....	554.3
	Rocky Point formation: middle member	
5	Siltstone, sandy, bluish gray, finely micaceous and tuffaceous with moderate to low cementation; joint system well developed, joint surface assumes dark iron stains of hematite and a black carbonaceous stain locally; faint stratification noted locally; weathers to rust brown rubble talus on lower slope and to 1-2 foot soil cover on upper low rolling hill surface; carbonaceous material common and where present imparts streaky appearance to texture; where tuff predominates, rock color generally lighter gray, retains most of primary color on weathered surface to give outcrop a light irregular gray and brown appearance. Top concealed, megafossils uncommon, few badly altered gastropods noted; foraminifera common (Sample C-1-7). Dip 7° S70E.	25

Petrography (fragments)

Composition

60-70% plagioclase feldspars: unidentifiable, euhedral and subangular.
10-15% quartz: subangular, few subrounded.
5-10% volcanic glass shards: greenish brown, few clear shards.
2- 4% muscovite
<1% pyrite: authigenic, angular

4	Siltstone, sandy, finely micaceous, coarse grained, gray, weathers uneven tan brown to yellow brown and light gray; coarse subrounded fragments appear to be reworked rock components; one foot above Unit 3 coarse components diminish to minor percentages in small pockets and stringers; upward unit is uniform in composition and texture, and on fresh surface is sandy, with finely mottled spots of red brown particles, mixed with a dominant composition of dark to medium gray,	7

Unit		Feet
	finely micaceous, sandy siltstone; rich stains of hematite on joint surfaces; large pelecypods scarce. Color change near upper contact with overlying terrigenous gravels; unit assumes rich uniform orange brown (Sample C-1-5).	
3	Sandstone, calcareous, tuffaceous, ledge forming, well indurated, medium to coarse grained; fresh surface medium gray, sharply angular fragments embedded in yellow calcareous matrix that constitutes nearly 50% of rock. One quarter of an inch of peripheral edge leached to a mottled yellowish-blackish brown, that shows up on the outcrop surface as a rough, pitted surface; in places unit has been completely broken down to form a black and richly yellow loose, friable sand; the black color is carbonaceous residue; above this unit, lithology again changes sharply in resistance with a gradational size change (Sample C-1-3).	2
2	Siltstone, sandy, medium gray, carbonaceous, weathers gray black, grades upward to moderately indurated silty sandstone; contact sharp with above ledge forming sandstone; macrofossils very common, preservation poor (Sample C-1-2).	7
1	Siltstone, medium gray, micaceous, partly tuffaceous, stratification faint, weathers to soil and small amount of rubble in light shades of brown; joint surfaces weather deeper shades of limonite and hematite, induration poor; sorting generally fair to locally poor where sand sizes predominate; particles irregular, mostly tabular, macrofossils uncommon, usually badly weathered; foraminifera common; carbonaceous material disseminated locally in small amounts (Sample C-1-1).	15

Unit		Feet
	Petrography (fragments) Composition	
	30-40% plagioclase feldspars: euhedral, few crystals show round corners. oligoclase albite	
	10-15% quartz: subangular	
	1% hornblende: prismatic, irregular edges.	
	5-10% volcanic glass shards: green and brown.	
	35-40% matrix: feldspathic silt and clay.	
	Total thickness of exposed Rocky Point formation.....	56
	Concealed interval tentatively assigned to Rocky Point formation.....	425
	Total interpretative thickness.....	481

NEHALEM RIVER SECTIONS

Nine partial sections were measured along the Nehalem River between Timber and Vernonia including strata of Rocky Point, Nehalem and Keasey formations. The lack of continuity of exposures and uncertainty regarding structure rendered the correlation of the section with standards on Rock Creek more difficult. Individual sections are located on plate 2, Sections were measured by hand level methods.

Section A-6

Rocky Point formation		
3	Sandstone, fine grained, micaceous, gray,	15

Unit		Feet
	weathers light brown, spheroidal weathering; black carbonaceous stains on foliated surfaces; sandstone slopes broken by two coarse grained sandstone ledges.	
2	Sandstone, coarse grained, pebbly, grayish black, weathers uneven brown, pitted surface, ledge forming, well indurated; composition dominantly angular basalt fragments, small amount subrounded; mean size about 3 mm., cemented by calcareous matrix (Sample A-6-2). Dip 20° east.	0.7
1	Sandstone, fine grained, partly micaceous, gray, weathers light brown, particles angular, approaching silt size, few subrounded components; induration low to moderate; unit becomes more coarse about 5 inches below contact with sandstone ledge above. Base concealed (Sample A-6-1).	18
	Total thickness of exposed Rocky Point formation.....	33.7

Section A-1

5	Terrigenous sands and gravels derived locally from Nehalem River.	7
	Keasey formation: lower member	
4	Siltstone, sandy, dark blue gray, weathers light shades reddish brown, induration low; concretions rare, small 2-3 inch nodules (Sample A-1-5). Near base of unit gray, hard arenaceous limestone lens in contact with lower glauconitic sandstone unit; lens largely covered, thickness estimated to be 20 feet, moderately large venerid clams common (Sample A-1-4).	30

Petrography (thin section of limestone lens)

Composition

92% matrix: finely divided calcite
1-2% glauconite
1% basaltic fragments; subrounded
1-2% biotite and muscovite
3% plagioclase: medium to acidic, subhedral, fresh.

Unit		Feet
3	Sandstone, glauconitic, medium grained, partly tuffaceous, gray to mottled black, weathers greenish gray in resistant ledges, induration moderate to hard, sorting fair, well stratified, form lenticular. Base marked by poorly sorted pebble conglomerate about 2 feet thick; pebble composition predominantly shale and few basaltic pebbles, 2-4-inch calcareous concretions common, macrofossils fairly common (Sample A-1-3).	22

Petrography (thin section)

Composition

80% glauconite
8% plagioclase feldspars
andesine
oligoclase
12% rock fragments
9% basalt
2-3% limestone
1% quartzite
1% quartz
7% calcite: cement
1% pyrite: authigenic
1% biotite
1% volcanic glass shards

2	Sandstone, tuffaceous, fine grained, light gray green, weathers brownish gray, induration low, carbonaceous material abundant locally, joint system well developed, texture finely granular with fair amount tabular silt particles. Recognizable particles include minor amounts of calcite, muscovite, rock fragments, lath shaped feldspars, pyrite and one unidentifiable mafic embedded in a slightly calcareous silt matrix.	15
1	Siltstone, sandy, gray black, weathers reddish brown, deep hematite stains on joint planes; minute calcite crystal growth on weathered surface. Induration moderate, 2-4 inch nodular concretions common, bedding expressed by two 1-2-inch sand lenses. Base concealed, contact at top uneven. Dip 9° S25W.	18

Unit | Feet

Macrofossils: No. 4122

Natica sp.
Dentalium sp.
Bracyuran fragments

Foraminifera

Nodosaria grandis Reuss
Pseudoglandulina sp.
Guttulina irregularis Cushman & Ozawa
Bulimina cf. pyrula d'Orbigny
Plectofrondicularia packardi Cushman & Schenck
Planulina haydoni Cushman & Schenck
Pullenia salisburyi Stewart & Stewart
Cibicides sp.
Cibicides aff. perlucida Nuttall

Age: Refugian (lower Oligocene)

Total thickness of exposed lower member Keasey formation..... 92

Section A-2

Nehalem formation

3	Sandstone, pebbly at basal contact, grades upwards within 2 feet of base to medium grained tuffaceous sandstone, fresh surface brownish gray, weathers light brown. Glauconite pellets disseminated locally, induration moderate (Sample A-2-3).	12
2	Basalt flow, amygdaloidal, deeply altered, preservation of original texture rarely seen; fresh surface variegated green and black, weathers brownish green. Vessicles appear both on weathered surface and in fresh rock; large percent vessicles filled with calcite, quartz, zeolites and brown chalcedony; chalcedony also occurs locally in veins shot throughout exposure. Irregular contact with above sandstone (Sample A-2-2).	40

Unit		Feet
1	Sandstone, medium grained, partly micaceous, brownish gray, weathers same, few disseminated glauconite pellets, induration moderate, resistant, largely concealed (Sample A-2-1).	3

Petrography (thin section)

Composition

1% muscovite and biotite
2-3% quartz: subrounded and irregular.
10-15% glauconite pellets: grows around quartz and feldspars.
40% matrix: calcareous and ferruginous clay and silt.
<1% hornblende: euhedral crystals.
7-10% rock fragments: basalt and calcareous fragments, subrounded dominantly with some angular forms.
30% plagioclase feldspars: sharply angular dominantly fresh forms, alternation noted on a few crystals.
labradorite
andesine
albite

Total thickness..... 55

Section A-3

Keasey formation: lower member

1	Siltstone, sandy, tuffaceous, dark bluish gray, weathers light reddish brown, joint surfaces deep hematite red; secondary growth of calcite crystals on weathered surface, induration moderate. Three resistant concretionary beds weather resistant ledges, 6-10-inch discoidal concretions common, few 2-3-foot concretions. Base and top concealed, fossils common, preservation generally poor (Sample A-3-1). Attitude: Dip 6° S30W.	68

Total thickness of exposed lower member, Keasey formation..... 68

Section A-4

Nehalem formation

Unit		Feet
1	Sandstone, coarse grained, pebbly calcareous, dark blue gray, weathers light brown, resistant ledges, well indurated, stratified; largely concealed (Sample A-4). Attitude: Dip 16° N85E.	15

Petrography (thin section)

Composition

60% calcite: occurs both as angular detrital fragments and cement; many of the detrital fragments exhibit polysynthetic twinning.

17% rock fragments: basaltic, well rounded.

12% plagioclase feldspars: forms predominantly euhedral; labradorite and bytownite usually angular; zoning common.
- albite
- oligoclase
- labradorite
- bytownite

10% volcanic glass; green and sharply angular.

1-2% glauconite; green pellets, some forms suggest alteration from biotite.

2-3% quartz: small fragments, subrounded to very nearly rounded.

1% biotite
hornblende
augite
magnetite

Total thickness of exposed Nehalem formation... 15

Columbia County Quarry Section

Rocky Point formation

2	Sandstone, pebbly, silty, gray, weathers grayish green, locally to zones of hematite stains, induration poor; basaltic pebbles commonly	4

Unit		Feet
	discoidal and polished; highly fossiliferous, preservation poor.	
	Fossil Collection: No. 4123	
	Nuculanids Ficopsis sp. Septifer sp. Mytilus sp. Acmea persona Eschscholtz Rhynochonella washingtonia Weaver Ostrea cf. griesensis Effinger Hexacorals Fish teeth Unidentifiable gastropod and pelecypod genera. Vertebrate, unidentifiable bone fragments.	
1	Conglomerate, cobble, grades up within 2 feet to pebble conglomerate, well indurated; cobbles and pebbles subrounded, polished surfaces common, matrix moderately calcic and sandy, crystalline calcite veins common; pebble types dominantly basaltic, few andesitic types suggested, unit makes irregular contact with underlying basalt flow, fossils common.	5
Tillamook volcanics		
4	Basalt, gray black, dense, partly glassy and crystalline, contains black, vitreous, soft unidentifiable mineral as phenocrysts; weathered surface brownish green, locally white calcite stains, large vertical joint system controls break up of flow into 2-5-foot angular blocks.	12
3	Volcanic breccia, interbed, greenish gray, contains conglomerate locally in pockets.	3
2	Basalt flow, same as Unit 4.	25
1	Siltstone, light blue, weathers pale green, brittle, crumbly, induration moderate, fracture irregular.	3

Unit		Feet
	Total thickness of exposed Tillamook volcanics.....	52

Timber Section

Rocky Point formation

4	Sandstone, micaceous, argillaceous, partly carbonaceous, well stratified; poorly exposed in small slump area at bend of Nehalem River. Large 2-3-foot calcareous, well stratified concretions found in river bed at this locality could not be found in place.	450
3	Siltstone, sandy, micaceous, carbonaceous, gray, weathers light grayish brown, largely concealed, base and top covered.	15
2	Interbeds, five coarse sandstone forms 1-2-foot resistant ledges with intervening sandy siltstones, all dark greenish gray, weathering grayish brown, base and top covered.	20
1	Siltstone, micaceous, gray, weathers light brown gray, small nodular and rounded concretion very common, induration low to moderate, base and top concealed.	30
	Total thickness of poorly exposed Rocky Point formation.....	515

Landslide-Scarp Section

Keasey formation: lower member

3	Siltstone, sandy, harsh, tuffaceous, blue gray, weathers gray black and light reddish brown, moderately indurated; one resistant concretionary bed, nodular concretions absent, fossils rare, preservation poor (Sample LS-4).	14

Petrography (thin section)

Composition

3% glass shards
2% glauconite: green and yellow green.
1% muscovite

Unit		Feet
	1% quartz: angular 6% plagioclase feldspars: mostly unidentifiable due to irregularity of forms and lack of prominent twinning. andesine 87% matrix: silty, ferruginous, calcareous, plagioclase abundant in matrix as silt size particles.	
2	Sandstone, dark brownish gray, tuffaceous, glauconite, disseminated in small amounts, weathers brownish gray, induration low, large nodular concretions common near base and middle, two broken concretionary ledges near top (Sample LS-2). Becomes dominantly glauconitic near top, weathers greenish gray and yellow; fossils common, poorly preserved, (Sample LS-3).	43
1	Sandstone, silty, fine grained, tuffaceous, slightly calcareous, blue gray, weathers light reddish brown, induration moderate; four 8-10-inch concretionary beds weather to resistant ledges; macrofossils rare. Base concealed, Dentalium sp. (Sample LS-1).	24
	Total thickness of exposed lower member, Keasey lithology.....	81

Section A-7

Keasey formation: lower member

4	Sandstone, very fine grained, silty, tuffaceous, carbonaceous material locally in thin bands, light gray, weathers gray brown; induration fair, joint surfaces assume deep red iron residual, black carbonaceous stains are locally common, four inch coal lens, soft, crumbly near base, brown to white sandy tuff beds intercalated, about 4 feet thick near top of exposure; macrofossils rare; top concealed.	15
3	Sandstone, fine to medium grained, tuffaceous, partly glauconitic, gray black, weathers uniform light brown; well indurated, cemented by calcareous matrix; macrofossils common, preservation poor, few small nodular concretions,	40

Unit		Feet
	attitude taken from resistant concretionary ledge, (Sample A-7-3). Dip 8° S65W.	
2	Conglomerate, pebbly, partly glauconitic, grayish green, massive, weathers greenish brown, induration high. Size range from fine sand matrix to 3/4 inch subrounded and dominantly discoidal pebbles; grades upward to sandstone (Sample A-7-2).	25

Petrography (thin section)

Composition

60% calcite: predominantly matrix, small amount detrital.
20% rock fragments: well rounded, basalt types common, few quartzites also present.
10% plagioclase feldspars: angular or euhedral, remarkably fresh.
oligoclase
andesine
labradorite
8% glauconite: dark and light yellowish green, few pellets show composition of microlitic silt particles.
2% quartz; small fragments, scattered, angular to subangular
<1% augite: small fragments
hornblende
hypersthene

1	Siltstone, brown gray, weathers deep shades reddish and yellowish brown, crumbly; base concealed, unit largely covered (Sample A-7-1).	5
	Total thickness of exposed lower member, Keasey formation.....	85

Section A-5

Rocky Point formation

18	Sandstone, medium grained, micaceous, partly carbonaceous, grayish brown, weathers light brown; contains large, elongate, stratified,	25

Unit		Feet
	calcarenite concretions, largely covered, base and top concealed (Sample A-5-8).	
	Concealed.....	100
17	Siltstone, brown gray, finely micaceous, weathers variable light brown and limonite yellow, crumbly, induration poor, largely concealed (Sample A-5-7).	38.4
16	Siltstone, uniform texture, dark gray, weathers same, local sand pockets near base, well indurated, ledge forming.	1.6
15	Sandstone, medium grained, gray, weathers brownish gray, induration moderate, ledge forming (Sample A-5-6).	2
14	Siltstone, greenish gray, weathers pale green, induration low.	4.5
13	Sandstone, fine grained, gray, poorly sorted, well indurated, ledge forming; yellowish calcite gives unit mottled appearance, near upper contact unit becomes more coarse, fragments largely angular, few subrounded (Sample A-5-5).	1.5
12	Siltstone, sandy, gray brown, weathers . brown, induration low to moderate.	2
11	Sandstone, greenish gray, weathers greenish brown, well indurated, ledge forming.	2
10	Siltstone, sandy, greenish gray, weathers grayish brown, induration moderate, ledge forming.	2
9	Siltstone, sandy, green, weathers greenish gray, induration moderate.	1.5
8	Siltstone, sandy, gray brown, weathers light brown, induration moderate.	1
7	Grit, grayish black, weathers same, composed mostly of angular igneous rock fragments, induration low.	0.5

Unit		Feet
6	Siltstone, fine grained, dark gray, weathers greenish gray, ledge forming.	1
5	Grit, pebbly, gray brown, weathers light greenish brown, well indurated, ledge forming.	0.5
4	Siltstone, sandy, gray, brittle, weathers light buff (Sample A-5-4).	0.3
3	Grit, gray green, pebbly, weathers greenish brown, well indurated, ledge forming, pebble size components sharply angular, small percentage sand size particles subrounded with dull surfaces. Composition essentially basaltic rock fragments, cemented by a calcareous matrix (Sample A-5-3). Dip 6° S20W.	1
2	Sandstone, fine grained, tuffaceous, medium gray, partly micaceous, weathers mottled gray brown, massive, induration moderate, breaks with even fracture, exposure partly covered, locally micaceous; dominantly tabular; active ground water seep at contact with lower unit, fossils common, mostly gastropods (Sample A-5-2).	15
1	Siltstone, micaceous, brown gray, weathers light brown, locally red hematite zones appear, stratification faint, induration low, joint system well developed, exposure mostly covered, small, round concretions common; fossils rare, preservation poor, no foraminifera noted; base covered, grades rapidly into above sandstone (Sample A-5-1).	27
	Total thickness of exposed Rocky Point formation.....	225.8

Gales Creek Section

Tillamook volcanics

3	Basalt flow, amygdaloidal, deeply altered, top covered.	12
2	Siltstone, brownish gray, partly sandy,	60

Unit		Feet
	weathers light grayish brown; thin sand seams rather common; radiolaria common.	
1	Basalt, greenish gray, deeply altered.	
	Total thickness of exposed Tillamook volcanics.....	72

ROCK CREEK SECTION

This section was measured along Rock Creek near Keasey Station beginning at an exposure of bluish gray sandy siltstone on the south side of Rock Creek approximately 1.3 miles northeast of Keasey Station and extending approximately 1/2 mile southwest of Keasey Station a few hundred feet beyond the Pacific Railroad trestle. The section includes the type sections of the Rocky Point and Nehalem formations and strata of the lower Keasey formation. A plan and profile map was drawn from a compass and pacing traverse up Rock Creek and unit thickness was computed graphically from the cross section (plate 8). Structural complexity and the largely concealed nature of the section, plus the usual percentage of error in a pacing traverse suggest caution in accepting thickness figures at face value. Because of the difficulties involved in measuring this section, detailed stratigraphic description was impossible. Consequently, separation of lithologies was largely limited to member classification.

Keasey formation: lower member

Unit		Feet
1	Siltstone, sandy, tuffaceous, faintly stratified, bluish gray, weathers light gray locally but typically light and dark reddish brown, induration low to moderate, spherical and nodular concretions common, 3-6 inches in size, rarely 10-12 inches, concretionary beds weather to 8-12 inch resistant ledges and occur every 15-20 feet throughout the unit; macrofossils common, appearing predominantly on bedding planes and local zones, preservation generally poor. Foraminifera locally common; approximately 40% of unit covered. Dip 10° S20W.	170
	Total thickness.....	170
	Concealed interval not known. Throw of northerly fault must be known in order to compute this thickness. Fault shown on plate 8.	

Nehalem formation

3	Sandstone, fine to medium grained, micaceous, dark gray black, weathers light gray to spotty yellow, joint weathers rust brown; extremely irregular and nodular calcareous concretions common. Three foot bed of sandy limestone makes irregular contact above sandstone; limestone, grayish blue, weathers same with pitted, irregular surface, induration high, macrofossils common (pelecypods) but cannot be collected because of the high induration of the rock in which they are contained; two fish teeth found; base and top concealed.	20
	Concealed.....	7
2	Siltstone, fine, sandy, dark gray to black, weathers gray and spotted reddish brown, induration poor (Sample B-14). Contains pebble conglomerate bed about 10 feet from base, conglomerate massive, well indurated, dark brownish gray, weathers light gray green, pitted surface, calcite veinlets	15

Unit | Feet

common; pebbles, subrounded, basaltic;
lens thickness about 7 feet.

Petrography (thin section from conglomerate lens)

Composition

50% calcite: predominantly matrix.
30% glauconite: green pellets.
10% plagioclase feldspars: predominantly labradorite, most forms have been fractured, but still retain euhedral form, very little alteration.
albite
andesine
labradorite
10% rock fragments: well rounded, basaltic.
<1% augite: small, angular.
<1% pyrite

Foraminifera: No. 4127

Karreriella cf. contorta Beck
Robulus inornatus d'Orbigny
Pseudoglandulina sp.
Guttulina irregularis Cushman & Ozawa
Sigmomorphina ? sp.
Plectofrondicularia packardi Cushman & Schenck
Plectofrondicularia packardi var multilineata Cushman & Simonson
Cassidulina globosa Hantken
Eponides umbonota Reuss
Planulina haydoni Cushman & Schenck
Cibicides hodgei Cushman & Schenck
Cibicides sp.

Age: Refugian (lower Oligocene)

Concealed..... 12

1 Mudstone, dark brownish gray; weathers brownish gray, locally reddish brown, white calcareous material covers most of surface; weathered surface hackly, crumbly, well stratified, partings about 1/2 inch thick; stratification not well expressed in fresh 210

Unit		Feet
	rock, induration moderate, two to three inch sand beds occur occasionally; near base glauconitic sandstone occurs as thin 6-10-inch interbeds. Amussium sp. abundant. Dip 5° N30W.	210
	Foraminifera: No. F4126	
	Cyclammina sp. Spiroloculina sp. Robulus sp. Robulus welchi Church Nodogenerina sp. Uvigerina garzaensis Cushman & Siegfuss Cibicides hodgei Cushman & Schenck Cibicides sp.	
	Age: Fossils undiagnostic (upper Eocene or lower Oligocene)	
	Total thickness of Nehalem formation.....	264
	Concealed, not assigned to either Nehalem formation or Rocky Point formation.....	25
Rocky Point formation		
5	Sandstone, fine to medium grained, micaceous, locally carbonaceous material abundant on bedding planes, occasionally as thin coal seams. Near base, massive, blue gray and quartzose, weathers dark brown and contains large discoidal calcareous concretions. Medial phase well stratified; stratification thickness varies from fine laminated structure to 3-8-inch beds, locally irregular cut and fill structures in fine stratification, fresh surfaces gray to gray brown, weathers light uniform brown, 2-3-foot calcareous concretions weather to conspicuous nodular ledges and themselves are micaceous, well stratified and contain carbonaceous fragments on 1/4-1/2-inch bedding planes. Top retains same composition, lacks the concretions, and weathers light brown.	520

Unit		Feet

Petrography (thin section)
Composition

40% plagioclase feldspars: sharply angular to subangular, few euhedral forms.
oligoclase
andesine
20-25% quartz: angular, few pieces subrounded.
17% biotite and muscovite: deformed xls., generally oriented along bedding planes.
2% rock fragments: subrounded, igneous types.
<1% hornblende (common)
<1% pyrite: authigenic
15% matrix: feldspathic silt.

Concealed..... 60

4 Siltstone, micaceous, dark even gray, weathers light gray and locally reddish brown, jointing mostly obscure, small rounded concretions common. Near the middle, siltstone become partly sandy, alternating with a series of coarse calcareous gritstone that weather to resistant ledge, five ledges were exposed; 6-10-inch discoidal concretions common with siltstone here, some reach major dimensions of 2-foot diameters. Near top unit becomes uniformly sandy, micaceous siltstone with 4-7-inch discoidal and nodular concretions; contact with above sandstone is gradational through thickness of about 2 feet; the lower siltstone becomes locally sandy, macrofossils rare, preservation poor, approximately 65% of this unit concealed; thickness listed is minimum. 100

Concealed interval is not known. Throw of southerly fault must be known in order to compute this interval. Fault is shown on plate 8.

3 Conglomerate, pebbly, brown, poorly indurated, composed of basalt pebbles, contact above 7

Unit		Feet
	sharp, grades up to fine grained micaceous sandstone.	
2	Sandstone, coarse grained, brown, weathers light reddish brown, induration moderate, composed of subangular to subrounded basalt fragments cemented by a ferruginous matrix; near top sandstone becomes medium grained with occasional pebbles, dark marine green, and well indurated; few, less than one-inch sandy concretions, largely concealed.	80
1	Conglomerate, boulder, massive, dark brown, weathers lighter brown, induration moderate, boulders and pebbles all basaltic, but largely altered to chlorite and serpentine; matrix sandy and ferruginous, volume about 15%; sorting poor, size range from sand to 2-foot discoidal boulders, medium size between 1/2-1-inch pebbles, all subrounded to well rounded, some show evidence of polished surfaces, base and top concealed, exposure poor, largely concealed.	60
	Total thickness of Rocky Point formation.....	859
	Concealed interval not assigned to either Rocky Point formation or Tillamook volcanics.....	40
Tillamook volcanics		
5	Basalt flows.	40
	Concealed.....	20
4	Sandstone, coarse grained, pebbly, mottled light green, induration moderate, composition essentially angular basalt fragments, minor amounts of plagioclase, quartz, calcite, and pyrite.	8
3	Basalt flow, blue black, fresh, partly glassy, weathers uneven reddish brown, few amygdules of calcite, large 2-3-foot columnar joints extend full thickness of flow. Near basal contact with baked shale, flow is brecciated and ranges in thickness from 1-5 feet.	12

Unit		Feet
2	Sandstone, coarse grained, pebbly, dark green, weathers light gray green surface, well indurated. Composition essentially rock fragments with minor amounts of plagioclase, quartz and calcite, grades up to baked shale zone averaging about 8 inches thick; unit makes sharp irregular contact with above basalt flow.	7
1	Basalt, highly altered, grayish green, amygdules of calcite and zeolites common, surface covered with white calcite stains; base concealed, flow breccia near upper contact with sandstone interbed.	50
	Total thickness of Tillamook volcanics.....	137

Plate 4

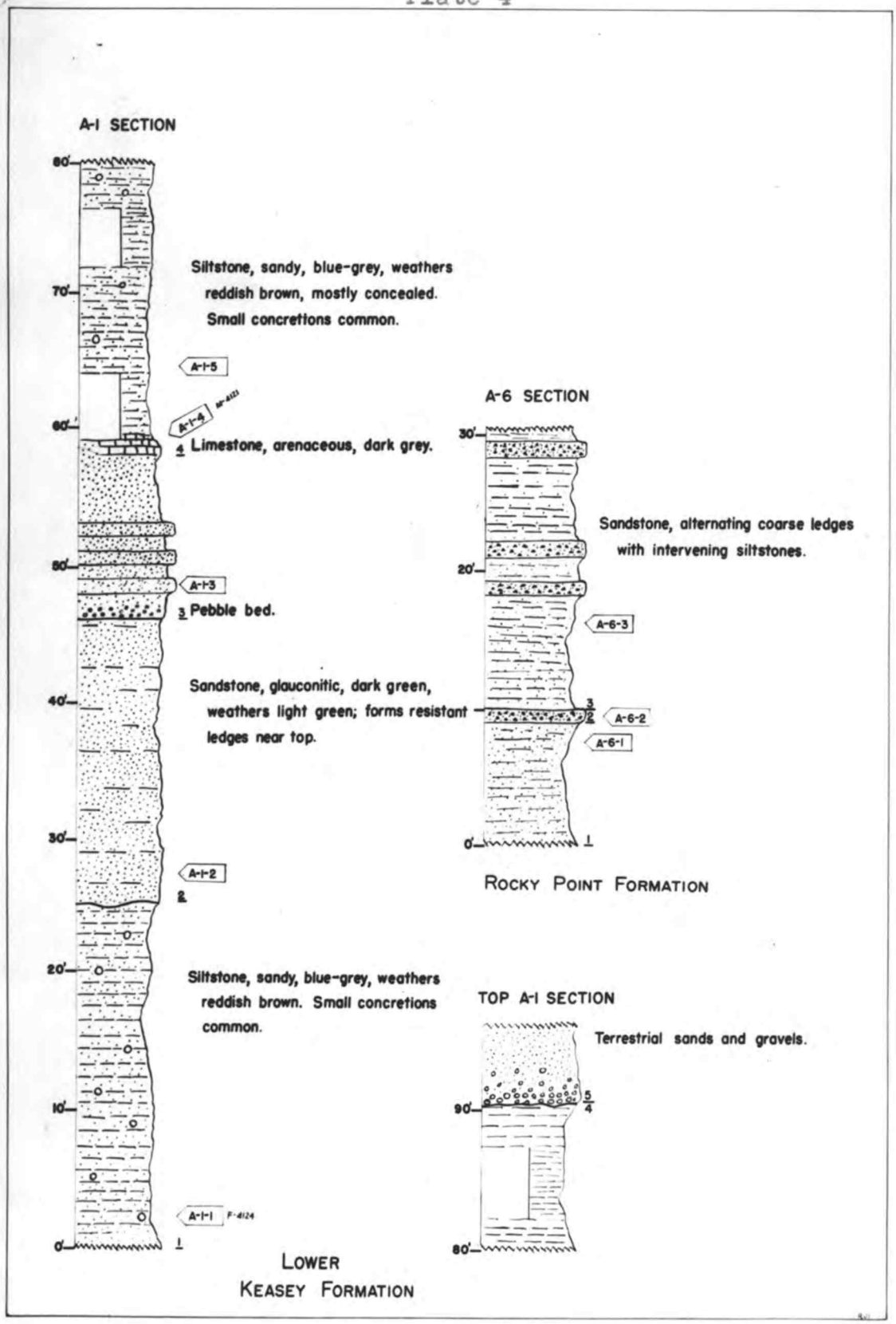
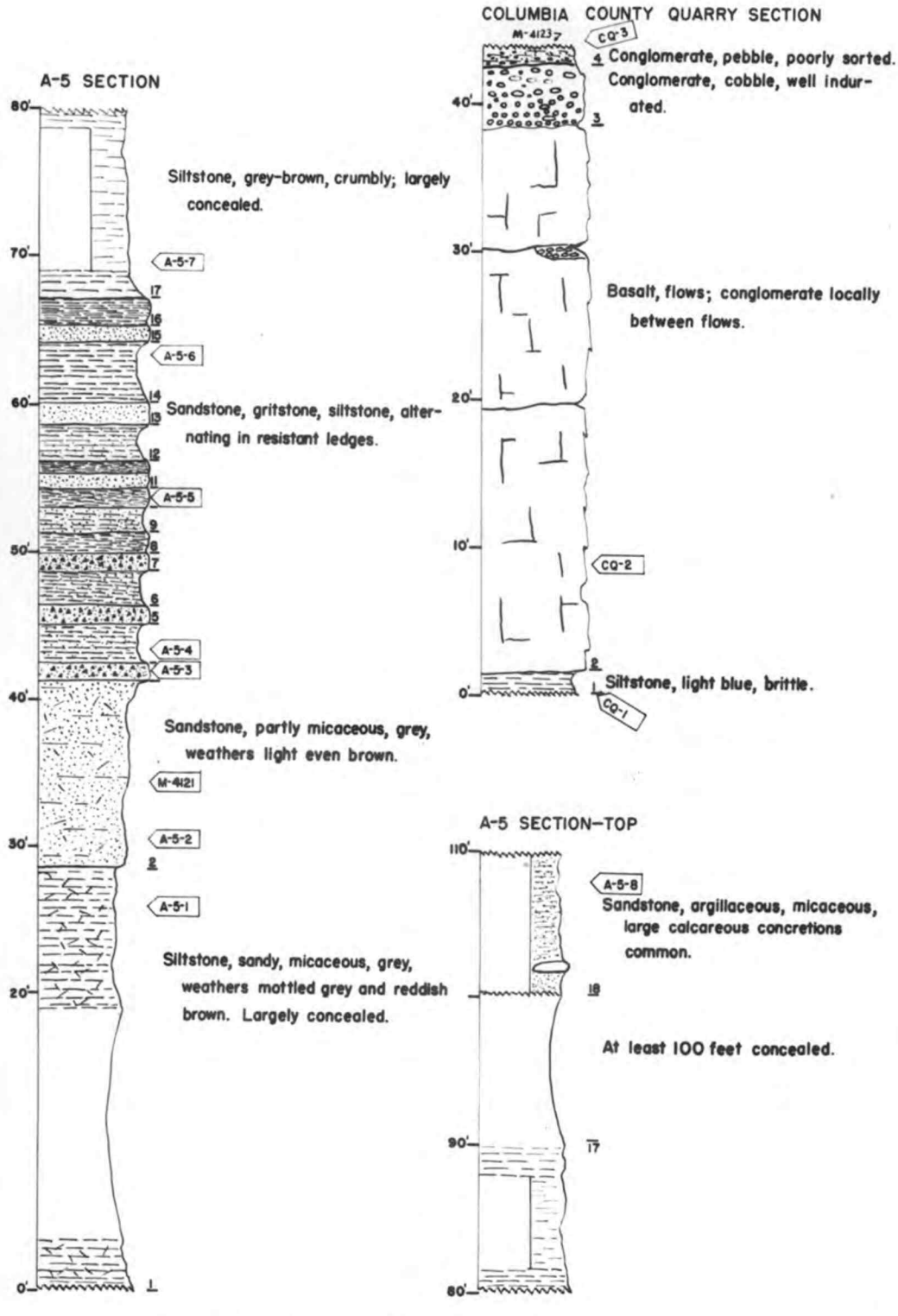
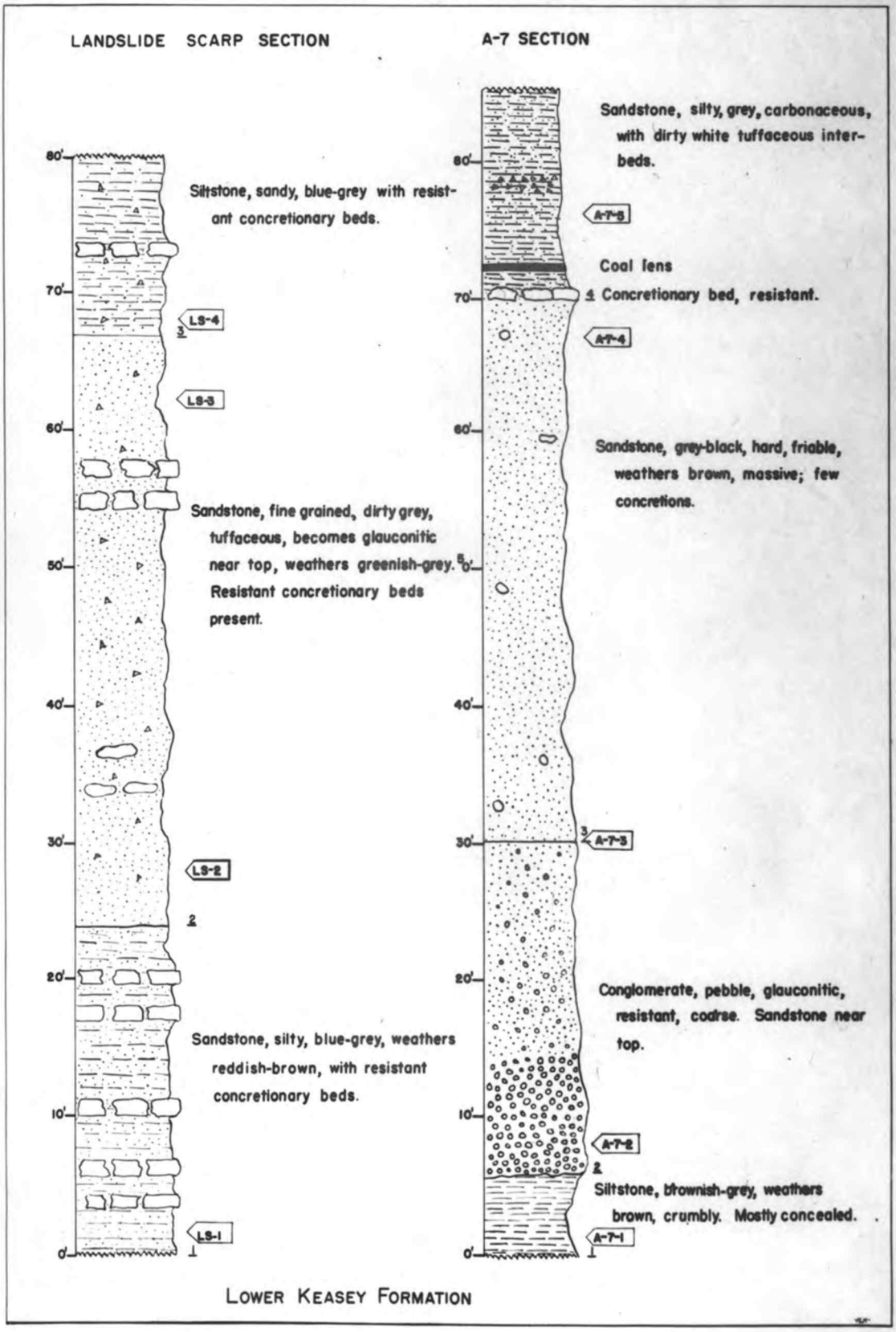

A-1 SECTION
80'
70'
60'
50'
40'
30'
20'
10'
0'
Siltstone, sandy, blue-grey, weathers reddish brown, mostly concealed. Small concretions common.
A-1-5
A-1-4
4 Limestone, arenaceous, dark grey.
A-1-3
3 Pebble bed.
Sandstone, glauconitic, dark green, weathers light green; forms resistant ledges near top.
A-1-2
2
Siltstone, sandy, blue-grey, weathers reddish brown. Small concretions common.
A-1-1
1
LOWER KEASEY FORMATION
A-6 SECTION
30'
20'
0'
Sandstone, alternating coarse ledges with intervening siltstones.
A-6-3
3
2
A-6-2
A-6-1
1
ROCKY POINT FORMATION
TOP A-1 SECTION
90'
80'
Terrestrial sands and gravels.
5
4

Plate 5



ROCKY POINT FORMATION

Plate 6



LOWER KEASEY FORMATION

Plate 7

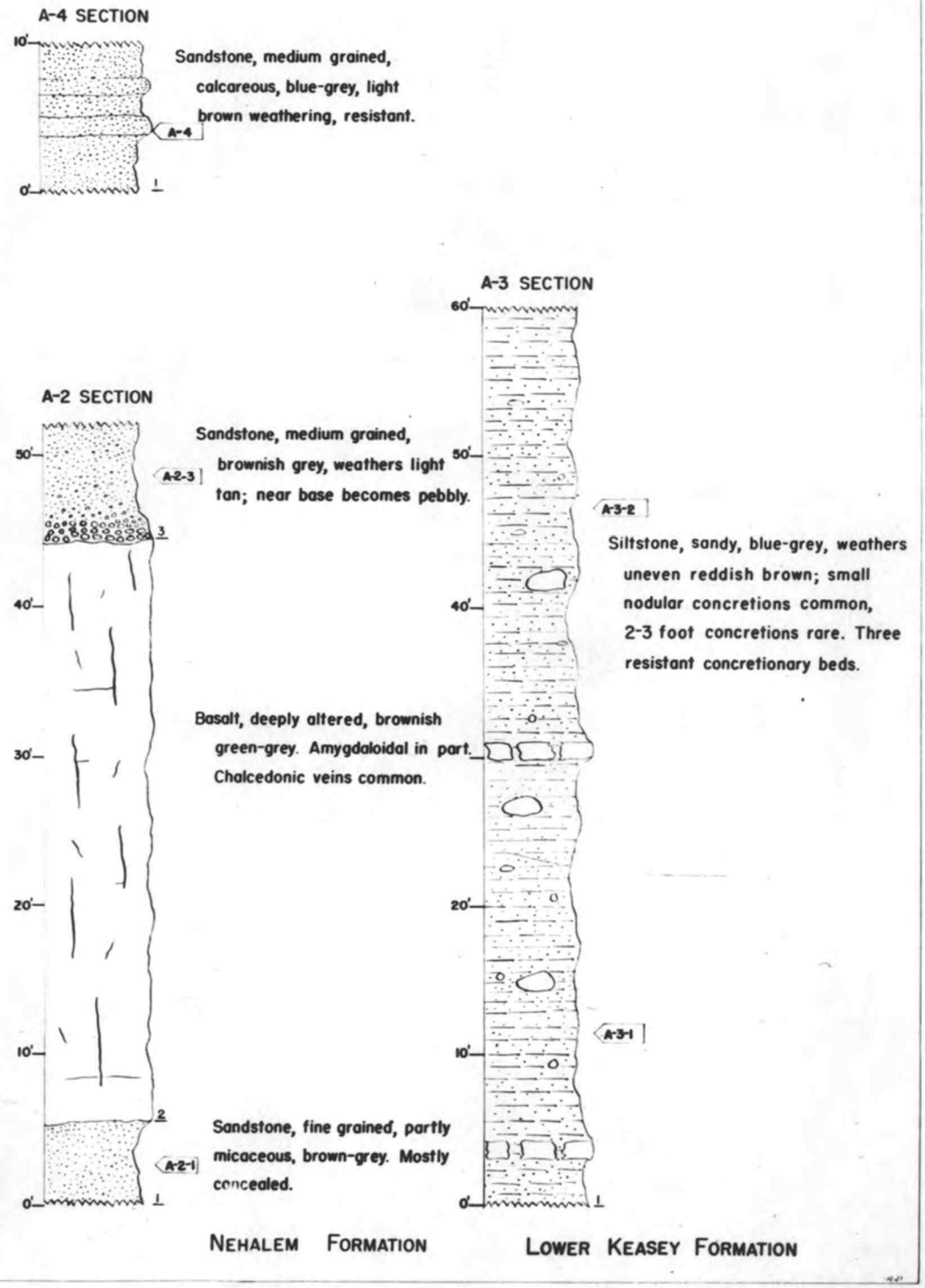

A-4 SECTION
10'
0'
A-4
Sandstone, medium grained, calcareous, blue-grey, light brown weathering, resistant.
A-3 SECTION
60'
50'
40'
30'
20'
10'
0'
A-3-2
Siltstone, sandy, blue-grey, weathers uneven reddish brown; small nodular concretions common, 2-3 foot concretions rare. Three resistant concretionary beds.
A-3-1
A-2 SECTION
50'
40'
30'
20'
10'
0'
A-2-3
Sandstone, medium grained, brownish grey, weathers light tan; near base becomes pebbly.
3
Basalt, deeply altered, brownish green-grey. Amygdaloidal in part. Chalcedonic veins common.
2
A-2-1
Sandstone, fine grained, partly micaceous, brown-grey. Mostly concealed.
1
NEHALEM FORMATION
LOWER KEASEY FORMATION

Plate 8

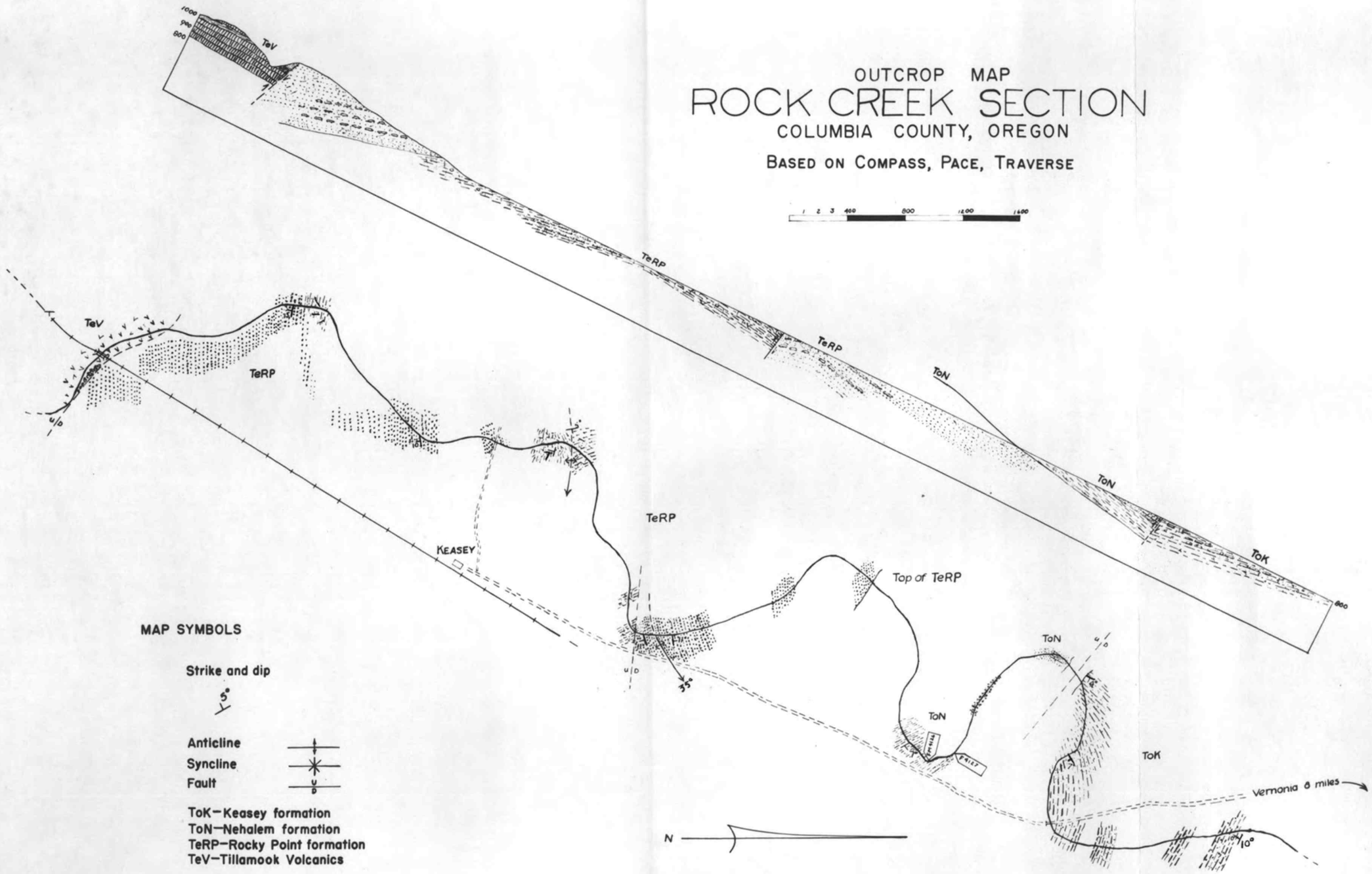
OUTCROP MAP

ROCK CREEK SECTION

COLUMBIA COUNTY, OREGON

BASED ON COMPASS, PACE, TRAVERSE

1 2 3 400 800 1200 1600



MAP SYMBOLS

Strike and dip

5°

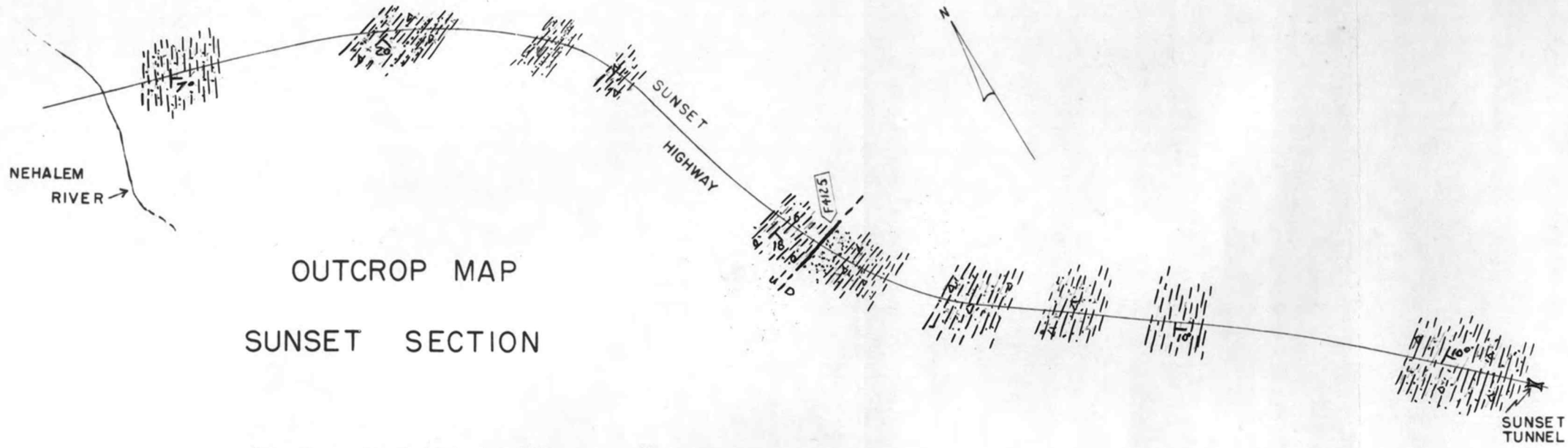
Anticline

Syncline

Fault U D

TeK—Keasey formation
TeN—Nehalem formation
TeRP—Rocky Point formation
TeV—Tillamook Volcanics

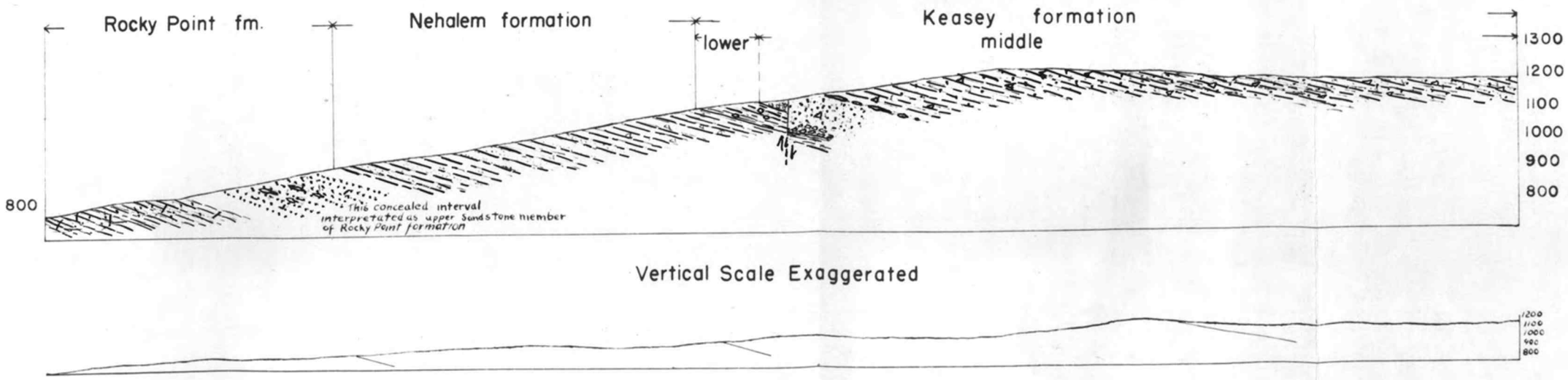
Plate 9



OUTCROP MAP

SUNSET SECTION

0 500 1000 2000 3000



Vertical Scale Exaggerated

Vertical Scale True

APPENDIX I

Fossil Localities. The Oregon State College fossil localities occurring within the Rocky Point and Keasey formations are listed along with the stratigraphic unit in which they occur. Localities are also designated in section descriptions and on plates 4-9. They have been deposited in the Oregon State College Paleontology laboratory as permanent collections.

Locality Number	Section	Stratigraphic Unit
4121	A-5	Rocky Point formation
4122	A-1	Lower Member, Keasey formation
4123	Col. Co. Quarry	Rocky Point formation
4124	A-1	Lower Member, Keasey formation
4125	Sunset	Lower Member, Keasey formation
4126	Rock Creek	Nehalem formation
4127	Rock Creek	Nehalem formation

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